Waterbird Nesting and Breeding Activity

Hattah Lakes Icon Site - 2022/23

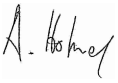
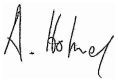
Project code 3054 3128

Mallee Catchment Management Authority

June 2023

Waterbird nesting and breeding activity - Hattah Lakes Icon Site - 2022/23

Project code 3054 3128. June 2023

Project name		Project code 3054 3128 - Nesting and breeding activity at the Hattah Lakes Icon Site following reestablishment of aquatic habitat at the Hattah Lakes Icon Site.					
Document title		Waterbird nesting and breeding activity - Hattah Lakes Icon Site - 2021/22 | Project code 3054 3128					
Project number		12540265					
File name		Report Waterbird nesting and breeding activity Hattah Lakes Icon Site 2022_23.docx					
Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
S3	A	D.Eyles	R. Retallick		A.Holmes		30/5/2023
Final	O	D. Eyles	A.Holmes		A.Holmes		22/6/2023

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Cover photos, clockwise from top left: Great Cormorant chicks on nest with camera trap, White-necked Heron chicks, and Great Cormorant eggs in nest, all from Lake Konardin.

Referencing can be made as: GHD. (2023) Waterbird nesting and breeding activity - Hattah Lakes Icon Site - 2022/23. Project code 3054 3128. May 2023. Client report for the Mallee CMA by GHD.

Acknowledgments

This project was funded by The Mallee Catchment Management Authority through The Living Murray. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian and Commonwealth governments, coordinated by the Murray–Darling Basin Authority.

This work was commissioned by Emma Pacholli and David Wood of the Mallee CMA. We are grateful to the CMA and their colleagues for their support and enthusiasm. The work was conducted under FFG Act 1988 and National Parks Act 1975 Research Permit 10008653, and Wildlife Act 1975 Research Authorisation (permit no: 10010378).

Executive Summary

Widespread and large-scale water extraction has degraded wetlands across the world, and in Australia this has been particularly evident across the Murray-Darling Basin. Intensive management of water has changed natural flow regimes, reducing breeding opportunities and impacting reproductive success of aquatic organisms, including colonially breeding waterbirds and their prey that rely on periodic wetland inundation. To overcome some of the adverse impacts of historical water resource development and change in management, there has been an increasing focus on the management of environmental flows for ecosystems and specific groups of organisms. Environmental water and environmental flows are the management of water to improve or maintain the health of rivers and wetlands – including the plants and animals that depend on them, through the artificial provision of water through active management.

Due to changed natural flow regimes, the wetting and drying cycles of the Hattah Lakes system in northern Victoria are now largely dependent on deliberately managed, artificial environmental flows. The lack of reliable hydrological connectivity between the lakes and the Murray River, and the complete drying of the lakes during the millennium drought has had detrimental effects on the Hattah Lakes ecosystem and its ability to act as a refuge during prolonged drought. The completion of The Living Murray Hattah Lakes Infrastructure project in 2013 has allowed the implementation of broad scale environmental watering to mitigate the effects of the reduced frequency of natural flooding, by inundating the Hattah Lakes Icon Site.

Colonial nesting waterbirds are an important target group for the management of environmental flows, providing a measure of the success or failure of environmental flow management. The success of breeding events in wetlands may be used as a measure of overall wetland health, as successful breeding by these species indicates the presence of a wide range of aquatic organisms upon which the birds feed.

This report describes the targeted survey and monitoring of colonial breeding waterbird nests at 21 lakes across the Hattah-Kulkyne National Park in late 2022 and early 2023. The surveys were commissioned by the Mallee CMA, during the area's biggest natural flood event since 1956, and following the delivery of environmental water to the Hattah Lakes in autumn and spring 2021, which followed an extended drying phase in which all lakes had been completely dried out for between one and four years. In late 2022, floodwaters extended into large areas of floodplain which had not been inundated since the mid-1970s and some areas since the 1956 flood.

Surveys were completed from October 2022 to April 2023, almost entirely from kayaks, which were essential to access the flooded lakes and surrounding floodplains. Surveys were undertaken to monitor waterbird species, locations and numbers of active nests across the Hattah Lakes Icon Site, and subsequent development of hatchlings through to fledging. The results of these surveys will assist in informing recommendations for the planning, prioritisation and management of future environmental water flows within the Hattah Lakes and potentially the broader Murray-Darling Basin, with particular regard to informing hydrological cues that maximise waterbird recruitment by improving breeding outcomes for cormorants and other colonial nesting waterbirds.

The natural flooding of the already wet Hattah Lakes system in the summer of 2022/23 triggered a very large waterbird breeding event across much of the lakes system. In total, 28 waterbird species were observed breeding, including ten colonial nesting species, and 7,176 nests and 27,188 chicks were recorded, the vast majority (6,979 nests and 25,362 chicks) of which were classified as colonial breeding waterbird species. Dominant species recorded breeding successfully included very large colonies of Great Cormorant, Little Pied Cormorant, along with moderate numbers of Australasian Darter, Australian White Ibis, Nankeen Night-Heron and Yellow-billed Spoonbill. These observations follow earlier observations of smaller but substantial breeding colonies of these species documented following the previous large environmental watering event in 2021/22. Individual lakes varied greatly in the numbers of nests supported, ranging from no colonial nests at four lakes, to as many as 310 nests at Lake Roonki, 388 at Lake Mournpall, 727 at Lake Kramen, 1,098 at Lake Yelwell and 3,240 at Lake Cantala.

Locations of breeding colonies recorded in these surveys showed a very high degree of site fidelity compared with locations used in previous breeding events, with all large and medium colonies located in areas where colonies were detected in previous surveys in 2021/22 and 2020/21. The largest colonies were found in the same locations at Lakes Cantala, Yelwell, Konardin, Mournpall, Hattah, Roonki and Woterap. The reasons for the birds consistently choosing these locations are speculated on, but as theorised previously, it is likely that those areas contain more suitable nesting habitat in the form of trees with preferred size, orientation, density and shape, and

occurring in areas of high prey concentrations, reducing travel distance for breeding adult birds. A comparison of the numbers of colonial waterbird nests recorded in these 2022/23 surveys with those recorded in 2021/22 (GHD 2022) show a marked increase in the total number of nests at most lakes where colonies have been recorded in previous years, and an almost 400% increase in total numbers of nests across the lake system overall. The locations of nests in different years was seen to be a broadly similar across the lakes, and the relative proportions of nests within these, with lakes Cantala, Yelwell, Konardin, Mournpall, Roonki and Hattah all typically supporting large breeding colonies in most years of survey. In every year, Lake Cantala has supported more than twice as many nesting birds as any other lake, emphasising the significance of this isolated lake as a breeding habitat.

Many nests established early in the flood (November and December) were seen to be inundated and abandoned, with new nests established progressively at higher locations. Observations thereafter saw the development of multiple cohorts of chicks and subsequent high breeding success, with no signs of nest abandonment or predation and very few mortalities observed. An analysis of nestling data show mean numbers of chicks per nest was greatest for Great Cormorant (4.17), Australasian Darter (3.89), Little Black Cormorant (3.18) and Little Pied Cormorant (3.07), and that these values were greater than those observed in the previous surveys in 2021/22. Development of colonial nesting chicks was also considered successful, with the vast majority of chicks during March and April surveys seen to fledge. Most fledging was recorded earlier in the 2022-23 event than in previous surveys; many nests still contained large chicks when surveys were finalised in early April 2022. The earlier fledging of chicks in 2023 may also be a result of the already inundated system providing favourable feeding resources for initiation of breeding earlier in the summer than occurred in earlier years, where the system had been dry and had to build up from a lower baseline of biomass and feeding resource availability for the birds.

The large numbers of nests and chicks, and multiple cohorts, combined with the high percentage of chicks observed fledging by the end of surveys, show that chick development and breeding success during the 2022/23 summer breeding season was highly productive. Following the successful breeding season in the preceding year, these large numbers of fledging waterbirds clearly demonstrate that the Hattah Lakes system is an important area for waterbird breeding, especially colonially nesting waterbirds.

Seven threatened species were recorded breeding across the lake system in response to the flooding, including Blue-billed Duck (FFG Act listed Vulnerable), Eastern Great Egret (FFG Act listed Vulnerable), Hardhead (FFG Act listed Vulnerable), Little Eagle (FFG Act listed Vulnerable) Musk Duck (FFG Act listed Vulnerable), Regent Parrot (EPBC Act listed Vulnerable and FFG Act listed Endangered) and White-bellied Sea-eagle (FFG Act listed Endangered). The EPBC Act and FFG Act listed Vulnerable Regent Parrot was ubiquitous across the survey area and seen or heard at most lakes. Additionally, one Lace Monitor (FFG Act listed Endangered) was recorded incidentally during surveys.

This second comprehensive survey of colonial breeding waterbird nests across the Hattah Lakes system in 2022/23 has successfully built on knowledge gained in the surveys in 2021/22 and of unoccupied nests in 2020/21. Earlier surveys have proved invaluable in predicting the locations of breeding colonies with all large and medium colonies observed in 2022-2023 occurring in locations of colonies in previous years. This suggests that future monitoring could be streamlined with some confidence to target these areas of known colony locations, as those areas are likely to be reused.

The filling of the Hattah Lakes with environmental water in the winter and spring of 2021, in a largely dry landscape, appears to have not just supported a breeding event of colonial nesting waterbirds in that summer, but primed the area for a very large and successful breeding event with the subsequent large flood in December 2022.

The overall success of waterbird breeding observed in these 2022/23 surveys, both in species diversity, numbers of chicks and their successful development, suggests that the provision of environmental water, followed by a natural flood, has provided ideal conditions for cormorants and other species of colonial and non-colonial nesting waterbirds. Future environmental watering events, particularly when linked to natural flood events, are likely to provide conditions suitable for waterbird recruitment. The large numbers of breeding birds recorded in 2021/22 and 2022/23 also suggest that the Hattah Lakes do provide an important breeding ground for a number of species of colonial nesting waterbirds. It is hoped that the results of these surveys will further assist in informing recommendations for the planning, prioritisation, and management of environmental water flows within Hattah-Kulkyne National Park and potentially the broader Murray-Darling Basin and assist with maximising waterbird recruitment into the future.

This report is subject to, and must be read in conjunction with, the limitations set out in sections 1.5 and 2.1 and the assumptions and qualifications contained throughout the Report.

Abbreviations

CMA	Catchment Management Authority
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEECA	Victorian Department of Energy, Environment and Climate Action (formerly DELWP, DEPI, DSE and NRE)
EPBC	Commonwealth *Environment Protection and Biodiversity Conservation* Act 1999
FFG	Victorian *Flora and Fauna Guarantee* Act 1988
GHD	GHD Pty Ltd
GPS	Global Positioning System
HKNP	Hattah-Kulkyne National Park
MDBA	Murray Darling Basin Authority
SDL	Sustainable Diversion Limits
TLM	The Living Murray
VBA	Victorian Biodiversity Atlas

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1. Introduction

1.1 Project Background and Objectives

This report describes targeted surveys of colonial nesting waterbird breeding which were completed between October 2022 and April 2023, in response to the largest natural flooding event in over 60 years at the Hattah Lakes Icon Site. Following environmental watering in autumn and spring 2021, a naturally occurring flood inundated broad areas of the floodplain in late 2022. It was anticipated that the flooding of the lake system at this time would promote a breeding response by colonial nesting waterbird species, in particular cormorants. The surveys were commissioned by the Mallee CMA, following previous monitoring of the lakes within Hattah-Kulkyne National Park (HKNP) associated with the environmental watering in 2021 (GHD 2022). The 2021 watering occurred after a period of drying of all lakes over the preceding two years, and surveys in 2020/21 of the lakes in a dry state, identifying and mapping previously used waterbird nests (GHD 2021).

General monitoring of waterbird richness and abundance has been completed at the Hattah Lakes Icon Site over the last 16 years following environmental watering, but this monitoring has not specifically targeted waterbird breeding events, and typically didn't have the resources required to access broad areas over the time frames necessary to accurately monitor this. Information on breeding to date has been mostly anecdotal, and the lakes were not known to be a site for regular large-scale colonial nesting birds. Surveys of unoccupied nests in the lakes when dry in 2020/21, and occupied nests in the lakes when inundated in 2021/22, recorded significant numbers of nests, suggesting that the Hattah Lakes system does provide habitat suitable for regular large-scale colonial waterbird nesting.

It is hoped that, through repeated assessments of waterbird nest site locations, densities, successes and failures relative to the specific characteristics of inundation, future watering events can be planned and implemented to provide the hydrological cues needed to improve breeding outcomes for cormorants and other species of colonial nesting waterbirds.

The key objectives of this study were to:

– Quantify the extent of cormorant and other colonial nesting waterbird breeding at the Hattah Lakes Icon Site in response to widespread natural flooding in 2022/23, which occurred after environmental watering in autumn and spring 2021.
– Accurately map the species, location and number of active waterbird nests across the Hattah Lakes Icon Site, and to monitor these nests to observe and document the success of nesting birds, development of eggs and hatchlings through to fledging, and occurrence of nest abandonment or predation.
– Summarise the findings to assist in the planning and development of future watering events that aim to provide the hydrological cues to improve breeding outcomes for cormorants and other colonial nesting waterbirds.

These objectives were achieved by mapping the locations and key attributes of colonial nesting waterbird nests across the lakes, creeks and floodplain at the Hattah Lakes Icon Site. This technical report outlines the results of the 2022-2023 surveys of this area and provides spatial representations and physical details for each nest and breeding sign recorded. The results of these surveys will assist in informing recommendations for the planning, prioritisation and management of environmental water flows within HKNP and potentially the broader Murray-Darling Basin, and assist with maximising waterbird recruitment.

1.2 Study Area

The HKNP lakes (Hattah Lakes) are part of a Ramsar listed wetland located in northern Victoria within the Murray-Darling Basin. The area contains a series of floodplain lakes representing wetlands classified as permanent freshwater lakes and seasonal intermittent freshwater lakes, subject to flooding from the Murray River with flows entering predominantly via Chalka Creek. This series of interconnected lakes is the most extensive lake system along the Murray River. Twelve of the wetlands are listed as Wetlands of International Importance under the International Convention on Wetlands (Ramsar Convention). To be listed as a Ramsar site, a wetland must meet one or more internationally accepted criteria in relation to its zoology, botany, ecology, hydrology or limnology and

importance to waterfowl. At the time of listing, the Hattah Lakes site met four criteria as outlined on the Ramsar wetlands website (Ramsar 2021). The Ramsar site is also part of the Hattah Lakes Icon Site under The Living Murray program.

The lake system supports a number of vegetation groups, the most dominant of which is Lake Bed Herbland, as well as Grassy and Swampy Woodland. On the periphery of each lake, tree species such as River Red Gum (*Eucalyptus camaldulensis*), Black Box (*Eucalyptus largiflorens*) and River Coobah (*Acacia stenophylla*) provide sheltering and nesting habitat for a range of fauna species, particularly bats, parrots, possums, snakes and waterbirds. The lake beds support submerged and aquatic plant communities when flooded and terrestrial species during dry phases. When the lakes are filled, the peripheral trees become inundated to varying degrees, such that they may be standing in water for long periods of time. It is these conditions that attract waterbirds to breed, particularly colonial nesting species.

The Hattah Lakes are also an important cultural heritage site, having been a focus for traditional Aboriginal society for thousands of years, as evidenced by over 1000 registered Aboriginal archaeological sites within the Hattah-Kulkyne National Park.

