The Whistler

Features

Rufous Scrub-bird
Bush Stone-curlew
Broughton Island Group
Tomago Wetland
Morpeth waterfowl
Hunter Estuary waterbirds
Blue Gum Hills Regional Park

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- ***To encourage bird observing as a leisure-time activity***

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Front cover: Rufous Scrub-bird *Atrichornis rufescens* - Photo: Allan Richardson
Back cover: Wandering Whistling-Duck *Dendrocygna arcuata* - Photo: Stephanie Owen
Spine: Sharp-tailed Sandpipers *Calidris acuminata* - Photo: Rob Palazzi

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Editorial

Because of the COVID-19 pandemic, the past year was very challenging for everyone. For birdwatchers, COVID-related travel restrictions added to the frustrations, because their birding activities were restricted for a considerable portion of the year. However, some used the additional available time productively, by analysing some of the long-term data sets that have been developed through regular surveys by HBOC members. The results of three long-term, multi-species studies of waterbirds in the Hunter Region are presented in this issue of *The Whistler*. Ann Lindsey and Alan Stuart present the results of a 22-year study of the population trends for large waterbirds in the Hunter estuary. The trend for most species was either stable or increasing – the authors relate this to the impact of local rehabilitation projects. Mike Newman, Ann Lindsey and Grant Brosie present the results from a 20-year study of *Anatidae* waterfowl at the Morpeth Wastewater Treatment Works. They show the importance of the wetlands there as refuges for some species in times of drought and highlight the successful management practices. In the third long-term study, Ann Lindsey examines the utilisation of Tomago Wetland by waterbirds following the re-establishment there of tidal inundation as part of a major rehabilitation project. She compares results from an eight-year study with those from an earlier baseline study. Her analysis reveals increases in the number of waterbird species, including shorebird species, reflecting the success of the project. However, she also highlights the issues which arise when management practices do not adequately maintain water levels in the wetland.

In the fourth article about long-term studies, Greg Little presents the results of a five-year study of birds in the Blue Gum Hills Regional Park, which has been partially rehabilitated following historic coal-mining activities. The study identifies differences in diversity and abundance of species between disturbed and undisturbed areas.

Two important themes are often repeated in the above articles – the importance of long-term studies in establishing population trends for species, and the positive impact that well planned and managed conservation projects have had on a wide range of species.

When contemplating possible content for this edition of *The Whistler* in early 2021, the editors decided to include a Broughton Island-themed focus, with the aim of documenting some of the results of the extensive studies undertaken by HBOC members on the island over the past 10 years. This has been achieved, with four articles covering different aspects of avian presence on the island. Collectively, the articles also demonstrate the positive impacts for bird populations on offshore islands from the removal of feral animals.

An article by Neil Fraser describes recently discovered instances of Sooty Oystercatcher breeding on Broughton Island. It reinforces the findings of an earlier study, presented in Volume 13, that identified the importance of the island for Sooty Oystercatcher. A second article by Neil analyses raptor records from the island spanning a 20-year period and compares the population trends with that of the Hunter Region. Broughton Island is arguably one of the best locations in our region to observe raptors. Typically, multiple species can be closely observed on any day. Twelve of the 16 raptor species found in the Hunter Region have been recorded on the island.

Alan Stuart documents the status of passerines on Broughton Island. From relatively few species present when surveys started in 2012, it is now evident that several new species have become resident or are regular visitors. The article

demonstrates that some species have benefitted from management changes on the island, while others have been adversely impacted. Of particular interest is the temporal variation in occurrence of the three Silvereye subspecies. The relationship of the change in some passerine populations to the changing habitat on the island is discussed.

The fourth Broughton Island Group article is a short note by NPWS Ranger Susanne Callaghan and ecological consultant Martin Schulz on the birds of Little Broughton Island. Due to the difficulty of accessing the island and its rugged topography, previous visits have been infrequent, and this is the first specific account of the island's land birds.

This edition of *The Whistler* includes two articles about threatened species that occur in the Hunter Region – Rufous Scrub-bird and Bush Stone-curlew. Both articles highlight the parlous state of the local populations of these two species. Rob Kyte and Greg Little present results from a detailed regional survey for Rufous Scrub-birds. They visited all parts of the region for which there were past records of scrub-birds and/or which seemed might have suitable habitat for them. The result was a small extension to the known area of occupied habitat; however, they found no scrub-birds anywhere else. In the second article, Neil Fraser examines the population trend for Bush Stone-curlew in the Hunter Region and reviews the status of conservation efforts. Local extinction seems a real possibility. However, it is encouraging that Neil's article may be galvanising a re-start of local conservation activities for this species.

As with every edition of *The Whistler*, there are many people to be thanked – starting with the authors, of course, the referees whose constructive comments always lead to better articles, Liz Crawford who formats and proof-reads every article, and Rob Kyte who puts everything together for the hard copy and arranges its printing. We also thank the Newcastle Coal Infrastructure Group for their continuing financial support for publication of this journal.

Neil Fraser and Alan Stuart
Joint Editors

Recent nesting records for Sooty Oystercatcher within the Broughton Island group

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INTRODUCTION

This note describes recent observations of Sooty Oystercatcher *Haematopus fuliginosus* nesting within the Broughton group of islands. The Sooty Oystercatcher has a widespread but low-density population on rocky coastal shorelines and near islands around all parts of Australia (Marchant & Higgins 1993; Geering *et al*. 2007). The species is listed as Vulnerable under the NSW *Biodiversity Conservation Act* 2016. This listing reflects its relatively low numbers and limited areas of suitable habitat (NSW Scientific Committee 2008; Harrison 2009; NSW Department of Planning, Industry and Environment 2011).

Sooty Oystercatcher were first reported on Broughton Island in 1959 (Hindwood & D'Ombrain 1960). The only two confirmed breeding records for that island were in January 1998, when dependent young were present with adult birds (Stuart 1999), and January 2008, when a pair had a nest with eggs (Stuart *et al*. 2017). Also, a pair was exhibiting defensive behaviour on the northwest of the island in mid-January 2014 (L. Crawford pers. comm.), suggesting that they may have been breeding. A pair of Sooty Oystercatcher with a nestling were present on Gandja-Baa in December 2011 (Carlile *et al*. 2013); the location of the record is indicated in **Figure 1**.

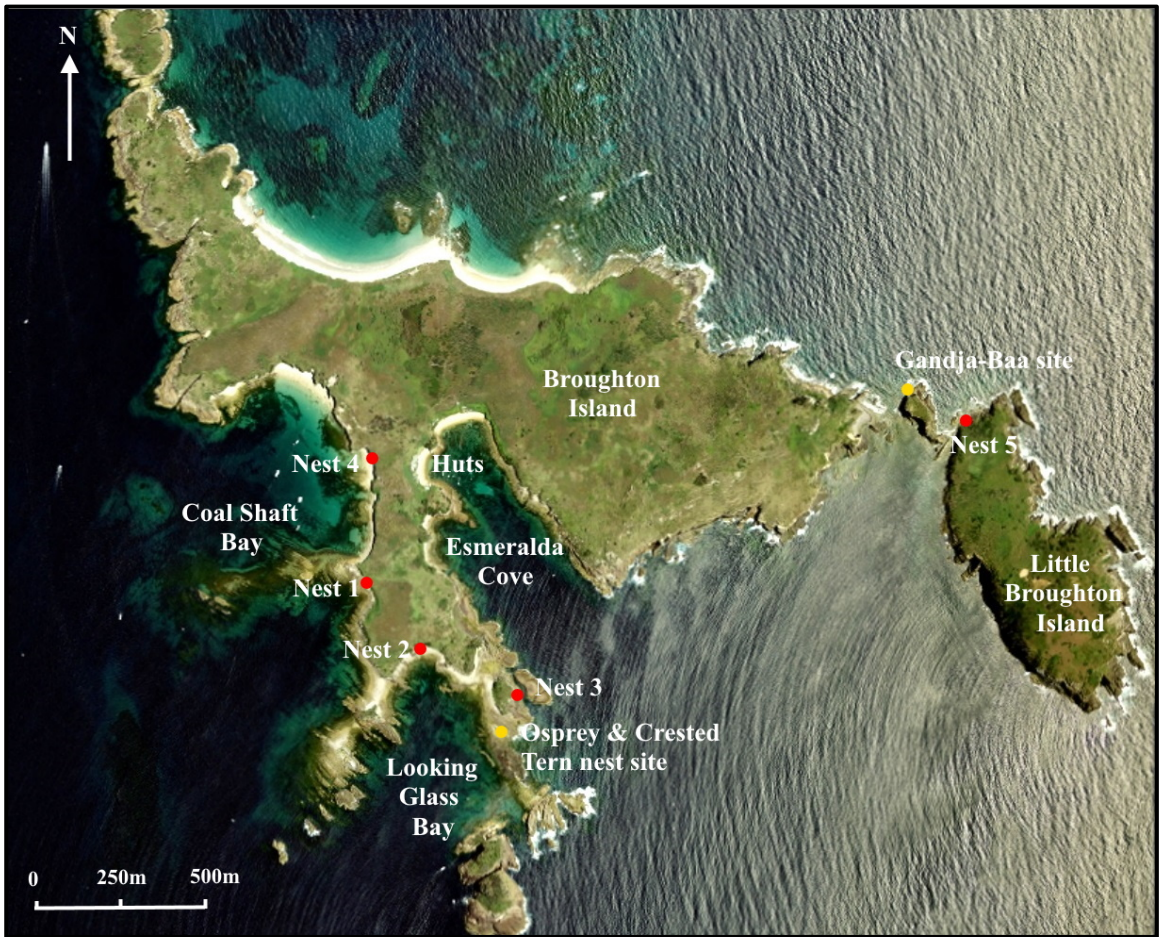

Figure 1. Location of known Sooty Oystercatcher nest sites within the Broughton Island group.

A recent review of Sooty Oystercatcher in the Hunter Region (Wooding 2019) identified Broughton Island as one of the most important sites for the species in the region. Surveys of terrestrial avian species on the island from 2012 to 2020 by members of the Hunter Bird Observers Club (HBOC) on behalf of NSW National Parks and Wildlife Service (NPWS) identified an estimated 30-35 birds regularly present around the rocky shores of the island (Stuart 2020). Four nests described here were discovered by members of HBOC while conducting surveys on the island in 2019 and 2020. A fifth nest was discovered by a consultant working for NPWS on Little Broughton Island in 2020.

Sooty Oystercatcher nests are typically located on shorelines, rocky islands, headlands, ledges and cliffs up to 15 m above sea level and up to 250 m from shore; and in sandy and shell-strewn areas, among pebbles, at the foot of steep sandy banks, in sandy hollows, on top of rocks, between rocks and in clefts of rock or on the floor of caves. Nests have been located in close proximity to other shorebird species nesting simultaneously in the same habitat. The nest consists of a scrape in the ground, either unlined or else lined with gravel, pebbles, shells, grass, samphire, twigs, seaweed or seagrass. Clutch-size is 1-2 eggs that are laid between October and January in southern Australia. Nest scrapes may be surrounded by or close to vegetation and pairs exhibit a high level of site fidelity during breeding (Lane 1987; Lauro & Nol 1995; Marchant & Higgins 1993). Nests on Chalky Island in Bass Strait were 50-100 m apart (Wakefield & Robertson 1988) but on the north coast of NSW, nest densities were low (0.11-0.53 pairs/ha) and with only one pair per island during nesting (Harrison 2009).

Nest Descriptions

Nest 1. This nest was discovered on 26 October 2019 on the southern shoreline of Coal Shaft Bay (**Figure 1**). The nest contained two eggs laid on a bed of medium to coarse gravel and shell fragments, surrounded by larger cobbles and boulders of local sandstone (**Figure 2**). The nest was at the boundary between the coastal vegetation and the rocky shoreline. The site was 12 m from, and approximately 50 cm above, the high-tide line. This site was used again in 2020. Two eggs were present in the nest on 30 October 2020.

Nest 2. This nest was found on 26 October 2019 on the northern shore of Looking Glass Bay (**Figure 1**). The nest contained two eggs laid on a bed of coarse to very coarse gravel surrounded by larger cobbles and boulders of local sedimentary rocks, and was located at the base of a massive, steep-sided sandstone outcrop. Dried vegetation fragments, wood flotsam and dried grass were present (**Figure 2**). The site was on the boundary between the coastal vegetation and the rocky shoreline. The site was 20 m from, and approximately two metres above, the high-tide line. This site was again used in 2020. Two eggs were in the nest on 30 October 2020.

Nest 3. This nest was discovered on 30 October 2020 on the southwestern shore of Esmeralda Cove (**Figure 1**). The nest contained two eggs laid within a small patch of medium-sized rock fragments on an elevated platform of volcanic rock (**Figure 2**). The site was close to the boundary between the coastal vegetation and the rocky outcrop. The site was 20 m from, and approximately three metres above, the high-tide line.

Nest 4. This nest was found on 28 November 2020 on the central part of the Coal Shaft Bay shoreline, at the base of a cliff (**Figure 1**). The nest contained one egg laid on grey sand with a small number of medium to coarse rocky fragments and cobbles (**Figure 2**). The site was at the foot of a slope resulting from a land slip of volcanic rock. It differed from the other four sites as it had an adjacent sandy shoreline. The nest was within a metre of, and only a few cm above, the high-tide line, and was located at the boundary between a small patch of coastal vegetation and the sandy scree.

Nest 5. This nest was discovered on 30 October 2020 on the northwestern tip of Little Broughton Island, at the base of a low cliff (**Figure 1**). The nest contained two eggs laid within an area of shell grit on a raised sandstone platform. A photo of this nest was not obtained. The site was near the boundary of the coastal vegetation which was present at the top of the cliff. The nest was 16 m from, and eight metres above, high-tide level.

The substrate of all sites on which eggs were laid did not appear to have been excavated and external material had not been brought in to line the nests. Eggs were well camouflaged by the nest substrate and surrounding materials. The distances between nests ranged from 345 m to 1,560 m (measured as shoreline length, not as the direct distance). In the area south from the huts in Esmeralda Cove to Looking Glass Isle, the nest density was 0.15 pairs/ha. The area (26.2 ha), including Looking Glass Isle, was determined using the NSW Spatial

Services Six Maps area tool (www.maps.six.nsw.gov.au). All nest sites were adjacent to areas of shallow rocky reefs and tidal platforms that could be used for foraging at low tide.

There was an active nest of a pair of Osprey *Pandion haliaetus* on a small knoll, 100 m southwest of nest 3 (location of the Osprey nest is indicated in **Figure 1**). In 2019 many pairs of Greater Crested Tern *Thalasseus bergii* nested on the slopes surrounding the Osprey nest. In the same period, a colony of Silver Gull *Chroicocephalus novaehollandiae* nested in the same area. No agonistic behaviour between Sooty Oystercatcher and the other species was observed during visits to the nest sites.

Figure 2. Sooty Oystercatcher nests, Broughton Island. Top left: nest 1, photo by N. Fraser, 30/11/2019. Top right: nest 2, photo by N. Fraser, 30/11/2019. Bottom left: nest 3, photo by T. Clarke, 30/11/2020. Bottom right: nest 4, photo by G. Little, 28/11/2020.

Breeding Success

Breeding success for the pairs from nests 1 and 2 was confirmed on visits to Broughton Island in December 2019 and January 2020. Both pairs were accompanied by dependent chicks. Breeding outcomes for 2020 are unknown at the time of writing.

DISCUSSION

The nests discovered on Broughton Island and Little Broughton Island were present in a variety of different surroundings and the eggs had been laid on a number of different substrates. It is probable that many factors influenced the selection of nest sites. These factors could include competition from other breeding pairs, the availability of foraging

resources, the presence of camouflage materials, partial vegetation cover and the absence of human disturbance. The nest sites conformed with the descriptions of Lane (1987), Lauro & Nol (1995) and Marchant & Higgins (1993). Nest site fidelity was also confirmed.

Territories were widely-spaced across sections of the southern coastline of Broughton Island where there are large areas of shallow rocky reefs and tidal platforms suitable for foraging at low tide. The low nest density and large distances between nest sites suggests there could be opportunities for additional pairs to nest on the island. It is likely that additional breeding territories are present on the northeast and northwest shores of the island where there are extensive sections of rocky coastline with suitable foraging and nesting conditions, in areas with minimal human disturbance. Pairs and small parties of Sooty Oystercatcher have been recorded in surveys of this section of the island but as yet no nests have been located. A pair was observed behaving defensively near Providence Point in January 2014, suggesting they were concealing dependent young (L. Crawford pers. comm.). The previously reported occurrence on Gandja-Baa in 2011 is 175 m northwest of nest 5.

It is problematic to compare the recent breeding successes with previous years. The earlier surveys, especially those during 2012-2017, were not focused on obtaining breeding/nesting records and most surveys of any particular section of the island were of relatively short duration. While pairs and small groups were often seen around the southern areas of the island, no specific nest searches were conducted. Also, prior to 2017, the surveys were only carried out twice yearly, in autumn and spring (Stuart *et al*. 2017). That timing was outside the normal breeding period for Sooty Oystercatcher. Hence, it is quite possible that breeding activity on the island was overlooked until recently. However, breeding success will probably have increased following eradication of ship rats *Rattus rattus* from the island in 2009. Rats were known predators of shorebird eggs and chicks on the island (Priddel *et al*. 2011; Fawcett *et al*. 2016).

CONCLUSION

The recent discovery of multiple Sooty Oystercatcher nests and confirmation of breeding success on Broughton Island and Little Broughton Island further emphasises the importance of the Broughton Island group for the species in the Hunter Region.

ACKNOWLEDGEMENTS

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The birds of Tomago Wetland after reinstatement of tidal flushing

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Tomago Wetland, within the Hunter Estuary of NSW, has recently been returned to tidal inundation as part of a major rehabilitation project. The main aims of the Tomago Wetland Restoration Project were the re-establishment of shorebird habitat and improvement of fish passage, through the reintroduction of tidal flushing. Regular tidal flushing has led to the demise of freshwater-influenced vegetation, regeneration of salt marsh, creation of shallow lagoons and mudflats and an ensuing increase in the diversity and abundance of waterbird species.

Sixty-one waterbird species including 20 species of shorebirds were recorded at least once at Tomago Wetland during surveys over 2012-2020. These were notable increases compared with the preceding five-year period when 33 species, including just five species of shorebird, were recorded. The site regularly hosted more than 1% and on one occasion almost 6% of the world population of Sharp-tailed Sandpiper *Calidris acuminata* and more than 1% of the populations of Red-necked Avocet *Recurvirostra novaehollandiae* and Chestnut Teal *Anas castanea.*

Before flood gates were installed in the 1970s, shorebirds utilised Tomago Wetland diurnally and nocturnally. Recent crepuscular and nocturnal surveys have shown that shorebird species such as Red-necked Avocet, Pied Stilt *Himantopus leucocephalus*, Far Eastern Curlew *Numenius madagascariensis,* Sharp-tailed Sandpiper, Curlew Sandpiper *Calidris ferruginea*, Red Knot *Calidris canutus* and Common Greenshank *Tringa nebularia* were again roosting and foraging on the site during non-daylight hours.

As a result of the tidal gates being closed for long periods, there were negative impacts on wetland habitat including the complete drying of mudflats. The impacts were exacerbated when drought conditions prevailed. It was found that even a limited amount of tidal flushing allowed tidal pools to be retained, which was beneficial for Common Greenshank, Marsh Sandpiper *Tringa stagnatilis*, and White-faced Heron *Egretta novaehollandiae*.

INTRODUCTION

The Tomago Wetland Precinct ("Tomago Wetland"), part of the Hunter Wetlands National Park (HWNP), is located north of the Hunter River near Fullerton Cove (**Figure 1**). According to Clarke & van Gessel (1983), open Samphire *Sarcocornia quinqeflora* meadows provided diurnal and nocturnal roosting habitat for migratory shorebirds. After flood gates were installed in the 1970s as part of a flood mitigation scheme, salt marsh habitat at Tomago Wetland was greatly reduced, and shorebirds and other waterbirds abandoned the site (Russell *et al*. 2012). The 1983 Moss report recommended restoration of salt marsh habitat at Tomago by re-introduction of tidal flushing. Tidal flow and its management are the main mechanisms in the restoration process of shorebird habitat (Spencer & Howe 2008).

In this report I summarise the results from regular bird monitoring programs carried out at the site in 2012-2020 and discuss bird population changes in relation to a 2007-2012 baseline study (Lindsey & McNaughton 2012). The present study commenced in April 2012.

Conservation history of Tomago Wetland

In 1985, 716.6 ha of land at Tomago of which c. 450 ha was wetland (the future Tomago Wetland) were donated by BHP and added to the-then Kooragang Nature Reserve. Kooragang Nature Reserve was gazetted in 1983 and became a Ramsar site the following year (Lindsey & McNaughton 2012). In 2011, Kooragang Nature Reserve along with Hexham Swamp Nature Reserve and Ash Island were combined to form the HWNP.

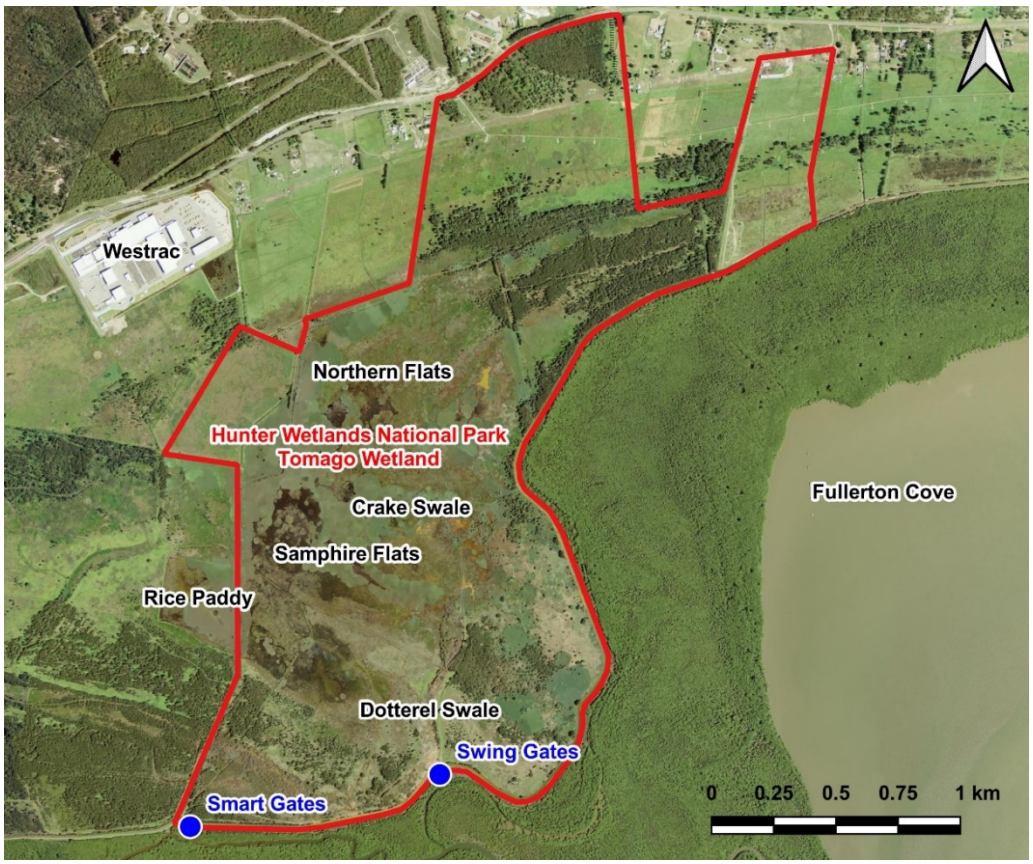

Figure 1. Tomago Wetland precinct of Hunter Wetlands National Park, near Newcastle, NSW.

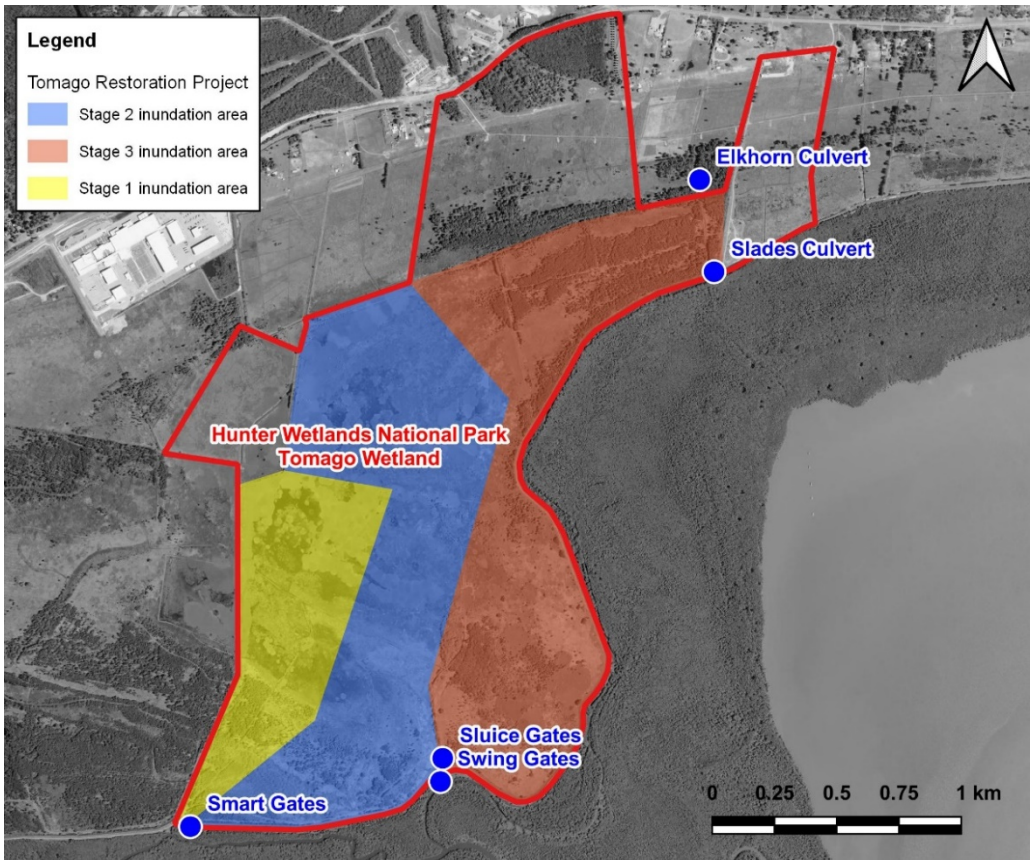

Figure 2. Tomago Wetland Restoration Project, showing the three stages of tidal inundation areas in Hunter Wetlands National Park.

The Kooragang Wetland Rehabilitation Project (KWRP) commenced in 1993; one aim of the project was to restore tidal flushing to former wetland sites within the Hunter Estuary. Tomago Wetland was included into KWRP's purview; however, it was not until 2008 that tidal gates were installed. The gates did not become fully functional until October 2012. Thus, Tomago Wetland was freshwater from the 1970s until 2012. Since 2012 it has been re-converting into tidal land, a process which is not yet complete.

Re-introduction of tidal flushing

The restoration of Tomago Wetland is a collaborative project managed by the NSW National Parks and Wildlife Service. Expansions to the potential tidal footprint occurred in three stages – in 2008, 2011 and 2012-2015 (**Figure 2**) and involved the installation of tidal gates on the south-western and south-eastern sides as well as culverts and levees. On the south-western corner the SmartGate Environmental Control System ("SmartGate") designed by the University of New South Wales Water Research Laboratory was installed. In this system, four independently-operated gates automatically control the amount of tidal flushing, based on real-time water level measurements (Russell *et al*. 2012). On the south-eastern side adjustable floodgates known as Swing Gates were installed. Swing Gates can be set to regulate natural tidal flows so that the wetlands do not dry out and flooding of neighbouring properties is prevented (Russell *et al*. 2012).

In October 2008, the SmartGate system began operating, to allow tidal flushing of c. 250 ha of the western part of Tomago Wetland (**Figure 2**). Tidal flushing of a further 62 ha commenced in 2011 (Russell *et al*. 2012). However, there were various operational issues and tidal flushing was not fully underway until October 2012.

In 2015 additional works on culverts and levees commenced enabling further inundation during Stage 3 (Russell *et al.* 2012) (**Figure 2**).

METHODS

In most months during 2012-2020, Tomago Wetland was surveyed in the morning twice each month by Hunter Bird Observers Club (HBOC) members, with three additional crepuscular surveys and one nocturnal survey. The various sites within the wetlands were accessed by motor vehicle, but the actual surveys were carried out on foot, with participants using binoculars and telescopes to identify and count species.

One set of monthly surveys was a continuation of the 2007-2012 baseline study (Lindsey & McNaughton 2012). These surveys took place on the third Tuesday of each month and usually involved 4-6 surveyors. Although the Tuesday surveys often served as a training ground for newcomers to shorebird identification, they always involved a core of experienced surveyors. The Tuesday surveys had a regular start time (approximately 9.00 am at Samphire Flats) and as a result, a variety of tidal cycles were sampled.

The second set of monthly surveys took place on a Saturday morning at high tide. The timing was chosen so that these surveys coincided with estuary-wide waterbird surveys in which multiple teams visit simultaneously all the known shorebird roost sites in the estuary in order to obtain total numbers of shorebirds and other waterbirds (Stuart *et al*. 2013). These surveys commenced in September 2013. Typically, the intervals between each of the Saturday surveys were 3-5 weeks. The start time for the survey varied, being dependent upon the time of the high tide. Each survey involved 1-2 experienced surveyors.

For the purposes of this article, "migration period" is defined as the period between August of one year and April of the following year i.e. the period when most migratory shorebirds are recorded in the Hunter Estuary. Observations from any other dates are referred to as "winter records".

Crepuscular and nocturnal surveys

Three members of Conservation Volunteers Australia participated in a nocturnal survey of Samphire Flats on 2 March 2018 commencing at 2000 h on a rising tide. The duration of the survey was two and a half hours. It was full moon and, with the aid of a spotlight, participants were able to identify some species using a telescope, Acuter ST20-60x80A (T. Mouton pers. comm.).

In September 2014 I twice went to Samphire Flats at low tide - from 1630 h on 21 September, staying for 110 minutes, and from 1600 h on 23 September, staying for 130 minutes. On both occasions it was almost dark when I left. I made a high-tide survey of Samphire Flats in February 2018 from 1830 h and stayed for 90 minutes. Observations were made using Swarovski 10x42 binoculars and Swarovski telescope x 20.

In the 2007-2012 baseline study, the survey effort was concentrated onto two sites – Rice Paddy and Samphire Flats (Lindsey & McNaughton 2012). As the restoration progressed, changes in vegetation and general topography (e.g. locations and sizes of mudflats, depressions and channels) occurred. For example, by 2015 changes within the vegetation communities had already occurred (Kleinfelder Australia 2015). The gradual transformation of vegetation and topography

over 2012-2020 led to various modifications over time to the monitoring regime used in this current study. Three new monitoring sites were incorporated - Crake Swale, Dotterel Swale and Northern Flats (**Figure 1**).

The Crake Swale survey commenced in 2013 but in 2017 it was absorbed into the Samphire Flats site survey since, with regular tidal flushing, the belt of Common Reed *Phragmites australis* separating the two sites had disappeared.

Monitoring of the Northern Flats site commenced in January 2016 when tidal flushing led to the disappearance of previously impenetrable vegetation and an increase in the area of salt marsh. On the Saturday surveys, 1-2 people covered both Samphire Flats and Northern Flats, walking a 6-km route which took approximately three hours. On the Tuesday surveys, participants fanned out over Samphire Flats so that as much area as possible was covered, with each person walking only a relatively short distance. If large numbers of birds were present, the survey took up to two hours. Northern Flats was rarely monitored during the Tuesday surveys.

Dotterel Swale surveys commenced in 2013 and are ongoing. The south-eastern Swing Gates were subject to closures in 2012, 2015 and 2018 to 2020 due to malfunction and/or storm damage. With irregular and/or lack of tidal flushing this site became unsuitable for waterbirds from 2015.

Initially, Rice Paddy was monitored by walking around a levee with the survey taking up to an hour. However, when vegetation died back allowing a clear line of sight, the area was surveyed using binoculars and telescopes from a fixed point on the access track. This reduced survey time to about 20 minutes.

Data management

Data from regular monthly surveys and the four additional surveys were entered into the Birdata database (www.birdata.birdlife.org.au). In May 2020, I extracted the data for all relevant surveys from April 2012 to May 2020 for analysis. For each month, I selected the highest total count for each species. Rainfall data were sourced from Bureau of Meteorology, using data for the nearest weather station, which was at the University of Newcastle. Information about the level of water at various sites came from my own field notes (as entered into the Birdata portal). The status of the tidal gates was sourced from National Parks and Wildlife Service (J. Erskine pers. comm.) and from my own observations.

RESULTS

The total number of surveys (Tuesdays and Saturdays combined) was 164 out of a possible 179 surveys. The main reason for surveys being missed was inclement weather – either rain or extreme heat. In addition, three crepuscular and one nocturnal survey took place.

Table 1. Number of regular surveys completed and number of scheduled surveys.

Survey Days	Completed Surveys	Scheduled Surveys
Tuesday	88	98
Saturday	76	81
Total	**164**	**179**

Sixty-one waterbird species were recorded from April 2012 to May 2020 during surveys conducted twice a month (usually). The species are listed in **Tables 2, 4, 6, 7** and **8**. Ten species had Reporting Rates (RR) of 50% or more while for a further 20 species, the RR was above 10%. The RR is the number of times a species was recorded divided by the number of surveys conducted (164), expressed as a percentage. Most of the remaining species were seen on fewer than six occasions with the exceptions of Great Pied Cormorant *Phalacrocorax varius* seen on 11 occasions, Australasian Bittern *Botaurus poiciloptilus*, on nine occasions, and Bar-tailed Godwit *Limosa lapponica*, on 14 occasions.

Threatened species

Seven species which are listed as threatened under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* and/or the NSW *Biodiversity Conservation Act 2016 (BC Act)* (Roderick & Stuart 2016) were recorded (**Table 2**). Five of the species were migratory shorebirds, only one of which, Curlew Sandpiper *Calidris ferruginea*, had an RR above 10%. The other two threatened species were Black-necked Stork *Ephippiorhynchus asiaticus* and Australasian Bittern.

Black-necked Stork

This species used Samphire Flats as both a foraging area and roosting area. **Figure 3** shows the monthly highest counts at Tomago Wetland from the twice-monthly regular surveys while **Table 3** lists other dates on which birds were recorded. Most of the records involved 1-2 adult birds; however, adults were with immature birds on three occasions: August 2017, January 2018 and December 2019. Three birds were also present in March 2014; however, the birds' ages and sexes were not recorded. On 19 May 2018, an emaciated immature stork was captured near the Smart Gates (**Figure 1**) and taken into care. It was assumed to be the fledgling from a 2017 breeding event (Lindsey 2019).

Table 2. Threatened species recorded in the study area, with their maximum and median counts, Reporting Rate and conservation status as determined under the EPBC and BC Acts.

Common Name	Scientific Name	Maximum	Median[#]	RR%	EPBC Act	BC Act
Black-necked Stork	*Ephippiorhynchus asiaticus*	3	1	12.2		Endangered
Australasian Bittern	*Botaurus poiciloptilus*	2	1	4.9	Endangered	Endangered
Far Eastern Curlew	*Numenius madagascariensis*	32	14	3.7	Critically Endangered	
Bar-tailed Godwit	*Limosa lapponica*	12	2	8.5	Vulnerable	
Black-tailed Godwit	*Limosa limosa*	4	1	3.7		Vulnerable
Red Knot	*Calidris canutus*	1		0.6	Endangered	
Curlew Sandpiper	*Calidris ferruginea*	41	6	20.7	Critically Endangered	Endangered

[#]Medians are not reported when there were fewer than three records

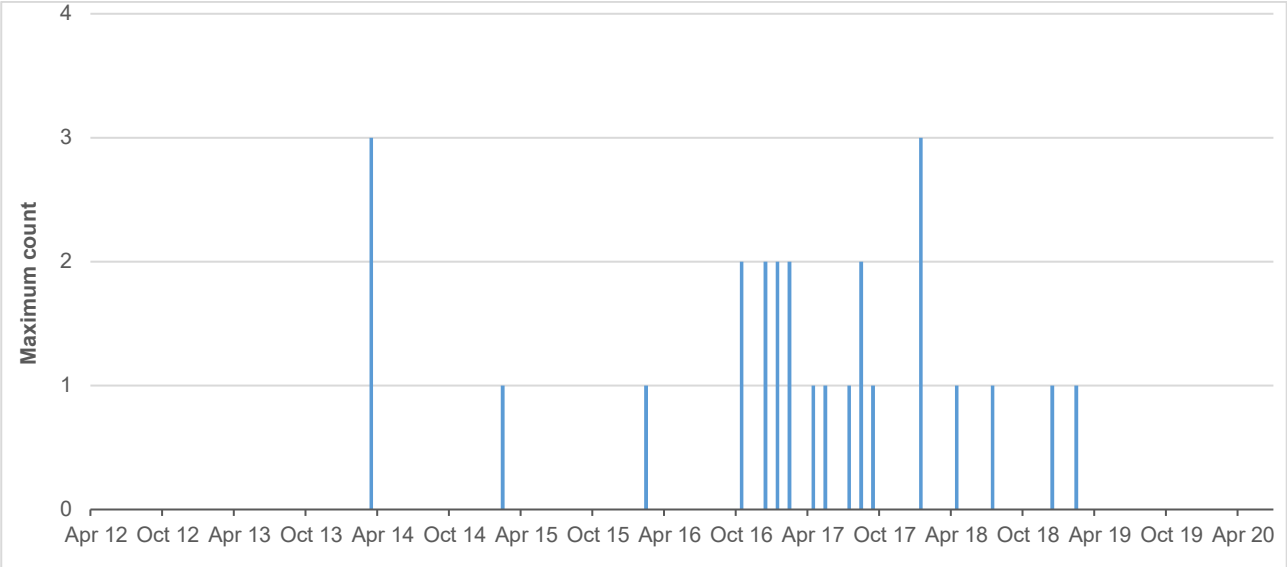

Figure 3. Monthly highest counts of Black-necked Stork at Tomago Wetland.

Table 3. Details for records of Black-necked Stork from outside of the scheduled survey dates.

Date	Number	Sex & Young	Observer
29 December 2016	2	Adult pair	N. McNaughton
21 January 2017	2	Adult pair	A. Lindsey
5 February 2017	2	Adult pair	A. Lindsey
15 August 2017	2	Adult female + 1 immature	N. McNaughton
12 February 2018	2	Adult pair	A. Lindsey
04 April 2019	2	Adult pair	B. McDonald
30 December 2019	4	Adult pair + 2 immatures	J. Erskine, W. Mayers

Australasian Bittern

Australasian Bittern was recorded on eight occasions during 2012-2013, predominantly from within the Common Reed areas of Rice Paddy. There were no further records.

Far Eastern Curlew *Numenius madagascariensis*

This species was recorded on six occasions with the highest counts being 32 birds and 28 birds in January and February 2015, respectively. It was last recorded in August 2017 when six birds were present. There were two records outside the regular

survey dates: a single bird in March 2013 and two birds during the March 2018 nocturnal survey. There were two winter records, which are presented in a later section.

Bar-tailed Godwit *Limosa lapponica*

This species was recorded on fourteen occasions. It was present during most of the 2014/15 season in small numbers, but was otherwise seen only in September 2013 (four birds), November 2013 (three birds), October 2017 (two birds) and October 2018 (single bird). There were three records from outside of the survey dates: September 2012 (two birds), September 2013 (single bird) and 35 birds in a September 2014 crepuscular survey. There were two winter records, which are presented in a later section. This species was not recorded after October 2018, when the mudflats had dried out.

Black-tailed Godwit *Limosa limosa*

This species was recorded on six occasions with the highest count being of four birds on 20 August 2013. There was one winter record in 2014, which was the last time that this species was recorded.

Red Knot *Calidris canutus*

There were two records of this species: a single bird on 21 October 2017 and four birds during the March 2018 nocturnal survey.

Curlew Sandpiper

Curlew Sandpiper occurred in counts of more than 15 birds during five of the eight migration periods (**Figure 4**) with the highest count being 41 birds in September 2016 (following heavy rain). This species largely abandoned the area after September 2018 coinciding with the mudflats having dried out. It was observed on five occasions outside the survey dates including during the nocturnal survey in March 2018. There were four winter records, which are presented in a later section.

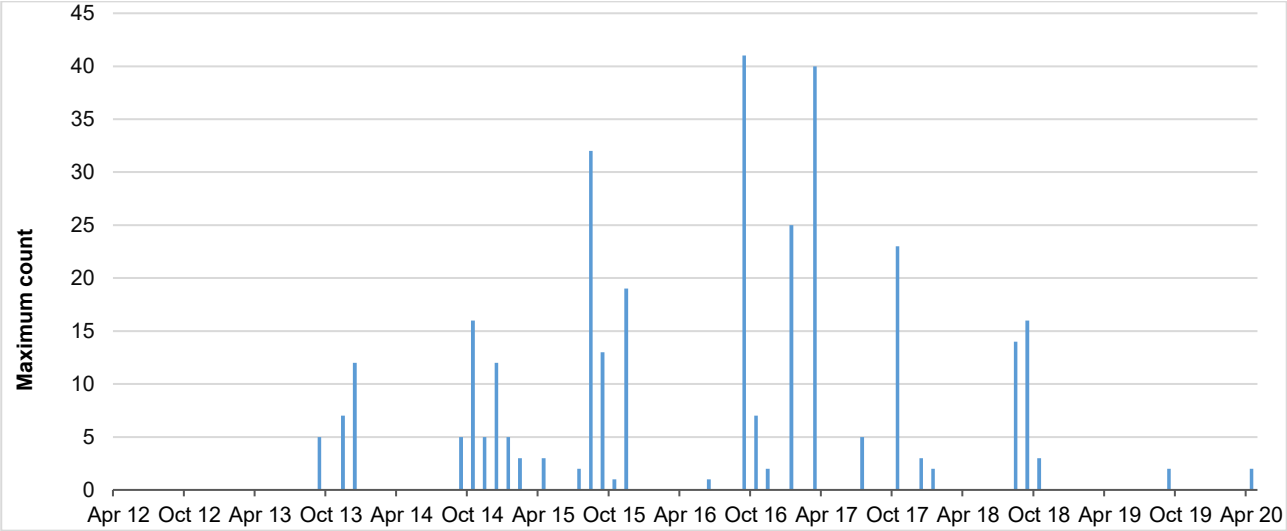

Figure 4. Monthly highest counts of Curlew Sandpiper at Tomago Wetland.

