

Monitoring Waterbird Outcomes in NSW:

Summary report 2016-17



Office of
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Cover photos (clockwise): Booligal ibis colony monitoring in the Lower Lachlan (Credit: J Spencer); Monkeygar ibis colony; nesting Little Egret; and advanced Australian white ibis chicks in the Macquarie Marshes (Credit: N Brookhouse).

Summary

Monitoring objectives

We carried out ground and aerial surveys in 2016-17 to collect information on waterbird species, waterbird abundance and breeding activity in significant floodplain wetlands in the Murray-Darling Basin (MDB). These surveys complemented aerial surveys undertaken by the University of New South Wales (UNSW) in spring 2016 and UNSW's monitoring of ibis colonies at selected sites.

Our surveys were carried out to:

- **measure waterbird species richness and abundance, and non-colonial waterbird breeding activity** to assess progress towards Basin-scale and NSW wetland-scale expected waterbird outcomes;
- **determine the location, size and stage of active colonial waterbird sites** to inform the active management of environmental water in 2016-17 and to support the assessment of Basin-scale and NSW wetland-scale expected outcomes for colonial waterbird breeding;
- and **determine waterbird use of Ramsar wetlands** and wetlands managed as part of NSW National Parks Estate.

Survey coverage in 2016-17

We completed ground surveys for waterbirds in eight wetland regions in inland NSW (covering 166 sites and 8,610 ha in total) in spring 2016. These sites were located in important waterbird areas in the MDB including the: Gwydir Wetlands, Narran Lakes, Macquarie Marshes, Mid-Lachlan, Lower Lachlan, Mid-Murrumbidgee Wetlands, Lowbidgee Floodplain and NSW Mid-Murray region. In collaboration with UNSW, we also undertook surveys of colonial waterbird breeding sites in seven of the wetland regions.

Key findings

- The extensive wet conditions experienced by large parts of the MDB in spring 2016 supported many waterbird species in the surveyed wetland regions. We observed **66 waterbird species in total** during the 2016-17 ground and aerial surveys. This included six species listed on international migratory bird agreements, the nationally endangered Australasian Bittern (Commonwealth *EPBC Act 1999*) and six waterbird species listed in NSW (*Biodiversity Conservation Act 2016*).
- **Large waders (egrets, herons and ibis) contributed most to waterbird abundance across the surveyed wetland regions.** Straw-necked Ibis was the most abundant waterbird species in four of the eight wetland regions.
- **Widespread breeding activity was recorded during spring 2016**, particularly in wetland regions where major flooding occurred.
- **At least 41 waterbird species were recorded breeding in 2016-17.** This included 19 colonial waterbird species including egrets, ibis, herons, spoonbills, cormorants and pelicans, and 22 non-colonial waterbird species such as ducks, grebes and waterhens.
- **Colonial waterbird breeding activity was detected in all of the wetland regions excluding the Narran Lakes.** Heavy rainfall in the upper catchments of most valleys over winter and early spring 2016 resulted in extensive flooding in many of the surveyed wetlands. This provided suitable conditions for colonial waterbird breeding in the Macquarie Marshes, Mid-Lachlan, Lower Lachlan, Lowbidgee Floodplain, Mid-Murrumbidgee and Mid-Murray wetland regions.

- **In total 83 active waterbird colonies were detected across the wetland regions in 2016-17.** Eleven large (>5,000 nests) colonies, 25 medium-sized (>250-<5,000 nests) colonies and 47 small (<250 nests) colonies were detected.
- Many of the active sites in 2016-17 were historical sites but there were **an additional 10 colony sites initiated in new locations** where colonial waterbird breeding had not previously been recorded.
- **The largest colonies were Straw-necked Ibis colonies** (seven sites in total, which ranged in size from 6,000 ->100,000 nests), **Australian Pelican colonies** (two sites with an estimated 6,000 nests in each site) and **egret and heron colonies** (two sites, ranging in size from 5,500 – 11,500 nests).
- **Environmental flows were delivered to extend flood duration in some colonies** to allow species to complete their nesting cycle. There were 11 environmental watering actions in total that supported active waterbird colonies in the NSW MDB in 2016-17.
- **Two Ramsar sites supported colonial waterbird breeding:** the Macquarie Marshes Ramsar site (Macquarie Marshes Northern Nature Reserve) and the NSW Central Murray Forests Ramsar site (Millewa Forest, Koondrook-Perricoota Forest and Werai Forest).
- **The Ramsar wetlands supported many waterbird species.** In total 61 waterbird species were observed across the five Ramsar sites surveyed in 2016-17 with Fivebough-Tuckerbil Swamp Ramsar site in the Murrumbidgee Catchment supporting the most species overall (60 in total), followed by the Macquarie Marshes Ramsar site (37 species), Narran Lakes Ramsar site (35 species), Gwydir Wetlands Ramsar site (34 species) and Central Murray Forests Ramsar site (Millewa Forest only, 34 species).
- **The Fivebough Swamp Ramsar site is important for supporting waterbird species richness and abundance in the NSW MDB.** Notably it provides habitat for many migratory shorebird species when conditions are suitable.

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Abbreviations

AEW	NSW Adaptive Environmental Water
AWSEA	Aerial Waterbird Survey of Eastern Australia
BC Act	<i>Biodiversity Conservation Act 2016</i> (NSW)
BWS	Basin-wide Environmental Watering Strategy (MDBA 2014)
CAMBA	China-Australia Migratory Bird Agreement
CEWO	Commonwealth Environmental Water Office
CEW	Commonwealth Environmental Water holdings
EPBC	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)
EWA	Environmental Water Allowance
EWKR	Environmental Water Knowledge and Research Project (Commonwealth funded)
HIS	Hydrological Indicator Sites
JAMBA	Japan-Australia Migratory Bird Agreement
LTIM	Long-term Intervention Monitoring Project (Commonwealth funded)
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
ML	Megalitres
NPWS	NSW National Parks and Wildlife Service (OEH)
OEH	Office of Environment and Heritage (NSW)
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEA	Specified Environmental Assets
STIM	Short-term Intervention Monitoring Project (Commonwealth funded)
TLM	The Living Murray Program
UAV	Unmanned Aerial Vehicle
UNSW	University of New South Wales
WRPA	Water Resource Plan Area

1 Background

1.1 Managing habitat for waterbirds in the NSW Murray-Darling Basin

Many wetlands in the Murray-Darling Basin (MDB) are recognised as nationally and internationally significant based on their importance for waterbirds. Waterbirds are a highly mobile group relying on a network of wetland habitats within and outside of the MDB to complete critical parts of their life cycle. While there are many wetlands available at various times across eastern Australia, wetlands in the MDB can support large concentrations of waterbirds when conditions are suitable (Kingsford and Porter 2009). Long-term surveys of waterbird populations in Eastern Australia have shown continued decline in waterbird numbers in the MDB since the surveys began in 1983 (Kingsford *et al.* 2017a). This decline has been linked to reductions in the size and frequency of flood events in the regulated catchments of the MDB, which has impacted the availability of wetland feeding and breeding habitats for waterbirds (Kingsford and Auld 2005, Kingsford and Thomas 1995; Kingsford *et al.* 2017a).

The *Basin Plan* was developed as a requirement under the Commonwealth *Water Act 2007* to regulate the amount of water extracted for human consumptive use without negative impact on the river systems in the MDB. Long-term quantified targets have been developed in the Basin-wide Environmental Watering Strategy (BWS) (MDBA 2014) to support monitoring of this approach, using four key indicators that are known to respond strongly to changes in flow regimes: river flows and connectivity, vegetation, native fish and waterbirds. Improvements in waterbird populations, by maintaining the number and type of waterbird species, increasing their abundance and providing opportunities for breeding, is listed as one of the environmental objectives of the *Basin Plan* which aims to achieve sustainable waterbird populations in the MDB by 2024 (see Box 1) (MDBA 2014).

Box 1: Expected outcomes for waterbirds from 2024 identified in the BWS (from MBDA 2014) are:

- that the **number and type of waterbird species** present in the Basin will not fall below current observations
- there will be a **significant improvement in waterbird populations**, in the order of 20 to 25% more than the baseline scenario, with increases in all waterbird functional groups
- **breeding events** (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds **will increase by up to 50%** compared to baseline scenario
- **breeding abundance (nests and broods)** for the other functional groups **will increase by 30-40%** compared to baseline scenario, especially in locations where the *Basin Plan* improves over-bank flows

Noting that achieving these outcomes would result in waterbird populations similar to those in the early 1990s, which is necessary to ensure resilience of populations across the Basin.

The NSW Office of Environment and Heritage (OEH) is responsible for managing discretionary environmental water in NSW. The primary goal is to make a significant contribution to the rehabilitation and protection of stressed rivers and iconic wetlands for improved environmental and cultural benefits. OEH manages environmental water allowances provided for under water sharing plans and NSW environmental water holdings and also delivers environmental water held by the Commonwealth Environmental Water Office (CEWO) and non-government organisations.

OEH prepares annual environmental watering priorities for five Water Resource Plan Areas (WRPAs) in NSW: the Gwydir, Macquarie-Castlereagh, Lachlan, Murrumbidgee, and NSW Murray and Lower Darling (OEH 2016 a,b,c,d,e). These plans outline OEH’s annual environmental water management objectives and actions which vary according to water availability and environmental demand. Examples of annual water management objectives relating to waterbirds include the provision and maintenance of wetland habitat to support regional waterbird populations which include threatened species, migratory shorebirds and colonially-nesting waterbirds.

Inundation depth and duration are important drivers for habitat availability and these components of the flow regime can be manipulated by delivering environmental water. For example, large wading birds such as spoonbills tend to feed in shallow vegetated floodplain habitats, while fish-eating waterbirds forage in deeper more open waterbodies, and shorebirds and dabbling ducks prefer open shallow waterbodies with muddy shorelines. When timed correctly flows can provide outcomes for a succession of waterbird groups, changing in response to the rise and drawdown of water levels (Taft *et al.* 2002).

Environmental water can also be used to maintain stable water levels in active waterbird colony sites and adjoining feeding habitats to support successful breeding and recruitment. Colonially-nesting species such as egrets and ibis, are particularly sensitive to changes in flows as they require appropriately timed flows of sufficient duration, depth and extent to complete their breeding cycle (Kingsford and Auld 2005; Scott 1997). Once nesting begins, the duration of flooding and water depth needs to be sufficient to meet total breeding duration requirements (laying and incubation of eggs through to raising offspring through the nestling and post-fledgling dependent period) which varies among species (Figure 1). Environmental water has been delivered to initiate and support small-scale colonial waterbird breeding (generally less than 500 nests in total) at some wetlands in the Lower Murrumbidgee and Mid-Murray regions (Spencer 2017). However, environmental water deliveries generally have the largest influence on waterbird populations by extending the duration of large flood events which have already triggered large-scale breeding events.

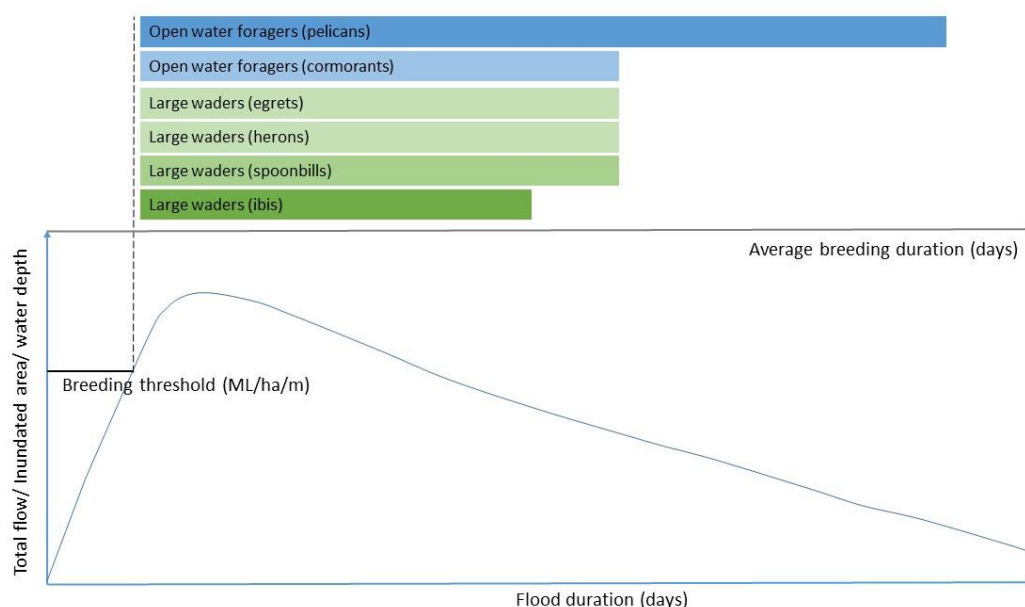


Figure 1 Representation of how key flow parameters (total river flow, inundated area, water depth and flood duration) influence colonial waterbird breeding, where different waterbird groups respond to a breeding threshold at which flow volumes are sufficient to trigger the initiation of breeding (adapted from Brandis and Bino 2016).

1.2 Monitoring waterbird outcomes

Waterbirds are useful indicators of wetland health as they are a generally conspicuous group, making them relatively easy to identify, and their abundance and diversity can be related to wetland area, the health of wetland vegetation and the abundance of food resources e.g., microcrustacea, fish and aquatic vegetation (Kingsford 1999). Most waterbird species disperse over great distances in response to the availability of inundated habitats and so assessment of population trends relies on data collected on species richness, abundance and breeding activity across multiple wetlands and wetland regions. Data collected from waterbird breeding events can provide a useful index of the effectiveness of wetland management. Colonially-nesting waterbirds (including cormorants, egrets, herons, ibis and pelicans) are dependent on wetlands for breeding, and often congregate in very large numbers when conditions are suitable. In the MDB, breeding opportunities for colonial waterbirds are often triggered by high rainfall events in the upper catchments of rivers. These events can result in widespread flooding in the lower part of the catchments providing conditions suitable for large colonies to establish (Leslie 2001; Kingsford and Auld 2005; Brandis and Bino 2016).

Combining ground surveys with aerial surveys is an effective way to monitor waterbird populations in floodplain wetlands (Baldwin *et al.* 2005). Aerial surveys can be used to determine the distribution of birds, make a rapid cost-effective assessment of relative abundance and locate active waterbird breeding colonies (Kingsford 1999; Kingsford and Porter 2011). Ground surveys provide information on less abundant (threatened and/or cryptic species) and more detailed information on colonial waterbird breeding events (Baldwin *et al.* 2005).

Long-term data on changes in waterbird numbers and wetland extent in NSW has been collected annually since 1983 as part of the Aerial Waterbird Survey of Eastern Australia (AWSEA) program. Ten survey bands (30 km wide) have been monitored across eastern Australia each spring, providing an effective long-term measure of waterbird species abundance and breeding activity across wetlands in Eastern Australia (Kingsford *et al.* 2017a). The project was originally initiated by the NSW, Queensland, Victorian and South Australian Governments, the Commonwealth Government and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The NSW National Parks and Wildlife Service (NPWS) ran the project from 1987-2004 and University of New South Wales (UNSW) has coordinated the project from 2005 onwards (Kingsford and Porter 2009). UNSW have also coordinated aerial surveys of MDB wetlands, including sites not covered by the AWSEA survey bands, through the National Waterbird Aerial Survey Program undertaken in 2008, annual surveys of the Living Murray Icon sites since 2007 and Murray-Darling Basin Authority's (MDBA) funded aerial survey programs since 2010 (now known as the Specified Environmental Assets (SEA) surveys) (Kingsford *et al.* 2013) (see Figure 2 for coverage of the combined aerial survey programs).

NSW OEH and partner organisations have undertaken spring ground surveys in the Gwydir Wetlands since 2007, the Lowbidgee Floodplain, and Millewa Forest (NSW Mid-Murray) since 2008, and the Narran Lakes, Macquarie Marshes and Mid-Murrumbidgee Wetlands since 2012 (Spencer *et al.* 2014; 2016). The Mid-Lachlan and Lower Lachlan wetland regions were added to the OEH waterbird ground survey program in 2016 (Figure 3).

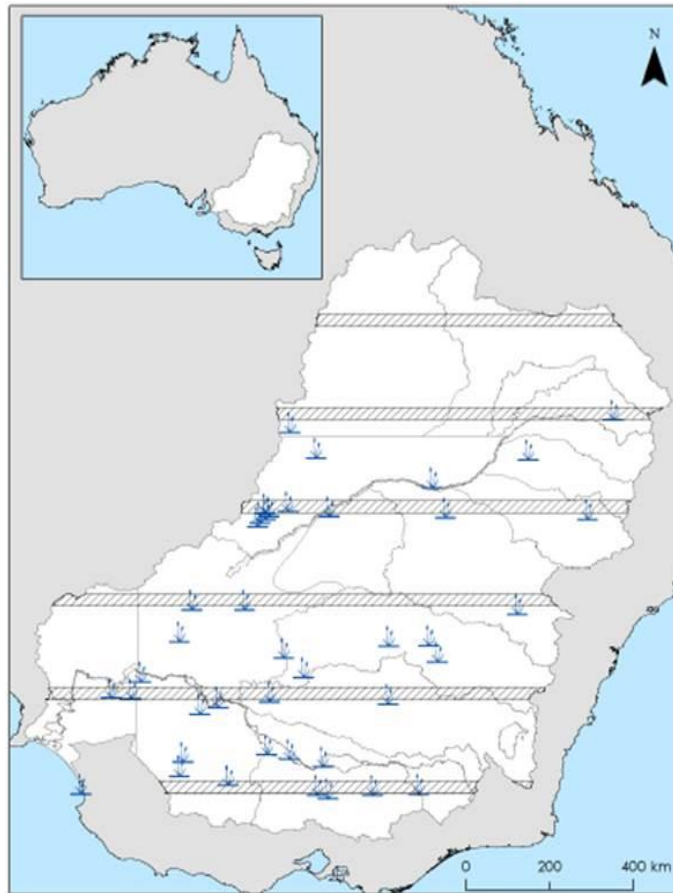


Figure 2 MDB wetlands surveyed annually through UNSW’s waterbird aerial survey programs including the AWSEA long-term annual surveys where six 30 km wide survey bands are surveyed across major river systems in the Murray-Darling Basin, and additional MDBA funded aerial surveys of wetlands during the SEA (formerly the HIS and TLM surveys) survey program (Source: Bino *et al.* 2015).

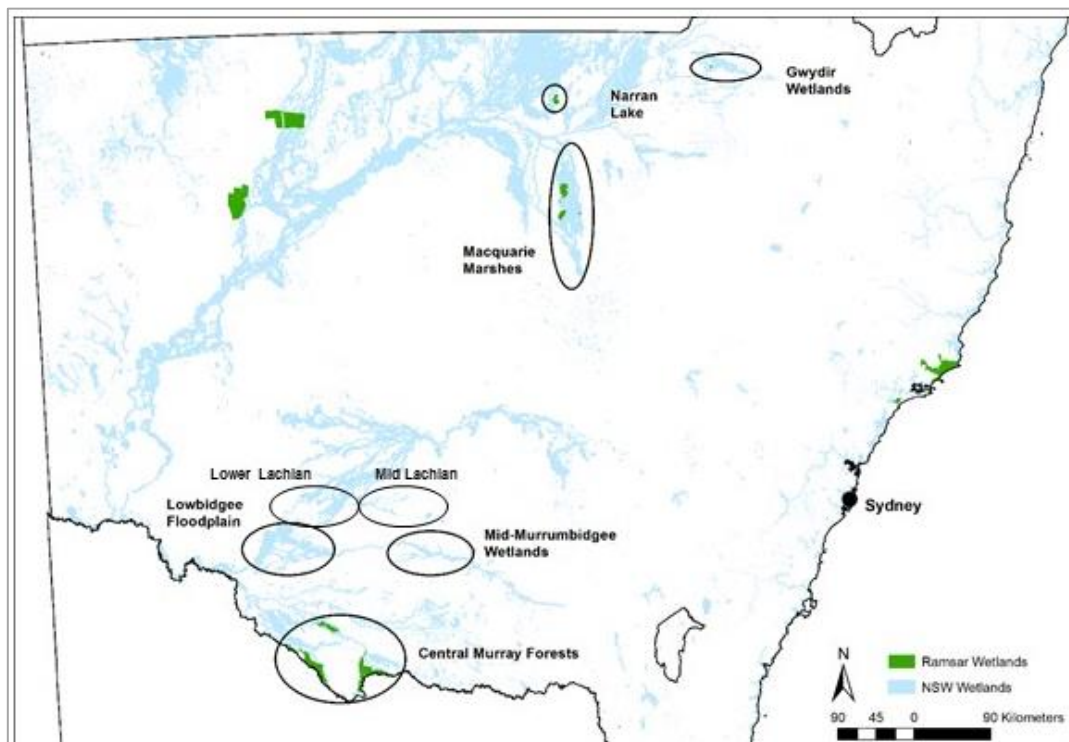


Figure 3 Location of the eight wetland regions where OEH ground surveys were conducted in 2016-17 and the distribution of wetlands, including Ramsar sites, across NSW (Source of NSW Wetlands layer: Kingsford *et al.* 2004).

1.3 Monitoring objectives

We carried out ground and aerial surveys in 2016-17 to collect information on waterbird species, including the identification of threatened and migratory species, and waterbird abundance and breeding activity in floodplain wetlands in the NSW section of the MDB. These surveys complemented spring aerial survey monitoring undertaken by the UNSW as part of the long-term AWSEA Program and annual aerial surveys of the MDBA's SEA wetlands. We also undertook event-based colony surveys which complemented Commonwealth-funded monitoring of large ibis colonies in the 2016-17 water year (Brandis 2017; Dyer *et al.* 2017; McGinness *et al.* 2018; Wassens *et al.* 2018).

