Evaluation of waterbird objectives and targets

Technical report supporting the NSW Basin Plan Matter 8 reporting 2019 to 2024

Department of Climate Change, Energy, the Environment and Water

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

Artist and designer Nikita Ridgeway from Aboriginal design agency Boss Lady Creative Designs created the People and Community symbol.

Cover photo: Flocks of feeding egrets, herons, ibis and terns in the lower Lachlan. Warren Chad, Weejugla Wildlife

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Abbreviations

Term	Meaning
BC Act	*Biodiversity and Conservation Act 2016* (NSW)
BWS	Basin-wide environmental watering strategy
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CSU	Charles Sturt University
DCCEEW	Department of Climate Change, Energy, the Environment and Water (NSW)
EAWS	Eastern Australian Waterbird Survey
EPBC Act	*Environment Protection and Biodiversity and Conservation Act 1999* (Cth)
EWAG	environmental water advisory group
Flow MER	Flow Monitoring, Evaluation and Research Program
GLM	generalised linear model
GLMM	generalised linear mixed model
JAMBA	Japan-Australia Migratory Bird Agreement
LTIM	Long Term Intervention Monitoring Project
LTWP	long-term water plan
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
MER	monitoring, evaluation and reporting
ML/d	megalitres per day
NPWS	National Parks and Wildlife Service (NSW)
NSW	New South Wales
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RPA	remotely piloted aircraft
SEA	specified environmental asset program
SoS	Saving our Species program (NSW)
STIM	short term intervention monitoring project
TLM	The Living Murray program

Term	Meaning
UNSW	University of New South Wales
WRPA	water resource planning area

Summary

Waterbirds are a diverse group of bird species that can be highly mobile and rely on a range of floodplain habitats in the Murray–Darling Basin (MDB). Improvements in waterbird populations are an expected outcome of the Murray–Darling Basin Plan as waterbirds respond strongly to floodplain inundation. The Basin-wide environmental watering strategy (BWS) and NSW long-term water plans (LTWP) set out waterbird objectives and targets for important wetland regions in the NSW MDB. These objectives focus on maintaining the number of species, increasing waterbird abundance, and providing greater opportunities for breeding.

Available aerial and ground survey data collected in the 2012 to 2016 period was used to quantify targets for waterbird species richness, abundance and breeding activity in the NSW LTWP. Aerial survey programs coordinated by the University of New South Wales provide an effective method for monitoring waterbird populations in large floodplain wetlands over time. The aerial survey data provides information on waterbird species richness, abundance and breeding activity. Ground survey data collected by the department and partners provided complementary information on more cryptic waterbird species that are difficult to identify from the air.

Waterbird objectives and targets were assessed for the 2019 to 2023 period to support the 2024 NSW Matter 8 reporting. A Bayesian modelling approach was used to assess overall trends in waterbird species richness, abundance and breeding activity. The analyses used available waterbird monitoring data. Ground survey data indicated that the number of waterbird species has been maintained across 6 monitored wetland regions. Trends in waterbird abundance varied among the assessed wetland regions. Aerial survey data showed evidence of an increasing trend in total waterbird abundance in the Gwydir Wetland system, stable trends in the Macquarie Marshes, Lowbidgee floodplain and Booligal Wetland system, and potential declines in the Narran Lakes, Great Cumbung Swamp and Barmah–Millewa Forest.

Widespread waterbird breeding was recorded in the 2021–22 and 2022–23 water years in response to prolonged, large-scale inundation events. In these water years, breeding was detected in 18 group-nesting species, and there were 25 individual breeding sites that each supported more than 5,000 nesting pairs. Increased breeding activity in other waterbird species, including waterfowl and water hens, was also detected in the wetland regions during the reporting period.

Environmental water delivery influenced the timing, extent and duration of inundation in waterbird breeding and feeding habitats in the 2019 to 2023 period. The delivery of water for the environment and management of infrastructure was critical for maintaining water depths within and surrounding managed breeding sites in the very wet 2021 to 2023 period. The use of water for the environment during drier periods also provided waterbird feeding habitat and opportunities for small-scale breeding events in some wetland regions.

1. Introduction

1.1 Waterbird responses to flows

Waterbirds are a group of highly mobile species that can respond strongly to river flows which inundate floodplain wetlands (Amat and Green 2010; Kingsford and Norman 2002). They are a key indicator of water-dependent ecosystems of the Murray–Darling Basin (MDB) and are of cultural significance to Aboriginal people. Improvements in waterbird breeding opportunities and abundance are also listed as one of the expected environmental outcomes in the Basin-wide environmental watering strategy (BWS) (MDBA 2019).

The MDB supports some of the most important wetlands used for waterbird breeding in Australia (Brandis 2010; Kingsford et al. 2013). In total, 33 wetland assets have been identified in the MDB that are important for achieving improvements in waterbird populations (MDBA, 2019). With more water available for the environment, increases in the frequency, duration and extent of wetland inundation are expected to provide more habitat for waterbirds and improved outcomes for waterbird populations.

Monitoring linked to environmental watering events provides evidence of ecological outcomes and improved understanding of waterbird responses to flows and inundation. Environmental water delivery can be used to influence the timing, extent and duration of inundation of key waterbird breeding and feeding sites. Many group-nesting species, such as egrets, ibis, and pelicans, can nest in their thousands at individual breeding sites in the NSW MDB. They require adequately timed flows of sufficient duration, depth and extent to cover their breeding cycle so they can raise their young successfully.

1.2 Objectives, targets and expected outcomes

Waterbird ecological objectives and targets were developed as one of 5 themes in NSW long-term water plans (LTWP) published in 2019–20 by the NSW Department of Climate Change, Energy, the Environment and Water (the department) (see Table 1 and Appendix A). These objectives align closely with waterbird expected outcomes specified in the BWS (MBDA 2019). The BWS and LTWPs identify objectives that focus on waterbird species richness, abundance and breeding activity. The NSW LTWPs also include an additional waterbird habitat objective that aligns with the BWS objectives for increased opportunities for breeding (Table 1). For further information on the development of the waterbird objectives and targets see the NSW LTWP background document (DPE 2023).

Table 1 **Summary of waterbird objectives and targets listed in the BWS and NSW LTWPs. See Appendix A for full list of LTWP 5-year waterbird objectives and targets for WRPAs assessed in this report**

BWS expected environmental outcomes	LTWP Objective	LTWP targets	2024 LTWP evaluation (measure of success)
The number and type of waterbird species will not fall below current observations	WB1: Maintain the number and type of waterbird species	Maintain number of waterbird species across the 5 functional groups in the wetland region (as determined by annual spring surveys).	No decline in total number of waterbird species recorded in the wetland region in the 2019 to 2024 period.
There will be a significant improvement in waterbird populations	WB2: Increase total waterbird abundance across all functional groups	Maintain total waterbird abundance across all functional groups in the wetland region (as determined through annual spring surveys).	No decline in total waterbird abundance (across all functional groups) in the wetland region in the 2019 to 2024 period.
There will be increased breeding abundance of other functional groups	WB3: Increase breeding opportunities for other waterbird species (non-group-nesting species)	Maintain number and abundance of non-group-nesting species in the wetland region (as determined by annual spring surveys).	No decline in number of breeding species and total abundance of non-group-nesting species in the wetland region in the 2019 to 2024 period.
There will be increased opportunities for breeding events for group-nesting species	WB4: Increase breeding opportunities for group-nesting waterbird species	Support waterbird breeding sites in the wetland region by maintaining the water depth and duration of inundation (as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) and maintain duration of inundation in key foraging habitats to enhance breeding success and the survival of young.	Successful completion of waterbird breeding events at sites active during the 2019 to 2024 period. Water levels in waterbird breeding sites and associated feeding habitats in the 2019 to 2024 period maintained for the duration of breeding.

BWS expected environmental outcomes	LTWP Objective	LTWP targets	2024 LTWP evaluation (measure of success)
		Where possible, initiate and support small-scale waterbird breeding events in line with natural cues in the wetland region.	Small-scale waterbird breeding recorded in the wetland region in the 2019 to 2024 period.
	WB5: Maintain extent and improve condition of waterbird habitats	Maintain extent and improve condition of nesting vegetation, including river red gum, common reed, lignum, cumbungi and river cooba in known breeding locations in the wetland region.	To be evaluated as part of known water requirements (duration and frequency of inundation) of wetland vegetation communities.
		Maintain or increase extent and improve condition of waterbird foraging habitats and potential breeding locations in the wetland region.	To be evaluated under LTWP targets set for native vegetation.

1.3 Scope of this report

Waterbird objectives and targets were assessed for the 2019–20 to 2022–23 period to support the 2024 NSW Matter 8 reporting. Trends in waterbird indicators were assessed for 6 of the 9 water resource plan areas (WRPA) in the NSW MDB. This included the Gwydir, Intersecting Streams, Macquarie–Castlereagh, Lachlan, Murrumbidgee and NSW Murray–Lower Darling WRPAs. These WRPAs have long-term aerial and/or ground survey data available. Due to time constraints for reporting it was not possible to include the 2023–24 data and all wetland regions in this first evaluation of the LTWP waterbird objectives and targets.

The trend assessments focused on 8 wetland regions spread across the northern, central and southern NSW MDB (Figure 1):

- Gwydir Wetland system (Gwydir)
- Narran Lakes (Intersecting Streams)
- Macquarie Marshes (Macquarie–Castlereagh)
- Booligal Wetland system (Lachlan)
- Great Cumbung Swamp (Lachlan)
- lower Murrumbidgee (Lowbidgee) floodplain (Murrumbidgee)
- mid Murrumbidgee wetlands (Murrumbidgee)
- Barmah–Millewa Forest (NSW Murray–Lower Darling).

There are other important wetland regions that support waterbirds in these WRPAs including Yantabulla Swamp, Cuttaburra Channels, Paroo Overflow lakes (Intersecting Streams), Lake Brewster, Lake Cowal (Lachlan), Fivebough–Tuckerbil Swamp (Murrumbidgee), Gunbower-Koondrook-Perricoota, Menindee Lakes and Darling Anabranch (Murray–Lower Darling), which were not assessed in this report. The NSW LTWPs also include an additional waterbird habitat objective focused on wetland vegetation extent and condition (Table 1) which was not evaluated as part of this report.

The University of New South Wales (UNSW) aerial survey data and available ground survey data collected by the department and partners were used to evaluate waterbird objectives and targets for species richness, abundance and breeding activity. The aerial survey data provides a highly effective way of monitoring waterbird populations over time (Kingsford et al. 2020). Complementary ground survey data provided information on more cryptic and less common species that can be difficult to identify from the air.

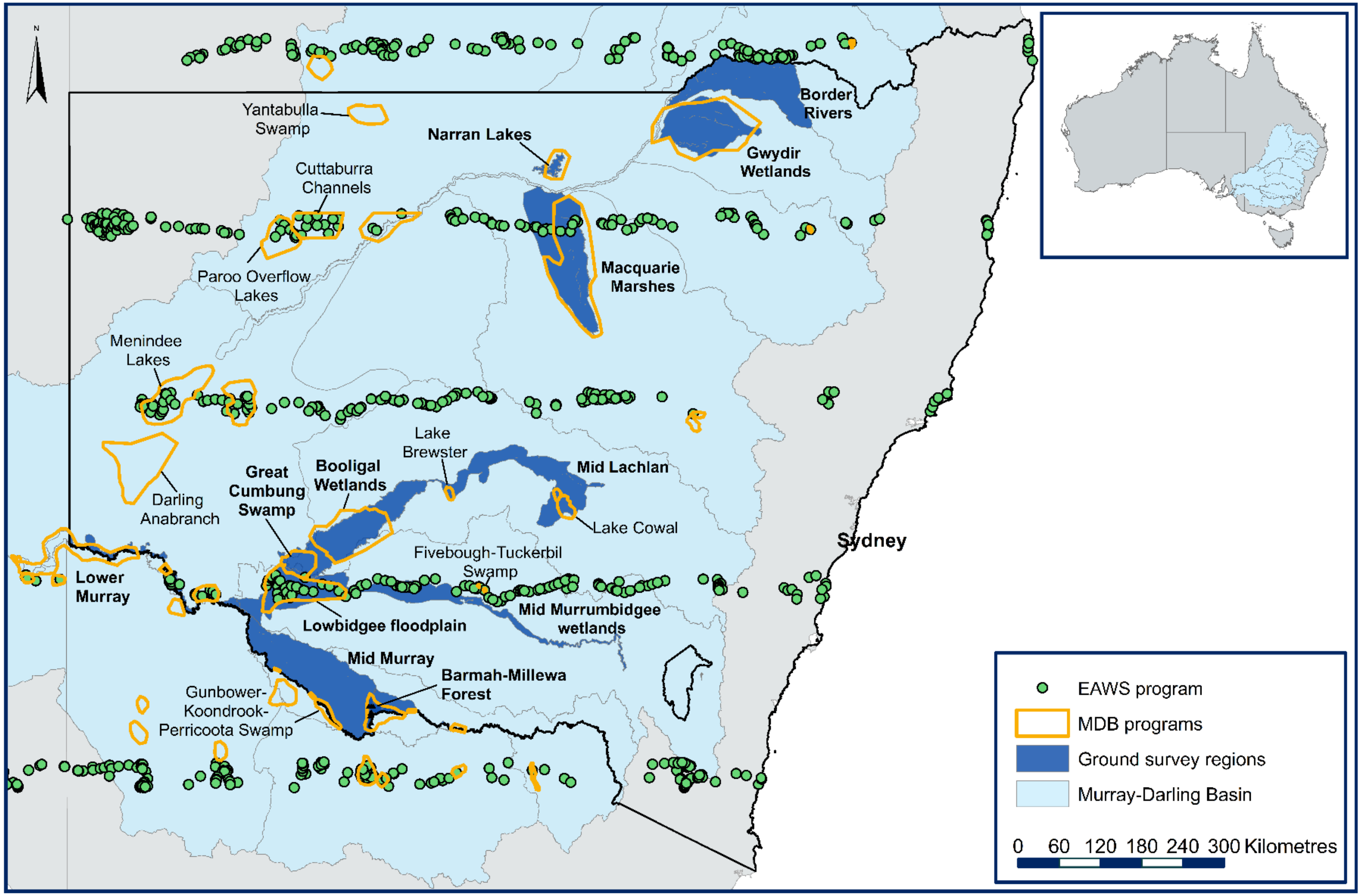

Figure 1 **UNSW aerial surveys and the department's annual ground surveys were the main datasets used for evaluating objectives and targets in the NSW LTWPs. The aerial survey datasets include the Eastern Australia Waterbird Survey (EAWS) and Murray-Darling Basin (MDB) programs. The ground survey data included sites monitored through The Living Murray (TLM) program in Barmah–Millewa Forest**

2. Methods

2.1 Wetlands monitored

There are 19 wetland regions monitored as part of UNSW MDB aerial survey programs in the NSW MDB. The department and partner agencies also undertake ground surveys in 10 wetland regions (Figure 1). This evaluation is focused on 3 wetland regions in the northern MDB (the Gwydir Wetlands system, Narran Lakes and Macquarie Marshes), 2 wetland regions in the central MDB (Booligal Wetland system and Great Cumbung Swamp) and 3 wetland regions in the southern MDB (mid Murrumbidgee wetlands, Lowbidgee floodplain and Barmah–Millewa Forest) (Figure 1). These wetland regions have long-term aerial and/or ground survey data.

The Gwydir Wetlands system (Gwydir Wetlands) includes the Gingham, lower Gwydir and Mehi–Mallowa watercourses. The Narran Lakes receive flows from the Narran River and is an intermittently flooded lake system. The Macquarie Marshes is an extensive floodplain wetland that receives flows from the Macquarie River. All 3 wetland regions contain areas identified as wetlands of international importance under the Ramsar Convention.

The lower Lachlan comprises vast areas of floodplain wetlands including the Booligal Wetlands system (Booligal Wetlands) and Great Cumbung Swamp. The Booligal Wetlands includes a group of wetlands fed by the Merrimajeel and Muggabah creeks and, on large inundation events, the Merrowie Creek. The Great Cumbung Swamp receives flows from the Lachlan River and can connect to, and is influenced by, inundation in the Murrumbidgee River to the south during periods of high river flows.

The Murrumbidgee River connects to the mid Murrumbidgee wetlands and Lowbidgee floodplain, which supports diverse floodplain wetlands located in the Gayini wetlands, Redbank wetlands and Western Lakes. Barmah–Millewa Forest is located on the central Murray River floodplain and is also recognised under the Ramsar Convention as an important site for waterbirds.

2.2 Survey coverage

Aerial surveys

Long-term data on changes in waterbird populations and wetland extent in NSW have been collected annually since 1983 as part of several aerial survey programs managed by UNSW and supported by the department and other eastern states. The longest running program is the Eastern Australian Waterbird Survey (EAWS) which uses 10 survey bands (30 km wide) across eastern Australia each spring, providing an effective long-term measure of waterbird species abundance and breeding activity (Kingsford et al. 2020). Since 2007 UNSW has also conducted additional aerial surveys of wetlands in the MDB supported by the Murray–Darling Basin Authority (MDBA) and the department, including sites not covered by the EAWS survey bands (Figure 1) (Kingsford et al. 2020). The MDB aerial survey program was the main dataset used to assess waterbird trends in the assessed wetland regions. These surveys cover the entire area of each monitored wetland region and usually include 2 replicate surveys per wetland. The EAWS data was used for the Lowbidgee floodplain (only) as this program is transect based and provided the best coverage for this region (Figure 1).

Waterbirds are counted by a front and rear observer from a high-winged aircraft at a height of 30 to 46 m. The counts are recorded onto audio recorders and later transcribed to produce complete counts for each wetland region (see Kingsford et al. 2020 for detailed methods). Due to the nature of the surveys, several species need to be grouped, including small egrets (little egret, cattle egret, intermediate egret), small grebes (hoary-headed grebe, Australasian grebe) and migratory shorebird species (as either small or large migratory shorebirds), as these species cannot be easily identified from the air.

Ground surveys

Ground surveys are coordinated annually by the department in key wetlands in the NSW MDB as part of the NSW Water for the Environment Program's monitoring, evaluation and reporting (MER) projects (Figure 1). Timing of the department's annual ground surveys (October to November) coincides with the EAWS and MDB aerial surveys each spring. Noting that the ground survey and aerial survey coverage for each wetland region does not align exactly. Surveys began in 2008 for the Lowbidgee floodplain and in 2010 for the Gwydir Wetlands. Ground survey coverage was expanded to include the Narran Lake Nature Reserve, Macquarie Marshes and mid Murrumbidgee in 2012 (Spencer et al. 2014), wetlands in the mid and lower Lachlan in 2016 (Spencer et al. 2018), and the NSW mid and lower Murray in 2018 (Thomas et al. 2023). Due to the short time frame of ground survey data collection for the Lachlan and Murray wetland regions these datasets are not included in this evaluation. The MDBA has funded quarterly ground surveys of Barmah–Millewa Forest (Figure 1) as part of The Living Murray (TLM) program since 2008. Data for both Millewa Forest (NSW) and Barmah Forest (Victoria) are included in this evaluation. High river flows limited ground survey access in all wetland regions in spring 2022 and so ground survey data availability was restricted to the 2012 to 2022 water years. See Table 2 for survey coverage for each wetland region.

Table 2 **Summary of annual spring ground survey coverage 2008 to 2022. 'Y' represents the inclusion of survey data for each wetland region in each survey year**

WRPA	Wetland region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Intersecting Streams	Narran Lakes	–	–	–	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gwydir	Gwydir Wetlands	–	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	–
Macquarie–Castlereagh	Macquarie Marshes	–	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	–
Lachlan	Mid Lachlan wetlands	–	–	–	–	–	–	–	–	Y	Y	Y	Y	Y	Y	Y
	Lower Lachlan wetlands	–	–	–	–	–	–	–	–	Y	Y	Y	Y	Y	Y	–
Murrumbidgee	Mid Murrumbidgee wetlands	–	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Lowbidgee Floodplain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	–
NSW Murray–Lower Darling	NSW mid Murray	–	–	–	–	–	–	–	–	–	–	Y	Y	Y	Y	Y
	NSW lower Murray	–	–	–	–	–	–	–	–	–	–	Y	Y	Y	Y	Y
	Barmah–Millewa Forest	Y	Y	Y	Y	Y	–	Y	Y	Y	Y	Y	Y	Y	Y	–

Survey methods and survey locations for the spring ground surveys are outlined in more detail in the NSW Water for the Environment Program's standard methods for monitoring waterbirds (DCCEEW, 2024). The field monitoring is focused on collecting data on waterbird species richness, abundance and evidence of breeding activity. A range of sites were surveyed in each wetland region each spring. These included open lakes and lagoons, vegetated marsh/sedgelands, channel or riverine sites, and artificial wetlands. Waterbird species were counted with binoculars (and/or a telescope for large open waterbodies) at each site on at least 2 occasions (on separate days) during each survey period. The replicate counts are used to estimate the maximum number of waterbird species and maximum count of each species per site. Dry sites were only surveyed once. The total number of each waterbird species was recorded along with any evidence of breeding activity (i.e. the number of broods or nests). Additional ground surveys of group-nesting sites were undertaken to capture information on number of breeding species, number of nests and extent of each breeding site (see details below).

2.3 Waterbird breeding

Known group-nesting sites were surveyed during the annual spring aerial and ground surveys to determine the location and size of active breeding sites. Additional aerial surveys to identify active breeding sites were carried out in a fixed-wing aircraft or by helicopter during summer. Large breeding events occur relatively infrequently, and some species can be sensitive to rapid changes in water levels (Brandis et al. 2011). Therefore, regular ground monitoring over the breeding period (4 to 6 months) is needed to support the management of flows and to document the outcomes of environmental water management.

Departmental staff and partner agencies undertook ground surveys of active waterbird breeding sites to document the number of breeding species and the stage of nesting (see DCCEEW 2024). UNSW also undertook repeat drone-based surveys at very large ibis and pelican nesting sites to document breeding site extent, total numbers of nests, stage of nesting, and evidence of mortality (Brandis et al. 2023; Francis et al. 2023).

Information from the aerial, ground and drone surveys was collated to assess total number of nests per species and number of breeding species for 6 wetland regions that support large breeding events in the NSW MDB. A combination of survey techniques, including aerial (fixed-wing and helicopter), ground, boat, and drone-based surveys, were used to document the locations and size of active waterbird breeding sites and the number of breeding species. Departmental staff and contractors monitored over 80 breeding sites in the 2021–22 and 2022–23 water years across the northern and southern NSW MDB. This was done in collaboration with researchers from UNSW and Charles Sturt University (CSU) funded through Commonwealth Environmental Water Holder (CEWH) monitoring programs.

Other waterbird species, such as waterfowl and waterhens, do not generally form large breeding aggregations and can show cryptic nesting behaviour. For these waterbirds, the total number of breeding species detected in each spring period was determined by combining records from the annual spring aerial and ground survey data. This approach was used to compare the number of breeding species detected during the baseline (2012 to 2016) and reporting (2019 to 2023) periods.

2.4 Information reliability

The information reliability scoring system established by Battisti et al. (2014) was used to assess the datasets used for this evaluation of waterbird objectives and targets (see Appendix B). A combination of aerial, ground and drone-based survey programs was required to collect data on key waterbird indicators to measure progress towards long-term waterbird objectives and targets. Difficulties with counting waterbirds using aerial and ground survey methods are well recognised, with there being advantages and disadvantages in using either method (Kingsford 1999). The aerial surveys are effective at covering very large floodplain wetland systems that can be difficult to access on ground. Ground surveys complement aerial surveys by providing detailed information for waterbird groups that cannot be identified to species level during the aerial counts, for example migratory shorebirds, small grebes and small egrets, and cryptic species such as bitterns, rails and crakes (Kingsford 1999).