Other migratory shorebirds

Nine other species of migratory shorebirds were recorded (**Table 4**). Two species, Sharp-tailed Sandpiper *Calidris acuminata* and Common Greenshank *Tringa nebularia* had RRs above 50% and a further four species had RRs above 10%. Pectoral Sandpiper *Calidris melanotos* and Ruddy Turnstone *Arenaria interpres* were recorded only once and twice respectively.

Sharp-tailed Sandpiper

During five of eight migration periods, over 3,000 birds were recorded peaking in November 2014 at 5,008 birds (**Figure 5**). An estimate of 100 birds were present during the nocturnal survey in March 2018. There were four winter records.

Common Greenshank

On six of the eight migration periods, more than 80 birds were recorded with the highest number being 101 birds in February 2015. Numbers usually built up over the autumn months (**Figure 6**). Eighty-five birds were recorded at sunrise (0700 h) on 21 March 2020 and may have been present overnight. Some Common Greenshank were present in winter every year from 2013 onwards.

Red-necked Stint *Calidris ruficollis*

Fewer than ten birds were usually recorded, but on four occasions more than 30 birds were present, the

highest numbers being 88 birds in March 2015 and 60 birds in October 2017 after heavy rainfall (**Figure 7**). Twenty-six birds were recorded in September 2014 in twilight surveys. There were two winter records.

Pacific Golden Plover *Pluvialis fulva*

There were maximum counts of at least 25 birds in six of the eight migration periods in the 2012-2020 study, the highest counts being of 35 birds in January 2013 and March 2017 (**Figure 8**). Thirty-two birds were present in October 2018 but there were no further records for the 2018-19 season. The only record for the 2019-20 season was that of a single bird in September 2019. Seven birds were recorded in the September 2014 twilight survey and there was one winter record.

Marsh Sandpiper *Tringa stagnatilis*

There were maximum counts of at least 25 birds in four of the eight migration periods of the 2012-2020 study, the highest counts being of 43 birds in March 2017 (**Figure 9**). There were two winter records.

Latham's Snipe *Gallinago hardwickii*

Counts of up to eight birds occurred during the migration periods from 2012 to 2016. After February 2016 there were only two further records, once in 2017 (two birds) and once in 2018 (three birds).

Double-banded Plover *Charadrius bicinctus*

This east/west winter migrant was recorded in numbers (of up to 11 birds) during five migration periods of the 2012-2020 study. In August 2018, an unusually high number of 60 birds was recorded. The earliest arrival date was 17 February, in 2015.

Winter records of migratory shorebirds

Small numbers of nine species were recorded from mid-May to mid-August in at least some years. Common Greenshank was recorded in all eight winter periods, and both Sharp-tailed Sandpiper and Curlew Sandpiper were recorded in four winter periods. **Table 5** has details of all the winter records of migratory shorebirds.

Table 4. Additional migratory shorebirds species recorded at Tomago Wetland, with their maximum and median counts and Reporting Rate (presented in descending order of RR).

Common Name	Scientific Name	Maximum	Median[#]	RR%
Sharp-tailed Sandpiper	*Calidris acuminata*	5008	202	68.9
Common Greenshank	*Tringa nebularia*	101	17	64.6
Red-necked Stint	*Calidris ruficollis*	88	3	26.2
Pacific Golden Plover	*Pluvialis fulva*	35	9	19.5
Marsh Sandpiper	*Tringa stagnatilis*	43	4	17.7
Latham's Snipe	*Gallinago hardwickii*	8	2	12.2
Double-banded Plover	*Charadrius bicinctus*	60	2	6.1
Ruddy Turnstone	*Arenaria interpres*	1		1.2
Pectoral Sandpiper	*Calidris melanotos*	1		0.6

[#]Medians are not reported when there were fewer than three records

Table 5. Winter records of migratory shorebird species at Tomago Wetland.

Common Name	2013	2014	2015	2016	2017	2018	2019	2020
Pacific Golden Plover				1				
Far Eastern Curlew				13	12			
Bar-tailed Godwit		7	1					
Black-tailed Godwit		1						
Sharp-tailed Sandpiper		1	2			3	8	
Curlew Sandpiper			2	1	5	14		
Red-necked Stint				1		28		
Common Greenshank	2	19	12	38	1	4	33	27
Marsh Sandpiper			1				2	

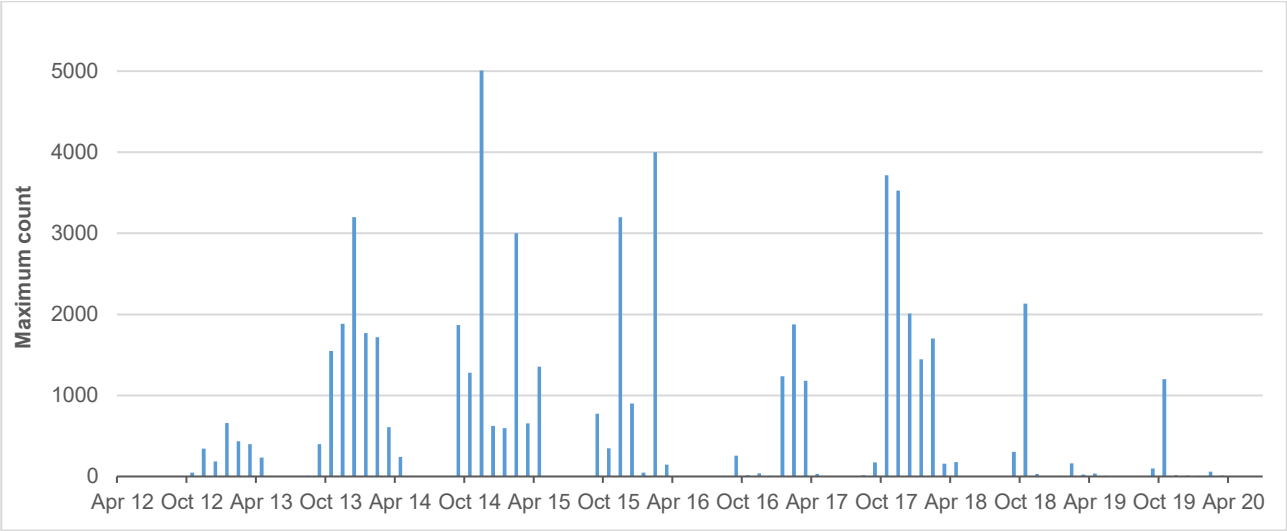

Figure 5. Monthly highest counts of Sharp-tailed Sandpiper at Tomago Wetland.

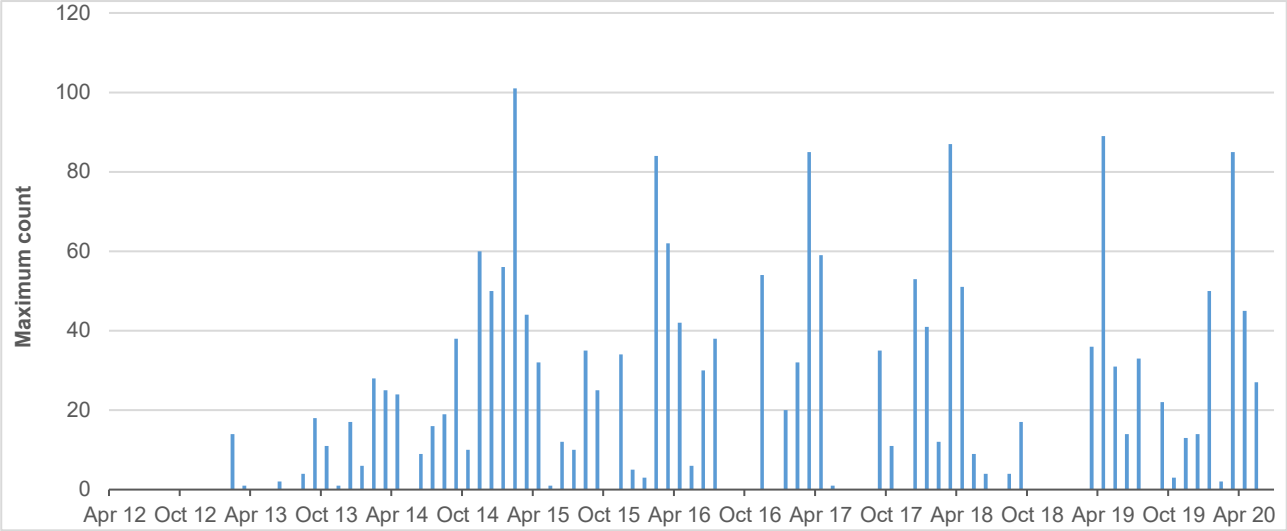

Figure 6. Monthly highest counts of Common Greenshank at Tomago Wetland.

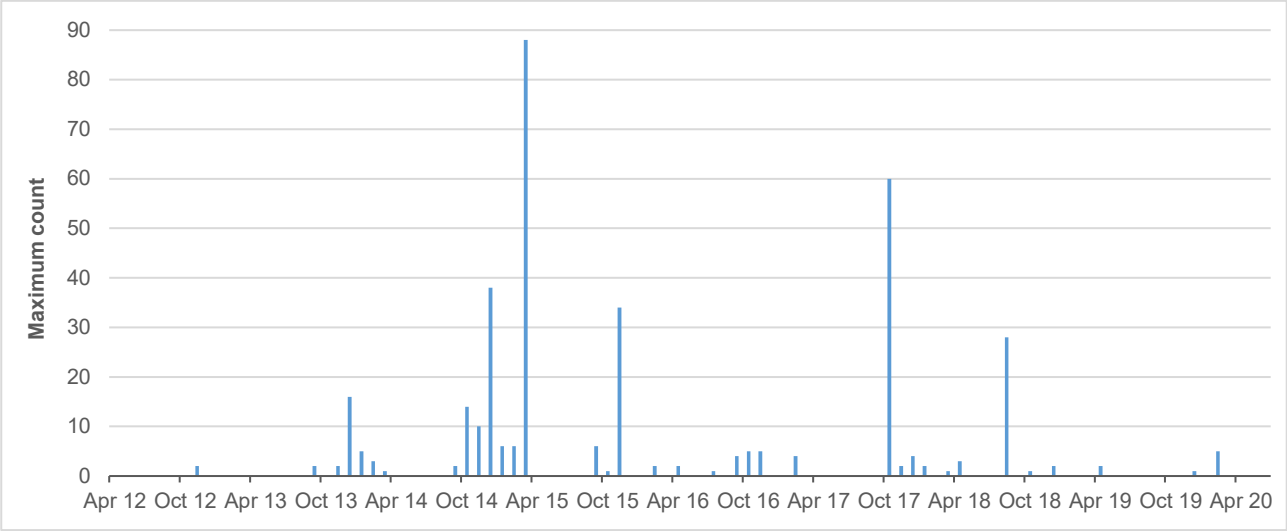

Figure 7. Monthly highest counts of Red-necked Stint at Tomago Wetland.

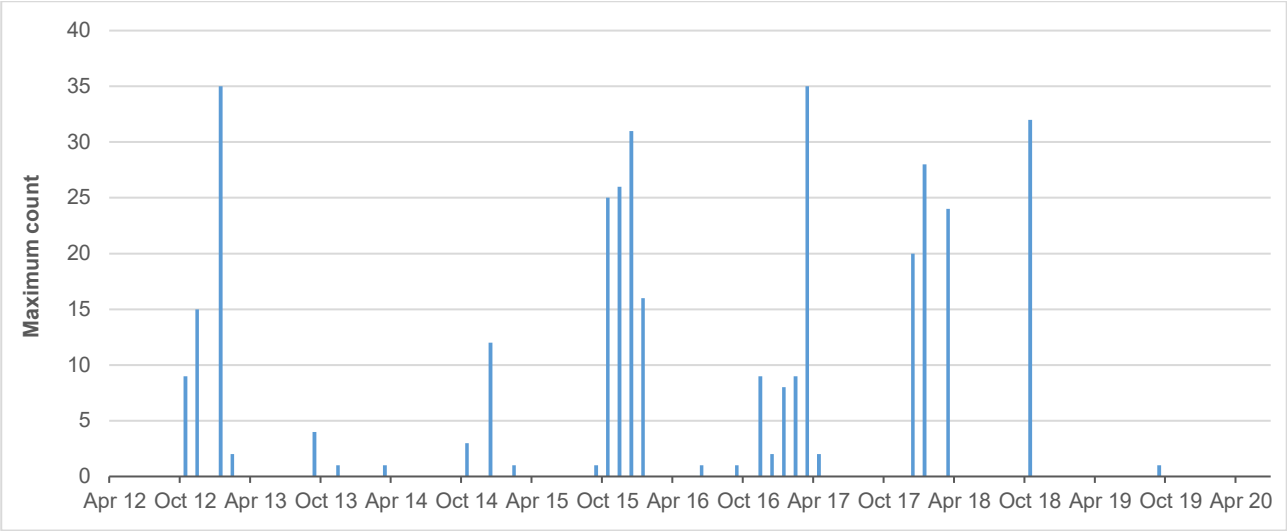

Figure 8. Monthly highest counts of Pacific Golden Plover at Tomago Wetland.

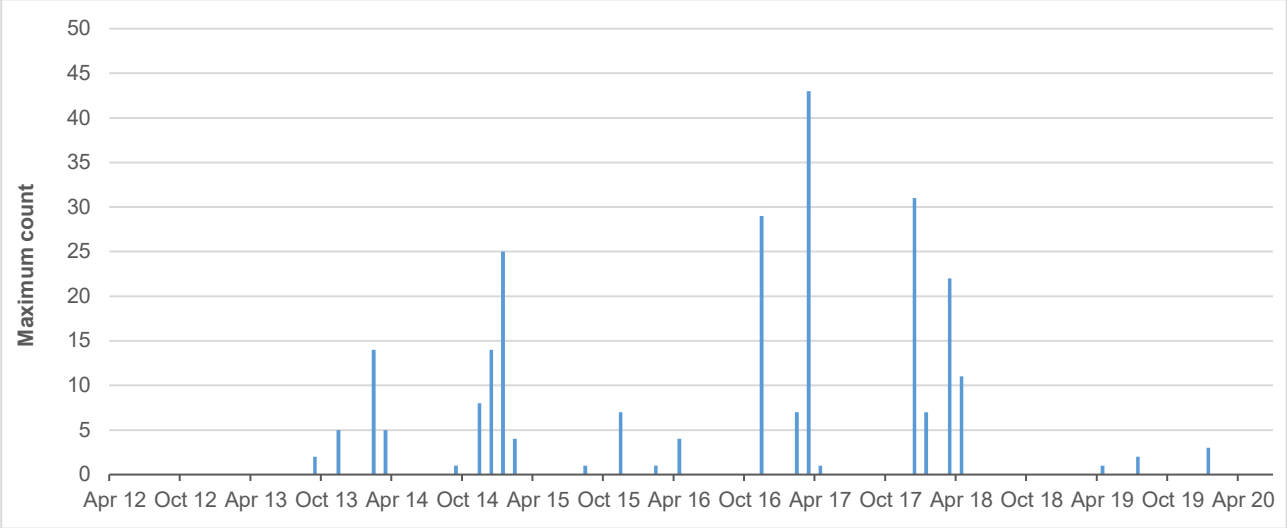

Figure 9. Monthly highest counts of Marsh Sandpiper at Tomago Wetland.

Australian resident shorebirds

Six species of Australian resident shorebirds were recorded (**Table 6**). Two species had RRs of over 50% and the others had RRs above 10%.

Masked Lapwing *Vanellus miles*

This species had the highest RR of all waterbird species recorded at Tomago Wetland. It was absent on only one survey during the 2012-2020 study. More than 60 birds were present in 12 of the surveys (in nine different months), the highest number being 164 birds in April 2018 (**Figure 10**). There was one breeding event, when a pair had a dependent young in October 2016.

Table 6. Resident shorebirds recorded in the study area, with their maximum and median counts and Reporting Rate (presented in descending order of RR).

Common Name & Scientific Name	Max	Median	RR%
Masked Lapwing *Vanellus miles*	164	16	99.4
Pied Stilt *Himantopus leucocephalus*	605	44	50.6
Red-kneed Dotterel *Erythrogonys cinctus*	57	4	23.8
Black-fronted Dotterel *Elseyornis melanops*	48	7	21.3
Red-necked Avocet *Recurvirostra novaehollandiae*	1421	37	18.9
Red-capped Plover *Charadrius ruficapillus*	157	5	14.0

Pied Stilt *Himantopus leucocephalus*

In 2013, 2014 and 2017 this species was regularly present in numbers of more than 300 birds, with the maximum being 605 birds in December 2014 (**Figure 11**).

Red-necked Avocet *Recurvirostra novaeholl-andiae*

The first record for this species at Tomago Wetland was in November 2013. Numbers rose to a peak of 1,421 birds in May 2015 then declined again (**Figure 12**). After September 2018 there were no further records. On two twilight counts in September 2014 I estimated 500 and 2000 birds flying in after sunset. They settled on Samphire Flats and were still present when I left at dark.

Red-capped Plover *Charadrius ruficapillus*

Small numbers were present in five of the years during the study period 2012-2020. An unusually high count of 157 birds was recorded on 11 August 2018 (**Figure 13**).

Red-kneed Dotterel *Erythrogonys cinctus*

In 2013 and 2014 Red-kneed Dotterel favoured two sites – Samphire Flats and Dotterel Swale. The species abandoned Dotterel Swale from January 2015 but continued to be recorded regularly at Samphire Flats. From April 2017 it began to regularly utilise Northern Flats. The highest number was 57 birds on 11 August 2018 after which it disappeared from the study area (**Figure 14**). Birds had dependent young in November and December 2013, September 2014 and October 2015.

Black-fronted Dotterel *Elseyornis melanops*

After April 2017 there was a steady increase in numbers of Black-fronted Dotterel to a maximum of 48 birds on 11 August 2018 (**Figure 15**). This species was observed twice as frequently on the Rice Paddy site as on Samphire Flats (22 records, compared with 11 records).

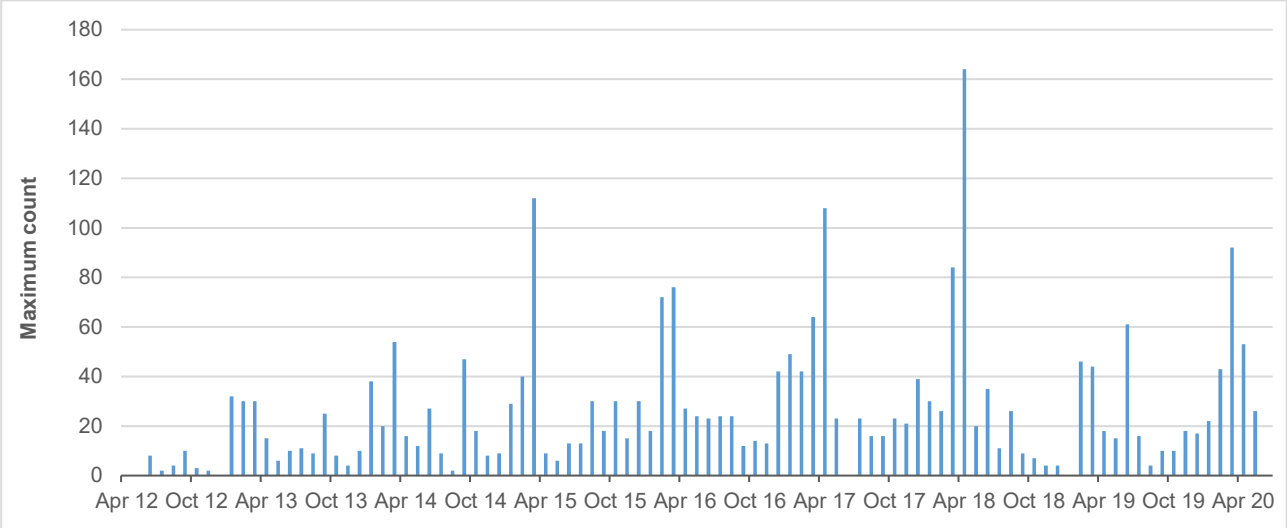

Figure 10. Monthly highest counts of Masked Lapwing at Tomago Wetland.

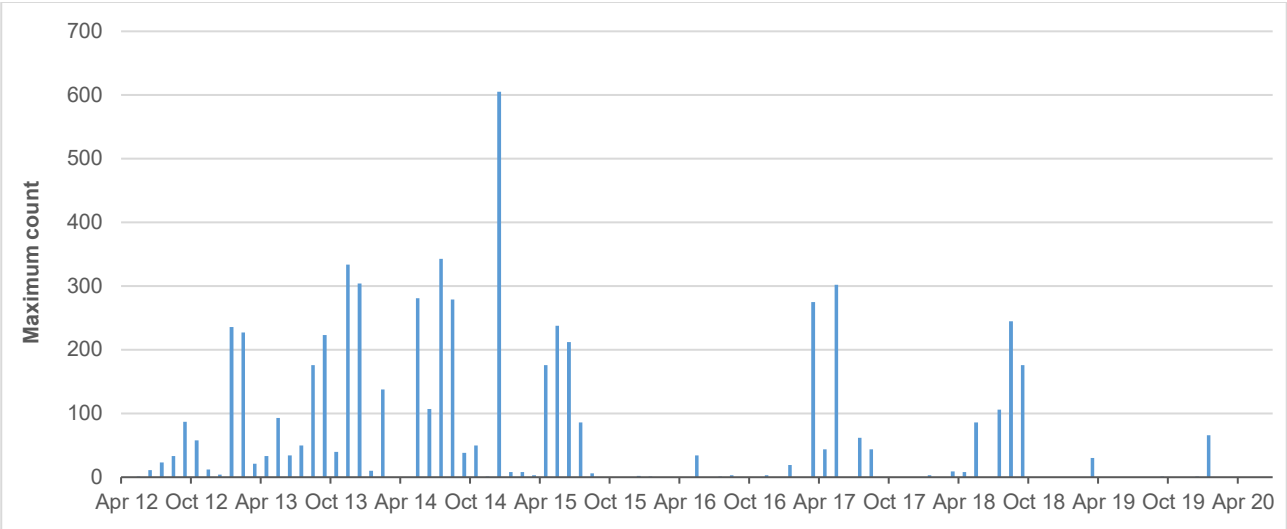

Figure 11. Monthly highest counts of Pied Stilt at Tomago Wetland.

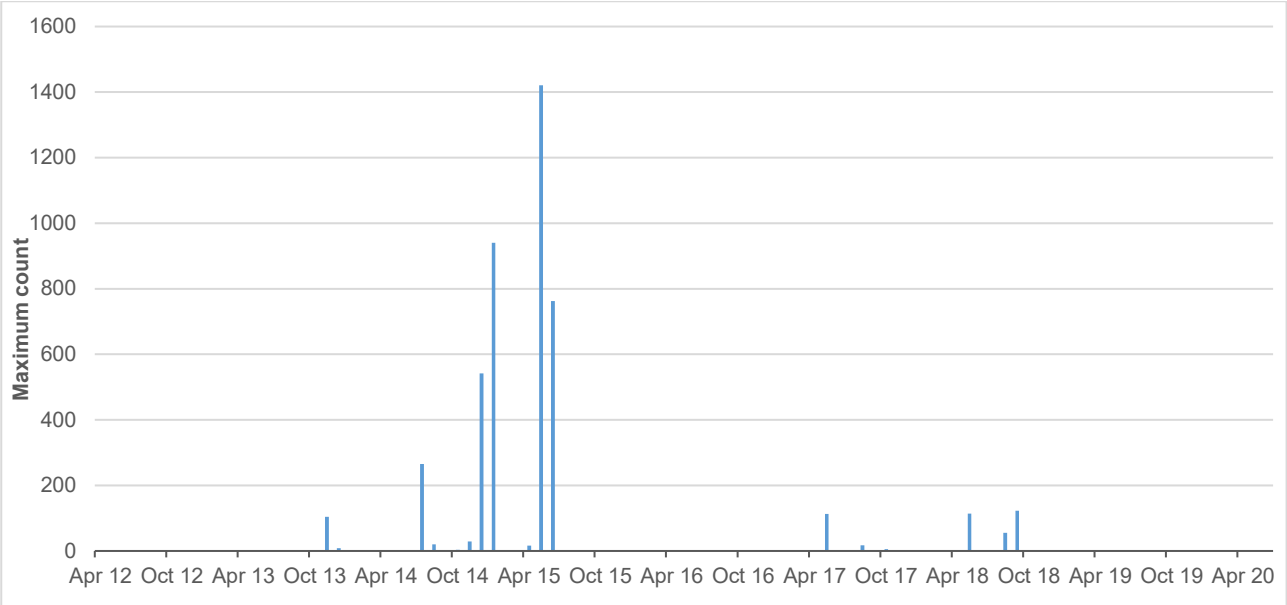

Figure 12. Monthly highest counts of Red-necked Avocet at Tomago Wetland.

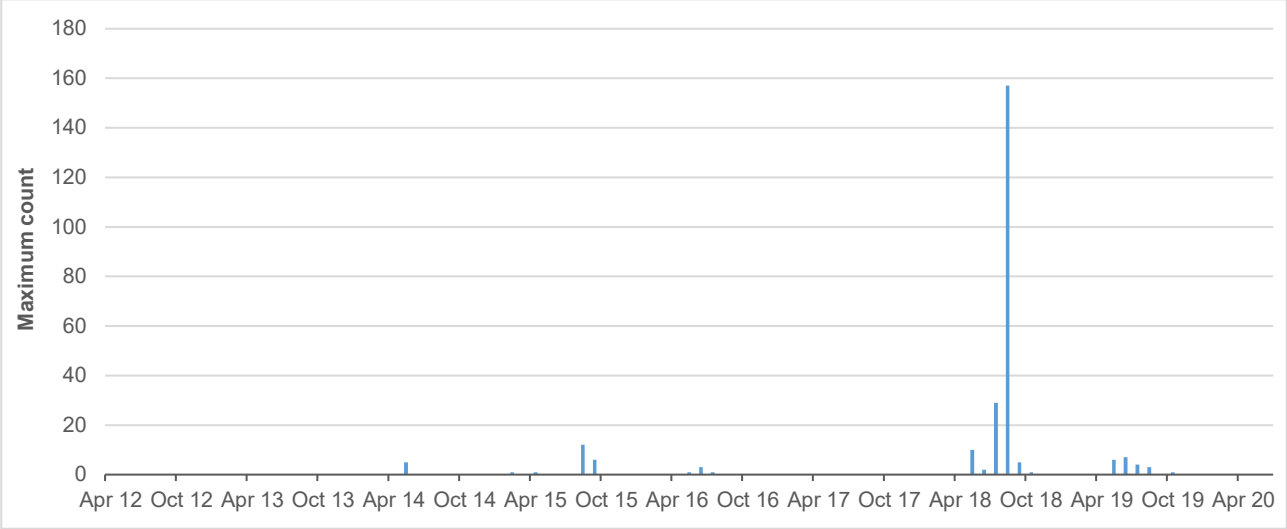

Figure 13. Monthly highest counts of Red-capped Plover at Tomago Wetland.

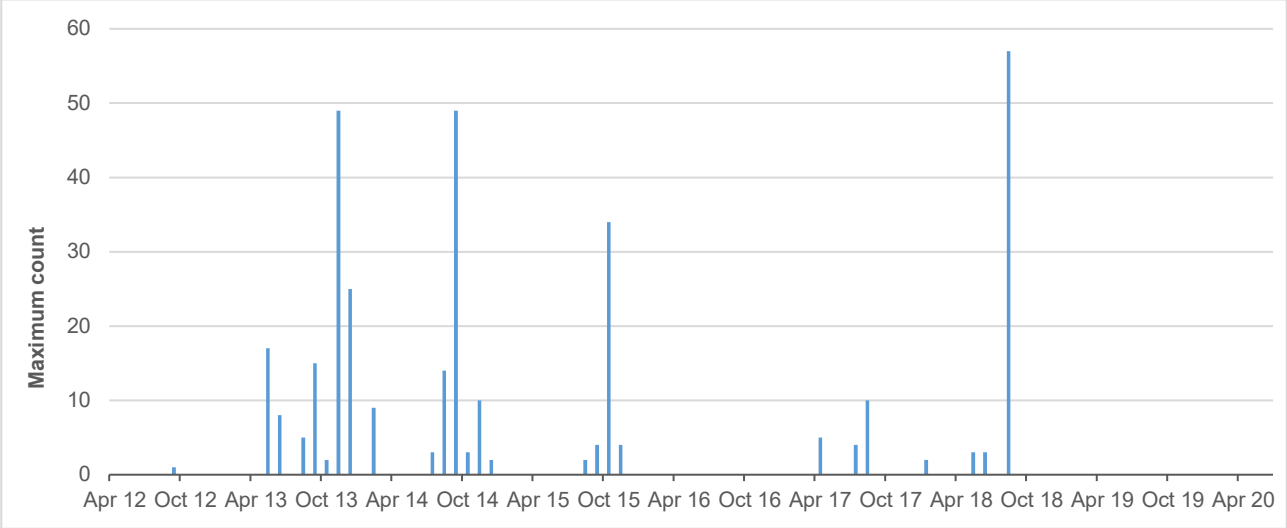

Figure 14. Monthly highest counts of Red-kneed Dotterel at Tomago Wetland.

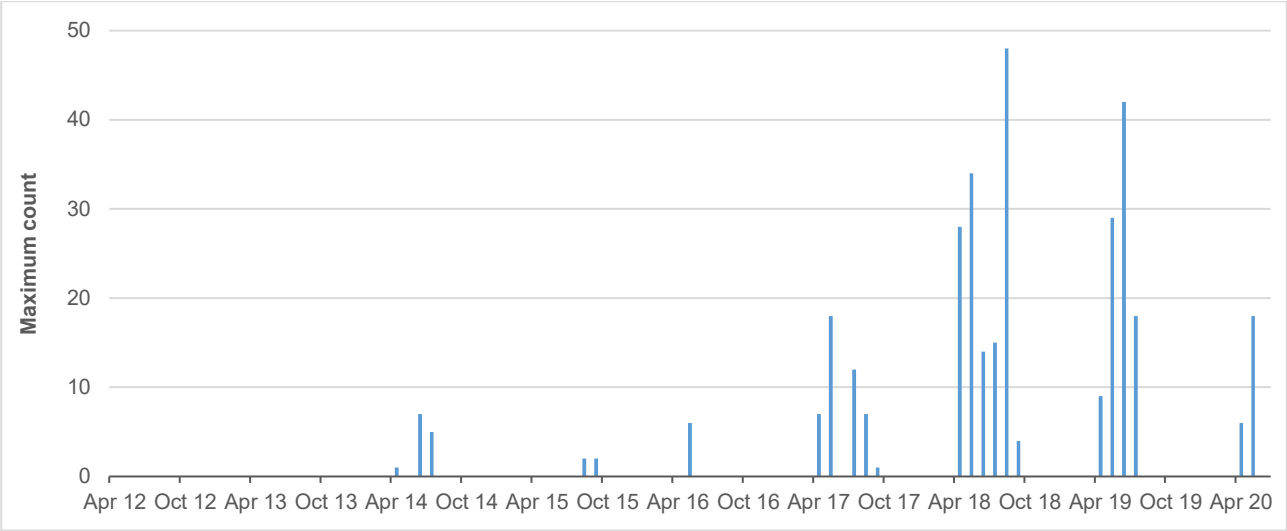

Figure 15. Monthly highest counts of Black-fronted Dotterel recorded at Tomago Wetland.

Waterfowl

Eight species of waterfowl were recorded (**Table 7**). However, three species, Australian Wood Duck *Chenonetta jubata*, Pink-eared Duck *Malacorhynchus membranaceus* and Hardhead *Aythya australis*, were each recorded on only 2-3 occasions.

Black Swan *Cygnus atratus*

Figure 16 shows that the highest counts were during April to July 2015 with a maximum of 198 birds in May 2015. Birds had dependent young in May 2013, May 2017 and October 2017.

Chestnut Teal *Anas castanea*

From February to May 2017 more than 600 birds were present during each monthly count with the highest number being 1506 birds in March (**Figure 17**). Birds had dependent young in April 2013, September, October and November 2016 and March 2020, and a nest with eggs in October 2019.

Pacific Black Duck *Anas superciliosa*

Pacific Black Duck was regularly recorded with the maximum count being 74 birds in March 2015 (**Figure 18**). Birds had dependent young in October 2014 and March 2016.

Grey Teal *Anas gracilis*

Grey Teal was regularly recorded with the maximum count being 1,622 birds in May 2013 (**Figure 19**).

Australasian Shoveler *Spatula rhynchotis*

Australasian Shoveler was regularly recorded in autumn with the maximum count being 142 birds in April 2015 (**Figure 20**).

Table 7. Main waterfowl species recorded at Tomago Wetland, with their maximum and median counts and Reporting Rate (presented in descending order of RR).

Common Name	Scientific Name	Maximum	Median	RR%
Black Swan	*Cygnus atratus*	198	12	68.9
Chestnut Teal	*Anas castanea*	1506	36	64.6
Pacific Black Duck	*Anas superciliosa*	74	11	53.0
Grey Teal	*Anas gracilis*	1622	150	49.4
Australasian Shoveler	*Spatula rhynchotis*	142	6	21.9
Australian Wood Duck	*Chenonetta jubata*	10	2	1.8
Pink-eared Duck	*Malacorhynchus membranaceus*	8	6	1.8
Hardhead	*Aythya australis*	6	4	1.2

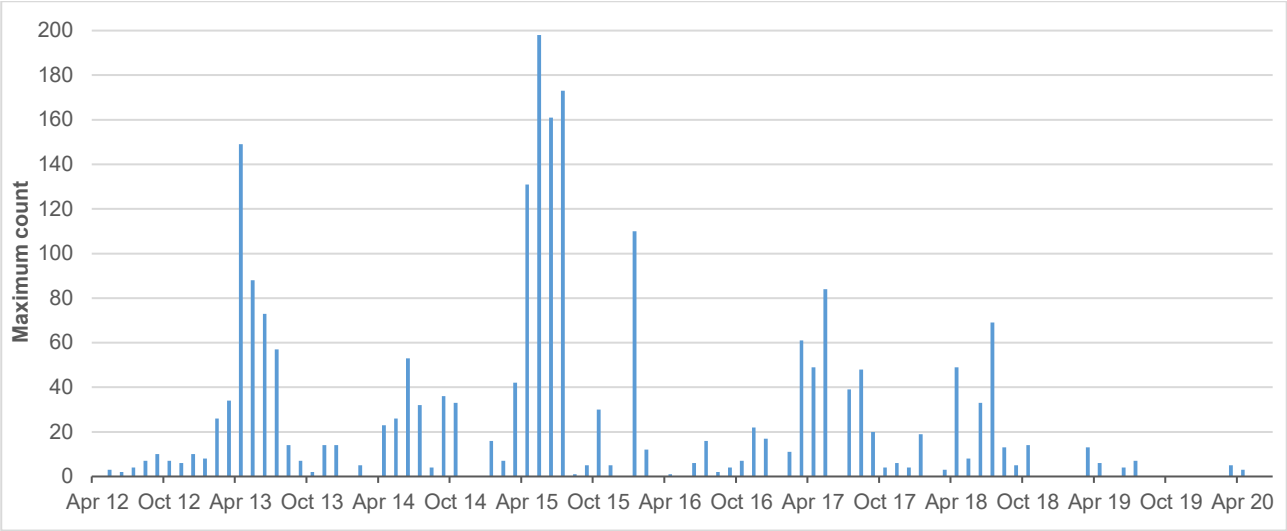

Figure 16. Monthly highest counts of Black Swan at Tomago Wetland.

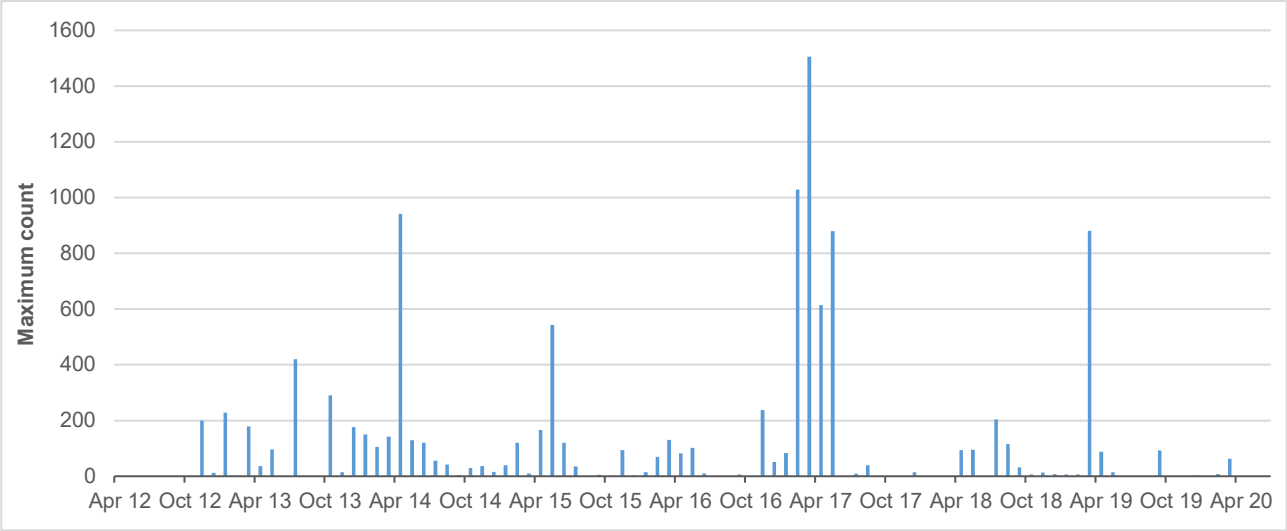

Figure 17. Monthly highest counts of Chestnut Teal at Tomago Wetland.

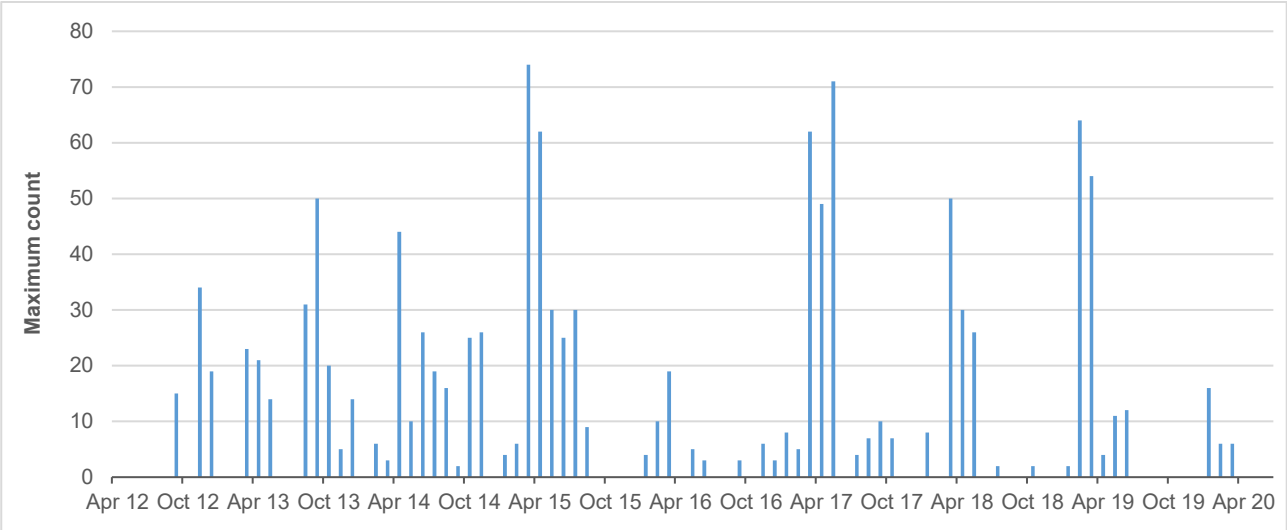

Figure 18. Monthly highest counts of Pacific Black Duck recorded at Tomago Wetland.

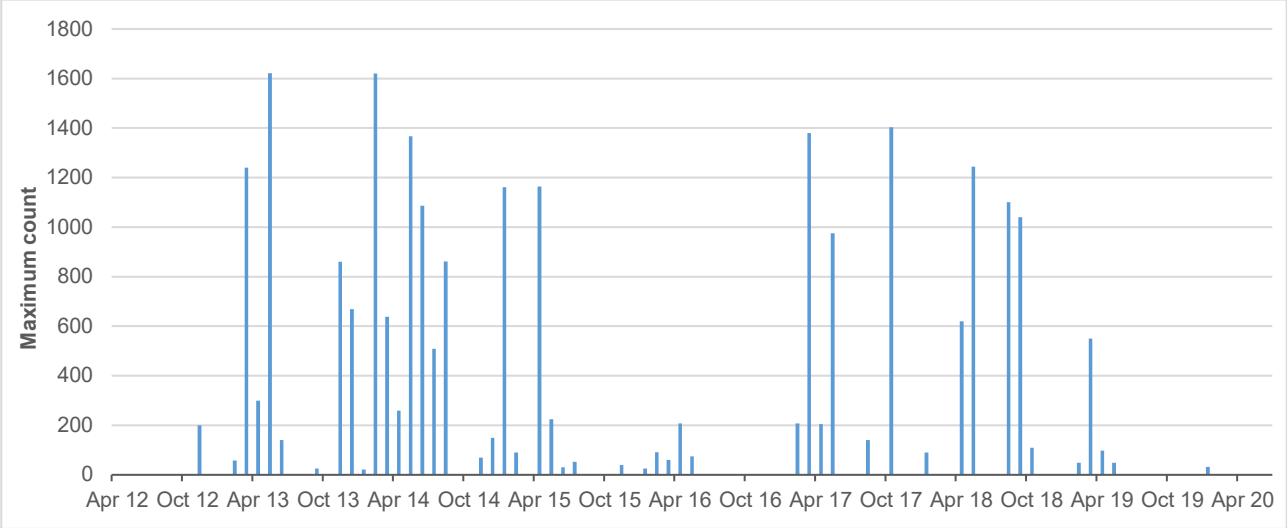

Figure 19. Monthly highest counts of Grey Teal at Tomago Wetland.