OEH surveys were carried out to:

- measure waterbird species richness and abundance, and non-colonial waterbird breeding activity to assess progress towards Basin-scale and NSW wetland region-scale expected waterbird outcomes;
- determine the location, size and stage of active colonial waterbird sites to provide information to support the management of sites with environmental water in 2016-17 and to support the assessment of Basin-scale and NSW wetland region-scale expected outcomes for colonial waterbird breeding;
- and determine waterbird use of Ramsar wetlands and wetlands managed as part of NSW National Parks Estate.

1.4 Summary of wetland conditions and watering actions in 2016-17

Rainfall was above average for most of Australia in 2016, with central and southern parts of inland NSW recording the highest rainfall for NSW (BOM 2017). Six of the eight wetland regions experienced major flooding in spring 2016. In contrast, the Gwydir Wetlands and Narran Lakes in the Northern MDB only received limited inflows over 2016-17. Many of the 2016-17 watering actions had objectives for the provision and maintenance of wetland habitat for waterbirds and support of colonial waterbird breeding (see summary in Appendix 1).

Narran Lakes

The Narran Lakes Nature Reserve was largely dry during the previous two spring survey periods (2014 and 2015) with the last major flooding occurring in 2013. Small inflows in the Narran River reached Clear Lake in October 2016 and April 2017 (Figure 4A). The larger October 2016 flow event inundated around 1,500 ha of the Narran Lakes. In total 43,750 megalitres (ML) of Commonwealth environmental water was delivered across the two flow events (CEWO 2018a).

Gwydir Wetlands

The Gwydir River system includes priority wetlands located in the Lower Gwydir and Gingham watercourses, and the Mallowa Creek and Wetlands. While no proactive watering of the Gwydir Wetlands was planned for 2016-17, the NSW OEH annual plan had provision for releases in the event of substantial rainfall and river flows in the upper Gwydir Catchment (OEH 2016a). During August and September 2016 heavy rainfall in the upper Gwydir catchment generated large river flows (Figure 4A) and moderate flooding in the upper Gingham and some inundation of the central and lower Gingham watercourse. A total of 46,847 ML of NSW and Commonwealth environmental water was delivered over summer 2016-17. Most of the environmental water was delivered from late December 2016 to late February 2017 to maintain water levels and prevent rapid draw down of the Lower Gwydir and

Gingham watercourses to support waterbird and frog habitat. The Mallowa system also received Commonwealth environmental water from mid-January to early April 2017 to support the recovery of wetland vegetation and provide habitat for waterbirds and frogs (CEWO 2018b).

Macquarie Marshes

Watering priorities for the Macquarie-Castlereagh in 2016-17 were originally set in May 2016, during a time of very limited water availability. These priorities focused on supporting inundation of wetlands in the Macquarie Marshes if opportunities arose to build on natural tributary flows (OEH 2016b). The Macquarie Catchment received widespread rainfall from early June 2016 onwards which resulted in Burrendong Dam reaching 100% capacity in early September 2016. The objectives of flow management were reset to adaptively manage for these rapidly changing conditions.

NSW and Commonwealth environmental supplementary water releases (8,677 ML) were made to enhance the effect of high flows in July to early September 2016. The objective of these releases was to maximise inundated area. These flows, in addition to the subsequent Flood Mitigation Zone airspace operations, catchment tributary flows and local rainfall, resulted in widespread inundation of the Macquarie Marshes (154,000 ha, Thomas and Heath 2018). A total inflow of around 960 GL was recorded at Marebone Weir during the 2016-17 water year. NSW and Commonwealth environmental water (46,410 ML in total) was delivered from late January through to mid-February 2017 (Figure 4A) to maintain water levels in waterbird colony sites and adjoining feeding habitats in the Northern and Eastern Marshes and to inundate key foraging grounds (OEH 2017a, CEWO 2018c).

Mid-Lachlan and Lower Lachlan Wetlands

During winter 2016, the Lachlan Valley experienced above average rainfall in the upper and lower catchment resulting in widespread flooding. NSW licenced environmental water (1,000 ML) was delivered to the Lower Lachlan (Merrimajeel Creek offtake to Murrumbidgee Swamp reach) to inundate core wetland vegetation. The Lachlan River reached major flood levels between late September and early October 2016 (Figure 4A) which filled major storages in the mid-Lachlan, including Lake Brewster and Lake Cowal, inundated the Lower Lachlan area around Booligal Swamp and further west, reaching the Great Cumbung Swamp. Ongoing high river flows continued through October and early November 2016 which supported a very large ibis breeding event in the upper Merrimajeel Creek system through to completion in late December 2016. Following the large winter-spring flood event the Lachlan catchment was generally dry through summer and autumn months in 2017 when below-average rainfall was recorded. NSW and Commonwealth environmental water (4,895 ML) was delivered to the Lower Lachlan from early January 2017 to mid-March 2017 (OEH 2017a, CEWO 2018d) to maintain water levels for a second ibis nesting event detected at the Block Bank in Booligal Swamp in mid-December 2016. NSW Environmental Water Allowance (1,513 ML in total) was also delivered to maintain water levels in Lake Brewster for a pelican breeding event from mid-February to late June 2017 (OEH 2017a).

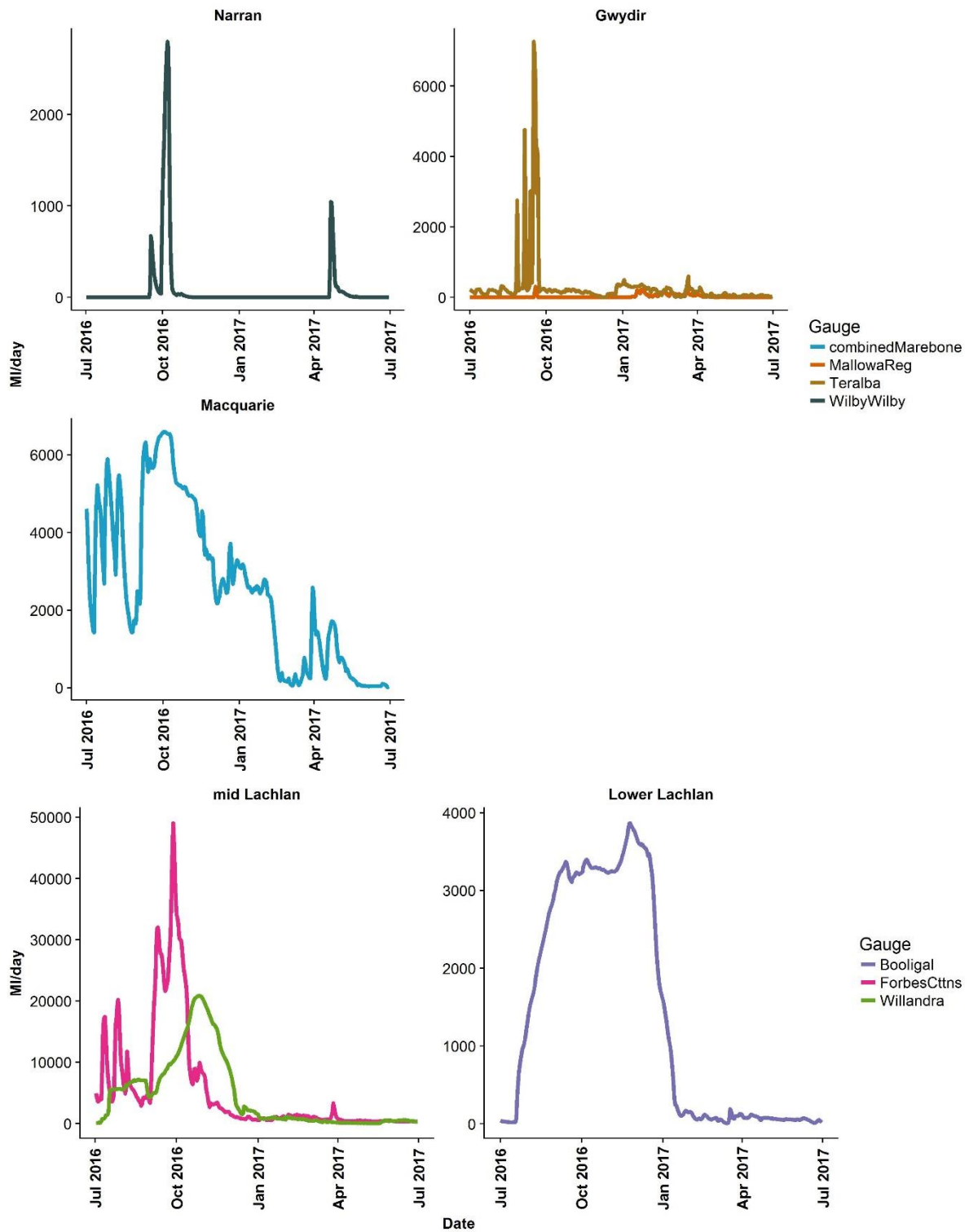


Figure 4A River flows (ML/day) for the Narran Lakes, Gwydir Wetlands, Macquarie Marshes, Mid-Lachlan and Lower Lachlan wetland regions during the 2016-17 water year (1 Jul 2016 – 30 Jun 2017). River flow gauge data was the sum of two gauges (Marebone Break, 421088 and downstream Marebone Weir, 421090) to represent inflows in to the Macquarie Marshes. Note the differences in the y-axis for each plot.

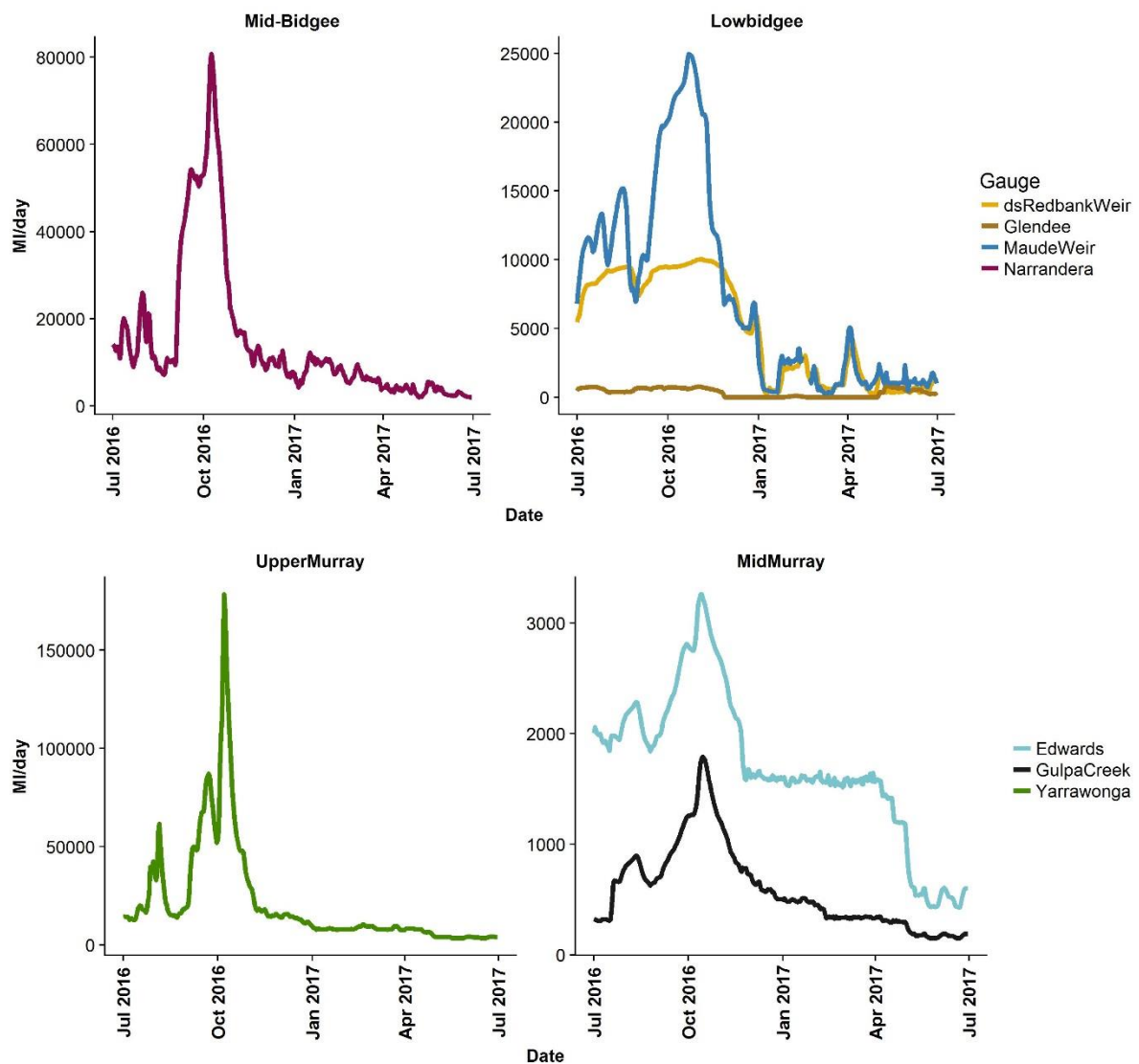


Figure 4B River flows (ML/day) for the Murrumbidgee (*upper*) and NSW Murray (*lower*) during the 2016-17 water year (1 Jul 2016 – 30 Jun 2017). Note the differences in the y-axis for each plot.

Mid-Murrumbidgee and Lowbidgee Wetlands

In total, 530,424 ML of environmental water was delivered to wetlands and river targets in the Murrumbidgee Catchment in 2016-17 (OEH 2017a). Both the Mid-Murrumbidgee Wetlands and Lowbidgee Floodplain were inundated by major flooding in spring 2016 (Figure 4B), which followed watering actions in August-September 2016 for wetlands in the Lowbidgee Floodplain (Nimmie-Caira and Redbank (Yanga National Park) systems) and Mid-Murrumbidgee Wetlands (Gooragool Lagoon). Follow up environmental watering (27,146 ML in total) was undertaken following the peak of the flood, from late November 2016 to late March 2017, to maintain water levels in active waterbird colonies in the Lowbidgee Floodplain (OEH 2017a).

Mid-Murray

The River Murray also experienced a large and sustained flood event from October through to December 2016 (Figure 4B) which was generated by very high rainfall in the upper Murray catchment. These flows inundated the Mid-Murray wetlands initiating colonial waterbird breeding. A total of 683,394 ML of managed environmental water was delivered to river and wetland targets in the NSW Murray and Lower Darling valleys in 2016-17. There was a large multi-site environmental watering

throughout the water year (282,213 ML of Commonwealth, NSW and TLM environmental water) targeting the River Murray through to the Lower Lakes and the Coorong. This watering action was delivered to support river connectivity and provide habitat for wetland dependent species, including habitat in Barmah-Millewa. There were also targeted deliveries to colony sites in Millewa Forest over spring-summer 2016-17. This included delivery of 4,488 ML of environmental water to the Reedbeds colony in Millewa Forest from early November 2016 to late January 2017, and 4,500 ML of environmental water (TLM) to colonies at St Helena Swamp and Black Swamp (also part of the Gulpa Creek Wetland Complex) from November-December 2016. A further 1,224 ML of TLM and NSW licensed environmental water was delivered to Pollack Swamp in Koondrook-Perricoota Forest from early December 2016 to late February 2017 to support colonial waterbird breeding (OEH 2017a).

1.5 Survey coverage in 2016-17

On-ground surveys

We completed waterbird ground surveys in eight wetland regions in spring 2016, covering 166 sites and 8,610 ha in total. The sites were located in a network of important waterbird areas across the MDB including the: Gwydir Wetlands (32 sites), Narran Lakes Nature Reserve (10 sites), Macquarie Marshes (29 sites), Mid-Lachlan (7 sites), Lower Lachlan (23 sites), Mid-Murrumbidgee Wetlands (11 sites), Lowbidgee Floodplain (48 sites), and NSW Mid-Murray (Millewa only – 6 sites) (Figure 3). Wetlands monitored included important sites identified for their contribution to Basin-scale expected outcomes (MDBA 2014) and sites within the NSW NPWS reserve estate system. Five of the 12 Ramsar wetlands listed in NSW were also surveyed including: the NSW Central Murray Forests (Millewa in the Mid-Murray), Fivebough and Tuckerbil swamps (Mid-Murrumbidgee), Macquarie Marshes (Macquarie Marshes Nature Reserve, Wilgara and U-Block), Gwydir Wetlands (Goddard's Lease and Old Dromana (Big Leather)), and the Narran Lake Nature Reserve.

Additional ground surveys were carried out by OEH and partners in selected wetlands during 2016-17. Ground surveys of the Gwydir Wetlands were completed in March 2017 and the Mid-Murrumbidgee Wetlands and Lowbidgee Floodplain were surveyed in September, November, January and March as part of the CEWO's Long-term Intervention Monitoring (LTIM) Projects in the Gwydir (Commonwealth of Australia 2018) and Murrumbidgee (Wassens *et al.* 2018) Selected Areas. OEH supported surveys of Fivebough-Tuckerbil Ramsar site in July 2016, October 2016, January 2017 and April 2017. The NSW Central Murray Forests Ramsar site (Millewa Forest – Murray Valley National Park) was also surveyed quarterly through TLM and NSW NPWS funding (OEH 2017b). Bird interest groups also provided incidental counts for the Narran Lakes (Birdlife Australia Guardian), Gwydir Wetlands (Moree Bird Club) and Mid-Murrumbidgee region (Murrumbidgee Field Naturalists).

Aerial surveys

UNSW completed aerial surveys of the Lowbidgee Floodplain, Fivebough Swamp and the Macquarie Marshes Northern Nature Reserve in October 2016 as part of the AWSEA survey program (Porter *et al.* 2016). The Gwydir Wetlands, Narran Lakes, Macquarie Marshes, Mid-Lachlan, Lower Lachlan and Mid-Murray wetland regions were surveyed as part of annual MDBA SEA aerial surveys in November 2016 (Kingsford *et al.* 2017b). OEH and CEWO staff undertook aerial reconnaissance in fixed-wing aircraft or helicopter from October to December 2016 in wetland regions that had active waterbird colonies. Observations of breeding activity from the aerial surveys guided on-ground surveys of active waterbird colonies.

Event-based colony surveys

UNSW and OEH monitored active colonial waterbird breeding sites in seven wetland regions in the 2016-17 water year. UNSW led fortnightly monitoring of large ibis colonies active in the Macquarie Marshes (two sites, Brandis 2017), Lower Lachlan (Brandis and Lyons 2016; Dyer *et al.* 2017), Lower Murrumbidgee (Wassens *et al.* 2018) and Mid-Murray (Barmah-Millewa, McGinness *et al.* 2018) during the September 2016 to March 2017 period.

OEH led additional ground surveys of active ibis, egret, spoonbill, heron, pelican and cormorant colonies during the October 2016 to May 2017 period. This included one colony in the Gwydir Wetlands, 12 colonies in the Macquarie Marshes, two colonies in the Lower Lachlan, three colonies in the Mid-Lachlan, 27 colonies in the Lower Murrumbidgee (and adjoining Junction wetlands), three colonies in the Mid-Murrumbidgee (and adjoining Yanco-Billabong wetlands) and seven colonies in the Mid-Murray (Murray Valley National Park) (OEH 2017c). Where access permitted surveys were done monthly from the start to the end of nesting.

Forests NSW (Hutton 2017) also completed event-based surveys of active colonies in Koondrook-Perricoota Forest NSW (Central Murray Forests Ramsar site). Note that no colonies were active in the Narran Lakes in 2016-17.

1.6 Survey methods

Survey methods and survey locations for the OEH spring ground surveys are outlined in more detail in Spencer *et al.* (2014). Briefly, a range of sites are surveyed each spring including open lakes and lagoons, vegetated marsh/sedgeland, channel or riverine and artificial wetlands across the wetland regions. Waterbird species are counted with binoculars (and/or telescope for large open waterbodies) at each site on at least two occasions (over separate days) during each survey period to estimate the maximum number of waterbird species and maximum count of each species per site. Dry sites are only surveyed once. Total number of each waterbird species are recorded along with any evidence of breeding activity, i.e. the number of broods or nests. The ground surveys are timed to coincide, where possible, with UNSW aerial spring surveys (see Section 1.2).

Additional event-based colony monitoring is done each water year (September-May) to complement the annual spring aerial and ground surveys (see Spencer 2017). Any active colonies detected through the spring ground or aerial surveys are revisited during summer and autumn months where needed. The timing (October-November) of the annual ground and aerial waterbird surveys (AWSEA and SEA) coincides, in most years, with the initiation of waterbird breeding activity across the catchments. These monitoring programs therefore provide key information on the location, size and species composition of active waterbird colonies in all eight wetland regions.

OEH undertakes additional aerial surveys over summer months in either fixed-wing aircraft or helicopter to detect late-stage waterbird colonies. This is particularly important where peak river flows occur over late spring-early summer. Transects are flown over each wetland system to survey known colony sites and assess whether new colony sites are active (see Spencer 2017). For example, new Straw-necked Ibis and Australian Pelican colonies were detected in the Lower Lachlan and Lowbidgee Floodplain during aerial surveys in mid-December 2016. Subsequent ground visits were undertaken by OEH and UNSW from January-May 2017 to monitor these sites.

Ground surveys of active colonies are done on foot and/or by kayak, or small boat. Information on the number of breeding species, estimates of total numbers of nests and stage of nesting (nest building, eggs, early (<2 weeks old) or late (>2 weeks old) nestling stages, or fledglings), water depth, and start and end of nesting are recorded. This information is used to inform the management of environmental water (where needed) to active colony sites. During the ground surveys each colony site is

circumnavigated to determine the colony boundary and the size of each colony (ha), where access permits. A combination of aerial and on-ground surveys is used to determine total colony size if the colony is too large or difficult to access by foot or boat. UNSW used Unmanned Aerial Vehicles (UAVs or drones) to capture aerial photographs of large ibis colonies active in the wetland regions in 2016-17 (Lyons *et al.* 2018) and analysis of this imagery was undertaken to determine total colony size (see example in Plate 1).