The aerial survey programs have used the same methodology and established survey techniques have been used on the ground. The aerial survey datasets used for this assessment cover 33 wetland assets identified as important for waterbirds in the MDB (MDBA, 2019). The same survey methods are used for all sites including the 7 wetland regions in the NSW MDB included in this trend analysis. Ground survey methods were consistent across all sampled wetland regions in the monitoring programs. Repeat visits to individual wetland sites were undertaken in spring (October–November) each year for both the assessment and baseline periods. Established survey sites were revisited during each set of spring surveys for each wetland system over both the baseline and assessment periods. The analysis focused on wetland regions where long-term ground survey data was available from at least 2012 onwards.

A combination of ground, drone and aerial survey methods was used to collate information on the location, estimated number of total nests and total number of group-nesting species for active breeding sites in the baseline and assessment periods. Expansion in the use of drone survey technology in recent years has provided high resolution data on the number of nests in very large ibis and pelican breeding sites (Brandis et al. 2023; Francis et al. 2023). This has improved the reliability and repeatability of counts for monitoring large (>5,000 nests) breeding sites (Francis et al. 2020). Ground and aerial data was used to estimate total number of nests and number of breeding species for other active sites. Repeat ground and drone surveys focused on large breeding sites (>5,000 nests) in each wetland region. Less intensive monitoring has been undertaken at smaller breeding sites from 2012 onwards. A combination of ground and aerial annual spring survey data was used to gather information on the breeding activity of other species of waterbirds (e.g. waterfowl, water hens and shorebirds) for the baseline and assessment periods. These types of waterbirds can be cryptic when nesting, so the total number of breeding species recorded in each wetland region each spring is likely to be an underestimate.

2.5 Trend assessment

Data collected from aerial (since 2010) and ground (since 2012) surveys was used to examine trends in waterbird indicators across the monitored wetlands (Table 2). The MDBA-funded Specified Environmental Asset (SEA) program was the main dataset used to assess waterbird trends in wetland regions in our analyses. The EAWS data was used for the Lowbidgee floodplain (only). Aerial data collected across 2 replicate surveys as part of the SEA and/or EAWS aerial survey programs was used to calculate total species richness for each survey year. As not all years or wetland regions have matching replicate counts, aerial survey data from the first replicate survey (only), was used for calculating total waterbird abundance and total abundance for each functional group (see Appendix C).

The aerial survey data was used to calculate total number of species, total waterbird abundance, total abundance of each functional group (as per Kingsford et al. 2020), number of breeding species (non-group-nesting species) and total abundance of non-group-nesting species.

The 5 functional groups included:

- ducks (e.g. ducks and grebes)
- herbivores (e.g. swans and geese)
- large waders (e.g. ibises and egrets)
- piscivores (e.g. cormorants, terns, and pelicans)
- shorebirds (e.g. sandpipers and plovers).

Ground survey data collected by the department and partner agencies, including TLM data for Barmah–Millewa Forest, provided another source of data to examine trends in total species richness. A trend assessment was undertaken for waterbird species that are not considered group-nesting species (i.e., ducks, herbivores, and shorebirds) (see Appendix C) by combining the total number of breeding species recorded each spring in aerial and ground surveys. This data was used to determine the total number of breeding species in this group recorded during the baseline and current reporting periods. The total abundance of non-group-nesting waterbirds was based on aerial data alone (Table 3). Breeding activity for group-nesting species (i.e. large waders and piscivores) was collated to determine the total number of breeding species and the total number of nests per water year in the 2008 to 2023 period for 6 wetland regions (Table 3). This information was also used to assess targets set for supporting small breeding events in selected wetland regions in the 5-year reporting period (see Appendix A).

Table 3 **Trends assessed for each of the waterbird indicator variables using available aerial and ground survey data in the assessed wetland regions.* 'Y' represents the inclusion of survey data for each wetland region for each indicator**

Waterbird indicator*	Datasets	GWY	NAR	MAC	BOO	GCS	MID	LOW	BMF
Species richness	Aerial	Y	Y	Y	Y	Y	–	Y	Y
	Ground	Y	Y	Y	–	–	Y	Y	Y
Total abundance	Aerial	Y	Y	Y	Y	Y	–	Y	Y
Functional group abundance	Aerial	Y	Y	Y	Y	Y	–	Y	Y
Breeding species (non-group-nesting)	Aerial and ground	Y	Y	Y	–	–	–	Y	Y
Total abundance (non-group-nesting)	Aerial	Y	Y	Y	Y	Y	–	Y	Y
Breeding species (group-nesting species)	Aerial and ground	Y	Y	Y	Y	–	–	Y	Y
Total nests (group-nesting species)	Aerial, drone and ground	Y	Y	Y	Y	–	–	Y	Y
Number of breeding sites	Aerial and ground	–	–	–	Y	Y	Y	Y	Y

*Assessed wetland regions included the Gwydir Wetlands (GWY), Narran Lakes (NAR), Macquarie Marshes (MAC), Booligal Wetlands (BOO), Great Cumbung Swamp (GCS), mid Murrumbidgee wetlands (MID), Lowbidgee floodplain (LOW) and Barmah–Millewa Forest (BMF).

A Bayesian approach was used to model trends in waterbird indicators based on the time-series data. This approach is seen as more reliable than traditional hypothesis testing when assessing trends over different time periods (McBride 2019).

Two types of trends were modelled:

1. long-term trends, which show continuous trends across consecutive years from the start of surveys to the present year
2. current compared to baseline, which compare the years following a baseline period set out in the LTWP to that baseline period.

The statistical package 'rstanarm' (Goodrich et al. 2020) was used in program R version 4.3.2 to conduct generalised linear models (GLMs) and generalised linear mixed models (GLMMs), depending on whether the model included a random variable (e.g. functional group). Bayesian models were run at 4,000 iterations to give a posterior sample size of 8,000. This was to prevent instances of Markov chains not converging (Goodrich et al. 2020). The slope was then estimated from the posterior distribution, and trend direction and likelihood were determined using Markov chain Monte-Carlo simulations. The probability mass function was altered gradually to define credible intervals from which an estimated slope of 0 was excluded as per the trend assessment procedure outlined by McBride (2019). These predetermined credible intervals illustrate the direction (+/-) and likelihood of a trend, with the outcome of the trend analysis being simplified into the form of a report card (Table 4).

Reporting categories were used to describe whether each waterbird indicator was increasing, declining, or stable, based on the method proposed by Mastrandrea et al. (2010). Depending on the type of trend, the direction and likelihood of the trend were determined from the relationship between the mean of the sample population and either an estimated slope of 0 (for long-term trends) or the mean of the posterior distribution of the sample population from the baseline period (for current compared to baseline). See Appendix D and Appendix E for more detailed explanation of the model outputs.

Table 4 **Reporting categories were used to describe whether each waterbird indicator was increasing, declining or stable based on the method proposed by Mastrandrea et al. (2010). See further details in Appendix D. Depending on the type of trend, the direction and likelihood of the trend were determined from the relationship between the mean of the sample population and either an estimated slope of 0 (for long-term trends) or the mean of the posterior distribution of the sample population from the baseline period (for current compared to baseline)**

Outcome	Report card category	Likelihood of increase/decrease (%)	Code
Virtually certain increase	Increasing	100 to 99	↑↑↑↑
Extremely likely increase		99 to 95	↑↑↑
Very likely increase		95 to 90	↑↑
Likely increase		90 to 66	↑
About as likely as not	Stable	66 to –66	=
Likely decrease	Declining	–66 to –90	↓
Very likely decrease		–90 to –95	↓↓
Extremely likely decrease		–95 to –99	↓↓↓
Virtually certain decrease		–99 to –100	↓↓↓↓

3. Results

3.1 River flows and wetland inundation

Catchment rainfall, river flows (Figure 2 and Figure 3) and wetland inundation varied considerably across the monitored wetlands during the 2019 to 2023 assessment period. NSW and Commonwealth environmental water was delivered over this period to key wetland regions with objectives to support waterbird breeding and/or feeding habitat (see Appendix F). At the beginning of 2019–20, widespread dry conditions occurred across the MDB which impacted wetland inundation in all wetland regions. Some environmental water was delivered during this dry period to maintain refuge habitats in Barmah–Millewa Forest, the Lowbidgee floodplain and the Gwydir Wetlands. Although very dry conditions continued through to early 2020, rainfall increased in the northern river catchments from February 2020 resulting in wetland inundation from natural and/or managed flow events.

As wet conditions were maintained in the 2020 to 2023 period, this allowed for greater environmental water deliveries alongside natural high river flows. There were some large watering actions in 2020–21 to inundate core wetland areas. High catchment rainfall and high river flows from winter 2021 onwards resulted in 2 consecutive years of extensive inundation in all northern and southern wetland regions. These wet conditions vastly expanded the availability of inundated wetland habitat for waterbird breeding. Targeted or discretionary environmental water was delivered to maintain the duration of wetland inundation at many waterbird breeding sites. This water for the environment was sourced from NSW, Commonwealth, and joint government water accounts. The 2021–22 and 2022–23 water years were the wettest period since 2016–17 for many wetland regions; however, the Narran Lakes and Gwydir Wetlands had not received high river flows since 2011–12 (Figure 2 and Figure 3).

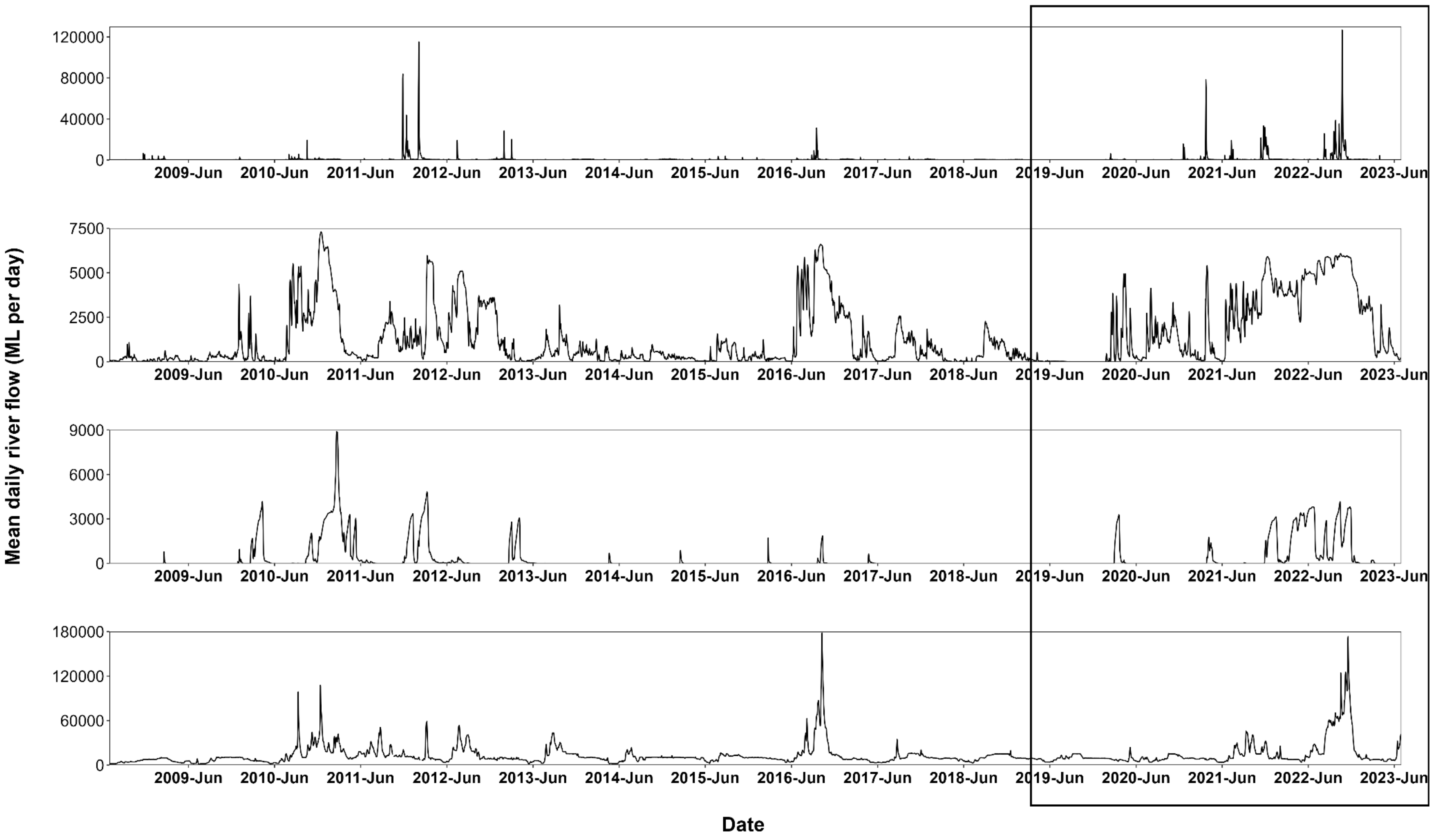

Figure 2 **Mean daily river flow rates (megalitres (ML) per day) recorded at river gauging stations in the 1 July 2008 to 30 June 2023 period (the 2019 to 2023 reporting period is highlighted) upstream of the (a) Gwydir Wetlands (418004 [Yarraman Bridge]), (b) Macquarie Marshes (421090 and 421088 [Macquarie River combined]) (c), Narran Lakes (422029 [Narran Park]), and (d) Barmah–Millewa Forest (409025 [downstream Yarrawonga Weir]). Data provided by Water NSW (2024). Note there are different scales for the Y-axis (daily river flows) in each plot**

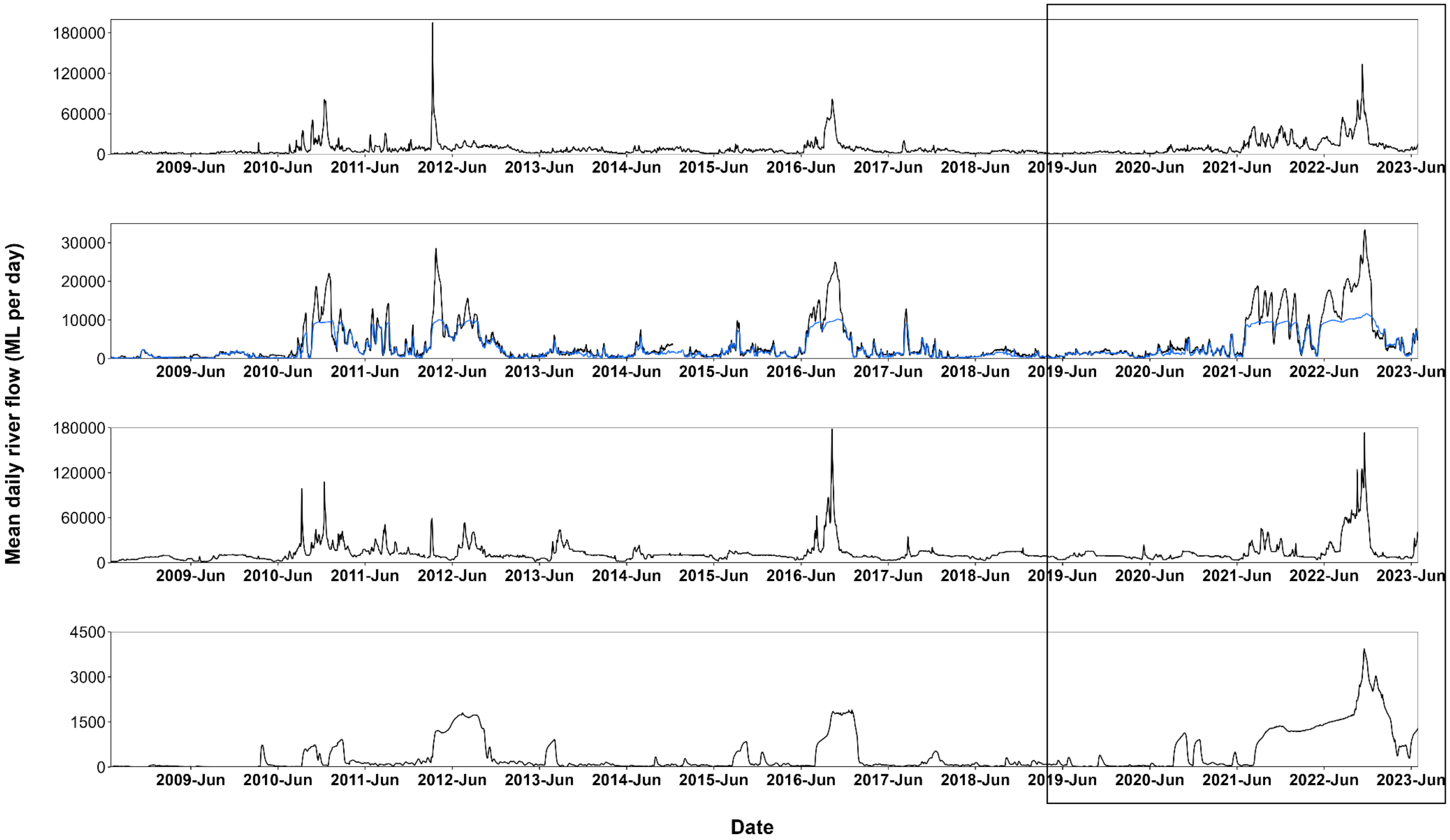

Figure 3 **Mean daily river flow rates (megalitres (ML) per day) recorded at river gauging stations in the 1 July 2008 to 30 June 2023 period (the 2019 to 2023 reporting period is highlighted) upstream of the (a) mid Murrumbidgee wetlands (410005 [Narrandera]), (b) Lowbidgee floodplain (410040 [downstream Maude Weir (black line)] and 410041 [downstream Redbank Weir (blue line)]) (c), Booligal Wetlands (412005 [Booligal]), and (d) Great Cumbung Swamp (410245 [Corrong]). Data sourced from Water NSW (2024). Note there are different scales for the Y-axis (daily river flows) in each plot**

3.2 Objective 1: Maintain the number of waterbird species

The objectives and targets for waterbird species in the assessed WRPAs are outlined in Appendix A. The species richness targets were assessed using ground survey data for 6 wetland regions (Table 5). To meet the species richness targets, the total number of waterbird species recorded in ground survey data over the 2012 to 2016 (baseline) period needed to be maintained for the 2019 to 2023 (current) reporting period. UNSW aerial data was also used to assess long-term trends in species richness for 7 wetland regions (Table 5).

Based on the ground survey data the total number of waterbird species was maintained in all 6 wetland regions assessed (Table 5). This result was observed in the Gwydir Wetlands, Narran Lakes, Macquarie Marshes, mid Murrumbidgee wetlands, Lowbidgee Floodplain and Barmah–Millewa Forest (Figure 4 and Figure 5). Long-term trends in the aerial survey data collected over the 2010 to 2022 period were also stable for species richness in 6 of the 7 wetland regions assessed (Figure 6 and Figure 7). This did not include the Narran Lakes where extended dry periods were recorded in the 2014 to 2019 period (Table 5 and Figure 2).

Table 5 **Summary of trends in waterbird species richness in the monitored wetland regions based on ground and aerial survey data. Trend directions are classed as increasing (green), stable (yellow) or declining (orange and red). The likelihood values (%) provide confidence values for the direction of the trends (see Table 4 for explanation of trends). Ground survey data was used to compare current (2019 to 2022) with the baseline (2012 to 2016) period and the aerial data was used to evaluate long-term trends (2010 to 2022) in total number of waterbird species**

WRPA	Wetland region	Ground data Likelihood of outcome (%)[a]	Ground data Overall trend	Code	Aerial data Likelihood of outcome (%)[a]	Aerial data Overall trend	Code
Gwydir	Gwydir Wetlands	10	Stable	=	40	Stable	=
Intersecting Streams	Narran Lakes	60	Stable	=	–88	Likely decrease	↓
Macquarie–Castlereagh	Macquarie Marshes	15	Stable	=	0	Stable	=
Murrumbidgee	Lowbidgee floodplain	0	Stable	=	50	Stable	=
	Mid Murrumbidgee wetlands[b]	65	Stable	=	–	–	–
Lachlan	Booligal Wetlands[c]	–	–	–	60	Stable	=
	Great Cumbung Swamp[c]	–	–	–	45	Stable	=
NSW Murray–Lower Darling and Victorian Murray	Barmah–Millewa Forest	10	Stable	=	10	Stable	=

Note: [a] Depending on the type of trend, the direction and likelihood of the trend were determined from the relationship between the mean of the sample population and either an estimated slope of 0 (for long-term trends) or the mean of the posterior distribution of the sample population from the baseline period (for current compared to baseline). [b] The SEA aerial survey program does not include the mid Murrumbidgee wetlands. [c] There was also no ground survey data available for Booligal and Great Cumbung wetlands in the lower Lachlan for the baseline period (2012 to 2016)

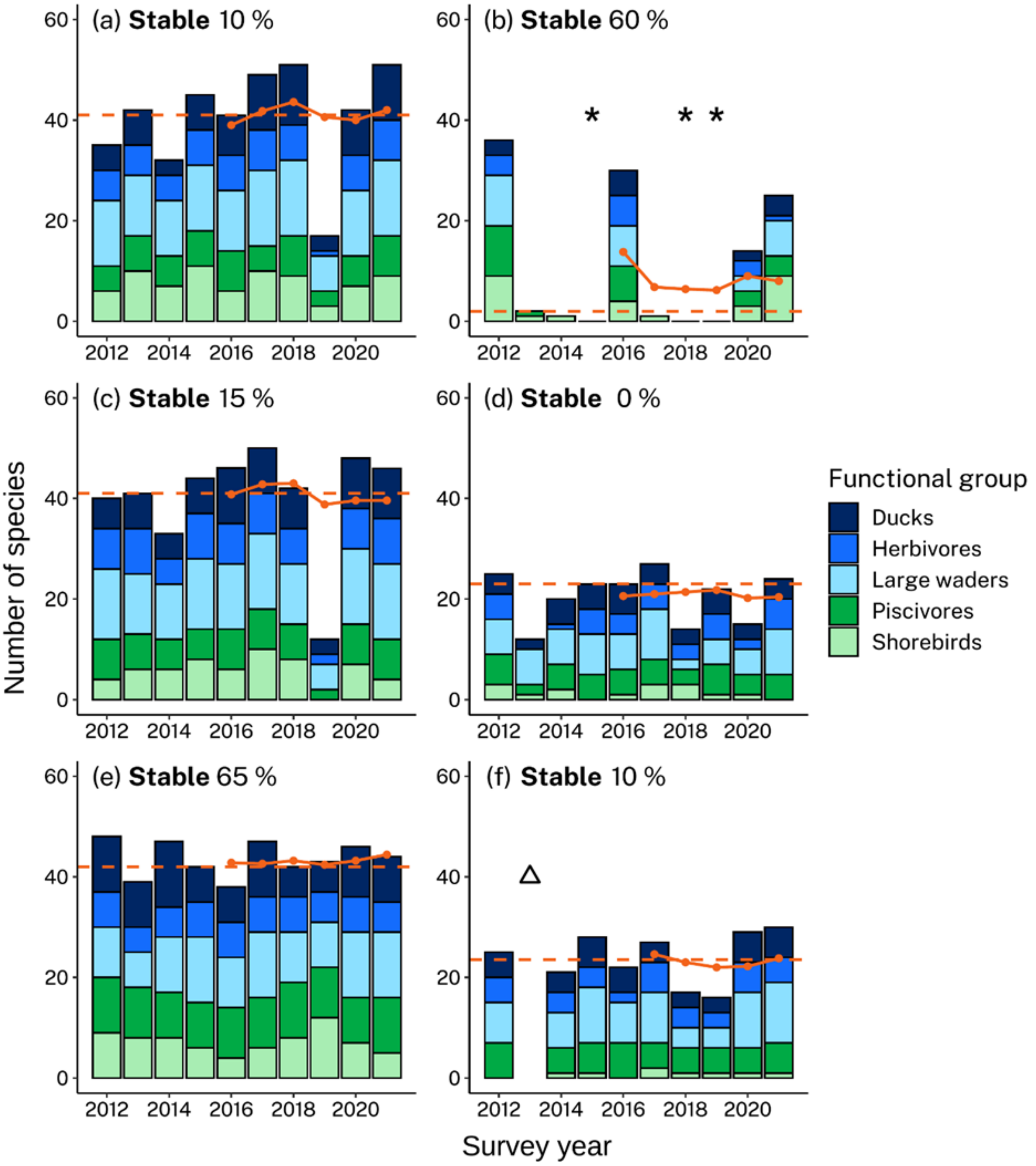

Figure 4 **Total number of waterbird species in each functional group (ducks, herbivores, large waders, piscivores and shorebirds) detected during annual ground surveys 2012 to 2021 for: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) mid Murrumbidgee wetlands, (e) Lowbidgee floodplain and (f) Barmah–Millewa Forest (mid Murray). The dashed orange line represents the median value for the 2012 to 2016 period. The solid orange line represents the 5-year rolling average from 2016 onwards. Narran Lakes were dry (*) during annual spring surveys in 2015, 2018 and 2019, and water levels were very low in spring 2013, 2014 and 2017 surveys. Data collected through the department's annual spring ground surveys and the MDBA's TLM Program (Barmah–Millewa Forest only). No data was available for Barmah–Millewa Forest in spring 2013 (triangle) and for all regions in spring 2022. Trends (stable/increasing/declining) and likelihood values (%) are reported relative to the 2012 to 2016 baseline period**