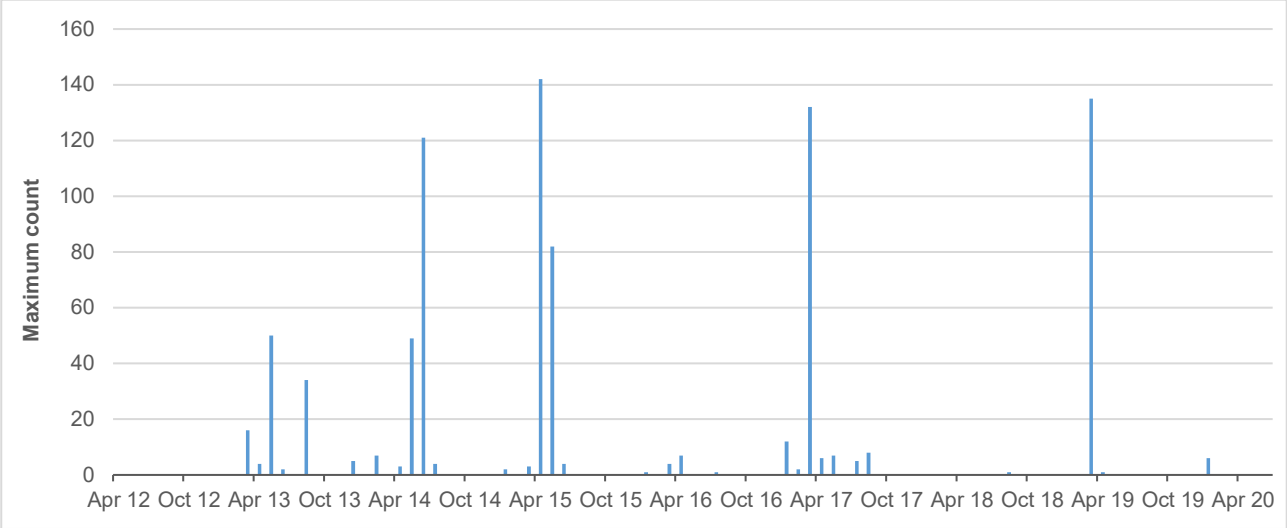

Figure 20. Monthly highest counts of Australasian Shoveler at Tomago Wetland.

Additional waterbird species

In addition to the species already detailed, 31 other waterbird species were recorded. They are listed in **Table 8**. I have selected three of the species for analysis.

White-faced Heron *Egretta novaehollandiae*

This species had the second highest RR of all waterbird species, 98.2%. It was present on 161 out of 164 surveys and the counts were frequently of more than 50 birds (**Figure 21**).

White-necked Heron *Ardea pacifica*

Most of the counts were in the single digits, but there were two notably larger ones – 29 birds were present in January 2014 and 22 birds in August 2014.

Purple Swamphen *Porphyrio porphyrio*

After April and December 2013 when the highest counts of 146 birds and 125 birds were recorded, there was a gradual decrease in numbers (**Figure 22**). Birds had dependent young in May 2013. This normally sedentary, swamp-dwelling bird (Pringle 1985) is now seldom seen within the study site.

Table 8. Thirty-one additional waterbird species recorded in the study area, with their maximum and median counts and Reporting Rate (presented in descending order of RR).

Common Name	Scientific Name	Maximum	Median[#]	RR (%)
White-faced Heron	*Egretta novaehollandiae*	162	31	98.2
Great Egret	*Ardea alba*	28	2	81.7
Australian White Ibis	*Threskiornis moluccus*	185	13	78.1
Little Pied Cormorant	*Microcarbo melanoleucos*	5	2	48.2
Australian Pelican	*Pelecanus conspicillatus*	56	3	42.1
Royal Spoonbill	*Platalea regia*	68	4	42.1
Purple Swamphen	*Porphyrio porphyrio*	146	7	33.5
Little Black Cormorant	*Phalacrocorax sulcirostris*	40	3	32.9
Little Egret	*Egretta garzetta*	4	1	23.2
White-necked Heron	*Ardea pacifica*	29	2	18.9
Caspian Tern	*Hydroprogne caspia*	15	2	15.9
Straw-necked Ibis	*Threskiornis spinicollis*	96	6	11.0
Silver Gull	*Larus novaehollandiae*	19	2	9.1
Australian Spotted Crake	*Porzana fluminea*	4	-	8.5
Great Pied Cormorant	*Phalacrocorax varius*	4	1	6.7
Intermediate Egret	*Ardea intermedia*	2	1	5.5
Australasian Darter	*Anhinga novaehollandiae*	3	1	4.9
Eurasian Coot	*Fulica atra*	451	117	3.7
Australian Gull-billed Tern	*Gelochelidon macrotarsa*	2	1	3.7
Striated Heron	*Butorides striata*	2	1	3.1
Cattle Egret	*Bubulcus ibis*	5	3	1.8
Glossy Ibis	*Plegadis falcinellus*	42	36	1.8
Baillon's Crake	*Zapornia pusilla*	1	-	1.2
Great Cormorant	*Phalacrocorax carbo*	2	2	1.2
Spotless Crake	*Zapornia tabuensis*	1	-	1.2
Yellow-billed Spoonbill	*Platalea flavipes*	2	-	1.2
Australasian Grebe	*Tachybaptus novaehollandiae*	6	2	0.6
Australian Little Bittern	*Ixobrychus dubius*	1	-	0.6
Buff-banded Rail	*Hypotaenidia philippensis*	1	-	0.6
Dusky Moorhen	*Gallinula tenebrosa*	6	-	0.6
Hoary-headed Grebe	*Poliocephalus poliocephalus*	1	-	0.6

[#]Medians are not reported when there were fewer than three records

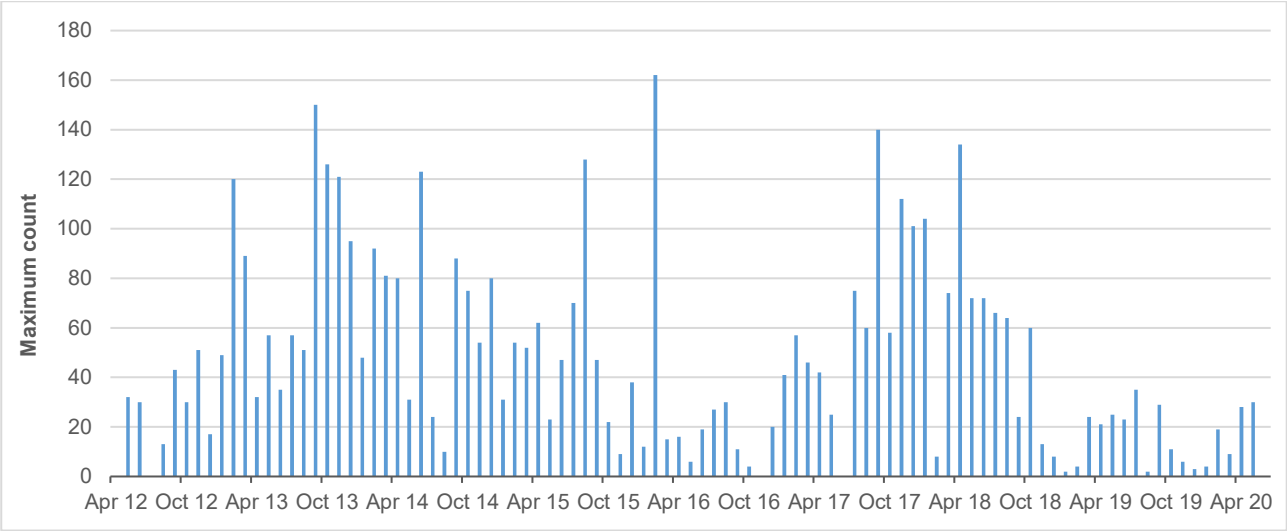

Figure 21. Monthly highest counts of White-faced Heron at Tomago Wetland.

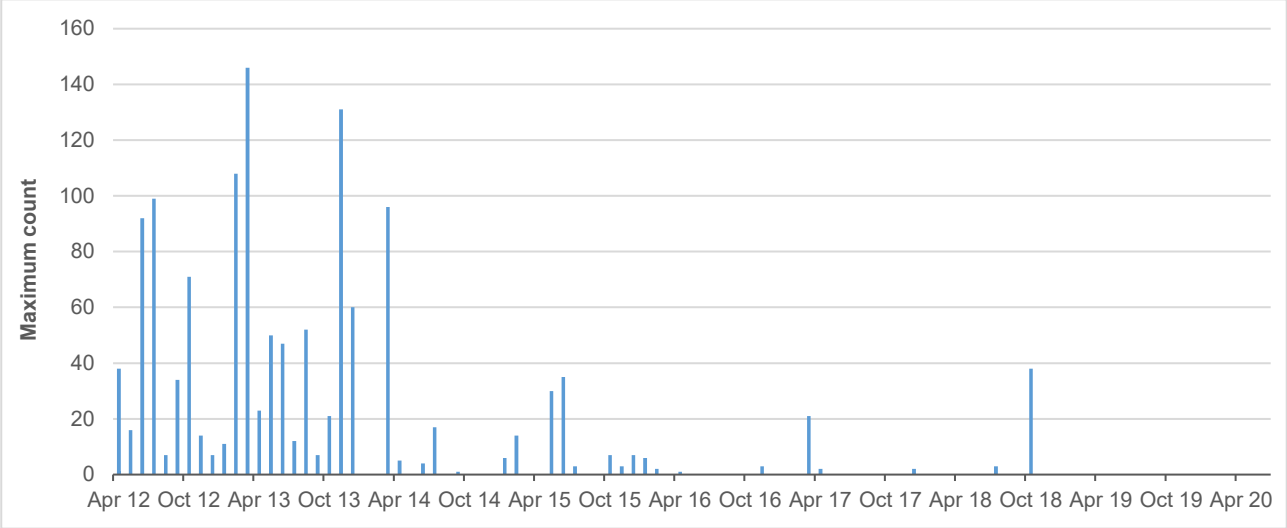

Figure 22. Monthly highest counts of Purple Swamphen at Tomago Wetland.

The date 11 August 2018

The highest numbers of Double-banded Plover (60 birds), Red-capped Plover (157 birds), Black-fronted Dotterel (48 birds) and Red-kneed Dotterel (57 birds) all occurred on this date. Five other species of shorebirds were present as were four species of waterfowl including over 1,000 Grey Teal. Good conditions prevailed that day, with wet mudflats and a high level of water in depressions and channels.

Breeding records

Six species of waterbirds were recorded as breeding during the 2012-2020 study period: Black Swan, Chestnut Teal, Pacific Black Duck, Purple Swamphen, Masked Lapwing and Red-kneed Dotterel. Details are provided within the individual species accounts.

Nocturnal survey

In a nocturnal survey on 2 March 2018, eleven waterbird species were identified (**Table 9**) including four migratory shorebird species.

Table 9. Waterbirds recorded on Samphire Flats nocturnally.

Common Name	Number
Black Swan	4
White-faced Heron	1
Australian Pelican	1
Great Pied Cormorant	1
Red-necked Avocet	12
Pied Stilt	4
Far Eastern Curlew	2
Red Knot	4
Sharp-tailed Sandpiper	100
Curlew Sandpiper	2
Silver Gull	present

DISCUSSION

Comparison of this 2012-2020 study with the previous one (Lindsey & McNaughton 2012) reveals a substantial increase in diversity and abundance of waterbirds in the second study period. During the initial five-year study, only a small increase in the diversity and abundance of waterbirds occurred after the reintroduction of tidal water. Among the factors contributing to changes initially being only small may have been the intermittent closure of the tidal gates, at one stage for almost two years (Lindsey & McNaughton 2012). Also, heavy inland rains in 2010 after a period of prolonged drought conditions would have attracted waterbird species to inland areas.

From 2012 to 2020, the overall diversity almost doubled, from 33 species to 61 species. The number of shorebird species quadrupled from five to 20. The number of other waterbird species increased from 28 to 41 species. The increase in diversity was mirrored by a substantial increase in abundance of the common species. Overall diversity and abundance began to decrease during the latter years of the study as drought conditions intensified and salt marsh and mudflats intermittently dried out.

The increase in birdlife, and in particular shorebirds, coincided with more consistent tidal flushing which resulted in the spread of salt marsh and the creation of mudflats and tidal pools which were independent of rainfall. The nocturnal survey along with crepuscular surveys suggested that waterbirds were once again utilising Tomago Wetland during non-daylight hours. It also became important for shorebirds during the Australian winter months. Although 14 species of migratory shorebirds responded initially to the reintroduction of tidal water, only Sharp-tailed Sandpiper and Common Greenshank regularly returned in significant numbers. They would have been able to benefit from the increased amount of time that they could spend roosting on and foraging in suitable habitat. However, when the tidal gates were closed for long periods, the amount of water retention diminished and the salt marsh and mudflats dried out. As a result, most species departed. The role of tidal flushing in the increased abundance of waterfowl from 2013 is unclear but during periods when the tidal gates were open to maximum capacity, water would have been retained in depressions and channels thus providing suitable habitat for a longer time especially during periods of low rainfall.

One of the negative effects of the Tomago Wetland Restoration Project has been the decrease in suitable habitat for some species. It is likely that the transition from freshwater to an estuarine environment caused the disappearance of Australasian Bittern, Purple Swamphen and Latham's Snipe from their former sites. However, tidal flushing has not extended over the entire wetland area and large areas of freshwater-influenced habitat have continued to flourish. Such areas are not monitored regularly and those species may still be present there.

Effects from droughts and floods and closures of tidal gates

The process of managing the Restoration Project is complex and involves multiple interests, objectives and on-ground works (Russell *et al.* 2012). Since commissioning of the SmartGate system in October 2008 (Lindsey & McNaughton 2012) and the Swing Gates in 2011 (Russell *et al*. 2012), it became necessary to close both systems either separately or together for varying amounts of time. The main reasons for closures were maintenance/repairs, long rain periods impacting on neighbours' drainage channels and threat of flooding or failure of levees designed to protect private land from salt-water encroachment (J. Erskine pers. comm.).

The consequences of the interruptions were that tidal flushing reached only as far as Rice Paddy and the depressions/channels on the western side of Samphire Flats. The ingress of saline water to northern and eastern salt marsh and mudflat areas (Stage 2 of the project) was to come via the Swing Gates which were essential to the success of the project (Russell *et al.* 2012). The Swing Gates were non-operational for varying periods in 2012 (one month), 2013 (two months), 2015 (four months) and from October 2018 to May 2020 (20 months) (J. Erskine pers. comm.) In tandem with the Swing Gates closures, it was also necessary, although not on every occasion, to close the SmartGate system; this further exacerbated the problem of drying salt marsh and mudflats, especially in drought periods. The closure of these systems led to an extensive area, in fact most of the site, being completely dry over several months particularly during 2016, 2018 and 2019. As a result, most waterbird species disappeared and Tomago Wetland went from being a haven for waterbirds to a virtual desert for long periods. The effects on shorebird species were particularly detrimental when closures occurred during the southern (spring) migration period.

It was observed that if one or two inlets of the SmartGate system remained open, allowing some limited tidal flushing to Samphire Flats and Rice

Paddy, some species remained. Common Greenshank, Marsh Sandpiper and White-faced Heron persisted on Samphire Flats because of their preference for foraging and/or roosting in shallow water retained in channels/depressions rather than on mudflats. As Rice Paddy converted from a freshwater-influenced site largely covered in Common Reed to salt marsh and mudflats, it began to attract small shorebirds such as Black-fronted Dotterel, Red-kneed Dotterel and Red-capped Plover. Perhaps because it is much smaller than Samphire Flats and is enclosed by a levee, Rice Paddy retained moist mudflats or shallow water even when mudflats away from channels/depressions on Samphire Flats were totally dry. This may explain why Rice Paddy attracted small shorebirds during extensive dry periods.

Response of some species to average and above-average rainfall/flooding

Red-necked Avocet

The Hunter Estuary supports between 1% and 6.5% of the total population of Red-necked Avocet (Stuart 2017). Although the species favours roosting sites on Stockton Sandspit and Kooragang Dykes, small numbers started to appear at Tomago Wetland from 2013. Numbers peaked in May 2015 at 1,421 birds - which is more than 1% of the population. The peak occurred after an East Coast Low in April 2015 had caused widespread local flooding. Numbers decreased after May 2015 with no records in 2016, 2019 and 2020 probably due to the dry condition of the mudflats. Although numbers fluctuated, Red-necked Avocet continued to be present at other sites in the Hunter Estuary.

White-necked Heron

This species is usually seen singly or in pairs (Marchant & Higgins 1990). The sudden increases in numbers at Tomago in 2014 may reflect its irruptive behaviour after heavy rainfall (Marchant & Higgins 1990). A sudden increase was similarly observed during the study period 2007-2012 when 26 birds were recorded in November 2008 (Lindsey & McNaughton 2012).

Waterfowl

Comparison of RRs and maximum numbers of three common species, Black Swan, Chestnut Teal and Pacific Black Duck, with those in the previous study period shows increases in their populations. However, it is difficult to ascertain the reason for that. Although prolonged heavy rain from late 2009 broke the long-term drought, and coastal wetlands filled to capacity, waterfowl seldom were recorded at Tomago until late 2012. An explanation for this may be that waterfowl remained inland during 2010-2012 because the conditions there were optimal, and that they moved to coastal areas only in response to drying inland conditions. Eight of the ten highest waterfowl counts at Tomago occurred in the autumn months, March to May (**Table 10**), when there is usually an increase in rainfall on the east coast of NSW (Bureau of Meteorology 2020). Average to high rainfall had filled channels and depressions attracting waterfowl irrespective of the status of the tidal gates. This was the case with Black Swan, Chestnut Teal and Grey Teal. Black Swan and Grey Teal are well-known for their response to rainfall especially after dry periods (Chambers & Loyn 2006). The numbers of Australasian Shoveler usually built up over autumn and winter and they disappeared during the spring months. Some summer visits occurred, again seemingly prompted by rainfall.

Table 10. Dates of the ten highest waterfowl counts in descending order and showing in which month(s) rainfall was above average.

Date of survey	Number of water-fowl	Month/s with above-average rainfall	Rainfall in the month/ months (ml)
11 March 2017	3107	March	272.4
13 May 2017	2007	April	106.6
21 May 2013	1870	March/ April	193.8/ 142
18 February 2014	1739	February	99.1
18 April 2015	1665	April	360.3
19 March 2019	1633	March	109.3
20 May 2014	1581	April/ May	135.2/ 85.5
19 March 2013	1492	March	193.8
16 May 2017	1477	April	106.6
21 October 2017	1408	October	113.8

Tomago Wetland – a site of international and national importance

Sharp-tailed Sandpiper

The Hunter Estuary is a site of international importance for Sharp-tailed Sandpiper as it regularly hosts more than 1% of the world population (Stuart 2019). Tomago Wetland alone hosted more than the threshold number of 850 birds (Hansen *et al.* 2016) in six migration periods from 2013/14 to 2018/19 and more than 4% of the world population in three periods - 2014, 2016 and 2017.

The peak count of 5,008 birds in 2014 was approximately 6% of the world population. In November 2015 and February 2016, Tomago Wetland was the favoured site for this species within the Hunter Estuary, with the majority of birds in the estuary being recorded there. The remarkable response of this species may be due to an apparent preference for newly-established salt marsh where tidal inundation has been restored (Stuart 2019). Along with other shorebird species such as Curlew Sandpiper, Red-necked Stint and Pacific Golden Plover, Sharp-tailed Sandpiper numbers decreased whenever the tidal gates were closed and the salt marsh, mudflats and shallow tidal pools had dried out.

It was often difficult to obtain an accurate count of Sharp-tailed Sandpiper because of its propensity to roost and forage in moist salt marsh especially Samphire, its prime habitat (Daly 2013). Counts made whilst the birds were on the ground may have been under-estimates. More accurate estimates became possible when flocks were put to flight by raptors such as Swamp Harrier *Circus approximans*. The problem of obtaining accurate counts of this species is considered by Stuart when attempting to account for periodic departures from the estuary (Stuart 2019).

Double-banded Plover

Under the Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia 2015), if a site regularly supports 0.1% or more of an East Asian-Australasian Flyway population of any migratory shorebird species, it is considered to be of national importance for that species. The threshold for Double-banded Plover is 19 birds (Hansen *et al.* 2016). The count of 60 birds far exceeds this threshold but whether counts greater than 19 birds occur regularly is unknown as no data exist outside of the survey visits.

Chestnut Teal

The Hunter Estuary was identified as a site of international importance for Chestnut Teal (Lindsey & Roderick 2011) from application of the 1% population threshold criterion (Wetlands International 2020). In February-March 2017, Tomago Wetland met that criterion when more than 1% of the Chestnut Teal population was present (i.e. more than 1,000 birds).

Impact of acid sulphate soils (ASS)

Tomago Wetland has the unfortunate distinction of being the second highest priority area in the Hunter Region for remediation owing to extensive presence of ASS (Russell *et al.* 2012). Opening the tidal gates may dilute and neutralise ASS discharge from the wetlands (Russell *et al*. 2012). The ecological impacts of acidification include loss of benthic communities, loss of native aquatic macrophytes and fauna, mortality of crustaceans and shellfish, and fish kills (Ward *et al*. 2013). It is speculated that food supplies at Tomago Wetland were affected by ASS which may account for some species appearing only a few times and not returning. Common Greenshank and Marsh Sandpiper are described as carnivorous (Higgins & Davies 1996). They may have been less affected as they often prefer to forage in water where the food items available include fish, and where acidification may have had less impact. Bar-tailed Godwit, which is also described as mainly carnivorous (Higgins & Davies 1996), was recorded on 14 occasions, but its visits did persist until 2018. Sharp-tailed Sandpiper is described as omnivorous (Higgins & Davies 1996) and may have been less vulnerable as its diet seems to include a broader range of food items, such as insects and larvae, arachnids and dead fish as well as molluscs and crustaceans. However, other visiting species of shorebirds such as Black-tailed Godwit which occurred only six times and which had disappeared by 2014 are also described as omnivorous (Higgins & Davies 1996).

Nocturnal and crepuscular surveys

In the 1970s, shorebirds used Tomago Wetland for diurnal and nocturnal roosting and foraging (Lindsey & McNaughton 2012). The recent crepuscular/nocturnal surveys suggest that waterbird species are again utilising the site during non-daylight hours. More high-tide evening, nocturnal and dawn surveys are required in order to establish the utilisation of the site by waterbirds during these times.

CONCLUSIONS

The restoration of Tomago Wetland is an ongoing process and because of its complexity will undoubtedly require constant management. Estuarine habitat which was formerly present has been partially reinstated. The reintroduction of tidal water has created a mosaic of habitats, filling channels and depressions, creating mudflats and promoting the growth of salt marsh. Waterbirds responded positively utilising the area for foraging and roosting. However the process has not been without its setbacks. The lack of tidal flushing through the intermittent failure of infrastructure such as levees and tidal gates caused drying out of

mudflats and salt marsh, often for long periods. That was detrimental to the waterbird population, especially if the closures coincided with drought periods or dry spells. It was found that partial tidal inflow was sufficient in the short term to maintain salt marsh and retain water in shallow depressions and channels on the western side of the site, which was beneficial for some waterbird species.

A study of benthic fauna would be invaluable in ascertaining whether ASS were harmful to this important shorebird food source. A targeted program of regular crepuscular and nocturnal surveys would lead to better understanding of how waterbirds use Tomago Wetland in non-daylight hours.

Tidal flow is the main driver for the restoration of tidal marshes; however, if the intention is to restore wetland habitat for shorebirds, then water levels need to be managed accordingly so as to maintain shallow tidal pools and fringing salt marsh vegetation, while preventing the establishment of mangroves. The findings from this study have highlighted the importance of protecting a suite of habitats for shorebirds, both for roosting and foraging. In order to further improve the outlook for migratory shorebird populations in the Hunter Estuary, rehabilitation efforts should now focus on restoring and protecting priority roosting and foraging habitat and maintaining the integrity of remaining areas of salt marsh.

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Broughton Island raptors

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Surveys conducted on Broughton Island between 1999 and 2020 recorded 12 raptor species. The most common was White-bellied Sea-Eagle *Haliaeetus leucogaster* followed by Whistling Kite *Haliastur sphenurus*, Swamp Harrier *Circus approximans,* Osprey *Pandion haliaetus* and Black-shouldered Kite *Elanus axillaris*. Less common were Peregrine Falcon *Falco peregrinus* and Brown Goshawk *Accipiter fasciatus*. Other infrequently recorded species were Brahminy Kite *Haliastur indus*, Spotted Harrier *Circus assimilis*, Brown Falcon *Falco berigora*, Nankeen Kestrel *Falco cenchroides* and Australian Hobby *Falco longipennis*.

Of the common species, the populations of White-bellied Sea-Eagle and Swamp Harrier appear stable, Osprey and Brown Goshawk appear to be increasing and Black-shouldered Kite, Whistling Kite and Peregrine Falcon appear to be decreasing. The abundance of most species reflects the long-term trends from the Hunter Region, except for Brown Goshawk whose abundance was increasing on Broughton Island but decreasing in the Hunter Region.

Local factors that have impacted the abundance of species were the eradication of exotic mammals and the subsequent change in vegetation structure. This has reduced open-country foraging opportunities for Black-shouldered Kite, Swamp Harrier and Whistling Kite, that prey on small mammals and rodents, and increased foraging opportunities for still-hunting species such as Brown Goshawk and Brown Falcon that utilise the denser vegetation. The reason for decline in abundance of Peregrine Falcon is not apparent and further study is required. Brahminy Kite abundance is forecast to increase in the future as it expands its presence in the Hunter Region.

Four species have been recorded breeding on the island: Osprey, Swamp Harrier, Peregrine Falcon and Whistling Kite. Breeding conditions also appear suitable for White-bellied Sea-Eagle.

INTRODUCTION

Broughton Island (32º 37'S, 152º 19'E) is located 16 km northeast of the entrance to Port Stephens, and 3.5 km offshore from the adjacent coastline, on the New South Wales lower north coast. It is part of Myall Lakes National Park.

In August 2009 NSW National Parks and Wildlife Service (NPWS) conducted a programme to eradicate exotic mammals from the island. The target species were rabbits *Oryctolagus cuniculus* and ship rats *Rattus rattus*. The islands were declared free of exotic mammals in August 2011 (Priddel *et al*. 2011; Fawcett *et al*. 2016). Following eradication, the vegetation structure has changed and small to medium size shrubs (Broad-leaved Paperbark *Melaleuca quinquenervia*, broom heath *Monotoca elliptica* and Coastal Wattle *Acacia longifolia*) have proliferated over some parts of the island (Stuart 2020). The population of small passerine species that utilise this habitat has also increased (Stuart *et al*. 2017).

Since 2012, members of Hunter Bird Observers Club (HBOC), in collaboration with NPWS, have conducted regular surveys aimed at monitoring population change of terrestrial birds in response to the changed vegetation regime. The first five years (2012-16) involved twice-yearly surveys carried out in autumn and spring (Stuart *et al*. 2017). An expanded study to identify resident species, the size of their populations and movements to and from the island was commenced in 2017, with surveys conducted approximately quarterly (Stuart *et al*. 2017). Raptors were recorded during these surveys. Six more common and five less frequently recorded species were present 2012-2016 (Stuart *et al*. 2017), and nine species were recorded 2017-2020 (Stuart 2020). Two species that are regularly present on the island, Osprey *Pandion haliaetus* and White-bellied Sea-Eagle *Haliaeetus leucogaster*, and one less frequent visitor, Spotted Harrier *Circus assimilis*, are listed as Vulnerable under the NSW *Biodiversity Conservation Act* 2016 (BC Act).

The objectives of this study were to describe the change in raptor abundance following eradication of

exotic mammals, evaluate the patterns of monthly occurrences and review breeding records.

METHODS

Records were extracted from the BirdLife Australia Birdata portal (www.birdata.birdlife.org.au) for 1999-2020. There were no records from Broughton Island for 2001-2006. HBOC survey records for 2012-2020 were from five sites surveyed according to BirdLife Australia's standard 500-m radius protocols (Stuart *et al*. 2017). These sites covered all areas of the island plus the immediate coastal waters of Providence Bay and Esmeralda Cove. Surveys for 1999-2011 were mostly conducted according to BirdLife Australia's 5-km area survey protocols. As there were only 10 of these surveys over this 13-year period, the records were combined. Some 5-km area single day surveys from 2012-2020 were extracted from the Birdata database for periods in which there were no 500-m surveys.

Survey records were also extracted from the Cornell Lab of Ornithology eBird Australia portal (https://ebird.org/australia/home). There were a small number of these records for 2017 and 2019.

The number of surveys conducted each year for each species was compiled and the annual Reporting Rate (RR) calculated. Monthly records for each species were also compiled and monthly RR was calculated. (RR is the number of records for a species divided by number of surveys, expressed as a percentage.) For the purposes of this study, RR has been used as a measure of abundance. The results for Broughton Island were charted, local RR trends established and the mean annual rate of change of RR determined. For comparative purposes, Hunter Region RR data from 1999-2020 surveys for the same species, conducted according to BirdLife Australia's 500-m, 5-km, fixed route and shorebird protocols, was downloaded from the Birdata portal. Regional trends were established and mean annual rate of change of RR determined. Undocumented breeding records were obtained from NPWS personnel and contractors who worked on Broughton Island during the study period.

RESULTS

A total of 588 records for 12 raptor species were downloaded from the Birdata portal, from 264 surveys. There were 14 additional records for five species downloaded from five surveys on the eBird portal. In the period 1999-2011, prior to commencement of HBOC surveys, there were 41 records for eight species from ten surveys. From 2012-2020 there were 561 records for 12 species from 259 surveys.

The mean annual RR and the mean annual rate of change of RR for the 12 species from both Broughton Island and the Hunter Region are shown in **Table 1**. The most common species on Broughton Island was White-bellied Sea-Eagle followed by Whistling Kite *Haliastur sphenurus*, Osprey, Swamp Harrier *Circus approximans* and Black-shouldered Kite *Elanus axillaris*. Peregrine Falcon *Falco peregrinus* and Brown Goshawk *Accipiter fasciatus* were less common. The overall RR for all seven species was greater than 10%. Reports of Brahminy Kite *Haliastur indus*, Spotted Harrier, Brown Falcon *Falco berigora*, Nankeen Kestrel *Falco cenchroides* and Australian Hobby *Falco longipennis* were infrequent.

Table 1. Mean annual reporting rate (RR) and mean annual RR rate of change, Broughton Island and Hunter Region raptors, 1999-2020.

Common name	Scientific name	Broughton Island		Hunter Region	
		Mean Annual RR (%)	Mean annual RR rate of change	Mean Annual RR (%)	Mean annual RR rate of change
Osprey	*Pandion haliaetus*	38.7	2.77%	4.5	0.18%
Black-shouldered Kite	*Elanus axillaris*	19.0	-2.52%	6.0	-0.26%
Swamp Harrier	*Circus approximans*	37.9	-2.51%	8.0	-0.03%
Spotted Harrier	*Circus assimilis*	3.0	*	0.3	**
Brown Goshawk	*Accipiter fasciatus*	11.2	2.07%	2.8	-0.14%
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	54.3	-2.23%	14.2	-0.17%
Whistling Kite	*Haliastur sphenurus*	40.5	-3.70%	13.3	-0.52%
Brahminy Kite	*Haliastur indus*	3.0	*	1.4	0.04%
Nankeen Kestrel	*Falco cenchroides*	1.1	*	6.7	-0.46%
Australian Hobby	*Falco longipennis*	1.1	*	3.1	-0.07%
Brown Falcon	*Falco berigora*	2.2	*	3.3	-0.20%
Peregrine Falcon	*Falco peregrinus*	11.9	-1.93%	1.5	-0.09%

* Insufficient records ** Irruptive species

Charts of annual reporting rate and linear trendlines for eight species are shown in **Figure 1**. Histograms of mean monthly RR are shown in **Figure 2**. There were insufficient data to chart trends for the remaining infrequently reported species.

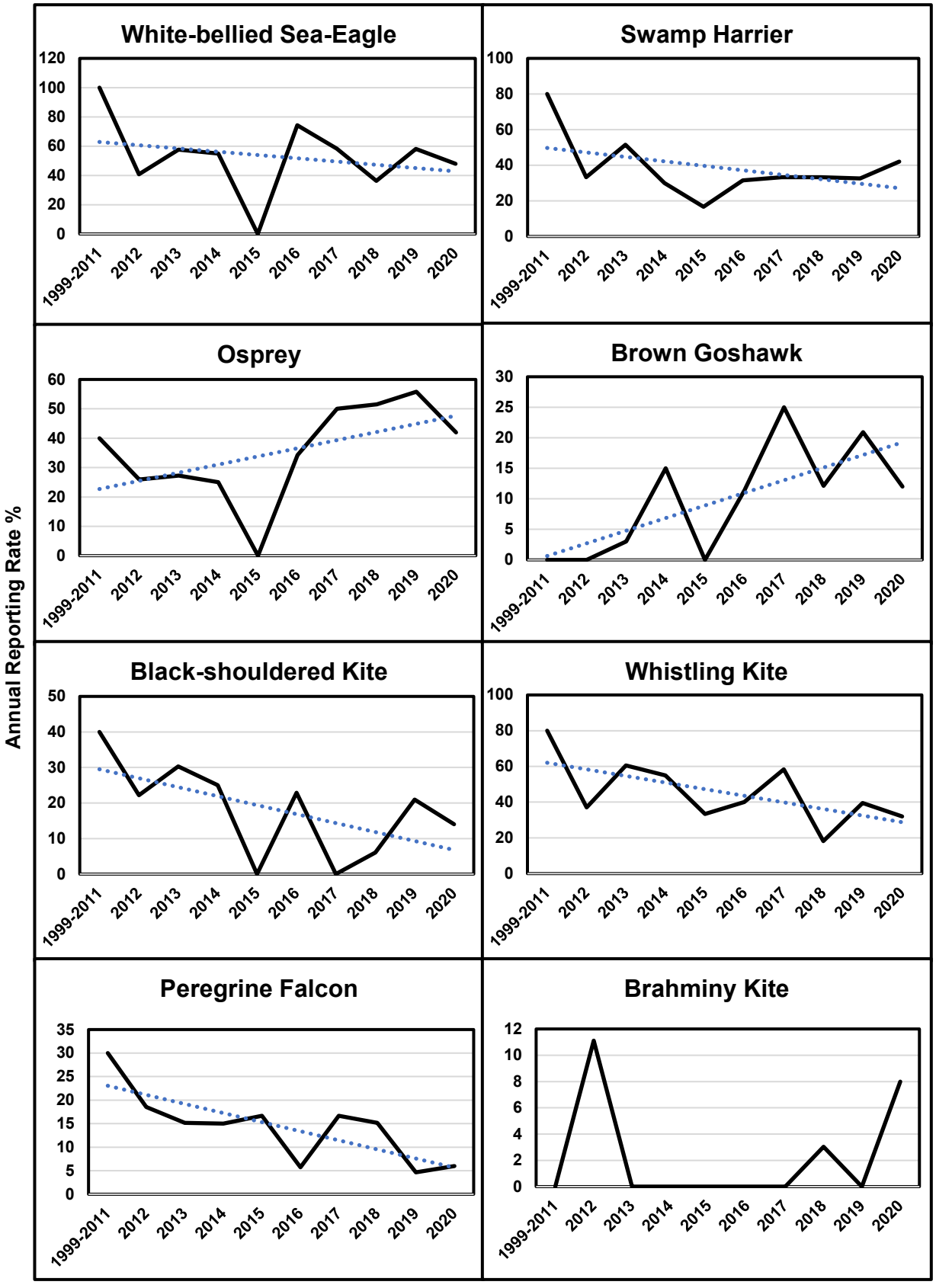

Figure 1. Charts and trendlines of annual reporting rates, Broughton Island raptors, 1999-2020.

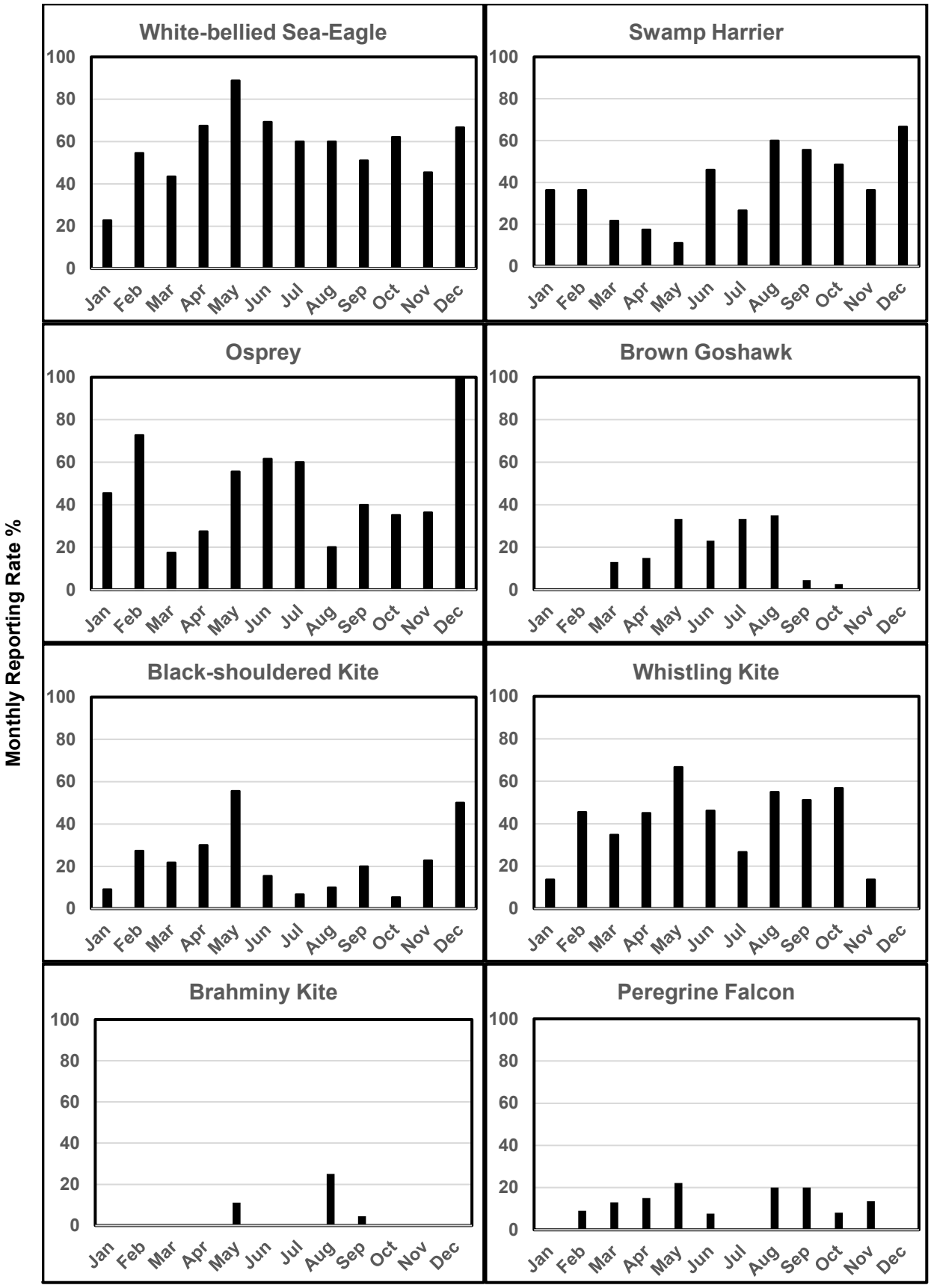

Figure 2. Histograms of monthly reporting rates, Broughton Island raptors, 1999-2020.

DISCUSSION

The mean annual RR trends presented in **Figure 1** show that the abundance of five species on Broughton Island has declined: Black-shouldered Kite, Swamp Harrier, White-bellied Sea-Eagle, Whistling Kite and Peregrine Falcon. However, the trend for White-bellied Sea-Eagle and Swamp Harrier has remained relatively constant since 2012. The RR trend for two species, Osprey and Brown Goshawk shows they have increased in abundance. There were insufficient data to establish trends for five other species: Spotted Harrier, Brahminy Kite, Nankeen Kestrel, Australian Hobby and Brown Falcon.

In the period 1999-2011, six of the 5-km surveys were conducted over several days and consequently, the average RR for some species was higher than would be expected from a 500-m survey. A notable decline in RR for some species was evident between the earlier surveys and 2012, reflecting the change in survey methodology (**Figure 1**). This decline has generally been disregarded in the evaluation of trends. The lack of records for most species in 2015 was anomalous. Six surveys were conducted and only three species were recorded.

The possibility of secondary poisoning of raptors by rodenticide used in the eradication programme affecting White-bellied Sea-Eagle, Swamp Harrier, Peregrine Falcon and Nankeen Kestrel abundance has not been considered here. However, it was unlikely to be significant as every possible step to avoid such events was taken during the eradication programme (Priddel *et al*. 2011; Fawcett *et al*. 2016).

Detailed discussion of individual species is presented below.

White-bellied Sea-Eagle

The RR trend in **Figure 1** has remained relatively constant since 2012, following an initial decline. The initial decline was attributed to the influence of 5-km survey data from 1999-2011. When this data was ignored, the mean annual RR rate of change shows a slight increase, 0.9%. Over the same period, the Hunter Region has a slight decline of -0.2%. (**Table 1**).

The species has been recorded flying above all parts of the island all year round and was more abundant between April and June (**Figure 2**). This may represent post-breeding dispersion from elsewhere to the island. The species is a regular visitor from the mainland and one or more birds were often observed flying to the island in the morning or returning late evening. Its prey includes small mammals up to the size of rabbits, birds and eggs, large insects, frogs, fish and reptiles (Marchant & Higgins 1993). The removal of rabbits would have produced a reduction in foraging opportunities, but other options were available on and around the island. The change in vegetation structure in some areas should not have impacted its foraging options.