UNSW also collected reproductive success information for large ibis and spoonbill colonies using established survey methods by Brandis (2010) where colonies are visited fortnightly (six to eight visits in total per site) to measure the success of individually-marked nests. This monitoring approach was used in the Lower Lachlan (two colonies, Sep 2016 – Mar 2017) (Dyer *et al.* 2017), Lowbidgee Floodplain (two colonies, Nov 2016 – Mar 2017) (Wassens *et al.* 2018), Macquarie Marshes (two colonies, Oct 2016 – Jan 2017) (Brandis 2017) and Millewa Forest (one colony, Oct 2016 – Jan 2017) (McGinness *et al.* 2018). The remaining colonies were visited at monthly intervals by OEH staff to track the progress of each site and document mortality. The presence of predators (for example, birds of prey, ravens, feral pigs, foxes) and nest disturbance were also recorded during the colony surveys. Detailed measures of nesting success were not undertaken during the monthly OEH ground surveys.

All colony surveys were limited to two periods during the day, early morning (6-10am) or late afternoon (4-8 pm), to minimise disturbance and avoid causing heat stress to nesting birds and chicks. Water levels in the colony sites were monitored through a combination of onsite measurements under nests, manual staff gauges with time lapse cameras, continuous data collection through telemetry water level gauges installed by OEH and CEWO, and the NSW DPI established river gauge network.

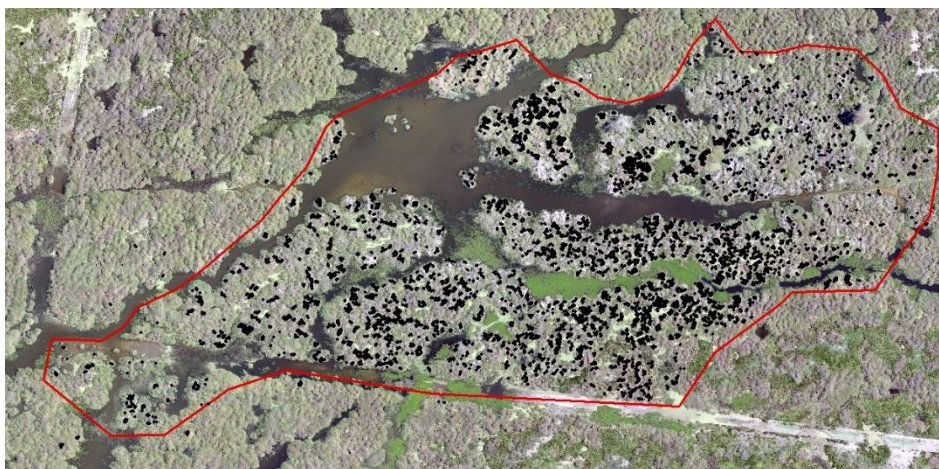


Plate 1 Orthomosaic of imagery collected for the Booligal Block Bank ibis colony in the Lower Lachlan in January 2017. This imagery was used to create a colony boundary (red line) and estimate total number of ibis and spoonbill nests (black dots). Reproduced by permission of Kate Brandis (UNSW).

2 Summary of waterbird outcomes in 2016-17

2.1 Total number of waterbird species was maintained in some regions

The extensive flood conditions seen in large parts of inland NSW in spring 2016 supported many waterbird species (Figure 5). In total, 66 waterbird species were observed during the 2016-17 ground and aerial surveys (Appendix 2). This included six species listed on international migratory bird agreements, the nationally endangered Australasian Bittern (Commonwealth *EPBC Act 1999*) and six waterbird species listed in NSW (NSW *Biodiversity Conservation Act 2016*). The total number of waterbird species recorded during the spring 2016 surveys was comparatively high, even in the Gwydir Wetlands (GWY) where inflows were minimal in comparison to other wetland regions which recorded widespread floodplain inundation (Figures 4 A,B and Figure 5). The total number of waterbird species recorded in the Narran Lakes (NAR) in spring 2016 had increased compared to the previous three years (Figure 6) due to greater inflows in 2016-17.

Fifty-seven waterbird species were recorded during the spring 2016 ground surveys: 30 species in the Narran Lakes, 41 species in the Gwydir Wetlands, 46 species in the Macquarie Marshes, 35 species in the Mid-Lachlan Wetlands, 42 species in the Lower Lachlan wetlands, 24 species in the Mid-Murrumbidgee Wetlands, 38 species in the Lowbidgee floodplain and 22 species in the Mid-Murray (note survey coverage was limited to Millewa Forest only in the NSW Central Murray Forests Ramsar site) (Table 1, Figure 6).

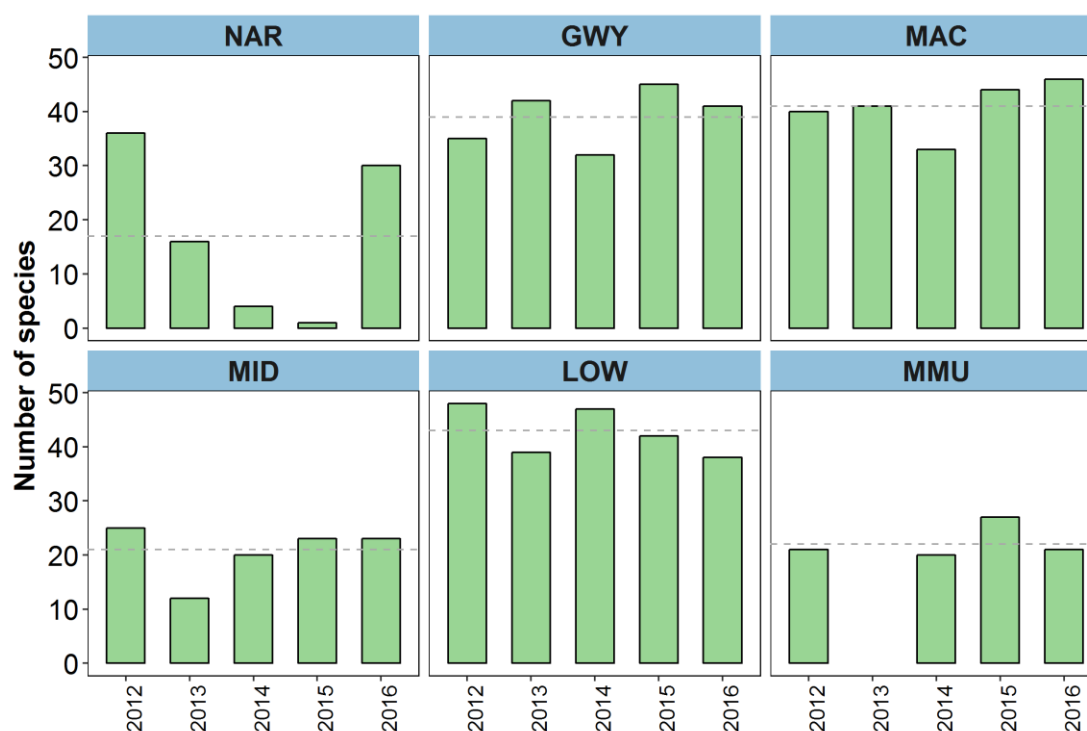


Figure 5 Total number of waterbird species recorded in the wetland regions during ground surveys completed in spring from 2012-16 (dotted line shows the average for this five-year period). Wetland region codes are: NAR = Narran Lakes, GWY = Gwydir Wetlands, MAC = Macquarie Marshes, MID = Mid-Murrumbidgee Wetlands (not including Fivebough-Tuckerbil Ramsar Site), LOW = Lowbidgee Floodplain and MMU = Mid-Murray (Millewa only). Note no spring surveys were completed in Millewa Forest in spring 2013.

Broadly, all waterbird functional groups were observed in the wetland regions, excluding the Mid-Murray (MMU) region where herbivores and small waders (resident and migratory shorebird species) were not detected at the time of the spring 2016 surveys (Figure 6). This may have been caused by the major flood conditions during the time of the surveys making the survey sites unsuitable for these species that prefer shallow wetland habitat. Some herbivores and small waders (resident species) were subsequently recorded in the Millewa summer and autumn 2016-17 surveys (see OEH 2017b and Appendix 4B).

Waterbird breeding activity was recorded in all wetland regions during spring 2016, and was greatest in wetland regions where major flooding occurred. Breeding activity was greatest in the Macquarie Marshes, Lowbidgee Floodplain, Gwydir Wetlands and Lower Lachlan wetlands during the spring 2016 surveys (Table 1). Breeding was detected in at least 41 species based on available records for the eight wetland regions over 2016-17. This included 19 colonial waterbird species (egrets, ibis, herons, spoonbills, cormorants and pelicans) and 22 non-colonial waterbird species (grebes, coots and duck species) (see Section 2.3).

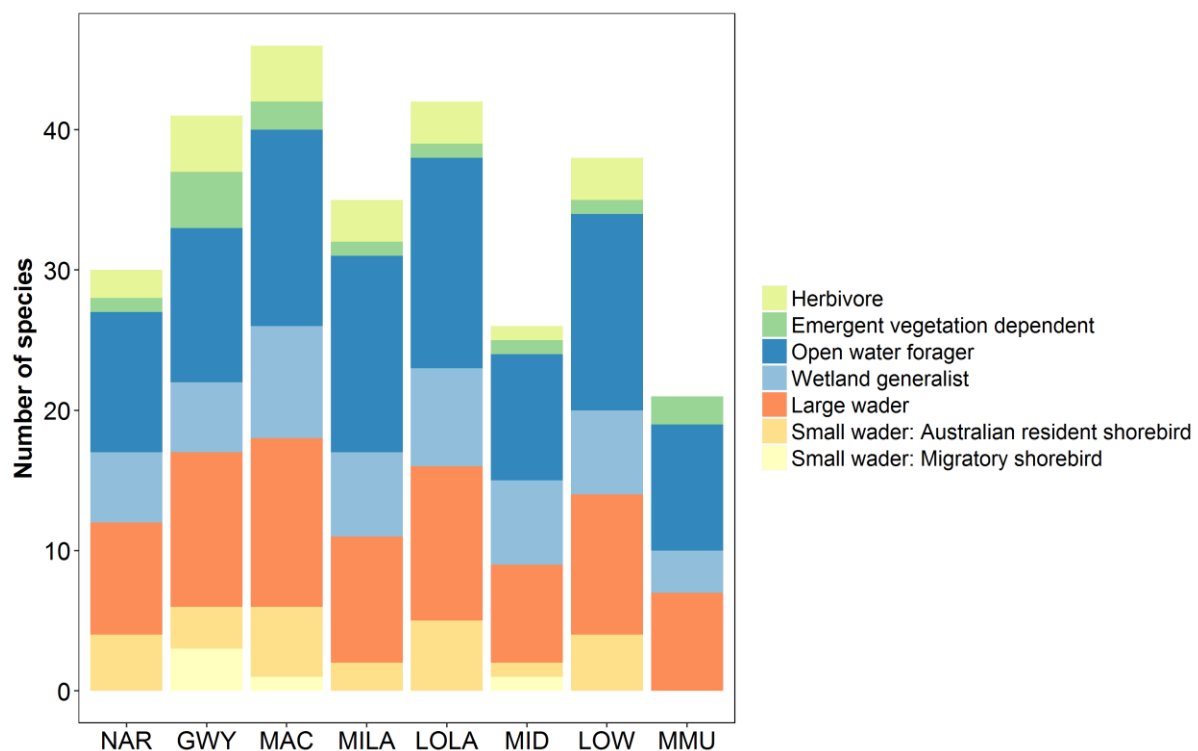


Figure 6 Total number of waterbird species, grouped by the seven ecohydrological groups, observed during ground surveys in the eight wetland regions in spring 2016. NAR = Narran Lakes, GWY = Gwydir Wetlands, MAC = Macquarie Marshes, MILA = Mid-Lachlan Wetlands, LOLA = Lower Lachlan Wetlands, MID = Mid-Murrumbidgee Wetlands (not including Fivebough-Tuckerbil Ramsar Site), LOW = Lowbidgee Floodplain, and MMU = Mid-Murray (Millewa only).

Table 1 Maximum count of each waterbird species recorded across the eight wetland regions in the spring 2016 ground surveys. *Indicates breeding species (nesting activity and/or young detected for species observed).

Common Name	NAR	GWY	MAC	MILA	LOLA	MID	LOW	MMU
Emergent vegetation dependent								
Australasian Bittern (Ee)	0	0	3	0	0	0	0	3
Australian Little Bittern	0	3	0	0	0	0	0	0
Buff-banded Rail	0	3	0	0	0	0	0	0
Comb-crested Jacana (v)	0	1	0	0	0	0	0	0
Purple Swamphen	1	31*	62*	7	3	1	7	8
Herbivore								
Australian Shelduck	0	0	8*	0	9	0	50*	0
Australian Wood Duck	44	141*	53	28	28	72*	36*	0
Magpie Goose (v)	0	217*	118*	58*	0	0	0	0
Plumed Whistling-Duck	6	1301*	196	74	13	0	9	0
Wandering Whistling-Duck	0	6	0	0	0	0	0	0
Large wader								
Australian White Ibis	13	177	327*	115	20	62	93*	109*
Brolga (v)	0	19	0	0	0	0	0	0
Cattle Egret	1	185	13	0	3	0	19	0
Eastern Great Egret	0	123	178	3	13	5	43*	20*
Glossy Ibis	0	18	134	7	0	0	0	0
Intermediate Egret	24	23	200	0	3	8	53*	0
Little Egret	2	0	75	1	2	0	0	0
Nankeen Night-Heron	7	3	15	4	2	0	12	5
Royal Spoonbill	21	28	40	0	1	0	8	90*
Straw-necked Ibis	4	229	1160*	36	1743	20	1987*	457*
White-faced Heron	13	45*	47	16	27	28	47*	2
White-necked Heron	0	12*	58*	21	53*	14	101*	2
Yellow-billed Spoonbill	0	0	18*	4	8	2	5*	0
Open water forager								
Australasian Darter	2	48	36*	10	23*	2	26*	9*
Australasian Grebe	3	202*	28	1	5	0	12*	0
Australian Pelican	26	111	47	514	36	9	219	7
Blue-billed Duck (v)	0	0	5	2	15	0	0	0
Caspian Tern (J)	0	0	0	1	0	0	2	0
Eurasian Coot	7	151*	142*	41*	205*	23*	55*	0
Great Cormorant	3	12	24	0	57	3*	76*	12
Great Crested Grebe	0	15	34	64	55	3	53*	23
Hardhead	36	230*	377*	41	141*	0	34	3
Hoary-headed Grebe	0	0	6*	3	53*	0	10	0
Little Black Cormorant	2	59	124*	18	108*	38	32*	105*
Little Pied Cormorant	1	92	61	8	81*	11	79*	271*
Musk Duck	0	0	4	1	3	0	0	5
Pied Cormorant	0	9	7	23	10	0	171	0
Silver Gull	19	0	0	0	1	0	6	0
Whiskered Tern	66	23	41	47	26	0	1	5

Common Name	NAR	GWY	MAC	MILA	LOLA	MID	LOW	MMU
Small wader: Australian resident shorebird								
Banded Lapwing	9	0	0	0	0	0	6	0
Black-fronted Dotterel	0	16	17	0	3	0	11	0
Black-winged Stilt	22	32	170	10*	37	0	60	0
Masked Lapwing	22	25*	30	7	7	2	7*	0
Red-kneed Dotterel	0	0	1	0	2	0	0	0
Red-necked Avocet	68	0	2	0	3	0	0	0
Small wader: Migratory shorebird								
Latham's Snipe (J,R)	0	52	2	0	0	6	0	0
Marsh Sandpiper (J,C,R)	0	30	0	0	0	0	0	0
Sharp-tailed Sandpiper (J,C,R)	0	16	0	0	0	0	0	0
Wetland generalist								
Australasian Shoveler	0	0	12	0	5	4	23*	0
Black-tailed Native-hen	2	0	0	0	1	0	0	0
Black Swan	60*	31*	120*	166*	144*	0	147*	12*
Chestnut Teal	0	0	1	4	0	2	0	0
Dusky Moorhen	0	44*	14*	4	17*	4	2	0
Freckled Duck (v)	0	0	1	0	0	0	0	0
Grey Teal	343	598*	1082	153*	553*	247*	960*	22
Pacific Black Duck	109	396*	198	17	76*	106*	77*	8
Pink-eared Duck	31	34*	37*	38*	65*	43*	41*	0
Total Species	30	41	46	35	42	24	38	22
Total no. of Ecohydro Groups	6	7	7	6	6	6	6	4
Total no. of BWS Guilds	5	5	5	5	5	5	5	4
Maximum Total Abundance	967	4792	5847	1547	3660	741	4990	898
<i>Total number of species observed breeding during spring 2016 surveys*</i>	<i>1</i>	<i>15</i>	<i>16</i>	<i>6</i>	<i>12</i>	<i>6</i>	<i>22</i>	<i>8</i>

^ Status: J = JAMBA, C = CAMBA, R = ROKAMBA (listed under international migratory bird agreements Australia has with Japan, China and Republic of North Korea, respectively), listing under the NSW BC Act 2016 (e = endangered, v = vulnerable), and under Commonwealth EPBC Act 1999 (E = Endangered).

Common names are based on Christidis and Boles (2008) and species groupings in the ecolohydrological and BWS functional guilds (based on UNSW aerial surveys) are described in Appendix 2.

Wetland Regions: NAR = Narran Lakes, GWY = Gwydir Wetlands, MAC = Macquarie Marshes, MILA = Mid-Lachlan Wetlands, LOLA = Lower Lachlan Wetlands, MID = Mid-Murrumbidgee Wetlands (not including the Fivebough-Tuckerbil Ramsar site), LOW = Lowbidgee Floodplain, and MMU = Mid-Murray (Millewa only).

The nationally endangered Australasian Bittern (*EPBC Act 1999*) was detected in four of the wetland regions during the spring 2016 surveys. The Macquarie Marshes and Gwydir Wetlands supported the greatest number of listed waterbird species in the spring 2016 surveys (five and seven species, respectively) (Figure 7). The vulnerable Blue-billed Duck (*BC Act 2016*) was detected in three wetland regions in spring 2016 (Macquarie Marshes, Mid-Murrumbidgee and Lowbidgee Floodplain). Previously, most records for this species were from spring surveys in the Lowbidgee Floodplain (Figure 7). Three migratory shorebird species were detected during the spring 2016 surveys: Sharp-tailed Sandpiper, Latham’s Snipe and Marsh Sandpiper. Sharp-tailed Sandpipers (Plate 2) have been the most frequently detected migratory shorebird species across the regions during the last five years of spring ground surveys (Figure 7). We also observed Pied Heron (Plate 2) during the 2016-17 colony surveys. This species typically resides in wetlands in Northern Australia and has only been recorded in small numbers in the MDB during large flood events. Similarly, Comb-crested Jacana (*BC Act 2016*) are more common in Northern Australia, but were observed in the Gwydir Wetlands in spring 2016.

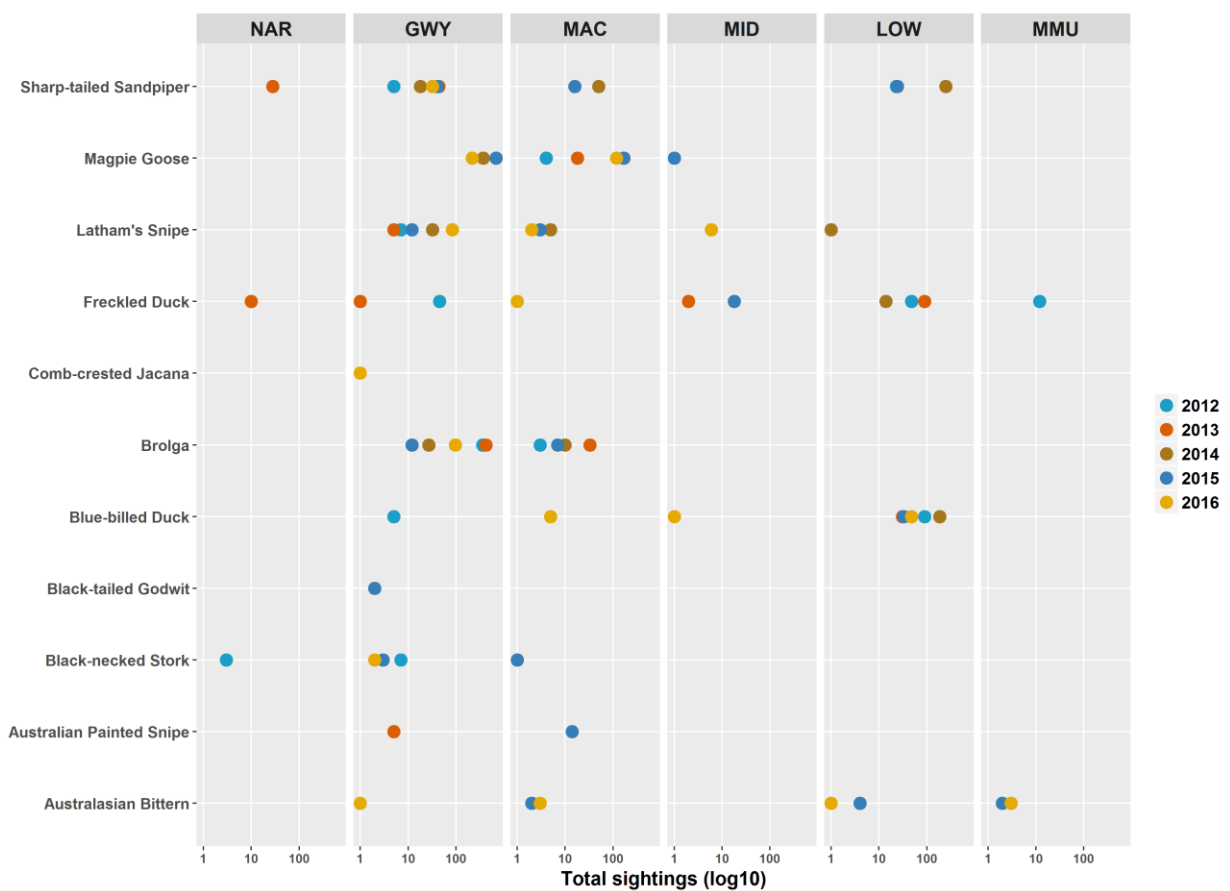


Figure 7 Number of sightings of listed waterbird species in selected wetland regions over five years of counts (2012-16). See Table 1 for Wetland Region codes.