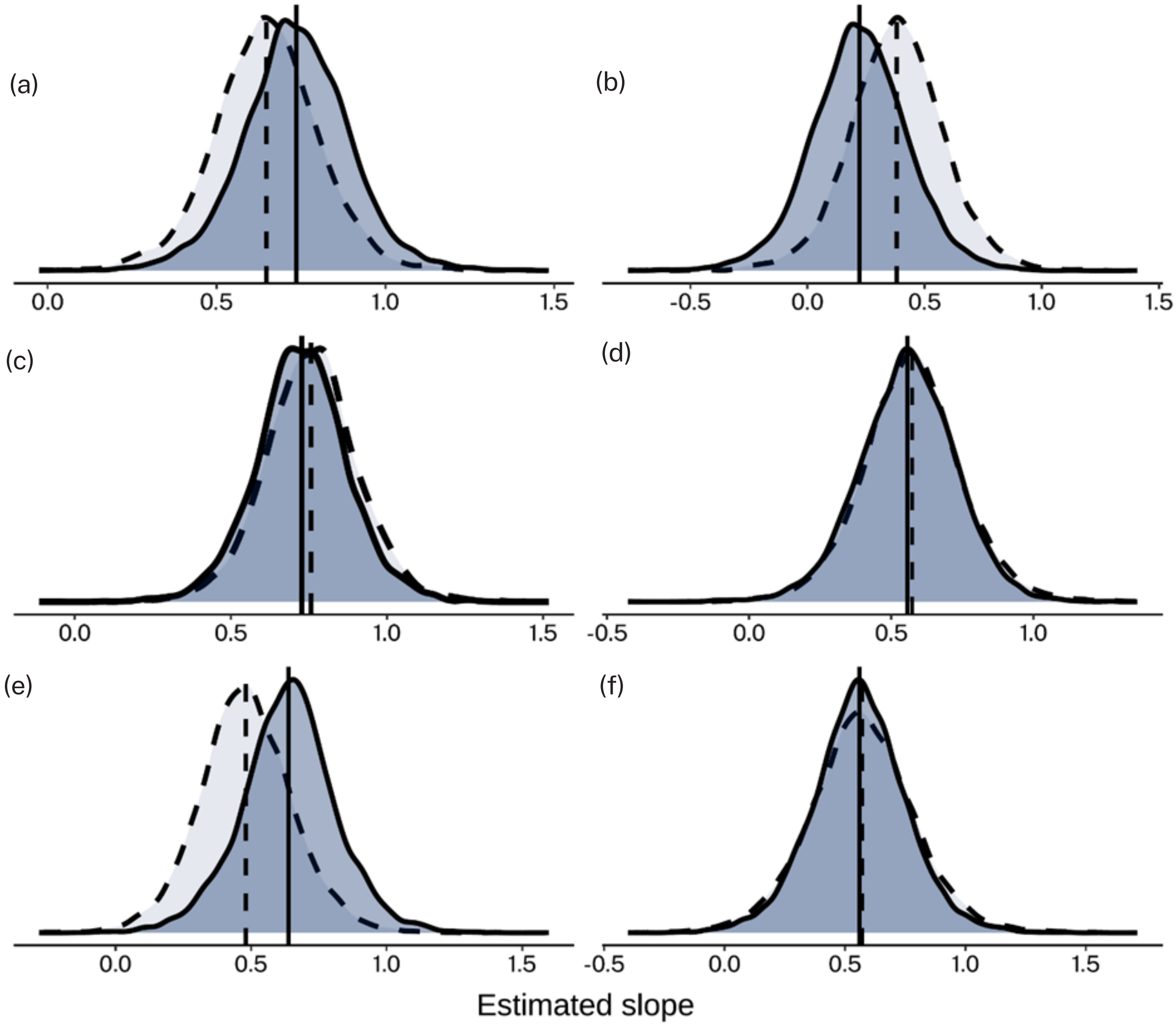

Figure 5 **Bayesian plots showing trends in species richness data collected through ground surveys completed in the 2012 to 2022 period for each wetland region: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) mid Murrumbidgee wetlands (e) Lowbidgee floodplain, and (f) Barmah–Millewa Forest (mid Murray). The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed black line)**

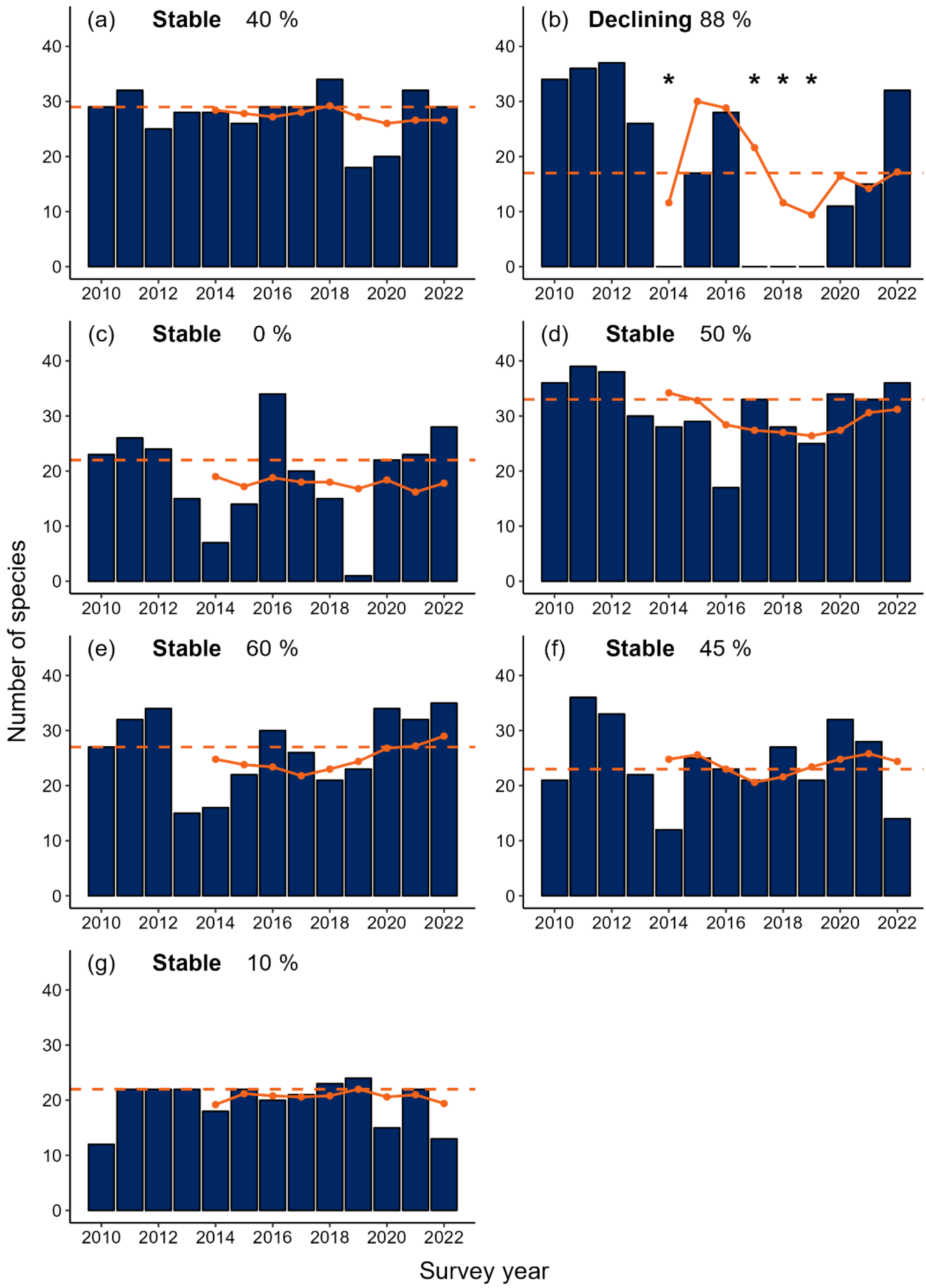

Figure 6 **Total number of waterbird species detected during annual aerial surveys for: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) Lowbidgee floodplain (e) Booligal Wetlands (lower Lachlan) (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). Dashed orange line shows the median value and dotted orange line shows the 5-year rolling average for the 2010 to 2022 period. *Narran Lakes were dry during annual spring aerial surveys in 2014, 2017, 2018 and 2019. Trends (stable/increasing/declining) and likelihood values (%) reported relative to the long-term 2010 to 2022 period. Data was provided by UNSW**

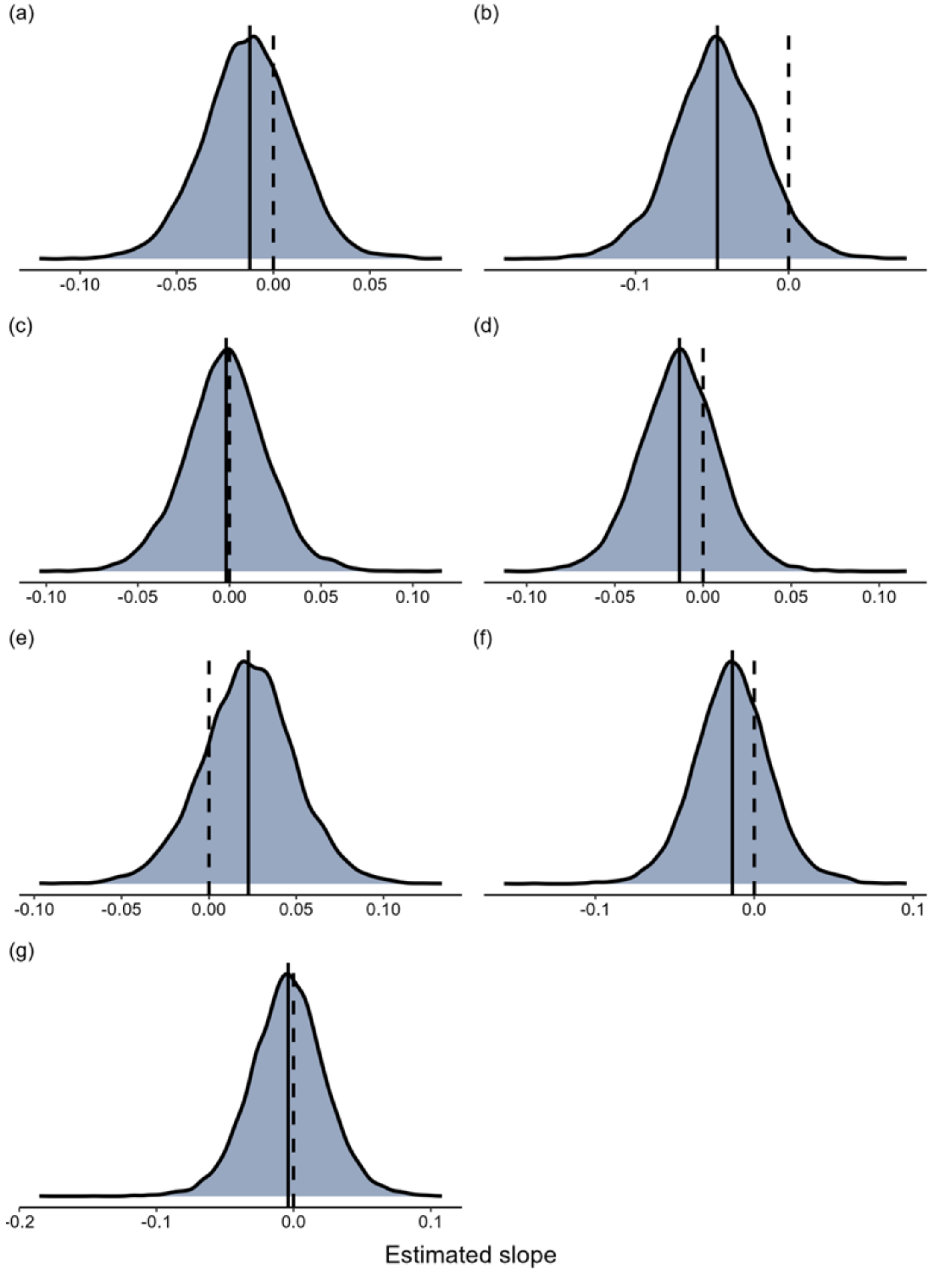

Figure 7 **Bayesian plots showing trends for species richness data collected in aerial surveys completed in the 2012 to 2023 period for each wetland area: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) Lowbidgee floodplain (e) Booligal Wetlands (lower Lachlan) (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to an estimated slope of zero (dashed black line)**

3.3 Objective 2: Increase waterbird abundance

The waterbird abundance objective and targets for the assessed WRPAs are outlined in Appendix A. These targets were set and evaluated based on available aerial survey data provided by UNSW. To meet the waterbird abundance targets, the total waterbird abundance recorded over the 2012 to 2016 (baseline) period had to be maintained over the 2019 to 2023 (current) reporting period (Table 6).

Trends in total waterbird abundance determined from aerial survey data remained stable in 3 wetland regions (Macquarie Marshes, Lowbidgee floodplain, Booligal Wetlands), increased in one wetland (Gwydir Wetlands) and declined in 3 wetland regions (Narran Lakes, Great Cumbung Swamp and Barmah–Millewa Forest) (Figure 8 and Figure 9). Some of these patterns in abundance were driven by changes in individual functional groups. For example, large increases in the numbers of ducks, large waders and herbivores were detected in aerial surveys of the Gwydir Wetlands in the 2021 and 2022 spring surveys following widespread floodplain inundation, while fewer birds in these groups were observed in Barmah–Millewa Forest and the Great Cumbung Swamp in the current compared to the baseline period (Figure 8). See Appendix E for detailed results of the functional group analyses.

Table 6 **Summary of trends in total waterbird abundance in 7 wetland regions based on UNSW aerial survey data. Aerial survey data was used to compare current (2019 to 2023) to baseline (2012 to 2016) periods. Trend directions are classed as increasing (green), stable (yellow) or declining (orange and red). The likelihood values (%) provide confidence values for the direction of the trends (see Table 4)**

WRPA	Wetland region	Likelihood of outcome (%)	Overall trend	Code
Gwydir	Gwydir Wetlands	99	Extremely likely increase	↑↑↑↑
Intersecting Streams	Narran Lakes	-75	Likely decrease	↓
Macquarie–Castlereagh	Macquarie Marshes	55	Stable	=
Lachlan	Booligal Wetlands	65	Stable	=
	Great Cumbung Swamp	-90	Likely decrease	↓
Murrumbidgee	Lowbidgee floodplain	35	Stable	=
NSW Murray–Lower Darling and Victorian Murray	Barmah–Millewa Forest	-88	Likely decrease	↓

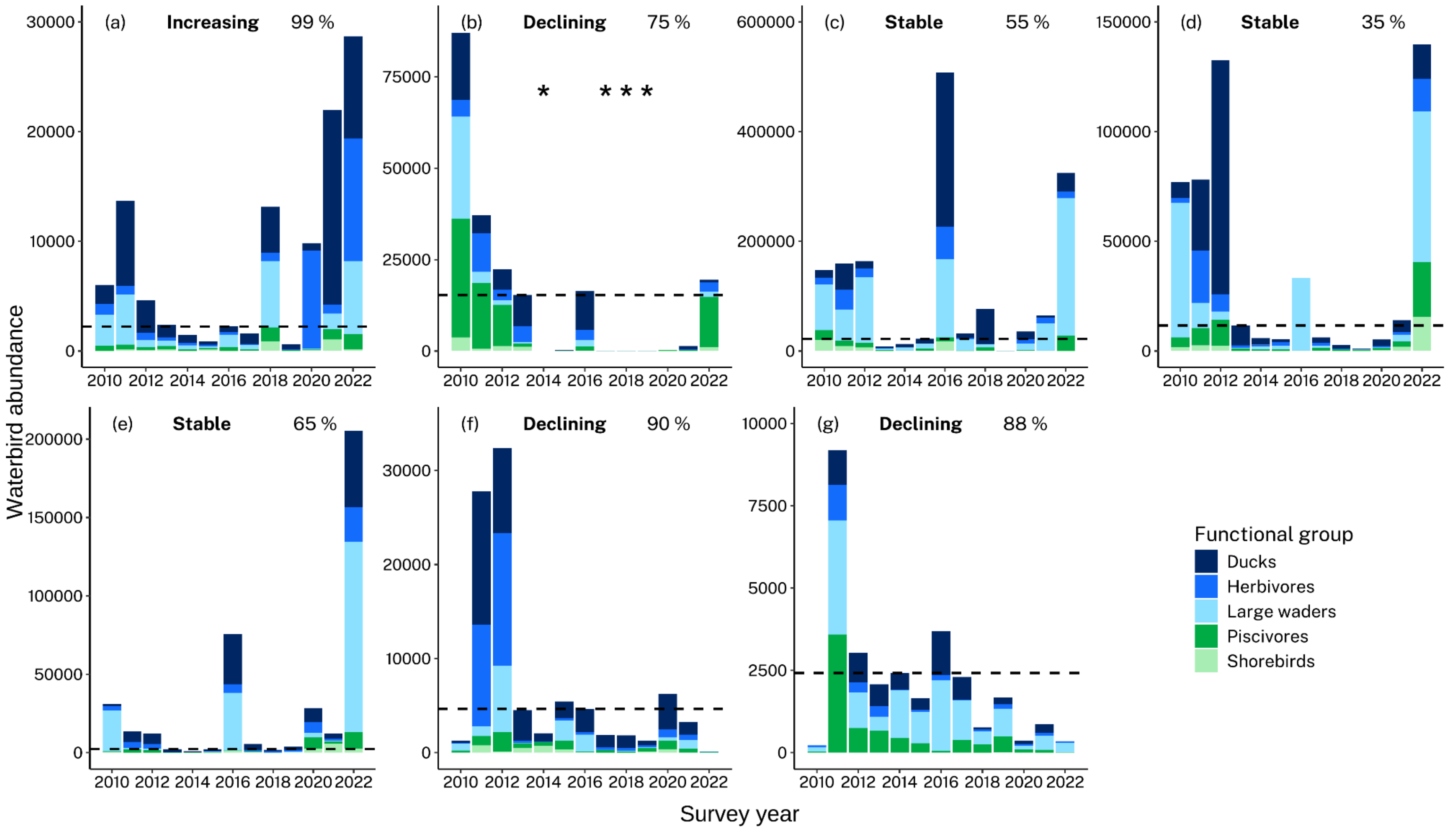

Figure 8 **Total waterbird abundance (blue shading) and total number of waterbirds by functional group detected during annual aerial surveys for: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) Lowbidgee floodplain (e) Booligal Wetlands (lower Lachlan) (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). The dotted line is the median value for total waterbird abundance for the spring 2012 to 2016 baseline period. Trends (stable/increasing/declining) and likelihood values (%) reported relative to the 2012 to 2016 baseline period. *Dry periods in the Narran Lakes are indicated. Data provided by UNSW**

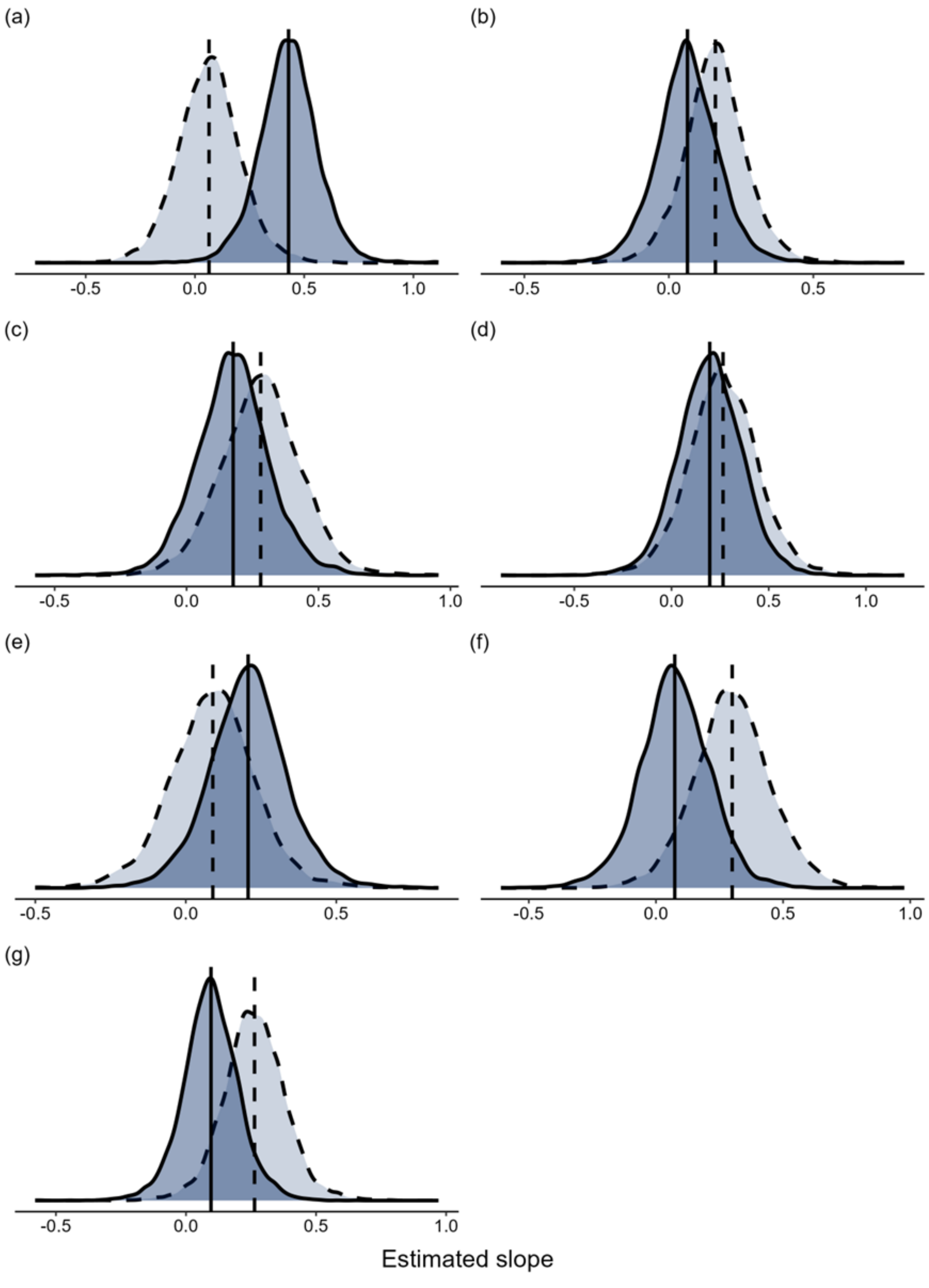

Figure 9 Bayesian plots showing trends for total waterbird abundance data collected through aerial surveys for each wetland area: (a) Gwydir Wetlands, (b) Narran Lakes, (c) Macquarie Marshes, (d) Lowbidgee Floodplain, (e) Booligal Wetlands (lower Lachlan), (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed black line)

3.4 Objectives 3, 4 and 5: Increase breeding opportunities

The NSW LTWPs have objectives and targets for waterbird breeding. These objectives include providing opportunities for breeding in all species (WB3, WB4) and maintaining the extent and condition of waterbird breeding and feeding habitat (WB5). The 2024 evaluation focused on two aspects of waterbird breeding:

- the total abundance of non-group-nesting species such as waterfowl, waterhens and resident shorebirds species, and total number of these species confirmed breeding (WB3)
- the total number of breeding species, total number of nests and number of breeding sites for group-nesting species such as egret, ibis and pelicans (WB4).