The White-bellied Sea-Eagle's nest is a large pile of sticks lined with leaves, grass and seaweed, placed on the ground or a cliff on offshore islands, otherwise 3-40 m above the ground in a large tree (Marchant & Higgins 1993). Although suitable locations for ground or cliff nesting were present on Broughton Island, there were no breeding records. A large, disused stick nest that could have been used by White-bellied Sea-Eagle or Osprey was present on the north side of Looking Glass Isle (M. Schulz pers. comm.). In early December 2020 two adult and two juvenile birds were observed soaring in the vicinity of Little Broughton Island over several days (M. Schulz pers. comm.).

Whistling Kite

The RR trend in **Figure 1** shows a continuing decline in abundance over the study period, although this may be partially influenced by the 5-km survey data from 1999-2011. The mean annual RR rate of change was -3.7% and the Hunter Region exhibits a decline, -0.5%. (**Table 1**). A decrease in Whistling Kite abundance in nearby Port Stephens since 2013 has also been reported (Stuart 2016). The species has been recorded flying above all parts of the island all year round but was less abundant from November to January (**Figure 2**). This may represent a reduced presence during breeding activity at another location.

The Whistling Kite's prey includes small mammals, birds, fish, reptiles, amphibians, crustaceans, insects and carrion. Food items are taken either from the ground or from the water surface, while insects are sometimes hawked from the air (Marchant & Higgins 1993). The eradication of exotic mammals should not have substantially impacted the foraging options for Whistling Kite but the change in vegetation structure in some areas may have done so. However, as the species is very catholic in its diet, this impact was considered to have been minimal. The decline in abundance was probably a reflection of the regional trend.

Whistling Kite build their nest in trees 3-62 m above the ground. The nest is a bowl of sticks 60-150 cm across, 30-100 cm deep and lined with green leaves.

Pairs often re-use the same nest year after year. (Marchant & Higgins 1993). In 2020, the species nested in a small stand of Swamp Oak *Casuarina glauca* on the north slope of Pinkatop Head (M. Schulz pers. comm.). This nest has been observed in this location since 2012.

Swamp Harrier

The RR trend in **Figure 1** has remained relatively constant since 2012 following an initial decline. This initial decline was attributed to the influence of 5-km survey data from 1999-2011. When these data were ignored, the mean annual RR rate of change is -0.02% which was comparable to the Hunter Region with -0.03%. (**Table 1**). The species was most abundant from August to December (**Figure 2**) which is the breeding season for the species (Marchant & Higgins 1993). On Montague Island, Swamp Harrier numbers increase in March and April as they harvest shearwater fledglings (N. Carlile pers. comm.). The reduced abundance of Swamp Harriers on Broughton Island at that time (**Figure 2**) suggest this does not happen locally.

The species has been recorded flying above all parts of the island all year round. Its prey includes small mammals, birds and eggs, large insects, frogs, fish and reptiles (Marchant & Higgins 1993). The eradication of exotic mammals would have led to a reduction in foraging opportunities. The change in vegetation structure in some areas may have impacted abundance as the species prefers to forage over open country. The recent increase in the population of small passerine species (Stuart *et al*. 2017), however, will have provided a new foraging option for the species.

The species nests on a low platform of sticks, reeds and grass constructed in swamps, near or on water, and rarely on the ground (Marchant & Higgins 1993). There are two ephemeral Common Reed *Phragmites australis* swamps on the island and extensive areas of Kangaroo Grass *Themeda triandra*, Blady Grass *Imperata cylindrica* and Bracken Fern *Pteridium esculentum* which could provide suitable nesting habitat.

There was one confirmed breeding record and several instances of diagnostic behaviour. A nest was discovered in June 2005 in a Broad-leaved Paperbark located in a swamp to the west of the track from Esmeralda Cove to Providence Beach. A Swamp Harrier was observed flying to the nest over several days. The nest was of similar size to a raven's nest and was about one metre above water (C. Anderson pers. comm.). A nest that appeared to have been recently used was discovered on the north slope of Pinkatop ridge, near the Swamp Oak stand in April 1998 (N. Carlile pers. comm.). On more recent occasions, birds have been regularly observed by HBOC surveyors descending into grassy areas along the north slope of Pinkatop ridge. In early December 2020 a pair was observed landing repeatedly in the same location in tall grass on the north slope of the ridge and disappearing from view. Other raptors were aggressively chased from the area and the pair was assumed to be nesting (M. Schulz pers. comm.). In February 2020, a very young bird accompanying an adult was recorded over Looking Glass Bay and Esmeralda Cove.

Osprey

The RR trend in **Figure 1** shows a steady increase in abundance from 2012 to 2020. An initial decline to 2012 was attributed to the influence of 5-km survey data from 1999-2011. The absence of records from 2015 reflects a lack of survey effort in that year. The mean annual RR rate of change was 2.8% while for the Hunter Region, the increase was much less at 0.2% (**Table 1**).

The species was recorded flying above all parts of the island, all year round and was most abundant in December and February (**Figure 2**). The greater February abundance may reflect the presence of recently fledged juvenile birds, prior to dispersal. The Osprey's prey consists mainly of fish, and occasionally may include crustaceans, reptiles, small mammals or birds (Marchant & Higgins 1993). It would not have been adversely affected by the exotic mammal eradication programme. The increasing abundance however, may in part be due to the success of this programme. Removal of rats that were known to predate eggs and chicks (Priddel *et al*. 2011), may have allowed the species to breed with greater success and hence the more recent increase in abundance.

There is one active Osprey nest on Broughton Island, located on top of a steep-sided knoll on the southeast coastline of Looking Glass Bay. The nest is a large pile of sticks and driftwood with a central bowl lined with dried grass, seaweed and Prickly Pear *Opuntia stricta* (**Figure 3**). This nest was not present at this site in August 2009, although Osprey were present on the island (N. Carlile pers. comm.). One or more Osprey were regularly seen at the nest in April and October 2016 and breeding was confirmed in December 2016 when a near-fledged chick was photographed in the nest (N. Carlile pers. comm.). Two chicks were photographed on the nest in mid-December 2019 (**Figure 3**) and were subsequently banded. A banded bird was recorded at Looking Glass Bay in February 2020 and at

Esmeralda Cove in June 2020. Osprey are sedentary, and it is expected the pair will continue to utilise this site.

A large, disused stick nest that could have previously been used by Osprey or White-bellied Sea-Eagle was present on the north slope of Looking Glass Isle (M. Schulz pers. comm.). On the northeast coast of the island, a pair of Osprey have been observed repeatedly around a section of cliff below Pinkatop Head that cannot be seen from land. The pair exhibited distressed behaviour, circling and calling loudly, when approached in November and December 2020. Similar behaviour was noted in the previous two years. A juvenile accompanied by one or both adults was subsequently recorded in March and April (M. Schulz pers. comm.)

Figure 3. Osprey chicks on nest, Looking Glass Bay, Broughton Island. Photo by T. Clarke, 23/12/2019.

Black-shouldered Kite

The RR trend in **Figure 1** shows a continuing decline in abundance over the study period, although this may have initially been influenced by the 5-km survey data from 1999-2011. The mean annual RR rate of change was -2.5%. This was greater than the Hunter Region which exhibits a decline of -0.3%. (**Table 1**).

The species has been recorded flying above all parts of the island all year round. Maximum abundance was in May and low abundance was recorded from June to November (**Figure 2**). The latter low RRs between July and October probably represent a reduced presence during breeding activity at another location.

The Black-shouldered Kite's main prey is small rodents plus occasional small birds, small reptiles and insects (Marchant & Higgins 1993). The removal of rats would have produced a reduction in foraging opportunities. The change in vegetation structure following exotic mammal eradication may also have impacted abundance, as the species prefers to forage over open country. However, the species has taken advantage of other foraging options and has been observed taking Eastern Water Skink *Eulamprus quoyii* and Bar-shouldered Dove *Geopelia humeralis*. However, the abundance of Black-shouldered Kite on Broughton Island does appear to have been adversely affected by the exotic mammal eradication programme.

There were no breeding records for Black-shouldered Kite on the island, although an adult with two juveniles was observed in May 2019 and juvenile birds were present in October 2016 and November 2019. No behaviour suggestive of breeding has been observed. There are fewer records during the spring breeding season (**Figure 2**) suggesting that birds have departed the island to breed in another location. The Black-shouldered Kite prefers to nest in tall trees up to 35 m above the ground (Marchant & Higgins 1993). Trees of this stature are not present on the island.

Peregrine Falcon

The RR trend in **Figure 1** shows a continuing decline in abundance over the survey period, although this may have initially been unduly influenced by the 5-km survey data from 1999-2011. The mean annual RR rate of change was

- 1.9% which was higher than the Hunter Region with a decline of -0.1% (**Table 1**).

The species was most abundant in May, August and September and was not reported in December or January (**Figure 2**). The species' nesting period is August to November (Marchant & Higgins 1993). It has been recorded from all parts of the island although was most commonly recorded soaring over the slopes of Pinkatop Head. It mostly eats flocking birds, particularly pigeons, parrots and starlings, and on the coast, commonly takes seabirds. It occasionally eats large insects, and rarely takes fish, reptiles, small mammals or carrion. It forages by still-hunting from a high perch, by high quartering and soaring, or by low fast flight (Marchant & Higgins 1993).

The Peregrine Falcon nest is a scrape on a cliff ledge, an old stick nest of another raptor, or a ledge on a structure, up to 150 m above ground (Marchant & Higgins 1993). There were three records of breeding on the cliffs below Pinkatop Head in 2012, 2016 and 2017 (N. Carlile pers. comm.). A pair was reported behaving aggressively in this area and around the adjacent northern cliff edge in November and early-December 2019 (M. Schulz pers. comm).

Although the removal of rabbits may initially have affected foraging opportunities, there were numerous other options. Changes that have occurred to the vegetation in some areas were unlikely to have affected these opportunities. There has been no obvious impact on potential seabird prey. The species is sedentary and the island habitat has been demonstrated to be suitable for both foraging and nesting. There was no obvious reason for their decline in abundance on the island.

Brown Goshawk

The RR trend in **Figure 1** shows an increase in abundance from 2013. There were no records prior to this date. The mean annual RR rate of change was 2.1% which contrasts with the Hunter Region, at -0.1%. (**Table 1**). The Brown Goshawk was a relatively recent arrival on Broughton Island and has been recorded from all areas during its non-breeding season between March and October. It has been most abundant between May and August and has been absent from November to February (**Figure 2**). The absence of records during this period suggests that it breeds elsewhere.

Its prey is mainly birds and young rabbits, plus reptiles, amphibians and arthropods, and occasionally carrion. It forages mostly by still-hunting from a concealed perch in foliage. Its presence from 2013 suggests it has been attracted by the increasing number of small passerines utilising the recently emerging habitat of small to medium shrubs on some parts of the island. An adult female and a juvenile male were captured in this habitat during banding studies in May 2018. This suggests the species' presence represents post-breeding dispersion from elsewhere to the island.

Brahminy Kite

Brahminy Kite, although an infrequent visitor, may be expected to become more abundant in the future. The species has a mean annual RR rate of change in the Hunter Region of 0.04% (**Table 1**). It has been recorded on eight occasions since 2012, in July, August and September (**Figure 2**), during its non-breeding season. It has been expanding its range south into the Hunter Region since the mid-2000s (Stuart 2016) and was described breeding at Lemon Tree Passage in 2016 (Wooding 2017). A pair bred there subsequently in 2017 (Wooding 2019) and again more recently (L. Wooding pers. comm.). Records of the species on Broughton Island may be the result of post-breeding dispersal. A sub-adult bird was present in Esmeralda Cove for several days in August 2020.

Spotted Harrier

Spotted Harrier has been recorded on the island on eight occasions: in 2009, 2013 and 2014, most frequently in March and April. It is an uncommon resident and irruptive visitor to the Hunter Region (Williams 2019). The most recent irruptive peak was 2013 to 2015 and there were six corresponding records on Broughton island in 2013 and 2014. Its prey is terrestrial birds (including quail and pipit), mammals (including rabbits and rodents), reptiles, large insects and rarely carrion (Marchant & Higgins 1993). The eradication of exotic mammals and the change in vegetation structure may have reduced foraging options for the species, but the lack of records since 2014 more likely reflects its uncommon regional status.

Brown Falcon

Brown Falcon has been recorded on five occasions, in 2012, 2018 and 2020; the records were in June, August and November. It is an uncommon bird in the Hunter Region (Williams 2019) with a mean annual RR rate of change of -0.2% (**Table 1**). It feeds on mammals, birds, reptiles, amphibians, arthropods, carrion and rarely fish (Marchant & Higgins 1993). It forages mostly by still-hunting from an exposed perch. Three of the five records were from 2020 and it is possible that the areas of changed vegetation structure were providing more suitable foraging habitat for the species. The recent

increase in the population of small passerine species (Stuart *et al*. 2017) will have provided an additional foraging option for the species.

Nankeen Kestrel

Nankeen Kestrel has been recorded on four occasions, in 1999, 2000 and 2012; the records were in January, June and September. It is a common species in the Hunter Region (Williams 2019) with a mean annual RR rate of change of -0.4% (**Table 1**). It mostly eats invertebrates, particularly insects such as grasshoppers and crickets. It also occasionally takes small mammals, birds and reptiles. It forages by hovering or still-hunting from a perch in open country (Marchant & Higgins 1993). Hordern & Hordern (1931: 24) described the species as *'fairly common in cleared areas and on Broughton Island'*. Lane (1976) records grass on the island as being frequently burned by local fishermen. This would have maintained open areas suitable for foraging by the species. The lack of records since 2012 suggests the eradication of rats and the change in vegetation structure in some areas has made the island an unsuitable foraging habitat for the species.

Australian Hobby

Australian Hobby has been recorded on three occasions, in 2014 and 2016 (**Table 1**); the records were in March and April during its non-breeding season (**Table 2**). It is a common, widespread species in the Hunter Region (Williams 2019) with a mean annual RR rate of change of -0.1%. It eats small birds, insectivorous bats and flying insects, and forages by low fast flight, still-hunting from a prominent perch, or by quartering. It is most frequently recorded in open habitats including open woodland, water courses and vegetated urban areas. It is rarely recorded around cliffs or escarpments (Marchant & Higgins 1993). It is unlikely that the island provides suitable habitat to support a permanent presence of the species.

CONCLUSION

The abundance of three common raptor species on Broughton Island, Black-shouldered Kite, Whistling Kite and Peregrine Falcon, has declined since 2009. The populations of two other common species, Swamp Harrier and White-bellied Sea-Eagle appear relatively stable while those of Osprey and Brown Goshawk have increased. The mean annual RR rate of change of six of the species reflects the regional trend over the study period, although generally with a greater rate of change. The increasing trend for Brown Goshawk, however, was the reverse of that for the region. Five additional raptor species were infrequently recorded and were considered to be vagrants to the island.

Following the eradication of exotic mammals, foraging options for some species were reduced. The change in vegetation structure in some areas may also have reduced options for some species while providing new options for others. As the vegetation structure continues to change, it is expected that opportunities for species that prefer open-country foraging, such as Black-shouldered Kite, Swamp Harrier and Whistling Kite, will decrease and their future abundance will continue to decline. On the other hand, the changes will favour still-hunting species such as Brown Goshawk and Brown Falcon, and it is anticipated that future abundance of these species will increase. This will be supported by the expected increasing population of small passerines.

It is anticipated that Osprey numbers will remain stable with an established nesting site on the island. It is also anticipated that Brahminy Kite abundance will increase as the species establishes an expanded presence in the region.

Four species have confirmed breeding records from the island: Osprey, Swamp Harrier, Whistling Kite and Peregrine Falcon. There were no breeding records for White-bellied Sea-Eagle, although there is suitable habitat for ground or cliff nesting and a variety of foraging options. Other raptor species appear to be daily or short-term visitors to the island in search of suitable foraging opportunities, mainly during their non-breeding seasons.

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Land birds of Little Broughton Island

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Little Broughton Island (32^{0}37'S, 152^{0}20' E) situated off the Myall Coast is a roughly oval-shaped island covering 27 hectares and rising to a height of 98 m above sea level. It has a rocky shoreline backed by cliffs rising in height from 15 m in the north-west to 98 m in the south-east, composed primarily of Carboniferous rhyolite with basalt intrusions (Carlile *et al.* 2013). Above the cliffs is a vegetated area of 19 ha comprising primarily dense 'grassland' characterised by Spiny-headed Mat-rush *Lomandra longifolia*, Coast Tussock Grass *Poa poiformis*, Blue Flax Lily *Dianella caerulea* and Kangaroo Grass *Themeda australis*. Scattered stunted scrub patches are dominated by Tuckeroo *Cupaniopsis anacardioides* and Tree Broom-heath *Monotoca elliptica*, with various vine species present. An elevated aeolian dune north of the summit is dominated by low Coast Banksia *Banksia integrifolia* and Coast Tea-tree *Leptospermum laevigatum* with a Bracken *Pteridium esculentum* understorey. There are few soaks and no permanent wetlands are present. The island is separated by a narrow channel from the eastern end of the far more regularly visited Broughton Island.

The island is seldom accessed as there are no easy landing points and successful landing is highly dependent on suitable sea conditions (Hull 1911; Lane 1976). As a result the terrestrial avifauna present on this island has been poorly documented. During a visit in March 1911, Hull (1911) made no mention of land birds observed when traversing the island over a three-hour period in search of nesting seabirds. Similarly, Hindwood & D'Ombrain (1960) and Lane (1976) made no mention of land birds encountered on the island. Carlile *et al*. (2013) noted the presence of raptor species: White-bellied Sea-Eagle *Haliaeetus leucogaster,* Swamp Harrier *Circus approximans* and Peregrine Falcon *Falco peregrinus*. However, no mention was made by those authors of other land birds present during visits on one day in April 1998 and over four days during visits in October and December 2010. Similarly, no land bird records were documented in the Atlas of Living Australia or BioNet prior to 2020.

We visited the island on three occasions in 2020: circumnavigated the island with a failed attempted landing on 21 April; visited the island between 30 and 31 October to set remote cameras to document cryptic island fauna, confirm the successful eradication of the Black Rat *Rattus rattus* and determine whether the Green and Golden Bell Frog *Litoria aurea* was present; and on 7 December to search for the presence of nesting Gould's Petrel *Pterodroma leucoptera* in the north-eastern section. During all these visits, land birds seen while traversing the island or from close inshore were recorded.

Unsurprisingly, the assemblage of land birds present on Little Broughton Island was similar but less diverse than that of the close-by and larger Broughton Island, with no additional species recorded (Stuart 2020). Larger birds, such as various raptors and the Australian Raven *Corvus coronoides* were regularly seen commuting between the two. The following section summarises the land birds recorded:

Brown Quail *Synoicus ypsilophorus*: Widespread and common across the island, with an adult accompanied by chicks observed in the December 2020 visit.

White-throated Needletail *Hirundapus caudacutus*: Two seen flying low over the island after the passage of a storm front on the morning of 31 October.

Lewin's Rail *Lewinia pectoralis*: One heard calling from dense vegetation dominated by Spiny-headed Mat-rush and Coast Tussock Grass on the western end of the island following rain on 31 October.

Buff-banded Rail *Hypotaenidia philippensis*: Scattered single individuals seen and heard in dense vegetation, including around the summit, during all visits.

Osprey *Pandion haliaetus*: Single individuals were frequently seen flying over the island or perched, including one on the island's automatic light on 31 October.

Black-shouldered Kite *Elanus axillaris*: One bird was observed perched on the automatic light in the late afternoon on 30 October.

Swamp Harrier *Circus approximans*: Maximum of two individuals seen during all visits hunting over dense grassland and adjacent vegetation.

White-bellied Sea-Eagle *Haliaeetus leucogaster*: The most frequently observed raptor, with a maximum of two adults and two immature birds observed on 7 December. A careful scan of the cliff-lines along the shoreline from the water failed to locate evidence of nesting.

Whistling Kite *Haliastur sphenurus*: A single individual was regularly observed, including at the summit during the October visit.

Peregrine Falcon *Falco peregrinus*: Occasional single individuals were seen flying past during all visits.

Yellow-faced Honeyeater *Caligavis chrysops*: Scattered in small numbers across the island in taller denser vegetation stands, such as clumps of Tree Broom-heath and Tuckeroo, including adjacent to the summit during October. Fewer individuals were present in similar vegetation in the December visit.

Grey Fantail *Rhipidura albiscapa*: One seen in a stunted Tuckeroo patch on the plateau edge on 30 October and perhaps the same bird in relict dune vegetation below the summit on the following morning.

Australian Raven *Corvus coronoides*: Widespread across the island, with a maximum of four birds seen together in December.

Golden-headed Cisticola *Cisticola exilis*: Scattered in small numbers across the island, especially in extensive areas of Spiny-headed Mat-rush, Blue Flax Lily and Coast Tussock Grass.

Tawny Grassbird *Cincloramphus timoriensis*: Common and widespread across island in dense vegetation.

Welcome Swallow *Hirundo neoxena*: Widespread across island and along the shoreline, with up to eight birds seen hawking insects at the summit in October. Several recently used nests were found in overhangs along the western rocky shoreline.

Silvereye *Zosterops lateralis*: The most frequently observed passerine species. Widespread across the island, particularly in taller denser vegetation stands.

A number of species which are resident on nearby Broughton Island were not observed but may occur at times. These were Bar-shouldered Dove *Geopelia humeralis*, Pheasant Coucal *Centropus phasianinus*, Little Wattlebird *Anthochaera chrysoptera*, and Australasian Pipit *Anthus novaeseelandiae*. Similar to Broughton Island, it is likely that a variety of land birds visit the island as irregular visitors or vagrants (Stuart 2020). It is hoped that the documentation of the land bird component of the avifauna on Little Broughton Island will provide baseline information that will assist in biodiversity management, including the strategic control of various weed species, such as the Bitou Bush *Chrysanthemoides monilifera* and Dolichos Pea *Dipogon lignosus*.

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Bird surveys of Blue Gum Hills Regional Park 2012-2016

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The community of diurnal birds at Blue Gum Hills Regional Park was surveyed monthly between 2012 and 2016. Birds were surveyed using six survey areas located in vegetation with various levels of disturbance condition. Most of the birds recorded were common local woodland and forest species although some less-common species were also recorded. A finding of the survey was the greater diversity and abundance of species in disturbed habitat. The results of this survey will provide baseline information for future comparison, particularly as nearby areas of native vegetation are cleared for urban development.

INTRODUCTION

Blue Gum Hills Regional Park ("the park"; 32º 53' S 151º 38' E) is located near Minmi NSW (**Figure 1**). The park, of approximately 129 ha, was first gazetted in February 2007. Population growth in the lower Hunter Valley in recent years has resulted in considerable loss of habitat from adjacent areas, plus habitat fragmentation (**Figure 2**). However, the park itself continues to provide a range of habitat types for native bird species. During any visit to the park, a range of bird species can be readily found.

The aim of the present study was to compare the bird species diversity occurring within the main vegetation habitat types of the park, to consider possible reasons for any differences found and to provide baseline information for future studies.

Main topographic and vegetation features

The park is located within a gently sloping valley from 60 m AHD (Australian Height Datum) in the southwest to 20 m AHD to the southeast. A minor watercourse drains the park and there are several small shallow man-made ponds associated with it. These ponds are fringed with water plants. The watercourse (apparently unnamed) flows into nearby Back Creek, which is a permanent water source.

The park has a history of disturbances, mainly for coal mining but it appears that some parts of the park were partially cleared or logged. Soil mapping studies (Matthei 1995) indicate that nearly 70% of the park (**Figure 3**) was affected by mining. According to the Newcastle Soil Landscapes (Matthei 1995) the Killingworth landscape is described as undulating to rolling low hills on the Newcastle Coal Measures with predominantly uncleared tall open forest.

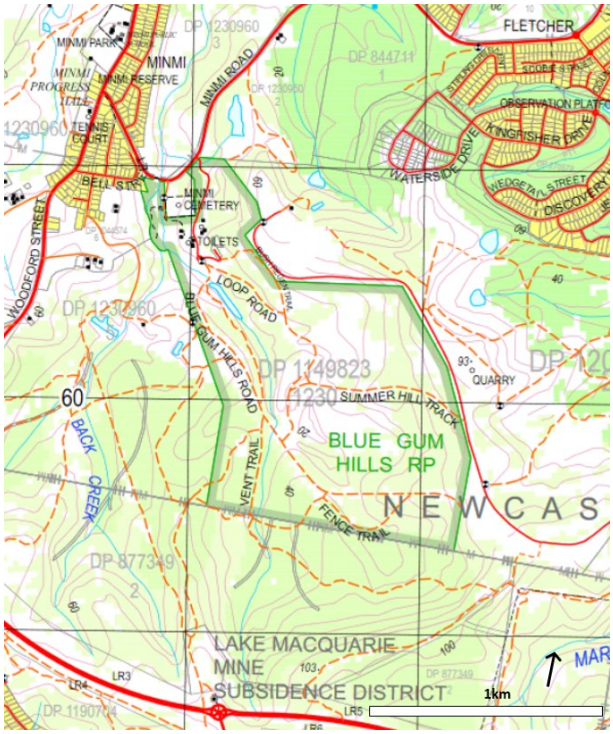

Figure 1. Location of Blue Gum Hills Regional Park in relation to the local area.

The park contains a mix of natural native vegetation, rehabilitated vegetation and cleared areas. There are some hollow-bearing trees; however, these are not numerous, possibly due to past logging activities. In vegetation mapping as part of the Lower Hunter and Central Coast Regional Environmental Management Strategy the main vegetation for the park was described as Spotted Gum - Ironbark Forest and Smooth-barked Apple Woodland plus small areas of Alluvial Tall Moist Forest (House 2003). More recently, the

park's vegetation was classified as a mix of Dry Open Forest and Cleared areas, with areas also of regenerating Dry Open Forest and Dry Open Forest with regenerating acacias (Cockerill *et al*. 2013).

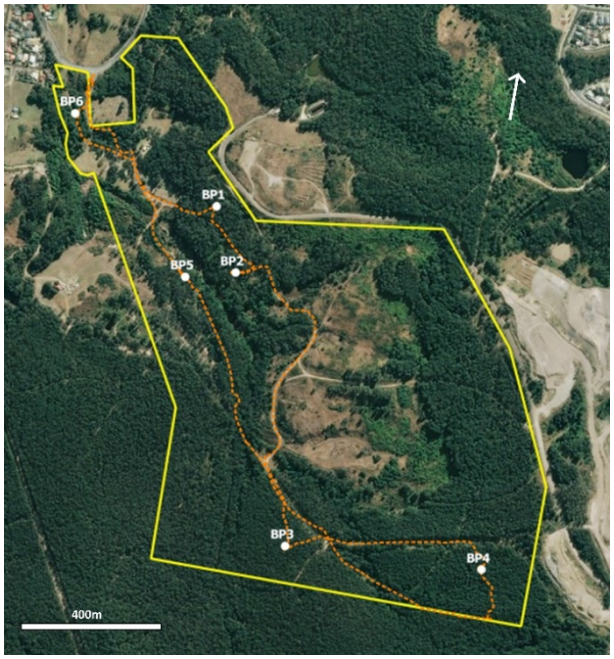

Figure 2. The six survey sites BP1-BP6 in Blue Gum Hills Regional Park, plotted onto an aerial image (courtesy Google Earth).

METHODS

After an initial reconnaissance, six sites (here designated as BP1 to BP6) were selected as being representative of the main vegetation types (plus they were conveniently located near to the park's main walking tracks). Between July 2012 and November 2016, surveys were conducted on an approximately monthly basis. The six sites were visited in random order i.e. a different route was used each month. A standard 2-ha/20-minute survey (www.birdata.birdlife.org.au) was conducted at each of the six sites. During the 20-minute survey each bird species present was recorded, and their total numbers noted. Thus, the two parameters for each site in each survey were the species diversity i.e. how many species were recorded during that survey, and the total abundance ie the total number of birds of all species.

All species encountered while moving between the sites were recorded separately (as an "All park" list) but their numbers were not estimated.

Surveys commenced at about 7.00 am and took *c*. four hours to complete.

Reporting Rates (RR) for each species at each site were calculated. The RR is the number of times the species was recorded divided by the number of surveys conducted, expressed as a percentage. The RR is based on presence/absence; records of multiple birds within the same survey do not affect the RR.

Location of sites BP1-BP6

The locations for the six survey sites are shown in **Figures 2-4** in relation to:

- An aerial view of the park (**Figure 2**).
- Previous site disturbance (**Figure 3**, based on Matthei (1995)).
- Vegetation types within the park. (**Figure 4**, based on Cockerill *et al*. (2013)).

Most of the central and northern portions of the park have been disturbed, as indicated in the soil map (**Figure 3**). From on-site inspection the extent of site disturbance appears to be mostly correct, however, BP1 is located in a narrow section of undisturbed native forest in relatively good condition, and BP6 is within a disturbed and rehabilitated location supporting many introduced weeds. The vegetation type at each survey site is shown in **Figure 4** and described below.

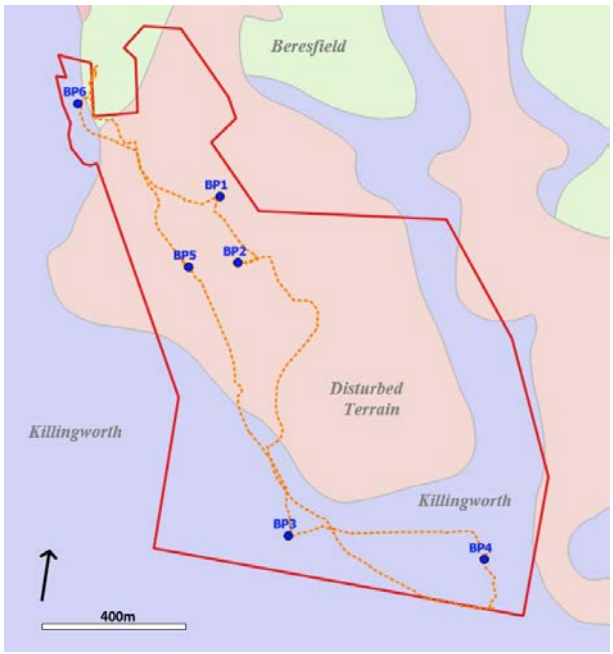

Figure 3. The six survey sites BP1-BP6 in Blue Gum Hills Regional Park, overlaid on a soil map from the Soil Landscapes of Newcastle 1:100,000 sheet (taken from Matthei 1995).

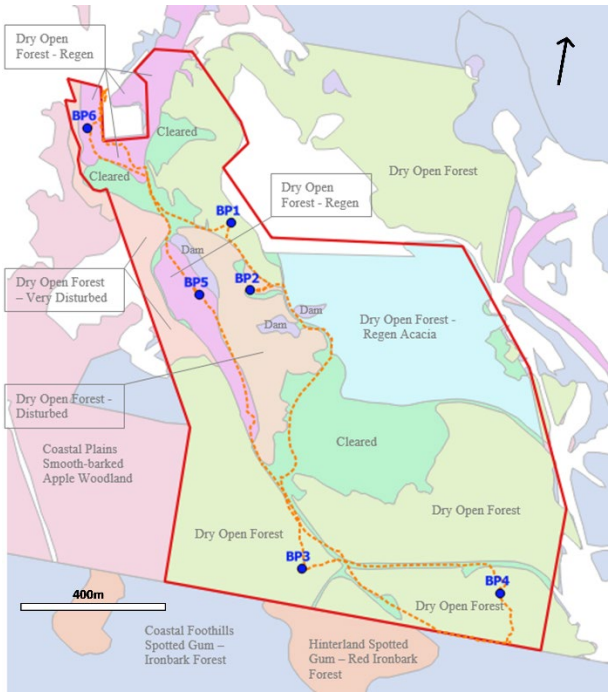

Figure 4. The six survey sites BP1-BP6 in Blue Gum Hills Regional Park, overlaid on a vegetation map from Lower Hunter vegetation mapping (taken from Cockerill *et al*. 2013).

Description of sites BP1-BP6

BP1 (**Figure 4**) is in a narrow strip of native forest vegetation between completely cleared land to the north-east and disturbed areas to the south. This plot supports a range of Eucalypt tree species of mixed ages, a relatively open understorey with good horizontal visibility, low open mostly fine leaved shrubs and a groundcover of mixed native grasses and herbs.

BP3, BP4 (**Figure 4**) are located within larger areas of native forest vegetation in relatively good condition with disturbance limited mainly to partial clearing and tracks. Partial clearing is evidenced by the lack of larger hollow-bearing trees. BP3 supports mostly young Spotted Gum *Corymbia maculata* with some Ironbark *Eucalyptus sp.* and Stringybark *Eucalyptus sp.*, an understorey of Prickly-leaved Paperbark *Melaleuca nodosa* and limited groundcover. BP4 also supports mostly young Spotted Gum but has a very open understorey and some groundcover of low shrubs, grasses, herbs and rushes. The canopy of both BP3 and BP4 appears the same from aerial photographs. However, the understorey and groundcover horizontal views are different. Within BP3 the horizontal view through the canopy is somewhat restricted due to the melaleucas and the groundcover is open, whereas in BP4 the understorey is very open, and the groundcover is of grasses and low shrubs etc.

BP2, BP5 (**Figure 4**) are located in disturbed and regenerating native forest vegetation with open areas and areas of replanting and numerous weeds. BP2 includes a cleared open area with only thick grass and grassy weeds plus an area of mostly young Spotted Gum trees and an area of tree replanting with a relatively open understorey plus dense clumps of Lantana *Lantana camara* and some wattles *Acacia sp.* below which is a groundcover of grasses and herbs. BP5, which appears to have undergone disturbance to the ground, also has open cleared areas, young eucalypt trees, a range of understorey shrubs plus clumps of Lantana and groundcover of grasses and herbs. The horizontal view in both plots is very open in some parts and closed in other areas due to broad-leaved vegetation, such as Lantana. Both sites are located close to a source of water in a shallow man-made dam.

BP6 (**Figure 4**) is on land that appears to have been completely cleared and heavily disturbed with much of the existing vegetation having been replanted and now weed-infested. A sign indicates this location is the "Minmi Heritage Garden" and was probably subject to revegetation. BP6 has a ridge, ephemeral watercourse, tracks, fencing and what appears to be the base of an old rail line. Taller planted Eucalypt trees with a dense understorey of shrubs and Lantana grow on the ridge. Shorter plants, including Cheese Tree *Glochidion ferdinandi*, Sweet Pittosporum *Pittosporum undulatum* and Small-leaved Privet *Ligustrum sinense*, grow on the lower ground and over the watercourse. The horizontal view throughout much of this site, except along the tracks, is closed due to the density of broad-leaved vegetation. There is a heavily weed-infested but shady location close to a permanent source of water in Back Creek.

RESULTS

Of the 53 possible monthly surveys during the 2012-2016 study period, 45 were carried out. A survey was missed in 2014, two were missed in 2015 and five in 2016. Overall, 91 bird species were recorded in the park, with 64 species recorded in the 2-ha sites and an additional 27 species incidentally while walking between sites. **Table 1** has a list of species including the RRs for each of the 2-ha sites and for the park overall. Twenty-one species were recorded at all six 2-ha sites and ten species at only a single site.

The Spotted Dove *Streptopelia chinensis* was the only non-native bird recorded at the park during the surveys. There were records for four species listed as threatened under the NSW *Biodiversity Conservation Act 2016*: White-bellied Sea-Eagle (recorded flying over the park), Little Lorikeet *Glossopsitta pusilla*, recorded twice in BP2 and five times in BP5, Varied Sittella *Daphoenositta chrysoptera*, recorded once incidentally on 21 June 2012, and White-throated Needletail *Hirundapus caudacutus*, recorded incidentally three times – on 28 February 2013, 26 February 2014 and 30 January 2015.

The total species diversity recorded at the 2-ha survey sites ranged from a low of 29 species at site BP3 to a maximum of 51 species at BP6 (**Figure 5**). Fewer species were recorded at sites BP3 and BP4 than at the other four sites. BP3 and BP4 also had lower average monthly species diversity counts, and lower average monthly total abundance of birds, than the other sites.

Table 1. Species recorded during the surveys, with Reporting Rates (RR) at each of the 2-ha sites and overall.

Common Name	Scientific Name	RR (%)						
		All park	BP1	BP2	BP3	BP4	BP5	BP6
Australian Wood Duck	*Chenonetta jubata*	13.3						
Hardhead	*Aythya australis*	2.2						
Pacific Black Duck	*Anas superciliosa*	28.9						
Chestnut Teal	*Anas castanea*	20.0						
Australasian Grebe	*Tachybaptus novaehollandiae*	11.1						
Spotted Dove	*Streptopelia chinensis*	2.2						2.2
Brown Cuckoo-Dove	*Macropygia phasianella*	22.2		4.4				4.4
Wonga Pigeon	*Leucosarcia melanoleuca*	22.2						
Bar-shouldered Dove	*Geopelia humeralis*	77.8		4.4			15.6	24.4
Australian Owlet-nightjar	*Aegotheles cristatus*	4.4						
White-throated Needletail	*Hirundapus caudacutus*	6.7						
Eastern Koel	*Eudynamys orientalis*	26.7						2.2
Channel-billed Cuckoo	*Scythrops novaehollandiae*	35.6						
Shining Bronze-Cuckoo	*Chalcites lucidus*	26.7	2.2	4.4			2.2	
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	66.7	6.7	8.9	2.2	6.7	11.1	2.2
White-necked Heron	*Ardea pacifica*	2.2						
White-faced Heron	*Egretta novaehollandiae*	6.7						
Masked Lapwing	*Vanellus miles*	11.1						
Black-shouldered Kite	*Elanus axillaris*	11.1						
Pacific Baza	*Aviceda subcristata*	4.4						
Grey Goshawk	*Accipiter novaehollandiae*	35.6					6.7	
Brown Goshawk	*Accipiter fasciatus*	2.2						2.2
Collared Sparrowhawk	*Accipiter cirrocephalus*	4.4					2.2	
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	4.4						
Whistling Kite	*Haliastur sphenurus*	8.9						
Oriental Dollarbird	*Eurystomus orientalis*	20.0					2.2	2.2
Sacred Kingfisher	*Todiramphus sanctus*	40.0	11.1	4.4	13.3	2.2	2.2	4.4
Laughing Kookaburra	*Dacelo novaeguineae*	86.7	15.6	8.9		2.2	6.7	15.6
Yellow-tailed Black-Cockatoo	*Zanda funereus*	15.6						
Galah	*Eolophus roseicapilla*	4.4						
Sulphur-crested Cockatoo	*Cacatua galerita*	35.6						
Crimson Rosella	*Platycercus elegans*	2.2						
Eastern Rosella	*Platycercus eximius*	91.1	6.7				33.3	8.9
Little Lorikeet	*Glossopsitta pusilla*	28.9		4.4			11.1	
Rainbow Lorikeet	*Trichoglossus moluccanus*	91.1	11.1	6.7	8.9	4.4	4.4	6.7
Australian King-Parrot	*Alisterus scapularis*	73.3	6.7	4.4			33.3	8.9
Noisy Pitta	*Pitta versicolor*	2.2						
Regent Bowerbird	*Sericulus chrysocephalus*	8.9		2.2				6.7
Satin Bowerbird	*Ptilonorhynchus violaceus*	71.1	2.2				51.1	15.6
White-throated Treecreeper	*Cormobates leucophaea*	91.1	17.8	11.1	33.3	31.1	2.2	
Variegated Fairy-wren	*Malurus lamberti*	66.7	20.0	15.6	2.2	4.4	4.4	13.3
Superb Fairy-wren	*Malurus cyaneus*	95.6		22.2			11.1	68.9
Southern Emu-wren	*Stipiturus malachurus*	2.2						

Table 1. Species recorded during the surveys, with Reporting Rates (RR) at each of the 2-ha sites and overall (cont.)