Plate 2 Sharp-tailed Sandpipers (*left*) were the most common migratory shorebird species during our spring surveys and can reach large numbers when conditions are suitable (Credit: Peter Knock, Ecological Australia). Pied Herons (*right*) were observed breeding in small numbers in the Macquarie Marshes and Lowbidgee Floodplain in 2016-17 (Credit: N Brookhouse, NPWS).

2.2 Total waterbird numbers increased in response to flooding

Overall, the results of the ground spring surveys were consistent with the findings of UNSW’s aerial surveys. Total waterbird abundance was high in the regions where there was inundation of survey sites. The Macquarie Marshes, Lower Lachlan and Lowbidgee Floodplain supported the most waterbirds during the aerial surveys. The ground surveys recorded high waterbird abundance in the Macquarie Marshes relative to the other wetland regions, with large numbers of large waders and ducks recorded in the Macquarie Marshes in spring 2016 (Figure 8 and Figure 9). Total waterbird abundance had increased in the Macquarie Marshes during the 2016 ground surveys compared to the three previous years of spring surveys (Figure 8). In the Lowbidgee Floodplain, Gwydir Wetlands and Mid-Murray regions, total waterbird abundance in the spring 2016 surveys had not increased relative to the previous wet period recorded between 2010-12. Total waterbird abundance remained relatively low in the Narran Lakes and Mid-Murrumbidgee wetlands in 2016 (Figure 8).

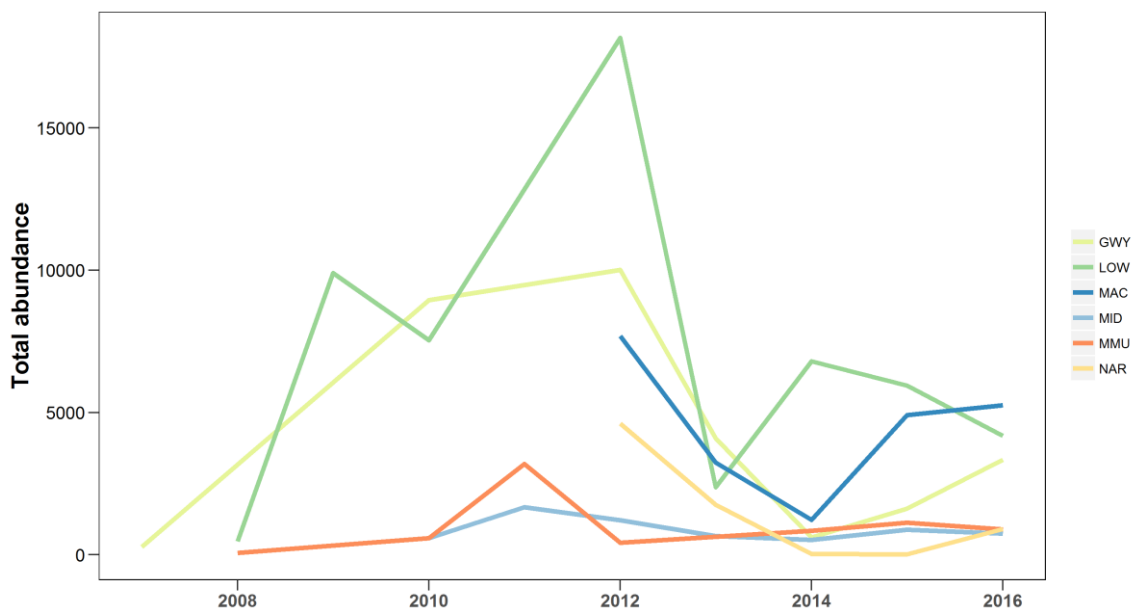


Figure 8 Total abundance of waterbirds observed during spring ground counts for the selected wetland regions where counts are available from 2007 onwards. Wetland Regions: NAR = Narran Lakes, GWY = Gwydir Wetlands, MAC = Macquarie Marshes, MID = Mid-Murrumbidgee Wetlands (not including the Fivebough-Tuckerbil Ramsar Site), LOW = Lowbidgee Floodplain, and MMU = Mid-Murray (Millewa only).

Large waders (ibis and egrets) and ducks contributed most to waterbird abundance across the surveyed wetland regions (Figure 9). Straw-necked Ibis were the most abundant waterbird species in four of the eight wetland regions. Grey Teal were the next most abundant species overall (Figure 10). With the wetter conditions, there was a general shift in the patterns of occurrence of many species. Notably, Hardheads and Great Crested Grebes featured in the top ten species for many of the wetland regions in 2016-17 (Figure 10). In contrast, during drier conditions in the previous year (2015-16) Hardheads were only common in the Mid-Murrumbidgee Wetlands and Great Crested Grebes did not feature in the top ten species in any of the wetland regions (see Spencer *et al.* 2016).

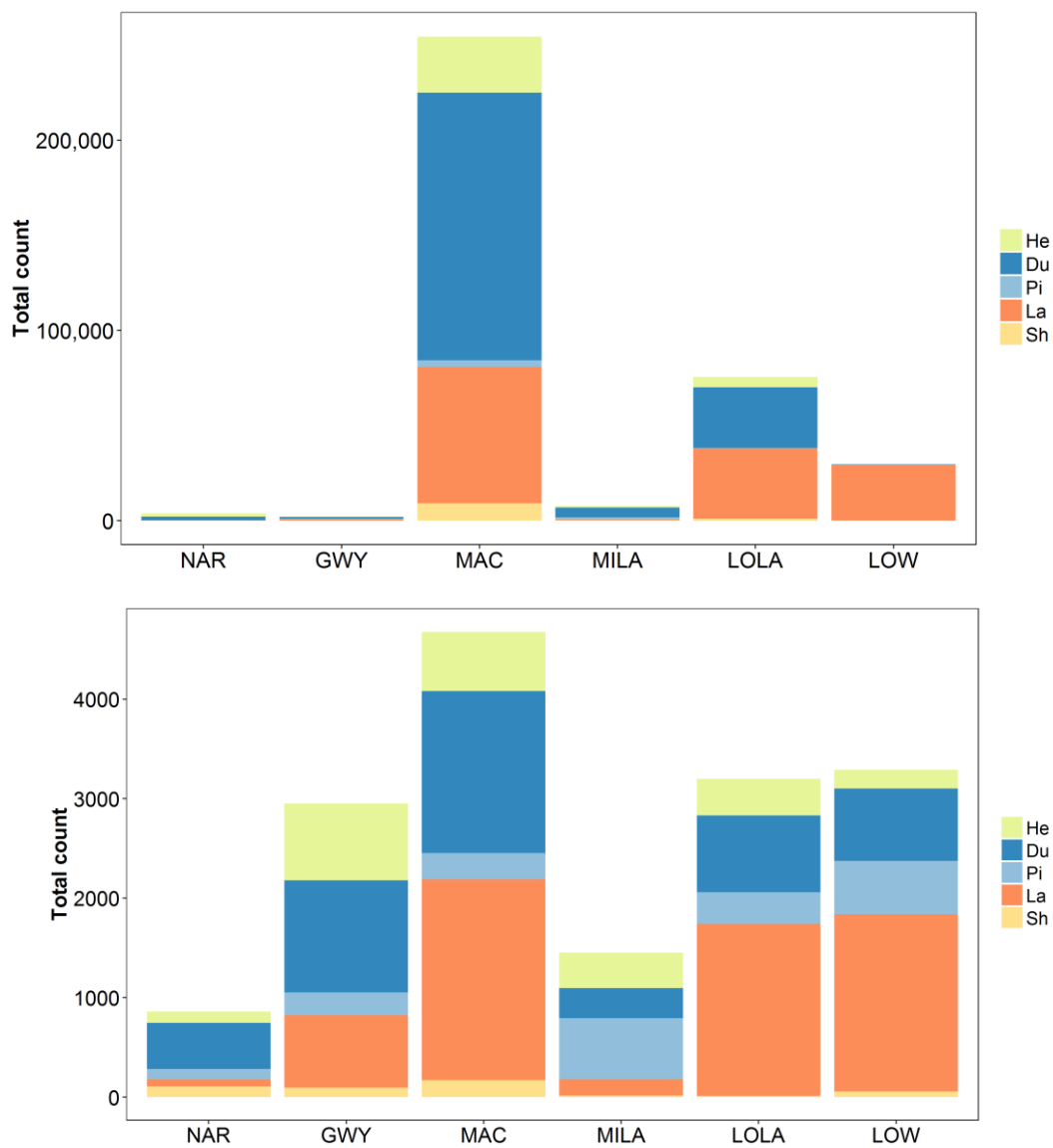


Figure 9 Total abundance of waterbird guilds from six selected wetlands regions from UNSW aerial surveys (*upper*) and OEH ground surveys (*lower*) in spring 2016. Note the difference in the scale of the y-axis between the two survey types and the difference in survey coverage where aerial surveys cover the entire floodplain and the ground surveys cover a subset of wetland sites each spring. See Figure 9 for wetland region codes. UNSW aerial survey functional group (Bino *et al.* 2015): Du = Ducks and small grebes, He = Herbivore, Pi = Fish-eating waterbird, Lw = Large wader, Sh = Shorebird.

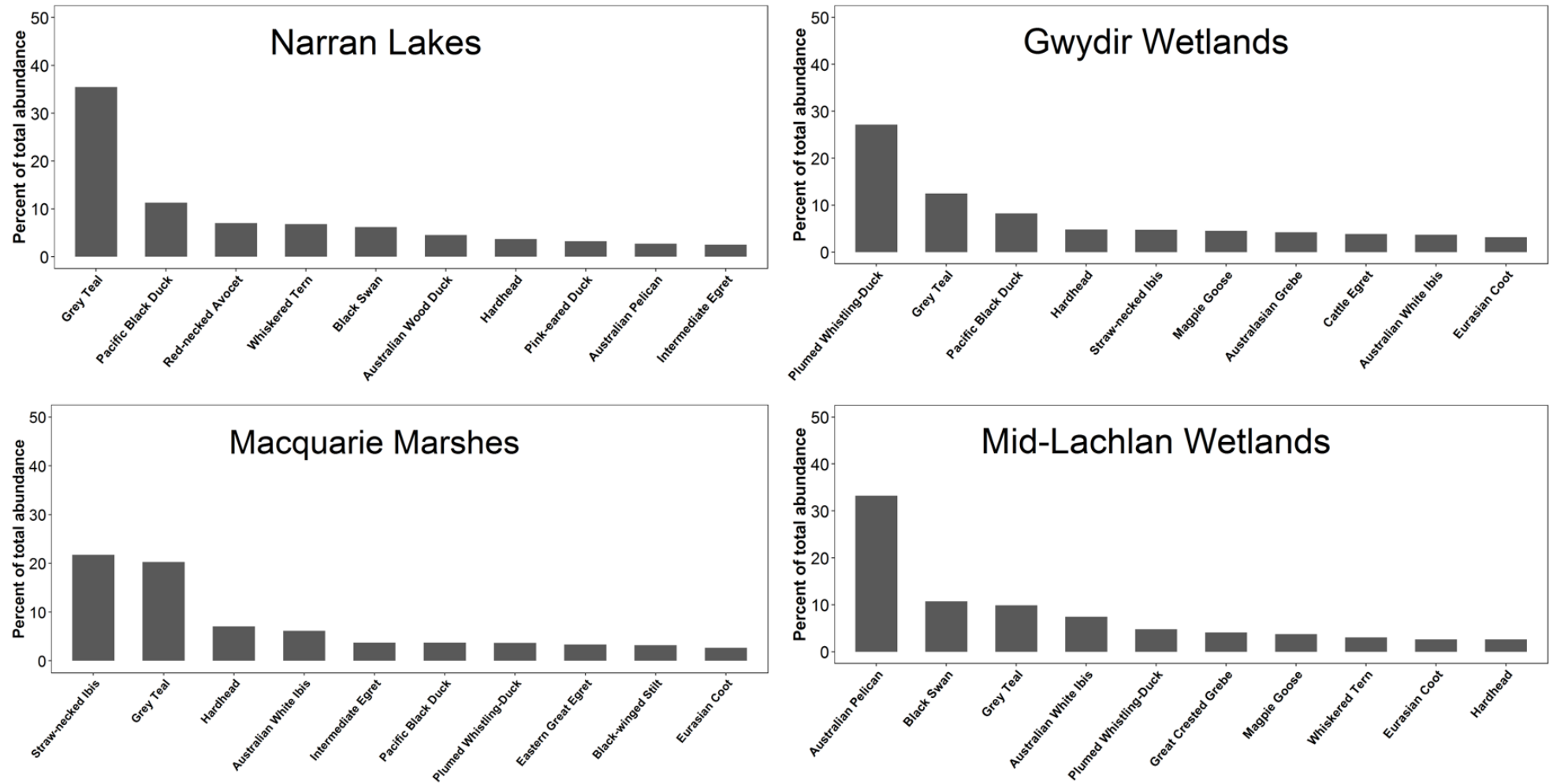


Figure 10A Percentage composition of the ten most numerous waterbird species recorded in the wetland regions during the spring 2016 ground surveys.

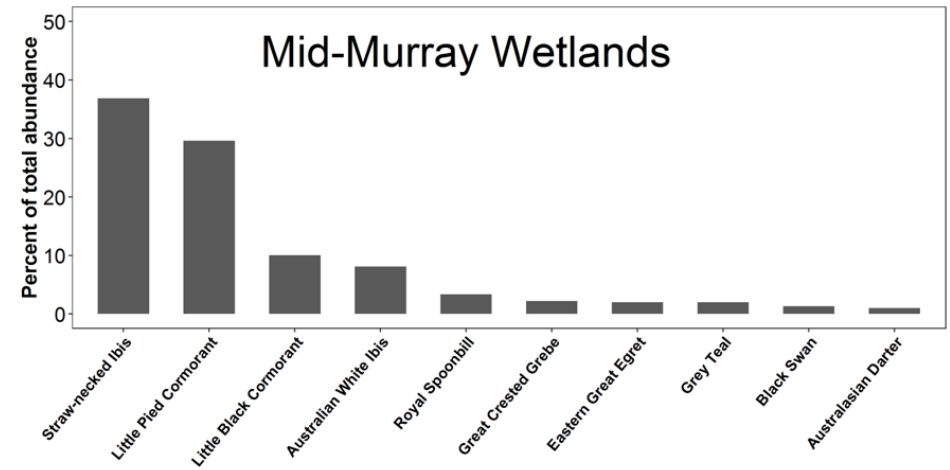
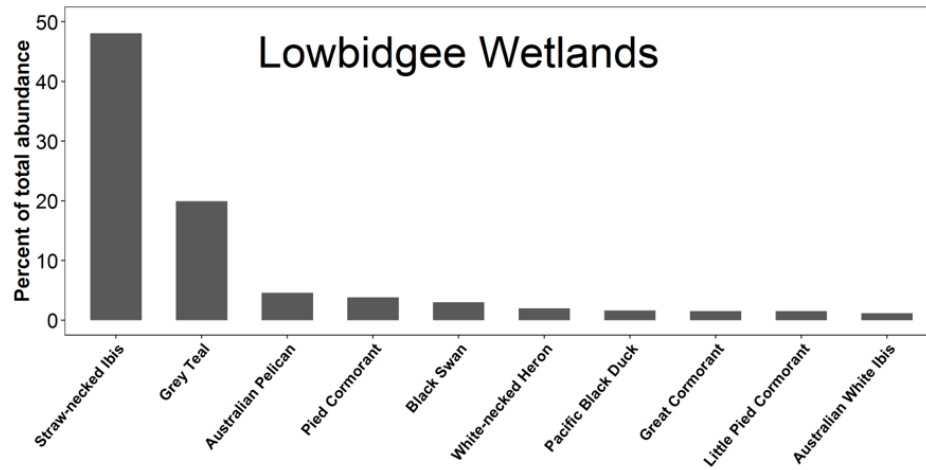
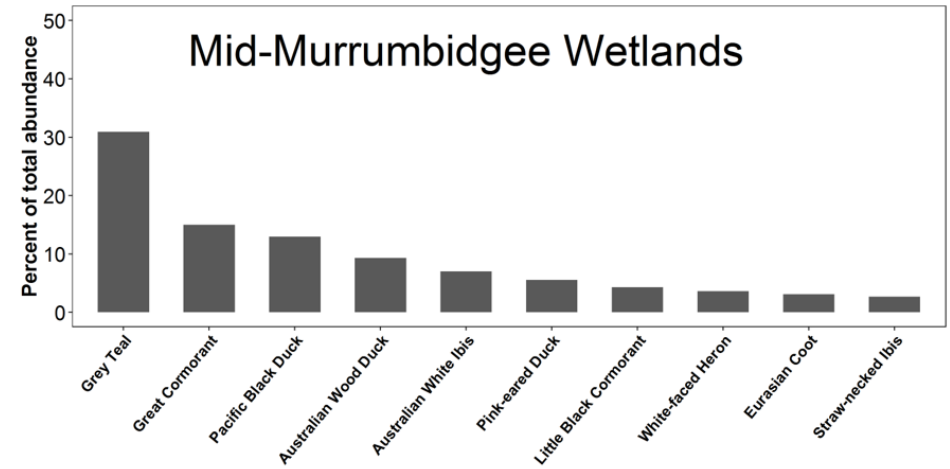
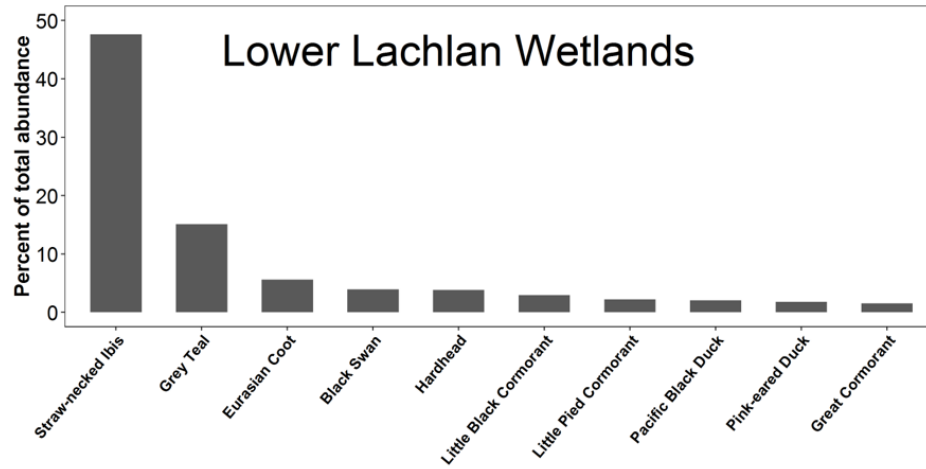


Figure 10B Percentage composition of the ten most numerous waterbird species recorded in the wetland regions during the spring 2016 ground surveys.

2.3 Waterbird breeding activity was significant and widespread

Waterbird breeding activity was detected in all surveyed wetland regions in 2016-17. Waterbird breeding activity was greatest in the Macquarie Marshes, Lowbidgee Floodplain, and Lower Lachlan wetlands (Figure 11): 32 breeding species were recorded in the Lowbidgee wetlands, 30 breeding species in the Macquarie Marshes and 28 breeding species in the Lower Lachlan. Heavy rainfall recorded locally and in the upper catchments of most valleys over winter and early spring 2016 resulted in extensive flooding in the MDB. The flooding provided suitable conditions for widespread colonial waterbird breeding in the Macquarie Marshes, Lowbidgee floodplain, Lower Lachlan, Mid-Lachlan, Mid-Murrumbidgee and Mid-Murray wetland regions. No colonies were active in the Narran Lakes in 2016-17.

At least 83 colony locations supported waterbird breeding across seven wetland regions in 2016-17. Eleven major colonies (>5,000 nests), 25 medium size colonies (>250 – <5,000 nests) and 47 small (<250 nests) colonies were detected. In comparison, only 15 colonies (3 medium and 12 small colonies) were detected across the wetland regions in 2015-16. In 2016-17 the large colonies were spread across the Macquarie (four sites), Lowbidgee (four sites), Lower Lachlan (two sites) and Mid-Lachlan (one site) (Figures 11 and 12). The largest colonies supported Straw-necked Ibis breeding (seven sites in total, which ranged in size from 6,000 ->100,000 nests), Australian Pelican breeding (two sites, 6,000 – 6,500 nests) and egret and heron breeding (two sites, 5,500 – 11,500 nests).