An evaluation of waterbird habitat condition (WB5) was not completed for the current reporting period.

Objective 3: Increase breeding opportunities for non-group-nesting species

The objectives and targets for breeding in non-group-nesting species in the assessed WRPAs are outlined in Appendix A. This includes a target for maintaining the total abundance of non-group-nesting waterbirds and the total number of breeding species.

To meet this objective, the total abundance of non-group-nesting waterbirds recorded over the 2012 to 2016 (baseline) period had to be maintained over the 2019 to 2023 (current) reporting period (Table 7). This target was set and evaluated based on available aerial spring survey data. Trends in the total abundance of non-group-nesting waterbirds remained stable in 2 wetland regions (Narran Lakes and Lowbidgee floodplain) and increased in 2 wetland regions (Gwydir Wetlands and Booligal Wetlands). Potential declines in abundance were detected in the Macquarie Marshes, Great Cumbung Swamp and Barmah–Millewa Forest (Figure 10 and Figure 11).

To meet the second target for this objective, the total number of breeding species recorded over the 2012–16 (baseline) period also had to be maintained over the 2019 to 2023 (current) reporting period. This target was set and evaluated based on available aerial and ground spring survey data. The number of non-group-nesting species that were confirmed breeding was highest in the Gwydir Wetlands, Macquarie Marshes and Lowbidgee Floodplain. Overall, fewer species were detected breeding in the Gwydir Wetlands and Lowbidgee floodplain in the current reporting period compared with the baseline period. A greater number of species were detected breeding in the Narran Lakes, Macquarie Marshes and Barmah–Millewa Forest in the current reporting period (Figure 12).

Table 7 **Summary of trends in total abundance of non-group-nesting species based on analysis of UNSW aerial survey data. Aerial survey data was used to compare current (2019 to 2023) versus baseline (2012 to 2016) periods. Trend directions are classed as increasing (green), stable (yellow) or declining (orange and red). The likelihood values (%) provide confidence values for the direction of the trends (see Table 4)**

WRPA	Wetland region	Likelihood of increase or decrease (%)	Overall trend	Code
Gwydir	Gwydir Wetlands	99	Extremely likely increase	↑↑↑↑
Intersecting Streams	Narran Lakes	40	Stable	=
Macquarie–Castlereagh	Macquarie Marshes	–75	Likely decrease	↓
Murrumbidgee	Lowbidgee floodplain	55	Stable	=
Lachlan	Booligal Wetlands	85	Likely increase	↑
	Great Cumbung Swamp	–70	Likely decrease	↓
NSW Murray–Lower Darling and Victorian Murray	Barmah–Millewa Forest	–98	Extremely likely decrease	↓↓↓

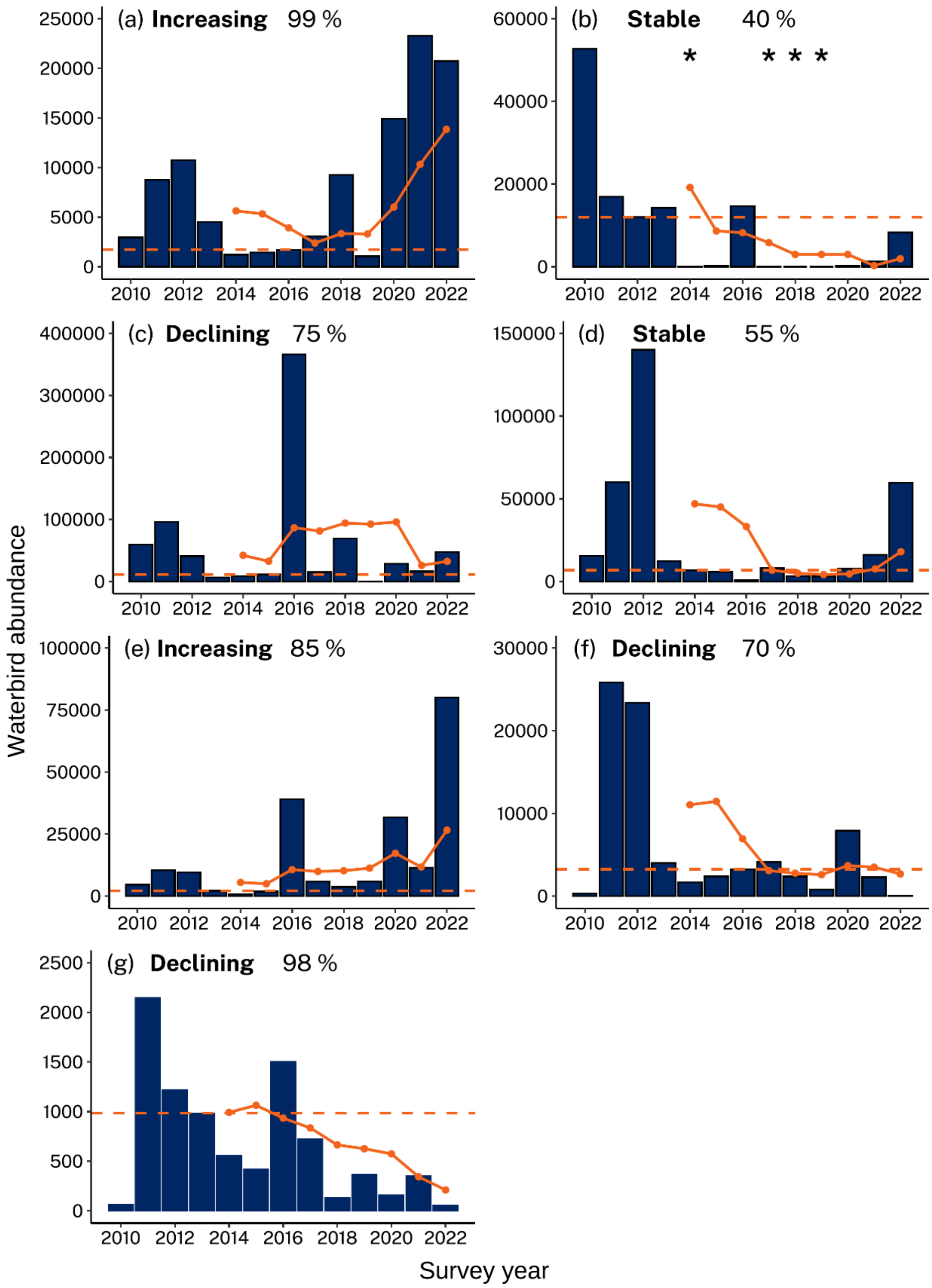

Figure 10 **Total abundance of non-group-nesting waterbirds detected during annual aerial surveys for: (a) Gwydir Wetlands, (b) Narran Lakes, (c) Macquarie Marshes, (d) Lowbidgee floodplain, (e) Booligal Wetlands (lower Lachlan), (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). Dashed orange line shows the median value and dotted orange line shows the 5-year rolling average from 2014 onwards. Trends (stable/increasing/decreasing) and likelihood values (%) are reported relative to the 2012 to 2016 baseline period. Aerial survey data provided by UNSW. * Dry survey periods in the Narran Lakes are indicated**

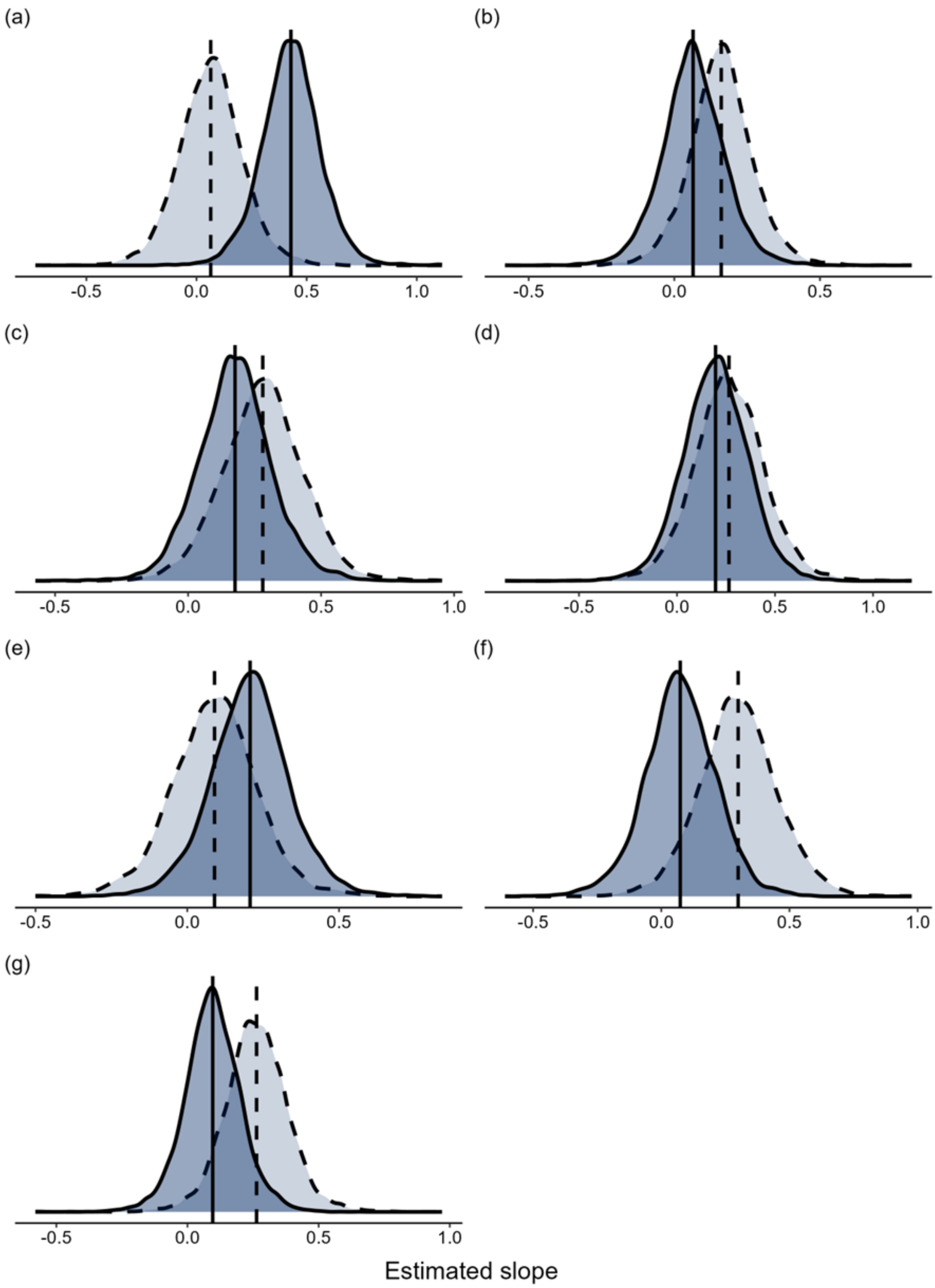

Figure 11 **Bayesian plots showing trends for total abundance of non-group-nesting waterbirds detected in the aerial surveys for each wetland region: (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) Lowbidgee floodplain (e) Booligal Wetlands (lower Lachlan) (f) Great Cumbung Swamp (lower Lachlan) and (g) Barmah–Millewa Forest (mid Murray). The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed black line)**

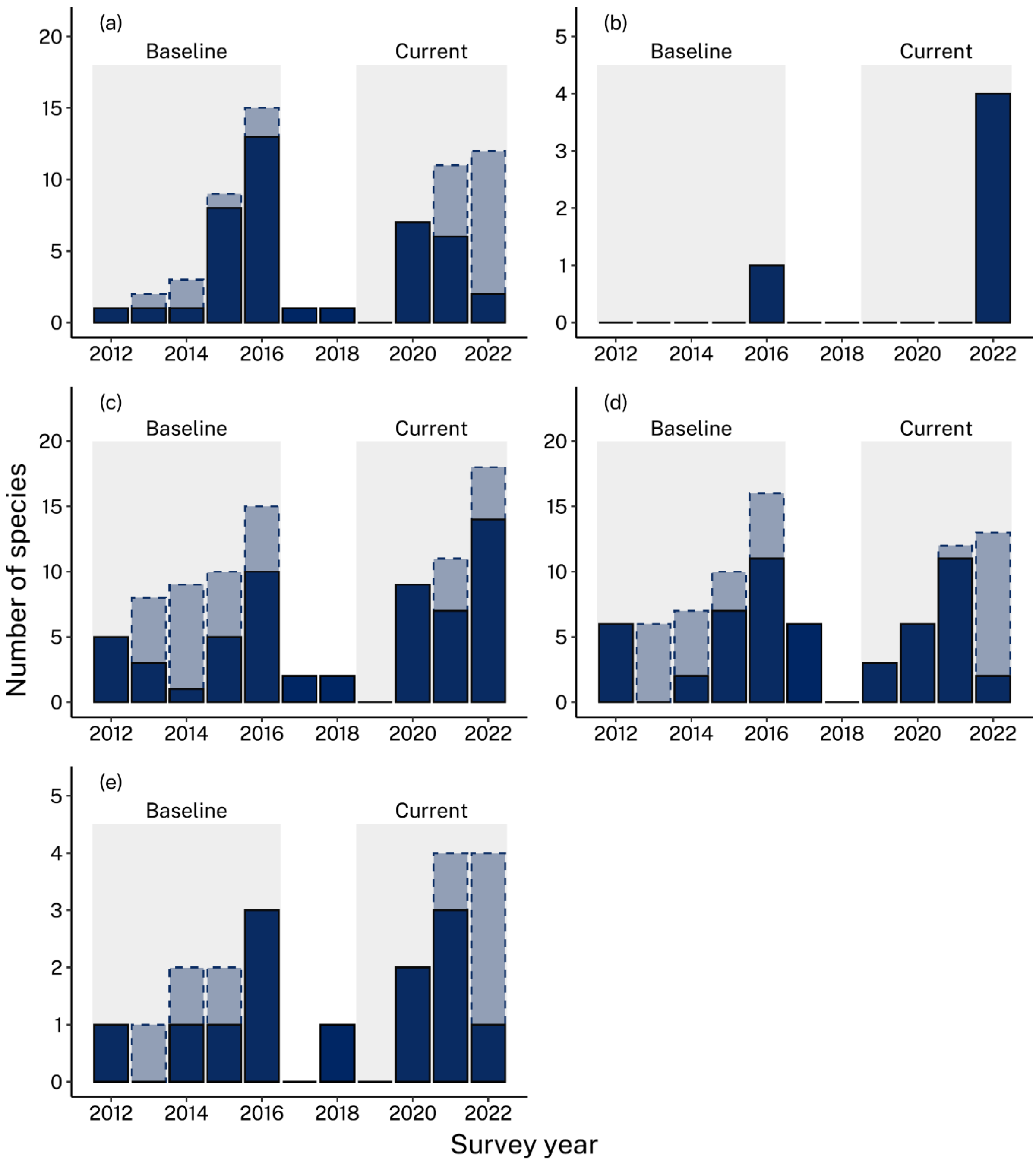

Figure 12 **Total number of non-grouping waterbird breeding species (e.g. ducks, herbivores and resident shorebird species) detected during annual spring aerial and ground surveys per year (filled) and cumulative total number of breeding species (dashed) over the baseline (2012 to 2016) and current reporting period (2019 to 2023) for 5 monitored wetland regions: (a) Gwydir Wetlands, (b) Narran Lakes, (c) Macquarie Marshes, (d) Lowbidgee floodplain, and (e) Barmah–Millewa Forest. UNSW aerial survey data, and the department and TLM ground survey data were used to estimate total number of breeding species. Note that due to widespread inundation in all wetland regions ground data was not collected in spring 2022 and so records of breeding species for this period are based on aerial survey data alone**

Objective 4: Increase breeding opportunities for group-nesting species

The fourth set of waterbird objectives and targets for waterbird breeding activity in the monitored WRPAs is outlined in Appendix A. To meet these targets, successful waterbird breeding events had to be recorded in the wetland regions in the 2019 to 2023 period. Group-nesting waterbird species such as egrets, ibis and pelicans can nest in very large numbers (thousands to tens of thousands) at an individual breeding site. These species have specific flow requirements, needing adequately timed flows of sufficient duration, depth and extent to allow adult birds to pair up, build nests, lay eggs, and raise and fledge their young successfully. Wetland inundation also needs to encompass foraging grounds adjoining their breeding sites to support successful nesting. Some species, such as the straw-necked ibis (*Threskiornis spinicollis*) are particularly sensitive to falling water levels in their breeding sites and surrounding habitats, particularly in early stages of nesting, which can cause nest and chick abandonment.

Widespread waterbird breeding was recorded in 2021–22 and 2022–23 in response to large natural inundation events in the monitored wetland regions. Waterbird breeding events were recorded simultaneously in the northern and southern MDB in both water years (Figure 13). Prior to this, Basin-wide waterbird breeding events were last recorded in 2016–17 (Figure 14). In the 2021 to 2023 period, 25 large breeding sites (supporting more than 5,000 nests in each site) were recorded.

Three of these large breeding sites were recorded in the Lowbidgee floodplain. In 2020–21, a breeding event (13 breeding species and 17 breeding sites) was initiated in the Lowbidgee floodplain and maintained solely by deliveries of water for the environment when there were limited waterbird breeding opportunities available across much of the NSW MDB (Figure 14). The 2021–22 and 2022–23 breeding events in the Lowbidgee floodplain (15 breeding species recorded in each, with 26 and 27 breeding sites detected, respectively) were initiated by high river flows and maintained by water for the environment.

These events coincided with widespread breeding in the northern and southern MDB including neighbouring breeding habitat in the Booligal Wetlands and Barmah–Millewa Forest wetland regions. An estimated 183,000 active nests were recorded across multiple sites in the Lowbidgee floodplain in 2022–23, the largest number of nests recorded since monitoring began in 2008 (Figure 14). At the same time, UNSW drone survey data revealed that 145,000 straw-necked ibis nests were recorded in a single breeding site in the neighbouring Booligal Wetlands in the Lachlan catchment following release of translucency flows and other unregulated flows in 2022–23.

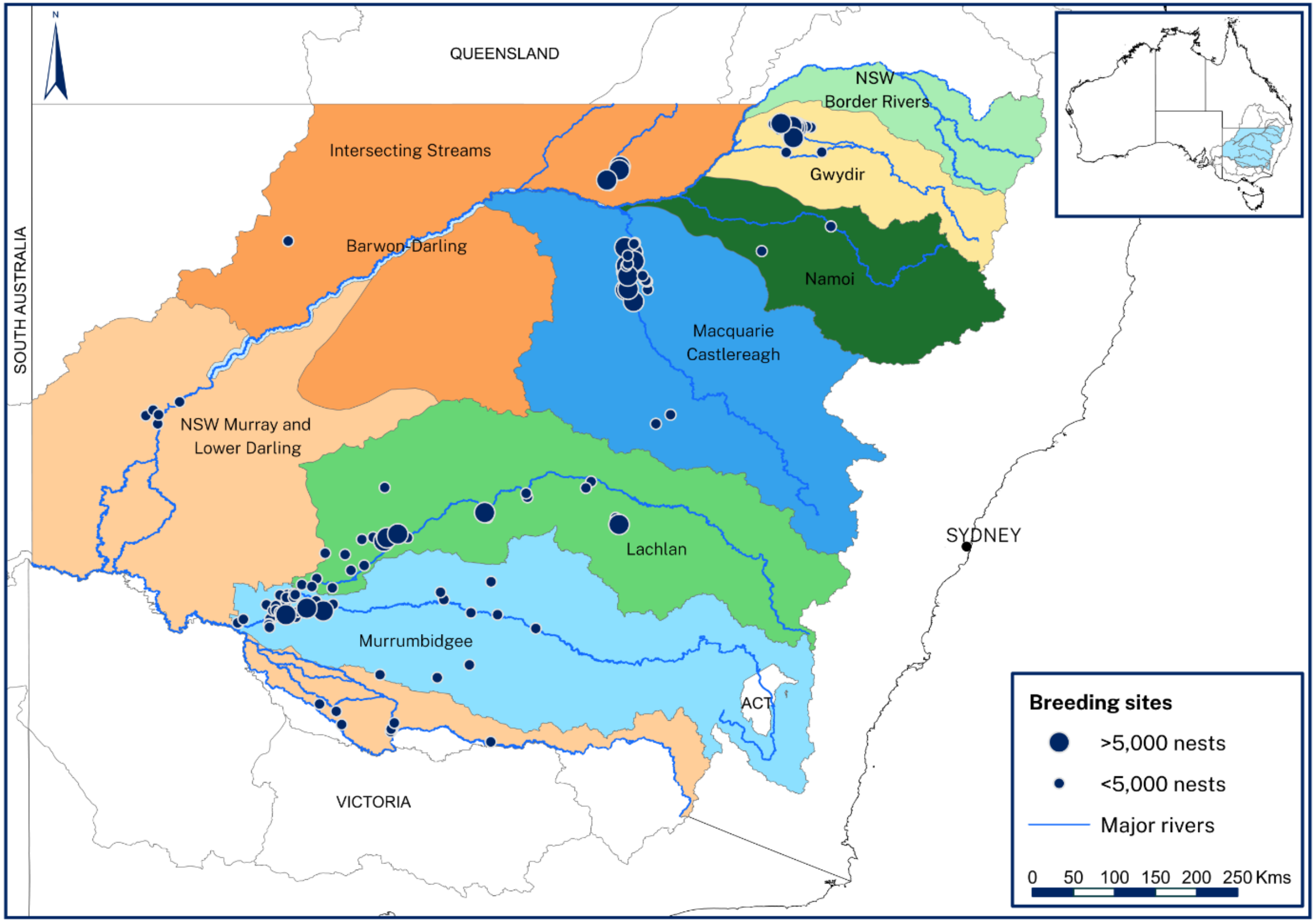

Figure 13 **Distribution of waterbird breeding sites across monitored areas of the NSW MDB WRPAs including sites with very large numbers (more than 5,000 nests per site) of nesting waterbirds in the 2019 to 2023 period. Aerial, drone and ground survey data were collected by the department and partners. UNSW and CSU monitoring was supported through CEWH Flow MER and TLM programs**