1.3 Colonial nesting waterbirds

Colonial nesting is common among many species of Australian waterbirds, in particular species of cormorants, herons, egrets, spoonbills, ibises, pelicans, Black Swans and wading birds (Beruldsen, 2003, Brandis 2010, Marchant and Higgins 1990). Breeding colonies can range from several loosely associated nests, to many thousands of densely crowded nests. These colonial nesting waterbirds are dependent on river flows for the critical breeding stage of their lifecycle, and breed in response to large flows and the associated flooding on relatively few wetlands in Australia (Brandis 2010, Kingsford and Johnson 1998). Colonial nesting species relevant to the lakes of HKNP include cormorants (*Phalacrocorax* spp.), egrets (*Ardea/Egretta* spp.), darters, spoonbills, herons, pelicans, ibis and Black Swan (Beruldsen, 2003). There are many other species that may not breed in colonies, but that may increase breeding in response to this watering event (e.g., ducks). Australian waterbird populations depend on suitable feeding and nesting habitats, coupled with suitable rain and flood events that trigger breeding events. Wetlands within the Murray-Darling Basin provide critical waterbird habitats for many species; however, the quality and availability of these sites are greatly influenced by water and vegetation management decisions. Protecting and maintaining suitable feeding and nesting habitats between, and during flood events is essential to maximise waterbird recruitment, maintain populations, and conserve biodiversity. This requires careful management of both vegetation and water regimes at a range of scales across the basin.

The development and management of water resources through water extraction and impoundment has degraded wetlands across the world, and in Australia this has been particularly evident across the Murray-Darling Basin. Intensive management has changed natural flow regimes, affecting aquatic organisms, including colonially breeding waterbirds and their prey that rely on periodic wetland inundation, reducing the frequency of breeding opportunities and impacting reproductive success (Brandis 2010). To overcome some of the adverse impacts of past water resource management, there has been an increasing focus on the management of environmental flows for ecosystems and specific groups of organisms. Colonial nesting waterbirds are an important target group for the management of environmental flows, as they provide an opportunity to measure of the success or failure of environmental flow management. The success of waterbird breeding events in wetlands may be used as a measure of overall wetland health, as successful breeding by these species indicates the presence of a wide range of aquatic organisms including fish, frogs, crustaceans, molluscs and other aquatic macroinvertebrates, upon which the birds feed.

Wetting and drying cycles of the Hattah Lakes system are now largely dependent on environmental flows, with just two natural, unregulated flooding events occurring in the last 20 years (2022/23 and 2016), and the last major floods before that occurring in 2010/11 and 1993 (Mallee CMA 2010). The lack of reliable hydrological connectivity between the lakes system and the Murray River, and the complete drying of the lakes during the millennium drought has had detrimental effects on the Hattah Lakes ecosystem and its ability to act as a refuge during prolonged drought (MDBA 2012). The ecological productivity of the system has declined and the habitat value for fauna has been degraded (MDBA 2012). The completion of the Hattah Lakes The Living Murray (TLM) infrastructure project in 2013 has allowed the implementation of broad-scale environmental watering to partially mitigate the effects of the reduced frequency of natural flooding, by inundating much of the Hattah Lakes Icon Site. Environmental watering of some lakes was implemented between 2005 and 2010, with broad-scale filling of the

system completed between 2013 and 2015, and again between 2016 and 2018. A complete drying of all lakes within the Hattah system between 2019 and summer 2020/21 was followed by environmental watering in the autumn and spring of 2021, and spring 2022. The area then flooded naturally in late 2022, in what was the biggest flood of the area since 1956, during which all 12 RAMSAR lakes and all surrounding areas of floodplain were inundated. These surveys were undertaken during the 2022-2023 flood.

1.4 Target species

Many of the waterbird species which have been previously recorded across the Hattah Lakes are known to typically breed in colonies, ranging from a loose aggregation of several nests, to dense colonies of thousands of birds. Territories immediately around nests are typically defended (Marchant and Higgins 1990), often resulting in nests within groups being 'pecking distance' from each other.

Species targeted during the 2022/23 surveys include the Great Cormorant (*Phalacrocorax carbo*) and Pied Cormorant (*Phalacrocorax varius*), which typically breed in colonies of ten to many thousands, often with other species of cormorants, herons, spoonbills and ibises (Beruldsen 2003, Marchant and Higgins 1990). Other species targeted include the Little Pied Cormorant (*Microcarbo melanoleucos*) and Little Black Cormorant (*Phalacrocorax sulcirostris*), which typically breed in colonies of 3-400 nests, often with other species of cormorants, herons, spoonbills and ibises (Beruldsen 2003, Marchant and Higgins 1990).

Other species of waterbird known to nest in the HKNP lakes, and often colonially, include the Australasian Darter (*Anhinga novaehollandiae*), White-faced Heron (*Egretta novaehollandiae*), White-necked Heron (*Ardea pacifica*), Eastern Great Egret (*Ardea alba modesta*), Little Egret (*Egretta garzetta*), and Plumed Egret (*Ardea intermedia plumifera*). Australasian Darter typically nest solitarily, as do Little Egret, and White-faced Heron. Plumed and Eastern Great Egrets, and White-necked Heron sometimes nest in loose colonies with cormorants, other herons, egrets, ibises and spoonbills (Beruldsen 2003, Marchant and Higgins 1990). Most of these species also typically build relatively thin and frail nests, higher in trees, 7-25 m above water level (Beruldsen 2003).

1.5 Scope and limitations

This report: has been prepared by GHD for the Mallee Catchment Management Authority and may only be used and relied on by Mallee Catchment Management Authority for the purpose agreed between GHD and Mallee Catchment Management Authority as set out in section 1.1 and 2.1 of this report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

2. Methods

2.1 Assumptions and Limitations

A number of important limitations were identified for the surveys of colonial nesting waterbird nests at HKNP in 2022-23. As summarised in the introduction, the surveys were completed during the largest natural flood event in the region since 1956, and when large areas of HKNP were inundated for long periods of time, making access very challenging. Vehicle access was severely limited for much of the survey period, with some main routes still inaccessible when surveys concluded five months after peak flood, greatly increasing the effort required to get to most areas. As a result, many nesting areas required long kayak trips to access and, at times, overnight kayak camping was required. While these challenges limited access to an extent, they also forced water-based access to areas that may otherwise not have been accessible.

The Hattah Lakes cover a very large area, and the 2022/23 flooding was tentatively estimated to have inundated an area of over 16,840 ha and more than 70 km of creeks, which all provide potential waterbird breeding habitat. As shown in Figure 1, this is much greater than the 2021 spring environmental watering, which inundated 3,403.9 ha of floodplain (Mallee CMA pers. comm.) including over 1,000 ha of lakes (Butcher & Hale 2011), and more than 50 km of creek . Despite much walking and extensive kayak-based travel, some areas will have been missed during the survey. In addition to this, nesting birds are highly adept at hiding nests in difficult to access areas, out of view in thick stands of saplings, thereby discreetly avoiding predators, people and easy detection.

Previous surveys during 2020/21 and 2021/22 (GHD 2021 and GHD 2022) provided a very good indication of the areas to focus on for the 2022-23 surveys and the types of habitats likely to be used. Previous colonies were typically around the inlet/outlet areas of lakes, along peninsulas and isthmuses, and especially areas with inundated trees or dense stands of saplings that provide good cover from predators, are hidden from view, and provide an ability for large numbers of birds to nest close to one other.

While undertaking the monitoring of active nests, utmost consideration was given to avoiding disturbance of birds. Motion-sensor and timer-triggered camera traps were used to monitor a limited number of nests, but were deemed unsuitable for broad area monitoring as positioning cameras close enough to nests to collect meaningful information would potentially risk distress, causing nest abandonment or chicks jumping from nests. Four camera traps were deployed before nesting began and removed after chicks had vacated. All GHD fauna related projects require Animal Ethics consideration and approval, and animal welfare is always a primary consideration.

Overall numbers and development stages of chicks were estimated by extrapolating numbers from a representative sub-set of nests where counts and sizes were accurately assessed. Nests numbers were accurately counted but not always assessed for chick numbers and size. This method was employed for three reasons: not all nests allowed the contents to be viewed due to the height above water; in some cases the density of nests made close inspection impossible without risk of significantly disturbing the birds; and the sheer numbers of nests often made counting all chicks in all nests unfeasible. Sub-sets of numbers were taken from all lakes where the relevant species were recorded, in numbers relative to the number of nests, making the sub-sets proportional.

The large numbers of nests and high variability of water levels also led to less morphometric data being recorded for nest trees, with values such as tree height, nest height and tree diameter being very hard to estimate and subject to considerable change, as water levels varied during the surveys by over 4 metres in some places. These variables were considered secondary data and so not critical to achieving the scope of the surveys.

The numbers of nests and chicks counted during this survey can be considered minimum values, as invariably some nests will have been missed during surveys due to obstruction of views or poor access, and some nests are likely to occur in areas of the Chalka Creek or much broader floodplain that were beyond the scope of this project and could not be accessed during surveys.

Figure 1 *Extent of inundation after e-watering (Dec 2021) at left, and height of 2022/23 natural floods (December 2023) at right.*

2.2 Field Survey

Field surveys were primarily completed by GHD Ecologists Dan Eyles, Shelley Thompson, Richard Retallick, Zoe Jellie and Alex Holmes, with assistance from Emma Pacholli of Mallee CMA, and guidance by Richard Loyn of Eco Insights. Surveys were completed between October 2022 and April 2023, with over fifty field-survey days completed..

All 18 TLM lakes, along with three additional lakes, areas of the Chalka Creek and a number of unnamed wetlands were assessed across HKNP, as listed in Table 1 below, and shown in Appendix A.

Field surveys initially focussed on reconnaissance visits on a fortnightly basis to all accessible lakes, looking for signs of waterbird nest building and courtship or breeding behaviours. A kayak was used to gain access to most areas and proved essential in locating nesting colonies and counting nests and chicks. Monitoring from the water in a kayak allowed greater freedom to quietly approach nests and observe from a wider range of angles to detect and count occupants (adults, chicks). Data was collected using the ArcGIS Collector GPS application to accurately record the location, species, nest status (number of chicks, stage of chick development etc), tree metrics (tree species, tree dead or alive, height of nest above water, tree diameter, tree height, and count of nests) and a unique ID number assigned to allow ongoing repeat assessments of each nest over time.

Nests are known to be typically and preferentially constructed over water, and therefore surveys focussed on the perimeter of each lake, along with any islands or isthmuses to inspect all fringing trees, as this is the area where nest building was anticipated. It would be expected that most colonial nests would be detected using this thorough method. Ecologists also recorded evidence or signs of other waterbird breeding such as duck, swan, coot or grebe.

For the purpose of this study, a waterbird was defined as any species that habitually wades or swims in water, and includes species that forage almost exclusively within wetlands such as terns, gulls and White-bellied Sea-Eagle.

Table 1 Summary of survey site dimensions

Wetland Name	Lake Area (ha)	Approximate Perimeter (km)
Lake Arawak	40	4.2
Lake Bitterang	73	13.4
Lake Brockie	28	5.8
Lake Boich	10	1.9
Lake Bulla	40	5.2
Lake Cantala	101	15.2
Lake Hattah	61	4.7
Lake Konardin	121	6
Little Lake Hattah	7.3	5.5
Lake Lockie	141	8.6
Lake Marramook	7	4.2
Lake Mournpall	243	7
Lake Nip Nip	3	1.2
Lake Roonki	38	5
Lake Tullamook	14	5.6
Lake Woterap	50	5.2
Lake Yelwell	81	6.5
Lake Yerang	65	2.5
TOTAL Area	**1,123.3**	**107.7**
Estimated TLM e-water maximum inundation areas within HKNP	**6,000**	
Estimated January 2023 Total Inundation Area within HKNP	**16,842**	

2.2.1 Camera Traps

Four camera traps were installed on trees, focussing on Great Cormorant nests at Lake Konardin, to allow unobtrusive and remote observation and recording of nesting activity and success over a prolonged period. Cameras were installed at the height of the natural flood in late December 2022, and set on time-lapse to take a series of three still images every four hours. Cameras were installed while nest construction was being finalised, before egg-laying, to minimise disturbance to the nesting birds and avoid risk of nest abandonment. For this same reason, cameras were not retrieved until April 2023, after chicks had fledged from nests. The images captured by these cameras allow post-survey assessment of nest establishment, egg incubation, hatching, chick feeding and development and fledging success.

2.2.2 Incidental records

Any noteworthy species observed during field surveys were recorded as incidental records. Noteworthy species may include those listed under the FFG or EPBC Act, or considered as regionally significant due to location or time of year. These records will be submitted to the VBA to add to the knowledge of fauna of the area and potential indirect benefits of environmental watering to additional species. These observations are summarised in section 3.6 and Appendix B.

2.3 Permits

Surveys were completed under DELWP Flora & Fauna Guarantee Act (1988) Research Permit 10009910, Victorian National Parks Research Permit Ref #10009923, Animal Ethics Scientific Procedures Licence SPFL20067 and Wildlife Act 1975 Research Authorisation (permit no: 10010378).

3. Results

3.1 Overview of survey results

A total of 7,517 breeding events and an estimated 27,188 chicks were recorded for 28 waterbird and wetland utilising species during the 2022/23 surveys, including 7,176 nests containing 26,557 chicks (Table 2). Waterbird breeding was recorded at all lakes except for Lakes Boich, Marramook, Nip Nip and Tullamook (Table 3, Table 4, Table 5). The most numerous breeding species were Great Cormorant (3,990 nest records, 16,633 chicks), Little Pied Cormorant (1,496 records, 4,596 chicks), Little Black Cormorant (1,126 records, 3,585 chicks), Australasian Darter (299 records, 1,164 chicks), Nankeen Night-heron (147 records, 153 chicks), Yellow-billed Spoonbill (79 records, 132 chicks), White-faced Heron (53 records, 111 chicks), Eurasian Coot (53 records, 109 chicks), Australian White Ibis (50 records, 146 chicks), and White-necked Heron (45 records, 90 chicks) (Table 2).

Of the colonial nesting species, 6,979 nests and 25,362 chicks of ten species were recorded, across all lakes except Boich, Marramook, Nip Nip and Tullamook (Table 4). Lake Cantala supported the greatest number of colonial waterbird nests and chicks, with 3,240 and 12,661 counted respectively, followed by Lake Yelwell (1,098 nests, 3,642 chicks), Lake Konardin (727 nests, 2,328 chicks), Lake Mournpall (388 nests, 1,529 chicks), Lake Roonki (310 nests, 1,298 chicks), Lake Hattah (279 nests, 951 chicks) and Bulla (206 nests, 646 chicks).

Waterbird nest data (Table 6) show the range of variables such as number of chicks per nest. Mean number of chicks per nest was greatest for Great Cormorant (4.17), Australasian Darter (3.89), and Little Black Cormorant (3.18), Little Pied Cormorant (3.07), Australian White Ibis (2.92), and Pied Cormorant (2.86). The very large numbers of nests, combined with the high variability of water levels led to less morphometric data being recorded for nest trees than in 2021/22 surveys, with values such as tree height, nest height and tree diameter being very hard to estimate and subject to considerable change, as water levels varied during the surveys by over 4 metres in some places. The peak of the Murray River flood in late December 2022, compared to late winter and spring during the 2021 environmental watering led to many nests becoming drowned, following early nesting by waterbirds. Subsequent to this, birds quickly renested and bred continuously at least until the final survey in May 2023. Nest height was observed to be largely determined by when the nest was constructed before water levels dropped, with an apparent preference for low nests near water for many species, which then became high above water when levels dropped by up to 5 metres in places.

The total number of waterbird nests can be seen to vary greatly between lakes (Table 4, Table 5, Figure 3), from none detected at Lake Boich, Marramook, Nip Nip or Tullamook (0), very few at Lakes Arawak (10), Dry Lakes (15), Boolca (16) and Yerang (36), to extremely large numbers at others, particularly Lake Cantala (3,312 nests), Yelwell (1,098), Konardin (783), Mournpall (425), Roonki (315) and Hattah (279).