Common Name	Scientific Name	RR (%)						
		All park	BP1	BP2	BP3	BP4	BP5	BP6
White-cheeked Honeyeater	*Phylidonyris nigra*	71.1		55.6			24.4	22.2
White-naped Honeyeater	*Melithreptus lunatus*	84.4	35.6	64.4	13.3		28.9	6.7
Brown-headed Honeyeater	*Melithreptus brevirostris*	6.7	2.2	4.4				
Noisy Friarbird	*Philemon corniculatus*	64.4	13.3	15.6	20.0	31.1	8.9	8.9
Scarlet Honeyeater	*Myzomela sanguinolenta*	64.4	26.7	46.7	15.6	8.9	13.3	37.8
Eastern Spinebill	*Acanthorhynchus tenuirostris*	91.1	20.0	53.3	11.1	20.0	26.7	55.6
Lewin's Honeyeater	*Meliphaga lewinii*	100.0	4.4	48.9	4.4	13.3	51.1	73.3
Little Wattlebird	*Anthochaera chrysoptera*	6.7		4.4				2.2
Red Wattlebird	*Anthochaera carunculata*	37.8	4.4	6.7			2.2	11.1
Yellow-faced Honeyeater	*Caligavis chrysops*	100.0	71.1	77.8	64.4	62.2	15.6	66.7
Bell Miner	*Manorina melanophrys*	100.0	15.6	95.6			100	60.0
Noisy Miner	*Manorina melanocephala*	53.3	13.3					2.2
Spotted Pardalote	*Pardalotus punctatus*	80.0	33.3	33.3	42.2	26.7	4.4	42.2
Brown Gerygone	*Gerygone mouki*	88.9		11.1			4.4	75.6
White-browed Scrubwren	*Sericornis frontalis*	95.6	4.4	33.3	2.2	2.2	57.8	55.6
Yellow Thornbill	*Acanthiza nana*	40.0	8.9	8.9				11.1
Striated Thornbill	*Acanthiza lineata*	93.3	20.0	46.7	4.4	24.4		15.6
Brown Thornbill	*Acanthiza pusilla*	91.1	26.7	42.2	2.2	8.9	4.4	26.7
Varied Sittella	*Daphoenositta chrysoptera*	2.2						
Olive-backed Oriole	*Oriolus sagittatus*	51.1	13.3	11.1	8.9	13.3	13.3	11.1
Eastern Shrike-tit	*Falcunculus frontatus*	4.4			2.2			
Rufous Whistler	*Pachycephala rufiventris*	40.0	4.4	13.3		2.2		2.2
Golden Whistler	*Pachycephala pectoralis*	100.0	35.6	62.2	40.0	51.1	26.7	71.1
Grey Shrike-thrush	*Colluricincla harmonica*	75.6	2.2	17.8	11.1	2.2	8.9	4.4
Eastern Whipbird	*Psophodes olivaceus*	100.0		55.6			57.8	37.8
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	60.0	8.9	4.4	11.1	11.1	6.7	4.4
Common Cicadabird	*Edolisoma tenuirostris*	17.8				2.2		
Pied Currawong	*Strepera graculina*	73.3	4.4	2.2		4.4	11.1	4.4
Australian Magpie	*Gymnorhina tibicen*	80.0				2.2		4.4
Pied Butcherbird	*Cracticus nigrogularis*	31.1						
Grey Butcherbird	*Cracticus torquatus*	88.9	4.4		6.7	17.8	4.4	
White-browed Woodswallow	*Artamus superciliosus*	2.2						
Willie Wagtail	*Rhipidura leucophrys*	24.4					13.3	
Rufous Fantail	*Rhipidura rufifrons*	15.6		2.2	2.2			6.7
Grey Fantail	*Rhipidura albiscapa*	100.0	51.1	55.6	33.3	28.9	4.4	77.8
Spangled Drongo	*Dicrurus bracteatus*	11.1				2.2		
Leaden Flycatcher	*Myiagra rubecula*	17.8	4.4		4.4	2.2		
Magpie-lark	*Grallina cyanoleuca*	46.7	2.2					
Black-faced Monarch	*Monarcha melanopsis*	13.3		2.2	2.2			4.4
Australian Raven	*Corvus coronoides*	93.3	6.7	8.9	6.7	31.1	2.2	15.6
White-winged Chough	*Corcorax melanorhamphos*	4.4						
Rose Robin	*Petroica rosea*	22.2	6.7	2.2				2.2
Eastern Yellow Robin	*Eopsaltria australis*	91.1	8.9	31.1	13.3	13.3	6.7	64.4
Tawny Grassbird	*Cincloramphus timoriensis*	15.6						
Welcome Swallow	*Hirundo neoxena*	55.6					11.1	28.9
Silvereye	*Zosterops lateralis*	100.0	28.9	73.3	13.3	11.1	37.8	91.1
Mistletoebird	*Dicaeum hirundinaceum*	77.8	28.9	44.4	26.7	15.6	26.7	11.1
Red-browed Finch	*Neochmia temporalis*	95.6	2.2	42.2			35.6	60.0

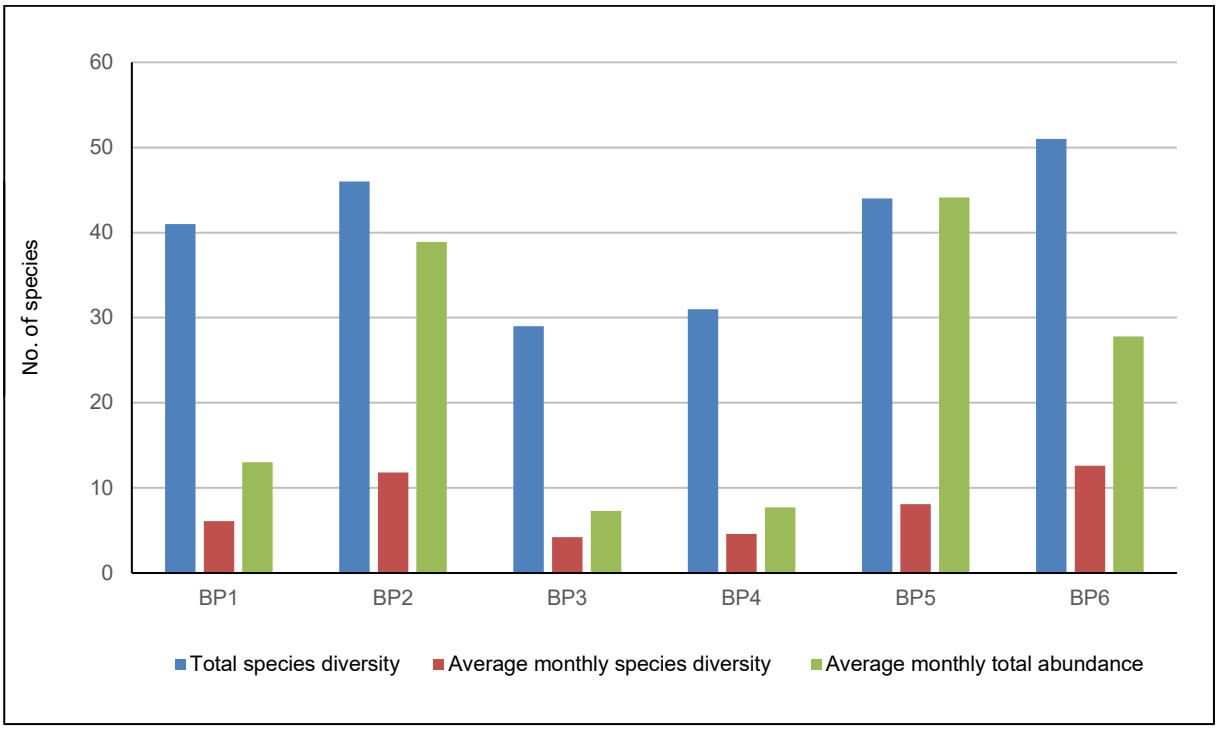

Figure 5. Total number of bird species recorded at each 2-ha site.

DISCUSSION

Bird species diversity was greater at sites BP2, BP5 and BP6. A contributing factor for higher abundance at BP2 and BP5 was because these sites were located within (BP5) or at the edge of (BP2) a large colony of Bell Miners *Manorina melanophrys*. Many Bell Miners from the colony were recorded during the surveys of BP2 and BP5, inflating the overall counts for those two sites.

The reason why bird species diversity and total abundance numbers were lowest at sites BP3 and BP4 is unclear, given that both sites were located within larger sections of native forest vegetation in relatively good condition. However, BP3 has an understorey dominated by fine-leaved paperbarks and minimal groundcover while BP4 has a very open understorey and grassy groundcover. It is possible that a higher density of broad-leaved shrubs (Creagh *et al.* 2004), even if weeds such as Lantana, in the understorey of BP2, BP5 and BP6 provides safer refuge from predators and weather extremes plus potentially better foraging habitat for some birds.

Of the 91 species recorded in this survey, most were resident, that is they occur and live their lives year-round in the local area. At least sixteen of the species recorded were known north-south seasonal migrants (e.g. Eastern Koel *Eudynamys orientalis* and Common Cicadabird *Edolisoma tenuirostris*), altitudinal migrants (e.g. Rose Robin *Petroica rosea*) or nomadic / irruptional (e.g. White-browed Woodswallow *Artamus superciliosus*).

The only introduced bird species recorded in the park during this survey was the Spotted Dove *Streptopelia chinensis*, recorded at BP6 which is the survey site closest to the residential area of Minmi. Exotic species may currently be deterred from using those parts of the park consisting mostly of either natural or regrowth native vegetation. The extent of native vegetation contiguous with the park probably helps. Future clearing and residential development around the park might lead to additional introduced species using the park.

Across the whole park, 18 bird species had RRs above 80%, while *c.* 35 species had RRs below 20%. Only seven species had RRs of 100%, these being Bell Miner *Manorina melanophrys*, Lewin's Honeyeater *Meliphaga lewinii*, Yellow-faced Honeyeater *Caligavis chrysops*, Eastern Whipbird *Psophodes olivaceus*, Golden Whistler *Pachycephala pectoralis*, Grey Fantail *Rhipidura albiscapa* and Silvereye *Zosterops lateralis*. For the 2-ha sites, only two species had high RRs at any site: namely, the Bell Miner at sites BP5 and BP2 and the Silvereye at BP6. Most of the common species had rather variable RRs. The Yellow-faced Honeyeater had a consistent moderately high (61-

80%) RR at all 2-ha sites except BP5 where its RR was low. All other bird species had variable RRs, reflecting differences in availability of foraging, refuge and breeding habitats within each site.

Noisy Miners were recorded a few times at BP1 and once at BP6. They are recognised as an aggressive native species that harasses other birds in their territory. They are common in urban areas where the heavily disturbed vegetation is opened and providing them with favourable habitat. Further clearing in and adjacent to the park could potentially attract greater numbers of this species.

Only a small number of threatened species were recorded during this survey. Two of those, White-bellied Sea-Eagle and White-throated Needletail, were only recorded flying over the park. Little Lorikeet and Varied Sittella were recorded and potentially might breed in the park although they are mobile and wide-ranging species and were not recorded regularly. Sedentary threatened woodland species such as Brown Treecreeper *Climacteris picumnus* and Speckled Warbler *Pyrrholaemus sagittatus* were not recorded, nor were more mobile species such as Dusky Woodswallow *Artamus cyanopterus* and Scarlet Robin *Petroica boodang*. The habitat may be suitable for forest owls including Masked Owl *Tyto novaehollandiae* and Powerful Owl *Ninox strenua*; however, there were no nocturnal surveys to check for the presence of night birds.

CONCLUSIONS

Blue Gum Hills Regional Park is a small, mostly disturbed area of local native vegetation which is likely to become a more important remnant in the future due to clearing of nearby land for housing. The bird surveys between 2012 and 2016 found that the park supports a good variety of native bird species, both local resident species and migratory ones. Very few introduced bird species were recorded. This report provides some baseline information for future studies.

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Passerines on Broughton Island

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Surveys on Broughton Island during 2012-2020 found that seven species of passerine were resident on the island or were regular visitors to it: Yellow-faced Honeyeater *Caligavis chrysops*, Australian Raven *Corvus coronoides*, Australasian Pipit *Anthus novaeseelandiae*, Golden-headed Cisticola *Cisticola exilis*, Tawny Grassbird *Cincloramphus timoriensis*, Welcome Swallow *Hirundo neoxena* and Silvereye *Zosterops lateralis*. There were multiple records for four other species, Little Wattlebird *Anthochaera chrysoptera*, Golden Whistler *Pachycephala pectoralis*, Willie Wagtail *Rhipidura leucophrys* and Grey Fantail *R. fuliginosa*, but their status on the island is less clear.

The population of Yellow-faced Honeyeater on the island has been increasing and its distribution has been expanding. The changes were found to be statistically significant at greater than 95% confidence level. In contrast, the population of Golden-headed Cisticola has decreased, with birds now absent or declining from areas where shrub cover has been displacing previous areas of grassland and heath. The changes were found to be statistically highly significant, at greater than 99% confidence level. The changes for both species were associated with an increase in shrub coverage on the island, whereby small to medium-sized shrubs such as Tree Broom Heath *Monotoca elliptica*, Coastal Wattle *Acacia longifolia* and Broad-leaved Paperbark *Melaleuca quinquenervia* have been displacing grasslands and heath.

INTRODUCTION

In 2011 Broughton Island was declared free of feral animals, following a successful program in 2009 to eradicate its populations of Black Rat *Rattus rattus* and Rabbit *Oryctolagus cuniculus* (Priddel *et al*. 2011, Fawcett *et al*. 2016). In mid-2012, a bird monitoring project was initiated jointly by Hunter Bird Observers Club (HBOC) and NSW National Parks and Wildlife Service (NPWS), with initial inputs also from members of the Broughton Island Conservation Society. The focus for the project was to monitor the island's terrestrial bird populations and identify any changes that might occur. In a separate study, NPWS is monitoring the island's seabird population.

Changes in bird populations on Broughton Island were considered likely to happen for two reasons. Black Rat was a known predator for eggs and nestlings; its eradication was expected to improve the success rate for the then-current breeding species and perhaps spur other species to breed. Secondly, in many parts of the island, changes in habitat were expected to occur post-eradication of Rabbit plus from the implementation of new fire management strategies. Such habitat changes were expected would affect bird populations.

The predictions about habitat change are proving to be correct. For example, the extent of shrub cover has increased substantially in the central parts of the island – the heights of small to medium-sized shrubs such as Tree Broom Heath *Monotoca elliptica*, Coastal Wattle *Acacia longifolia* and Broad-leaved Paperbark *Melaleuca quinquenervia* have increased, as has the size of the area with shrubs present (Stuart 2020).

An interim report presented baseline data from surveys carried out during 2012-2016 (Stuart *et al*. 2017). The baseline study identified five main passerine species on the island: Yellow-faced Honeyeater *Caligavis chrysops*, Golden-headed Cisticola *Cisticola exilis*, Tawny Grassbird *Cincloramphus timoriensis*, Welcome Swallow *Hirundo neoxena* and Silvereye *Zosterops lateralis*. In this report, I review the status of those five species and also consider other changes that may be occurring in Broughton Island's passerine populations.

METHODS

Broughton Island terrestrial bird monitoring project

Broughton Island (32º 37'S, 152º 19'E) is located 16 km northeast of the entrance to Port Stephens, and 3.5 km offshore from the adjacent coastline, on the New South Wales central coast (see inset to **Figure 1**). It is part of Myall Lakes National Park. Eleven sites on Broughton Island were surveyed regularly as part of the terrestrial bird monitoring project; however, two of those sites comprised predominantly coastal habitat and thus they were not considered for this report. Of the others, there were six sites with nominal area of 2 ha (sites BT1 to BT6) and three larger sites (BT7 to BT9). General descriptions of all the survey sites have been presented previously (Stuart *et al*. 2017). **Figure 1** shows the locations of the eleven survey sites and indicates the survey routes. From mid-2012 to 2016, the island was surveyed at approximately six-monthly intervals, and approximately quarterly since 2017. The most recent surveys were carried out in late November 2020.

Sites BT1 to BT6 were surveyed using BirdLife Australia's 2-ha survey protocol, in which all species detected within a 20-minute timeframe are recorded (www.birdata.birdlife.org.au). Sites BT7 to BT9 were surveyed as 500 m-radius sites, where all species detected were recorded but the survey duration was not fixed and usually it was much longer than 20 minutes. In the Broughton Island monitoring project, the surveys of BT7-BT9 typically spanned 1-2 hours.

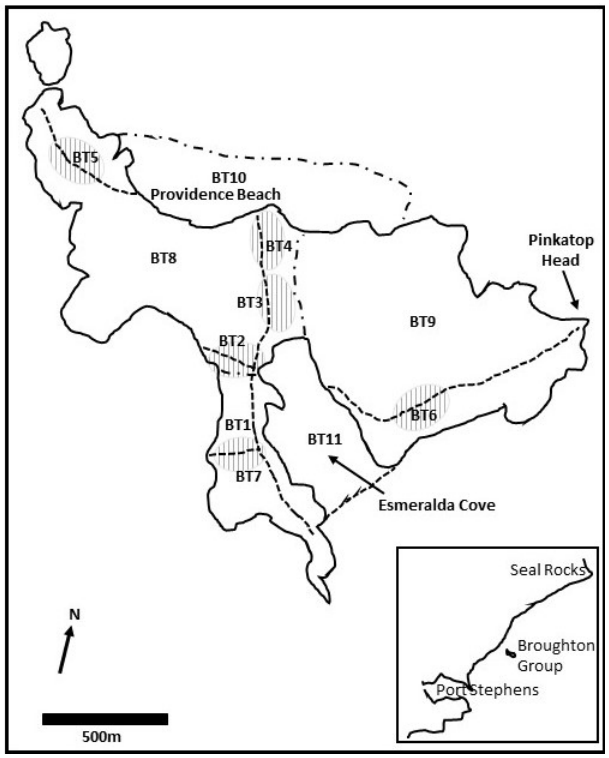

Figure 1. Broughton Island showing the survey areas and indicating the survey routes (Inset: location of the Broughton Group of islands). Modified from Stuart *et al*. (2017).

Data management and data analysis

The records from all surveys were entered into BirdLife Australia's Birdata portal (www.birdata.birdlife.org.au). In February 2021 I downloaded all the results and calculated the Reporting Rate (RR) for each of the five target species at each of the nine survey sites, for two time periods: 2012-2016 and 2017-2020. RR is the number of records for a species divided by number of surveys, expressed as a percentage. I also calculated the RRs for the six 2-ha sites collectively, and for the three 500-m radius sites collectively, for each of the two time periods. In addition, I analysed some subset combinations of sites, whenever that seemed warranted.

The two time periods, 2012-2016 and 2017-2020, were arbitrarily selected although many of the habitat changes began to become more obvious from 2017 onwards. The two time periods also correspond to the initial baseline study period and the start of the subsequent study period.

I used the Pearson's Chi-Square (Goodness-of-Fit) test (Fowler & Cohen 1994) to assess the statistical significance of any differences in the number of records for a species across the two time periods. Calculated Chi-Square values above 3.84 indicate a significant difference in the two data sets, to at least 95% confidence level, while Chi-Square values above 6.63 indicate that the difference is highly significant, to at least 99% confidence level (Fowler & Cohen 1994). Although in this report I usually refer to analysing changes in RR, the Chi-Square test uses raw data (number of surveys, number of records) because the size of the data set is an important factor in the evaluation of statistical significance.

Analysis of the status of Broughton Island's main passerine species has been assisted by including key findings from a bird banding project which commenced in mid-2017. A general description of the methods used in the banding project has been presented previously (Stuart 2020).

RESULTS

Species recorded

Twenty-five species of passerine were recorded on Broughton Island during the HBOC surveys in 2012-2020 (**Table 1**). No additional passerine species were recorded in any of the pre-2012 Birdata surveys. The five most commonly recorded passerines were Yellow-faced Honeyeater, Golden-headed Cisticola, Tawny Grassbird, Welcome Swallow and Silvereye. There also were many records for Australian Raven *Corvus coronoides* and Australasian Pipit *Anthus novaeseelandiae*. For four other species, there were fewer records and the status of each species on Broughton Island is unclear. Thirteen species were vagrants, with

usually only one or two records of them (Spangled Drongo *Dicrurus bracteatus* and Eastern Yellow Robin *Eopsaltria australis* each had three records but in both cases the three records were from within the same three-day visit by HBOC members).

Table 1. Passerine species recorded during surveys of Broughton Island during 2012-2020, grouped by Reporting Rate ranges (RRs are for 2-ha and 500-m surveys combined).

Status	Common name	Scientific name
Resident or regular visitor (RR above 10%)	Yellow-faced Honeyeater	*Caligavis chrysops*
	Australian Raven	*Corvus coronoides*
	Australasian Pipit	*Anthus novaeseelandiae*
	Tawny Grassbird	*Cincloramphus timoriensis*
	Golden-headed Cisticola	*Cisticola exilis*
	Welcome Swallow	*Hirundo neoxena*
	Silvereye	*Zosterops lateralis*
Uncertain (RR 1-10%)	Little Wattlebird	*Anthochaera chrysoptera*
	Golden Whistler	*Pachycephala pectoralis*
	Willie Wagtail	*Rhipidura leucophrys*
	Grey Fantail	*Rhipidura fuliginosa*
Vagrant (RR below 1%)	Scarlet Honeyeater	*Myzomela sanguinolenta*
	White-cheeked Honeyeater	*Phylidonyris niger*
	Spotted Pardalote	*Pardalotus punctatus*
	White-throated Gerygone	*Gerygone olivacea*
	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
	Olive-backed Oriole	*Oriolus sagittatus*
	Dusky Woodswallow	*Artamus cyanopterus*
	Spangled Drongo	*Dicrurus bracteatus*
	Forest Raven	*Corvus tasmanicus*
	Rose Robin	*Petroica rosea*
	Eastern Yellow Robin	*Eopsaltria australis*
	Mistletoebird	*Dicaeum hirundinaceum*
	Brown Songlark	*Cincloramphus cruralis*
	Tree Martin	*Petrochelidon nigricans*

Comparison of results from the two time periods

Table 2 summarises the results from the surveys for each of the five main passerine species and shows the calculated Chi-Square (χ^2) value from the comparison of the two time periods, 2012-2016 and 2017-2020. In **Table 2**, all six of the 2-ha sites BT1 to BT6 have been analysed collectively, and similarly all three of the 500-m radius sites BT7 to BT9 were grouped for analysis.

Table 2. The number of surveys and the number of records, and the Reporting Rates, for the five main passerine species on Broughton Island for two time periods, and the calculated Chi-Square values for the comparisons.

Species	Survey type	2012-2016			2017-2020			χ^2 Value
		Surveys	Records	RR (%)	Surveys	Records	RR (%)	
Yellow-faced Honeyeater	2-ha	140	36	25.7	103	23	22.3	0.16
	500-m	69	16	23.2	73	32	43.8	3.88
Golden-headed Cisticola	2-ha	140	115	82.1	103	51	49.5	8.78
	500-m	69	63	91.3	73	62	84.9	0.10
Tawny Grassbird	2-ha	140	109	77.9	103	73	70.9	0.30
	500-m	69	63	91.3	73	67	91.8	0.00
Welcome Swallow	2-ha	140	100	71.4	103	72	69.9	0.00
	500-m	69	55	79.7	73	61	83.6	0.03
Silvereye	2-ha	140	85	60.7	103	67	65.0	0.12
	500-m	69	58	84.1	73	59	80.8	0.01

The results from the 2-ha surveys suggested that there may have been changes to the Golden-headed Cisticola population on Broughton Island. Thus, the data from the six 2-ha sites were examined individually plus as grouped subsets of sites: BT1 and BT6; sites BT2 to BT5 collectively; sites BT2 and BT4-BT5 collectively (**Table 3**).

Table 3. The number of surveys and the number of records, and the Reporting Rates, for Golden-headed Cisticola on Broughton Island for two time periods, and the calculated Chi-Square values for the comparisons.

Site/s	2012-2016			2017-2020			χ2 Value
	Surveys	Records	RR (%)	Surveys	Records	RR (%)	
BT1	26	20	76.9	21	15	71.4	0.00
BT2	26	21	80.8	18	7	38.9	2.31
BT3	25	19	76.0	18	4	22.2	4.70
BT4	26	23	88.5	17	8	47.1	1.90
BT5	20	17	85.0	13	5	38.5	1.91
BT6	17	15	88.2	16	12	75.0	0.05
BT1, BT6	43	35	81.4	37	27	73.0	0.09
BT2-BT5	97	80	82.5	66	24	36.4	12.38
BT2, BT4, BT5	72	61	84.7	48	20	41.7	7.28

Similarly, the results from the 500-m radius surveys suggested that there may have been changes to the Yellow-faced Honeyeater population on Broughton Island. Thus, the data from the three 500-m sites were examined individually plus as a grouped subset of sites BT7 and BT8 collectively. The details are reported in **Table 4**.

Table 4. The number of surveys and the number of records, and the Reporting Rates, for Yellow-faced Honeyeater on Broughton Island for two time periods, and the calculated Chi-Square values for the comparisons.

Site/s	2012-2016			2017-2020			χ2 Value
	Surveys	Records	RR (%)	Surveys	Records	RR (%)	
BT7	23	0	0.0	24	5	20.8	3.03
BT8	27	11	40.7	29	24	82.8	3.31
BT9	19	5	26.3	20	3	15.0	0.18
BT7 and BT8	50	11	22.0	53	29	54.7	6.27

DISCUSSION

The most obvious habitat change on Broughton Island has been the increase in shrub cover in the more-sheltered central parts of the island, particularly within site BT8 and the northern section of BT7. Four of the 2-ha sites have been similarly affected: sites BT2 to BT5. The habitats within the two other 2-ha sites, BT1 and BT6, have not substantially changed from when the surveys started in 2012, except that areas of grassland and heath within them have grown slightly taller and/or denser. Similarly, the habitat within the 500-m site BT9 seems not to have substantially changed. All three sites are more exposed to the prevailing winds and the vegetation within them is affected by wind shear.

The habitat changes that have occurred at some of the survey sites, and the lack of substantial change at other sites, seems to have been an important factor affecting changes in the distribution of some passerine populations on the island, as discussed below.

Yellow-faced Honeyeater

Some Yellow-faced Honeyeater were present on Broughton Island during the inaugural set of HBOC surveys in August 2012 (Stuart *et al*. 2017). At the time, that was understood to be the first record of the species on the island. However, the Birdata archives reveal that two birds were recorded in April 2009 (www.birdata.birdlife.org.au). There are 13 Broughton Island surveys in Birdata for the period 1999 to mid-2012; Yellow-faced Honeyeater was only recorded in the one survey in 2009, which was during the known migration period for this species (Higgins *et al*. 2001).

Since 2012, Yellow-faced Honeyeater has been recorded in every visit by HBOC to Broughton Island for bird surveys and there have been breeding records. The usual estimates have been of a total of

5-10 birds present; however, by June 2020 19 different individuals had been trapped in a bird-banding program which was established in mid-2017, with a 42% re-trap ratio (Stuart 2020). The re-trap ratio suggests a population of 40-50 birds if the entire population was resident on the island. Although the overall numbers have increased in recent years, that size of population of Yellow-faced Honeyeater seems not to be permanently present, based on the estimates of numbers made for each visit. This implies that at least some of the birds move between the island and the mainland. The one-off record in 2009 is a further indication that birds may move to and from the mainland.

The Yellow-faced Honeyeater is a long-distance migratory species (Higgins *et al*. 2001); the journey of a few kilometres between the mainland and Broughton Island would not present a challenge for it.

Initially, Yellow-faced Honeyeater was only recorded in the area immediately adjacent to a large Coastal Banksia *Banksia integrifolia* located within the 2-ha site BT3. The Coastal Banksia also lies within the 500-m radius site BT8. There is clear evidence that the species now uses a larger part of the island than formerly. The RRs in both BT7 and BT8 have increased substantially. Although the changes were not statistically significant at 95% confidence level when the results for each 500-m radius site were considered separately (Chi-Square values of 3.0-3.3), that was largely because of the limited sizes of the data sets. When the results from BT7 and BT8 were analysed together, there was a statistically significant increase in RR for Yellow-faced Honeyeater for the 2017-2020 period, at approximately 98% confident level (Chi-Square 6.27).

The spread of Yellow-faced Honeyeater across a wider area of the island, and the probable rise in its total numbers, seems to be linked with the increased extent of shrub cover in BT8 and the northern section of BT7. In contrast, there has been no significant difference in RR for site BT9, where the habitat has not substantially changed since 2012.

Golden-headed Cisticola

During 2012-2016, the Golden-headed Cisticola was considered to be a common bird of Broughton Island, with an estimated population of 200-400 birds (Stuart *et al*. 2017). There is strong evidence that the population has declined although it remains a common species in large parts of the island. The RRs within four of the 2-ha survey sites have decreased substantially. The biggest decline has been in site BT3, where the RR dropped from 76.0% for 2012-2016 to 22.2% for 2017-2020. The change is statistically significant, at greater than 95% confidence level (Chi-Square value 4.70). Furthermore, there have been no recent records from BT3; a single bird was recorded there during an October 2019 survey, but in the five subsequent visits to the island for surveys, no Golden-headed Cisticola have been detected in BT3.

Analysing the RR results for the five other 2-ha sites more closely, there is no evidence for substantial changes having occurred in sites BT1 and BT6, both of which largely have retained the habitats that were present in 2012. For sites BT2, BT4 and BT5, the RRs at each site have decreased. Although the changes were not statistically significant at 95% confidence level when the results for each site were considered separately (Chi-Square values of 1.9-2.3), that was largely because of the limited sizes of the data sets. When the results from the three 2-ha sites were analysed together, the RR was found to have dropped from 84.7% to 41.7%; that change was statistically highly significant (Chi-Square value 7.28).

The Golden-headed Cisticola population on Broughton Island has declined in areas where much of the grassland and heath habitat has been overgrown by shrub cover.

Tawny Grassbird

Although, like the Golden-headed Cisticola, the Tawny Grassbird prefers grassland and heath habitat (Higgins *et al*. 2006), there is no evidence for any population change. The RRs in the 500-m radius sites and the 2-ha sites have been stable or perhaps have decreased slightly; however, none of the changes were statistically significant (the Chi-Square values were 0.0-0.3).

Despite the extent of shrub cover having increased in several of the survey sites, the habitat that remains within those sites is a mix of shrubs and grasses/heath. It seems that the Tawny Grassbird is able to sustain in such habitat mixes. In the banding program, almost 40 individuals have been trapped, with many re-traps. That has included regular re-traps of adult birds in and around site BT3.

There is no evidence that the Tawny Grassbird population on Broughton Island has changed or is beginning to change. However, it will be interesting to see what happens in future, if the extent of shrub coverage continues to increase.

Silvereye

From the 2012-2016 surveys, the Silvereye population on Broughton Island was estimated to be 50-100 birds (Stuart *et al*. 2017). It is quite possible that the species had not long arrived on Broughton Island when the HBOC surveys commenced in mid-2012. Of the 13 Broughton Island surveys in Birdata for the period before mid-2012, Silvereye was only recorded twice – in November 2011 and May 2012 (www.birdata.birdlife.org.au). As a generally very active and vocal species, it seems unlikely that it would have been overlooked in the surveys before November 2011 if it were present.

The Silvereye is now the most common species on Broughton Island. Around 550 individual birds have been banded on the island since 2017, with many re-traps (Little *et al*. 2020; Stuart 2020; G. Little pers. comm.). There is a resident or regularly visiting population of subspecies *cornwalli* which swells because of an autumn/winter influx of migratory *westernensis* and *lateralis* subspecies birds and then a spring influx of locally nomadic *cornwalli* birds (Little *et al*. 2020; Stuart 2020). Images taken on Broughton Island of the three Silvereye subspecies are presented in **Figure 2**.

Figure 2. The three Silvereye subspecies on Broughton Island: (Left) *cornwalli* (yellow throat, pale-buff flanks) (Middle) *westernensis* (grey-yellow throat, buff flanks) (Right) *lateralis* (grey throat, deep buff flanks).

The main areas used by Silvereye on Broughton Island are BT8 and the northern parts of BT7, where the extent of shrub coverage has increased the most. However, it is a very mobile species and small flocks have regularly been seen flying to various parts of the island, landing in any available shrubs to rest or to forage. The Chi-Square test suggests there has been no statistically significant change at any of the 2-ha or 500-m sites on the island. Importantly though, the test was based on presence/absence and did not take numbers of birds into account. Although in every survey there is an estimate made of the numbers of birds present, such estimates are very approximate; also, they are subject to variations in observer skill and observer effort (including, differences in the number of observers). Thus, it is difficult, from the bird surveys alone, to assemble conclusive evidence of an increased population of Silvereye. The bird banding program, which since June 2017 has operated in parallel with the bird surveys, offers important insights. Silvereye have been caught every visit, usually many birds. The re-trap ratio has been modest, which suggests that the size of any resident population must be small. Nevertheless, there have been many re-trapped birds (Stuart 2020).

The Silvereye population on Broughton Island, including resident birds and birds visiting regularly or nomadically, seems to have increased substantially since 2012 and it is now the most common bird species on the island.

Welcome Swallow

The Welcome Swallow has been a common species on Broughton Island over 2012-2021, and with many breeding records. Birds have been recorded regularly in every 2-ha and 500-m terrestrial survey site (i.e. sites BT1 to BT9). There is no evidence to suggest any substantial change in its population. The RRs for the 2-ha sites and the 500-m radius sites have scarcely changed across the two study periods, 2012-2016 and 2017-2020. For such a mobile species which forages aerially, i.e. more or less independently of the habitat below, it seems unsurprising that it has been little impacted from the habitat changes that have been occurring on Broughton Island.

Other passerine species

Australasian Pipit and Australian Raven were recorded in almost every visit and there have been some breeding records. Both species are considered to be resident on Broughton Island, but they have only ever been present in low numbers (estimated at 4-6 birds each) and there were insufficient data for meaningful analysis for changes in their populations. However, both populations appear to be stable.

The Little Wattlebird *Anthochaera chrysoptera* was first recorded on the island in March 2014. There were regular records of 2-4 birds in visits during 2014-2018, and since autumn 2019. However, only one bird was confirmed to be present in January 2019 when conditions on the island were dry and there have not been any breeding records (although evidence of breeding has not been specifically sought). It may be that the Little Wattlebird moves between the mainland and Broughton Island in

response to local conditions. The Little Wattlebird is a common species in coastal heath on the mainland directly opposite Broughton Island (Williams 2020).

Although there have been many records of Willie Wagtail *Rhipidura leucophrys* on Broughton Island over 2012-2020 (and, from before 2012), there also have been frequent absences. This species seems to move between the mainland and the island in response to local conditions.

The first record of a Golden Whistler *Pachycephala pectoralis* on the island was in April 2016. One to two birds were recorded in six of the subsequent field trips but there were several other visits with no records. For example, in 2020 Golden Whistler was only recorded in one of the five field trips, and in only two of the four visits in 2019. There have not been any summer records (in field trips spanning the months November to February). Three of the field trips with records were autumn ones but there have also been two winter records and two records from spring visits. It would be easy to overlook a Golden Whistler if it were inhabiting the dense shrubs in the central parts of the island and not calling. It is unclear as yet whether this species has colonised Broughton Island or if it makes occasional visits from the mainland.

The first records of Grey Fantail *Rhipidura fuliginosa* were in April and September 2013, the only two field trips in that year. There were no more records until April 2016. Since then, 1-2 birds were recorded in six of the subsequent field trips, all of those being autumn or winter ones. It would be easy to overlook a Grey Fantail if it were inhabiting the dense shrubs in the central parts of the island and not calling. It is unclear as yet whether this species has colonised Broughton Island or if it makes occasional visits from the mainland.

CONCLUSIONS

Of the 25 passerine species recorded on Broughton Island, seven species are resident or are regular visitors. An additional four species are often present, but it is not clear whether they are resident on the island or whether they make occasional visits from the mainland.

The population of Yellow-faced Honeyeater on the island has been increasing and its distribution has been expanding. In contrast, the population of Golden-headed Cisticola has decreased, with birds now absent or declining from some parts of the island. Both of these changes are associated with small to medium-sized shrubs displacing grasslands and heath.

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A twenty-year study of waterfowl *Anatidae* at Morpeth Wastewater Treatment Works near Maitland, NSW

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This paper documents the occurrence of waterfowl *Anatidae* at the Morpeth Wastewater Treatment Works (MWTW) during monthly surveys between 2001 and 2020. Thirteen species were recorded, eight frequently and often in large numbers; a further five occasionally in modest numbers. Counts often involved more than 500 waterfowl and seven species, with over 2500 birds occasionally present.

Waterfowl mainly congregate at MWTW for shelter and to feed. Breeding is unusual, although some species were occasionally observed with ducklings and Black Swan *Cygnus atratus* bred when conditions were suitable.

Some species, for example the Pink-eared Duck *Malacorhynchus membranaceus*, use peri-coastal habitat such as MWTW as a drought refuge when conditions in their core range in inland Australia are unsuitable. Other species, such as the Grey Teal *Anas gracilis* and Australasian Shoveler *Spatula rhynchotis,* also had peak occurrences suggesting that resident coastal populations may be periodically supplemented by influxes of birds from inland areas.

Although general patterns relating the abundance of waterfowl to inland conditions were apparent, the timing of peak occurrences of individual species at MWTW varied. Situated on the edge of the Hunter Estuary flood plain, MWTW is one of a number of fresh water and estuarine habitats. Hence, the attraction of waterfowl to MWTW is influenced by a complex combination of conditions, both local and in inland Australia.

MWTW demonstrates the value of wastewater ponds as habitat for waterfowl and other waterbirds, a resource increasingly important in regions where there are fewer alternatives than at Morpeth.

INTRODUCTION

In February 2001 members of Hunter Bird Observers Club Inc. commenced surveys at Morpeth Wastewater Treatment Works (MWTW). This report details the results for waterfowl *Anatidae* from 20 years of continuous monthly monitoring up to and including February 2021. Three previous papers reported on the importance of MWTW to heron, spoonbill and ibis species (Newman & Lindsey 2011a), to shorebird species (Newman & Lindsey 2011b) and to raptors (Newman & Lindsey 2016) respectively. A fourth paper reported on the first year of surveys, 2001 (Lindsey & Newman 2002). MWTW is listed in the Australian National Directory of Important Migratory Shorebird Habitat (Weller *et al.* 2020).

MWTW, 32°44'31"S, 151°37'24"E, owned by Hunter Water Corporation (HWC), is located approximately 10 km north-east of Maitland and covers an area of 72 ha. The original plant, which was decommissioned in 2000, was a biological filtration works constructed in 1936 (Newman & Lindsey 2011a). Currently MWTW provides secondary treatment using an activated sludge process. Four maturation ponds were used for waterbird habitat and effluent reuse storage (HWC website). HWC is required to manage the ponds as wetland and riparian habitats to encourage their use by indigenous and migratory species (Newman & Lindsey 2011a). Before decommissioning, the maturation ponds were receiving a nutrient load so high that large algal blooms were frequent. After the new plant started in 2000 the nutrient load ceased and, after about five years, the algal blooms also ceased (S. Clewes pers. comm.). Apart from the

water treatment facility, the MWTW site (**Figure 1**) consists of ponds which have permanent water (A), a sludge pond which retains water, but occasionally dries out (B), and a bunded ephemeral wetland (C). On the eastern, western and southern sides of the site (E and D) are privately owned ephemeral wetlands, which like area C (**Figure 2**), are subject to a wetting and drying regime in response to rainfall (Newman & Lindsey 2011a). Approximately 50 cattle graze the area around the ponds and in the ephemeral wetland. The wetland to the south was considered ephemeral but, after the creation of Chisholm, a new suburb of Maitland on formerly agricultural land, the hydrology underwent considerable change and this wetland now retains water for longer periods. Residential development continues in that area.

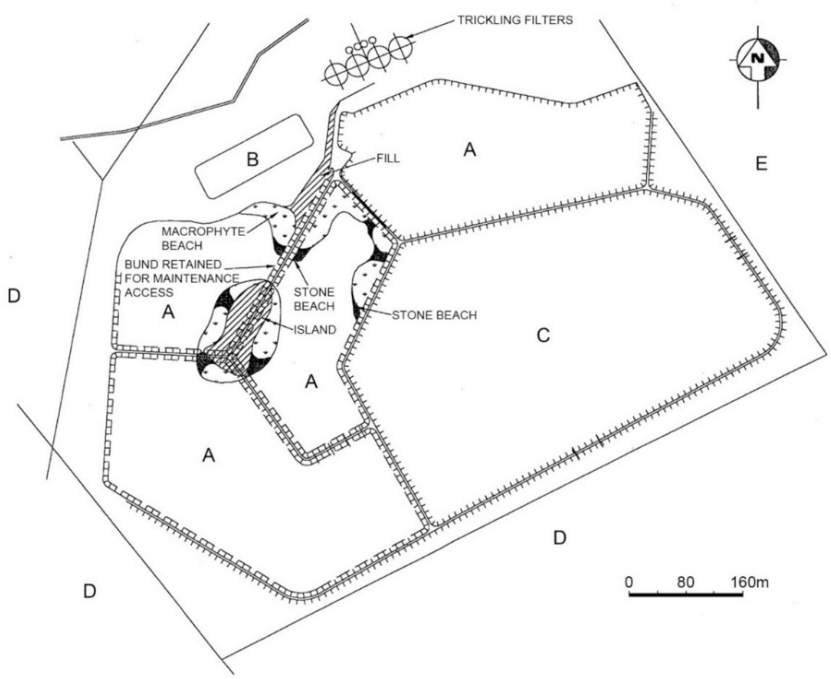

Figure 1. Morpeth Wastewater Treatment Works. (A: ponds with permanent water, B: sludge pond which occasionally dries out, C: ephemeral wetland in bunded area which intermittently floods, D & E: privately owned ephemeral wetlands).

Figure 2. Bunded ephemeral wetland (area C in **Figure 1**). Left: while flooded in winter with Black Swan on nest in foreground and cattle grazing in background. Right: while dried out in summer.

METHODS

Surveys were conducted monthly commencing in February 2001. Over the 20-year period, 236 surveys were completed. The same route around the maturation ponds was followed each time. Stops to count birds both on the ground and in flight were made at several fixed points and when birds were visible elsewhere. The surveys took between two and three hours and commenced between one and two hours after sunrise. Binoculars and telescope were used and care was taken

to minimise the risk of double counting if birds were disturbed, usually by raptors (Newman & Lindsey 2011a). Monitoring was carried out by two observers, one of whom (AL) participated from 2001 to December 2020 after which two new surveyors commenced.

Survey data were archived in the BirdLife Australia Birdata portal (www.birdlife.birdata.org.au). Notes were taken at the time of the surveys on the status of the ephemeral sites with regard to water levels. Terminology borrowed from Birdata - dry, below capacity, mud/sand flats exposed, at capacity, flooding – was used. Over the 20 years water has always been present in the ponds (A in **Figure 1**).

RESULTS

Thirteen species of waterfowl were recorded at MWTW during the 20-year period. Many of those were frequently present and in substantial numbers sometimes, while others were recorded infrequently and in small numbers. The results for all species are presented in **Table 1**, with the maximum and minimum counts and the median counts for when the species were present.

The number of ducks present during a survey ranged from 61 to 3651 birds (median number 826), involving between three and ten species (median seven species). Although ducks were scarce during the final year of the study there was no evidence of a statistically significant decrease in numbers (**Figure 3**) or species diversity (**Figure 4**). There were no statistically meaningful temporal trends in the numbers of individual species shown in **Figures 5** and **6**. Correlation coefficients for linear and polynomial models were used to assess the strengths of trends.

Four species, Black Swan *Cygnus atratus*, Pacific Black Duck *Anas superciliosa*, Grey Teal *Anas gracilis* and Chestnut Teal *Anas castanea* were recorded on more than 90% of surveys and a further three species, Australian Wood Duck *Chenonetta jubata*, Hardhead *Aythya australis* and Australasian Shoveler *Spatula rhynchotis*, on 70 to 80% of surveys (**Table 1**).

Chestnut Teal, an abundant species (median count 124 birds), was the only species recorded on every survey. However, as shown in **Figure 5a** its numbers fluctuated widely between surveys. It was least numerous between 2001 and 2004 and between 2019 and 2021 i.e. at the start and end of the study period. There was a sustained period of elevated numbers between 2012 and 2014.