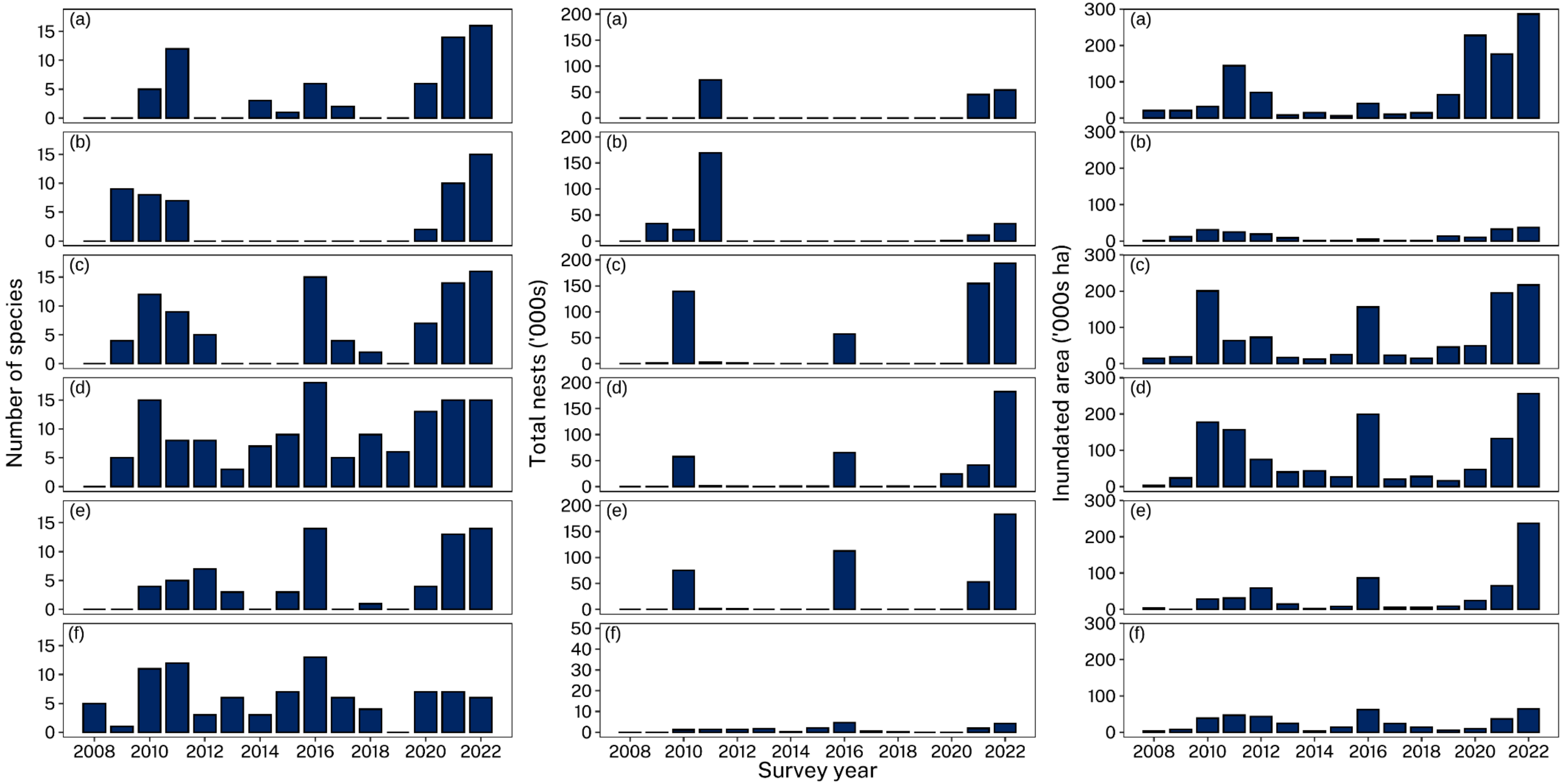

Figure 14 **Total number of waterbird group-nesting species detected, estimated number of total nests and total inundated area in 6 wetland regions from 2008 to 2023:** (a) Gwydir Wetlands (b) Narran Lakes (c) Macquarie Marshes (d) Lowbidgee floodplain (e) Booligal Wetlands (f) Barmah–Millewa Forest. **Total number of breeding species and total number of nests is based on compilation of all available ground, drone and aerial-based surveys. The estimated cumulative inundated area (hectares) for each wetland region for 2008 to 2023 was based on inundation mapping from sentinel imagery undertaken by the department**

There are also specific waterbird targets set for supporting small breeding events (<1,000 nests) in the Lachlan, Murrumbidgee and NSW Murray–Lower Darling LTWPs (see Appendix A). These targets identified the minimum number of breeding sites that could potentially be supported with the delivery of discretionary environmental water in the 2019 to 2024 period (Table 8). Breeding activity was recorded in each wetland region in the 2019 to 2021 period in the absence of high river flows. This included cormorant nesting sites in the lower Lachlan, mid Murrumbidgee wetlands, Lowbidgee floodplain and mid Murray (including Barmah–Millewa Forest) wetland regions that received environmental water in the 2019 to 2023 period (see Table 8).

Table 8 Assessment of small-scale (<1,000 nests per site) waterbird breeding targets set for 2024 under LTWP waterbird breeding objective (WB5)

WRPA	Wetland region	NSW LTWP 2024 target	Recorded events in the 2019 to 2023 period	2019 to 2023 evaluation
Lachlan	Lower Lachlan (Booligal Wetlands and Great Cumbung Swamp)	In line with natural cues initiate and support small-scale group-nesting in the lower Lachlan in 2 breeding sites in 2 of 5 years.	2020–21 (3 sites): Alma Lake (1 species), Moon Moon Swamp (8 species), Lake Waljeers (2 species)	Target partly met (3 breeding sites in 1 of 4 years)
Murrumbidgee	Mid Murrumbidgee wetlands	In line with natural cues, initiate and support small-scale waterbird group-nesting in at least 2 breeding sites in the mid Murrumbidgee in 2 of 5 years.	2019–20 (2 sites): Yarradda Lagoon (2 species), Gooragool Lagoon (2 species) 2020–21 (2 sites): Yarradda Lagoon (2 species), Gooragool Lagoon (1 species)	Target met (2 breeding sites in 2 of 4 years)
	Lowbidgee floodplain	In line with natural cues, initiate and support small-scale waterbird group-nesting in at least 5 breeding sites in the lower Murrumbidgee in 2 of 5 years.	2019–20 (4 sites): Narwie Swamp (2 species), Telephone Creek (2 species), House Creek (2 species), Bala Rookery (2 species) 2020–21 (15 sites[1]): (13 species in total)	Target partly met (at least 5 breeding sites in 2 of 4 years)

WRPA	Wetland region	NSW LTWP 2024 target	Recorded events in the 2019 to 2023 period	2019 to 2023 evaluation
NSW Murray–Lower Darling and Victorian Murray	Mid Murray (Barmah–Millewa Forest and NSW private property wetlands)	In line with natural cues, initiate and support small-scale waterbird breeding in the mid Murray in at least 2 breeding sites in 2 out of 5 years.	2019–20 (1 site): Thule Lagoon (3 species) 2020–21 (4 sites): Thule Lagoon (2 species),[2] Reed Bed Swamp (3 species), St Helena Swamp (3 sites), Pollack Lagoon (3 species) 2021–22 (2 sites): Pollack Lagoon (2 species), Reed Beds Swamp (2 species), Picnic Point (2 species)	Target met (at least 2 breeding sites in 2 of 4 years)

1. See Wassens et al. (2022) for more details.
2. See Francis and Brandis (2021) for more details.
Note that large-scale waterbird breeding was initiated by natural high river flows in all WRPAs in the 2021–22 and 2022–23 water years.

4. Discussion

4.1 Status and trends of waterbirds in monitored wetlands

Overall, the information reliability scores were high for the data used to assess the LTWP waterbird objectives in monitored wetland regions (see Appendix B). The ground survey data indicates the number of waterbird species has been maintained across 6 monitored wetland regions in the current reporting period. Trends in waterbird abundance varied among wetland regions. Aerial survey data showed evidence of an increasing trend in total waterbird abundance in the Gwydir Wetlands; stable trends in the Macquarie Marshes, Lowbidgee floodplain and Booligal Wetlands; and declines in the Narran Lakes, Great Cumbung Swamp and Barmah–Millewa Forest (Figure 8).

There was widespread waterbird breeding recorded in the NSW MDB in the 2021–22 and 2022–23 water years in response to prolonged, large-scale inundation events (Figure 14). In these water years, breeding was detected in 18 group-nesting species and there were at least 25 individual breeding sites that each supported more than 5,000 nesting pairs. Increased breeding activity in other waterbird species, including waterfowl and water hens, was also recorded in some wetland regions in the reporting period, including the Macquarie Marshes (Figure 12).

4.2 Is this result expected and why are we seeing these outcomes?

Waterbird responses are closely linked to the availability of inundated wetland habitat of suitable depth. The wetland regions were extremely dry in spring 2019 and early 2020 when extended dry conditions were recorded across much of the NSW MDB. During this time, total numbers of waterbird species and total abundance were low across most of the assessed wetland regions. However, there were some targeted environmental water deliveries to selected wetlands that created refuge habitats for waterbirds. These included Barmah–Millewa Forest and the Lowbidgee floodplain, which provide reliable habitat for many waterbirds including threatened species during dry and wet years.

In the very wet period recorded between 2021 and 2023, the abundance of waterbird species declined in some regions and increased in others in comparison with the baseline period (Figure 8). During this period, there was extensive inundated habitat available to waterbirds across the MDB causing waterbirds to be highly dispersed. Inundation of the major wetland systems also peaked at different times with some sites at their peak in depth at the time of the spring surveys. Waterbird abundance can have a lagged response following major inundation events as many species can take several years to reach breeding age, and so waterbird populations can take years to show increases in response to breeding events from the previous years. Continued monitoring and evaluation will be essential for understanding recorded declines in waterbird abundance, given the flood conditions that occurred simultaneously across the MDB in the 2019 to 2023 period.

Waterbird breeding fluctuated according to availability of inundated wetland habitat in the 2019 to 2023 period. Extended dry conditions in 2019–20 meant that limited breeding habitat was available in the monitored wetland regions. Waterbird breeding was restricted to the southern NSW MDB, with low numbers of ibis, spoonbills and cormorants recorded nesting in a small number of sites in the Lowbidgee floodplain, mid Murrumbidgee wetlands and mid Murray region. Increased water availability from 2020–21 onwards, and extended La Niña conditions in 2021 to 2023, resulted in greater opportunities for waterbird breeding across the 8 monitored wetland regions. The overall size of breeding response was determined by the scale of inundation, with larger and longer events in 2022–23 associated with a greater number of nests (Figure 14).

4.3 How has environmental water contributed?

Environmental watering is an important management tool that can be used to provide habitat for waterbirds including threatened species such as the Australasian bittern (*Botaurus poiciloptilus*), which has strongholds in Barmah–Millewa Forest and the Lowbidgee floodplain. Multiple watering actions in 2020–21 inundated large areas of the Lowbidgee floodplain including Yanga National Park and the Gayini Nimmie-Caira Wetlands, providing favourable habitat for Australasian bitterns and other listed waterbird species (Wassens et al. 2022). The delivery of environmental water to the Gulpa Creek Wetlands in Barmah–Millewa Forest in 2020–21 targeted Australasian bittern habitat resulting in large numbers of calling males in key sites in the November–December 2020 surveys (Belcher and Borrell 2020). This water delivery was critical for maintaining water levels in these wetlands over the summer months to increase the likelihood of breeding success. These watering events also supported the habitat requirements of many other waterbird species.

The MDB supports some of the most important wetlands for waterbird breeding in Australia (Brandis 2010), and increased opportunities for waterbird breeding are identified as an expected outcome of the Basin Plan. Supporting waterbird breeding events that are triggered by unregulated flows is a high priority for use of environmental water. In the 2019 to 2023 period, there were 75 individual watering actions managed by NSW environmental water managers alongside other types of flows that had primary objectives of supporting waterbirds and their habitat. In total, 21 of these individual actions were delivered to specifically support active waterbird breeding sites, many of which had been triggered by natural flows. In the Lowbidgee floodplain, environmental water delivery alone initiated and maintained a breeding event in 2020–21. Prior to this event, there had been no significant waterbird breeding recorded in the Lowbidgee floodplain since 2016–17 (Figure 14).

The delivery of environmental water to the Gwydir Wetlands also made a significant contribution to outcomes for waterbirds in 2021–22 and 2022–23 when heavy rainfall in the upper catchment triggered widespread floodplain inundation and 2 consecutive large breeding events. These events were the first in a decade, with the last significant breeding event recorded in the Gwydir Wetlands in 2011–12 (Figure 14). After the flood peak in mid-December 2021, environmental water was critical for preventing reductions in water levels at key breeding sites, which minimised the risk of nest abandonment. At this time, ibis breeding sites had active nests with eggs and young chicks. The timing of environmental water delivery was critical to ensure no further drop in water levels occurred in the central Gingham and lower Gwydir watercourses to support successful breeding. Flow rates were adjusted over the late January to March 2022 period following each set of ground surveys. These surveys provided critical information on water depths and stage of nesting for environmental water managers, and demonstrated successful breeding outcomes (Spencer et al. 2022).

4.4 What is being done to meet and monitor objectives in the future?

A commitment to long-term monitoring of waterbirds is essential to support on-ground management and to evaluate progress towards meeting LTWP objectives and targets. There were 5 wetland regions (Gwydir Wetlands, Narran Lakes, Macquarie Marshes, Lowbidgee Floodplain and Barmah–Millewa Forest) where both long-term aerial and ground survey data was available over a sufficient time frame to support the 2024 evaluation. There are additional wetland regions, for example the Menindee Lakes, Paroo Overflow Lakes and Lake Brewster, monitored through the existing aerial and ground survey programs, which provide important waterbird habitat that could be assessed in the 2029 evaluation. The current monitoring programs will need to be maintained over the 2024 to 2029 period to support the assessment of the 10-year objectives and targets.

Future trends in waterbird species and abundance will depend on the occurrence of natural inflows, availability of water for the environment and the impacts of climate change. Large natural inundation events complemented by managed flows are important for increasing overall waterbird abundance, as these events provide widespread breeding opportunities and promote the survival of a range of waterbird species. The delivery of water for the environment is equally important in dry periods to provide critical refuge habitat for waterbirds, including threatened species.

Small overbank flows, bankfull events and pumping water into small wetlands to inundate wetland habitat during spring and summer can promote the survival of waterbirds during periods of low flows to maintain their numbers and improve habitat condition. Constraints associated with the delivery of water for the environment apply to many areas across the NSW MDB (e.g. Gwydir Wetlands, mid Murrumbidgee wetlands and Koondrook-Perricoota Forest [mid Murray]). Complementary programs that seek to remove or reduce the impact of operating and physical constraints on environmental water delivery will provide greater opportunities for supporting waterbirds in these wetlands.

Management of waterbird breeding outcomes needs to continue to protect and, where required, augment natural flows with environmental water delivery, and support complementary management actions including feral animal control. The delivery of water for the environment is likely to be equally important in years following large inundation events to promote the survival of young birds. With longer intervals between large-scale inundation events, there is increasing evidence of the importance of regular breeding events of smaller sizes for improving waterbird populations across the MDB (Brandis et al. 2021). Opportunities to use environmental water to augment medium natural flow events, and to deliver small overbank flows to create breeding opportunities for some waterbird species, could be explored as part of annual watering planning (Kingsford and Auld 2005). This approach may be increasingly important when there are extended dry conditions recorded across the northern and southern MDB and there have been limited waterbird breeding opportunities in a continuous 3-to-4-year period.

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7. Appendices

Appendix A: NSW LTWP waterbird objectives and targets

Table 9 Assessment of LTWP waterbird objectives and targets set for 8 NSW WRPA

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
Gwydir	Gwydir Wetlands	WB1: Maintain the number and type of waterbird species.	Maintain a 5-year rolling average of 41 or more waterbird species across the 5 functional groups in the Gwydir Wetlands.	Yes
		WB2: Increase total waterbird abundance across all functional groups.	Total abundance of the 5 functional groups maintained in the Gwydir Wetlands compared to the 5-year 2012 to 2016 period.	Yes
		WB3: Increase opportunities for breeding in non-group-nesting waterbird species.	Total abundance of non-group-nesting species in the Gwydir Wetlands maintained compared to the 5-year 2012 to 2016 baseline and breeding recorded in at least 17 non-grouping nesting species.	Yes
		WB4: Increase opportunities for breeding in group-nesting waterbird species.	Maintain the water depth and duration of inundation (as required) to support active waterbird breeding through to completion (from egg laying through to fledging including post-fledging care) in the Gwydir Wetlands. Maintain duration of inundation in key foraging habitats to enhance breeding success and the survival of young.	Partly

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain extent and improve condition of nesting vegetation, including lignum, cumbungi, river cooba, river red gum and coolabah, in known group-nesting waterbird breeding locations in the Gwydir Wetlands. Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the Gwydir Wetlands.	No
Intersecting Streams	Narran Lakes, Yantabulla Swamp, Cuttaburra Channels, Paroo Overflow lakes	WB1: Maintain the number and type of waterbird species.	Maintain a 5-year rolling average of 21 or more waterbird species across the 5 functional groups in the identified waterbird habitats (Narran Lakes, Yantabulla Swamp, Cuttaburra Channels, Paroo River Overflow Lakes – within the Intersecting Streams).	Partly (Narran Lakes only)
		WB2: Increase total waterbird abundance across all functional groups.	Total abundance of the 5 functional groups maintained compared to the 5-year 2012 to 2016 period.	Partly (Narran Lakes only)
		WB3: Increase opportunities for breeding in non-group-nesting waterbird species.	Total abundance of non-group-nesting species maintained, and breeding recorded in at least 2 non-grouping nesting species compared to the 5-year 2012 to 2016 baseline.	Partly (Narran Lakes only)
		WB4: Increase opportunities for breeding in group-nesting waterbird species.	Support active waterbird breeding sites in the Intersecting Streams by maintaining the water depth and duration of inundation (as required) to support breeding through to completion (from egg laying through to fledging including post-fledging care) and maintain duration of inundation of key foraging habitats to enhance breeding success and the survival of young.	Partly (Narran Lakes only)
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the Intersecting Streams.	No

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
Macquarie–Castlereagh	Macquarie Marshes	WB1: Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 41 or more waterbird species across the 5 functional groups in the Macquarie Marshes.	Yes
		WB2: Increase total waterbird abundance across all functional groups	Total abundance of the 5 functional groups maintained in the Macquarie Marshes compared to the 5-year 2012 to 2016 period.	Yes
		WB3: Increase opportunities for non-group-nesting waterbird species.	Total abundance of non-group-nesting species in the Macquarie Marshes maintained compared to the 5-year 2012 to 2016 baseline and breeding recorded in at least 14 non-grouping nesting species over the 5-year period.	Yes
		WB4: Increase opportunities for group-nesting waterbird breeding.	Support active waterbird breeding sites in the Macquarie Marshes by maintaining the water depth and duration of inundation (as required) to support breeding through to completion (from egg laying through to fledging including post-fledging care) and maintain duration of inundation of key foraging habitats to enhance breeding success and the survival of young.	Partly
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain extent and improve condition of nesting vegetation, including common reed, lignum, cumbungi, river red gum and river cooba, in known group-nesting waterbird breeding locations in the Macquarie Marshes. Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the Macquarie Marshes.	No
Lachlan	Mid Lachlan, lower Lachlan		Maintain a 5-year rolling average of 33 or more waterbird species across the 5 functional groups in the mid Lachlan.	No

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
		WB1: Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 27 or more waterbird species across the 5 functional groups in the lower Lachlan.	Yes
		WB2: Increase total waterbird abundance across all functional groups	Total abundance of the 5 functional groups maintained in the mid Lachlan and lower Lachlan compared to the 5 years 2012 to 2016 period.	Partly (lower Lachlan – Booligal and Cumbung only)
		WB3: Increase opportunities for non-group-nesting waterbird species.	Total abundance of non-group-nesting species in the mid Lachlan maintained compared to the 5-year 2012 to 2016 baseline and breeding recorded in at least 7 non-grouping nesting species over the 5-year period.	No
			Total abundance of non-grouping nesting species in the lower Lachlan maintained compared to the 5-year 2012 to 2016 baseline and breeding recorded in at least 3 non-grouping nesting species over the 5-year period	Yes
		WB4: Increase opportunities for group-nesting waterbird breeding.	Support active waterbird breeding sites in the mid and lower Lachlan by maintaining the water depth and duration of flooding (as required) to support breeding through to completion (from egg laying through to fledging including post-fledging care) and maintain duration of inundation of key foraging habitats to enhance breeding success and the survival of young.	Partly (Booligal Wetlands only)
			In line with natural cues initiate and support small-scale group-nesting in the lower Lachlan in 2 breeding sites in 2 of 5 years.	Yes

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain extent and improve condition of nesting vegetation, including lignum, river cooba and river red gum, in known group-nesting waterbird breeding locations in the mid Lachlan.	No
			Maintain extent and improve condition of nesting vegetation, including common reed, lignum, cumbungi, river cooba and river red gum, in known group-nesting waterbird breeding locations in the lower Lachlan.	No
			Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the mid and lower Lachlan.	No
Murrumbidgee	Mid Murrumbidgee wetlands, Lowbidgee floodplain, Fivebough–Tuckerbil swamps	WB1: Maintain the number and type of waterbird species	Maintain a 5-year rolling average of waterbird species across the 5 BWS functional groups in each waterbird area (compared to the 5-year 2012 to 2016 period).	Partly (does not include Fivebough–Tuckerbil)
		WB2: Increase total waterbird abundance across all functional groups	Total abundance of the 5 BWS functional groups maintained compared to the 5-year 2012 to 2016 period.	Partly (does not include Fivebough–Tuckerbil)
		WB3: Increase opportunities for non-group-nesting waterbird species.	Total abundance of non-group-nesting waterbirds and number of breeding species maintained compared to the 5-year 2012 to 2016 baseline period.	Partly (does not include Fivebough–Tuckerbil)
		WB4: Increase opportunities for group-	Support active waterbird breeding sites in the lower and mid Murrumbidgee wetlands by maintaining the water depth and duration of inundation (as required) to support breeding through to completion (from egg laying through to fledging including post-fledging care) and maintain	Partly

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
		nesting waterbird breeding.	duration of inundation of key foraging habitats to enhance breeding success and the survival of young.	
			In line with natural cues, initiate and support small-scale waterbird group-nesting in at least 2 breeding sites in the mid Murrumbidgee in 2 of 5 years.	Yes
			In line with natural cues, initiate and support small-scale waterbird group-nesting in at least 5 breeding sites in the lower Murrumbidgee in 2 of 5 years.	Yes
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain extent and improve condition of nesting vegetation, including common reed, lignum, cumbungi, river red gum and river cooba, in known group-nesting waterbird breeding locations.	No
			Maintain or increase extent and improve condition of waterbird foraging and breeding locations.	No
NSW Murray–Lower Darling	Mid Murray, lower Murray, lower Darling	WB1: Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 23 or more waterbird species across the 5 functional groups in the mid Murray.	Partly (Barmah–Millewa only)
			Maintain a 5-year rolling average of 18 or more waterbird species across the 5 functional groups in the lower Murray.	No
			Maintain a 5-year rolling average of 25 or more waterbird species across the 5 functional groups in the lower Darling.	No
		WB2: Increase total waterbird abundance across all functional groups	Total waterbird abundance of the 5 functional groups maintained in the mid Murray, lower Murray and lower Darling compared to 5-year 2012 to 2016 period.	Partly (Barmah–Millewa only)

WRPA	Wetland region(s)	Ecological objective	5-year (2024) target*	Assessed in this report
		WB3: Increase opportunities for non-group-nesting waterbird species.	Total abundance of non-group-nesting waterbirds in the mid Murray maintained & breeding recorded in at least 1 non-group-nesting species compared to the 5-year 2012 to 2016 baseline period.	Partly (Barmah–Millewa only)
		WB4: Increase opportunities for group-nesting waterbird breeding.	Support active waterbird breeding sites in the mid Murray, lower Murray and lower Darling by maintaining the water depth and duration of inundation c(as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) and maintain duration of inundation in key foraging habitats to enhance breeding success and the survival of young.	Partly (Barmah–Millewa only)
			In line with natural cues, initiate and support small-scale waterbird breeding in the mid Murray in at least 2 breeding sites in 2 out of 5 years.	Yes
		WB5: Maintain the extent and improve the condition of waterbird habitats.	Maintain extent and improve condition of nesting vegetation, including common reed, lignum, cumbungi, river red gum, giant rush, black box, in known waterbird breeding locations in the mid Murray.	No
			Maintain extent and improve condition of nesting vegetation, including lignum, river cooba, black box, river red gum, in known waterbird breeding locations in the lower Murray and lower Darling.	No
			Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the mid Murray, lower Murray and lower Darling.	No

*There are also 10 year (2029) and 20 year (2039) waterbird targets set for each wetland region in the NSW LTWPs.