Ten threatened species were observed across the lake system during surveys (Table 7), including seven species recorded breeding. Breeding records included one juvenile Blue-billed Duck (*Oxyura australis*) (FFG Act listed Vulnerable), 16 records of nests and 37 young Eastern Great Egret (FFG Act Vulnerable), three individual young Hardhead (*Aythya australis*) (FFG Act Vulnerable), 13 young Musk Duck (*Biziura lobata*) (FFG Act Vulnerable) and 11 records of juvenile White-bellied Sea-eagle (*Haliaeetus leucogaster*) (FFG Act Endangered). The EPBC Act Vulnerable and FFG Act listed Endangered Regent Parrot (*Polytelis anthopeplus*) was ubiquitous across the survey area and was seen or heard at most lakes, but significantly, was observed breeding, or likely breeding at seven locations across the survey area, none of which were previously recognised breeding locations for this species. Breeding by the Regent Parrot is known to be seasonal, and may or may not be influenced by the extent of inundation. Little Eagle (*Hieraaetus morphnoides*) (FFG Act Vulnerable) were observed at three locations, including breeding at Lake Konardin. Additionally, one Lace Monitor (*Varanus varius*) (FFG Act Endangered) and two Major Mitchell's Cockatoo (*Lophochroa leadbeateri*) (FFG Act Critically Endangered and EPBC Act Endangered) were recorded incidentally during surveys.

Results are summarised below in Table 2, Table 4, Table 5, Table 6, shown visually in Figure 2 and Figure 3 and provided in their entirety in Appendix D. A summary of incidental records and threatened species observed during surveys is provided in Appendix B, and a selection of photographs of nests, nesting birds and species of interest is provided in Appendix C.

Table 2 Summary of all waterbird and wetland utilising breeding results 2022/23

Common Name	Scientific Name	FFG Act Status	Colonial nesting	No. Records	No. Chicks
Australasian Darter	*Anhinga novaehollandiae*		No	299	1,164
Australasian Grebe	*Tachybaptus novaehollandiae*		No	13	27
Australian Shelduck	*Tadorna tadornoides*		No	1	5
Australian White Ibis	*Threskiornis molucca*		Yes	50	146
Australian Wood Duck	*Chenonetta jubata*		No	12	50
Black Swan	*Cygnus atratus*		Yes	8	17
Blue-billed Duck	*Oxyura australis*	VU	No	1	1
Dusky Moorhen	*Gallinula tenebrosa*		No	1	1
Eastern Great Egret	*Ardea alba modesta*	VU	Yes	16	37
Eurasian Coot	*Fulica atra*		No	53	109
Great Cormorant	*Phalacrocorax carbo*		Yes	3,990	16,633
Great Crested Grebe	*Podiceps cristatus*		No	33	73
Grey Teal	*Anas gracilis*		No	35	125
Hardhead	*Aythya australis*	VU	No	3	3
Hoary-headed Grebe	*Poliocephalus poliocephalus*		No	3	13
Little Black Cormorant	*Phalacrocorax sulcirostris*		Yes	1,126	3,585
Little Pied Cormorant	*Microcarbo melanoleucos*		Yes	1,496	4,596
Musk Duck	*Biziura lobata*	VU	No	11	13
Nankeen Night-heron	*Nycticorax caledonicus*		Yes	147	153
Pacific Black Duck	*Anas superciliosa*		No	3	11
Pied Cormorant	*Phalacrocorax varius*		Yes	22	63
Pink-eared Duck	*Malacorhynchus membranaceus*		No	2	13
Sacred Kingfisher	*Todiramphus sanctus*		No	1	1
Whistling Kite	*Haliastur sphenurus*		No	5	5
White-bellied Sea Eagle	*Haliaeetus leucogaster*	EN	No	9	11

Common Name	Scientific Name	FFG Act Status	Colonial nesting	No. Records	No. Chicks
White-faced Heron	*Egretta novaehollandiae*		No	53	111
White-necked Heron	*Ardea pacifica*		Yes	45	90
Yellow-billed Spoonbill	*Platalea flavipes*		Yes	79	132
TOTALS	**28 species**	**4 VU, 1 EN**		**7,517**	**27,188**

Table 3 ***Summary of all waterbird and wetland utilising breeding results 2022/23 by lake***

Lake	Colonial species nests	Non-Colonial species nests	Total number of nests	Colonial species chicks	Non-Colonial species chicks	Total Number of chicks
Arawak	1	9	**10**	1	28	**29**
Bitterang	68	37	**105**	117	98	**215**
Brockie	146	47	**193**	517	185	**702**
Boich	0	0	**0**	0	0	**0**
Boolca	15	1	**16**	55	3	**58**
Bulla	206	25	**231**	646	100	**746**
Cantala	3240	72	**3312**	12,661	260	**12921**
Chalka Creek	1	18	**19**	2	66	**68**
Dry Lakes	15	0	**15**	64	0	**64**
Hattah	279	26	**305**	951	96	**1047**
Konardin	727	56	**783**	2,418	167	**2585**
Kramen	136	20	**156**	426	44	**470**
Little Hattah	59	19	**78**	96	44	**140**
Lockie	101	39	**140**	360	90	**450**
Marramook	0	0	**0**	0	0	**0**
Mournpall	388	37	**425**	1,529	97	**1626**
Nip Nip	0	0	**0**	0	0	**0**
Roonki	310	5	**315**	1,298	22	**1320**
Tullamook	0	0	**0**	0	0	**0**
Woterap	169	36	**205**	636	107	**743**
Yelwell	1098	75	**1173**	3642	278	**3920**
Yerang	20	16	**36**	33	51	**84**
TOTALS	**6934**	**583**	**7517**	**25362**	**1826**	**27188**

Table 4 Colonial species breeding data 2022/23 – by lake

Lake	Australian White Ibis nests/ chicks	Black Swan nests/ chicks	Eastern Great Egret nests/ chicks	Great Cormorant nests/ chicks	Little Black Cormorant nests/ chicks	Little Pied Cormorant nests/ chicks	Nankeen Night Heron nests/ chicks	Pied Cormorant nests/ chicks	White-necked Heron nests/ chicks	Yellow-billed Spoonbill nests/ chicks	TOTAL Colonial nests/ chicks
Arawak	1 / 1	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**1 / 1**
Bitterang	9 / 27	1 / 2	0 / 0	9 / 36	0 / 0	0 / 0	48 / 49	0 / 0	0 / 0	0 / 0	**68 / 117**
Boich	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Boolca	0 / 0	0 / 0	0 / 0	10 / 41	0 / 0	5 / 14	0 / 0	0 / 0	0 / 0	0 / 0	**15 / 55**
Brockie	0 / 0	0 / 0	0 / 0	67 / 286	0 / 0	70 / 216	0 / 0	0 / 0	0 / 0	9 / 15	**146 / 517**
Bulla	0 / 0	0 / 0	0 / 0	12 / 52	0 / 0	186 / 571	0 / 0	8 / 23	0 / 0	0 / 0	**206 / 646**
Cantala	0 / 0	3 / 6	0 / 0	2,460 / 10,307	267 / 848	476 / 1,466	34 / 34	0 / 0	0 / 0	0 / 0	**3,240 / 12,661**
Chalka Creek	0 / 0	1 / 2	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**1 / 2**
Dry Lakes	0 / 0	0 / 0	0 / 0	15 / 64	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**15 / 64**
Hattah	4 / 11	0 / 0	3 / 7	68 / 287	163 / 522	41 / 124	0 / 0	0 / 0	0 / 0	0 / 0	**279 / 951**
Konardin	22 / 65	1 / 2	13 / 30	216 / 905	226 / 724	184 / 556	0 / 0	14 / 40	21 / 45	0 / 0	**727 / 2,418**
Kramen	0 / 0	0 / 0	0 / 0	34 / 142	36 / 98	49 / 156	1 / 2	0 / 0	9 / 17	7 / 11	**136 / 426**
Little Hattah	0 / 0	0 / 0	0 / 0	15 / 42	0 / 0	1 / 3	35 / 38	0 / 0	8 / 13	0 / 0	**59 / 96**

Lake	Australian White Ibis nests/ chicks	Black Swan nests/ chicks	Eastern Great Egret nests/ chicks	Great Cormorant nests/ chicks	Little Black Cormorant nests/ chicks	Little Pied Cormorant nests/ chicks	Nankeen Night Heron nests/ chicks	Pied Cormorant nests/ chicks	White-necked Heron nests/ chicks	Yellow-billed Spoonbill nests/ chicks	TOTAL Colonial nests/ chicks
Lockie	0 / 0	0 / 0	0 / 0	52 / 217	0 / 0	45 / 138	3 / 3	0 / 0	1 / 2	0 / 0	**101 / 360**
Marramook	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Mournpall	0 / 0	1 / 4	0 / 0	356 / 1,491	0 / 0	0 / 0	25 / 25	0 / 0	0 / 0	6 / 9	**388 / 1,529**
Nip Nip	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Roonki	0 / 0	0 / 0	0 / 0	309 / 1,296	0 / 0	0 / 0	0 / 0	0 / 0	1 / 2	0 / 0	**310 / 1,298**
Tullamook	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Woterap	0 / 0	0 / 0	0 / 0	106 / 442	0 / 0	63 / 194	0 / 0	0 / 0	0 / 0	0 / 0	**169 / 636**
Yelwell	15 / 43	1 / 1	0 / 0	261 / 1,025	434 / 1,393	376 / 1,158	1 / 2	0 / 0	0 / 0	10 / 20	**1,098 / 3,642**
Yerang	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	4 / 8	16 / 25	**20 / 33**
TOTALS	**50 / 146**	**8 / 17**	**16 / 37**	**3,990 / 16,633**	**1,126 / 3,585**	**1,496 / 4,596**	**147 / 153**	**22 / 63**	**45 / 90**	**79 / 132**	**6,979 / 25,452**

Table 5 Dominant non-colonial species breeding data 2022/23 – by lake

Lake	Aust Darter nests/ chicks	Eurasian Coot nests/ chicks	Great Crested Grebe nests/ chicks	Grey Teal nests/ chicks	Musk Duck nests/ chicks	White-bellied Sea Eagle nests/ chicks	White-faced Heron nests/ chicks	Other species nests/ chicks	TOTAL non-colonial nests/chicks
Arawak	1 / 5	0 / 0	2 / 5	0 / 0	0 / 0	0 / 0	0 / 0	6 / 18	**9 / 28**
Bitterang	8 / 29	8 / 13	2 / 8	4 / 7	1 / 2	1 / 1	6 / 13	7 / 25	**37 / 98**
Boich	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Boolca	0 / 0	0 / 0	1 / 3	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**1 / 3**
Brockie	45 / 181	0 / 0	0 / 0	1 / 3	0 / 0	0 / 0	0 / 0	1 / 1	**47 / 185**
Bulla	18 / 73	0 / 0	2 / 4	3 / 17	0 / 0	0 / 0	0 / 0	2 / 6	**25 / 100**
Cantala	58 / 216	10 / 29	0 / 0	1 / 5	0 / 0	0 / 0	0 / 0	3 / 10	**72 / 260**
Chalka Creek	0 / 0	0 / 0	0 / 0	9 / 46	0 / 0	0 / 0	6 / 12	3 / 8	**18 / 66**
Dry Lakes	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Hattah	22 / 85	0 / 0	1 / 1	1 / 7	2 / 3	0 / 0	0 / 0	0 / 0	**26 / 96**
Konardin	25 / 96	1 / 1	6 / 15	2 / 6	2 / 2	0 / 0	14 / 31	6 / 16	**56 / 167**
Kramen	2 / 9	0 / 0	1 / 1	3 / 10	0 / 0	1 / 1	11 / 21	2 / 2	**20 / 44**
Little Hattah	5/ 19	3 / 4	2 / 4	1 / 3	0 / 0	0 / 0	7 / 12	1 / 2	**19 / 44**
Lockie	10 / 38	13 / 25	5 / 8	1 / 3	5 / 5	1 / 1	2 / 5	2 / 5	**39 / 90**

Lake	Aust Darter nests/ chicks	Eurasian Coot nests/ chicks	Great Crested Grebe nests/ chicks	Grey Teal nests/ chicks	Musk Duck nests/ chicks	White-bellied Sea Eagle nests/ chicks	White-faced Heron nests/ chicks	Other species nests/ chicks	TOTAL non-colonial nests/chicks
Marramook	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Mournpall	12 / 45	7 / 15	7 / 16	3 / 6	0 / 0	6 / 8	1 / 2	1 / 5	**37 / 97**
Nip Nip	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Roonki	2 / 9	0 / 0	0 / 0	2 / 7	0 / 0	0 / 0	0 / 0	1 / 6	**5 / 22**
Tullamook	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	**0 / 0**
Woterap	14 / 58	9 / 17	1 / 2	3 / 4	0 / 0	0 / 0	1 / 2	8 / 25	**36 / 107**
Yelwell	68 / 266	0 / 0	0 / 0	1 / 1	1 / 1	0 / 0	3 / 8	2 / 2	**75 / 278**
Yerang	9 / 35	2 / 5	3 / 6	0 / 0	0 / 0	0 / 0	2 / 5	0 / 0	**16 / 51**
TOTALS	**299 / 1,164**	**53 / 109**	**33 / 73**	**35 / 125**	**11 / 13**	**9 / 11**	**53 / 111**	**45 / 130**	**538 / 1,736**

Table 6 Waterbird nest data 2022/23 – by species

Common Name	Scientific Name	Number of nests	Number of chicks	Mean chicks per nest
Australasian Darter	*Anhinga novaehollandiae*	299	1,164	3.89
Australian White Ibis	*Threskiornis molucca*	50	146	2.92
Eastern Great Egret	*Ardea alba modesta*	16	37	2.31
Great Cormorant	*Phalacrocorax carbo*	3,990	16,633	4.17
Little Black Cormorant	*Phalacrocorax sulcirostris*	1,126	3,585	3.18
Little Pied Cormorant	*Phalacrocorax melanoleucos*	1,496	4,596	3.07
Nankeen Night-heron	*Nycticorax caledonicus*	147	153	1.04
Pied Cormorant	*Phalacrocorax varius*	22	63	2.86
White-faced Heron	*Egretta novaehollandiae*	53	111	2.09
White-necked Heron	*Ardea pacifica*	45	90	2.00
Yellow-billed Spoonbill	*Platalea flavipes*	79	132	1.67
All Species		**7,176**	**26,557**	

*Note - some nest data does not align with breeding data as young birds were also recorded away from nests.

3.2 Spatial distributions of breeding records

The following maps show the spatial distributions of waterbird breeding records, across the Hattah Lakes system, as locations (Figure 2), and as a 'heat map' which indicates the density of breeding/nest records (Figure 3).