Grey Teal (median count 325 birds) was more than twice as abundant as Chestnut Teal but had more pronounced fluctuations in numbers (**Figure 5b**), involving a combination of short-term monthly peaks, and periods of sustained scarceness in 2010/11 and 2020/21. The peak number of 2,563 birds was about three times higher than the peak number of Chestnut Teal.

Pacific Black Duck was usually present in modest numbers (median 68 birds) with occasional short-term spikes, including one of 1,242 birds (**Figure 5c**).

Black Swan (**Figure 5d**) was another regularly occurring species with similar abundance (median count 89 birds) and short duration peaks (maximum count 853 birds) to the Pacific Black Duck.

Table 1. Statistics for the occurrence of waterfowl at the Morpeth Wastewater Treatment Plant between 2001 and 2021 based on 236 surveys.

Common Name	Number of records	Percentage of surveys present (%)	Maximum count	Minimum count (when present)	Median count (when present)
Plumed Whistling-Duck	2	0.8	25	1	13
Wandering Whistling-Duck	6	2.5	19	1	5
Musk Duck	13	5.5	9	1	1
Pink-eared Duck	136	57.6	1010	1	15
Freckled Duck	21	8.9	37	1	3
Black Swan	230	97.5	853	1	89
Australian Wood Duck	182	77.1	107	1	7
Hardhead	172	72.9	1200	1	15
Australasian Shoveler	188	79.7	682	1	21
Pacific Black Duck	232	98.3	1242	3	68
Mallard	3	1.3	1	1	1
Grey Teal	228	96.6	2563	2	325
Chestnut Teal	236	100.0	836	4	124

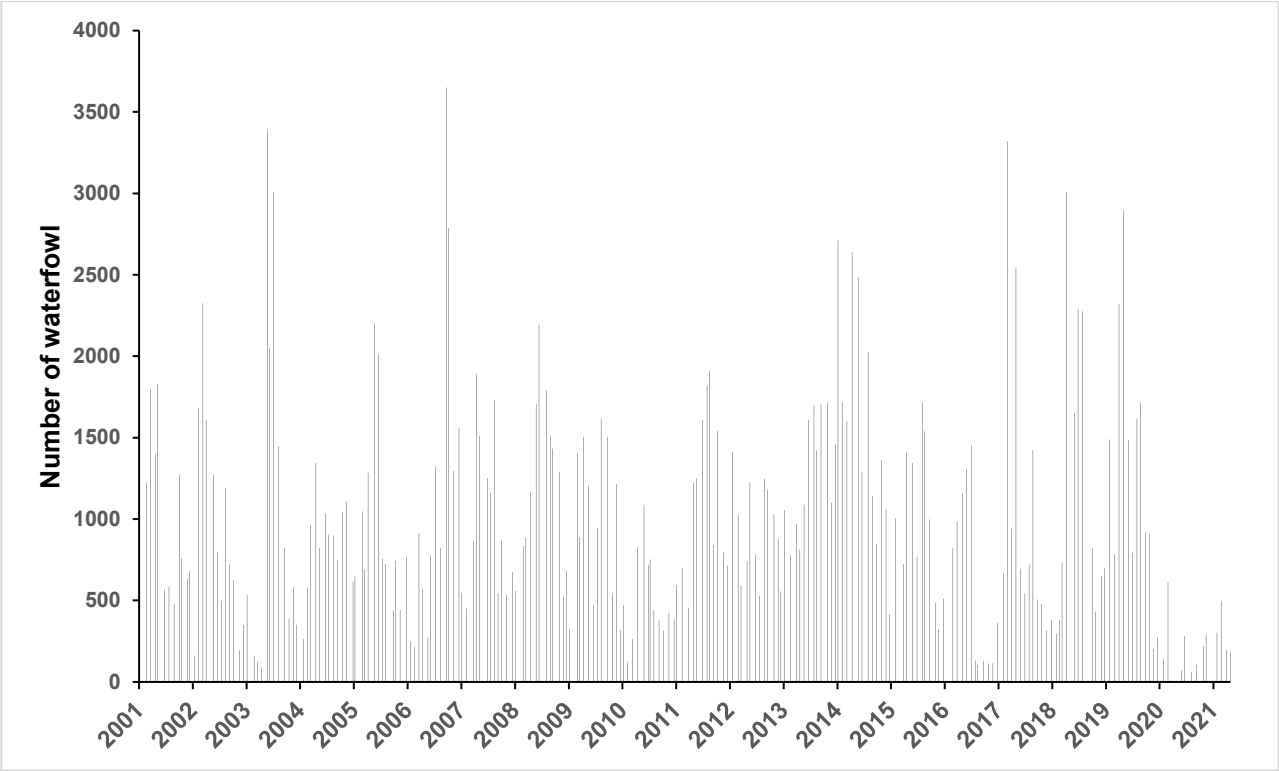

Figure 3. Variation in the number of all *Anatidae* waterfowl present at the Morpeth Wastewater Treatment Works between 2001 and 2021.

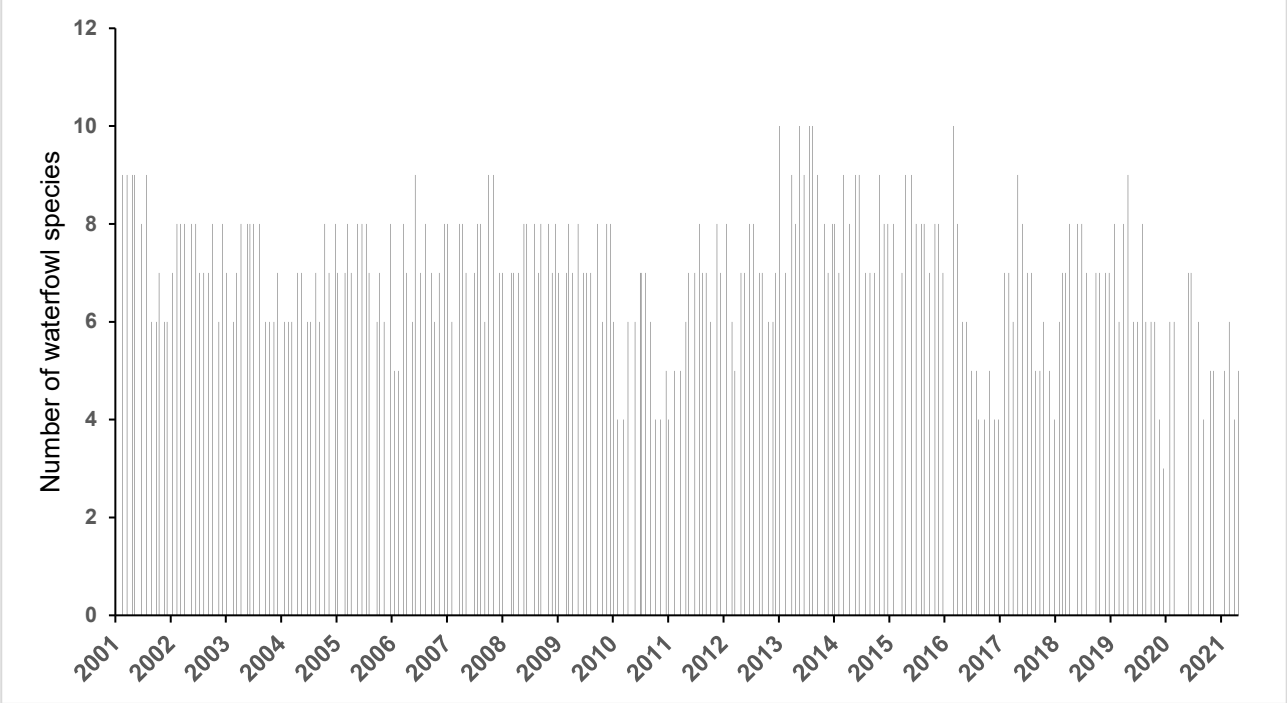

Figure 4. Variation in the number of *Anatidae* waterfowl species present at the Morpeth Wastewater Treatment Works between 2001 and 2021.

Figure 5. Variation in the numbers of the four most frequently recorded waterfowl species, (a) Chestnut Teal, (b) Grey Teal, (c) Pacific Black Duck and (d) Black Swan during surveys conducted at the Morpeth Wastewater Treatment Works between 2001 and 2021.

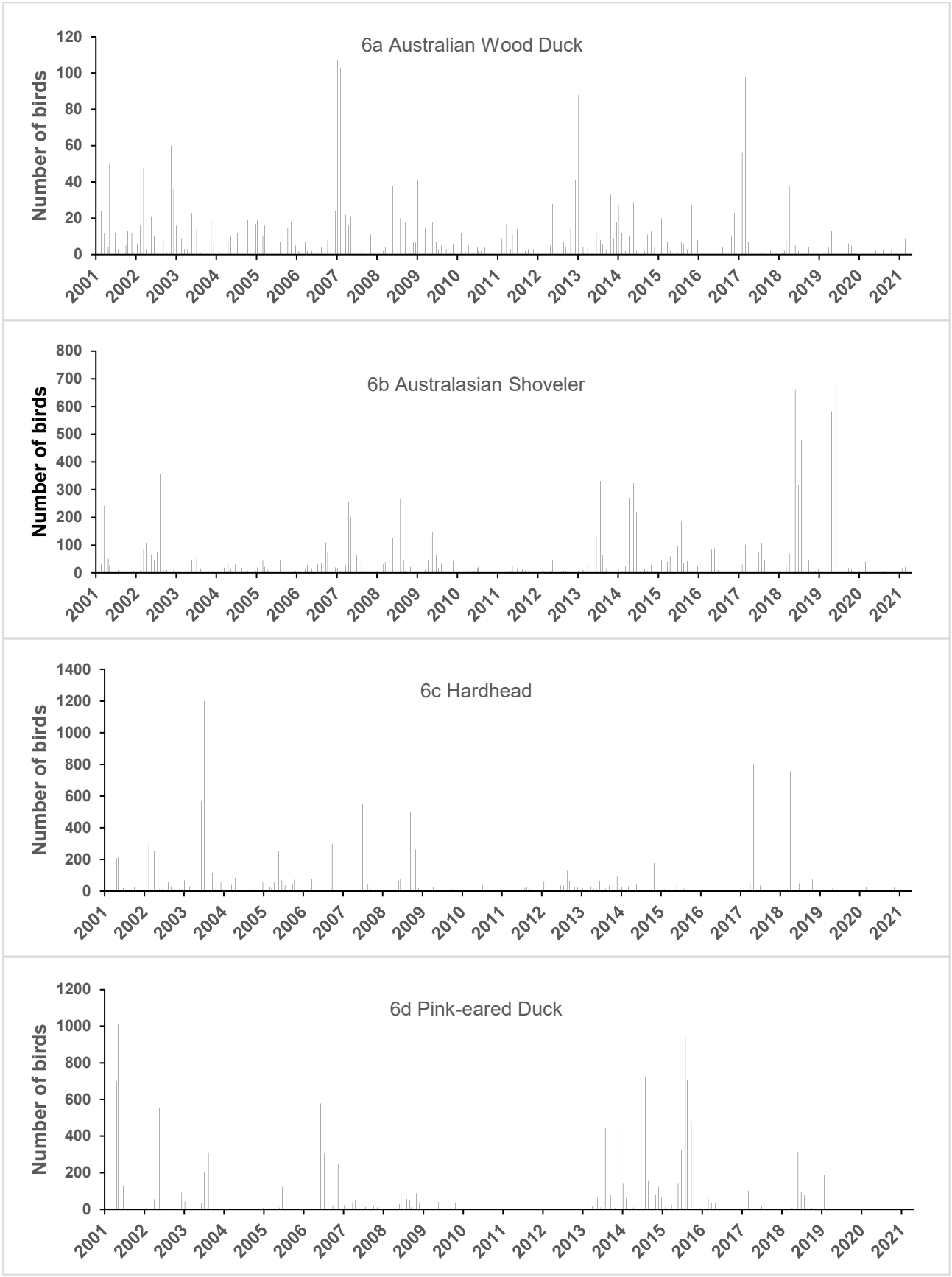

Figure 6. Variation in the numbers of four waterfowl species recorded, either regularly in modest numbers (a) Australian Wood Duck and (b) Australasian Shoveler, or intermittently in considerable numbers (c) Hardhead and (d) Pink-eared Duck for surveys conducted at the Morpeth Wastewater Treatment Works between 2001 and 2021.

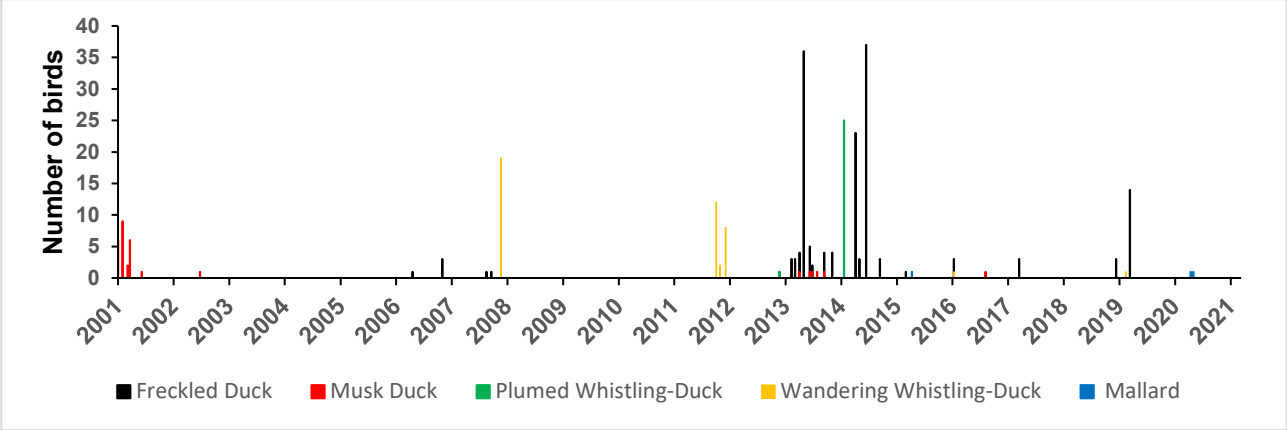

Figure 7. Variations in the numbers of five species of duck which were recorded occasionally during surveys conducted at the Morpeth Wastewater Treatment Works between 2001 and 2021.

Australian Wood Duck was recorded in 77% of surveys but was not numerous (median of seven birds), although flocks of up to 107 birds were occasionally present (**Figure 6a**). The occurrence of Australasian Shoveler (**Figure 6b**), recorded in 80% of surveys, was similar, except that the short-term spikes in occurrence involved much larger numbers with a maximum of 682 birds, increasing the median to 21 birds, three times that of the Australian Wood Duck. The intermittent occurrence of Hardhead (**Figure 6c**) and Pink-eared Duck *Malacorhynchus membranaceus* (**Figure 6d**) involved a number of short-term peaks in excess of 1,000 birds, but most counts were of small numbers, the median for both species being 15 birds.

The other five species were recorded during < 10% of surveys and in modest numbers (**Table 1**). The timing of their occurrence is shown in **Figure 7**. Most of these records were in the period 2013-15, when Freckled Duck *Stictonetta naevosa* were regularly present, with a maximum of 37 birds. Four of the nine records of Musk Duck *Biziura lobata* occurred in 2001 and 2002, including the highest counts of nine and six birds in 2001.

Breeding

Based on evidence of birds sitting on nests or of adults with cygnets or ducklings, five species bred at or in the vicinity of MWTW between 2001 and 2020. These were Black Swan (40 breeding records), Australian Wood Duck (four breeding records), Pacific Black Duck (23 records), Grey Teal (eight records) and Chestnut Teal (23 records). The maximum count of Chestnut Teal ducklings on any visit was 18.

Black Swan predominantly bred on the ephemeral bunded wetland C (**Figure 1**) when it flooded in winter. The maximum count of cygnets was 46 in September 2010. They may have experienced predation from Red Foxes *Vulpes vulpes* which were breeding in a burrow in the bund wall. Red Fox was recorded during 20 surveys. On seven of these surveys, two foxes and on one survey, three foxes were present.

Predator response

Wildfowl using the ponds alighted on the water, but often subsequently moved to the banks where they congregated and loafed for extended periods unless disturbed. Their response to disturbance (e.g. to raptors) was to return to the water or take flight before re-alighting on the water.

DISCUSSION

In attempting to understand the wide fluctuations in the number of individual species, the timing of those fluctuations and the differences between species, many factors have to be considered. These include the life-traits of the species, rainfall patterns on the Hunter flood plain surrounding MWTW, conditions outside the Hunter Region, including inland Australia and the changes in the suitability of habitat at the MWTW survey site. Consideration must also be given to the purpose of each species in frequenting MWTW; whether for breeding, feeding or for a secure location to shelter. Given the diurnal timing of the surveys, some aspects of these questions can be answered only through inferences drawn from other studies. For instance, Australian Wood Duck often congregate at wetlands during the day before dispersing near dawn and dusk, to forage in surrounding agricultural land within 10-km radius of wetlands, to which they show high short-term fidelity (McEvoy *et al.* 2019). Species like Grey Teal, Pink-eared and Freckled Ducks opportunistically breed in large numbers on

ephemeral wetlands of arid inland Australia and disperse when they dry (Peddler & Kovac 2013).

Changes in habitat at Morpeth Wastewater Treatment Works

Wetlands are dynamic ecosystems experiencing cycles of drying and flooding in response to climatic conditions. MWTW is no exception despite being a constructed wetland with a permanent supply of wastewater. Altered hydrology was the main factor driving changes to the habitat at the site. It mainly affected the southern ephemeral area (D) which now retains water for longer periods. Nevertheless, the site continued to have periods when water was shallow and waterfowl continued to forage or roost on higher areas.

Another change involves the reduction of nutrients entering the ponds and surrounding ephemeral wetlands following the implementation of secondary treatment using the activated sludge process, but we were unable to assess the effect this had on waterfowl.

Changes in the Hunter Estuary external to Morpeth Wastewater Treatment Works

Since 2008, rehabilitation projects in the lower Hunter Estuary centred around the reintroduction of partial tidal flushing have increased suitable habitat for most species of waterfowl at Ash Island, Hexham Swamp and Tomago Wetland (Stuart & Lindsey 2021.; Lindsey 2021). These increases in habitat do not seem to have affected the number of waterfowl visiting MWTW over the 20-year period. As a result of the only survey where Chestnut Teal were counted simultaneously at both MWTW and the Hunter Estuary, on 18 March 2011, we know that 2,296 Chestnut Teal were at sites in the estuary monitored monthly by HBOC members and 264 were at MWTW and immediately adjacent wetlands (Lindsey & Roderick 2011). Data collected over 22 years of Hunter Estuary surveys show similar fluctuations in Chestnut Teal numbers (HBOC unpublished data).

Common residents

Four species breed regularly in the lower Hunter Region surrounding MWTW: Chestnut Teal, Pacific Black Duck, Black Swan and Australian Wood Duck (Williams 2020). For the first three species, this was reflected in their presence during almost every survey. The Australian Wood Duck was less frequently recorded, although there was no clear seasonal variation in its presence.

Chestnut Teal

Within the Hunter Region and indeed throughout NSW, Chestnut Teal primarily breed in coastal and sub-coastal areas (Williams 2020; Cooper *et al*. 2014; Marchant & Higgins 1990). Consequently, fluctuations in the number present at MWTW are attributed to local birds responding to changes in conditions (e.g. water levels) at MWTW and in the surrounding flood-plain, rather than influxes from inland areas. However, there were instances where exceedingly large numbers, two or three times the background count levels, were briefly present (i.e. for one monthly survey). The five highest occurrences were spread across the summer months October (two peak occurrences) to May (one occurrence). There was a gradual increase in numbers throughout the first ten years, prior to a corresponding decrease in the following decade. Williams (2020) suggests that the Hunter Region's Chestnut Teal population is stable, which may indicate that the MWTW site provided optimal conditions for the Chestnut Teal mid-study. Although the number of Chestnut Teal did not meet the 1% threshold (1,000 birds) which identifies wetlands of international importance under the Ramsar Convention (Wetlands International 2021), MWTW remains an important site for this species. It was present on all surveys and over 500 birds were recorded on seven occasions.

Pacific Black Duck

Other than being less numerous at MWTW, the occurrence of the Pacific Black Duck had a generally similar pattern to the Chestnut Teal. On most surveys there were fewer than 50 birds, which is typical of counts at wetlands throughout the Hunter Region (Williams 2020), and these birds probably reflect the local breeding population. There was a similar, but less pronounced tendency for numbers to be highest mid-study, as noted for the Chestnut Teal. The intermittent short-duration spikes in numbers, which on five occasions exceeded 500 birds, all occurred in autumn. Large numbers of birds were seldom present in successive months. These spikes are tentatively attributed to influxes from inland as wetlands there dry out during summer and become unsuitable. Such movements are known to occur (Marchant & Higgins 1990).

Black Swan

Black Swan, which is a common resident in the Hunter Region, often breeds at MWTW. Numbers showed considerable variation, often building up from February onwards at about the beginning of the main breeding season in NSW (May-Sep.) (Marchant & Higgins 1990; Cooper *et al*. 2019). The pattern of long-term temporal changes was generally consistent with those of the Chestnut Teal and Pacific Black Duck, with the numbers greatest mid-study.

Australian Wood Duck

Although regularly present, numbers of Australian Wood Duck were small (median of seven birds). They forage mainly in paddocks and probably breed in close proximity to MWTW. Unlike the other resident species, Australian Wood Duck has less tendency to congregate in substantial numbers at large wetlands, which may explain the differences in the temporal profile of variations in its numbers compared with the other resident species. The short-term spikes in occurrence, involving up to 100 birds, are consistent with the formation of post-breeding season diurnal congregations that disperse to feed at night in the surrounding landscape (McEvoy *et al*. 2019).

Episodic species

The occurrence of the Pink-eared Duck, Hardhead, Australasian Shoveler and Grey Teal were differentiated from the resident species by the greater disparity between their peak occurrences and their background numbers associated with the resident breeding population.

Pink-eared Duck

There were five irruptions exceeding 500 birds. Unlike the species discussed previously, substantial numbers often remained for several months, including after the largest irruption that involved 1010 birds and peaked in May 2001 (**Figure 6d**). It was noted at that time that the birds were actively feeding, suggesting that there was abundant food available for this specialist filter-feeding species; this was in the period when nutrient levels in the ponds were high. Its presence was associated with water levels described as “flooding” or “at capacity” in 2001, 2014, 2015.

In contrast, 578 Pink-eared Ducks were on one of the ponds in June 2006, after being largely absent throughout the previous year. At that time drought conditions prevailed throughout NSW (Bureau of Meteorology 2007) and the ephemeral wetlands were dry, demonstrating the importance of the ponds as a drought refuge of last resort.

Hardhead

The occurrence of Hardhead at MWTW was consistent with their known status as a dispersive and irruptive species that breeds opportunistically in inland Australia (Marchant & Higgins 1990; Cooper *et al*. 2014). Four irruptions of over 600 birds occurred in autumn and one of 1200 in winter (**Figure 6c**). All occurred when the water levels in the ponds and ephemeral wetlands were either flooding (March 2001 and 2002) or at capacity (July 2003 and April 2017 and 2018). However, as Hardheads are diving ducks and mostly occurred on the bunded holding ponds (A in **Figure 1**), where the water level did not fluctuate, their occurrence at MWTW was concluded to be associated with changes elsewhere as opposed to inundations at the site.

Australasian Shoveler

Australasian Shoveler is described as a dispersive species with no seasonal pattern of abundance anywhere in its range (Marchant & Higgins 1990; Cooper *et al*. 2014). However, this does not seem to be the case in the Hunter Region. Numbers of Australasian Shoveler at MWTW usually built up over autumn and winter, with the birds often disappearing for spring and summer, or occurring only in small numbers. This is consistent with the occurrence of this species in the Hunter Estuary (BirdLife Australia Birdata database 2021) and at Tomago Wetland (a site within the Hunter Estuary). Its presence at Tomago in summer was seemingly prompted by rainfall (Lindsey 2021).

Grey Teal

Although considered locally resident (Williams 2020), Grey Teal travel large distances, often to inland areas to exploit ephemeral fresh-water breeding opportunities (Peddler & Kovac 2013), which may account for its absence in 2010/2011 and 2020/2021 periods when drought conditions eased and the inland experienced good rainfall (Bureau of Meteorology 2015; 2021).

Its occurrence at MWTW reflects its nomadic life-style. Although recorded during 97% of surveys there were often extended periods when Grey Teal were present in very small numbers. Yet when massive influxes occurred e.g. 2,563 birds on 27

February 2017, the elevated numbers continued for a number of months, sometimes for more than a year, and it is possible that many of the same individuals remained locally for several months. Rapid increases in numbers occurred at different times of the year (e.g. the five largest counts occurred in February, May, twice in June and September) rather than exclusively at the end of summer periods. Influxes may have been a consequence of varying weather conditions. For instance, 2017 was the driest year since 2006, but in mid-February severe thunderstorm activity brought heavy rain to the east coast of NSW. Similarly, influxes in May and June 2017 may have been associated with rainfall which filled wetlands in the aftermath of severe tropical cyclone Debbie (Bureau of Meteorology 2018). From June to September 2017 conditions inland were the second driest on record and September was driest since records began in 1900 and involved daytime temperatures 12 degrees warmer than average. This may account for the influx of 1107 birds at MWTW in August, even though dry conditions predominated with ephemeral wetlands on the site drying. The absence of Grey Teal in 2010/2011 and 2020/2021 may be explained by La Niña events bringing above-average rainfall to inland Australia.

Uncommon visitors

Musk Duck

Musk Duck, which is a scarce resident in the Hunter Region, is usually associated with larger and deeper bodies of water (Williams 2020) than are found at MWTW. There was a disproportionate number of records during the first two years of the study including the only counts which exceeded five birds. At that time the maturation ponds were known to hold elevated nutrient levels, presumably supporting conditions suitable for this specialist diving duck. It disappeared and was not seen again until May 2013 when one bird appeared and, presumably the same bird, remained until October of that year. A series of East Coast Lows produced heavy rain from May through June and the bird may have been attracted by the abundance of water present on the site.

Freckled Duck

In NSW Freckled Duck is listed as Vulnerable under the *Biodiversity Conservation Act 2016*. It is an uncommon, irruptive visitor to the Hunter Region (Williams 2020) periodically occurring in coastal areas in response to drought conditions inland (Marchant & Higgins 1990; Cooper *et al.* 2014). Most of the records were in 2013 and 2014 when East Coast Lows and heavy rain filled wetlands to capacity.

Mallard

Given the regular records of Mallard *Anas platyrhynchos* at coastal wetlands in the Hunter Region, it is perhaps surprising that there were only three records at MWTW involving a maximum of two birds. This may suggest that it remains largely habituated to exploiting situations involving supplementary feeding (i.e. being given bread by people).

Duration and timing of peak numbers

Most of the peak occurrences were of short duration and there was no synchronisation in the timing of peak occurrences of different species (e.g. **Figure 7**). This may suggest that flocks of irrupting species are highly mobile, moving round the landscape seeking suitable refuges. During their temporary presence at refuges such as MWTW they may deplete local resources and be forced to move elsewhere. If this proposition is correct, a monthly survey protocol may be insufficient to detect all the peak occurrences of the various species.

Population trends

Williams (2020) and Cooper *et al*. (2014) have assessed the stability of the waterfowl populations of the Hunter Region and NSW based on regional trends in reporting rates of Atlas data. This approach assumes that reporting rates, the frequency at which a species is present in surveys, is a reliable surrogate indicator of changes in population size. While this may be a viable assumption for many species, it is less reliable for species like waterbirds that congregate in large flocks. For instance, the widespread occurrence of a breeding species, such as the Pacific Black Duck, would be the dominant factor contributing to a stable reporting rate trend of a species, but would not reflect the large variation in the number of individuals from periodic influxes from outside the region. For instance, the Pacific Black Duck was present in 98% of the surveys at MWTW, with its numbers varying from three to 1,242 birds, with a median count of 68 birds. Consequently, it is not surprising that there are some differences in the conclusions drawn on the status of species in different studies. MWTW is just one wetland in the Hunter Estuary complex and the future challenge is to establish regional population trends based on an array of continually counted wetlands. Fortunately, many wetlands in the Hunter

Estuary have been monitored regularly during the last decade, providing an ideal resource for such analysis (Stuart 2018).

Maintenance as wetland habitat

Although the MWTW ponds were retained as a wetland resource, they were not maintained to enhance that function. Our observations have identified some potential opportunities and threats. For example, the habitat at the bunded ephemeral wetland (C in **Figure 1**) could be managed by periodically pumping water from the ponds (A in **Figure 1**) to control the level of flooding and to establish water meadow conditions in summer, benefitting both waterfowl and a number of other wetland species (e.g. migratory shorebirds).

Congregations of waterfowl inevitably attract raptors to MWTW (Newman & Lindsey 2009 and 2016). Although some tree cover may be beneficial, proposals to establish extensive tree plantations around the ponds have been opposed in order to preserve the ability of flocks of waterfowl to detect predators early (Newman & Lindsey 2009) and take evasive action, usually involving taking flight. This is particularly important when they are loafing on the banks of the ponds.

There need to be ongoing programs of weed and pest control. For example, the Red Fox is known to be attracted to breeding Black Swan (Peddler & Kovac 2013).

CONCLUSIONS

MWTW provides permanent habitat for waterfowl and is an important resource from a conservation perspective. Thirteen species of the family *Anatidae* were recorded during monthly surveys between 2001 and 2020; eight species were recorded regularly, often in large numbers, sometimes exceeding 2500. Five other species were recorded occasionally in modest numbers. These included the Freckled Duck, a threatened species which is listed as Vulnerable in NSW.

MWTW acts as a drought refuge for waterfowl breeding in inland Australia when conditions in their core habitat are unsuitable. When the drought extends to the coast the existence of permanent freshwater habitat at MWTW, supplementing the brackish habitat of the Hunter Estuary, is clearly important in sustaining waterfowl at a critical point in their life cycle.

Five species bred at or in the vicinity of MWTW. However, breeding was not the primary driver for the presence of any of those species.

This study demonstrates the importance of managing wastewater treatment ponds as habitat for waterbirds. This opportunity becomes increasingly important in inland situations where there are few alternative sources of permanent water during drought conditions.

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Targeted surveys for Rufous Scrub-birds in the Hunter Region in 2020

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The threatened Rufous Scrub-bird *Atrichornis rufescens* occurs in some isolated high-altitude locations in parts of north-eastern New South Wales and south-eastern Queensland, including within the Hunter Region where there is a known population of the southern subspecies *ferrieri* in the Gloucester Tops. The distribution of Rufous Scrub-bird elsewhere within the Hunter Region has been uncertain. Although there exist some reports from other locations, none of those reports appear to have been followed up for confirmation, and nor has there ever been any systematic assessment of other parts in the region. Bushfires in the summer of 2019-20 destroyed large amounts of habitat in New South Wales including in montane areas where the Rufous Scrub-bird potentially could occur.

The surveys conducted in this report covered areas that were burnt in the 2019-20 bushfires, seldom-visited sites where there was believed to be suitable habitat, and locations where there were historical reports for the species. A combination of transect-surveys and site-specific surveys was used. At each site surveyed, a description and current status of the habitat was recorded along with an assessment of suitability for the Rufous Scrub-bird.

The present study is the first systematic assessment of Rufous Scrub-bird distribution within the overall Hunter Region. Areas where scrub-birds might be present were identified by studying aerial photographs, topographical maps and vegetation maps and from a review of all the previous records. Three sub-sections of the Hunter Region were selected as priority areas for field assessment, and from within those areas 71 sites or transects were surveyed in 2020. All 71 sites/transects were visited during October/November when scrub-birds are most vocal. Many of the sites had been burnt in the 2019-20 bushfires.

Only six of the 71 surveys recorded a singing Rufous Scrub-bird. These sites were all near the periphery of the known population in the Gloucester Tops. Ten sites had previous reports of Rufous Scrub-birds calling but we did not hear birds calling at any of these sites. The majority of these ten sites did not appear to have the generally accepted habitat requirements for Rufous Scrub-bird. However, the habitat at 21 other sites was deemed to be suitable for scrub-birds and potentially suitable habitat was identified at 13 additional sites. At the six sites where scrub-birds were found in the surveys, the habitat was deemed to be typical of that used by scrub-birds elsewhere in the Gloucester Tops.

An important outcome of these surveys was that scrub-birds were only confirmed to be present in a small area of the Gloucester Tops, near to where there were previously-known territories. No scrub-birds were detected in any other part of the Hunter Region. This suggests that the local Rufous Scrub-bird population is much smaller than previously thought to be the case. That finding has important implications for the Rufous Scrub-bird's conservation status.

INTRODUCTION

The Rufous Scrub-bird *Atrichornis rufescens* is a cryptic species that lives in parts of north-eastern New South Wales and south-eastern Queensland. Its range is limited to a few isolated high-altitude locations, such as Barrington Tops National Park, the Hastings Range, and the New England National Park, where there is dense ground cover and deep leaf-litter in rainforest and wet eucalypt forest (Ferrier 1984). There are two subspecies, *rufescens* in the north of the range and *ferrieri* in the south (Garnett *et al*. 2011).

The Rufous Scrub-bird is classified as endangered under the Commonwealth *Environment Protection and Biodiversity Act 1999* and in the IUCN Red List of threatened species, and as vulnerable in NSW under the New South Wales *Biodiversity Conservation Act 2016*. Threats to the species include destruction of habitat through fire, predation by feral animals, increased frequency of drought, and extreme weather. For these reasons the

population of this cryptic species was thought to have contracted between 1984 and 2005 (Ekert 2005).

Within the Hunter Region, an area of core Rufous Scrub-bird habitat in the Gloucester Tops has been surveyed annually since 2010 and the status of that population is well understood (Stuart 2020). However, little is known about the distribution of scrub-birds elsewhere in the region. Although there were past reports from some other locations, very few of those reports were supported by a follow-up visit to the site to confirm the presence of a scrub-bird. The validity of those records was uncertain, and, in some instances, there even was uncertainty as to whether the habitat at that location would be capable of hosting a scrub-bird, which has specific habitat requirements particularly related to the structure of the habitat (Ferrier 1984). **Figure 1** shows an example of the habitat at a known Rufous Scrub-bird site in the Gloucester Tops.

Figure 1. Known Rufous-Scrub-bird habitat in the Gloucester Tops (photo: Rob Kyte)

Severe and widespread bushfires in 2019-20 adversely affected a considerable amount of the known and potential habitat for the *ferrieri* subspecies including sites from where there were past reports of Rufous Scrub-birds (Stuart *et al.* 2021). Because of the fires, funding became available for a study of the Rufous Scrub-bird's distribution status in the Hunter Region. We were commissioned by Hunter Local Land Services (HLLS) to carry out the study. The objectives were to identify the Rufous Scrub-bird's current distribution status in the region plus any areas where it may have been present prior to the recent bushfires and establish a baseline for future scrub-bird monitoring programs across the entire region.

We also used indicator avian species as an additional means of identifying suitable Rufous Scrub-bird habitat (as outlined in Barton *et al.* 2014).

Our intentions were:

- To identify all the sites in the Hunter Region from which there had been prior reports of the Rufous Scrub-bird;
- To identify potential additional scrub-bird sites through analysis of vegetation and topographic maps to find locations at which the habitat might be suitable;
- To prioritise the two sets of sites for in-field assessment;
- To visit the prioritised sites and determine if any scrub-birds were present;
- To assess each site's potential for hosting scrub-birds, by assessing its vegetation community and also noting the presence or absence of indicator bird species;
- To assess each site's burn status, as a baseline for future surveys.

METHODS

Identifying sites to survey

We identified sites with previous reports of Rufous Scrub-bird by reviewing the records in Birdata (www.birdata.com), the Atlas of Living Australia (ALA) and Bionet, the NSW threatened species database (http://www.bionet.nsw.gov.au/). The ALA records were provided to us by HLLS. To identify areas with potential scrub-bird habitat we analysed aerial photographs (sourced from Google Earth and the NSW Spatial Information Exchange https://six.nsw.gov.au/), digital topographic maps (sourced from NSW Government Spatial Services www.spatial.nsw.gov.au/products_and_services/topographic_maps) and Upper Hunter vegetation maps (sourced from Day & Roff 2018).

From the foregoing, we identified three Priority Areas for assessment – shown in **Figure 2** along with the locations of all previous reports of Rufous Scrub-bird in the region and from just outside the boundaries.

A few of the prior reports were not from higher altitude sites and did not lie within any of the Priority Areas (i.e., we did not consider them to have any of the required Rufous Scrub-bird habitat). These reports were considered unlikely, and it seemed that they probably were associated with incorrect data input (for example a report from Myall Lakes National Park, almost at sea level). We ignored those reports in planning our surveys.

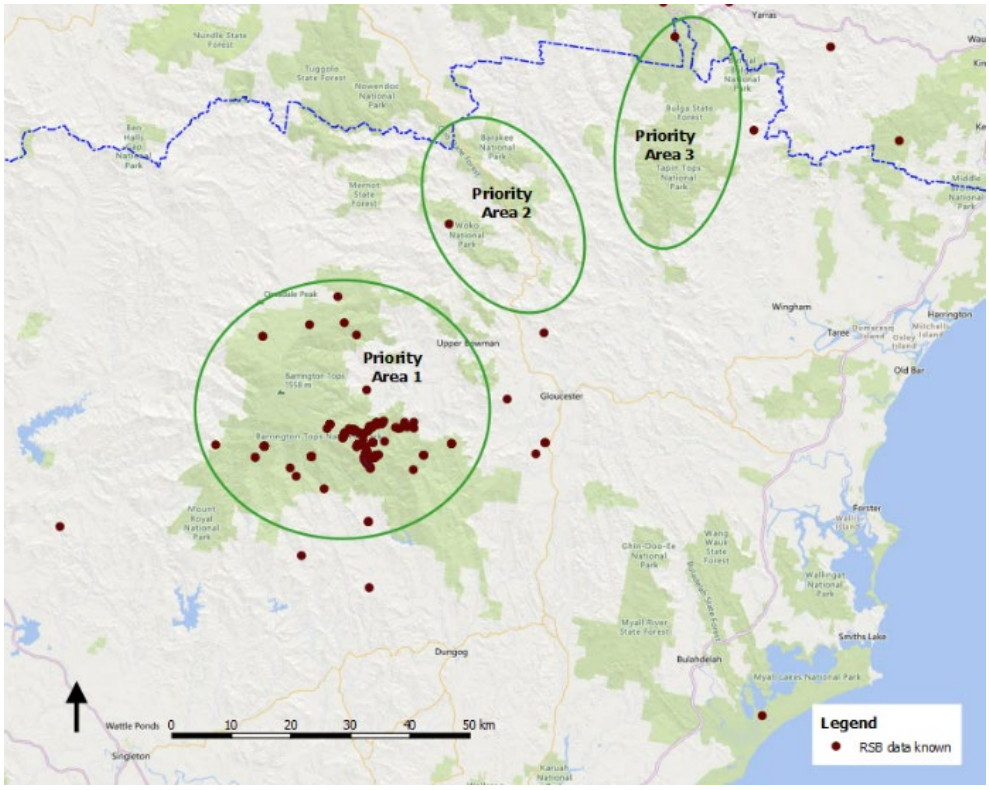


Figure 2. Rufous Scrub-bird data points in the Hunter Region (south of the blue dash-dot line). The red dots show all previously reported locations of a Rufous Scrub-bird. The three Priority Areas for field visits are also indicated.

Details of the three Priority Areas are as follows:

- Priority Area 1: this comprised a large section of the Barrington Tops National Park (including the Gloucester Tops section).
- Priority Area 2: this comprised Giro Nature Reserve, Bretti Nature Reserve and Woko National Park. Khatambuhl Nature Reserve was discounted from this survey as there were no previous records from this area and the highest point is only 661m.
- Priority Area 3: this comprised The Cells State Conservation Area, Cottan-Bimbang National Park, Bulga State Forest and Tapin Tops National Park.

We excluded from our planning, the area in the Gloucester Tops which is surveyed annually (Stuart 2020) although we walked through that area during parts of our study.

From within the three Priority Areas, we selected sites to survey as we travelled through them. The reason for this was because our task was to cover areas thought to have suitable habitat for Rufous Scrub-birds as well as covering sites where there were previous records. Each site was of an area of between two and five ha and seemed to be representative of the general habitat locally.

Our selection criteria for the survey sites were:

- Existence of prior Rufous Scrub-bird reports;
- The site's elevation and vegetation appeared to be suitable for scrub-birds to be present; and
- The general accessibility of the site (for example, the status of the road or track to the site, and if there were any access restrictions because of logging activities).

Site assessments

We received a pro forma Rufous Scrub-bird site assessment sheet from HLLS, which we modified to suit the purposes of the current study. A copy of the modified pro forma is provided in the **Appendix**. At each site we recorded: a general site description; the GPS coordinates and altitude; the presence or absence of any Rufous Scrub-bird; the presence or absence of any other bird species that may be indicative of Rufous Scrub-bird habitat; the burn status of the site; a general assessment of the vegetation community; and various weather-related conditions.

To determine whether the habitat at a site was potentially suitable for the Rufous Scrub-bird we drew upon our previous experiences with scrub-birds in the Gloucester Tops. The assessment criteria we used included altitude above 1,000m, presence of open woodland forest (of Messmate *Eucalyptus obliqua* and Brown Barrel *Eucalyptus fastigata*) with adjacent Antarctic Beech forest (*Nothofagus moorei*), relatively open under/middle storey, relatively dense groundcover comprised of grasses, Blechnum fern *Blechnaceae*, Lomandra *Lomandraceae* and Gahnia *Cyperaceae* patches, larger fallen logs, and some shrubs plus the presence of indicator bird species. In the Gloucester Tops, the Rufous Scrub-bird has been recorded at altitudes below 1,000m

but not for the past 20 or so years (Stuart & Newman 2018a).