Appendix B: Information reliability assessment

Table 10 Summary of information reliability assessment for ground survey datasets used to evaluate waterbird species richness

Assessment criteria	Question	Answer and justification	Score out of 2
Methods			
Methods used	Are the methods used appropriate to gather the information required for evaluation?	Yes	2
		Ground surveys are an appropriate method for documenting waterbird species richness in individual wetland sites. They are also effective for documenting the presence of cryptic and hard to identify waterbird species including shorebirds, crakes, rails and small grebes.	
Standard methods	Has the same method been used over the sampling program?	Yes	2
		Ground survey methods were consistent across all sampled wetland regions in the monitoring programs. Repeat visits to individual wetland sites were undertaken in spring (October–November) each year for both the assessment and baseline periods. The ground surveys consist of teams of observers (at least 2 people per team and up to 3 teams per region) visiting established survey sites to record the total number of individuals of each waterbird species present.	
Representativeness			
Space	Has sampling been conducted across the spatial extent of waterbirds within the wetland being assessed with equal effort?	Yes	2
		Ground survey sites were established across each wetland region to cover a range of habitat types and water management areas. Established survey sites were revisited during each set of spring surveys for each wetland system over both the baseline and assessment periods.	

Assessment criteria	Question	Answer and justification	Score out of 2
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	2
		The analysis for this indicator focused on wetland regions where long-term ground survey data was available from at least 2012 onwards.	
Repetition			
Space	Has sampling been conducted at the same sites/area over the assessment period?	Somewhat	1
		Established survey sites were revisited during the spring surveys for each wetland system over both the baseline and assessment periods. During periods of high flows, some sites were not accessible on ground and in permissions in the Gwydir Wetlands meant loss of a small number of survey sites in recent years.	
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	1
		The spring ground surveys provide an annual snapshot of total number of species recorded across each wetland region. Therefore, they are limited in capacity to support a more comprehensive assessment of total species richness over a whole water year. There was also missing data in the baseline period for one wetland region (Barmah–Millewa Forest in spring 2013) due to lack of funding for that period, and all wetland regions in spring 2022 had restricted site access following high river flows.	
Final score		**10/12**	
Information reliability		**Good**	

Note: Ground survey data was used to evaluate the waterbird species richness objectives and targets for 6 monitored wetland regions in the NSW MDB (Gwydir Wetlands, Narran Lakes, Macquarie Marshes, mid Murrumbidgee wetlands, Lowbidgee floodplain and Barmah–Millewa Forest). This data was collected through the department's Water for the Environment monitoring, evaluation and reporting (MER) and the TLM Program funded by the MDBA (Barmah–Millewa Forest only).

Table 11 **Summary of information reliability assessment for aerial survey datasets used to evaluate waterbird species richness and abundance**

Assessment criteria	Question	Answer and justification	Score out of 2
Methods			
Methods used	Are the methods used appropriate to gather the information required for evaluation?	Yes	2
		Aerial surveys are a rapid and effective way of collecting information on waterbird species richness and abundance across entire floodplain wetland systems.	
Standard methods	Has the same method been used over the sampling program?	Yes	2
		The aerial survey methods were consistent across all monitored wetland regions over the sampling program. All wetlands were surveyed each spring from a high-winged plane (Cessna 206) using 2 observers, one on each side of the aircraft, to estimate numbers of waterbirds of each species onto digital audio recorders.	
Representativeness			
Space	Has sampling been conducted across the spatial extent of waterbirds within the wetland being assessed with equal effort?	Yes	2
		The aerial surveys are effective at covering very large floodplain wetland systems that can be difficult to access on ground. The aerial dataset (Specified Environmental Asset surveys) used for this assessment covers 33 wetland assets identified as important for waterbirds in the MDB. The same survey methods are used for all sites including the 7 wetland regions in the NSW MDB included in the waterbird trend analysis.	

Assessment criteria	Question	Answer and justification	Score out of 2
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	2
		The waterbird aerial surveys were undertaken in spring (October–November) from 2010 onwards each year which covered the baseline and assessment periods.	
Repetition			
Space	Has sampling been conducted at the same sites/area over the assessment period?	Yes	2
		The aerial survey methods had consistent coverage across all monitored wetland regions over the survey program.	
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	1
		The spring ground surveys provide an annual snapshot of total number of species recorded across each wetland region. Therefore, they are limited in capacity to support a more comprehensive assessment of total species richness and waterbird abundance over a whole water year.	
Final score		**11/12**	
Information reliability		**Very good**	

Note: Aerial survey data was used to evaluate waterbird species richness and abundance targets for 7 monitored wetlands regions in the NSW MDB (Gwydir Wetlands, Narran Lakes, Macquarie Marshes, Great Cumbung Swamp, Booligal Wetlands, Lowbidgee floodplain and Barmah–Millewa Forest). This data was collected through UNSW Specified Environmental Asset surveys funded by the MDBA and EAWS program funded by the eastern states.

Table 12 **Summary of information reliability assessment for datasets used to evaluate waterbird breeding data (group-nesters)**

Assessment criteria	Question	Answer and justification	Score out of 2
Methods			
Methods used	Are the methods used appropriate to gather the information required for evaluation?	Yes	2
		A combination of ground, drone and aerial survey methods were used to gather information on the location, estimated number of total nests and total number of group-nesting species for active breeding sites in the baseline and assessment periods. Drone surveys provided highly precise counts number of nests for large Australian pelican and straw-necked ibis breeding sites. Ground and aerial data was used to estimate total number of nests and number of breeding species for other active sites.	
Standard methods	Has the same method been used over the sampling program?	Somewhat	1
		Drone surveys were used from 2016–17 onwards for pelican and straw-necked ibis breeding sites. Aerial estimates were used prior to 2016-17 to estimate total number of nests for very large breeding sites. Ground surveys have been done over both the baseline and assessment periods to estimate total number of breeding species in small and large breeding sites.	
Representativeness			
Space	Has sampling been conducted across the spatial extent of waterbirds within the wetland being assessed with equal effort?	Somewhat	1
		Coverage has varied with each survey method and within each wetland region. The aerial surveys cover each entire wetland region. Repeat ground and drone surveys have been focused on large breeding sites (>5,000 nests) in each wetland region. Less intensive monitoring has been undertaken at smaller breeding sites from 2012 onwards.	

Assessment criteria	Question	Answer and justification	Score out of 2
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	2
		The analysis for this indicator focused on wetland regions where long-term survey data was available from at least 2008 onwards.	
Repetition			
Space	Has sampling been conducted at the same sites/area over the assessment period?	Yes	2
		Known breeding sites are surveyed as part of annual ground and aerial survey programs every spring. New locations are also documented through these annual surveys. Follow-up ground, drone and aerial surveys were undertaken for active breeding sites over summer months where needed. Long-term data is available for all wetland regions assessed prior to the assessment period but coverage is most comprehensive from 2012 onwards.	
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	Yes	2
		As above known breeding sites are surveyed as part of annual spring ground and aerial survey programs each year. Follow-up ground, drone and aerial surveys were undertaken for active breeding sites over summer months to cover the core breeding season where needed. For large breeding sites where ground access was possible repeat surveys were done at large sites at least every 1 to 2 months.	
Final score		**10/12**	
Information reliability		**Good**	

Note: Aerial, ground and drone survey datasets was used to evaluate waterbird breeding for group-nesting species in 6 monitored wetland regions in the NSW MDB (Gwydir Wetland, Narran Lakes, Macquarie Marshes, Booligal Wetlands, Lowbidgee floodplain and Barmah–Millewa Forest). This data was collected through department's Water for the Environment Program and by UNSW through CEWH funded LTIM, STIM and Flow MER programs, and the MDBA TLM program.

Table 13 Summary of information reliability assessment for datasets used to evaluate waterbird breeding data (other waterbird species)

Assessment criteria	Question	Answer and justification	Score out of 2
Methods			
Methods used	Are the methods used appropriate to gather the information required for evaluation?	Somewhat	1
		A combination of ground and aerial annual spring survey data was used to gather information on the breeding activity of other species of waterbirds (e.g. waterfowl, water hens and shorebirds) for the baseline and assessment periods. These types of waterbirds can be cryptic when nesting so total number of breeding species is likely to be underestimated.	
Standard methods	Has the same method been used over the sampling program?	Yes	2
		As above, the aerial and ground survey methods were consistent across all monitored wetland regions over the sampling programs. The sampling programs were done each spring over the baseline and assessment periods.	
Representativeness			
Space	Has sampling been conducted across the spatial extent of waterbirds within the wetland being assessed with equal effort?	Yes	2
		As above, the aerial surveys are effective at covering very large floodplain wetland systems that can be difficult to access on ground. The ground survey sites were	

Assessment criteria	Question	Answer and justification	Score out of 2
		established across each wetland region to cover a range of habitat types and water management areas and complement the aerial survey coverage.	
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	2
		The analysis for this indicator focused on wetland regions where aerial and ground survey data was available from at least 2012 onwards to cover the assessment and baseline periods.	
Repetition			
Space	Has sampling been conducted at the same sites/area over the assessment period?	Somewhat	1
		As above, established survey areas in each wetland region were revisited during the spring surveys for each wetland system over the baseline and assessment periods. In high flow periods some sites were not accessible on ground and a change in permissions in the Gwydir Wetlands meant loss of a small number of survey sites in recent years.	
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	1
		As above, the spring ground and aerial surveys provide an annual snapshot of total number of breeding species recorded across each wetland region. Therefore, they are limited in capacity to support a more comprehensive assessment of total number of breeding species over a whole water year. There was also missing ground survey data in the baseline period for one wetland region (Barmah–Millewa Forest in spring 2013) due to lack of funding for that period, and all wetland regions in spring 2022 due to	

Assessment criteria	Question	Answer and justification	Score out of 2
		restricted site access following high river flows. This meant that data for spring 2022 was based on aerial survey data alone.	
Final score		**9/12**	
Information reliability		**Fair**	

Note: Aerial and ground survey data was used to evaluate the number of breeding species richness for other waterbirds in 5 monitored wetland regions in the NSW MDB (Gwydir Wetlands, Narran Lakes, Macquarie Marshes, Lowbidgee floodplain and Barmah–Millewa Forest). The ground survey data was collected through the department's Water for the Environment Program and TLM Program funded by the MDBA. The aerial survey data was collected through UNSW's SEA aerial surveys funded by the MDBA and EAWS Program funded by the Eastern States.

Appendix C: Waterbird functional groups

Table 14 List of waterbird species known to occur in the NSW MDB arranged by functional group

Functional group[a]	Family	Common name	Scientific name[b]
Duck	Anatidae	Australasian shoveler	*Anas rhynchotis*
Duck	Anatidae	Australian shelduck	*Tadorna tadornoides*
Duck	Anatidae	Blue-billed duck	*Oxyura australis v*
Duck	Anatidae	Chestnut teal	*Anas castanea*
Duck	Anatidae	Freckled duck	*Stictonetta naevosa v*
Duck	Anatidae	Garganey	*Spatula querquedula J,C,R vagrant*
Duck	Anatidae	Grey teal	*Anas gracilis*
Duck	Anatidae	Hardhead	*Aythya australis*
Duck	Anatidae	Musk duck	*Biziura lobata*
Duck	Anatidae	Northern shoveler	*Spatula clypeata vagrant*
Duck	Anatidae	Pacific black duck	*Anas superciliosa*
Duck	Anatidae	Pink-eared duck	*Malacorhynchus membranaceus*
Duck	Anatidae	Wandering whistling-duck	*Dendrocygna arcuata*
Duck	Jacanidae	Comb-crested jacana	*Irediparra gallinacea v*
Duck	Podicepidae	Australasian grebe	*Tachybaptus novaehollandiae*
Duck	Podicepidae	Great crested grebe	*Podiceps cristatus*
Duck	Podicepidae	Hoary-headed grebe	*Poliocephalus poliocephalus*
Duck	Rallidae	Australian spotted crake	*Porzana fluminea*
Duck	Rallidae	Baillon's crake	*Porzana pusilla*
Duck	Rallidae	Buff-banded rail	*Gallirallus philippensis*
Duck	Rallidae	Lewin's rail	*Lewinia pectoralis*
Duck	Rallidae	Spotless crake	*Porzana tabuensis*
Herbivore	Anatidae	Australian wood duck	*Chenonetta jubata*
Herbivore	Anatidae	Black swan	*Cygnus atratus*
Herbivore	Anatidae	Cape barren goose	*Cereopsis novaehollandiae*
Herbivore	Anatidae	Cotton pygmy-goose	*Nettapus coromandelianus e*
Herbivore	Anatidae	Green pygmy-goose	*Nettapus pulchellus*

Functional group[a]	Family	Common name	Scientific name[b]
Herbivore	Anatidae	Plumed whistling-duck	*Dendrocygna eytoni*
Herbivore	Anseranatidae	Magpie goose	*Anseranas semipalmata v*
Herbivore	Rallidae	Black-tailed native-hen	*Tribonyx ventralis*
Herbivore	Rallidae	Dusky moorhen	*Gallinula tenebrosa*
Herbivore	Rallidae	Eurasian coot	*Fulica atra*
Herbivore	Rallidae	Purple swamphen	*Porphyrio porphyrio*
Large wader	Ardeidae	Australasian bittern	*Botaurus poiciloptilus E,e*
Large wader	Ardeidae	Australian little bittern	*Ixobrychus dubius*
Large wader	Ardeidae	Cattle egret*	*Bubulcus ibis*
Large wader	Ardeidae	Eastern great egret*	*Ardea alba modesta*
Large wader	Ardeidae	Plumed egret*	*Ardea plumifera*
Large wader	Ardeidae	Little egret*	*Egretta garzetta*
Large wader	Ardeidae	Nankeen night-heron*	*Nycticorax caledonicus*
Large wader	Ardeidae	Pied heron*	*Egretta picata*
Large wader	Ardeidae	White-faced heron*	*Egretta novaehollandiae*
Large wader	Ardeidae	White-necked heron*	*Ardea pacifica*
Large wader	Ciconiidae	Black-necked stork	*Ephippiorhynchus asiaticus e*
Large wader	Gruidae	Brolga	*Grus rubicunda v*
Large wader	Threskiornithidae	Australian white ibis*	*Threskiornis moluccus*
Large wader	Threskiornithidae	Glossy ibis*	*Plegadis falcinellus*
Large wader	Threskiornithidae	Royal spoonbill*	*Platalea regia*
Large wader	Threskiornithidae	Straw-necked ibis*	*Threskiornis spinicollis*
Large wader	Threskiornithidae	Yellow-billed spoonbill*	*Platalea flavipes*
Piscivore	Anhingidae	Australasian darter*	*Anhinga novaehollandiae*
Piscivore	Laridae	Australian gull-billed tern	*Gelochelidon macrotarsa C*
Piscivore	Laridae	Caspian tern	*Hydroprogne caspia J*
Piscivore	Laridae	Franklin’s gull	*Leucophaeus pipixcan vagrant*
Piscivore	Laridae	Pacific gull	*Larus pacificus*
Piscivore	Laridae	Silver gull	*Chroicocephalus novaehollandiae*
Piscivore	Laridae	Whiskered tern	*Chlidonias hybrida*
Piscivore	Laridae	White-winged black tern	*Chlidonias leucopterus J,C,R*
Piscivore	Pelicanidae	Australian pelican*	*Pelecanus conspicillatus*

Functional group[a]	Family	Common name	Scientific name[b]
Piscivore	Phalacrocoracidae	Black-faced cormorant	*Phalacrocorax fuscescens*
Piscivore	Phalacrocoracidae	Great cormorant*	*Phalacrocorax carbo*
Piscivore	Phalacrocoracidae	Little black cormorant*	*Phalacrocorax sulcirostris*
Piscivore	Phalacrocoracidae	Little pied cormorant*	*Microcarbo melanoleucos*
Piscivore	Phalacrocoracidae	Pied cormorant*	*Phalacrocorax varius*
Shorebird	Charadriidae	Banded lapwing	*Vanellus tricolor*
Shorebird	Charadriidae	Black-fronted dotterel	*Elseyornis melanops*
Shorebird	Charadriidae	Double-banded plover	*Charadrius bicinctus*
Shorebird	Charadriidae	Grey plover	*Pluvialis squatarola J,C,R*
Shorebird	Charadriidae	Grey-headed lapwing	*Vanellus cinereus vagrant*
Shorebird	Charadriidae	Inland dotterel	*Charadrius australis*
Shorebird	Charadriidae	Lesser sand plover	*Charadrius mongolus J,C,R E,v*
Shorebird	Charadriidae	Masked lapwing	*Vanellus miles*
Shorebird	Charadriidae	Oriental plover	*Charadrius veredus J,C,R*
Shorebird	Charadriidae	Pacific golden plover	*Pluvialis fulva J,C,R*
Shorebird	Charadriidae	Red-capped plover	*Charadrius ruficapillus*
Shorebird	Charadriidae	Red-kneed dotterel	*Erythrogonys cinctus*
Shorebird	Glareolidae	Australian pratincole	*Stiltia Isabella*
Shorebird	Glareolidae	Oriental pratincole	*Glareola maldivarum J,C,R*
Shorebird	Recurvirostridae	Banded stilt	*Cladorhynchus leucocephalus*
Shorebird	Recurvirostridae	Black-winged stilt	*Himantopus leucocephalus*
Shorebird	Recurvirostridae	Red-necked avocet	*Recurvirostra novaehollandiae*
Shorebird	Rostratulidae	Australian painted snipe	*Rostratula australis E,e*
Shorebird	Scolopacidae	Bar-tailed godwit	*Limosa lapponica J,C,R E,v*
Shorebird	Scolopacidae	Black-tailed godwit	*Limosa limosa J,C,R E,v*
Shorebird	Scolopacidae	Common greenshank	*Tringa nebularia J,C,R E*
Shorebird	Scolopacidae	Common sandpiper	*Actitis hypoleucos J,C,R*
Shorebird	Scolopacidae	Curlew sandpiper	*Calidris ferruginea J,C,R CE,e*
Shorebird	Scolopacidae	Great knot	*Calidris tenuirostris J,C,R V,v*
Shorebird	Scolopacidae	Latham's snipe	*Gallinago hardwickii J,R V*
Shorebird	Scolopacidae	Little curlew	*Numenius minutus J,C,R*
Shorebird	Scolopacidae	Long-toed stint	*Calidris subminuta J,C,R*

Functional group[a]	Family	Common name	Scientific name[b]
Shorebird	Scolopacidae	Marsh sandpiper	*Tringa stagnatilis J,C,R*
Shorebird	Scolopacidae	Pectoral sandpiper	*Calidris melanotos J,R*
Shorebird	Scolopacidae	Red knot	*Calidris canutus J,C,R V*
Shorebird	Scolopacidae	Red-necked stint	*Calidris ruficollis J,C,R*
Shorebird	Scolopacidae	Ruddy turnstone	*Arenaria interpres J,C,R V*
Shorebird	Scolopacidae	Ruff	*Philomachus pugnax J,C,R vagrant*
Shorebird	Scolopacidae	Sanderling	*Calidris alba J,C,R v*
Shorebird	Scolopacidae	Sharp-tailed sandpiper	*Calidris acuminata J,C,R V*
Shorebird	Scolopacidae	Whimbrel	*Numenius phaeopus J,C,R*
Shorebird	Scolopacidae	White-rumped sandpiper	*Calidris fuscicollis vagrant*
Shorebird	Scolopacidae	Wood sandpiper	*Tringa glareola J,C,R*

[a] Functional groups are based on Kingsford et al. (2020). Nomenclature follows Christidis and Boles (2008).

[b] Status: CE = Critically Endangered, E = Endangered, V = Vulnerable (Commonwealth EPBC Act 1999), e = endangered, v = vulnerable (NSW BC Act 2016), J = JAMBA, C = CAMBA, R = RoKAMBA (listed under international migratory bird agreements Australia has with Japan, China and Republic of Korea, respectively). 'Vagrants' are identified as per Birdlife Australia (2022). Note: there were a further 3 vagrant species (Ringed Plover, Little Stint, Wilson's Phalarope) excluded from the list above as only single records for these species were available).

*Group-nesting waterbird species that breed in the MBD are indicated.

Appendix D: Bayesian model interpretation

A Bayesian modelling approach was used to determine trends in ecological indicator variables. Outputs from this analysis included Bayesian modelling plots that showed the credible intervals (starting at zero) until an estimate of zero was excluded to provide information for 3 reporting categories (Table 4) as per the trend assessment procedure outlined by McBride (2019). The mean of the posterior distribution and credible intervals were used to determine if trends were increasing, stable or declining (Figure 15 and Figure 16). This same approach was used to compare the current reporting period (2019 to 2023) with the baseline period (2012 to 2016) (Figure 17).