Figure 2 All waterbird breeding records from 2022/23 surveys

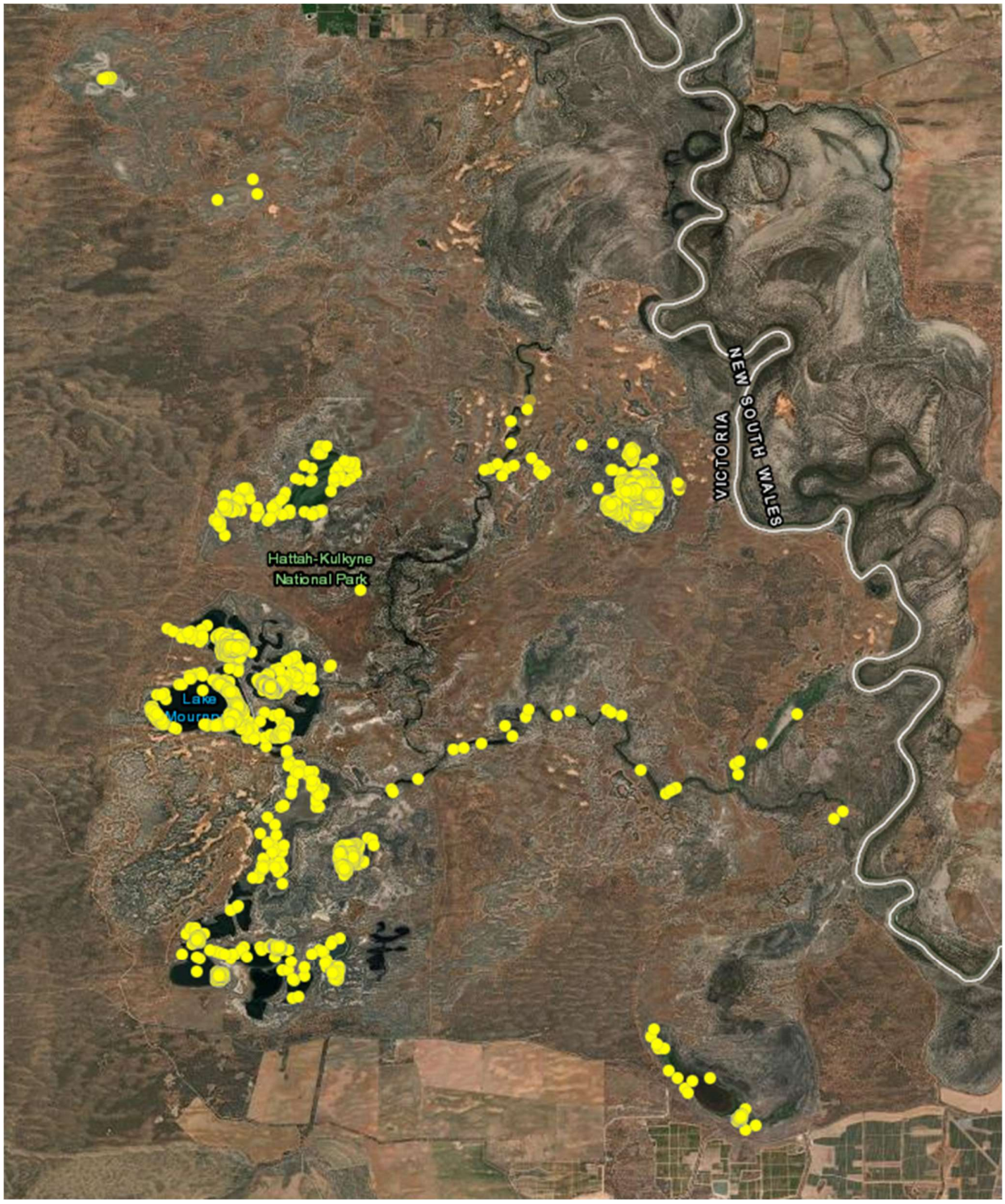
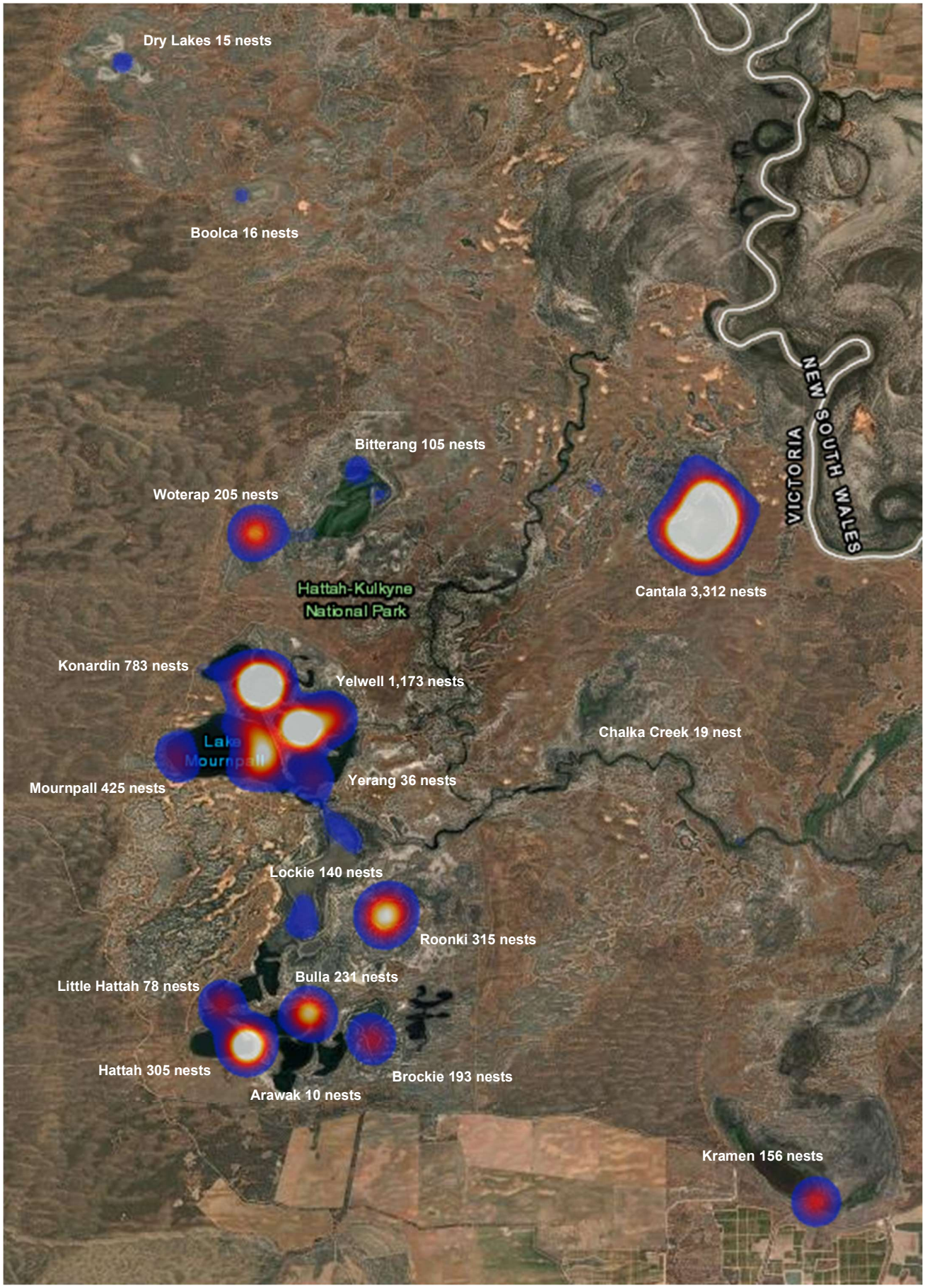


Figure 3 Heat map of waterbird nests detected during 2022/23 surveys



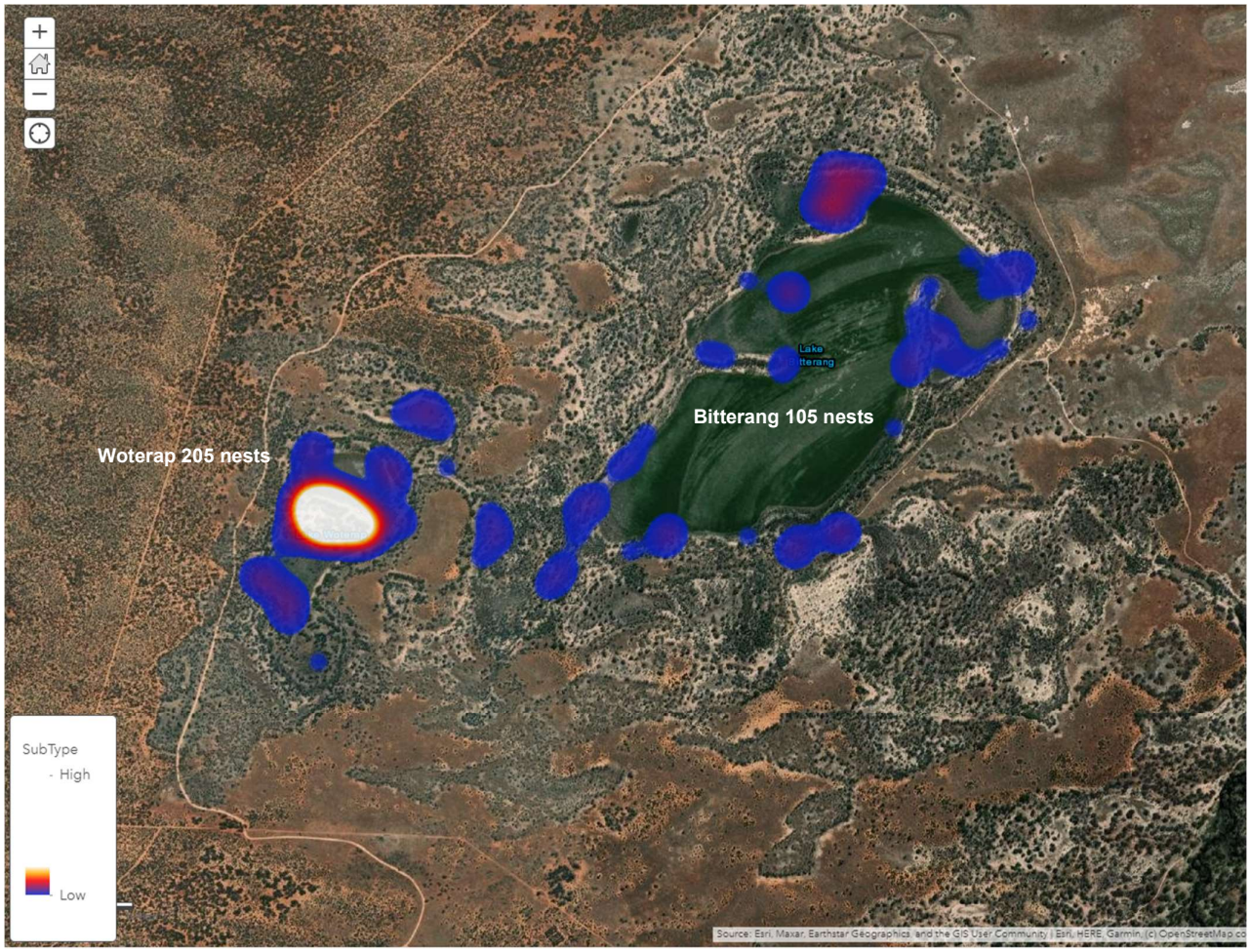
3.3 Spatial densities of nests

The following sections include heat maps that show the spatial densities of the nest sites in greater detail at each lake or group of proximate lakes, with descriptions of these areas provided.

3.3.1 Lakes Bitterang and Woterap

Nests at Lakes Bitterang (105 nests) and Woterap (205) can be seen in Figure 4 to be concentrated into 2 main areas, with smaller numbers widespread across the perimeter of Lake Bitterang. The majority of nests at Lake Woterap were in a single large colony of Great Cormorant and Little Pied Cormorants nesting in large old living River Red Gums on an isthmus between two lobes of the lake, while those in the north of Bitterang were a mix of species in recently dead medium sized River Red Gums in the lakebed. A large number and range of species of non-colonial waterbirds, including many ducks and Grebes were recorded at Lake Bitterang.

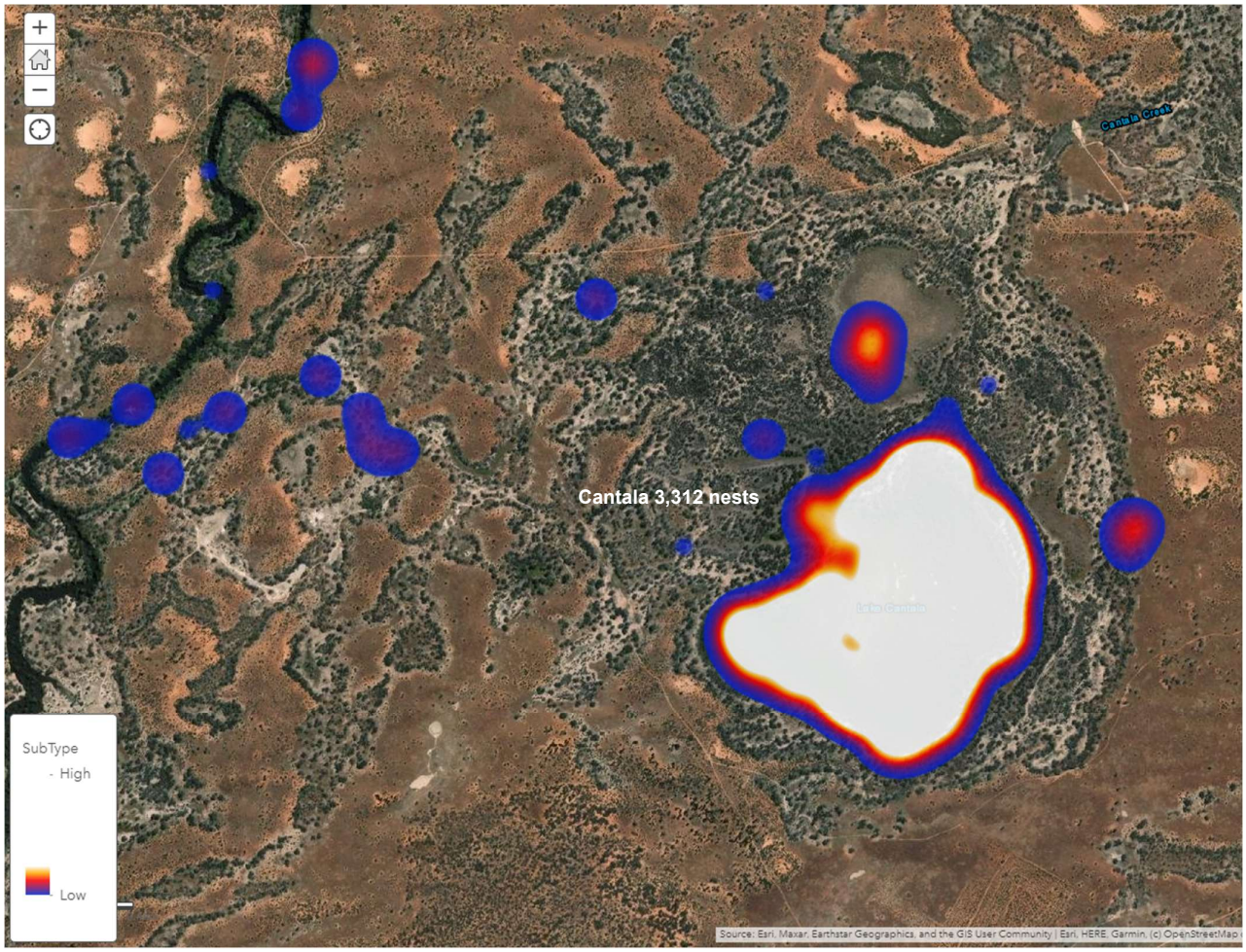
Figure 4 Spatial distribution of nests at Lakes Bitterang and Woterap



3.3.2 Lake Cantala

Of all the lakes assessed, Lake Cantala had the greatest number of nests (3,312), which can be seen in Figure 5 to be widespread across the southern lobe of the lake. As in the previous survey, the dominant species was Great Cormorant (2,460 nests), which were widespread across the entire area, and mostly associated with medium sized dead River Red Gum saplings growing across the lakebed, and a smaller number of nests in larger River Red Gums, particularly in the north-central areas of the lake. Smaller numbers of Little Pied Cormorants (476 nests) and Little Black Cormorants (267 nests) were recorded in tight colonies in smaller, live saplings of River Red Gums, concentrated in the east and north of the southern lobe of the lake.