We used the presence of indicator species as an additional pointer to potential habitat for the Rufous Scrub-bird. The indicator species were Red-browed Treecreeper *Climacteris erythrops,* Crescent Honeyeater *Phylidonyris pyrrhopterus*, Olive Whistler *Pachycephala olivacea*, Satin Flycatcher *Myiagra cyanoleuca*, Paradise Riflebird *Lophorina paradisaea*, Rose Robin *Petroica rosea* and Flame Robin *Petroica phoenicea.* Although some of these are altitudinal migrants, all six species are regularly recorded in and around Rufous Scrub-bird habitat in the Gloucester Tops in springtime (Stuart & Newman 2018b). However, Paradise Riflebird and Rose Robin are less useful indicator species because they also occur at lower altitude rainforest habitats in springtime (Stuart & Newman 2019).

Conducting the surveys

We chose the late spring period for the surveys, because male Rufous Scrub-birds sing actively and have high levels of detectability in that period (Stuart & O'Leary 2019; O'Leary & Stuart 2021; Ferrier 1984). The surveys spanned 19 October 2020 to 19 November 2020. For logistical purposes we surveyed each Priority Area in turn, visiting all the sites in that area in campaigns spanning several days. Because male scrub-birds are liable to sing at any time of day in spring (O'Leary & Stuart 2021) we were able to survey throughout the day. The surveys started in Priority Area 3 and concluded in Priority Area 1.

We walked or drove to each survey location, depending on the site's accessibility. Where required, we obtained access permission from the relevant authority, which usually was granted after a general discussion and after resolving any identified health and safety issues. For example, where a forestry road was blocked, we contacted the relevant Forestry Corporation office and received permission to carefully traverse that section.

Whilst walking or driving to each site we also conducted transect surveys en-route, during which we listened for singing scrub-birds. The transect surveys varied in their duration depending on the distance covered. If the transect survey was done whilst driving, we limited our speed to walking pace.

We spent 20 minutes at each survey location, listening for singing Rufous Scrub-birds and noting the presence of indicator bird species. We did not make records of any other species present. We were separated by up to 100 m while conducting each survey, in order to cover a larger area. We then re-convened and filled out the survey pro forma.

RESULTS

We visited 71 survey sites/transects in three campaigns spanning 2-3 days each (Priority Areas 2 and 3) and 17 days (Priority Area 1). We found six scrub-birds and identified 34 sites that potentially could host a scrub-bird. We did not find any scrub-birds during the transect surveys. A detailed report of the study was submitted to HLLS (Kyte & Little 2020).

Priority Area 3

This area had 15 sites or transects, which we surveyed during 19-21 October 2020. **Figure 3** shows the locations of the sites and transects. In the three-day period we experienced various issues such as forest closures for logging, trails being graded and fallen trees. Weather conditions also limited our ability to access certain areas by car, but these were accessed on foot instead.

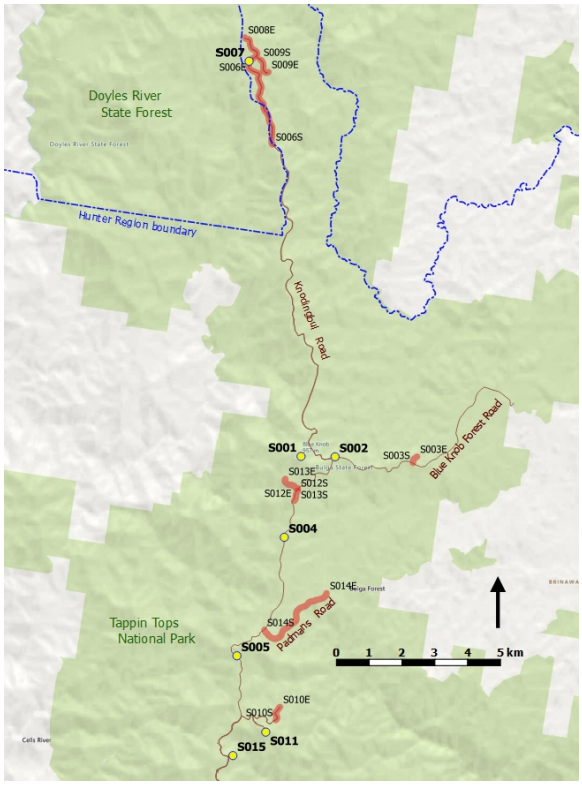


Figure 3. Map showing the survey points and transects for Priority Area 3

Table 1 summarises the site/transect assessment results for Priority Area 3. We did not find a Rufous Scrub-bird anywhere in the area and our assessment was that there was no suitable habitat for scrub-birds at any of the sites we visited. However, seven of the sites had been burnt to some extent with burning at four of those sites being moderate to extreme in severity. The only two indicator bird species we encountered were Paradise Rifle-bird and Rose

Robin, neither of which are strong indicators for the presence of Rufous Scrub-bird.

There had been a previous report of a Rufous Scrub-bird at site 007, which lies off Knodingbul Road in the Cottan-Bimbang National Park. The eBird data records three individuals at that site on 10 November 2014. This site, at 930m altitude, was not burnt in the 2019-20 bushfires. It did not appear to have suitable habitat for the Rufous Scrub-bird.

Table 1. Site assessment results for Priority Area 3

Site ID	GPS coordinates		Prior scrub-bird record	Habitat assessment			Scrub-bird this study
	Lat. (deg S)	Long. (deg E)		Suitable	Possible	Unsuitable	
001	31.5774	152.1700				●	No
002	31.5776	152.1809				●	No
003*	31.5792	152.2060				●	No
004	31.5996	152.1646				●	No
005	31.6321	152.1494				●	No
006*	31.4922	152.1608				●	No
007	31.4691	152.1533	●			●	No
008*	31.4686	152.1543				●	No
009*	31.4689	152.1569				●	No
010*	31.6497	152.1619				●	No
011	31.6530	152.1587				●	No
012*	31.5868	152.1690				●	No
013*	31.5861	152.1689				●	No
014*	31.6250	152.1581				●	No
015	31.6594	152.1481				●	No

* Indicates a transect survey. The GPS coordinates are the starting point for the survey. The finishing point for the survey was at the next site or transect.

Priority Area 2

We surveyed 14 sites or transects in this area between 22 and 23 October 2020. **Figure 4** shows the locations of the sites and transects. In this period we experienced occasional wet weather which affected the condition of some trails but did not disrupt the surveys as we were able to alter our schedule to suit the conditions. It was our intention to survey along the Pigna Barney Trail but this was impossible due to overgrown and impenetrable tracks. Logging activity at the edge of Bretti Nature Reserve also prevented us from surveying further down Baxters Ridge Road/Khatambuhl Creek Road.

Figure 4. Map showing the survey points and transects for Priority Area 2

Table 2 summarises the site/transect assessment results for Priority Area 2. Although we did not find any scrub-birds during the site visits, we recorded four indicator bird species (Paradise Riflebird, Rose Robin, Flame Robin and Red-browed Treecreeper) and we concluded that five sites had potential. Twelve sites had been burnt to some extent in the 2019-20 bushfires with ten of the sites estimated to suffer moderate to extreme burns. However, site 024, although burnt appeared to have potential habitat for scrub-birds, with Blechnum Fern, Gahnia and tree ferns present. Sites 016, 023, 025 and 026 were regarded as being possible scrub-bird habitat as the elevations of each were around the 1000m range but the ground cover and canopy had not recovered sufficiently from the fire.

Table 2. Site assessment results for Priority Area 2.

Site ID	GPS coordinates		Prior scrub-bird record	Habitat assessment			Scrub-bird this study
	Lat. (deg S)	Long. (deg E)		Suitable	Possible	Unsuitable	
016*	31.6021	151.7583			●		No
017*	31.6149	151.7643				●	No
018	31.6769	151.8501				●	No
019	31.6811	151.8684				●	No
020	31.7024	151.9002				●	No
021*	31.7114	151.9052				●	No
022	31.7082	151.9226				●	No
023	31.5648	151.7928			●		No
024*	31.5752	151.8057		●			No
025	31.5964	151.8257			●		No
026	31.6009	151.8397			●		No
027	31.7497	151.7504	●			●	No
028*	31.7561	151.7525				●	No
029	31.7273	151.7163				●	No

* Indicates a transect survey. The GPS coordinates are the starting point for the survey. The finishing point for the survey was at the next site or transect.

There had been a previous report of a Rufous Scrub-bird at site 027, which lies off the Mount Myra Trail in the western portion of Woko National Park. This record from the NSW Bird Atlassers was made on 17 November 1992 with no other information recorded. This site, which had not been affected by the 2019-20 bushfires, did not appear to have suitable habitat for Rufous Scrub-bird as the elevation was under 700m and there was very little ground cover or fallen timber.

Priority Area 1

We surveyed 42 sites or transects in this area over eight days during 3-19 November 2020. **Figure 5** shows the locations of the sites and transects. The surveys involved hiking and camping along The Mountaineer Trail and at the Polblue Swamp Campsite and the Wombat Creek Campsite near Careys Peak. **Table 3** summarises the results. None of the sites/transects had been burnt in the 2019-20 bushfires. Eight sites had prior reports of Rufous Scrub-bird being present but we did not find scrub-birds at any of those sites. However, several of them, and many other sites in this Priority Area, had suitable or potential habitat, as discussed below. We recorded five indicator bird species during the surveys (Olive Whistler, Rose Robin, Satin Flycatcher, Red-browed Treecreeper and Crescent Honeyeater) and we found a Rufous Scrub-bird at each of six sites.

Five of the sites where we found a Rufous Scrub-bird were towards the eastern end of the Careys Peak Link Trail (sites 065-067 and 069-070) and the other (site 053) was about half-way along the Glowang Trail. All these sites were in the Gloucester Tops and were in the general vicinity of known territories (Stuart 2020; www.birdata.com). The Rufous Scrub-bird locations found in this study are plotted in **Figure 6**, and the locations of nearby known scrub-bird territories are also indicated.

At four sites for which there were prior reports of a Rufous Scrub-bird (043, 044, 047 and 057), we did not consider the habitat to be suitable for scrub-birds. These sites were either on steep slopes and/or had very little ground cover. At three other sites (032, 035 and 056) the habitat seemed to be suitable with ground cover of bracken, Gahnia and Lomandra and fallen timber present and at a fourth site (055) it seemed potentially suitable with ground cover of Gahnia and ferns but with also a fairly dense mid-layer.

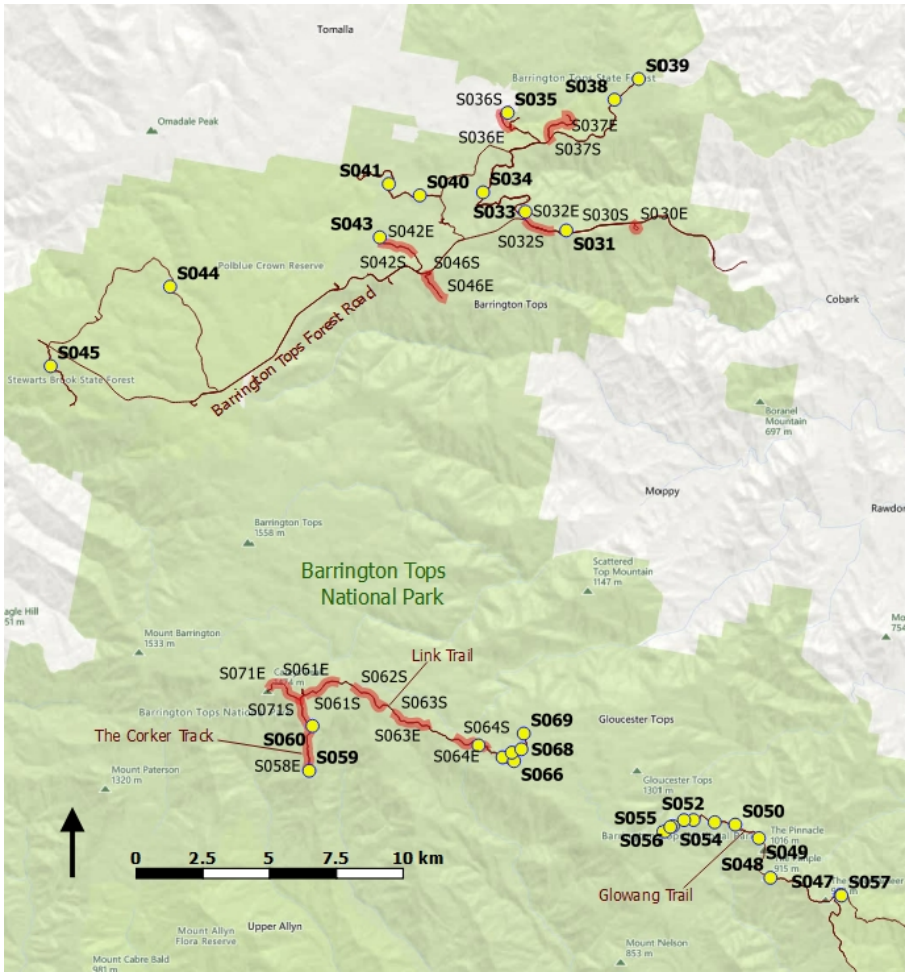
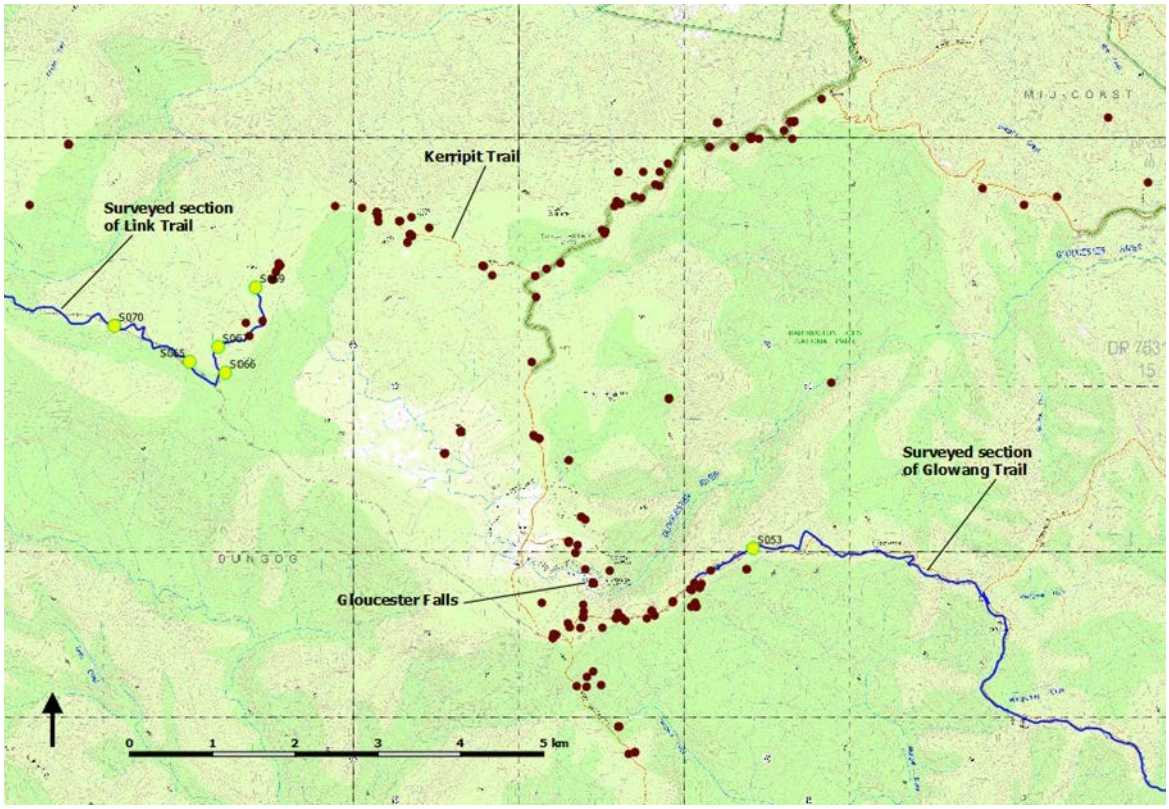


Figure 5 (left).
Map showing the survey points and transects for Priority Area 1

Figure 6 (below).
The six new Rufous Scrub-bird locations found in the current study (yellow dots) and the known Rufous Scrub-bird locations from the same general area (red dots).



Summary of overall results

In **Table 4** we have summarised the results from the overall study. Priority Area 1 had 29 sites which potentially could support a Rufous Scrub-bird, including 20 sites where the habitat seemed highly suited for scrub-birds. Priority Area 2 had five potential sites but only one of those seemed highly suited. We did not find any likely sites in Priority Area 3.

Table 3. Site assessment results for Priority Area 1.

Site ID	GPS coordinates		Prior scrub-bird record	Habitat assessment			Scrub-bird this study
	Lat. (deg S)	Long. (deg E)		Suitable	Possible	Unsuitable	
030*	31.8965	151.6011		●			No
031	31.8976	151.5742		●			No
032*	31.8979	151.5674	●	●			No
033	31.8913	151.5579		●			No
034	31.8848	151.5410		●			No
035	31.8579	151.5508	●	●			No
036*	31.8579	151.5508		●			No
037*	31.8668	151.5676		●			No
038	31.8535	151.5933		●			No
039	31.8465	151.6030			●		No
040	31.8859	151.5159			●		No
041	31.8820	151.5035			●		No
042*	31.9049	151.5125			●		No
043	31.9000	151.4999	●			●	No
044	31.9166	151.4165	●			●	No
045	31.9434	151.3690				●	No
046*	31.9126	151.5194		●			No
047	31.1212	151.6828	●			●	No
048	32.1154	151.6549				●	No
049	32.1025	151.6503				●	No
050	32.0979	151.6409				●	No
051	32.0971	151.6327				●	No
052	32.0964	151.6242			●		No
053	32.0964	151.6205		●			Yes
054	32.0984	151.6160		●			No
055	32.1002	151.6128	●		●		No
056	32.0987	151.6150	●	●			No
057	32.1212	151.6828	●			●	No
058*	32.0567	151.4684		●			No
059	32.0798	151.4719				●	No
060	32.0647	151.4732			●		No
061*	32.0537	151.4718				●	No
062*	32.0522	151.4905				●	No
063*	32.0609	151.5065			●		No
064*	32.0692	151.5313			●		No
065	32.0753	151.5488		●			Yes
066	32.0765	151.5534		●			Yes
067	32.0737	151.5525		●			Yes
068	32.0725	151.5563		●			No
069	32.0672	151.5572		●			Yes
070	32.0712	151.5392		●			Yes
071*	32.0558	151.4680				●	No

* Indicates a transect survey. The GPS coordinates are the starting point for the survey. The finishing point for the survey was at the next site or transect.

Table 4. Summary of survey effort and results.

Priority Area	No. of sites visited	Sites with suitable habitat	Sites with potential habitat	No. of scrub-birds found
1	42	20	9	6
2	14	1	4	0
3	15	0	0	0

DISCUSSION

Detection probabilities

Out of the 71 sites/transects visited in the surveys, only six scrub-birds were detected. Of the other 65 sites/transects, 37 were not considered to have suitable or potential habitat for a Rufous Scrub-bird. However, there were 28 sites/transects which potentially might have had a scrub-bird present but no bird was detected. This raises for consideration the possibility that a scrub-bird may have been present at some of those locations but that it was not detected.

In the Gloucester Tops between mid-September and December on fine days, male scrub-birds were found on average to produce more than 1,200 songs per day and to sing for 79% of the 20-minute daylight periods, with an average of 36 singing events in each 20-minute period (O'Leary & Stuart 2021). However, for any individual bird the singing behaviour was less predictable and at any time of the day there could be intervals with no singing.

We listened for 20 minutes at each site, generally in fine conditions although sometimes with light rain falling. In spring the Rufous Scrub-bird singing behaviour was found to be unaffected by light rainfall (Stuart & O'Leary 2019). At any single site, for the 20-minute time frame, there was a 21% probability (on average) that a Rufous Scrub-bird was present but not singing. Thus our surveys might have overlooked birds at some sites. However, the general behaviour of the bulk population of male scrub-birds is to sing often in spring. In Priority Area 2, for example, we identified five sites with apparently suitable habitat but found no scrub-birds. The probability of not detecting *any* of those birds, if present, after listening for 20 minutes at each site is *c* 0.04%. For Priority Area 1, with 14 such sites, the probability of not detecting a bird at *any* of the 14 apparently suitable sites is considerably lower still.

In addition to the 20-minute site surveys we also conducted transect surveys which allowed us to cover a greater area. We did not hear any Rufous Scrub-bird singing during our transect surveys.

These low probabilities of not detecting any scrub-birds at all, in an area where they occur, strongly suggests that there was not any Rufous Scrub-bird present in the bulk of the areas which we surveyed. At the time of our surveys in October-November 2020, the Gloucester Tops male Rufous Scrub-bird population was singing often (A. Stuart pers. comm.).

The 2019-20 bushfires

Of the 71 sites/transects which we surveyed, twenty of them had been burnt in the recent bushfires, at estimated fire extents ranging from 10% burn to 100% burn. At five of those burnt locations, all in Priority Area 2, we considered the habitat had been suitable (one site) or possibly suitable (four sites) for a Rufous Scrub-bird. Although we did not detect scrub-birds at any of the latter sites, birds might have been present prior to the fires. We suggest three scenarios are possible: the scrub-birds were unable to escape the fire and had perished; they had escaped the fires but had not returned to the site, because of the damage to the habitat; they were at the site but were not singing, perhaps because the habitat damage deterred them from attempting to breed.

Prior Rufous Scrub-bird records

Six of the sites we visited had prior reports of a Rufous Scrub-bird being present but, in our assessment, did not have habitat which was suitable for them. Thus they may be erroneous reports, arising from mis-identification or because incorrect coordinates were entered into a database. However, it is also possible that the habitat had changed from the time of the original report and/or that the reports involved birds dispersing outside of preferred core areas in search of mates and territories. Thus, they may be true historical records. However, the present study has shown that those six reports are not indicators of the current range for the Rufous Scrub-bird in the Hunter Region. For most purposes associated with studying the Rufous Scrub-bird, these six reports should be regarded as unconfirmed records.

Population estimates

Range maps often indicate that the Rufous Scrub-bird is distributed across much of the Barrington Tops National Park (Stuart *et al*. 2021). That presumably has been based upon an assumption that there are many areas with suitable habitat within the park and that scrub-birds would occur there. The present study suggests that understandings about the habitat requirements may have been over-simplified and that it is a small area within the Gloucester Tops section of the park which provides suitable habitat for scrub-birds. The absence of records away from the known Gloucester Tops population has been commented about previously (Newman *et al*. 2014, Stuart & Newman 2018a). The new locations from the present study are all within *c* 1 km of the previously known records.

Thus, all of the confirmed scrub-bird records lie within an area of about 5 km radius (*c* 8,000 ha or 80 km^2) within the Gloucester Tops. Stuart (2020) reported territory densities of 3.8 ± 1.5 territories km^{-2} from surveys in the Gloucester Tops carried out during 2010-2020 in an area of *c* 4 km radius. Extrapolating from that finding, we estimate that there are 190 ± 75 singing male scrub-birds in the Gloucester Tops. That is not a large population. The ratio of singing males to females and immature birds is unknown.

Management strategies

Clusters of Rufous Scrub-bird records found between the Barrington Tops and the Border Ranges National Park are "a series of high-altitude relictual populations that may be impacted by rising temperatures and/or other effects of climate change such as periodic drought" (Office of Environment and Heritage 2017). The Rufous Scrub-bird is classified as Endangered on the IUCN Red List (BirdLife International 2021b). According to BirdLife International (2021a) the scrub-bird has a very small, severely fragmented area of occupancy, and is experiencing habitat destruction and a continuing population decline. Inappropriate management such as logging and fire management in areas close to known scrub-bird habitat as well as the destruction of movement corridors linking suitable sites and known scrub-bird clusters could contribute to the shrinking of numbers from much of its current range. There is a risk that the Rufous Scrub-bird could become victim to the 'Twinkling Light' phenomenon (Ford 2011) that applies to species with poor dispersal abilities in isolated populations.

Dispersing scrub-birds should be able to reach other population clusters thereby helping genetic diversity of the clusters. However, land clearing and predators are making dispersal movements increasing difficult for the Rufous Scrub-bird especially considering this species is not a strongly-flying bird.

The forests of the Barrington Tops and Gloucester Tops area did not suffer from fires during the 2019-20 bushfire season. However, the Rufous Scrub-bird population in the Gloucester Tops appears to be highly vulnerable to bushfire. A fire within the *c* 8,000 ha area of confirmed Rufous Scrub-bird habitat potentially could wipe out much of the population. The fire risk is expected to increase in the future due to warming climatic conditions and the attendant droughts. It seems essential to develop management strategies that will minimise the potential for harm to the Rufous Scrub-bird population from bushfires.

Future Studies

Habitat recovery at the burnt sites which had suitable or possibly suitable Rufous Scrub-bird habitat should be monitored regularly, and the sites surveyed for the presence of any scrub-birds.

The 2020 surveys should be considered as merely a snapshot of the Rufous Scrub-bird's distribution in the Hunter Region. The surveys need to be repeated, focussed onto the areas where suitable scrub-bird habitat was considered to be present, and spending longer time in such areas including visits to additional sites within those areas. It is essential that the interim conclusion from the present study be tested; i.e. that the Rufous Scrub-bird distribution is limited to an 8,000-ha area within the Gloucester Tops.

The new Rufous Scrub-bird locations, as found in this study, cannot as yet be classified as scrub-bird territories. Such classification requires re-confirmation of the presence of a singing male more than four weeks after the original record, or in successive years (Stuart & Newman 2018a). At the moment, they could simply be records of roaming young males that were seeking to establish a territory and perhaps then moving on if unsuccessful.

There have been suggestions that, in future, some scrub-birds should be relocated to areas such as Tasmania where the climatic conditions are expected to be more favourable in future (Garnett *et al*. 2011). However, currently there is limited

understanding of the specific habitat requirements to support the Rufous Scrub-bird. There seems to be an urgent need to properly categorise the ecosystems at some known Rufous Scrub-bird sites (for example, the plant and insect communities, and the general topography) and understand why those sites are able to support scrub-birds whereas many other sites, apparently similar, do not host them.

A study is required to better understand the biology and movement of this vulnerable species where the genetic diversity of the population and its distinctness from other relict populations of the southern sub-species can be determined. In light of the 20-year decline in numbers of this species and to effectively maximise the long-term survival of *ferrieri* subspecies scrub-birds, it is recommended that further research is conducted, in conjunction with the preparation of a recovery plan.

CONCLUSIONS

The surveys conducted in October-November 2020 found that Rufous Scrub-birds were not present at ten locations where they had previously been recorded nor in locations where there was thought to be suitable habitat. While there were many survey points where the habitat, vegetation type and the altitude seemed to be suitable, only six new territories were located, all found in the Gloucester Tops region close to existing known territories.

The Rufous Scrub-bird in the Hunter Region is known to rely on a specific habitat type and current populations in this region only occur in protected areas in the Gloucester Tops as outlined in this report. As there are known ongoing threats to this isolated population through fire and the presence of pest species such as cats and foxes it is important that further surveys are conducted to identify other populations in the areas where habitat is thought to be suitable. Due to the unique nature of the Rufous Scrub-bird it will be very difficult to know the exact population size. However, based on this survey the population in the areas covered may be lower than previously thought. Further research into the population, movement and biology of this cryptic species is essential to help us understand the requirements for the survival of this endangered bird.

ACKNOWLEDGEMENTS

We thank Hunter Local Land Services for financial and logistical support for this study and for permission to publish this report. Representatives from NSW National Parks and Wildlife Service and NSW Forestry Corporation were very helpful. Our particular thanks go to Peter Beard, Ranger for the Barrington Tops National Park. To access the Careys Peak area he drove us and our kit to that location and then picked us up from there a few days later. We had helpful discussions with Alan Stuart while planning the surveys and he also reviewed our original manuscript and made many suggestions, as did the referee Mike Newman.

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Appendix
Pro forma used for site assessments

Rufous Scrub-bird Survey 2020 – Site Data

Site No

Date				**Observers**			**Elevation** metres		
Time start				**Finish time**			**Photos taken** Yes ☐ No ☐		
Atlas Record Site Yes ☐ No ☐				**New Opportunistic** Yes ☐ No ☐					
State Forest Name				**National Park Name**					
Road Name				**Side of road**					
Point survey Easting (GDA94)				**Point survey** Northing (GDA94)					
Transect survey Start Easting / Northing (GDA94)				**Transect survey** End Easting / Northing (GDA94)					
Temperature	Cold (≤14°C)	Cool (15 – 19°C)		Moderate (20 – 24°C)	Warm (25 – 29°C)	Hot (≥30°C)			
Wind Strength	Still	Rustle of leaves		Small branch moving	Large branch moving	Strong			
Cloud Cover	0	25%		50%	75%	100%			
Slope	Flat (0°)	Gentle (1 – 4°)		Moderate (5 – 14°)	Undulating *(Highly Variable)*	Steep (≥15°)			
Aspect	Nil	N	NE	E	SE	S	SW	W	NW
Position	Ridge Top	Upper Slope	Mid Slope	Lower slope	Plateau	River or Creek Flat		Drainage line	
Fire extent *(estimate % of habitat burnt)*		0 – 10 %		10 – 50%		50 – 90%		90 – 100%	
Fire severity	Nil	Cool understorey		Moderate partial canopy scorching		High canopy scorching		Extreme canopy burnt	
Forest type	Dry grassy	Dry multilayered		Moist ferny understorey		Wet mesic understorey		Rainforest	
Age Structure	Even aged regrowth <20cm dbh	Even aged immature <50cm dbh		Mixed but dominantly immature		Mixed mature		Old growth	
Canopy height	<20m	20 – 25m		25 – 30m		30 – 35m		35 – 40m	
Mid layer height	<5m	5 – 8m		8 – 11m		11 – 14m		14 – 17m	
Shrub height *(not below)*	<1m	1 – 2m		2 – 4m		4 – 6		6 – 8m	
Ground habitat type	Bracken	Lomandra		Vine thicket		Rainforest ecotone		Heath	
Ground habitat height	<0.5m	0.5 – 1m		1 – 1.5m		1.5 – 2m		2 – 2.5m	
Weeds present	Lantana	Camphor Laurel		Privet		Morning Glory		Other *(list below)*	
Weed coverage	<5%	5–30%		30–50%		50–75%		>75%	

METHOD *Listen for 20 mins with optional playback at end. Repeat if possible, up to 5 times or as long as possible. Stop if it rains.*

Observations	Was RSB heard calling	Yes ☐ No ☐		Time on site from start before RSB was heard calling minutes					
Type of call heard	Chips	Seeps	Whistles	Other			Recording made Yes ☐ No ☐		
Call playback used	Yes ☐ No ☐	Did RSB respond to playback Yes ☐ No ☐		Call playback used					
Approximate distance to call from survey point		<50m	50–100m	100–150m	150–200m	200–250m	250–300m	>300m	
Direction to call from survey point	N	NE	E	SE	S	SW	W	NW	

NOTES *Survey limitations (eg rain), specific habitat (eg dominant floristics of dense ground cover) and other comment.*

OTHER *Significant birds, plants or weeds (ecosystem transformers) observed:*

Circle the relevant points and tick boxes where applicable *v261020* *Layout by Rob Kyte from original artwork by Phil Spark*

Hunter Estuary surveys: results for large waterbirds

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Although the Hunter Estuary at Newcastle New South Wales is a well-known site for migratory shorebirds, its utilisation by other waterbirds has not previously been closely examined. This report presents the results for 21 species, representing five families of large waterbirds, from a 22-year study involving monthly surveys of the estuary.

Most of the species were found to have stable populations or the changes over 22 years were modest. The populations of eight species had increased – Black-necked Stork *Ephippiorhynchus asiaticus*, Royal Spoonbill *Platalea regia* Australian White Ibis *Threskiornis moluccus*, Glossy Ibis *Plegadis falcinellus*, White-faced Heron *Egretta novaehollandiae*, Great Egret *Ardea alba*, Little Black Cormorant *Phalacrocorax sulcirostris* and Great Pied Cormorant *Phalacrocorax varius*. The increased numbers of the two cormorant species perhaps reflect improvements to water quality in the lower estuary and Newcastle harbour. The other species have benefitted from local rehabilitation projects which have restored tidal flushing to wetlands located at Ash Island, Hexham Swamp and Tomago. Conversely, the Australasian Bittern *Botaurus poiciloptilus* may have been negatively affected by those projects.

Seven species had greater populations in the estuary in summer and autumn: Royal Spoonbill, Australian White Ibis, Glossy Ibis (in summer only), Great Egret, Cattle Egret *Bubulcus ibis*, Australian Pelican *Pelecanus conspicillatus* and Great Pied Cormorant. The populations of White-faced Heron and Australasian Darter *Anhinga novaehollandiae* rose in winter.

INTRODUCTION

In March 2021, members of the Hunter Bird Observers Club Inc (HBOC) completed 22 continuous years of monthly surveys of shorebirds and waterbirds in the Hunter Estuary ("the estuary"). The surveys are continuing indefinitely but it seemed timely to analyse the results to date and identify any trends for the populations of the main species recorded. To achieve this we are examining, in turn, groups of like species. In earlier reports we assessed shorebird population trends (Stuart & Lindsey 2021) and the status of gull and tern species (Lindsey & Stuart in preparation). In this report we present the findings for large waterbird species viz the members of five families of birds from the orders Ciconiiformes, Pelecaniformes and Suliformes.

The order Pelecaniformes comprises five families of birds (Gill *et al*. 2021), of which three families are represented in the Hunter Region – Threskiornithidae, Ardeidae and Pelecanidae. The storks (family Ciconiidae) are placed into a separate order, Ciconiiformes. However, these six families are closely related and in some previous taxonomies they were grouped, as the order Ciconiiformes (Marchant & Higgins 1990). All the members of those two orders are medium to large long-legged wading birds (except for Pelicans) with a large bill and a well-developed hallux (hind toe). They prefer to walk rather than run.

The local representative from the Ciconiidae family is the Black-necked Stork *Ephippiorhynchus asiaticus.* Five Threskiornithidae representatives have been recorded in the estuary: Yellow-billed Spoonbill *Platalea flavipes*, Royal Spoonbill *P. regia*, Australian White Ibis *Threskiornis moluccus*, Straw-necked Ibis *T. spinicollis* and Glossy Ibis *Plegadis falcinellus*, and nine Ardeidae species: Australasian Bittern *Botaurus poiciloptilus*, Nankeen Night-Heron *Nycticorax caledonicus*, Striated Heron *Butorides striata*, Cattle Egret *Bubulcus ibis*, White-necked Heron *Ardea pacifica*, Great Egret *A. alba*, Plumed Egret *A. plumifera*, White-faced Heron *Egretta novaehollandiae* and Little Egret *E. garzetta*. The sole local representative from the Pelecanidae family is the Australian Pelican *Pelecanus conspicillatus*.

Within the order Suliformes are two families which are represented in the estuary – the Phalacrocoracidae (cormorants and shags) and the Anhingidae (darters). Both these families are piscivores and hence they forage differently to the families in the other two orders and are not considered to be estuarine birds. However, many of them commonly roost in trees or on rock platforms within estuaries and thus are often encountered during surveys. The five locally-occurring species are Little Pied Cormorant *Microcarbo melanoleucos*, Great Cormorant *Phalacrocorax carbo*, Little Black Cormorant *P. sulcirostris*, Great Pied Cormorant *P. varius* and Australasian Darter *Anhinga novaehollandiae*.

Hunter Wetlands National Park and wetlands around the suburbs of Shortland, Tarro and Woodberry

Figure 1 shows the estuary and the main areas surveyed. Most of the sites monitored in HBOC monthly surveys are in Hunter Wetlands National Park (HWNP) much of which was listed in 1984 under the Ramsar Convention which aims to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. The process involves identifying wetlands of international importance (Department of Agriculture, Water and the Environment 2013). Key wetlands such as Hexham Swamp and Ash Island were however not included at the time of designation (NSW National Parks & Wildlife Service 2020). The park, especially Ash Island, is affected by a number of public utilities such as powerlines and pipelines and a corridor across Ash Island has been identified and zoned for future infrastructure development (NSW National Parks & Wildlife Service 2020). This corridor effectively cuts Ash Island into two sections and crosses the most important waterbird sites on the island. Sites included in HBOC surveys that are not in HWNP are Stockton Channel and parts of Kooragang Island.

It must be noted that the prime motivation for the monthly surveys has been to monitor shorebirds in the estuary. Thus, the focus was to visit tidally-influenced sites where shorebirds were more likely to be found. Several sites which only comprised freshwater wetlands were not surveyed – most notably the wetlands around Shortland and Tarro/Woodberry. The most important of these wetlands is at Hunter Wetlands Centre Australia (HWCA) at Shortland. It has a system of wetlands which were once a part of Hexham Swamp but the 45-ha site has been extensively modified over the years and its hydrological regime is no longer connected to Hexham Swamp. HWCA was listed as a Ramsar site in 2002 and is the only remaining colonial bird breeding site in the lower estuary. Wetlands at Shortland Waters Golf Club are breeding sites for cormorants and Australasian Darter and were also once part of the Hexham Swamp system.

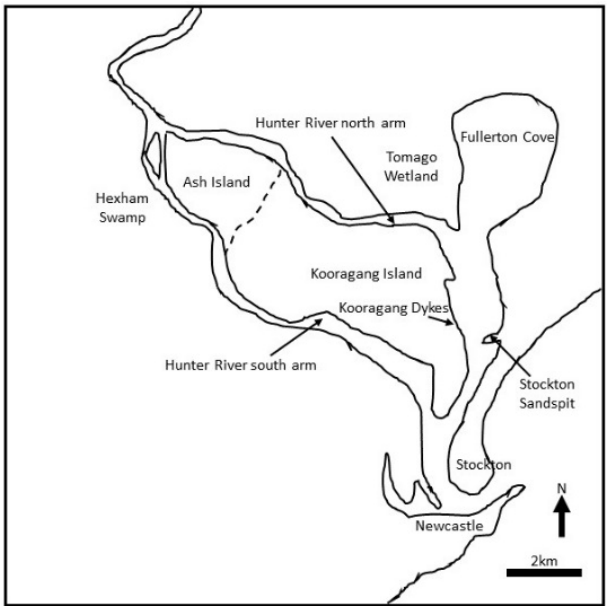


Figure 1. Hunter Estuary and the main sites surveyed.

METHODS

Once each month, coinciding with a Saturday morning high tide in the estuary, teams of HBOC members simultaneously visited sites where shorebirds could be expected to be found. At those sites, counts were made of all the shorebirds present and of all other waterbirds. A detailed description of the survey methodology is available (BirdLife Australia 2021).

Each month the results from each individual site were entered into Birdata (www.birdata.com.au). The monthly total numbers were also entered into a Microsoft Excel spreadsheet along with general notes (e.g. if any site had not been able to be surveyed that month). We used that spreadsheet as the basis for this report. To analyse the results, we used standard Excel graphing and data analysis tools. When comparing populations for two time periods we assessed if the changes were statistically significant by carrying out two-tailed t-tests assuming unequal variances ($\alpha < 0.05$) and determining the probability P of the change being significant. For P values below 0.05 we classified the differences as significant, and as highly significant for $P < 0.01$.

To assess long-term population trends, we compared the counts for two time periods – those for the first 11 years of surveys and those for the subsequent 11 years. For

seasonal comparisons, we grouped the data into December – February ("summer"), March-May ("autumn"), June-August ("winter") and September-November ("spring"). Where it was deemed relevant, we also compared seasonal data for the two 11-year time periods.

RESULTS

There were 263 surveys done in the 22-year period, of the 264 possible. In some surveys not every site was visited, because of access problems on the given day. When we assessed shorebird and gull and tern populations in the estuary (Stuart & Lindsey in preparation; Lindsey & Stuart in preparation), some of those surveys were excluded from analysis. However, for the present study we concluded that the total waterbird counts would not have been greatly affected, and thus we have used the results from all 263 surveys.

Twenty-one species from the three orders were recorded in the estuary during 1999-2021. **Table 1** lists the species, the number of records for each and their Reporting Rate (RR, the ratio of number of records to number of surveys, expressed as a percentage). Two species – White-faced Heron and Australian Pelican – were recorded in every survey, while six other species had RRs above 90% – Royal Spoonbill, Australian White Ibis, Great Egret, Little Egret, Little Pied Cormorant and Little Black Cormorant. The species with more than 90 records were analysed for trends, as detailed further below.

Black-necked Stork

Prior to September 2013 there were only two records of Black-necked Stork during the monthly surveys – in January 2000 and May 2001. Since then there have been 30 records (thus the RR since September 2013 was 39%, compared with an RR of 1.0% for the preceding period.

There were insufficient records for a close analysis of seasonal patterns. The four winter records involved a single bird and the three other seasons each had 7-11 records and often with multiple birds.

Yellow-billed Spoonbill

Apart from a record of seven birds in the first survey in April 1999, and another of three birds in August 2002, all the other records were of 1-2 birds and they were infrequent. No seasonal pattern was apparent.

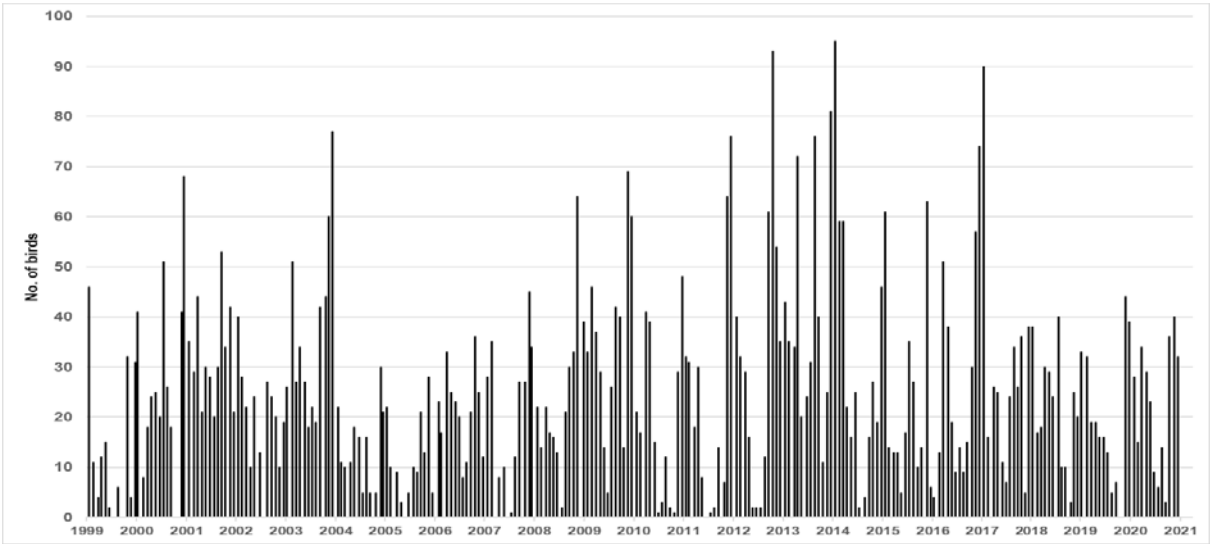
Table 1. Large waterbird species recorded in monthly surveys of the Hunter Estuary spanning 1999-2021, with their number of records and Reporting Rates (RR).