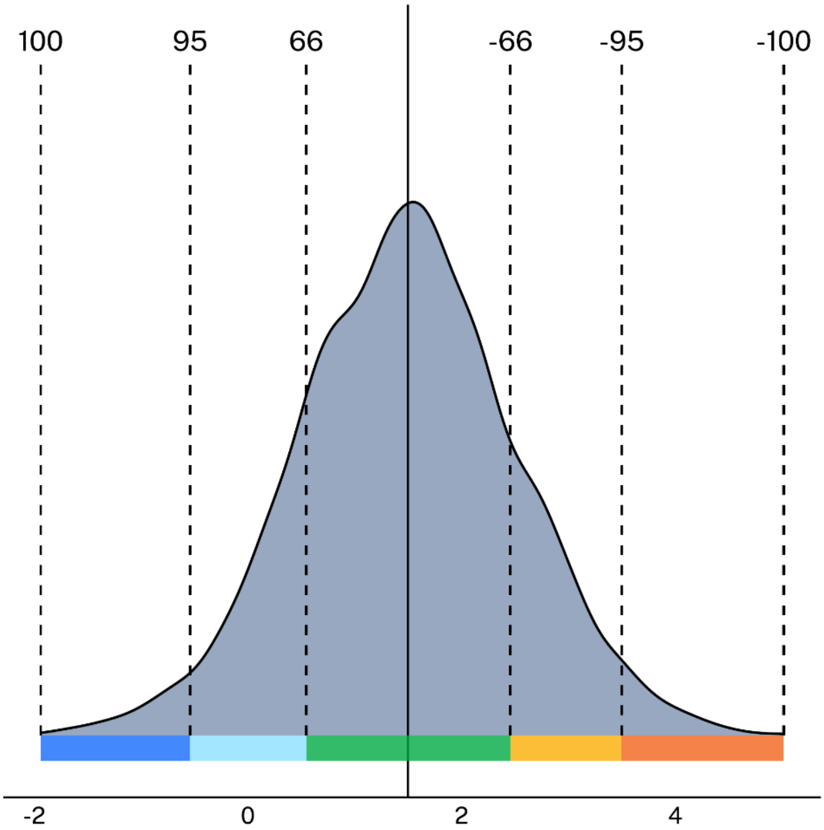

Figure 15 **Trend analysis outcomes were estimated by gradually increasing the credible intervals (starting at zero) until an estimated slope of zero was excluded and then simplified into one of 3 trend report cards: increasing, stable, or declining (see Table 3). If the mean of the sample distribution is located to the right of an estimated slope of zero (middle solid line), the trend is negative (declining). If it is located to the right of the zero, the trend is positive (increasing)**

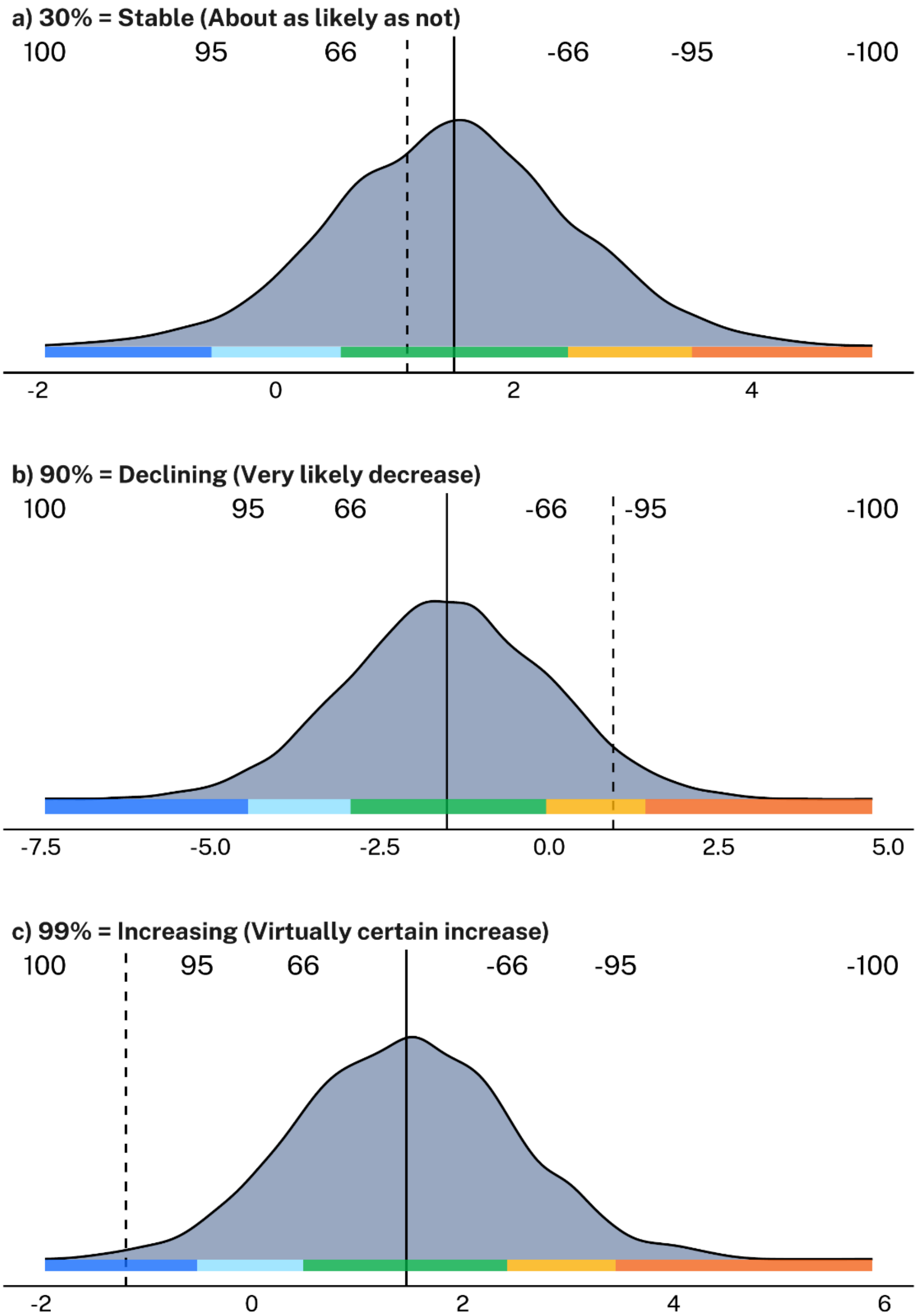

Figure 16 **An example of (a) stable, (b) declining, and (c) increasing long-term trends. The outcome is determined by the location of the mean of the posterior distribution (dotted black line) and credible intervals (numbered dashed black lines) relative to an estimated slope of zero (dashed red line)**

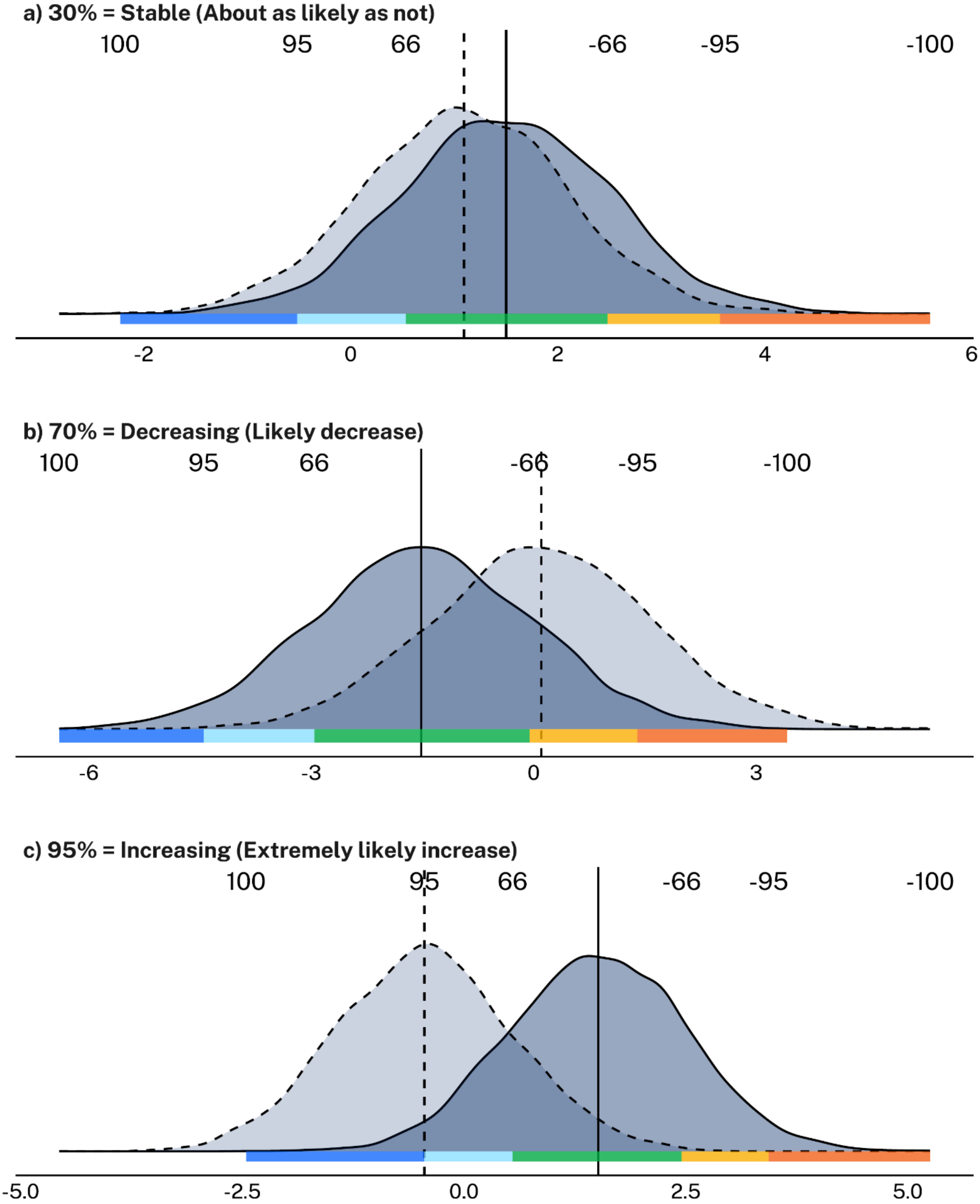

Figure 17 **An example of (a) stable, (b) declining, and (c) increasing trends comparing the current to the baseline period. The outcome is determined by the location of the mean of the posterior distribution (dotted black line) and credible intervals (smaller dashed black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed red line)**

Appendix E: Bayesian model outputs

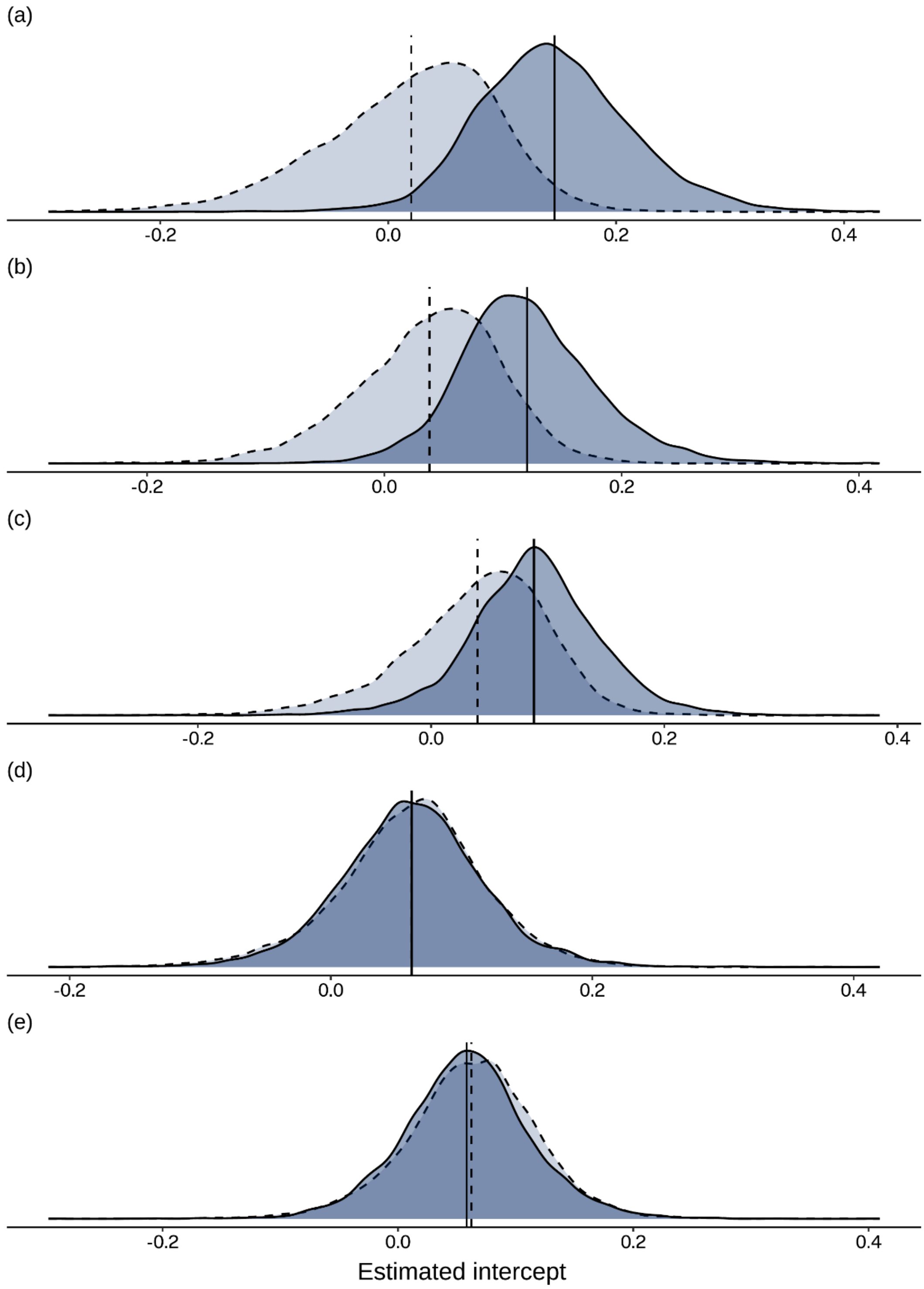

Figure 18 **Results of Bayesian modelling analysis in the Gwydir Wetlands showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

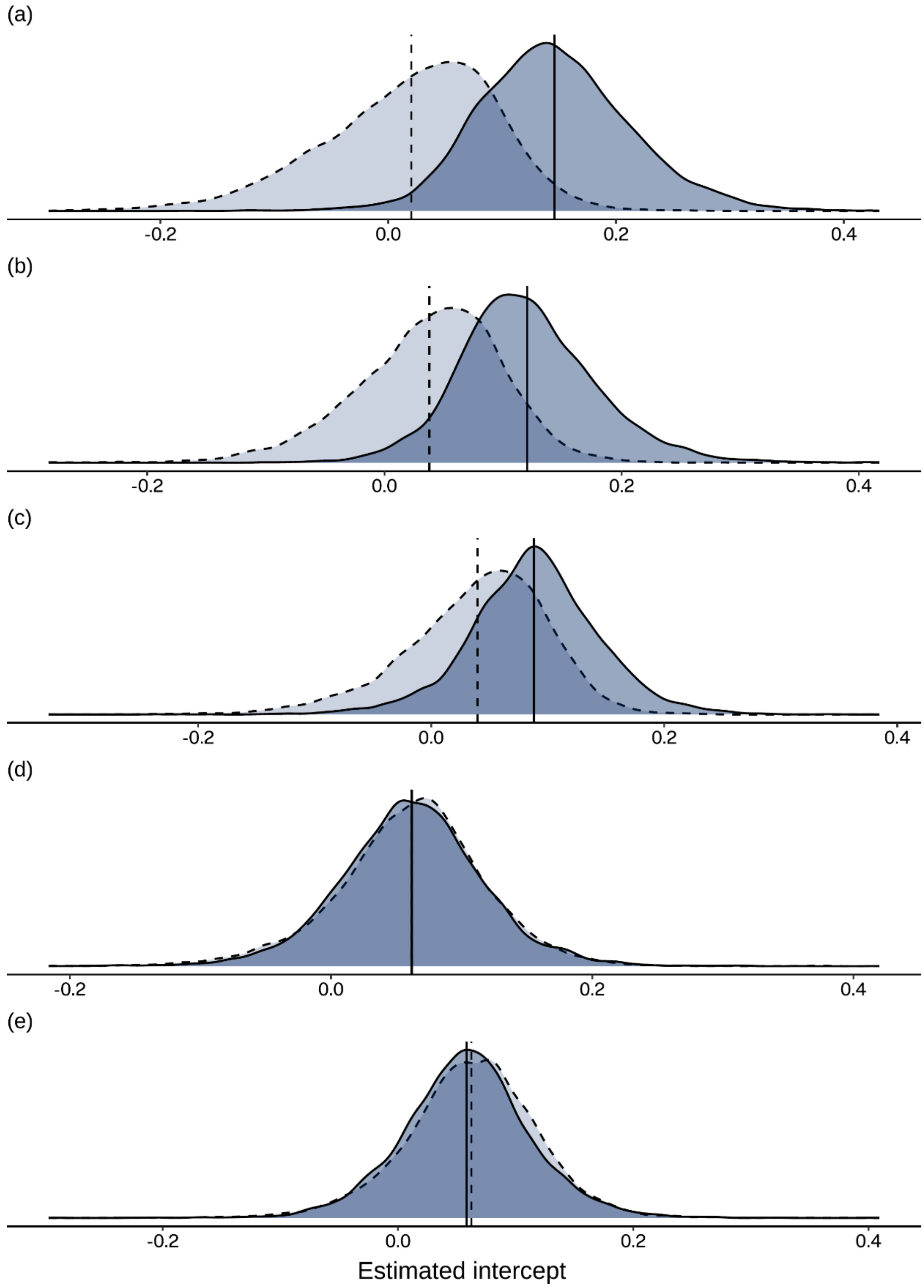

Figure 19 **Results of Bayesian modelling analysis in the Narran Lakes showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

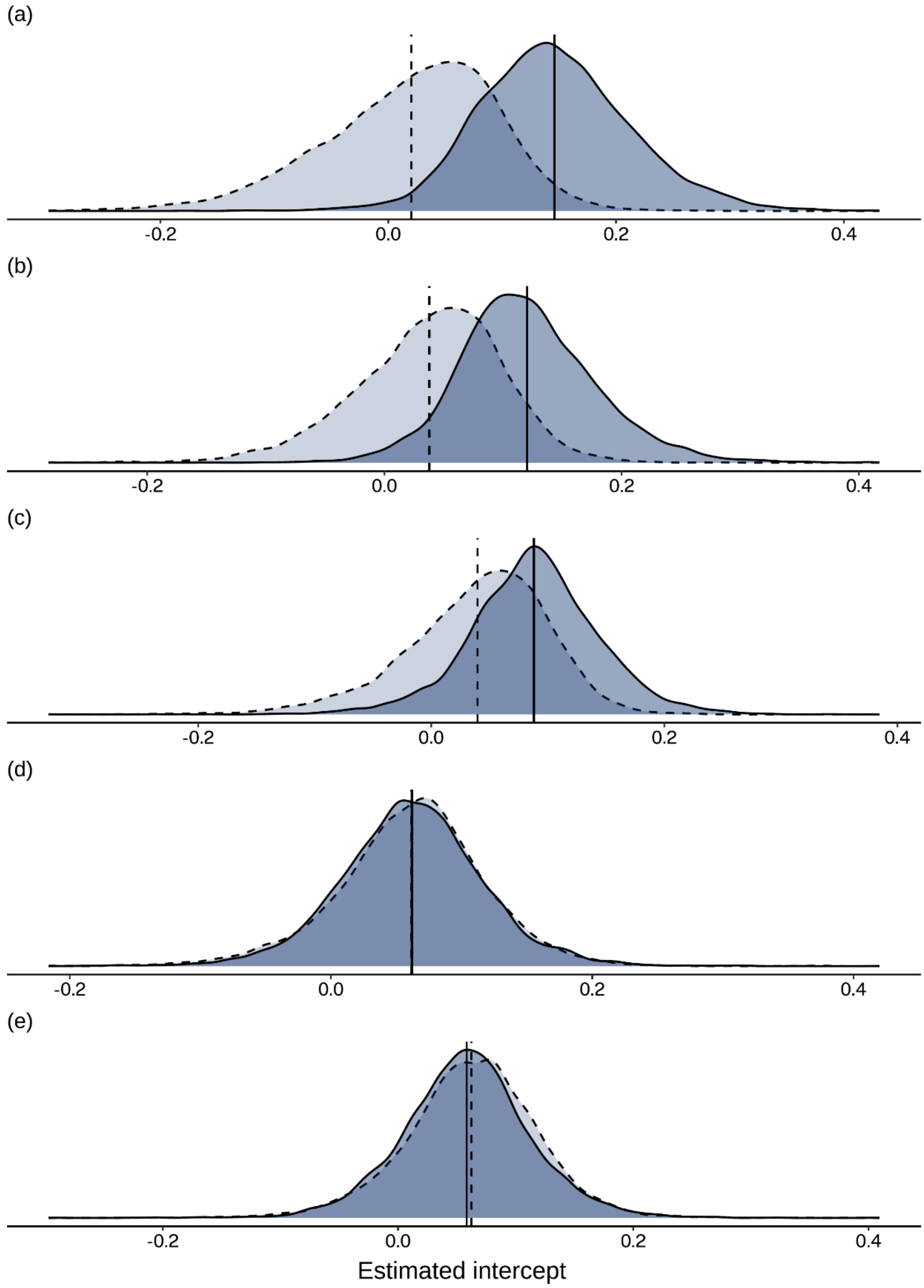

Figure 20 **Results of Bayesian modelling analysis in the Macquarie Marshes showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

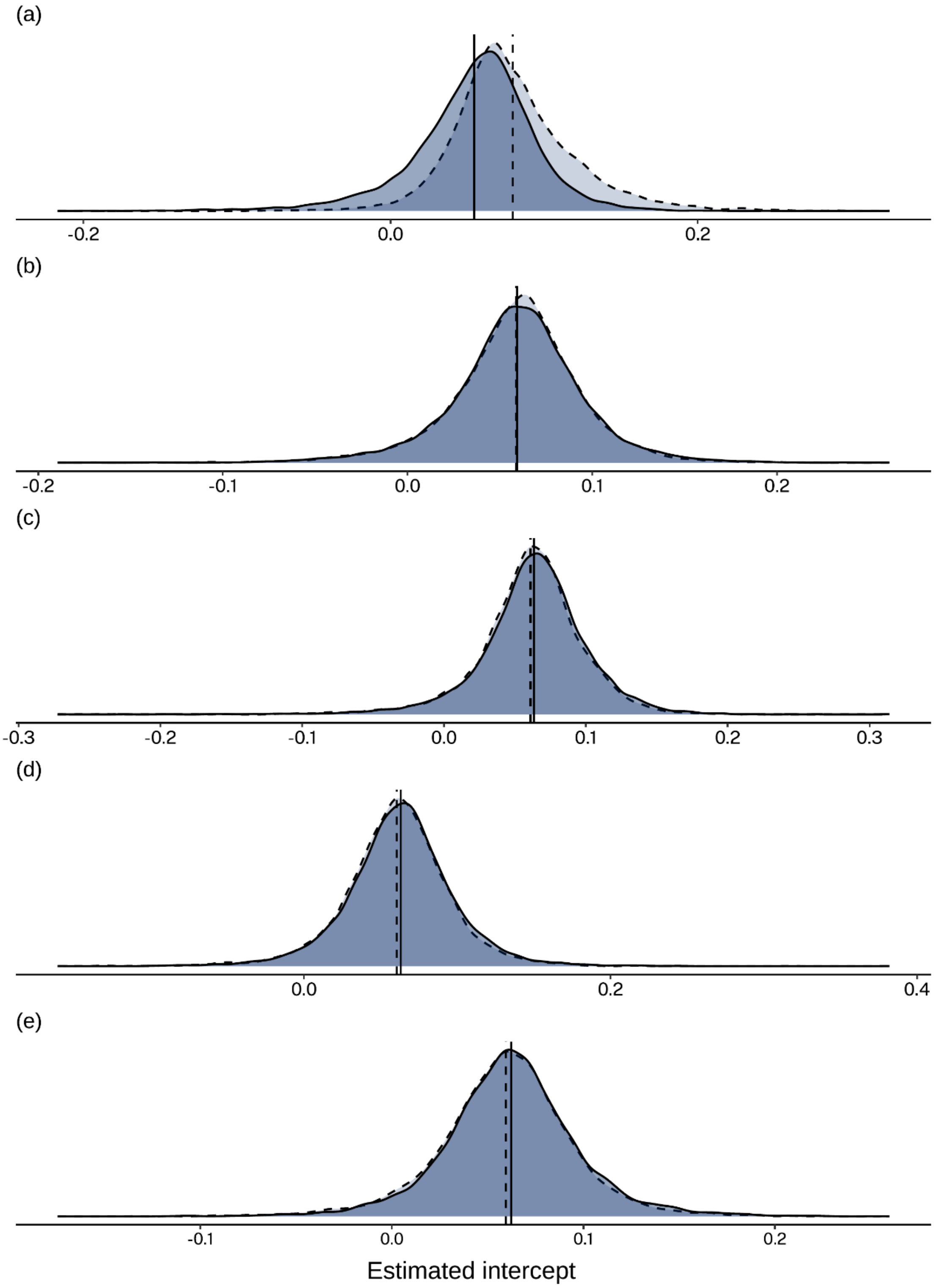

Figure 21 **Results of Bayesian modelling analysis in the Lowbidgee floodplain showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