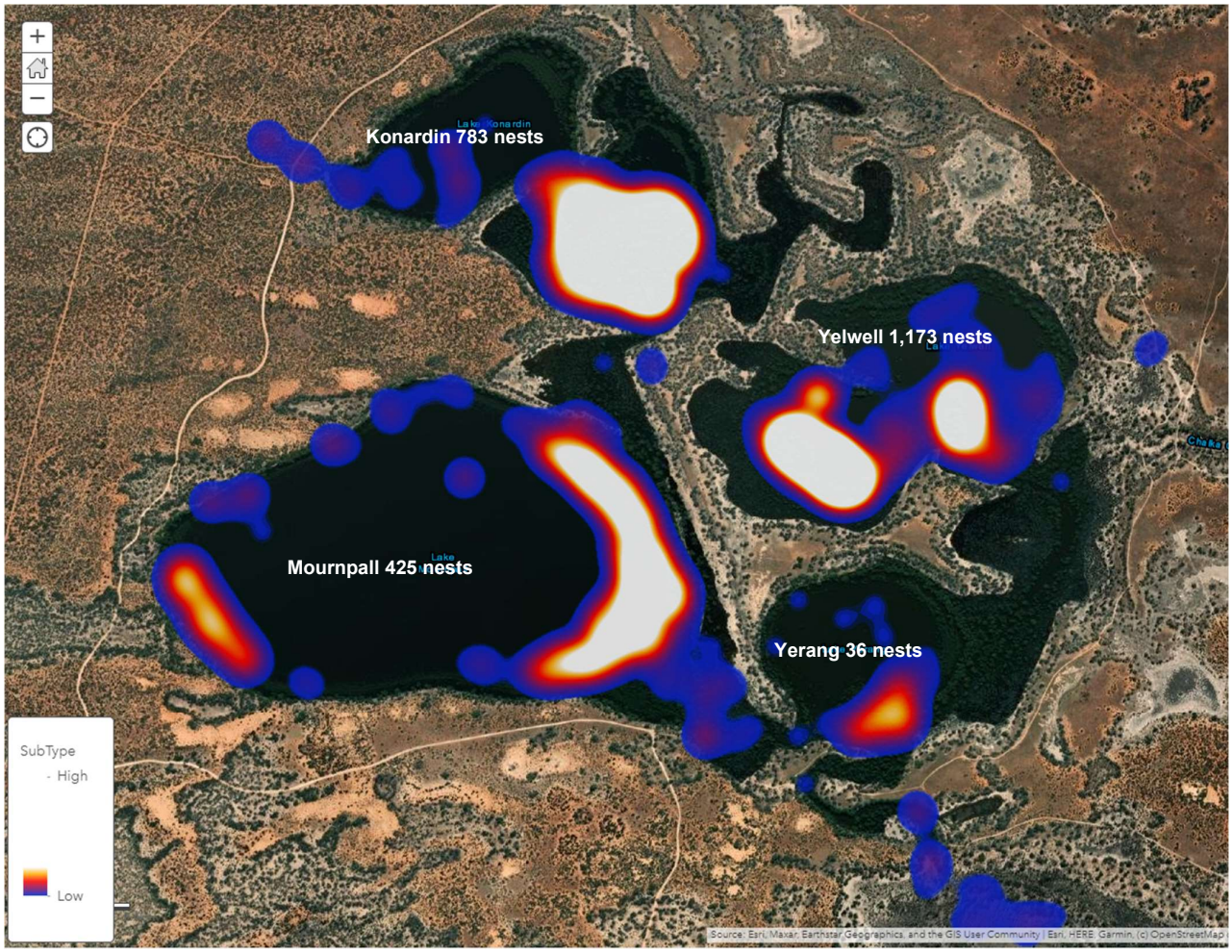
Figure 5 Spatial distribution of nests at Lake Cantala



3.3.3 Lakes Mournpall, Konardin, Yelwell and Yerang

Colonial waterbird nests at these central lakes (Figure 6) were concentrated in three areas, which were similar to those observed in previous surveys; in the southeast of Lake Konardin (783 nests), the south of Lake Yelwell (1,173 nests), and along the eastern edge of Lake Mournpall (425 nests). A number of smaller colonies were scattered across these lakes. Lake Yelwell contained two very large colonies of Little Black Cormorant (434 nests), Little Pied Cormorant (376 nests) and Great Cormorant (261 nests), nesting in live, very large old River Red Gums, as well as in medium sized live saplings of River Red Gum and River Coobah (*Acacia stenophylla*). The single very large colony at Lake Konardin consisted of Little Black Cormorant (226 nests), Great Cormorant (216 nests) and Little Pied Cormorant (184 nests), nesting in medium to large live saplings of River Red Gum and also live, very large old River Red Gums. Lake Mournpall consisted primarily of one large, elongated colony of Great Cormorant (356 nests) almost wholly located in medium to large dead saplings of River Red Gum.

Figure 6 Spatial distribution of nests at Lakes Mournpall, Konardin, Yelwell and Yerang



3.3.4 Lakes Hattah, Little Hattah, Bulla, Arawak, Marramook, Brockie, Tullamook, Boich and Nip Nip

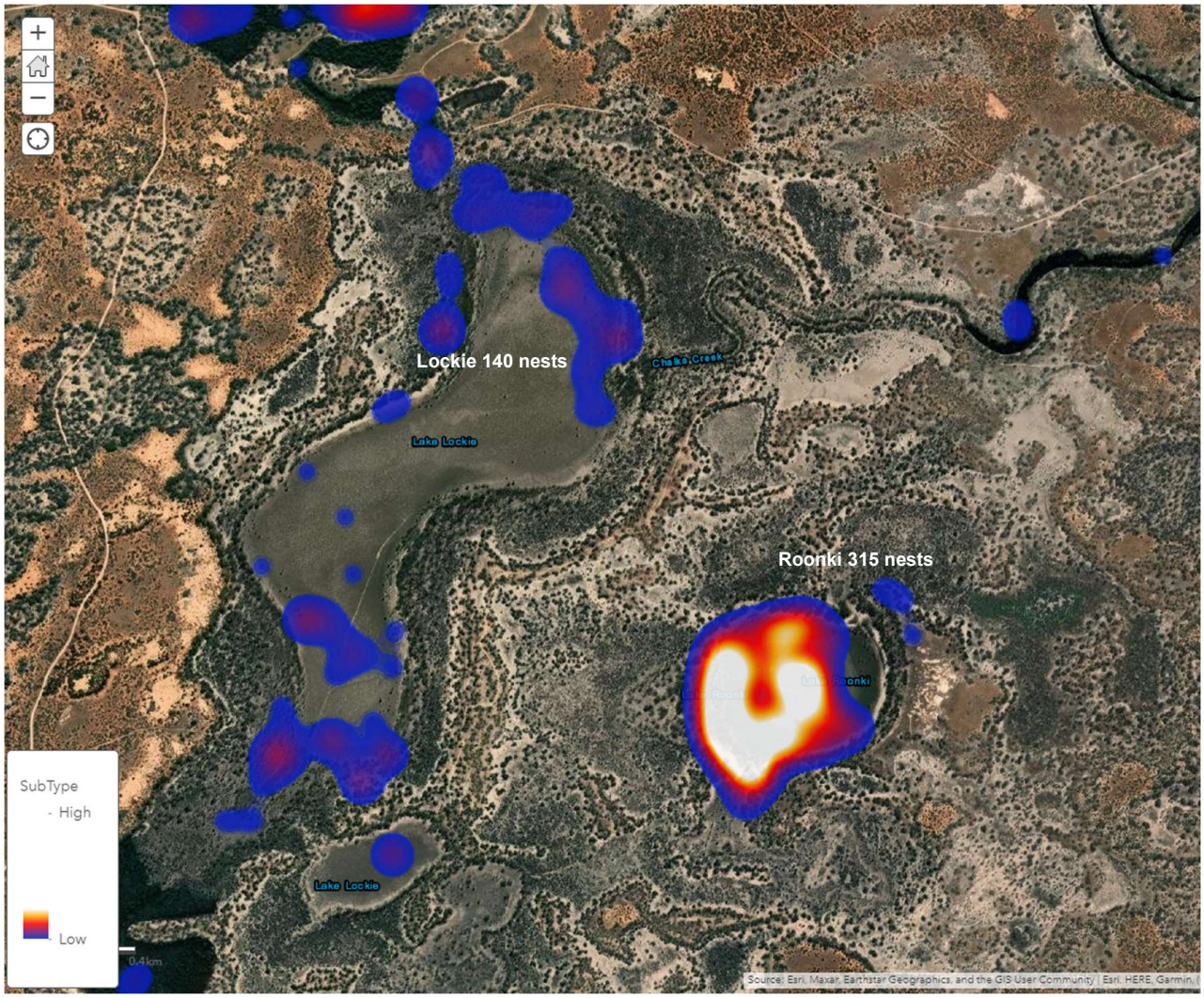
Colonial waterbird nests across the lakes in the south of HKNP can be seen in Figure 7 to be concentrated into four main areas, with a mixed colony of Little Black Cormorant (163 nests), Little Pied Cormorant (41 nests) and Great Cormorant (68 nests), nesting in River Red Gum regeneration in the south-eastern corner of Lake Hattah (305 nests), and smaller colonies in the east of Lake Bulla (231 nests, mostly Little Pied Cormorant) and south of Lake Brockie (193 nests, primarily Little Pied Cormorant, Great Cormorant). Most other breeding records in these southern lakes were of non-colonial species such as Australasian Darter, Ducks, Grebes and Eurasian Coot.

Figure 7 Spatial distribution of nests at Lakes Hattah, Little Hattah, Bulla, Arawak, Marramook, Brockie, Tullamook, Boich and Nip Nip

3.3.5 Lakes Lockie and Roonki

Despite its large size, Lake Lockie again contained relatively few colonial waterbird nests (101 of 140 nests) scattered around the north and south, whilst Lake Roonki contained at 315 nests, mostly Great Cormorants (309 nests) spread across much of the lake in medium sized River Red Gum regrowth.

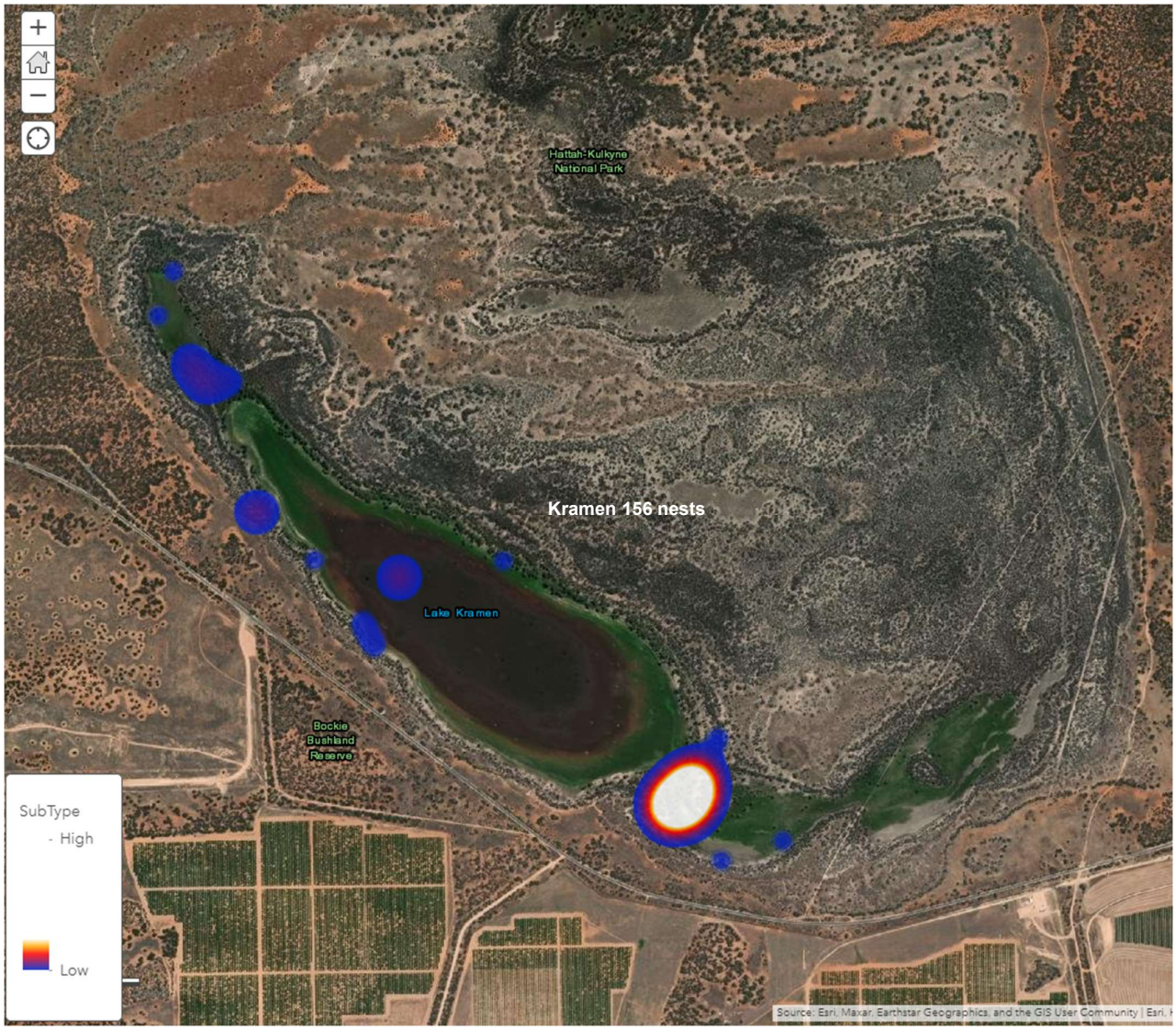
Figure 8 Spatial distribution of nests at Lakes Lockie and Roonki



3.3.6 Lake Kramen

Despite its large size, Lake Kramen contained only moderate numbers of colonial waterbird nests (136 colonial of 156 nests), mainly Little Pied Cormorant (49 nests), Little Black Cormorant (36 nests) and Great Cormorant (34 nests) concentrated in the south of the lake at a narrowing, in large, live old River Red Gum and also medium sized River Red Gum regrowth.

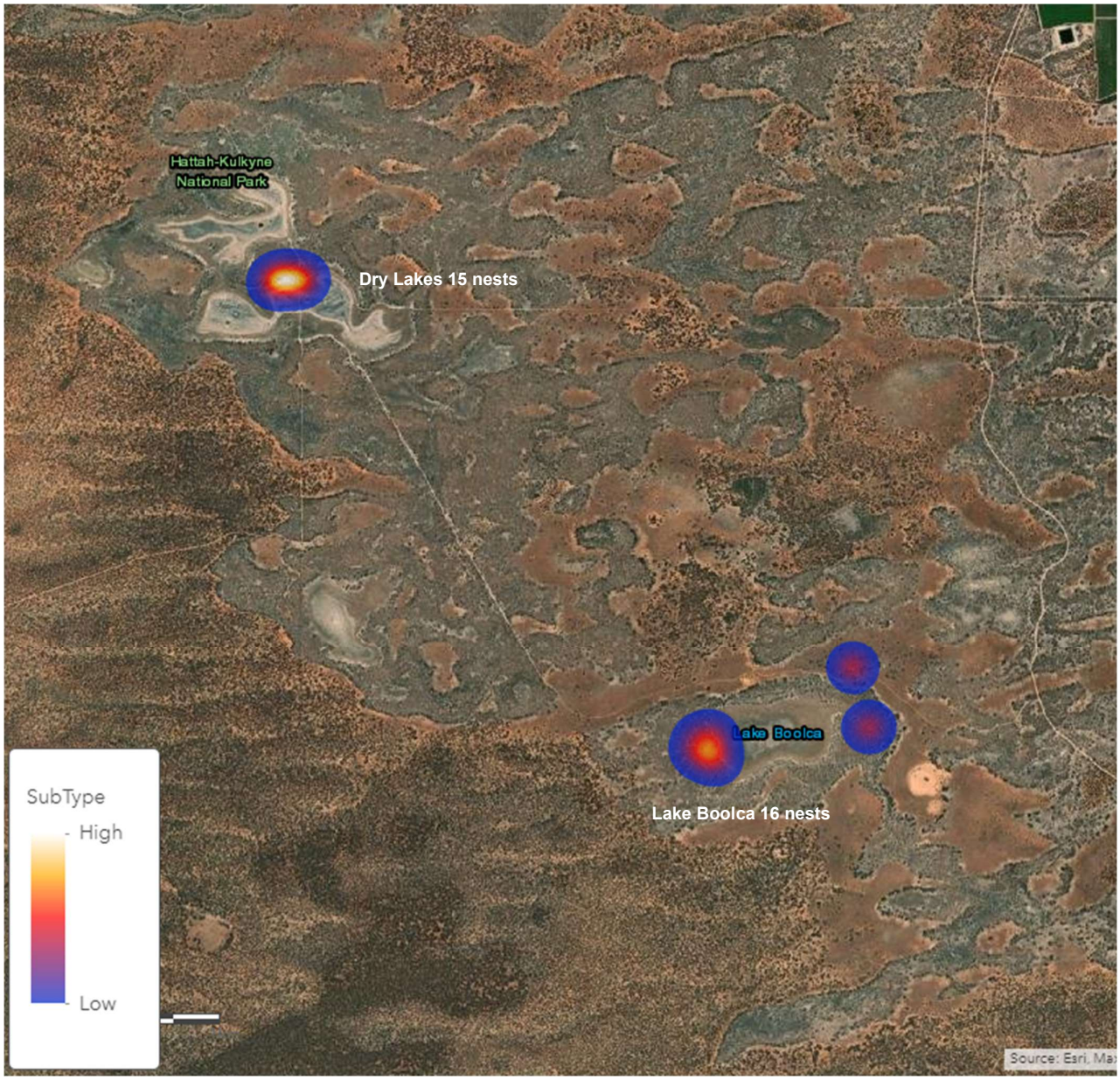
Figure 9 Spatial distribution of nests at Lake Kramen



3.3.7 Dry Lakes and Lake Boolca

The 2022/23 natural floodwaters inundated the northern Hattah areas of Dry Lakes and Lake Boolca, which are very rarely inundated. These Black Box dominated areas may not have been inundated since 1975 or potentially 1956. Brief surveys of these areas recorded small colonies of Great Cormorant nesting in large Black Box trees at Dry lakes, and Great Cormorant and Little Pied Cormorant nesting in sapling and medium Black Box trees at Lake Boolca.