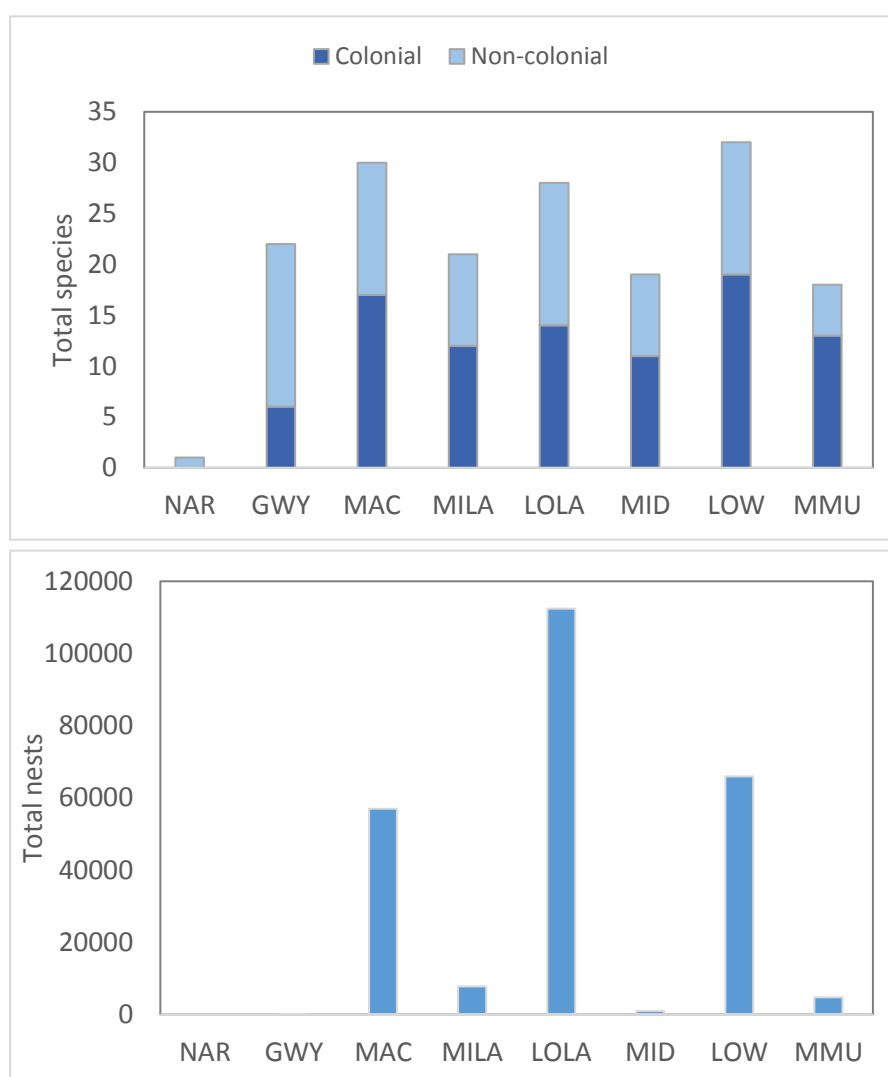


Figure 11 Total number of colonial and non-colonial waterbird species detected breeding (*upper*) and total number of nests (*lower*) in the surveyed wetland regions in 2016-17. See Table 2 for wetland region codes.

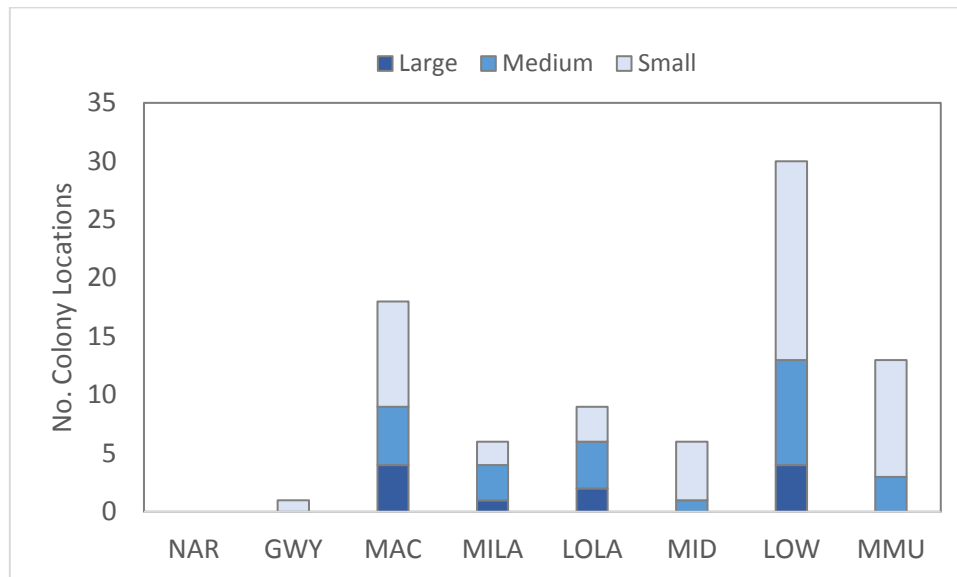


Figure 12 Total number of colony locations detected during ground and aerial surveys in the surveyed wetland regions in 2016-17. Eleven major colonies (>5000 nests), 25 medium size colonies (>250-<5000 nests) and 47 small (<250 nests) colonies were active. See Table 2 for Wetland Region codes.

Around 40% of known colony sites (more than 200 sites known in total) were active in the wetland survey regions in 2016-17. Many of the active sites in 2016-17 were historical sites but there were an additional 10 colonies that were initiated in new locations where colonial waterbird breeding had not previously been recorded. Nesting egrets, cormorants and herons utilised flooded river red gum (*Eucalyptus camaldulensis*) forests or woodlands. The next most commonly used nesting habitats were lignum (*Duma florulenta*) and reeds (*Phragmites australis*). The two large Australian Pelican colonies nested on artificial levee banks which provided island-like habitat (Figure 13, Plate 3).

The large river red gum colonies supported the greatest number (up to 14 species) of colonial-nesting waterbird species. These colonies were in the Macquarie Marshes and Lowbidgee floodplain, which supported the largest number of colonial waterbird breeding species overall (17 and 19 species, respectively) (Figure 12). The river red gum and river cooba colonies supported large numbers of Intermediate Egrets and Nankeen Night-Herons in the Lowbidgee floodplain and Macquarie Marshes, and smaller numbers of Cattle Egret, Little Egret, Australasian Darters and cormorants, White-necked Herons, Royal Spoonbill and Yellow-billed Spoonbill (Plate 4). Pied Herons were confirmed nesting in egret colonies in the Macquarie Marshes Northern Nature Reserve and Lowbidgee Floodplain in 2016-17 (Table 2). The lignum and reedbed colonies supported very large colonies of Straw-necked Ibis with smaller numbers of nesting Australian White Ibis and Royal Spoonbill. The colonies with dead trees supported nesting Pied Cormorant and Great Cormorant. The active colony sites also provided feeding and breeding habitat for many non-colonial waterbird species.

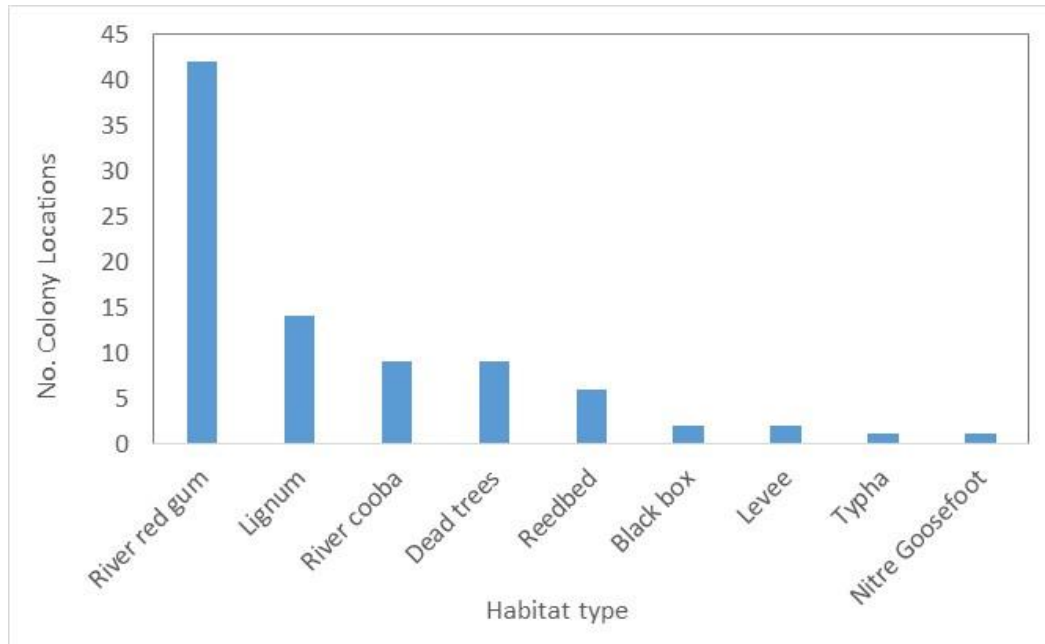


Figure 13 Types of nesting habitat used by colonial waterbird species included floodplain trees habitat (river red gum, cooba, dead trees and black box), emergent vegetation (lignum, reedbeds, cumbungi (*Typha* sp.) and nitre goosefoot) and island habitat (levee banks).



Plate 3 Large waterbird colonies (>5,000 nests) at Booligal Swamp (ibis), Lower Lachlan (*left*) and Lake Brewster (pelicans), Mid-Lachlan (*right*) in December 2016 (Credit: P Packard, OEH).

Table 2 Total numbers of surveyed nests for 19 colonial waterbird species in the eight wetland regions in 2016-17. Note there may have been additional cormorant colonies not detected during the spring and summer ground and aerial surveys and so total counts for these species for 2016-17 are likely to be underestimates. Total counts for large ibis colonies were provided by Kate Brandis (UNSW).

Common Name	NAR	GWY	MAC	MILA	LOLA	MID	LOW	MMU	Total nests
Australasian Darter	0	3	72	11	93	116	96	14	405
Australian Pelican	0	0	0	7,067	0	0	6,000	0	13,067
Australian White Ibis	0	0	1,720	22	272	19	5,777	1,150	8,960
Cattle Egret	0	17	93	0	0	0	3	0	113
Cormorant spp.	0	0	668	300	1,301	131	842	143	3,385
Eastern Great Egret	0	15	911	4	34	4	436	174	1,578
Egret spp.	0	70	155	0	0	0	425	0	650
Glossy Ibis	0	0	150	0	167	0	207	0	524
Great Cormorant	0	0	1	0	576	42	1,407	34	2,060
Intermediate Egret	0	1	9,673	21	8	0	466	50	10,219
Little Black Cormorant	0	0	209	209	475	489	1,049	269	2,700
Little Egret	0	0	18	0	0	0	8	0	26
Little Pied Cormorant	0	26	252	15	240	104	803	308	1,748
Nankeen Night-Heron	0	2	6,296	25	132	10	1,982	1,653	10,100
Pied Cormorant	0	0	0	63	3	0	81	30	177
Pied Heron	0	0	9	0	0	0	2	0	11
Royal Spoonbill	0	0	640	20	194	2	770	133	1,759
Spoonbill spp.	0	0	0	0	5	0	22	0	27
Straw-necked Ibis	0	0	35,912	11	108,892	0	44,944	403	190,162
White-faced Heron	0	0	1	0	0	1	4	0	6
White-necked Heron	0	0	52	16	62	2	608	301	1,041
Yellow-billed Spoonbill	0	0	110	0	4	7	27	1	149
Total nests	0	134	56,942	7,784	112,458	927	65,959	4,663	248,867
Total colonial waterbird breeding species	0	6	17	12	14	11	19	13	19

^Wetland region codes: NAR = Narran Lakes, GWY = Gwydir Wetlands, MAC = Macquarie Marshes, MILA = Mid-Lachlan Wetlands, LOLA = Lower Lachlan Wetlands, MID = Mid-Murrumbidgee Wetlands (including Yanco-Billabong Creek colonies), LOW = Lowbidgee Floodplain (including Junction Wetlands colonies) and MMU = Mid-Murray Wetlands.

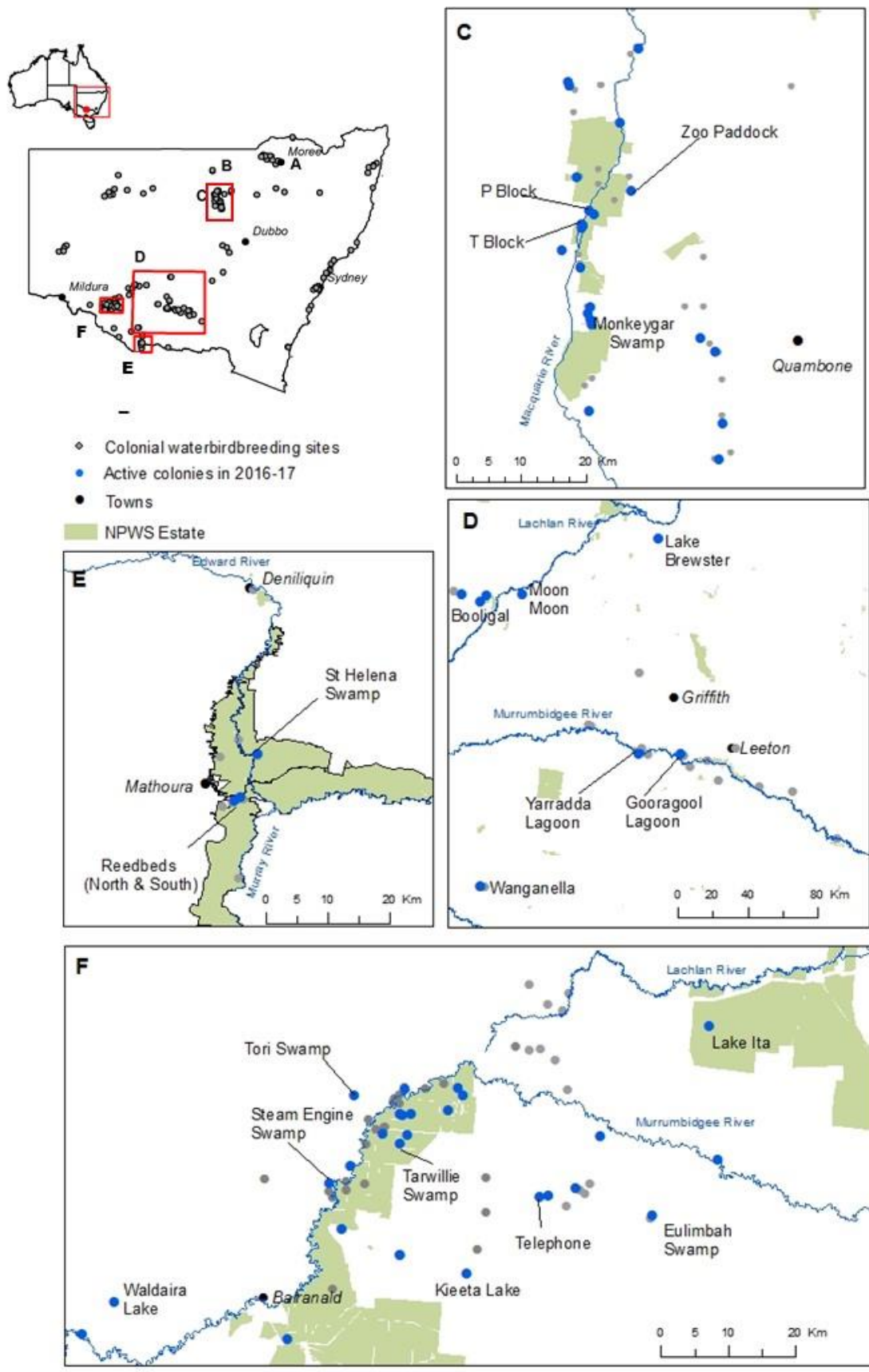


Figure 14 Distribution of active sites and other known (inactive) colonial waterbird breeding sites in 2016-17 across the surveyed wetland regions. Only one colony was detected in the Gwydir Wetlands (A) and no colonial waterbird breeding was detected in the Narran Lakes (B). Insets show distribution of colony sites in the Macquarie Marshes (C), Lower Lachlan, Mid-Murrumbidgee, Mid-Lachlan (D), Mid-Murray (E), Lowbidgee Floodplain, neighbouring Junction Wetlands and Lower Lachlan wetlands (F).

There were 11 environmental watering actions in total that supported active waterbird colonies in the NSW MDB in 2016-17. This included three watering actions in the NSW Mid-Murray, four watering actions in the Lowbidgee Floodplain, and one watering action in the Lower Lachlan, Mid-Lachlan Macquarie Marshes and Gwydir Wetlands. Ground surveys provided information on water levels and nesting stage which assisted water managers.

Gwydir Wetlands

Australian White Ibis and Magpie Geese were observed building nests in the Central Gingham (approximately 15 nests each) during spring ground surveys in early November 2016. UNSW also detected a small waterbird colony at Tillaloo in the central Gingham near the Goddards Lease Ramsar site (Figure 15) during aerial surveys of the Gwydir Wetlands on 14 and 15 November. An additional ground survey by OEH on 17 November confirmed active nesting egrets (around 100 nests) and cormorants (around 30 nests) at this location (see Table 2). Cattle Egret and Eastern Great Egret, were confirmed nesting, with Intermediate Egrets building nests at the time of the ground survey. NSW and Commonwealth environmental water was delivered to the lower Gwydir River and Gingham watercourses to build upon natural winter and spring flows which caused minor flooding in the upper parts of the Gingham during late September 2016 (see Section 1.4).

Environmental water delivered over summer extended the duration of wetland inundation in the Lower Gwydir and Gingham wetlands, and provided newly inundated habitat in the Mallowa wetlands to provide waterbird feeding habitat and support breeding cycles of waterbirds and frogs (Ocock and Spencer 2017; OEH 2017a). Site access to the Tillaloo colony was limited over summer 2017 so it was not possible to complete follow-up surveys to document colony completion.

Macquarie Marshes

Colonial waterbirds began nesting in the Macquarie Marshes in late September 2016 following extensive flooding from tributary flows, dam releases and local rainfall over winter months (Figure 16). Ground and aerial surveys from October 2016 to February 2017 confirmed that 17 colonial waterbird species were nesting across 18 colonies in the Macquarie Marshes. The two largest colonies, which in total supported an estimated 15,700 and 21,200 nests each, were dominated by Straw-necked Ibis with smaller numbers of nesting Australian White Ibis, Glossy Ibis and Royal Spoonbill. There were also two large egret colonies (supporting an estimated 5,610 and 11,230 nests each) in the Northern Macquarie Marshes Nature Reserve that supported large numbers of nesting Intermediate Egret and Nankeen-Night Heron, and smaller numbers of Eastern Great Egrets, Cattle Egrets and Little Egrets (Plate 3). Nesting Pied Heron (Plate 2) were also detected in the largest egret colony in December 2016 and January 2017. A medium-sized Royal Spoonbill and Australian White Ibis colony (estimated 500 nests) in Lake Paddock in the northern Marsh became active in early November 2016, a location where birds have not been previously recorded nesting. An additional Intermediate Egret and Nankeen Night-Heron colony (estimated 715 nests) was detected in the eastern Marsh which supported smaller numbers of Eastern Great Egret, Little Egret, White-necked Heron, Australasian Darter, Australian White Ibis and cormorants. There were a further 12 locations across the Macquarie Marshes which supported small colonies (<500 nests) of Australian white ibis, spoonbills, herons and cormorants.

The reproductive success of early-nesting Straw-necked Ibis in the Monkeygar Swamp colony was sustained by the delivery of flood mitigation water from Burrendong Dam from October 2016 to January 2017. Detailed nest monitoring by Brandis (2017) indicated that the success rates of marked Straw-necked Ibis nests in the Monkeygar Swamp and Zoo Paddock colonies (63-65%) were comparable to other colonies active in the southern MDB during spring 2016. Large numbers of juvenile ibis were observed foraging on the fringes of the colonies in mid-December 2016. Some ibis and spoonbills that started nesting late in the event were less successful (Brandis 2017) due to

dropping water levels and predation by ground-based predators (foxes and feral pigs) during the December 2016 to January 2017 period. Observations of marked nests of Glossy Ibis that started nesting in the Zoo Paddock colony in December 2016 recorded poor nest success (20.5%) compared to previous studies, and this was attributed to high rates of predation by ground predators which could access the nests because of low water levels (Brandis 2017). An avian botulism outbreak was also suspected to have impacted the Monkeygar and Zoo Paddock ibis colonies in December 2016. Limited laboratory testing did not confirm the outbreak, however, affected individuals of waterfowl species displayed symptoms of paralysis which is associated with avian botulism (USGS 1999). An estimated 100 dead juvenile Straw-necked Ibis, with no signs of predation, were recorded during ground surveys of the Monkeygar colony in mid-December 2016.

Ground surveys also indicated that the Lake Paddock spoonbill colony recorded poor success rates with dead young in more than 20% of nests in mid-December 2016. While there was some evidence of fox and pig predation, most failed nests had intact large chicks, indicating nest abandonment rather than predation. Water levels were very low in this site during the December 2016 survey with 45% of surveyed Royal Spoonbill nests recording no water underneath each nest. Water level monitoring at the site indicated that the colony was dry by 1 January 2017. However, some successful fledgling was evident during the December survey with an estimated 70 juvenile Royal Spoonbill and 50 Australian White Ibis juveniles observed feeding in the colony with adult birds.



Plate 4 (clockwise): Cattle Egret nesting in river cooba; Intermediate Egret nesting in river red gum; Nankeen Night-Heron and Australasian Darter Fledglings (Credit: N. Brookhouse, NSW NPWS, Macquarie Marshes Northern Nature Reserve, Dec 2016).

Once the flood mitigation releases had ceased in January 2017, NSW and Commonwealth environmental water was delivered from late January to mid-February 2017 (see Figure 16 and Section 1.4) to extend the duration of flows to the colonies and adjoining feeding habitat in the northern Marsh. The Zoo Paddock and Lake Paddock colony sites are located higher on the floodplain and so are more difficult sites to deliver managed flows to. The watering action benefited the Monkeygar ibis colony and the egret colonies in the Northern Nature Reserve and non-colonial species including Australian Little Bittern (detected breeding at Wilgara), Australasian Bittern, migratory Latham’s Snipe and resident shorebirds recorded on the margins of several of the colonies. At least 13 non-colonial waterbird species were detected breeding in the Macquarie Marshes over 2016-17 (Figure 12).