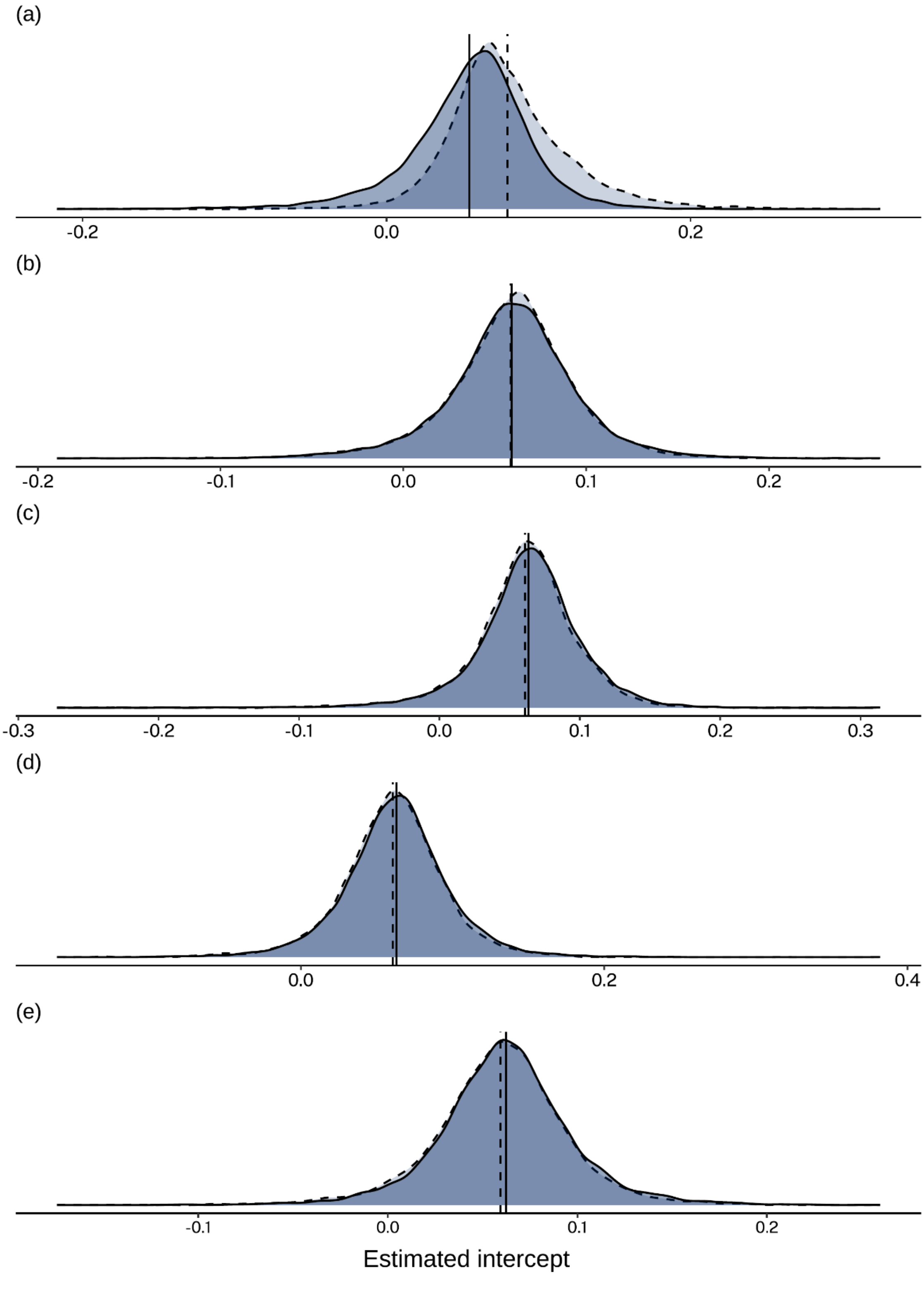

Figure 22 **Results of Bayesian modelling analysis in the Booligal Wetlands showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

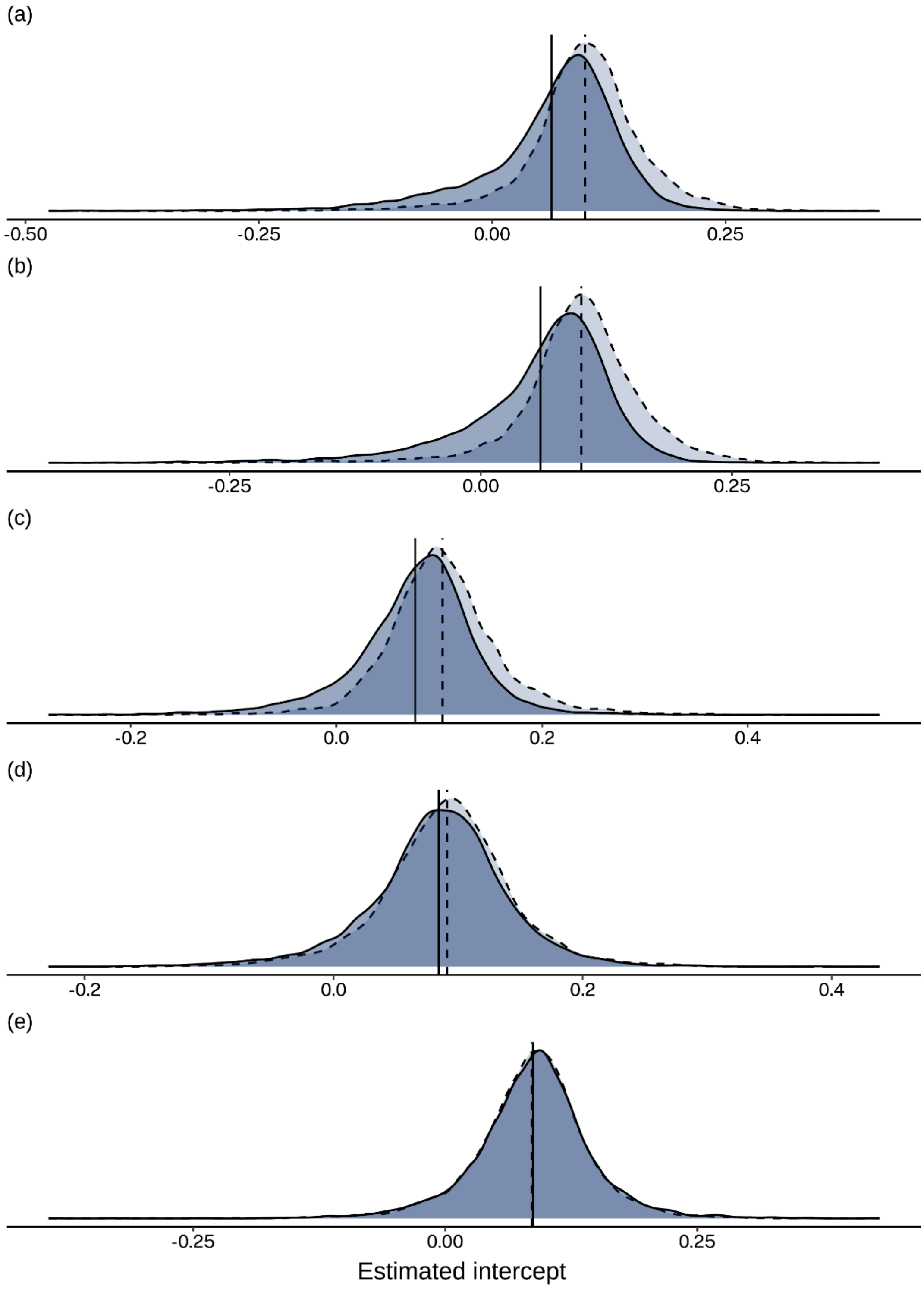

Figure 23 **Results of Bayesian modelling analysis in the Great Cumbung Swamp showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

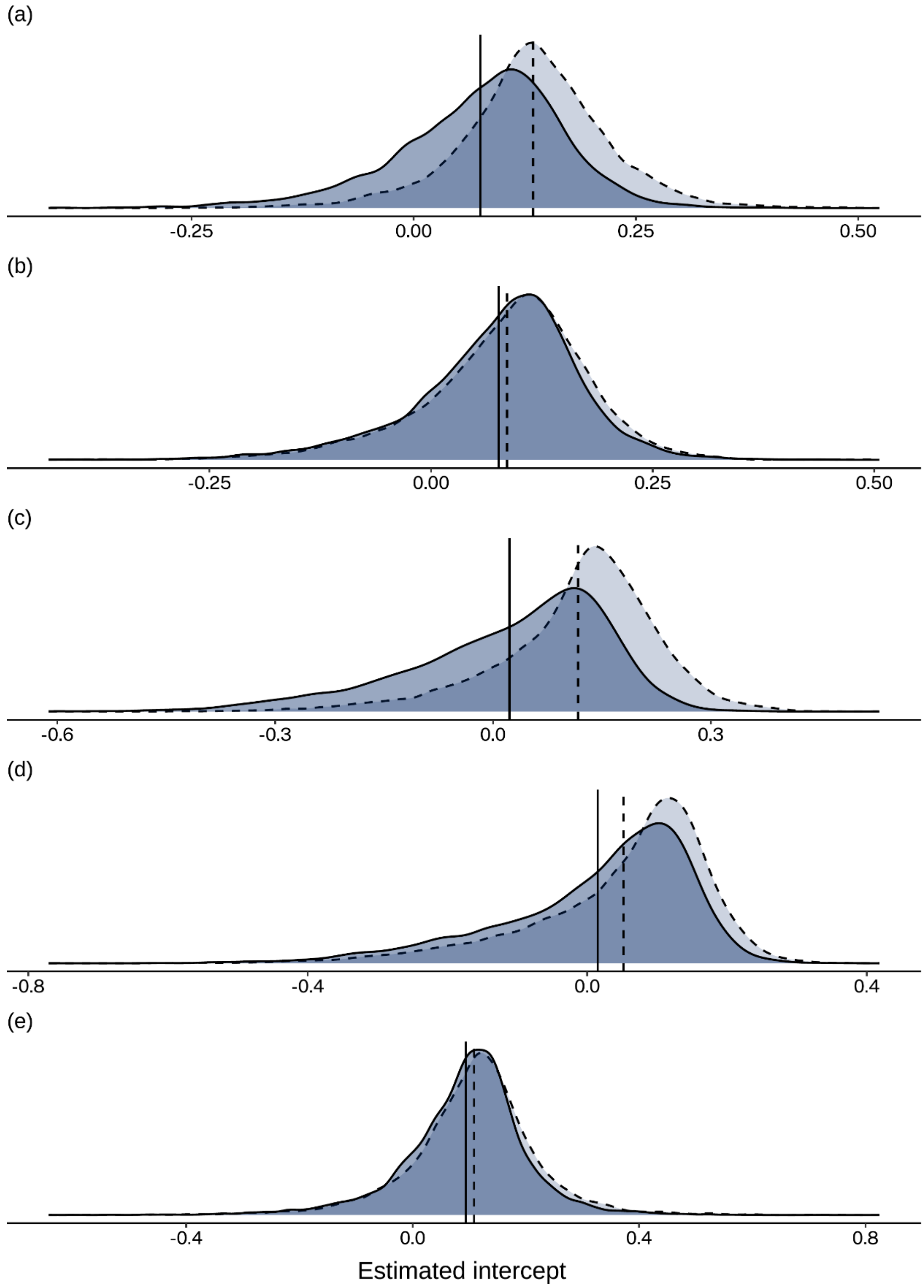

Figure 24 **Results of Bayesian modelling analysis in the Barmah–Millewa Forest showing the current distribution in front of the baseline distribution for 5 waterbird functional groups: (a) ducks, (b) herbivores, (c) large waders, (d) piscivores and (e) shorebirds. The outcome is determined by the location of the mean of the posterior distribution (solid black line) relative to the mean of the posterior distribution of the sample population from the baseline period (dashed line)**

Appendix F: Summary of watering actions

Table 15 Summary of watering actions delivered in 5 NSW WRPA in the 2019 to 2023 period which had objectives for supporting waterbird breeding and feeding habitats

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Gwydir	GWY19/20-03	Waterbirds	Feeding	Whitakers Lagoon	24/10/2019	26/10/2019	100.0
Gwydir	GWY20/21-04	Waterbirds	Breeding	Waterbird Breeding 20–21	11/02/2021	02/03/2021	4,340.0
Gwydir	GWY21/22-02	Waterbirds	Breeding	Waterbird Breeding 21–22	20/12/2021	31/03/2022	28,445.0
Gwydir	GWY22/23-01	Waterbirds	Breeding	Waterbird Breeding 22–23	12/12/2022	17/03/2023	8,053.0
Lachlan	LAC19/20-01	Waterbirds	Feeding	Kiagarthur Wetland	23/07/2019	24/11/2019	500.0
Lachlan	LAC19/20-02	Waterbirds	Feeding	Merrowie Creek to Murphys Lake	16/07/2019	28/07/2019	1,057.0
Lachlan	LAC19/20-08	Waterbirds; other species	Feeding	Noonamah 2019–20	28/10/2019	30/06/2020	590.7
Lachlan	LAC20/21-02	Waterbirds	Feeding	Comayjong 2020–21	01/09/2020	03/10/2020	365.0
Lachlan	LAC20/21-03	Waterbirds	Feeding	Fletchers Lake	02/10/2020	21/10/2020	600.0
Lachlan	LAC20/21-06	Waterbirds	Breeding	Brewster Pelicans	21/12/2020	30/04/2021	1,987.0
Lachlan	LAC20/21-10	Waterbirds; native vegetation	Feeding	Noonamah 20/21	01/06/2021	14/06/2021	164.0
Lachlan	LAC21/22-01	Ecosystem functions; waterbirds; native vegetation	Feeding	Merrowie – Tarwong 2021	01/07/2021	21/09/2021	4,348.0

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Lachlan	LAC21/22-02	Waterbirds; native vegetation	Feeding	Merrimajeel to Angora 2021	01/07/2021	30/07/2021	2,275.0
Lachlan	LAC21/22-03	Waterbirds; native vegetation	Feeding	Willandra-Morrison's lake	09/07/2021	29/07/2021	1,500.0
Lachlan	LAC21/22-06	Waterbirds	Breeding	Lake Brewster Pelicans	21/03/2022	21/03/2022	5,100.0
Lachlan	LAC21/22-07	Waterbirds; native vegetation	Feeding	Merrowie – Box creek	08/04/2022	29/06/2022	9,047.0
Lachlan	LAC22/23-01	Waterbirds; longitudinal connectivity	Feeding	Lower Merrimajeel Dry Lake Pumping	05/08/2022	12/11/2022	1,695.0
Lachlan	LAC22/23-03	Waterbirds	Breeding	Lake Brewster Pelicans 2023	17/02/2023	09/03/2023	1,782.9
Lachlan	LAC22/23-05	Waterbirds; longitudinal connectivity	Feeding	Lower Lachlan Flood Recession	22/02/2023	09/03/2023	10,933.4
Macquarie–Castlereagh	MAC19/20-01	Waterbirds; native vegetation; ecosystem functions	Feeding	MACQ19/20-02 Supplementary Flow Events	22/02/2020	16/04/2020	4,583.0
Macquarie–Castlereagh	MAC20/21-01	Waterbirds; native vegetation	Feeding	MACQ20/21-02 Supplementary Flow Events	01/08/2020	27/03/2021	1,250.0
Macquarie–Castlereagh	MAC20/21-05	Waterbirds; native vegetation; connectivity (flows and flooding)	Feeding	Macquarie Spring 2020 pulse event	22/10/2020	15/12/2020	68,829.0

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Macquarie–Castlereagh	MAC21/22-02	Waterbirds; native fish; native vegetation; connectivity (flows and flooding)	Breeding	Macquarie Translucent EWA use	01/07/2021	30/06/2022	39,993.0
Macquarie–Castlereagh	MAC21/22-03	Waterbirds; native fish; native vegetation; connectivity (flows and flooding)	Breeding	Macquarie Spring Flow	25/09/2021	05/11/2021	23,769.0
Macquarie–Castlereagh	MAC22/23-04	Waterbirds	Breeding	Macquarie Summer Rookery Support 22-23	20/02/2023	10/03/2023	29,897.0
Macquarie–Castlereagh	MAC22/23-02	Ecosystem functions; waterbirds; native fish; other species; native vegetation; connectivity (flows and flooding)	Breeding	Macquarie Translucent EWA use 2022–23	03/04/2023	23/05/2023	25,865.0
Murray	MUR19/20-13	Waterbirds	Feeding	Boomanoomana Lagoon	28/08/2019	26/09/2019	311.2
Murray	MUR19/20-16	Waterbirds	Feeding	The Pollack 19–20	06/09/2019	14/12/2019	2,000.0
Murray	MUR19/20-14	Waterbirds; other species	Feeding	Mid Murray Private wetlands (SOS 2019–20)	09/09/2019	8/09/2020	2,207.9
Murray	MUR19/20-06	Waterbirds; native vegetation	Feeding	Fletchers Creek Wentworth	09/10/2019	29/05/2020	146.0
Murray	MUR19/20-17	Waterbirds	Breeding	Gulpa Creek Wetlands	08/11/2019	07/12/2019	5,260.0

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Murray	MUR20/21-01	Waterbirds; native vegetation	Feeding	Bottle Bend floodplain	14/07/2020	18/07/2020	500.0
Murray	MUR20/21-15	Waterbirds	Breeding	The Pollack 2020–21	28/08/2020	24/01/2021	2,500.0
Murray	MUR20/21-11	Waterbirds; native fish; native vegetation	Feeding	Thule Creek 2020–21	06/09/2020	30/11/2020	4,410.0
Murray	MUR20/21-16	Waterbirds; other species	Feeding	Mid Murray private wetlands 2020–21	28/09/2020	1/04/2021	2,787.7
Murray	MUR20/21-14	Waterbirds; native fish; native vegetation; connectivity (flows and flooding)	Breeding	Gulpa Creek Wetlands 2020–21	05/10/2020	27/01/2021	5,690.0
Murray	MUR20/21-07	Waterbirds; native vegetation	Feeding	Bingerra Creek Top up	10/03/2021	19/06/2021	300.0
Murray	MUR20/21-21	Waterbirds; other species	Feeding	Lake Agnes	15/03/2021	28/05/2021	1,507.4
Murray	MUR20/21-22	Waterbirds; native vegetation	Feeding	Fletchers Creek autumn waterbird and veg flow	01/04/2021	8/04/2021	80.0
Murray	MUR20/21-06	Waterbirds; other species; native vegetation	Feeding	Grand Junction	06/05/2021	3/06/2021	900.0
Murray	MUR21/22-03	Waterbirds	Breeding	The Pollack 2021–22	04/08/2021	31/12/2021	3,500.0
Murray	MUR21/22-06	Waterbirds; native fish; other species	Feeding	Mid Murray private wetland pumping 2021–22	31/08/2021	27/03/2022	1,225.0

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Murray	MUR21/22-10	Waterbirds; other species	Feeding	Murray Irrigation area private wetlands 2021–22	10/09/2021	8/12/2021	6,956.0
Murray	MUR21/22-11	Waterbirds; native fish	Feeding	Cockrans-Jimaringle 2021–22	10/09/2021	7/01/2022	15,814.0
Murray	MUR21/22-12	Waterbirds; native fish	Feeding	Whymoul Creek 2021–22	29/10/2021	26/01/2022	206.0
Murray	MUR22/23-03	Waterbirds; native fish	Breeding	The Pollack 2022–23	27/07/2022	7/10/2023	2,089.0
Murray	MUR22/23-06	Waterbirds; other species	Feeding	Mid Murray private wetland pumping 2022–23	28/09/2022	21/03/2023	885.0
Murray	MUR22/23-07	Waterbirds; other species	Feeding	Murray irrigation area private wetlands 2022–23	01/11/2022	30/04/2023	927.4
Murray	MUR22/23-09	Waterbirds	Breeding	Gulpa Creek Wetlands 2022–23	22/12/2022	15/02/2023	4,152.0
Murrumbidgee	MBG19/20-01	Waterbirds; native fish; native vegetation	Feeding	Yarradda Lagoon Pumping 2019–20	18/09/2019	16/11/2019	2,000.0
Murrumbidgee	MBG19/20-02	Waterbirds; native vegetation	Feeding	Wanganella Swamp 2019–20	02/10/2019	23/03/2020	2,250.0
Murrumbidgee	MBG19/20-11	Waterbirds; native vegetation	Feeding	Lower Murrumbidgee pumping 2019–20	08/10/2019	04/02/2020	3,500.0
Murrumbidgee	MBG19/20-10	Waterbirds; other species	Feeding	Coleambally Irrigation Area Wetlands 2019–20	10/10/2019	23/12/2019	3,496.0

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Murrumbidgee	MBG19/20-05	Waterbirds	Feeding	Nimmie-Caira refuge flows (Gayini, Nap Nap and Waugorah) 2019–20	15/10/2019	12/02/2020	41,313.0
Murrumbidgee	MBG19/20-09	Waterbirds	Feeding	MIA 2019–20	01/11/2019	24/11/2020	3,612.0
Murrumbidgee	MBG19/20-03	Waterbirds	Feeding	Sunshower Lagoon 2019–20	12/11/2019	14/04/2020	513.5
Murrumbidgee	MBG19/20-04	Waterbirds; native vegetation	Feeding	North Redbank Wetlands 2019–20	15/11/2019	02/06/2020	17,101.0
Murrumbidgee	MBG19/20-08	Waterbirds; native vegetation	Feeding	Yanga 2019–20	15/11/2019	17/05/2020	3,114.0
Murrumbidgee	MBG20/21-01	Waterbirds; native fish; connectivity (flows and flooding)	Breeding	Yanga 2020–21 MBG20/21-01	06/07/2020	30/06/2021	116,253.0
Murrumbidgee	MBG20/21-02	Waterbirds; native vegetation; connectivity (flows and flooding)	Breeding	North Redbank	08/07/2020	30/06/2021	49,944.0
Murrumbidgee	MBG20/21-05	Waterbirds; native fish; connectivity (flows and flooding)	Feeding	Yanco and Forest Creeks	26/08/2020	26/06/2021	13,349.0
Murrumbidgee	MBG20/21-07	Waterbirds; native vegetation	Breeding	Wanganella Swamp and Middle Wetland Pumping	04/09/2020	27/01/2022	3,579.5
Murrumbidgee	MBG20/21-08	Waterbirds; other species; native vegetation	Feeding	Coleambally Irrigation Area – Wetlands	16/10/2020	16/10/2021	5,438.2

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Murrumbidgee	MBG20/21-09	Waterbirds	Feeding	Lower Murrumbidgee Pumping 2020–21	19/10/2020	29/03/2021	4,028.2
Murrumbidgee	MBG20/21-04	Waterbirds; native fish; other species; native vegetation	Feeding	Mid Murrumbidgee wetlands Pumping	05/11/2020	29/12/2021	3,239.3
Murrumbidgee	MBG20/21-10	Waterbirds; other species; native vegetation	Feeding	Murrumbidgee Irrigation Area - Wetlands	01/12/2020	24/10/2021	4,179.0
Murrumbidgee	MBG21/22-09	Waterbirds; other species; native vegetation	Feeding	Middle Wetland (Old Coree)	09/09/2021	02/02/2022	950.0
Murrumbidgee	MBG21/22-04	Waterbirds; connectivity (flows and flooding)	Breeding	Gayini Nimmie-Caira	15/09/2021	20/05/2022	455,053.0
Murrumbidgee	MBG21/22-13	Waterbirds; native vegetation	Feeding	Rhyola Wetland and Lake Complex Pumping 2021–22	27/10/2021	02/08/2022	2,256.6
Murrumbidgee	MBG21/22-07	Waterbirds; native fish; connectivity (flows and flooding)	Feeding	Yanco, Forest and Forest Anabranch	28/10/2021	27/01/2023	17,148.5
Murrumbidgee	MBG21/22-11	Waterbirds; native vegetation	Feeding	Murrumbidgee Irrigation Area Wetlands 2021–22	23/11/2021	04/01/2023	701.1
Murrumbidgee	MBG21/22-03	Waterbirds; native vegetation	Feeding	Western Lakes	02/05/2022	11/05/2022	2,715.0

WRPA	Event number	Primary watering objectives	Waterbird habitat	Event name	Start date	End date	Volume delivered (ML)
Murrumbidgee	MBG22/23-02	Waterbirds; native vegetation	Breeding	Gayini (Nimmie-Caira) 2022–23	17/12/2022	25/03/2023	76,303.0
Murrumbidgee	MBG22/23-03	Waterbirds; native vegetation	Feeding	Murrumbidgee Irrigation Area Wetlands 2022-23	15/02/2023	01/02/2024	891.2
Murrumbidgee	MBG22/23-06	Waterbirds	Feeding	Western Lakes Complex (Paika Lake and surrounds) 2022–23	04/04/2023	02/06/2023	14,308.0