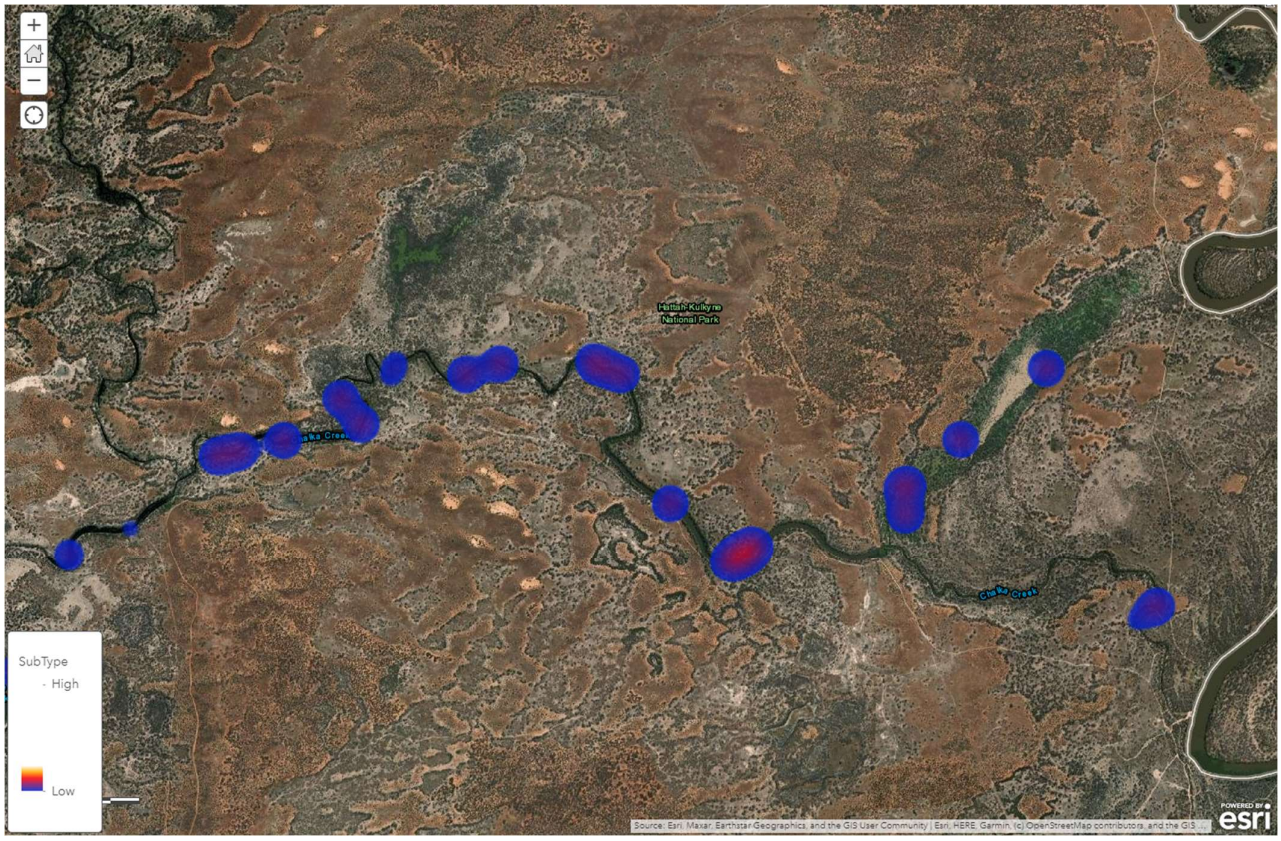
Figure 10 Spatial distribution of nests at Dry Lakes and Lake Boolca



3.3.8 Chalka Creek areas

The Chalka Creek between its inlet at Messengers and its junction at the Boolungal Crossing contained moderate numbers of non-colonial nesting waterbirds, mainly ducks, with likely many nests not detected as these species are very hard to detect when nesting in large tree hollows. Very large numbers of Grey Teal were seen along the creek and it is likely that these birds were nesting undetected in large numbers in this area.

Figure 11 Spatial distribution of nests across Chalka Creek areas



3.4 Waterbird breeding - chick development and multiple clutches

In previous surveys (GHD 2022), chick development was assessed on a scale of 1 to 5 where:

1 - A newly hatched altricial chick, largely naked, eyes closed (0-9% grown),

2 - Small chick but with eyes open (10-24% grown);

3 - Medium chick with some body feathers and pin-feathers on wings (25-59%grown);

4 - Large chick with most body feathers (60-89% grown); and

5 - Ready to fledge at any stage (90%+ grown).

During the latter stages of the 2022/23 surveys, it was observed that effectively all nests contained chicks that were ready to fledge or fledging. And many nests were observed to contain second or even third clutches of eggs or young. As it was impossible to determine if subsequent clutches of eggs/chicks were the same birds renesting or different birds, this could not be readily reported on.

It appears that the timing of the breeding event has given the opportunity for all nests to produce fledged chicks, and with very little chick mortality and no obvious failed nests (filled with dead chicks) aside from those nests observed to be drowned in December, or predation observed during surveys, it is assumed most chicks successfully fledged. This was also supported by the tremendous flocks of juvenile birds observed roosting, flying, and foraging in the vicinity of the nesting colonies towards the letter stages of the surveys. Additionally, the numbers of birds observed renesting late in the survey was too great to count, but was considered significant at lakes Cantala, Yelwell, Hattah and Konardin. Colonies at these lakes may be somewhat asynchronous from each other, and between lakes, and birds appear to be continually breeding. The success of late nesting efforts is unknown and could not be assessed during this timeframe.

Many of these values represent minimum stages of development, at the most recent surveys of these nest sites, and many birds were at this stage when surveys were concluded, and therefore many ‘large’ chicks would be expected to progress and fledge. Many young (stage 4 and 5) cormorants were observed moving through the water and roosting low in submerged trees showing that birds of this age can leave the nest and move about the lake following feeding parents etc.

3.5 Camera trap observations

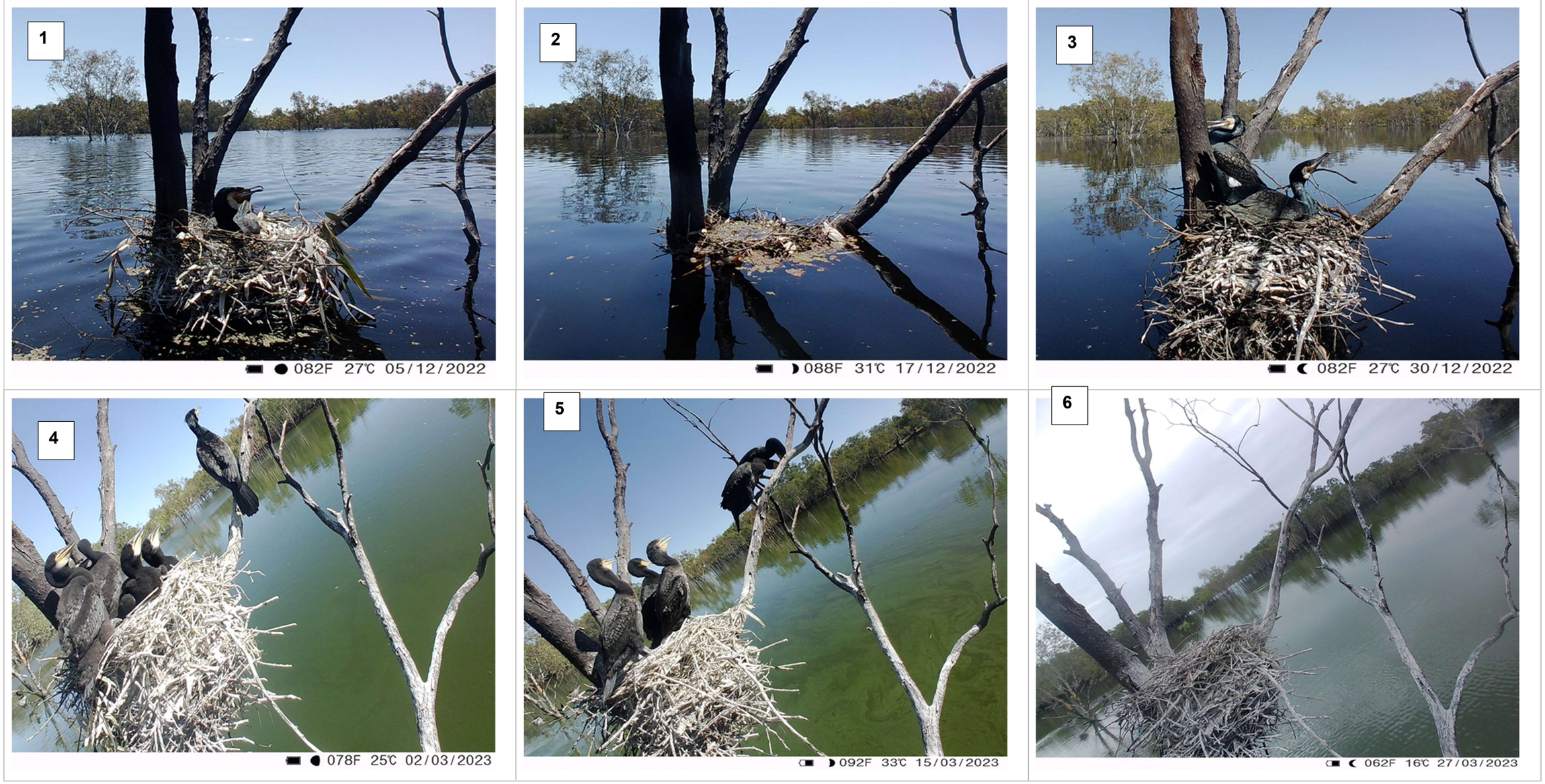
Four camera traps were installed on Great Cormorant nests at Lake Konardin in late December 2022, just as floodwaters peaked and collected in April 2023. Timelapse images taken every four hours over that four-month period were assessed and were found to show two nests becoming flooded, resulting in nest abandonment, followed by what appeared to be the same birds, sitting by the nests until water levels dropped. As soon as nests began to emerge from the water the birds were observed to rebuild and refresh the nest and began incubating eggs soon afterwards.

Views did not allow great certainty for dates of first incubation and eggs hatching, as birds sit very tightly during this time, but there was no sign of loss of chicks – and all nests monitored by cameras were observed to produce successful broods – of four, four, five and five chicks. Despite the small sample size, these results support the widespread observations of nests with large broods of eggs and chicks, with high success rates for fledging.

Images captured from two cameras were used to create an animated timelapse video, thanks to the Mallee CMA. An example of the images captured, at different stages of nest progress are provided below in Figure 12.

Figure 12 Camera Trap timeline of Great Cormorant nest at Lake Konardin showing: 1.initial nesting, 2.nest abandonment, 3.renesting, 4.large chicks, 5.ready to fledge chicks, and 6.an empty nest after fledging.

Note: camera moved for unknown reasons between frame 3 and 4.



3.6 Incidental and threatened species observations

Incidental observations and threatened species observed during surveys were recorded and are summarised in Table 7 and in detail in Appendix B. Observations of noteworthy species include those which are listed as threatened under state or federal legislation, or which are considered uncommon or significant from a regional perspective.

The nationally (EPBC Act Vulnerable) and state (FFG Act Endangered) listed Regent Parrot (*Polytelis anthopeplus*) is well known from HKNP and the surrounding area, and this species was regularly heard and seen across the study area during the surveys. Several other threatened and regionally significant species were observed to be breeding in response to the environmental watering, including Blue-billed Duck (1 young), Musk Duck (13 young), Eastern Great Egret breeding, and 13 records of recently fledged White-bellied Sea-eagle (*Haliaeetus leucogaster*).

Of interest were large numbers of European Carp (*Cyprinus carpio*), which were observed in the water and also observed being disgorged by cormorant and darters to feed chicks or when disturbed by surveyors. Several large groups of Australian Pelicans were observed at lakes and while not breeding, these lakes likely provide an important feeding habitat for these birds.

An unusual record was several apparently large colonies of micro-bats heard calling from under the bark of River Red Gum saplings at Lakes Cantala and Brockie. From these contact calls it was not possible to discern the species, and disturbing the bark had the potential to cause the bats to drop into the water, so no attempt was made to identify them. It would be expected that these bats are benefiting from the food source of large numbers of invertebrates resulting from the inundation of the lakes, and potentially the inundated trees provide good protection from predation, possibly as maternal roosts.

Table 7 Threatened species observed during 2022/23 surveys

Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Apostlebird	*Struthidea cinerea*	*20*	VU	-	No
Blue-billed Duck	*Oxyura australis*	*1*	VU	-	Yes – 1 juvenile
Eastern Great Egret	*Ardea alba modesta*	*37*	VU	-	Yes – 16 nests, 37 chicks
Hardhead	*Aythya australis*	*3*	VU		Yes – 3 juvenile
Lace Monitor	*Varanus varius*	*1*	EN	-	No
Little Eagle	*Hieraaetus morphnoides*	*3*	VU		Yes – 1 nest
Major Mitchell's Cockatoo	*Lophochroa leadbeateri*	*2*	CR	EN	No
Musk Duck	*Biziura lobata*	*13*	VU	-	Yes – 13 young
Regent Parrot	*Polytelis anthopeplus*	*186*	EN	VU	Yes – seven likely breeding areas identified
White-bellied Sea-eagle	*Haliaeetus leucogaster*	*11*	EN	-	Yes – 7 juvenile

4. Discussion

The landscape-wide natural flooding of the Hattah Lakes system in the summer of 2022/23, following environmental watering of the previously dry lakes in the autumn and spring of 2021, triggered a very large, prolonged and successful breeding event across much of the lakes system, with at least 28 species of waterbird and wetland utilising birds recorded breeding. A total of 7,517 nests and 27,188 chicks were recorded, of which the vast majority (6,979 nests and 25,452 chicks) were classified as colonial breeding waterbird species. Most chicks appear to have fledged successfully, and there was evidence of multiple clutches in the same nest. Indeed, by the final survey in April 2023, the breeding effort was still going strongly for most species, with newly laid eggs observed at up to at least April 2023.