Ground surveys of the other colonies from October 2016 to February 2017 recorded low mortality (<10 dead birds per monthly visit). During the January and February 2017 surveys few early stage nests (<5% of total nests) and juveniles (of every nesting species) were recorded in the colonies. The only exception was the Kia Ora (Ringorah Bridge) colony in the eastern Marsh, where relatively high mortality of fledged egrets and large chicks (>100 individuals) was observed in the mid-February 2017 survey. This site may have been impacted by the extreme heat (>45°C) observed in the days preceding the ground survey.

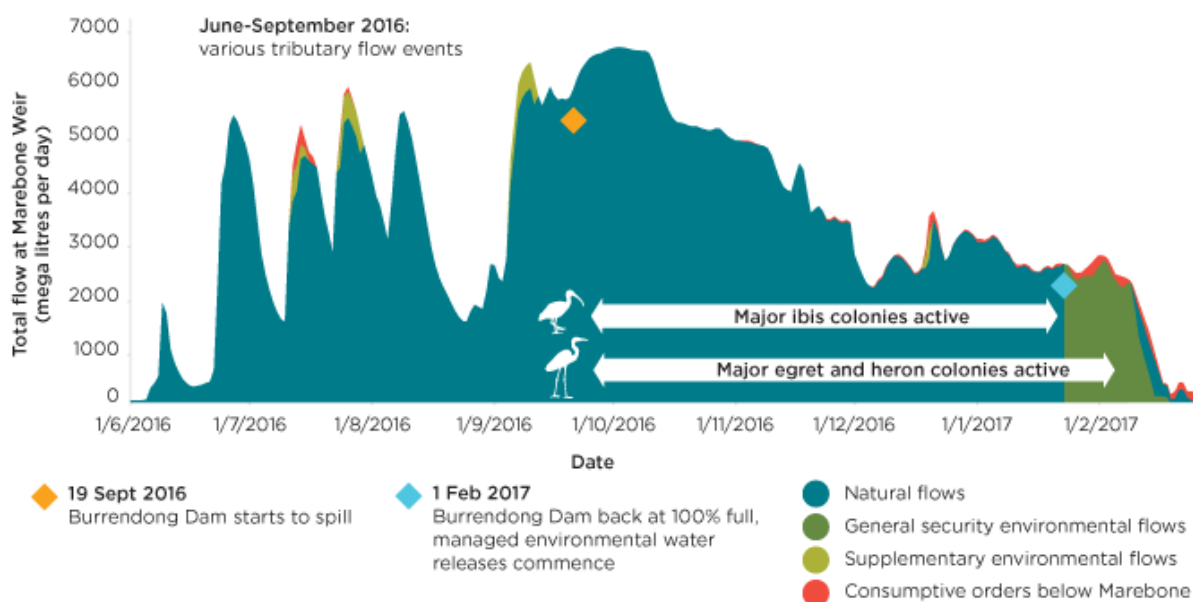


Figure 15 Flow type releases from Burrendong Dam and flow volumes at Marebone Weir in relation to waterbird breeding in the Macquarie Marshes (reproduced from OEH 2017d).

Mid-Lachlan wetlands

There were at least six separate colonies active in the Mid-Lachlan wetland region in 2016-17. Mixed colonies of ibis, cormorants, egrets, spoonbills and herons were recorded at Lake Cowal (around 330 nests) and Lake Cargelligo (estimated 300 nests) and smaller colonies were observed at (<50 nests) Gunning Gap (Goobang Creek) and Roto Paddock Swamp (Hunthawang National Park). The largest breeding events were recorded at Lake Brewster (Figure 15, Plate 3) where more than 7,000 Australian Pelican nests were recorded over two nesting events between November 2016 and July 2017.

A small nesting event (around 800 nests) in Lake Brewster was observed during OEH ground surveys and UNSW aerial surveys in early November 2016. In the following months, large numbers of pelicans congregated in Lake Brewster and began nesting in February 2017. Later in March 2017 these birds subsequently relocated to alternative levee banks and re-nested in the main site as used in previous

breeding events. Analysis of UAV imagery from March 2017 indicated that there were an estimated 6,242 pelican nests at the colony site. OEH staff conducted monthly surveys from February through to July 2017 to monitor the status of the pelican colony including stage of nesting, number of juveniles (Plate 5) and mortality. Following the establishment of a second pelican nesting event in Lake Brewster in February 2017, environmental water was delivered to Lake Brewster from mid-February to late June 2017 to maintain the depth and duration of inundation around the colony site to support the fledging of juvenile birds (see section 1.4). In mid-June there were an estimated 1,550 juvenile birds remaining at Lake Brewster and were observed being fed by adult birds. The on-ground surveys also indicated that there was some late stage mortality of young birds (<10% of total young) over the June-July 2017 period, which may have been caused by a rapid drop in air temperature from early June onwards.



Plate 5 Advanced pelican chicks at Lake Brewster (Credit: M. Carnegie, Lake Cowal Foundation, 16 May 2017).

Lower Lachlan wetlands

The Booligal Wetlands in the Lower Lachlan provide important breeding habitat for colonial waterbirds. Two large ibis colonies were recorded in the Booligal Wetlands (Figure 15) during 2016-17. The first event was very large (>100,000 nests, covering 68 ha) located on the Upper Merrimajeel Creek, on either side of the Booligal State Conservation Area boundary. The second nesting event was smaller (estimated 8,000 nests, covering 9 ha), located around 6 km downstream in the traditional nesting site at Booligal Block Bank in the Booligal State Conservation Area (see Plate 3). These colonies supported nesting Straw-necked Ibis, Australian White Ibis, Glossy Ibis and Royal Spoonbill, and many other wetland-dependent species (Dyer *et al.* 2018).

Large flocks of Straw-necked Ibis were observed by landholders in early August 2016 feeding in the Merrimajeel and Muggabah creek area following widespread rainfall and flooding. Ibis started laying eggs on the lignum in late August in the new Upper Merrimajeel site. This colony expanded from an estimated 4,000 nests to more than 100,000 nests over the September-October 2016 period (Dyer *et al.* 2018). The smaller Block Bank colony was detected during an aerial survey on 19 December 2016. Overall reproductive success at the Block Bank colony site was lower (64%) than in the earlier Upper Merrimajeel event (83%) (Dyer *et al.* 2018). Water levels were maintained at the Upper Merrimajeel site for the duration of the nesting event by natural inflows, from high rainfall and unregulated flows in the upper Lachlan Catchment over spring 2016 (Figure 4A). Commonwealth and NSW environmental water (4,895 ML) was needed to maintain water levels at the Booligal Block Bank colony from January to March 2017. Water levels were similar for both colonies with minimal

fluctuations in water depth, however, the Upper Merrimajeel colony started earlier in the season when temperatures were cooler the availability of surrounding foraging habitat was greatest. The Booligal Block Bank colony also experienced some predation by pigs and ravens, and there was some evidence of an outbreak of avian botulism (Dyer *et al.* 2018).

Smaller egret, heron, ibis, spoonbill and cormorant colonies were also active at Moon Moon Swamp (Figure 15) (around 670 nests) and Lake Tarwong (around 890 nests) over the October 2016 to March 2017 period. Top Lake, upstream of Lake Tarwong, supported small numbers of nesting Glossy Ibis (estimated 50 nests), egret, spoonbill, cormorant and heron nests (an additional 80 nests) from mid-December 2016 onwards. Ground surveys late in the season indicated that there had also been active cormorant nesting at Murphy's Lake (estimated 780 nests), Lake Bullogal (estimated 200 nests), Lake Ita (estimated 300 nests) and Murrumbidgee Swamp (estimated 20 nests).

Mid-Murrumbidgee region

There were at least three active waterbird colonies in the mid-Murrumbidgee wetlands in 2016-17. Yarradda Lagoon (estimated 170 nests, 10 species) and Gooragool Lagoon (estimated 600 nests, four species) (Figure 15) supported cormorant, heron, spoonbill, white ibis and egret nests from October 2016 to April 2017. This was the first record of Eastern Great Egrets nesting at Yarradda Lagoon since surveys began in 2010 (Spencer 2017). Small numbers (estimated 50 nests) of nests were also active in the neighbouring Yanco-Billabong system at Dry Lake, Wilson's Anabranche (cormorants) and Wanganella Swamp (white ibis and spoonbills) in 2016-17. These breeding events were initiated following natural overbank flooding from September to November 2016. NSW and Commonwealth environmental water was delivered to Yanco-Billabong system (9,300 ML) to inundate Wanganella Swamp and maintain nesting habitat (see Appendix 1).

Lowbidgee Floodplain

There were at least 30 colonies active in the Lowbidgee region in 2016-17, including two sites in the neighbouring Junction Wetlands (Mainie Forest and Waldaria Lake) (Figure 15). Breeding activity was detected in 19 colonial waterbird species including Australian Pelican and Pied Heron which have not previously been confirmed breeding in the Lowbidgee Floodplain. These colonies were initiated following heavy rainfall and widespread natural flooding in the Murrumbidgee Catchment from September to November 2016. These flows inundated an extensive area in the Lowbidgee Floodplain (194,076 ha, Thomas and Heath 2017) including known colony sites and surrounding foraging habitat. The natural flooding followed a period of environmental watering of large parts of the Nimmie-Caira and Redbank wetlands over August 2016. Following the peak of the natural flood, Commonwealth and NSW environmental water was delivered through multiple watering actions to support colony sites by extending the duration and depth of flooding at each site and inundating surrounding foraging areas (Thomas and Heath 2017; Wassens *et al.* 2018).

The watering actions were focused on three large ibis colonies in Telephone Swamp (30,000 nests), Eulimbah Swamp (15,000 nests) and Tori Swamp (6,000 nests) (Figure 15, Plate 6), a large pelican colony (6,000 nests) at Kieeta Lake, and four medium-sized (500-1,000 nests each) egret and heron colonies in the Redbank system (including Yanga National Park) and Nap Nap Swamp. The largest egret and heron colonies were at Steam Engine in North Redbank (estimated 1,400 nests), Two Bridges Swamp (estimated 1,000 nests) and Tarwillie Swamp (estimated 750 nests) in Yanga National Park and Nap Nap swamp in the Nimmie-Caira (estimated 650 nests). These sites were active from October 2016 to April 2017. The Kieeta Lake pelican colony was active from January to May 2017 with nests established on a levee bank in early January 2017 (Plate 7). Extended cormorant nesting (more than

500 nests in total) was also observed at Wagourah Lake (Yanga National Park) from October 2016 to June 2017.

Repeat measures of marked lignum clumps were completed in Tori Swamp and Eulimbah Swamp colonies. These clumps contained active Straw-necked Ibis, Australian White Ibis and Glossy Ibis nests. Overall reproductive success rates for Straw-necked Ibis nests were 59.4% for the Eulimbah Swamp colony and 39.7% for the Tori Swamp colony (Wassens *et al.* 2018). The Eulimbah Swamp colony had a low success rate for pairs which nested early in the event and abandoned nests after water levels dropped rapidly when levee banks were breached. The site was subsequently refilled with environmental water, ibis then re-nested and higher success rates were recorded with most nests completed by mid-January 2017 (Wassens *et al.* 2018). The Tori Swamp colony was a new breeding site in North Redbank and was active from early December 2016 to March 2017. Many dead juvenile ibis were observed in the Tori colony during a period of high temperatures in January and February 2017. Observations of the colonies and diagnostic testing indicated that avian botulism may have impacted some ibis and waterfowl in the Tori and Eulimbah colonies (Wassens *et al.* 2018). There was evidence of successful recruitment with several thousand juvenile birds foraging and roosting in the Tori, Telephone and Eulimbah colonies and surrounding areas during the final surveys from February-March 2017.

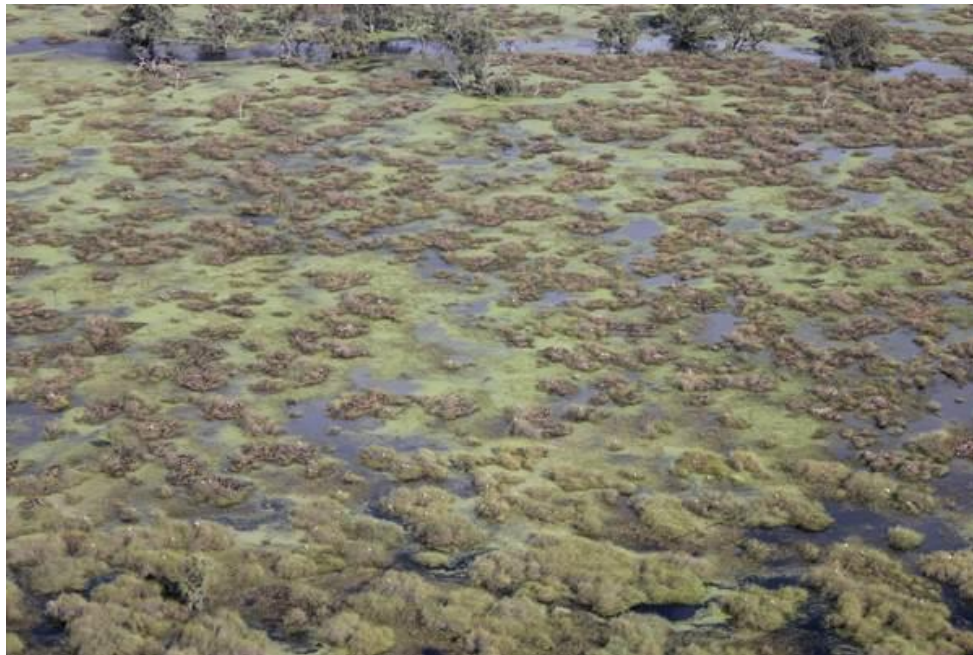


Plate 6 Aerial view of nesting Straw-necked Ibis, Glossy Ibis, Australian White Ibis and Royal Spoonbill in Tori Swamp, in the Lowbidgee Floodplain (Credit: A. Borrell, NSW NPWS, 20 December 2016).



Plate 7 Nesting Australian Pelicans at Kieeta Lake, Lowbidgee Floodplain (Credit: J. Spencer, NSW OEH, 1 February 2017).

Mid-Murray wetlands

At least 13 waterbird colonies were active in the NSW Mid-Murray region during 2016-17. These colonies were initiated following high river flows peaking in mid-October 2016 and widespread catchment rainfall over winter and early spring 2016. A ibis and spoonbill colony (estimated 1,700 nests) was active in the Reedbeds complex in Millewa Forest from October 2016 to January 2017 (McGinness *et al.* 2018). This nesting event was supported with environmental water delivered to maintain water levels from early November 2016 to late January 2017. There were also smaller cormorant and darter colonies in the adjoining wetlands at St Helena, Duck Lagoon, Coppingers Lagoon and Black Swamp. NSW NPWS staff detected a large Nankeen Night-Heron colony of more than 1,000 nests in the Niemur Precinct in October 2016. This site supported breeding Nankeen Night-Herons, and Eastern Great Egret (79 nests), Little Pied Cormorants (187 nests), White-necked Herons (129 nests), Little Black Cormorants (12 nests), Australasian Darter (3 nests) and Yellow-billed Spoonbills (1 nest) (A. Borrell, NSW NPWS, *pers. obs.* 2016). The Niemur colony was last active in 2010-11 during large-scale spring flooding (R. Webster, *pers. obs.* 2011).

Major flooding of the Murray River also created suitable conditions for waterbird colonies in the Koondrook-Perricoota Forest and Werai Forest. Pollack Swamp, in the Koondrook-Perricoota Forest supported around 500 nests of five colonial waterbird species including Eastern Great Egret (Hutton 2017). Environmental water was delivered to this site to maintain water levels in the colony and surrounding foraging area from early December 2016 to late February 2017 (OEH 2017a). The last recorded waterbird breeding at this site was recorded 25 years ago in 1992-93 (Hutton 2017). Small numbers of nesting Nankeen-Night Heron (around 20-30 nests) were also active in Werai Forest in 2016-17 (R. Webster, *pers. obs.* 2017).

2.4 Ramsar sites supported waterbird breeding & conservation-dependent species

In total 61 waterbird species were observed across the five Ramsar sites surveyed in 2016-17. This included the nationally endangered Australasian Bittern at three sites: Fivebough Swamp, U-Block in the Macquarie Marshes Southern Nature Reserve and Reedbeds in Millewa Forest (NSW Central Murray Forests Ramsar site). A further four species listed as vulnerable in NSW (*BC Act 2016*) and eight species listed under international agreements JAMBA, CAMBA and/or RoKAMBA were recorded in the Ramsar sites (see Appendix 4A for detailed summary tables for each Ramsar site). The Macquarie Marshes Ramsar site (Macquarie Marshes Northern Nature Reserve) and the NSW Central Murray Forests Ramsar site (Millewa Forest, Koondrook-Perricoota Forest and Werai Forest) both supported colonial waterbird breeding in 2016-17 (see details in section 2.3).

The Fivebough-Tuckerbil Swamp Ramsar site supported the most waterbird species overall (60 in total), followed by the Macquarie Marshes Ramsar site (37 species), Narran Lakes Ramsar site (35 species), Gwydir Wetlands Ramsar site (34 species) and Central Murray Forests Ramsar site (Millewa Forest only, 34 species). Due to extensive flooding across the MDB, total numbers of waterbirds were relatively low in Fivebough Swamp in 2016-17 compared to previous years (Figure 16). UNSW aerial surveys (Bino *et al.* 2014) and the ground surveys show that Fivebough Swamp is regionally significant for waterbird diversity and abundance, particularly during dry periods. Most notably this site provides habitat for a high number of migratory shorebird species (small waders) when shallow wading habitat is available (Figure 16).

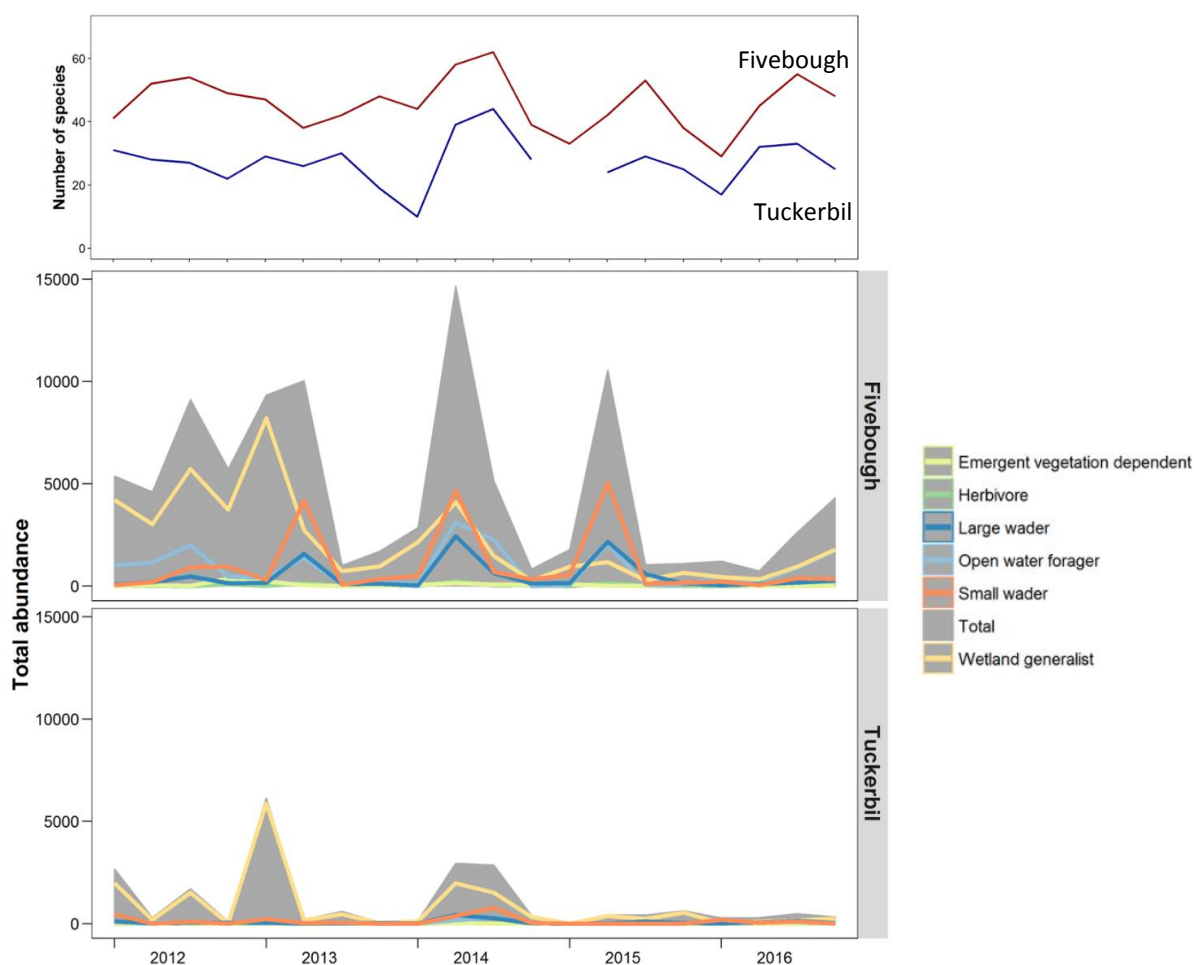


Figure 16 Total number of waterbird species (*upper*) and total waterbird abundance (in each guild) recorded in Fivebough (*mid*) and Tuckerbil (*lower*) swamps during quarterly surveys from July 2012 to April 2017.

3 Conclusions

Waterbirds are highly responsive to flooding, with large areas of wetland habitat made available across the MDB during spring 2016. During this period, many colonial and non-colonial waterbird species took advantage of favourable conditions for breeding. Where inundation was maintained with environmental water into summer, this allowed more individuals to complete their breeding cycles, from nest building, egg laying, chick raising through to fledging. Environmental water deliveries were needed for maintaining water levels in colony areas and surrounding foraging habitats for individuals who started nesting in summer. On-ground monitoring supported the management of these events by providing information on the stage of nesting and colony water levels to determine the duration of flows needed.