These large numbers of nests and chicks, and the successful development of the chicks, clearly show the importance of the Hattah Lakes system as an area for waterbird breeding, particularly in such a wet year when so many areas of potential habitat become available across the broader landscape of south-eastern Australia. The ability to fill the Hattah system through environmental water management, when the rest of the landscape is largely dry, also makes this area an important refuge for waterbirds during dry times. The 2022/23 surveys determined that, as in 2021/22, the lakes varied widely in abundances of nests and chicks and species compositions, ranging from no colonial nests at four lakes to as many as 3,240 at Lake Cantala. Non-colonial nesting species of waterbird were also recorded breeding at all lakes except four (Lakes Boich, Marramook, Nip Nip and Tullamook).

Locations of breeding colonies displayed a very high degree of site fidelity, with all active breeding colonies located in areas where nesting colonies had been detected in the earlier 2020/21 and 2021/22 surveys.

The following sections of the discussion investigate the numbers of nests and nestlings, their spatial distribution and densities, the successful development of the young, and provides recommendations for future monitoring.

4.1 Colonial waterbird nest numbers

The 2022/23 targeted surveys of colonial nesting waterbird breeding recorded a total of 6,979 nests and 25,362 chicks from ten species classified as colonial nesting waterbirds. The very large numbers of nests and chicks, their successful development (discussed in section 4.3), and the repeated breeding over multiple years, including a year when many potential areas of habitat were available across a flooded landscape, clearly show the importance of the Hattah Lakes system as an area for colonial nesting waterbird breeding. Individual lakes varied greatly in abundances of nests, ranging from no colonial nests at Lakes Boich, Marramook, Nip Nip and Tullamook, to as many as 3,240 at Lake Cantala, 1,098 at Yelwell, 727 at Konardin, 388 at Mournpall, 310 at Roonki, 279 at Lake Hattah and 206 at Bulla.

These counts of nests are considered to be a conservative estimate of the minimum number of nests in the areas surveyed, as it is almost certain that some individual nests were not observed or missed. Significant colonies, however, are not likely to have been missed – colonies of any larger size are unlikely to go undetected due to their obvious nature and the significant noise generated by large congregations of birds. Colonies of roughly 50 or more nests were typically audible from a long distance and very noisy up close.

A comparison of the numbers of colonial waterbird nests recorded in these 2022/23 surveys with those recorded in 2021/22 (GHD 2022), and also as unoccupied colonial waterbird nests in 2020/21 when the lakes were dry (GHD 2021) is provided below in Table 8, and shown graphically in Figure 13. These values show a dramatic increase in the total number of nests in 2022/23 at most lakes where colonies have been recorded in previous years, and an overall increase of almost 400% in total numbers of nests across the lake system, compared with the highest estimates at each lake from earlier surveys. The locations of nesting colonies over the years, and the relative proportions of nests within these, also show a broadly similar spread across the lakes, with lakes Cantala, Yelwell, Konardin, Mournpall, Roonki and Hattah all typically supporting large breeding colonies in most years of survey. In all surveyed years, Lake Cantala has supported more than twice as many nesting birds as any other lake, emphasising the significance of this isolated lake as a breeding habitat.

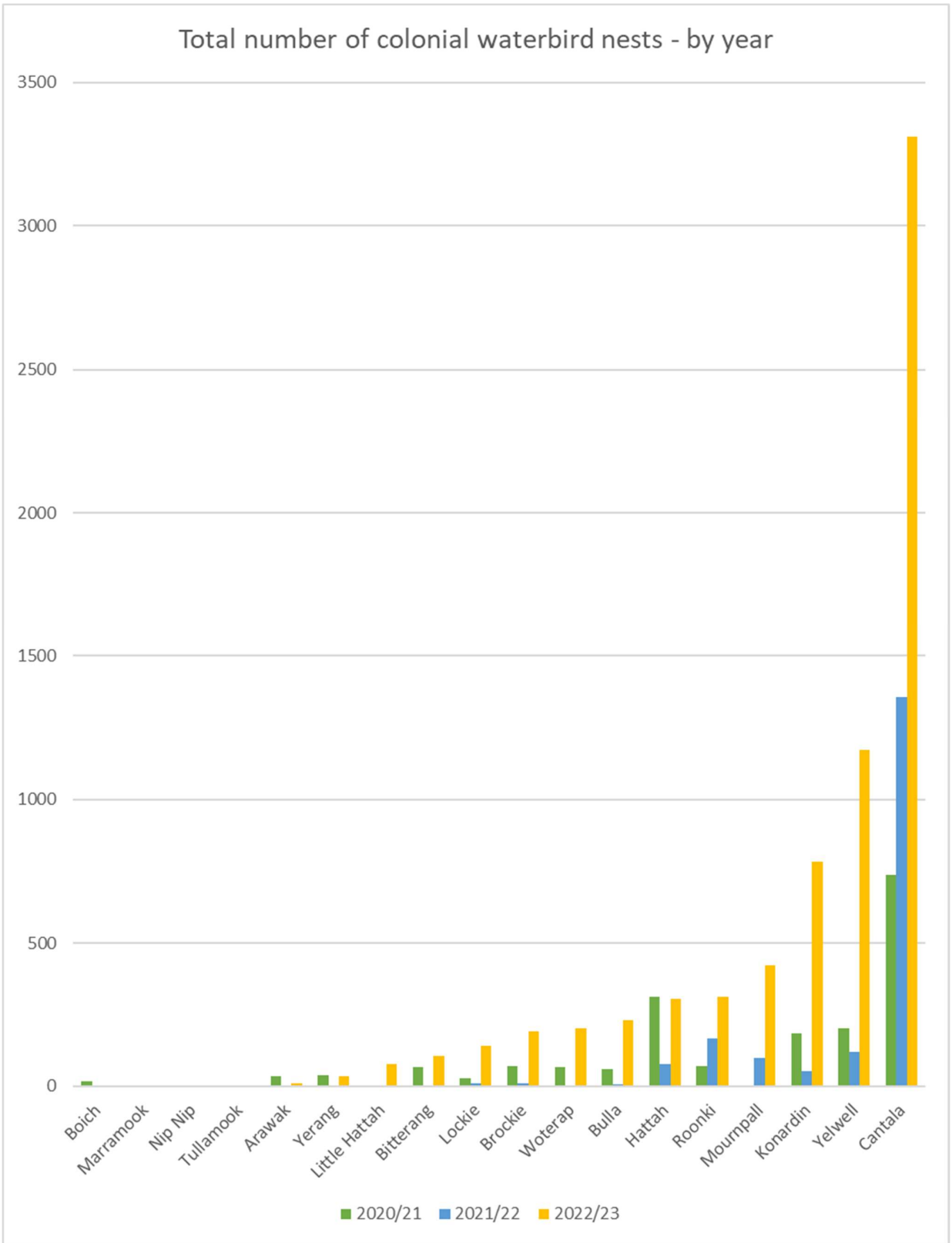
The high number of active nests recorded in 2022/23 clearly represents a large, widespread prolonged and successful breeding event. As far as can be ascertained, this represents the largest breeding event documented withing the Hattah Lakes system, with the previous greatest number recorded in the previous survey of 2021/22.

Table 8 Comparison of colonial waterbird nest numbers between years.

Lake	2020/21 – Unoccupied (cumulative) nests	2021/22 – Occupied nests	2022/23 – Occupied nests	% change in 2022/23 from previous maximum
Arawak	34	0	10	-29%
Bitterang	66	3	105	+159%
Brockie	70	9	193	+276%
Boich	15	0	0	NA
Bulla	58	5	231	+398%
Cantala	739	1,358	3,312	+244%
Hattah	315	77	305	-3%
Konardin	188	52	783	+416%
Little Hattah	4	1	78	+1,950%
Lockie	29	8	140	+483%
Marramook	1	0	0	NA
Mournpall	1	98	425	+434%
Nip Nip	0	0	0	NA
Roonki	70	168	315	+188%
Tullamook	1	0	0	NA
Woterap	66	0	205	+311%
Yelwell	205	118	1,173	+572%
Yerang	39	0	36	-8%
TOTALS	**1,901**	**1,897**	**7,517**	**+395%**

Comparison of colonial waterbird nest numbers – 2020/21 (unoccupied nests) and 2021/22 and 2022/23 (occupied nests).

Figure 13 *Comparison of colonial waterbird nest numbers – by year*



4.2 Spatial distribution and densities of nests

As summarised previously, lakes across HKNP varied greatly in the numbers of nests they supported, ranging from no colonial breeding waterbird nests at some lakes, to up to 3,240 nests at Lake Cantala. Mapping of nest locations using heat maps (Figure 3 to Figure 11 and Figure 14) shows a generally broad spread of nesting activity across the Hattah Lakes area, with clear areas of very intensive nesting activity. As in previous years, the nests across the Lake Cantala, Konardin, Mournpall, and Roonki lakebeds were relatively spread out in the medium-to-large trees that have regenerated across the lakes in recent decades. The distribution of the nesting colonies is likely to relate to selected areas containing more suitable nesting habitat in the form of trees of preferred size, orientation and shape, and just as importantly, in areas where high prey concentrations are accessible, reducing travel distance for adult birds foraging for their chicks. The colonial waterbird species present at the Hattah lakes, including cormorants, are strong fliers and can travel large distances between feeding grounds and nesting colonies (Marchant and Higgins 1990), and nesting locations therefore do not have to be immediately adjacent to feeding habitats. However, the presence of high quality feeding habitats close to suitable breeding habitats is likely to convey an advantage for birds to minimise energy expenditure where possible. While the suitability and productivity of feeding habitats is likely to vary over time, areas in and around the inlet/outlet creeks of the lakes may be particularly productive due to flows of water through those areas, potentially concentrating or trapping prey items including crustaceans (especially yabbies) and small to medium bodied fish (especially Carp). Incidental observations were made of large flocks of Great, Little Black and Little Pied Cormorants moving between lakes, potentially adult birds feeding in lakes distant to their breeding colonies.

The 2022/23 surveys also showed a continuation of a pattern that was observed in previous surveys: high densities of nests within dense clumps of River Red Gum regeneration standing in water, including some very small trees (dbh<5cm). The dense stands of regeneration are likely desirable as they provide protection to the nests from wind and sun, as well as cover from predators. They also provide a suitable support for large numbers of nests to be built in very close proximity to one another, both vertically and horizontally.

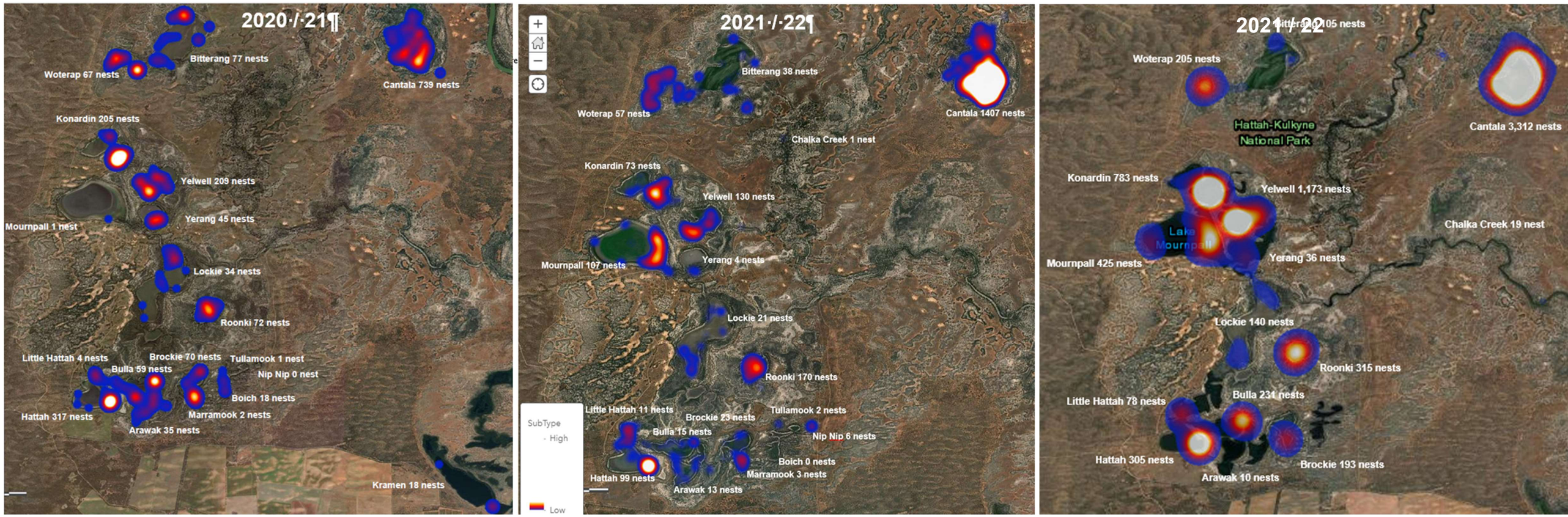
The previous surveys documented nesting colonial waterbirds with a strong preference for nesting in trees standing in water, and this corresponds to the locations and tree preferences observed during this study, with all nests observed in trees that were inundated at the time of survey. Large areas of River Red Gum regeneration exist within and around the perimeter of the lake beds of most of the lakes, whilst the largest old trees typically surround the lakes in slightly higher locations. Most of the larger diameter trees that supported nests occurred in higher areas of the lakes, such as on peninsulas. Previous surveys also observed that few of the largest trees become fully inundated during environmental watering events (GHD 2022), and when they were inundated, are often not standing in water for long before water levels begin to recede. The 2022/23 floods did however inundate all areas of River Red Gum, including all large and very large old trees, providing different and additional nesting habitats to those suitable during the more restricted environmental watering. As an aside from this observation – our ecologists have incidentally observed numerous small waterbird nesting colonies in areas that are rarely inundated and in locations where they have not been observed previously (e.g., at Kings Billabong, Lindsay Island, Belsar Island and along the Murray River corridor), as floodwaters provided inundated breeding habitats in areas that are typically dry.

While most breeding colonies recorded in the 2022/23 surveys were larger than those recorded previously, the locations of the colonies once again displayed a very high degree of site fidelity. All colonies of more than 25 nests in 2022/23 were located in areas where colonies had been detected in previous surveys in 2021/22 (GHD 2022) and 2020/21 (GHD 2021) – as shown in Figure 14 below. Larger colonies were found in the same locations over the years at Lakes Cantala, Woterap, Konardin, Yelwell, Roonki, Hattah and Lake Mournpall. The specific reasons for these consistent locations of colonies can only be speculated on, but as theorised previously, it is likely that preferred areas provide a favourable balance of reliable prey availability and suitable nesting trees of preferred size, orientation and shape.

Despite the huge areas of inundated habitat found across the south-east Australian landscape in 2022/23, large numbers of colonial nesting waterbirds used the Hattah Lakes for nesting, suggesting a preference for the Hattah Lakes area over others, even when all areas are inundated. This is likely due to a number of reasons, potentially including familiarity, where birds that have bred successfully in an area return to the same location. Natal philopatry may also be a factor – where young birds preferentially return to the areas of their birth to breed. This is common in many bird species, especially seabirds (Frederick & Ogden, 1997; Robert et. al. 2014), but would seem less likely for inland Australian freshwater dependent species, which must follow highly variable rainfall and

flooding patterns. Another factor that seems highly likely to be influential for colonial breeding waterbird species at Hattah is food availability, where birds will choose to nest close to preferential food sources. In recent years, the Murray-Mallee region has seen low river flows and no significant flooding events, limiting the wetland habitats available. The Hattah Lakes were filled in winter and spring of 2021 as a large environmental watering event, which provided food resources for a large and widespread breeding event in the summer of 2021/22 (GHD 2022). Pre-filling the lake system in 2021/22 may have allowed increased productivity for the summer months of 2022/23, because there were existing populations of fish, crustaceans and aquatic invertebrates. A more productive system, with greater food resources is likely to attract greater numbers of waterbirds and promote their breeding in the area if suitable nesting habitat is available, which seem probable in this case. A more productive system is also more likely to see more breeding efforts succeed, as was observed during the 2022/23 flood.

Figure 14 Spatial distribution of all waterbird nests as heatmaps from unoccupied nests in 2020/21 surveys (left) and occupied nests in 2021/22 (centre) and 2022/23 (right).