More than half of the environmental watering actions in NSW in 2016-17 had primary or secondary objectives for providing waterbird habitat. There were 30 watering actions, totalling more than 550,000 ML of licenced NSW and Commonwealth environmental water, that contributed to the provision of waterbird habitat in the NSW MDB in 2016-17 (see Appendix 1). This included 11 watering actions that supported active colony sites. While the total contribution of environmental water to breeding events can be relatively small compared to the total flood volume from a natural event, it is vital for extending the duration of inundation and preventing rapid drops in water levels (Dyer *et al.* 2017; Thomas and Heath 2018; Wassens *et al.* 2018). In some cases, this can be the difference between complete colony failure and much improved colony success rates. For example, without the delivery of environmental water the likelihood of nest abandonment would have been very high in the Lower Lachlan Booligal Block Bank colony (Dyer *et al.* 2017). Refilling of the Lowbidgee Eulimbah colony with environmental water after nest abandonment also promoted the success of active Straw-necked Ibis nests that remained and allowed for re-nesting to occur (Wassens *et al.* 2018). Where complementary pest control is undertaken in combination with watering events, this can also protect low-lying nests of ibis and pelicans which are vulnerable to predation by feral cats, foxes and pigs.

The extended duration of inundation in the colony sites and surrounding feeding habitats also provided feeding and breeding habitat for non-colonial waterbird species and so contributed to maintaining overall species richness across the MDB. Similarly, the delivery of environmental water over summer months provided feeding habitat for juvenile colonial waterbirds. This was observed in the Gwydir Wetlands in March 2017 when summer watering created habitat for 49 waterbird species, including migratory shorebird species and juvenile Straw-necked Ibis.

While large-scale flooding in 2016-17 provided breeding opportunities for many waterbird species, further monitoring is needed to determine if the large-scale breeding events have contributed to waterbird population recovery. The long-term annual aerial surveys have demonstrated that increases in total numbers of waterbirds can be observed in the years following large natural flood events (Kingsford *et al.* 2013). There was some increase in waterbird abundance detected in the 2017 spring annual aerial surveys following widespread flooding in 2016, but total waterbird abundance remained below the long-term average (Porter *et al.* 2017). The provision of environmental water in the years following large-scale breeding events is likely to be extremely important in creating feeding habitat to support the survival of young waterbirds. This is needed to allow juvenile birds to recruit into the breeding population to promote the recovery of waterbird populations in the Basin.

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Appendices

Appendix 1 Summary of 2016/17 environmental water actions which supported waterbird habitat across the wetland regions

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Intersecting Streams	Narran Lakes (CEWO 2018a)	Improve the health and complexity of waterbird rookery habitat in northern Narran Lakes system	Narran Lakes	Sep-Oct 2016	28,789 ML (CEW)	UNSW aerial surveys (Kingsford <i>et al.</i> 2017b) and OEH ground surveys (see Table 2) in spring 2016 detected 30 waterbird species in the Narran Lakes Nature Reserve. This included resident shorebird species, large waders and dabbling ducks which were feeding in shallow areas of the Clear Lake which had been inundated by the spring flow event.
Gwydir	Gwydir Wetlands (OEH 2016a, CEWO 2018b)	Inundate areas of semi-permanent wetland vegetation and extend duration of wetland inundation to support waterbird and frog species	Lower Gwydir and Gingham Watercourses	Dec 2016-Feb 2017	30,000 ML (3,000 NSW, 9,000 CEW, 18,000 EWA)	UNSW aerial surveys (Kingsford <i>et al.</i> 2017b) detected a small egret colony on the Gingham watercourse in November 2016. Overall, there was an increase in small and large waders between the November 2016 and March 2017 surveys. The autumn surveys followed the delivery of environmental water to wetland habitats over summer months. In total, 49 waterbird species were recorded in March 2017 across the Lower Gwydir and Gingham watercourses. This included Australasian Bittern (EPBC Act), Brolga, Black-necked Stork (NSW BC Act) and migratory Sharp-tailed Sandpipers, Marsh Sandpipers and Latham's Snipe. Juvenile Straw-necked Ibis were also observed in the autumn surveys following large-scale breeding events in the Macquarie Marshes and southern catchments.
		Improve condition of wetland vegetation and provide habitat for waterbirds and frogs	Mallowa Creek and Wetlands	Dec 2016-Apr 2017	7,496 ML (CEW)	In total 18 waterbird species were recorded in inundated sites in the Mallowa Wetlands during ground surveys in March 2017. This included the JAMBA and RoKAMBA listed Latham's Snipe in two wetland sites.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Macquarie-Castlereagh	Macquarie Marshes (OEH 2016b, CEWO 2018c)	Maximise inundation extent and duration and floodplain connections from naturally occurring high flow events	Macquarie Marshes and mid-Macquarie River	Jul-Dec 2016	8,677 ML (1,426 NSW, 7,251 CEW)	<p>OEH and University of NSW ground and aerial surveys confirmed at least 21 active waterbird colonies across the Macquarie Marshes. In total 17 colonial waterbird species were recorded breeding in response to the large flood event and extended supplementary water releases. The two largest colonies, which in total supported more than 35,000 nests, were dominated by Straw-necked Ibis, with smaller numbers of nesting Australian White Ibis, Glossy Ibis and Royal Spoonbills (Brandis 2017).</p> <p>Nest monitoring of two large ibis colonies by Brandis (2017) indicated that the overall success rates of Straw-necked Ibis nests (63-65%) were comparable to other colonies active in the southern MDB during 2016-17. Some mortality was observed in the large ibis colonies during December 2016 surveys which was linked to a suspected outbreak of avian botulism and pig predation.</p> <p>There were also two large egret colonies (supporting more than 15,000 nests combined of Intermediate Egret and Nankeen-Night Heron, and smaller numbers of Eastern Great Egrets, Cattle Egrets and Little Egrets and nesting pairs of Pied Herons, a species more typically seen in northern Australia).</p>
		Maintain inundation at colony sites and surrounding feeding areas to support fledging of colonial waterbirds	Macquarie Marshes and mid-Macquarie River	Jan 2016-Feb 2017	46,410 ML (6,384 NSW, 17,038 CEW, 22,988 EWA)	The use of the flood mitigation zone, plus addition of environmental water allocation in January and February 2017 maintained inundation extent in the known colony sites and adjoining foraging habitats in the Northern and Southern Marsh regions while inundation extents were contracting elsewhere (Thomas and Heath 2018).

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Lachlan	Mid-Lachlan Wetlands (OEH 2016c)	Maintain water levels and acceptable water quality parameters in Lake Brewster to support a large pelican breeding event	Lake Brewster	Feb-Jun 2017	1,513 ML (EWA)	Large numbers of pelicans congregated in Lake Brewster and began nesting from February 2017 onwards. An estimated 6,242 pelican nests were established in March 2017. The colony was monitored by OEH and UNSW from March to June 2017. An estimated 1,552 juvenile pelicans were at the site in mid-June 2017 and were still being fed by adult birds. OEH on-ground surveys indicated that there was some late stage mortality of young birds (<10% of total young) over the June-July period, which may have been caused by a rapid drop in air temperatures in from early June onwards.
	Lower Lachlan Wetlands (OEH 2016c, CEWO 2018d)	Extend the duration and depth of inundation of Murrumbidgee Swamp to protect and restore the health of wetland vegetation and provide habitat for waterbird species	Merrimajeel Creek offtake to Murrumbidgee Swamp	Jul 2016	1,000 ML (NSW)	Access to Murrumbidgee Swamp for ground surveys was not possible in 2016-17. Inactive cormorant and heron nests were detected during ground surveys in 2017-18 which indicated that the site supported a small colony in the previous year.
		Maintain water levels at the Booligal Block Bank to support a large ibis and spoonbill breeding event	Booligal Block Bank (Lachlan Valley State Conservation Area)	Jan-Mar 2017	4,895 ML (1,324 CEW, 3,571 EWA)	Colony monitoring by UNSW, CEWO and OEH indicated that overall reproductive success for the Booligal colony was 64% which was comparable to other sites active in the MDB in 2016-17 (Brandis 2017; Dyer <i>et al.</i> 2017). At the end of the breeding event in March 2017, large numbers of fledged juveniles were observed feeding in the colony and surrounding area. Some mortality of juvenile ibis and waterfowl was observed at the site during January-February 2017 ground surveys which was linked to a suspected outbreak of avian botulism at the site.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Murrumbidgee	Mid-Murrumbidgee Wetlands (OEH 2016d)	Improve the condition of wetland vegetation communities and provide habitat for waterbirds	Gooragool Lagoon (Murrumbidgee Valley National Park)	Jul 2016	4,365 ML (NSW)	No ground surveys of Gooragool Lagoon were completed over the July to August 2016 period. Seven waterbird species were detected during LTIM surveys in September 2016. This site was also inundated during large-scale natural flooding of the Murrumbidgee Catchment from October 2016 onwards and this site supported a colony of cormorants and spoonbills over the October 2016 to April 2017 period (four colonially-nesting species, estimated 629 nests in total).
		Improve the condition of wetland vegetation communities and provide habitat for waterbirds	Currawannana Lagoon	Jul 2016-Jun 2017	40 ML (NSW)	Event-based survey completed in December 2016 when waterfowl and fish-eating waterbirds were observed in the lagoon. White-faced herons were also recorded nesting on the edge of the lagoon.
	Lowbidgee floodplain (OEH 2016d, CEWO 2018e)	Improve the condition of wetland vegetation communities and provide habitat for the endangered southern bell frog, waterbirds, native fish and turtles	Nimmie-Caira to South Yanga	Aug-Sep 2016	15,507 ML (CEW)	The delivery of environmental water over late winter-early spring provided foraging habitat for waterbirds prior to natural overbank flooding. Dabbling ducks (Pink-eared Ducks, Grey Teal, Hardhead and Pacific Black Duck), small grebes and resident shorebirds were observed feeding in inundated wetlands in the Nimmie-Caira and Yanga National Park in ground surveys completed in August 2016. This watering action was paused once tributary flows were triggered in the upper Murrumbidgee Catchment.
		Inundate colony sites to support nesting ibis, spoonbills and pelicans and maintain surrounding foraging habitat	Nimmie-Caira wetlands	Nov 2016-Mar 2017	22,201 ML (2,196 NSW, 13,375 CEW, 6,630 EWA)	This watering event supported four colony locations in the Nimmie-Caira (Eulimbah Swamp, Telephone Bank, Nap Nap Swamp and Kieeta Lake) and inundated feeding habitat in Kia Lake after recession of natural floodwaters. Re-flooding the Eulimbah colony with environmental water and maintain water depths from November 2016-March 2017 improved reproductive success rates and allowed those young that survived the initial dry period to fledge (Wassens <i>et al.</i> 2018). It also allowed late nesting species (Royal Spoonbill) and non-colonial species to breed in Eulimbah Swamp.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Murrumbidgee	Lowbidgee floodplain (OEH 2016d, CEWO 2018e)					<p>Australasian bitterns were recorded calling at Eulimbah Swamp during targeted bittern surveys in December 2016 (Herring 2017).</p> <p>Water delivered to Kieeta Lake pelican colony and neighbouring Kia Lake maintained inundation to support the completion of a large Australian pelican colony (estimated 5,000-6,000 nests). Kia Lake habitat for pelicans and a high diversity (>40 species) of waterbird species, including migratory shorebirds.</p>
		Maintain inundation of colony site at Tori Swamp and surrounding foraging habitat	Tori Lignum Swamp (North Redbank)	Jan-Feb 2017	2,790 ML (1,350 NSW, 844 CEW, 596 EWA)	The North Redbank watering action inundated feeding habitat that adjoined the Tori Lignum Swamp colony (more than 6,000 ibis and spoonbill nests). The site supported more than 40 waterbird species including Australasian Bittern (EPBC Act), which were heard calling in January 2017, and NSW listed Blue-billed Duck and Magpie Goose (BC Act). This watering provided feeding habitat for adult ibis and spoonbills and newly fledged juveniles. Overall nest success rate for Tori Lignum Swamp ibis was low (40%) in comparison to other colonies (59-83%) active in the MDB in 2016-17 (Brandis 2017). This was partly attributed to the impact of avian botulism at this site.
		Maintain inundation of colony sites and surrounding foraging habitats in North Yanga	Yanga National Park colony sites	Jan-Feb 2017	2,155 ML (CEW)	The Yanga rookery maintenance watering action inundated feeding habitat in North Yanga to support active egret colonies at Two Bridges Swamp (1,049 nests), Top Narockwell (164 nests) and Tarwillie Swamp (793 nests), and the neighbouring Tori colony in North Redbank (see above). Juvenile Straw-necked Ibis were observed feeding in North Yanga during ground colony surveys in February 2017. Low chick mortality and advanced chicks and juvenile egrets, herons and cormorants were observed in the egret colonies during January and February 2017 surveys.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Murrumbidgee	Lowbidgee floodplain (OEH 2016d, CEWO 2018e)	Provide feeding habitat for waterbirds	Western Lakes and North Redbank (Narwie West Floodway)	Nov 2016 – Jun 2017	18,360 ML (13,300 NSW, 5,060 CEW)	This watering event supported a small cormorant colony (estimated 84 nests in total) monitored monthly from November 2016 to March 2017. Four Australasian Bitterns were heard calling in the Narwie Wetlands during targeted bittern surveys in December 2016 (Herring 2017). Song meters deployed by NSW OEH also detected the Australian Little Bittern at this site in December 2016.
	Yanco-Billabong system (OEH 2016d, CEWO 2018e)	Maintain water levels in Wanganella Swamp to support successful breeding	Yanco-Wanganella	Nov 2016- Jan 2017	9,300 ML (5,000 CEW, 4,300 EWA)	Surveys of Wanganella Swamp were completed in October and November 2016. In total, 25 waterbird species were recorded. This included NSW-listed Magpie Geese (BC Act). Small numbers of Australian White Ibis, Royal Spoonbill, Black Swans and Black-winged Stilts were recorded nesting in Wanganella Swamp in the October and November surveys.
	Murrumbidgee Irrigation Area and Mid-Murrumbidgee wetlands (OEH 2016d)	Maintain inundation of wetlands for waterbirds including threatened species	Fivebough-Tuckerbil Ramsar site, McCaughey's Lagoon (Murrumbidgee Valley National Park), Campbell and Nericon Swamps	Dec 2016- May 2017	1,000 ML (EWA)	In total 57 waterbird species were detected at Fivebough-Tuckerbil Ramsar site through ground surveys completed from December 2016 to June 2017. This included seven NSW-listed species (BC Act), six species listed under migratory bird agreements, and the nationally listed Australasian Bittern (EPBC Act 1999). In December 2016 four male bitterns were recorded at Fivebough Swamp (K. Hutton, <i>pers. obs</i>). In ground surveys completed in November 2016 Campbell and Nericon Swamps also supported the Australasian Bittern and the NSW-listed Magpie Goose, and the NSW-listed Blue-billed Duck was recorded at Campbells Swamp (Max O'Sullivan, <i>pers. obs</i>).

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
Murrumbidgee	Mid-Murrumbidgee wetlands (OEH 2016d)	Improve the condition of wetland vegetation communities and provide habitat for waterbirds	Sandy Creek	March 2017	300 ML (NSW)	15 waterbird species were recorded during ground surveys of Sandy Creek in June 2017. This site also supported some breeding Black Swans.
	Lowbidgee floodplain (OEH 2016d, CEWO 2018e)	Improve the condition of wetland vegetation communities and provide habitat for waterbirds	Toogimbie Wetlands	Mar-Jun 2017	998 ML (CEW)	No information available.
		Maintain inundation of permanent waterbodies to provide habitat for the endangered southern bell frog, waterbirds, native fish and turtles	Nimmie-Caria wetlands	May-Jun 2017	20,104 (15,104 NSW, 5,000 EWA)	This watering action contributed to habitat provision for waterbird species in the following spring period. In total 39 waterbird species were detected across the Nimmie-Caria system in spring surveys from September-October 2017. This included the nationally endangered Australasian Bittern (EPBC Act).
		Maintain inundation of wetlands for waterbirds including threatened species	Narwie and Paika East (North Redbank)	May-Jun 2017	7,673 ML (NSW)	In total 26 waterbird species were detected across the Western Lakes and Narwie system during ground surveys in June 2017 (R. Webster, <i>pers. obs.</i>).
	Coleambally Irrigation Area (CIA) (OEH 2016d)	Provide feeding habitat for waterbirds including threatened species	Bowna Swamp, Wargam Lakes and Nyangay Swamp	Mar-May 2017	5,000 ML (EWA)	No information available.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
NSW Murray-Lower Darling	Mid-Murray (OEH 2016e, CEWO 2018f)	Promote wetland-river connectivity to provide habitat for wetland-dependent species and provide flows to the Lower River Murray, Lower Lake and the Coorong	Multi-site (including Barmah-Millewa Forest)	Aug 2016-Jun 2017	282,213 ML (107,481 CEW, 84,032 EWA, 40,700 TLM, 50,000 Other)	<p>Colonial waterbird nesting was initiated following natural flooding in spring 2016. Aerial, ground surveys and UAV survey were used to locate colonies and estimate colony size (McGinness <i>et al.</i> 2018; OEH 2017c).</p> <p>Six colony sites were active in the Millewa Forest. More than 1,700 nests in total of Australian White Ibis, Straw-necked Ibis, Royal Spoonbill and Eastern Great Egret were recorded in Reedbeds Swamp (McGinness <i>et al.</i> 2018; OEH 2017c).</p>
		Maintain water levels in Reedbed Swamp for nesting colonial waterbird species and bitterns	Reedbeds Swamp (part of Gulpa Creek Wetland Complex in NSW Murray Valley National Park, Central Murray Forest Ramsar site)	Nov 2016-Jan 2017	4,488 ML (NSW)	<p>As above, with additional flows delivered to maintain nesting habitat for the Reedbed colony areas and bittern habitat. Reproductive success monitoring of marked ibis nest recorded an overall success rate of 63%, which was comparable to other colonies active in the NSW MDB during 2016-17 (Brandis 2017).</p> <p>Surveys by Belcher <i>et al.</i> (2017) in October-December 2016 indicated that the Barmah and Murray Valley National Parks provide critical habitat for bitterns. Australasian Bitterns (EPBC Act 1999) were heard calling in five of the six wetlands (54 Australasian Bitterns in total) monitored in Millewa Forest (Murray Valley National Park) and Australian Little Bitterns were detected in three of the six sites (18 Little Bitterns in total). Reedbeds Swamp supported an estimated 11 Australasian Bitterns during surveys in December 2016 (Belcher <i>et al.</i> 2017).</p> <p>Two pairs of Magpie Geese (BC Act 2016) were also detected in Reedbeds Swamp over summer 2016, although breeding was not confirmed (OEH 2017b).</p>

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
NSW Murray-Lower Darling	Mid-Murray (OEH 2016e, CEWO 2018f)	Maintain water levels in the Pollack swamp colony and extent of inundation in the surrounding foraging areas to support colonial waterbird breeding	Pollack Swamp (Koondrook-Perricoota Forest part of the Central Murray Forest Ramsar Site)	Dec 2016-Feb 2017	1,224 ML (1,000 NSW, 224 TLM)	Forests NSW conducted weekly surveys to monitor water levels and waterbird breeding activity (Hutton 2017). The Pollack Swamp colony support an estimated 1,115 nests in total for eight colonially-nesting species. By late February 2017 most Nankeen Night-Herons, White-necked Herons, Great Cormorants, Australian White Ibis, Eastern Great Egret, Intermediate Egrets and Cormorants had fledged their chicks. Low levels of chick predation and mortality were observed, although some mortality in early February 2017 was thought to be associated with an extreme heat event (Hutton 2017).
		Maintain water levels at St Helena Swamp and Black Swamp to support active waterbird colonies	St Helena Swamp and Black Swamp (part of Gulpa Creek Wetland Complex in NSW Murray Valley National Park, Central Murray Forest Ramsar site)	Nov-Dec 2016	4,500 ML (TLM)	Water delivery was needed to maintain water levels around nesting cormorants that established nests following widespread flooding NSW. NPWS monitored stage of nesting at Helena Swamp from October 2016 to January 2017. Colonial waterbird species were confirmed breeding at St Helena Swamp (five species, estimated 88 nests in total), and Black Swamp (two species, 13 nests in total) (OEH 2017c).
		Inundate Rosenhoe Swamp to maximum extent to provide habitat for waterbirds and frogs	Rosenhoe Swamp	Mar-Apr 2017	250 ML (NSW)	Incidental surveys by OEH staff and landholder documented 19 waterbird species in Rosenhoe Swamp in autumn 2017.

NSW WRPA	Wetland Region(s) (annual watering priorities)	Management Objective(s)	Targeted wetland(s)	Timing of environmental water delivery	Total volume of environmental water* delivered	Measured outcomes in 2016-17
NSW Murray-Lower Darling	Lower Murray (OEH 2016e)	Improve health of wetland vegetation, in particular River Red Gum, provide habitat for small bodied fish frogs and waterbirds.	Thegoa Lagoon	Jul-Aug 2016	1,400 ML (NSW)	Thegoa Lagoon supported at least 20 waterbird species in spring 2016. This included Black Swans and other waterfowl, and a five resident shorebird species observed during ground surveys completed in September 2016.
		Improve condition of wetland vegetation communities and provide habitat for frogs and waterbirds	Andruco Lagoon	Oct 2016	115 ML (NSW)	At least 15 waterbird species were observed in Andruco Lagoon during incidental surveys in August 2016 prior to the delivery of environmental water.
		Improve condition of wetland vegetation communities and provide habitat for waterbirds and frogs	Gol Gol Wetlands (Gol Gol Swamp and Lake Gol Gol)	Nov-Dec 2016	5,793 ML (NSW)	During surveys of Lake Gol Gol in early January 2017, 26 waterbird species were detected, including the NSW-listed Blue-billed duck, Freckled duck (BC Act 2016). Four species were confirmed breeding, including nesting Australian White Ibis. In mid-January 2017 27 waterbird species were detected at Gol Gol Swamp including Freckled Duck and four resident and two migratory shorebird species (Sharp-tailed Sandpiper, Marsh Sandpiper).