4.3 Colonial waterbird nestling numbers, chick development and breeding success

The 2022/23 targeted surveys of waterbird breeding recorded a total of 27,188 chicks, of which the vast majority (25,362 chicks) were colonial nesting species (Table 2, Table 4). Dominant species of colonial nesting species with the largest numbers of chicks observed were Great Cormorant with 16,633 chicks, Little Pied Cormorant with 4,596 chicks, Little Black Cormorant with 3,585 chicks, Nankeen Night-Heron with 153 chicks, Australian White Ibis with 146 chicks, and Yellow-billed spoonbill with 132 chicks. Observations of chick development and subsequent breeding success, as defined by the number of birds reaching independence, is hard to assess accurately as birds leave the nest upon fledging and their success or survival cannot easily be linked to a specific nest. Also, large colonies became so widespread and dense during the surveys that close access became difficult without disturbing nesting birds and chicks sitting on nests. However, no signs of nest abandonment or predation and very few mortalities were observed, suggesting the colonies had a very high success rate generally.

Mean numbers of chicks per nest were generally high for the colonial species observed (Table 6), and were greater in this survey than the previous survey for most species, particularly the dominant species, as shown below in Table 9. This suggests that appropriately sized food resources may have been more abundant and reliable in 2022/23 than 2021/22, particularly for piscivores (i.e., the cormorant species), which generally showed the highest clutch sizes.

Table 9 Mean numbers of chicks per nest, by species

Common Name	Scientific Name	Mean chicks per nest 2021/22	Mean chicks per nest 2022/23
Australian White Ibis	*Threskiornis molucca*	2.36	2.92
Great Cormorant	*Phalacrocorax carbo*	3.58	4.17
Little Black Cormorant	*Phalacrocorax sulcirostris*	2.81	3.18
Little Pied Cormorant	*Phalacrocorax melanoleucos*	2.75	3.07
Pied Cormorant	*Phalacrocorax varius*	3.5	2.86
Yellow-billed Spoonbill	*Platalea flavipes*	2.07	1.67

The timing of this 2022/23 survey appears to have been well timed, with most of all nests observed early in the surveys reaching their conclusion, with the vast majority of chicks fledging successfully, and as mentioned previously, with very little sign of chick mortality and no obvious failed nests (filled with dead chicks) aside from nests submerged in December 2022. It is therefore assumed that most chicks fledged successfully, an assumption supported by the tremendous flocks of juvenile birds observed roosting, flying, and foraging in the vicinity of the nesting colonies late in the survey. The previous survey concluded at a similar time of year (early April 2022), but at that time most nests still contained large chicks. This suggests the breeding in the 2022/23 flood had began earlier than in the previous year, despite peak water levels only being reached in late December 2022. The earlier onset of breeding in 2022/23 also led to the drowning of many early-built nests. In addition to this, large numbers of birds were observed nesting, or renesting, late in the survey, with eggs observed in many nests in the final surveys in late March and early April at lakes Cantala, Yelwell, Hattah and Konardin. Colonies at these lakes appear to be somewhat asynchronous in breeding timing, and birds appear to be continually breeding. A new colony or second or even third clutches by existing birds suggest that, at the end of the surveys, conditions at these lakes continued to be very productive for waterbirds and the fish and macroinvertebrates on which they depend. The success of late breeding efforts is unknown. Presumably, at some point as cooler weather arrives,

breeding attempts will begin to fail, as cooling ambient and water temperatures cause productivity levels within the lakes to drop dramatically.

The very large numbers of chicks, combined with the apparently high survival and fledging rate, strongly suggest that breeding during the 2022/23 summer breeding season was highly successful. These large numbers of nests and chicks clearly demonstrate the importance of the Hattah Lakes system as an area for waterbird breeding.

4.4 Future monitoring

This survey of colonial breeding waterbird nests across the Hattah Lakes system has successfully built on knowledge gained in the previous surveys of nests in 2021/22, as well as the inactive nests in the dry lakes in 2020/21. The most recent survey strongly reinforced the site fidelity and predictability of the locations of breeding colonies, as made in the previous Hattah colonial waterbird nest assessments; all larger colonies in the extensive flood of 2022/23 were recorded in locations where colonies were observed in previous surveys with less extensive flooded areas. This suggests that future monitoring may target these areas of known colony locations with some confidence, as areas appear likely to be reused, with species often renovating nests on top of existing nests (Beruldsen 2003). Targeting known colony sites in future surveys is likely to save time associated with completing reconnaissance of lakes searching for colonies. Future monitoring of active breeding colonies may therefore be completed with greater efficiency through less reconnaissance visits, targeting known preferred colony sites, and where possible visiting nests late in the breeding cycle, close to fledging stage.

Some consideration should also be given to timing of breeding events and the need for reconnaissance trips, to ascertain when breeding activity commences. Waterbird nesting colonies also typically have a protracted onset of breeding activity (Marchant and Higgins 1990), meaning that not all birds begin or finish breeding simultaneously, as observed across different lakes in these and previous surveys, adding a challenge to accurately counting active nests in a season without multiple surveys of each area. Nonetheless, surveys of breeding activity are essential to gather data on the species and their numbers breeding within the Hattah Lakes, and allow records of other waterbird breeding activity, including threatened species.

Simplified data on the presence or absence of colonial nesting waterbird breeding in a given year could be collected in a short survey of no more than a week, if completed in late December or January and targeting only those areas of previously known larger nesting colonies. This would allow a record of breeding activity to be made, providing abridged but valuable information on the use of the Hattah Lakes as a breeding ground for colonial nesting waterbirds over time, which could still be reconciled with environmental watering and natural flood events.

It must be conceded that all water-based surveys are potentially time consuming as accessing the lakes, and movement by boat can be slow, particularly when flooding is widespread. However, monitoring of actively breeding waterbird colonies from land-based surveys is not considered feasible, with only the colony at Lake Hattah detectable from land, and even then, accurate counts of nests and chicks in this colony would still be impossible. All other colonies were only really observable from the water. Water-based surveys allow accurate identification of species, numbers of nests and breeding success to be made.

Consideration of other potentially less-invasive, and more time and cost effective technologies for nest monitoring could be made, such as the use of unmanned aerial vehicles (drones) (Nowak et al. 2019) and the use of passive acoustic monitoring, which has increased in recent years (Sugai et al. 2019). Unmanned aerial vehicles have been used successfully to count waterbird nests in more exposed environments such as open marshes, but may not be suited to many of the colonies observed during these surveys across the Hattah Lakes, where nests are often well hidden in dense stands of River Red Gum saplings, with tree canopies overhead, and multiple nests often stacked vertically. Passive acoustic monitoring requires the placement of autonomous recording units (ARUs) in the field, programmed to record and followed up by an interpretation of the recordings. ARUs have proven to be a suitable alternative to traditional field surveys for monitoring wildlife across many research areas (Sugai et al. 2019). However most colonial waterbird species are not easily differentiated by call (potentially only Nankeen-Night Heron), and acoustic surveys would be very limited in their ability to assess numbers of nesting birds or chicks.

4.5 Conclusions

The natural flooding of the Hattah Lakes in 2022/23, following environmental watering of in 2021/22, triggered a very large, prolonged and successful breeding event for waterbirds across the lakes system. Pre-filling the lakes in 2021/22 may have contributed to a larger breeding event in 2022/23. The large number of nests and chicks and their successful development in both the 2021/22 and 2022/23 surveys, emphasise the importance of the Hattah Lakes area as a breeding ground for waterbird species, both in times of widespread natural flooding, and as a refuge in times when most other areas of the Murray-Darling basin are dry and suitable breeding and feeding habitats are few and far between.

Breeding by 28 waterbird species was observed, including ten species considered as colonial nesting, with 7,176 nests and 27,188 chicks recorded, of which the vast majority (6,979 nests and 25,362 chicks) were classified as colonial breeding waterbird species. Dominant species recorded breeding successfully included very large colonies of Great Cormorant, Little Black Cormorant and Little Pied Cormorant, along with sizeable numbers of Australasian Darter, Australian White Ibis, Nankeen Night-Heron and Yellow-billed Spoonbill. These observations follow similar previous observations of smaller but substantial breeding colonies of these species during the large environmental watering event in 2021/22.

Surveys in 2022/23 documented the high degree of site fidelity of these waterbird populations. Locations of breeding colonies recorded in the 2022/23 surveys closely matched those detected in previous surveys. In all years, the largest colonies were found in the same locations at Lakes Cantala, Yelwell, Konardin, Mournpall, Hattah, Roonki and Woterap.

Many early-built nests established in November and December were seen to be drowned by rising water and abandoned, with new nests built higher up as the water levels peaked in late December. Observations thereafter saw high breeding success, with no signs of nest abandonment or predation, very few mortalities observed, rapid rates of chick development, and high rates of successful fledging indicating a very high success rate. Mean numbers of chicks per nest were generally high and considerably greater for most species than those recorded in the previous survey. Most fledging was also recorded earlier in the year than in the previous year, where many nests still contained large chicks when surveys were finalised in early April. The earlier fledging of chicks may be linked to higher food availability.

Australian waterbird populations are reliant on suitable feeding and nesting habitats coupled with suitable rain and flood events to trigger breeding events. Wetlands within the Murray-Darling Basin provide many critical waterbird habitats; however, in such a heavily regulated system, the quality and availability of these sites are greatly influenced by water and vegetation management decisions. Protecting and maintaining suitable feeding and nesting habitats between and during flood events is essential to maximise waterbird recruitment, maintain populations, and conserve biodiversity. This requires careful management of water regimes at a range of scales across the basin.

The use of valuable ‘environmental water’ within the Murray-Darling Basin has become increasingly important in supporting successful completion of waterbird breeding events. Appropriately managing environmental water placement, volume and timing is critical to enable the recruitment of juveniles into waterbird populations and ultimately assist species survival. The success of nesting and breeding of colonial nesting waterbirds depends on water levels in wetlands in the build up to the breeding season, with appropriate water conditions needed to cue nest building and breeding behaviours. In what is likely to be a complex relationship involving food availability (fish, crustacean and macroinvertebrate populations) and nest predation risk (including land-based predators and nest raiders such as feral pigs, goannas, snakes, foxes, brush-tail possums), these species typically require stable or rising water for three or more months before nesting is attempted, with water required to be relatively stable during the breeding and chick rearing period. In periods of no natural flooding, application of environmental water to the right places at the right times is critical to promote the success of future breeding events and waterbird recruitment within the Hattah Lakes, and across the Murray-Darling Basin.

The overall success of waterbird breeding observed in these 2022/23 surveys, both in species diversity, numbers of chicks and their successful development, suggests that a large natural flood, preceded by the provision of environmental water, has provided ideal conditions for cormorants and other species of colonial and non-colonial nesting waterbirds. Future environmental watering events, particularly when linked to natural flood events, are likely to provide conditions suitable for waterbird recruitment.

The 2022/23 survey of colonial breeding waterbird nests across the Hattah Lakes system has successfully built on knowledge gained in the previous surveys in 2021/22 and 2020/21. Earlier surveys have proved invaluable in predicting the locations of breeding colonies. This suggests that future monitoring may be streamlined to target these areas of known colony locations with some confidence, as preferred areas appear likely to be reused, at least for larger watering events. It is hoped that the results of these surveys will further assist in informing recommendations for the planning, prioritisation, and management of environmental water flows within HKNP and potentially the broader Murray-Darling Basin, and assist with maximising waterbird recruitment into the future.

5. References

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Appendices

Appendix A

Locations of survey sites.


Lake Bitterang
Lake Cantala
Lake Woterap
Lake Konardin
Lake Yelwell
Lake Mournpall
Lake Yerang
Lake Lockie
Lake Roonki
Little Lake Hattah
Lake Nip Nip
Lake Brockie
LakeTullamook
Lake Bulla
Lake Hattah
Lake Marramook
Lake Arawak
Lake Boich
Lake Kramen

Appendix B

Incidental and Threatened Species records.

Incidental and Threatened Species records

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Arawak	Blue-billed Duck	*Oxyura australis*	1	VU		Juvenile
Bitterang	Musk Duck	*Biziura lobata*	2	VU		Juvenile
Bitterang	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Bitterang	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		
Boolca	Major Mitchell's Cockatoo	*Lophochroa leadbeateri*	2	CR	EN	
Bulla	Lace Monitor	*Varanus varius*	1	EN		
Cantala	Apostlebird	*Struthidea cinerea*	6	VU		
Cantala	Apostlebird	*Struthidea cinerea*	5	VU		
Cantala	Hardhead	*Aythya australis*	1	VU		Juvenile
Cantala	Regent Parrot	*Polytelis anthopeplus monarchoides*	1	EN	VU	
Cantala	Regent Parrot	*Polytelis anthopeplus monarchoides*	15	EN	VU	Probably breeding here, many birds, around hollows, begging calls heard.
Cantala	Regent Parrot	*Polytelis anthopeplus monarchoides*	2	EN	VU	
Chalka Creek	Apostlebird	*Struthidea cinerea*	1	VU		
Chalka Creek	Apostlebird	*Struthidea cinerea*	8	VU		

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Chalka Creek	Hardhead	*Aythya australis*	1	VU		
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	15	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	Possibly breeding in area
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	2	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	6	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	6	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	7	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	5	EN	VU	Likely nesting in this area
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	8	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	11	EN	VU	Likely nesting in this area

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	9	EN	VU	Likely nesting in this area
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	14	EN	VU	Likely nesting in this area
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	6	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	1	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	5	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	2	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	12	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	5	EN	VU	
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	5	EN	VU	

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Chalka Creek	Regent Parrot	*Polytelis anthopeplus monarchoides*	6	EN	VU	
Hattah	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest
Hattah	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest
Hattah	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest.
Hattah	Musk Duck	*Biziura lobata*	2	VU		Juvenile
Hattah	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Hattah	Regent Parrot	*Polytelis anthopeplus monarchoides*	4	EN	VU	
Konardin	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest.
Konardin	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest.
Konardin	Eastern Great Egret	*Ardea alba modesta*	1	VU		Bird on nest
Konardin	Eastern Great Egret	*Ardea alba modesta*	1	VU		
Konardin	Eastern Great Egret	*Ardea alba modesta*	1	VU		
Konardin	Little Eagle	*Hieraaetus morphnoides*	1	VU		
Konardin	Little Eagle	*Hieraaetus morphnoides*	2	VU		Bird on nest
Konardin	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Konardin	Musk Duck	*Biziura lobata*	1	VU		Juvenile

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Konardin	Regent Parrot	*Polytelis anthopeplus monarchoides*	1	EN	VU	
Konardin	Regent Parrot	*Polytelis anthopeplus monarchoides*	1	EN	VU	Female entered hollow - nesting
Kramen	Regent Parrot	*Polytelis anthopeplus monarchoides*	3	EN	VU	
Kramen	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		
Lockie	Hardhead	*Aythya australis*	4	VU		Juvenile
Lockie	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Lockie	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Lockie	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Lockie	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Lockie	Musk Duck	*Biziura lobata*	1	VU		Juvenile
Lockie	Regent Parrot	*Polytelis anthopeplus monarchoides*	2	EN	VU	
Lockie	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		Juvenile
Mournpall	Regent Parrot	*Polytelis anthopeplus monarchoides*	6	EN	VU	
Mournpall	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	3	EN		3 juvenile birds
Mournpall	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		Juvenile

Site	Common Name	Scientific Name	Number	FFG Act Status	EPBC Act Status	Breeding Activity?
Mournpall	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		Juvenile
Mournpall	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		Juvenile
Mournpall	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1	EN		Juvenile
Roonki	Regent Parrot	*Polytelis anthopeplus monarchoides*	2	EN	VU	
Yelwell	Musk Duck	*Biziura lobata*	1	VU		Juvenile

Appendix C

Images of breeding waterbirds and nests.

See separate attachment.

Appendix D

Results of 2022 surveys – Raw Data.

See separate attachment.

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→ The Power of Commitment