*Total flows can be a combination of NSW Adaptive Environmental Water (AEW), Commonwealth Environmental Water (CEW) holdings, NSW Environmental Water Allowance (EWA), The Living Murray (TLM) holdings and other managed flows (see OEH 2017a).

Appendix 2 Waterbird species identified during 2016-17 surveys

Family	Common Name	Scientific Name ^	Ecohydrological Group (BWS Functional Guild)^^
Anatidae	Australasian Shoveler*	<i>Anas rhynchotis</i>	Wetland generalist (Du)
	Australian Shelduck*	<i>Tadorna tadornoides</i>	Herbivore (Du)
	Australian Wood Duck*	<i>Chenonetta jubata</i>	Herbivore (He)
	Black Swan*	<i>Cygnus atratus</i>	Wetland generalist (He)
	Blue-billed Duck	<i>Oxyura australis</i> v	Open water forager (Du)
	Chestnut Teal	<i>Anas castanea</i>	Wetland generalist (Du)
	Freckled Duck	<i>Stictonetta naevosa</i> v	Wetland generalist (Du)
	Grey Teal*	<i>Anas gracilis</i>	Wetland generalist (Du)
	Hardhead*	<i>Aythya australis</i>	Open water forager (Du)
	Musk Duck*	<i>Biziura lobata</i>	Open water forager (Du)
	Pacific Black Duck*	<i>Anas superciliosa</i>	Wetland generalist (Du)
	Pink-eared Duck*	<i>Malacorhynchus membranaceus</i>	Wetland generalist (Du)
	Plumed Whistling-Duck*	<i>Dendrocygna eytoni</i>	Herbivore (He)
	Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>	Herbivore (He)
Anhingidae	Australasian Darter*	<i>Anhinga novaehollandiae</i>	Open water forager (Pi)
Anseranatidae	Magpie Goose*	<i>Anseranas semipalmata</i> v	Herbivore (He)
Ardeidae	Australasian Bittern	<i>Botaurus poiciloptilus</i> E e	Emergent vegetation dependent (Lw)
	Australian Little Bittern*	<i>Ixobrychus dubius</i>	Emergent vegetation dependent (Lw)
	Cattle Egret*	<i>Bubulcus ibis</i>	Large wader (Lw)
	Eastern Great Egret*	<i>Ardea alba modesta</i>	Large wader (Lw)
	Intermediate Egret*	<i>Ardea intermedia</i>	Large wader (Lw)
	Little Egret*	<i>Egretta garzetta</i>	Large wader (Lw)
	Nankeen Night-Heron*	<i>Nycticorax caledonicus</i>	Large wader (Lw)
	Pied Heron*	<i>Egretta picata</i>	Large wader (Lw)
	White-faced Heron*	<i>Egretta novaehollandiae</i>	Large wader (Lw)
	White-necked Heron*	<i>Ardea pacifica</i>	Large wader (Lw)
Charadriidae	Banded Lapwing	<i>Vanellus tricolor</i>	Small wader: Australian resident (Sh)
	Black-fronted Dotterel	<i>Euseyonis melanops</i>	Small wader: Australian resident (Sh)
	Masked Lapwing*	<i>Vanellus miles</i>	Small wader: Australian resident (Sh)
	Red-capped Plover	<i>Charadrius ruficapillus</i>	Small wader: Australian resident (Sh)
	Red-kneed Dotterel	<i>Erythrogonys cinctus</i>	Small wader: Australian resident (Sh)
Ciconiidae	Black-necked Stork	<i>Ephippiorhynchus asiaticus</i> e	Large wader (Lw)
Gruidae	Brolga	<i>Grus rubicunda</i> v	Large wader (Lw)
Jacaniidae	Comb-crested Jacana	<i>Irediparra gallinacea</i> v	Emergent vegetation dependent (Du)
Laridae	Australian Gull-billed Tern	<i>Gelochelidon macrotarsa</i>	Open water forager (Pi)
	Caspian Tern	<i>Hydroprogne caspia</i> J	Open water forager (Pi)
	Silver Gull	<i>Chroicocephalus novaehollandiae</i>	Open water forager (Pi)
	Whiskered Tern*	<i>Chlidonias hybrida</i>	Open water forager (Pi)
Pelicanidae	Australian Pelican*	<i>Pelecanus conspicillatus</i>	Open water forager (Pi)
Phalacrocoracidae	Great Cormorant*	<i>Phalacrocorax carbo</i>	Open water forager (Pi)
	Little Black Cormorant*	<i>Phalacrocorax sulcirostris</i>	Open water forager (Pi)
	Little Pied Cormorant*	<i>Microcarbo melanoleucos</i>	Open water forager (Pi)
	Pied Cormorant*	<i>Phalacrocorax varius</i>	Open water forager (Pi)

Family	Common Name	Scientific Name ^	Ecohydrological Group (BWS Functional Guild)^
Podicipidae	Australasian Grebe*	<i>Tachybaptus novaehollandiae</i>	Open water forager (Du)
	Great Crested Grebe*	<i>Podiceps cristatus</i>	Open water forager (Du)
	Hoary-headed Grebe*	<i>Poliiocephalus poliocephalus</i>	Open water forager (Du)
Rallidae	Australian Spotted Crake*	<i>Porzana fluminea</i>	Emergent vegetation dependent (Du)
	Baillon's Crake	<i>Porzana pusilla</i>	Emergent vegetation dependent (Du)
	Black-tailed Native-hen	<i>Tribonyx ventralis</i>	Wetland generalist (He)
	Buff-banded Rail	<i>Gallirallus philippensis</i>	Emergent vegetation dependent (Du)
	Dusky Moorhen*	<i>Gallinula tenebrosa</i>	Wetland generalist (He)
	Eurasian Coot*	<i>Fulica atra</i>	Open water forager (He)
	Purple Swamphen*	<i>Porphyrio porphyrio</i>	Emergent vegetation dependent (He)
	Spotless Crake	<i>Porzana tabuensis</i>	Emergent vegetation dependent (Du)
Recurvirostridae	Black-winged Stilt*	<i>Himantopus leucocephalus</i>	Small wader: Australian resident (Sh)
	Red-necked Avocet	<i>Recurvirostra novaehollandiae</i>	Small wader: Australian resident (Sh)
Scolopacidae	Latham's Snipe	<i>Gallinago hardwickii</i> J, R	Small wader: Migratory shorebird (Sh)
	Marsh Sandpiper	<i>Tringa stagnatilis</i> J, C, R	Small wader: Migratory shorebird (Sh)
	Red-necked Stint	<i>Calidris ruficollis</i> J, C, R	Small wader: Migratory shorebird (Sh)
	Sharp-tailed Sandpiper	<i>Calidris acuminata</i> J, C, R	Small wader: Migratory shorebird (Sh)
	Wood Sandpiper	<i>Tringa glareola</i> J, C, R	Small wader: Migratory shorebird (Sh)
Threskiornithidae	Australian White Ibis*	<i>Threskiornis moluccus</i>	Large wader (Lw)
	Glossy Ibis*	<i>Plegadis falcinellus</i>	Large wader (Lw)
	Royal Spoonbill*	<i>Platalea regia</i>	Large wader (Lw)
	Straw-necked Ibis*	<i>Threskiornis spinicollis</i>	Large wader (Lw)
	Yellow-billed Spoonbill*	<i>Platalea flavipes</i>	Large wader (Lw)

*Breeding detected (active nests with eggs or young observed). ^ Status: J = JAMBA, C = CAMBA, R = RoKAMBA (listed under international migratory bird agreements Australia has with Japan, China and Republic of North Korea, respectively), listing under the NSW BC Act 2016 (e = endangered, v = vulnerable), and under Commonwealth EPBC Act 1999 (E = Endangered). ^^ BWS (UNSW aerial survey) Functional Group (Bino *et al.* 2015): Du = Ducks and small grebes, He = Herbivore, Pi = Fish-eater, Lw = Large wader, Sh = Shorebird. Nomenclature follows Christidis and Boles (2008).

Appendix 3 Summary of top ten survey sites in each wetland region during spring ground surveys (based on species richness and total abundance)

Wetland Region, Site name	Site Type ^A	Total Species	Max. Total Abundance	No. Ecohydro Groups	No. BWS Functional Groups	Estimated % Inundated
Gwydir Wetlands						
Bunnor Bird Hide	FP	28	320	6	5	90
Old Boyanga Wetland	FP	23	352	7	5	80
Goddard's Lease (Ramsar)	FP	23	172	5	4	70
Little Lagoon	FP	23	310	7	5	75
Gingham Waterhole	OW	20	138	4	4	100
Racecourse Lagoon	OW	20	434	6	5	80
Westholme SE	FP	20	460	6	5	100
Boyanga Waterhole	OW	16	97	6	5	80
Wandoona Waterhole	FP	16	84	6	4	90
Lynworth	FP	15	176	6	5	50
Westholme NW	FP	15	105	6	5	80
Lowbidgee Floodplain						
Kia Lake (West)	OW	15	301	6	5	80
Murrundi Swamp	FP	15	124	3	4	100
Steam Engine Swamp	FP	14	55	5	4	100
Yanga Lake	OW	14	326	4	4	110
Kia Lake (East)	OW	12	240	5	4	40
Loorica Lake	OW	12	290	4	5	95
Maude Lagoon	OW	11	27	4	3	95
Piggery Lake	FP	11	116	4	4	100
Avalon Swamp	FP	10	208	5	3	95
Breer Swamp	FP	10	68	3	4	100
Penarie Creek	FP	10	54	5	4	70
Paika Lake (West)	OW	10	237	3	4	80
Macquarie Marshes						
Monkeygar Swamp East	FP	29	511	6	5	95
Northern Bypass Channel	Ch	29	333	6	5	95
Pillicawarrina Floodplain	FP	29	462	6	5	90
Monkeygar Return Lagoon	OW	28	458	6	5	99
Monkeygar Swamp West	FP	26	265	6	5	100
U-Block	FP	25	385	6	5	80
Big Terrigal Creek	Ch	25	298	6	5	100
Sinclair's Lagoon	OW	23	278	6	5	85
River Paddock Channel	Ch	23	310	5	5	70
Buckiinguy Lagoon & Milmiland Lagoon	FP	22	275	6	5	80
Mid-Murrumbidgee Wetlands*						
Turkey Flats	FP	14	91	4	4	100
Dry Lake	OW	10	120	4	4	100
Gooragool Lagoon	OW	10	23	5	5	95
Sunshower Lagoon	OW	9	126	4	3	100
McKennas Lagoon	OW	8	96	4	3	90

Wetland Region, Site name		Site Type [^]	Total Species	Max. Total Abundance	No. Ecohydro Groups	No. BWS Functional Groups	Estimated % Inundated
	Yanco Agricultural Wetlands	FP	8	20	4	4	30
	Yarradda Lagoon	OW	8	130	3	4	100
	Molleys Lagoon	Ch	7	36	3	2	90
	Narrandera SF	OW	5	48	3	2	100
	Berry Jerry Lagoon	OW	4	51	3	2	100
Mid-Murray (Millewa Forest)							
	Duck Lagoon	OW	12	139	4	4	100
	Reed Beds South	FP	12	681	4	4	100
	St Helena Swamp	FP	5	46	3	3	100
	Moirra Lake	OW	3	29	2	3	100
	Horseshoe Lagoon	OW	2	3	2	2	95
Lower Lachlan Wetlands							
	Lake Waljeers	OW	18	117	5	5	100
	Spells Paddock Swamp	FP	16	99	3	4	100
	Narran Lake	OW	16	121	3	4	100
	Dry Lake	OW	16	113	5	5	50
	Moon Moon	FP	15	215	3	4	100
	Lake Tarwong	OW	14	116	4	4	100
	Comauajong Lake	FP	14	189	4	4	80
	The Ville lagoon	FP	13	103	4	4	100
	Clear Lake	OW	13	56	4	5	100
	Lachlan River at Oxley	FP	13	77	4	4	100
Mid-Lachlan Wetlands							
	Lake Brewster	OW	22	965	6	5	100
	Banar Lake	OW	21	180	5	5	150
	Lake Cowal	OW	15	126	5	4	105
	Yarnel Wetland	FP	13	113	5	3	100
	Burrawang West	FP	11	25	3	4	90
	Lake Cargelligo	OW	11	75	4	4	170
	Wallamundry Creek	FP	9	42	4	2	130

Sites are listed in descending order of total species, with the total max number of waterbirds observed during surveys. The number of ecohydrological groups and number of functional groups specified in BWS, and estimated % inundated area Site Type ^ FP = Floodplain wetland, OW = Open waterbody, Ch = Channel/Riverine. * Does not include counts for Fivebough-Tuckerbil Ramsar site which are summarised in Table 4B.

Appendix 4A Maximum counts of each waterbird species recorded in the 7 of the 11 sites that comprise the Macquarie Marshes Ramsar wetlands which were accessible during spring ground surveys in 2016-17.

Common Name	Northern Macquarie Marshes Nature Reserve						Southern Macquarie Marshes Nature Reserve (U-Block only)
	Creswell Red Gum	Hall's Block Coolabah	Hall's Block Red Gum	Louden's Lagoon	Northern Bypass Channel	Sinclair's Lagoon	
Australasian Bittern	0	0	0	0	0	0	1
Australasian Darter	0	0	0	0	8*	1	0
Australasian Grebe	0	0	0	0	1	3	0
Australian Pelican	0	0	0	0	11	7	3
Australian White Ibis	0	0	0	0	44	18	19
Australian Wood Duck	0	0	0	0	1	0	3
Black-winged Stilt	0	0	0	0	0	16	7
Black Swan	2*	1	0	5	1	3	8
Blue-billed Duck	0	0	0	1	0	0	0
Cattle Egret	0	0	0	0	10	0	1
Dusky Moorhen	0	1	0	0	0	0	1
Eastern Great Egret	0	2	0	3	15	4	17
Eurasian Coot	1	1	1	0	6	4	1
Glossy Ibis	0	3	0	5	25	37	18
Great Cormorant	0	0	0	3	1	4	0
Great Crested Grebe	0	0	0	8	0	4	0
Grey Teal	5	2	3	0	43	78	50*
Hardhead	0	7	4	45*	15	6	24
Intermediate Egret	2	20	4	0	25	1	57
Little Black Cormorant	0	0	0	1	16*	0	17
Little Egret	0	0	0	0	7	0	2
Little Pied Cormorant	0	0	0	0	2	0	25
Magpie Goose	0	0	0	6	0	3	13
Masked Lapwing	0	0	0	0	3	0	0
Musk Duck	0	0	0	1	0	0	0
Nankeen Night-Heron	0	0	0	0	6	0	0
Pacific Black Duck	0	4	9	0	10	5	13
Pied Cormorant	0	0	0	0	5	0	0
Pink-eared Duck	0	0	0	0	0	3	0
Plumed Whistling-Duck	5	0	0	0	2	2	22
Purple Swamphen	0	1	3	5	1	1	5
Royal Spoonbill	0	0	0	0	1	0	14
Straw-necked Ibis	19	5	9	10	58	71	54
Whiskered Tern	0	0	0	5	5	5	5
White-faced Heron	2	2	1	0	3	1	5
White-necked Heron	0	1	0	0	4*	1	0
Yellow-billed Spoonbill	0	0	0	0	4*	0	0
Total no. of species	7	13	8	13	29	23	25
No. of species breeding	1	0	0	1	4	0	1

Appendix 4B Maximum counts of each waterbird species recorded in the Narran Lakes, Gwydir Wetlands, Fivebough-Tuckerbil and Mid-Murray Millewa Forest Ramsar wetlands during ground surveys in 2016-17 (* breeding detected)

Common Name	Narran Lakes	Gwydir Wetlands		Fivebough-Tuckerbil		NSW Central Murray Forests (Millewa)					
		Goddard's Lease	Old Dromana	Fivebough Swamp	Tuckerbil Swamp	Duck Lagoon	Horseshoe Lagoon	Moira Lake	Reedbeds North	Reedbeds South	St Helena Swamp
Australasian Bittern	0	0	0	6	0	0	0	0	2	1	0
Australasian Darter	2	6	1	7	2	7	0	0	0	1	5*
Australasian Grebe	2	0	16*	10*	4	2	11*	0	0	7	0
Australasian Shoveler	0	0	0	40	12	0	0	0	0	0	0
Australian Gull-billed Tern	0	0	0	56*	0	0	0	0	0	0	0
Australian Little Bittern	0	0	0	4	0	1	0	0	0	0	0
Australian Pelican	25	2	0	1338	11	7	0	24	0	0	0
Australian Shelduck	0	0	0	40	0	4	4	0	0	2	0
Australian Spotted Crake	0	0	0	1	0	0	0	0	0	0	0
Australian White Ibis	10	64	8	38	5	3	2	97	118*	208*	8
Australian Wood Duck	31	5	8	72*	10	1	8*	0	0	0	0
Banded Lapwing	9	0	0	3	0	0	0	0	0	0	0
Black-fronted Dotterel	0	0	0	83	0	3	0	0	0	0	0
Black-tailed Native-hen	2	0	0	1	0	4	0	0	0	0	0
Black-winged Stilt	20	0	1	190*	190	0	0	0	0	0	0
Black Swan	43*	1	0	622*	5	47	0	3	6	44*	6*
Blue-billed Duck	0	0	0	29	0	0	0	0	0	0	0
Brolga	0	0	0	6	4	0	0	0	0	0	0
Buff-banded Rail	0	0	1	3	2	0	0	0	0	0	0
Caspian Tern	0	0	0	7	0	0	0	0	0	0	0
Cattle Egret	1	26	37	120	1	0	0	0	0	0	0
Chestnut Teal	0	0	0	9*	1	0	0	0	0	0	0
Dusky Moorhen	0	2	1	21*	4	0	2	0	0	0	1

Common Name	Narran Lakes	Gwydir Wetlands		Fivebough-Tuckerbil		NSW Central Murray Forests (Millewa)					
		Goddard's Lease	Old Dromana	Fivebough Swamp	Tuckerbil Swamp	Duck Lagoon	Horseshoe Lagoon	Moira Lake	Reedbeds North	Reedbeds South	St Helena Swamp
Eastern Great Egret	0	5	39	69	7	2	1	220	1	38*	6
Eurasian Coot	6	5	3	671*	32	27	0	4	2*	5	2
Freckled Duck	0	0	0	43	1	0	0	0	0	0	0
Glossy Ibis	0	0	179	250	35	0	0	0	0	0	0
Great Cormorant	3	0	0	355	9	7	0	5	0	0	7*
Great Crested Grebe	0	1	0	187*	0	6	0	14	3	0	0
Grey Teal	261	2	7	1000*	75*	29	5*	41	2	137	13
Hardhead	33	1	6*	26*	3	0	0	0	2	1	0
Hoary-headed Grebe	0	0	2	51*	0	0	0	0	0	0	1
Intermediate Egret	24	1	0	2	2	0	0	7	0	0	0
Latham's Snipe	0	0	14	3	0	0	0	0	0	0	0
Little Black Cormorant	1	2	0	17	1	59*	5	12	15	13	100*
Little Egret	2	0	0	5	0	0	0	0	0	0	0
Little Pied Cormorant	1	12	1	100	22	36*	3	138	5	268*	19*
Magpie Goose	0	1	0	320*	0	0	0	0	0	0	0
Marsh Sandpiper	0	0	0	2	0	0	0	0	0	0	0
Masked Lapwing	18	0	8	39*	10	0	0	2	2	0	0
Musk Duck	0	0	0	8	1	3	0	5	2	0	0
Nankeen Night-Heron	7	1	1	14	32	4	4	7	2	11	6
Pacific Black Duck	97	16	63	114*	153*	12	8	149	7	59	1
Pied Cormorant	0	0	1	0	0	0	0	0	0	0	0
Pink-eared Duck	26	0	0	1000*	20	0	0	0	0	0	0
Plumed Whistling-Duck	4	0	40*	30	0	0	0	0	0	0	0
Purple Swamphen	1	4	4	59*	38	1	1	4	2	5	0
Red-capped Plover	0	0	0	32	0	0	0	0	0	0	0
Red-kneed Dotterel	0	0	0	135	5	0	0	0	0	0	0

Common Name	Narran Lakes	Gwydir Wetlands		Fivebough-Tuckerbil		NSW Central Murray Forests (Millewa)					
		Goddard's Lease	Old Dromana	Fivebough Swamp	Tuckerbil Swamp	Duck Lagoon	Horseshoe Lagoon	Moira Lake	Reedbeds North	Reedbeds South	St Helena Swamp
Red-necked Avocet	68	0	0	51	2	0	0	0	0	0	0
Royal Spoonbill	13	2	1	76	0	22	1	1	63*	30	0
Sharp-tailed Sandpiper	0	0	2	144	70	0	0	0	0	0	0
Silver Gull	19	0	0	500	3	0	0	1	0	0	0
Spotless Crake	0	0	0	10	0	0	0	0	0	0	0
Straw-necked Ibis	3	11	18	60	46	2	4	25	101*	329*	0
Wandering Whistling-Duck	0	0	0	4	0	0	0	0	0	0	0
Whiskered Tern	46	0	0	164	37	0	0	34	0	0	0
White-faced Heron	11	1	7	31	20	1	2	90	1	0	3
White-necked Heron	0	1	8	3	14	2	1	109	1	0	2
Wood Sandpiper	0	0	0	1	0	0	0	0	0	0	0
Yellow-billed Spoonbill	0	0	0	49	6	9	2	0	0	0	11
Total number of species	30	23	27	60	38	26	17	22	19	17	16
Number of species breeding	1	0	3	17	2	2	3	0	4	5	5