Species	Times recorded	RR (%)	Maximum count
Black-necked Stork	32	12.2	5
Yellow-billed Spoonbill	26	9.9	7
Royal Spoonbill	255	97.0	95
Straw-necked Ibis	162	61.6	965
Australian White Ibis	259	98.5	1126
Glossy Ibis	11	4.2	52
Australasian Bittern	4	1.5	1
Nankeen Night-Heron	15	5.7	21
Striated Heron	116	44.1	5
Cattle Egret	183	69.6	233
White-necked Heron	91	34.6	30
Great Egret	258	98.1	77
Plumed Egret	121	46.0	32
White-faced Heron	263	100	339
Little Egret	244	92.8	20
Australian Pelican	263	100	783
Little Pied Cormorant	259	98.5	41
Great Cormorant	203	77.2	51
Little Black Cormorant	261	99.2	151
Great Pied Cormorant	208	79.1	69
Australasian Darter	234	89.0	14

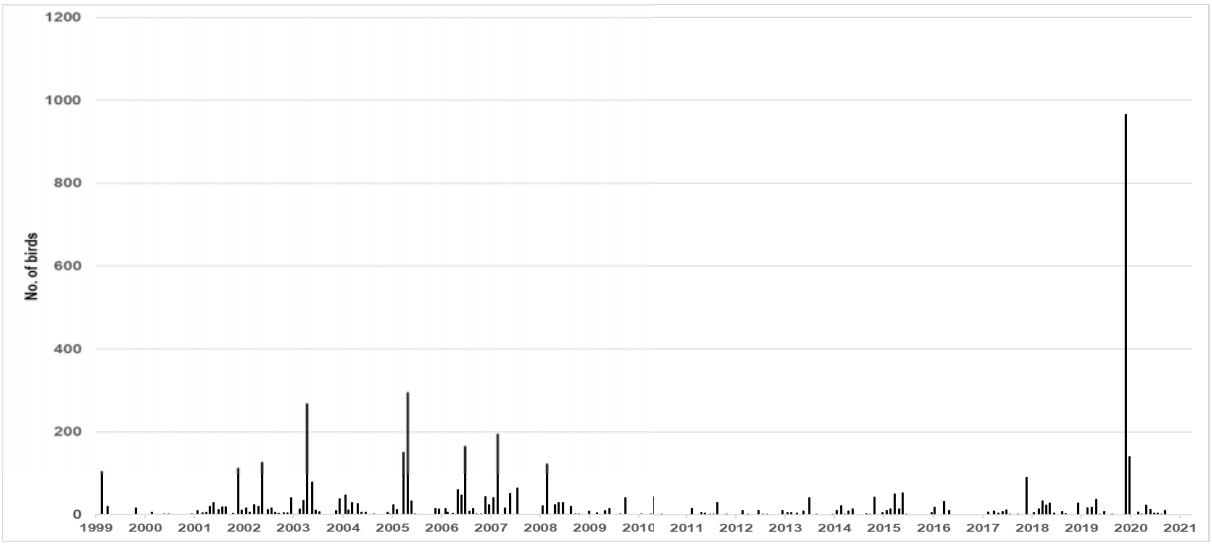
Royal Spoonbill

Birds were present most months, with most of the records being of 15-30 birds but there were frequent influxes when more than 60 birds were recorded (**Figure 2a**). Those influxes occurred in every season. Overall, the population has increased slightly. That change was mainly associated with a rise in autumn numbers in the second 11-year period, as shown in **Figure 3a**. The autumn means for the two periods were 29 and 43 birds respectively. The change was not statistically significant.

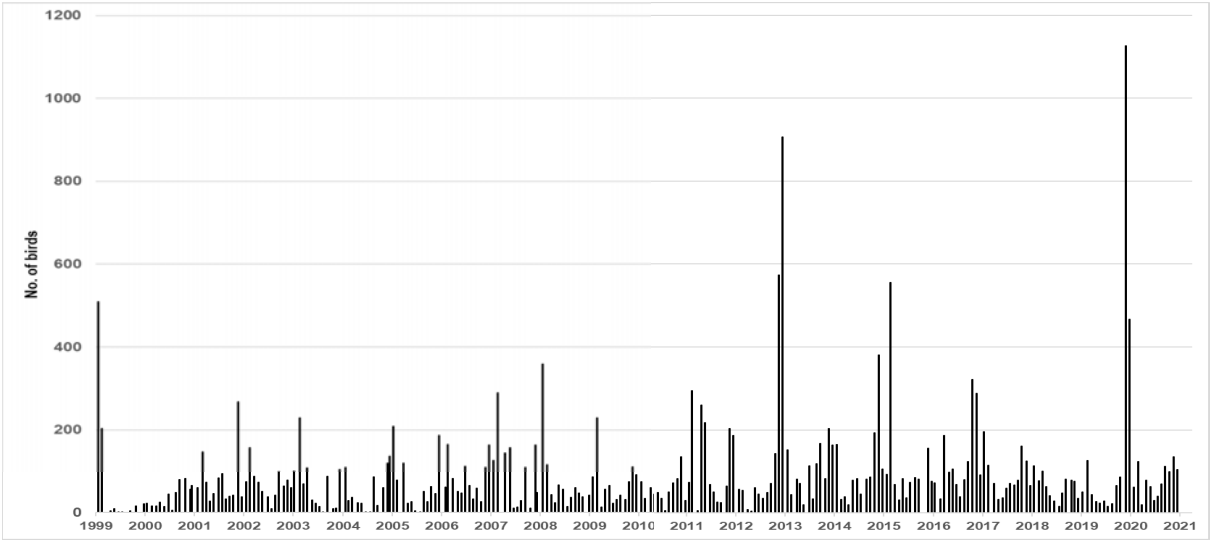
Seasonal analysis indicated that Royal Spoonbill was present in greater numbers in summer and autumn (22-year means of 29 and 35 birds, respectively) than winter and spring (22-year means



(a) Royal Spoonbill

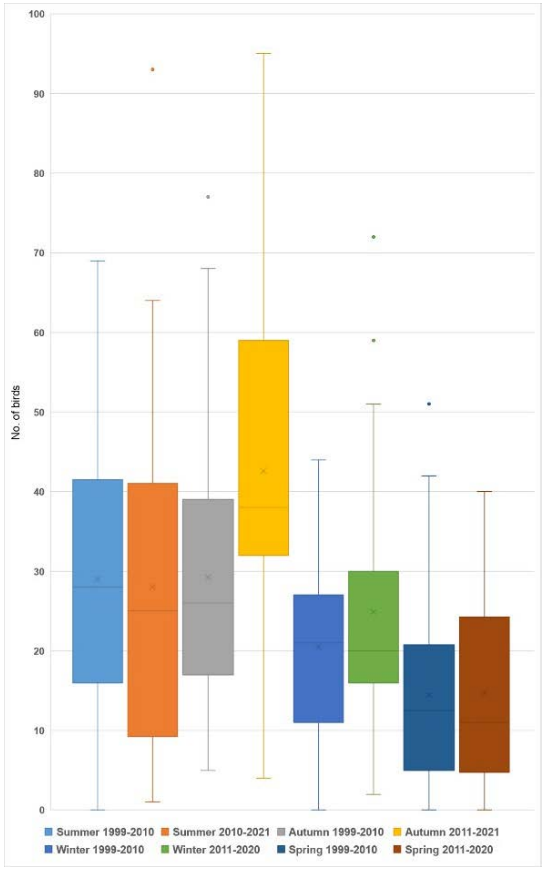


(b) Straw-necked Ibis

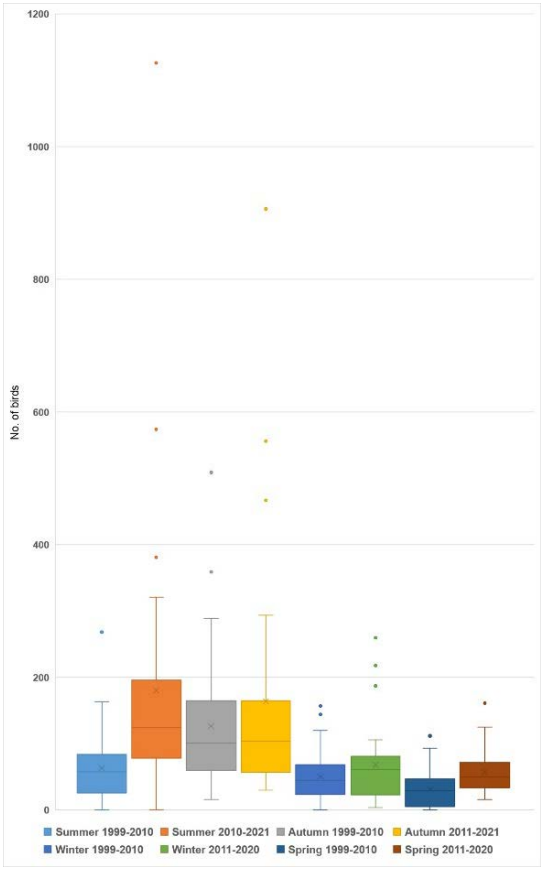


(c) Australian White Ibis

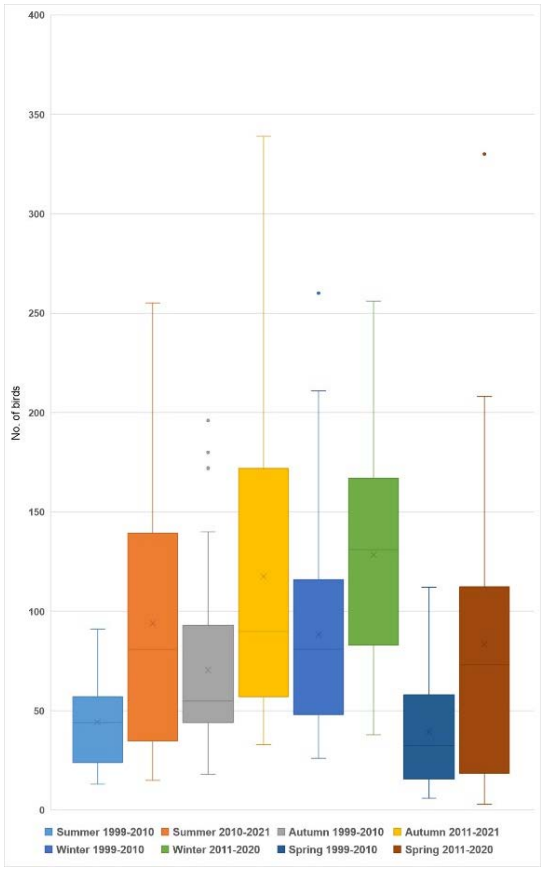
Figure 2. Monthly counts for a) Royal Spoonbill, b) Straw-necked Ibis and c) Australian White Ibis in the Hunter Estuary 1999-2021.



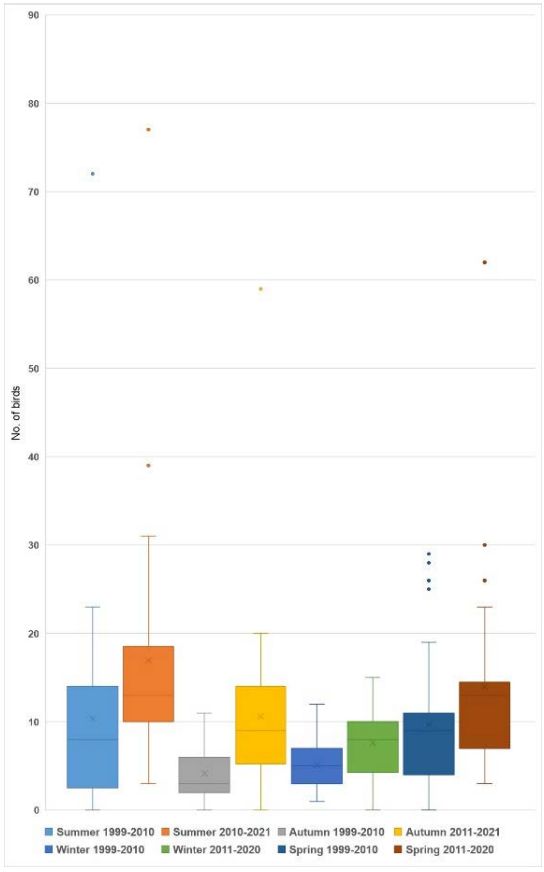
(a) Royal Spoonbill



(b) Australian White Ibis



(c) White-faced Heron



(d) Great Egret

Figure 3. Box and whisker plots for seasonal counts for a) Royal Spoonbill, b) Australian White Ibis, c) White-faced Heron and d) Great Egret in the Hunter Estuary for two time periods.

of 22 and 15 birds, respectively). The differences between the spring and either the summer or autumn numbers were statistically highly significant ($P < 0.01$). The differences between the winter and autumn numbers were also statistically significant ($P < 0.05$).

Straw-necked Ibis

Birds were recorded frequently, usually as counts of around 50 birds and with occasional spikes to 150-300 birds. There was no obvious seasonal pattern and the population was stable or slightly increasing (**Figure 2b**). The peak count, of 965 birds in February 2020, was anomalous being about three times as large as any previous count. Almost all of those birds were at Hexham Swamp where there were also more than 1,000 Australian White Ibis present.

Australian White Ibis

Usually 50-150 birds were recorded, and 200-400 birds occasionally (**Figure 2c**). There were five counts of more than 500 birds, with all of those being from the period February-May. The peak count of 1,126 birds occurred in February 2020, with most of those birds being at Hexham Swamp. The results indicated an increasing population although the change was dominated by counts of more than 500 birds in 2013, 2015 and 2020. The rise in summer numbers (see **Figure 3b** for seasonal changes) was statistically significant (means of 63 and 180 birds respectively for the two 11-year time periods) and so was the population change in spring (means of 31 and 57 birds respectively).

Seasonal analysis (**Figure 3b**) indicated that Australian White Ibis was present in greater numbers in summer and autumn (22-year means of 119 and 143 birds, respectively) than in winter and spring (22-year means of 58 and 43 birds, respectively). The differences between the spring and either the summer or autumn numbers were statistically highly significant ($P < 0.01$), as were the differences between the winter and autumn means. The differences between the winter and summer numbers were statistically significant ($P < 0.05$).

Glossy Ibis

All eleven records occurred from February 2013 onwards, with one record in spring (13 birds in November 2019), three records in autumn (52 birds in April 2014, the peak count from all surveys, and 2-4 birds in March 2014 and March 2017). There were no winter records. There were 42 birds in February 2013 and 27 birds in January 2017; all other summer records were of less than 20 birds.

Australasian Bittern

All four records were of single birds, and all were from prior to February 2013. Two of the records were from Kooragang Island, and one each from Ash Island and Tomago Wetland.

Nankeen Night-Heron

Of the 15 records of Nankeen Night Heron, one was in summer and two in autumn. Those three latter records involved 1-2 birds. There were six records in both winter and spring, with several of those being of multiple birds. The peak counts were of 21 birds in July 2002 and 14 birds in September 2001. Twelve of the records occurred in the first five years of the surveys. There were insufficient records for a more detailed analysis.

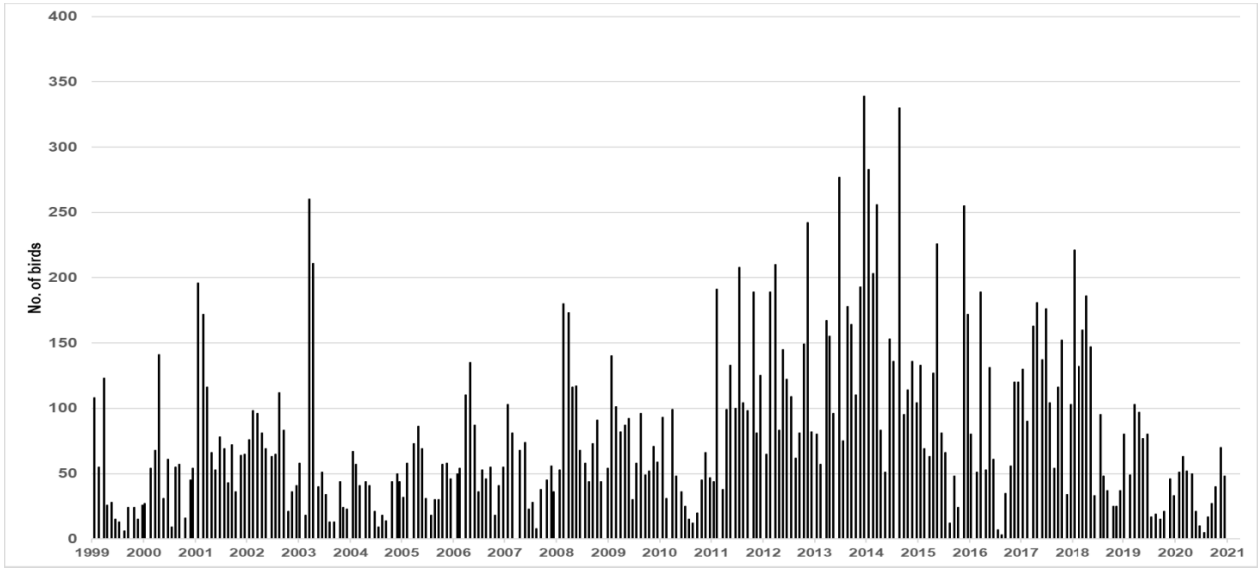
White-faced Heron

Birds were regularly present in the estuary. The long-term trend has been an increasing population (**Figure 4a**) although since 2019 the trend has reversed.

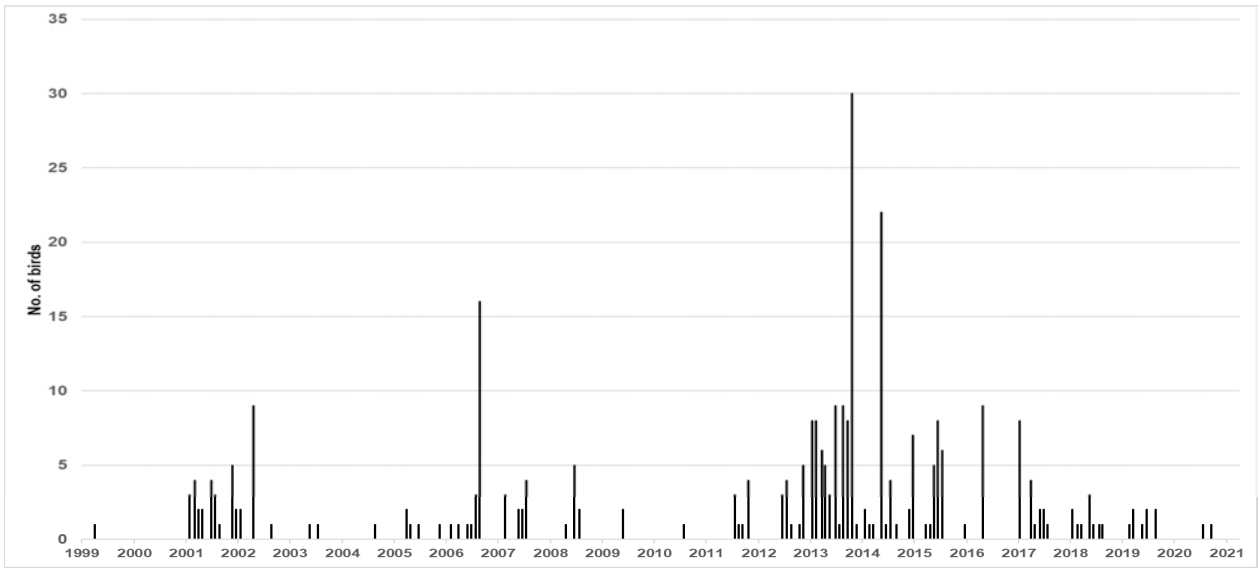
Data were analysed seasonally and for two time periods (**Figure 3c**). For three seasons – winter, spring and summer – the increase in numbers in the second time period was statistically highly significant. There is no significant difference for the autumn results although there probably has been an increase (means of 94 and 117 respectively for the two 11-year time periods). The differences between the summer and winter numbers in either of the two time periods were statistically significant (highly significant for the first time period). The differences between the summer and autumn numbers in the first time period were statistically significant.

White-necked Heron

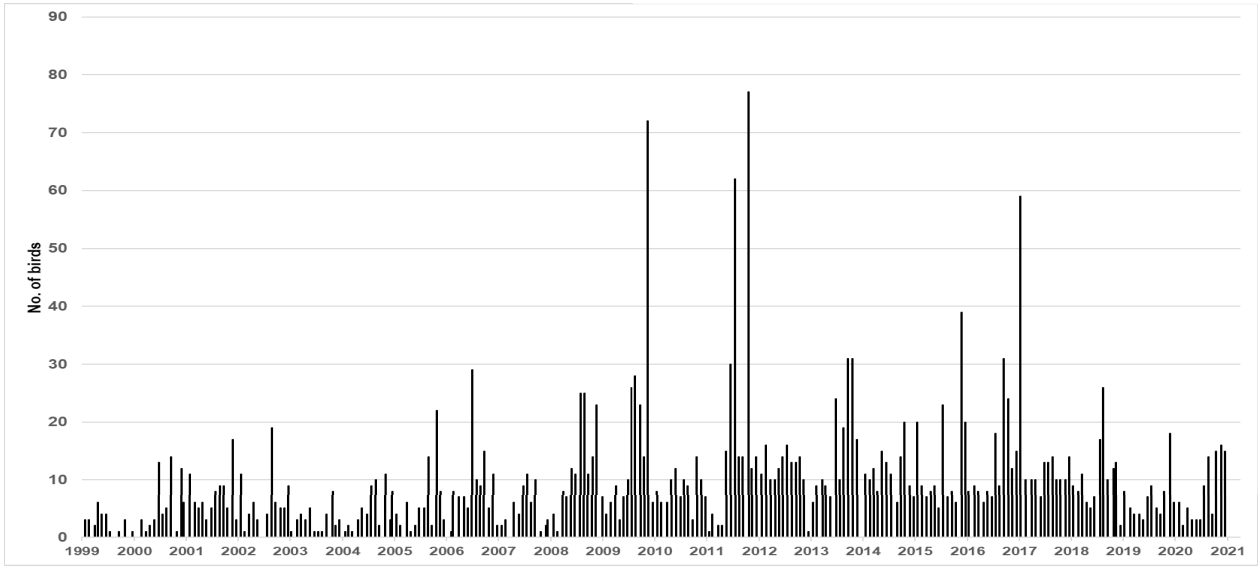
Birds were occasionally present in the estuary, usually in low numbers but with occasional spikes (**Figure 4b**). The main spikes were in November 2006 (16 birds), January 2014 (30 birds) and August 2014 (22 birds). There were no obvious seasonal differences or trends.



(a) White-faced Heron



(b) White-necked Heron



(c) Great Egret

Figure 4. Monthly counts for a) White-faced Heron, b) White-necked Heron and c) Great Egret in the Hunter Estuary 1999-2021.

Great Egret

Birds were regularly present in the estuary, usually as 5-15 birds, but with occasional larger influxes to 20+ birds (**Figure 4c**). The peak numbers were 72 birds (February 2010), 62 birds (October 2011), 77 birds (January 2012) and 59 birds (April 2017). The population in the estuary has increased. The increases have mainly occurred in the summer and autumn numbers. However, only the difference between the first and second autumn periods was statistically significant.

Figure 3d shows the seasonal differences for the two 11-year time periods. Although numbers are more likely to be lower in autumn and winter than in the other seasons (mean counts of seven and six birds respectively) than for spring and summer (mean counts of 12 and 13 birds respectively), the differences were assessed to be not statistically significant.

Plumed Egret

Birds were often present in the estuary, usually as 1-3 birds, but with occasional larger influxes (**Figure 5a**). The peak numbers have been 17 birds (November 2006), 32 birds (December 2012) and 22 birds (April 2017). The small population has in general remained stable over the survey period. This is supported by the observation that for any season there were no significant differences in the means between the first and second time periods. Also, there were no statistically significant differences in the seasonal numbers.

Little Egret

Small numbers of birds were present, with occasional spikes to 15-20 birds (**Figure 5b**). There was no change in the overall population across the survey period. This was confirmed when the seasonal data for two 11-year time periods were compared – for each of the seasons there were no significant differences for the two time periods, nor were there any significant differences in the seasonal populations.

Cattle Egret

Twenty to thirty birds were often present, with occasional spikes to 100-200+ birds (**Figure 5c**). The results indicated that there had been a small decrease in the overall population across the survey period. That was mainly associated with a decrease in summer numbers – the mean counts were of 33 and 19 birds for the first and second 11-year time periods respectively (**Figure 6a**). Those differences were not statistically significant. Numbers were greater in summer and autumn than in winter and spring, although the seasonal differences were not statistically significant. The two largest counts occurred in autumn (233 birds in May 2008 and 210 birds in March 2006).

Striated Heron

Small numbers of birds were recorded occasionally. The peak count, of five birds, occurred in December 2016, and also there were four birds in December 2012 and April 2017.

Australian Pelican

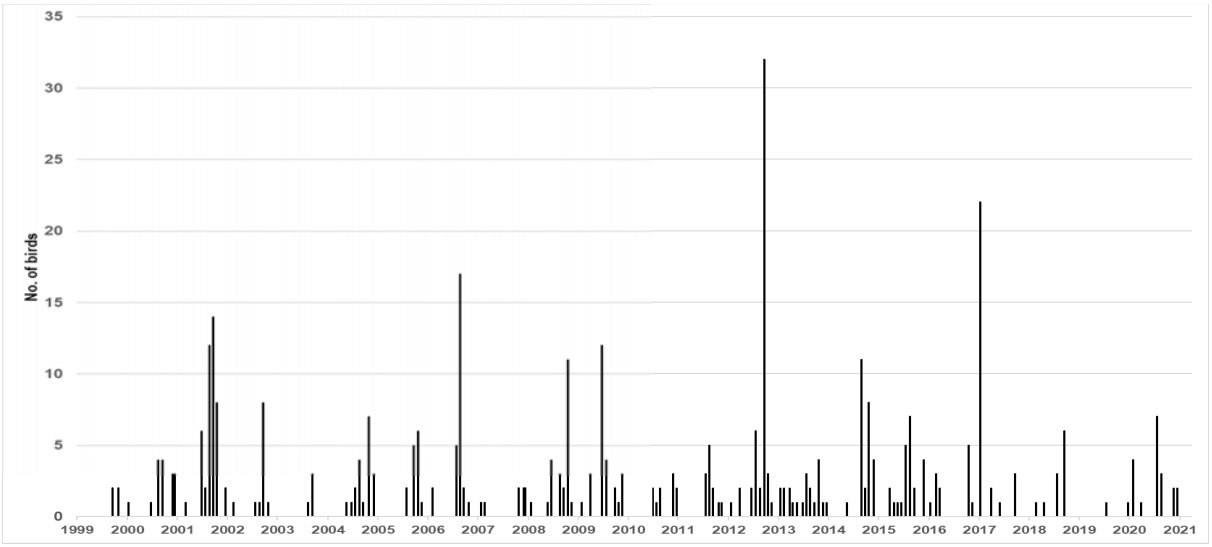
Most of the monthly counts were of 50-150 birds (**Figure 7a**). From October 2002 for six months there was a substantial influx, including the peak count overall of 783 birds in February 2003. Excepting for that short-term rise in numbers, the overall population was fairly stable. Seasonal analysis indicated that Australian Pelican was present in greater numbers in summer and autumn (22-year means of 134 and 119 birds, respectively) than winter and spring (22-year means of 72 and 97 birds, respectively). The differences between the winter and either the summer or autumn numbers were statistically highly significant ($P < 0.01$). **Figure 6c** shows the range of the seasonal counts for the first and second 11-year time periods.

Little Pied Cormorant

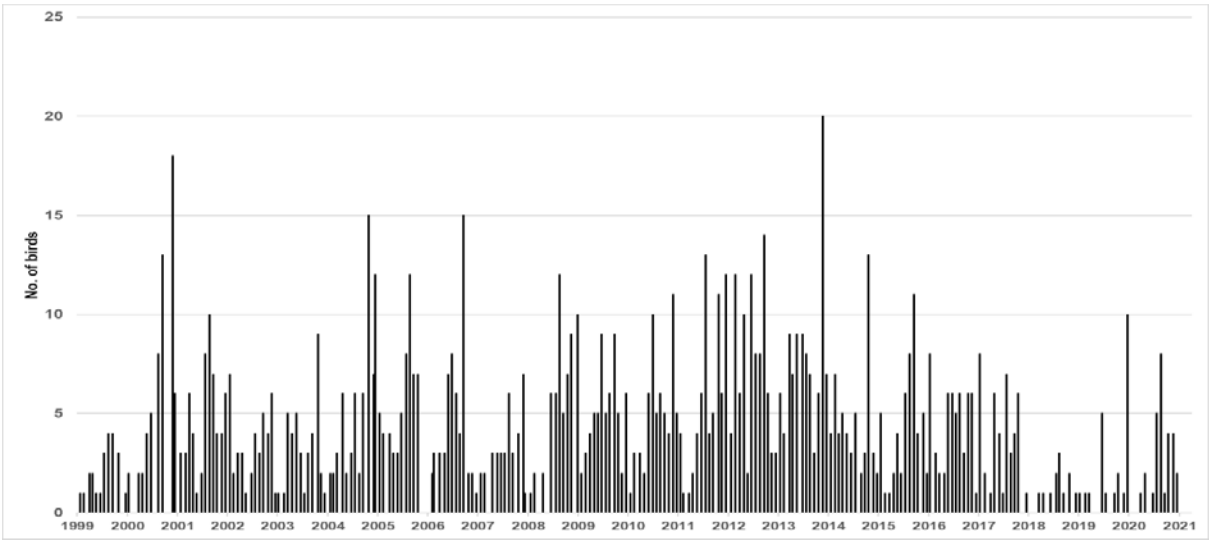
Little Pied Cormorant were recorded in most surveys, usually as total counts of 5-15 birds (**Figure 7b**). The peak count was 41 birds in March 2015. The population was stable and there were no significant seasonal differences in numbers.

Great Cormorant

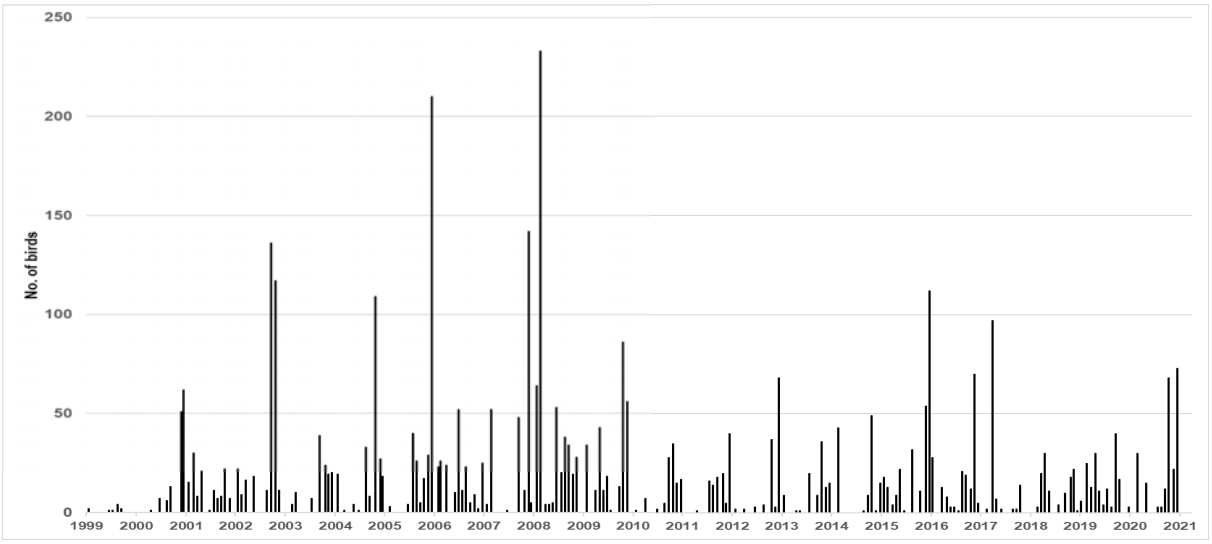
Great Cormorant were recorded in most surveys, usually as total counts of 5-15 birds. The peak count was 51 birds in September 2013. The results (**Figure 7c**) indicated a declining population which was mostly from decreases in the summer and spring numbers (see **Figure 6c**). For the first and second 11-year time periods the summer mean counts were eight and four birds respectively, and the means were eight and three birds for the two spring 11-year periods. However, the changes were not statistically significant nor were there any significant seasonal differences in the population.



(a) Plumed Egret

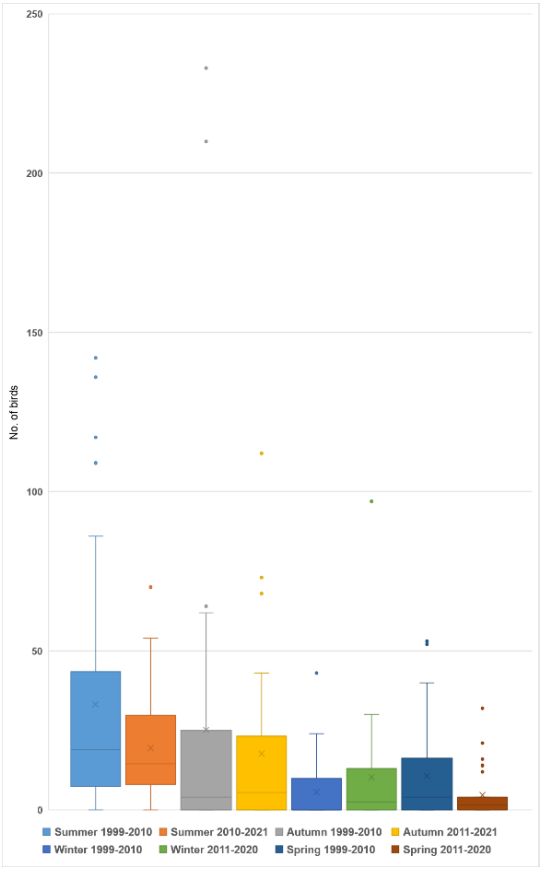


(b) Little Egret

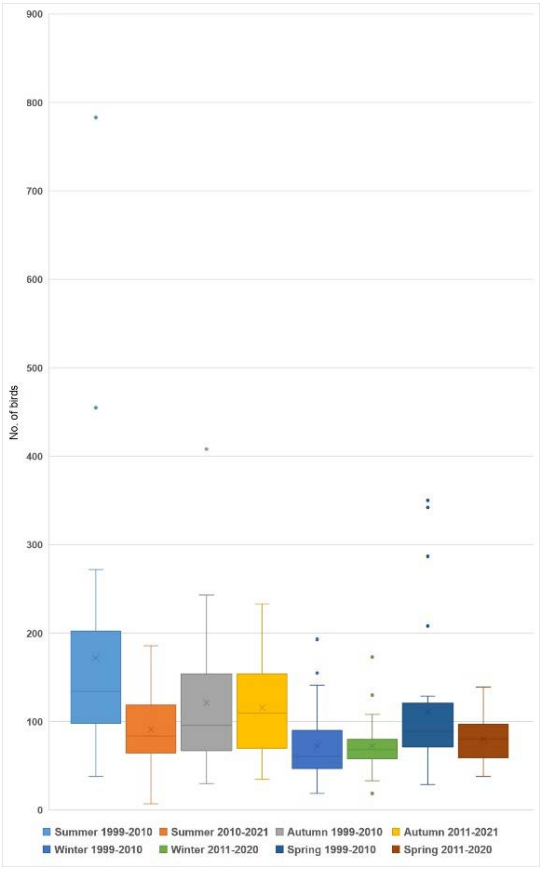


(c) Cattle Egret

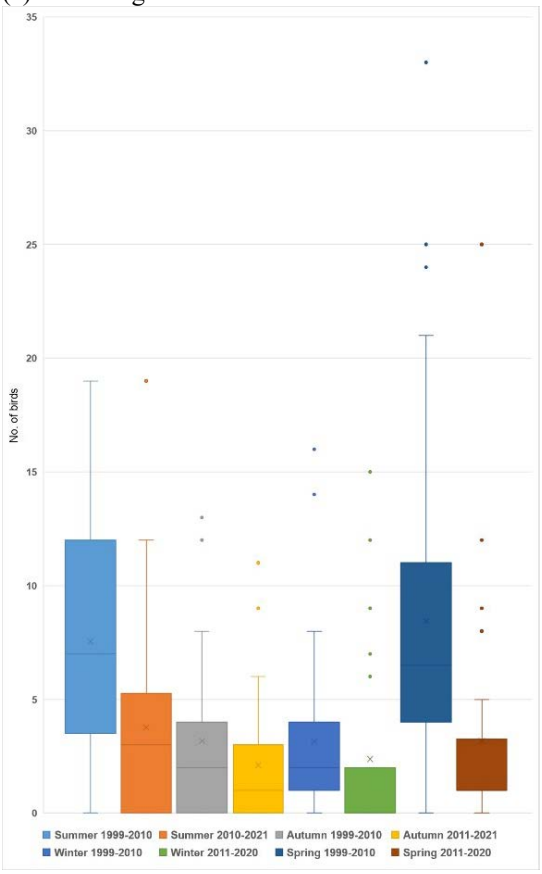
Figure 5. Monthly counts for a) Plumed Egret, b) Little Egret and c) Cattle Egret in the Hunter Estuary 1999-2021.



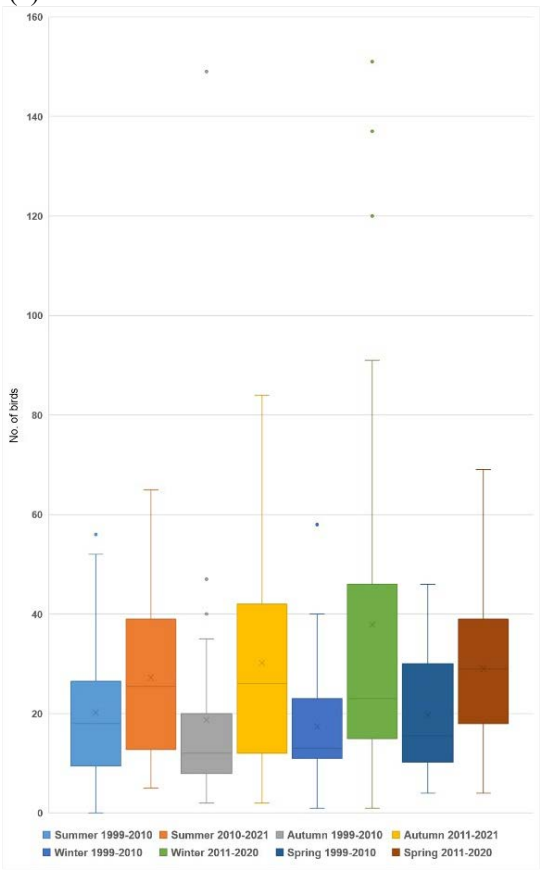
(a) Cattle Egret



(b) Australian Pelican

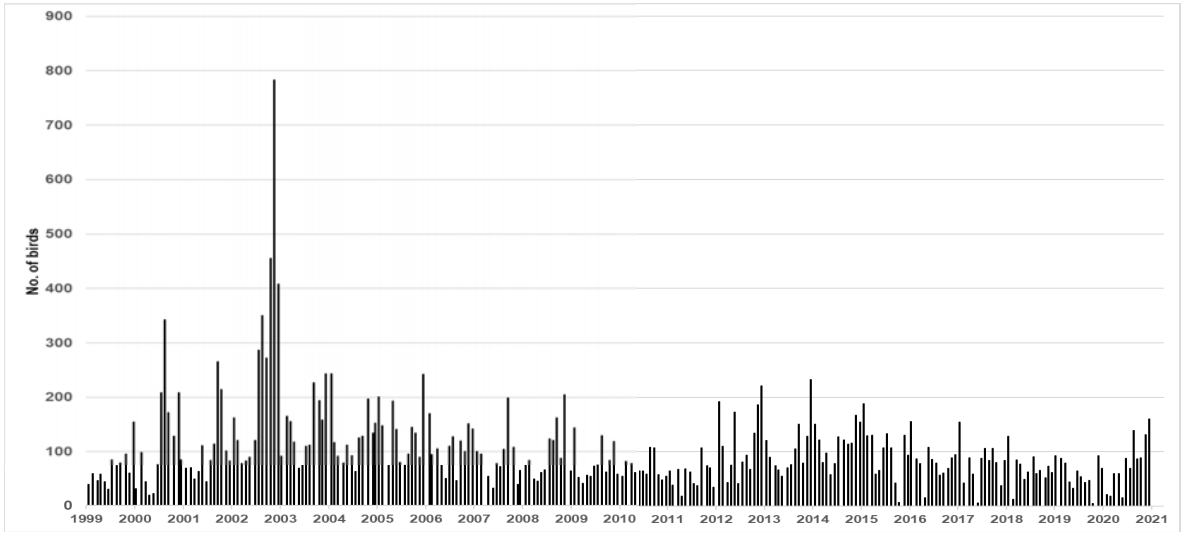


(c) Great Cormorant

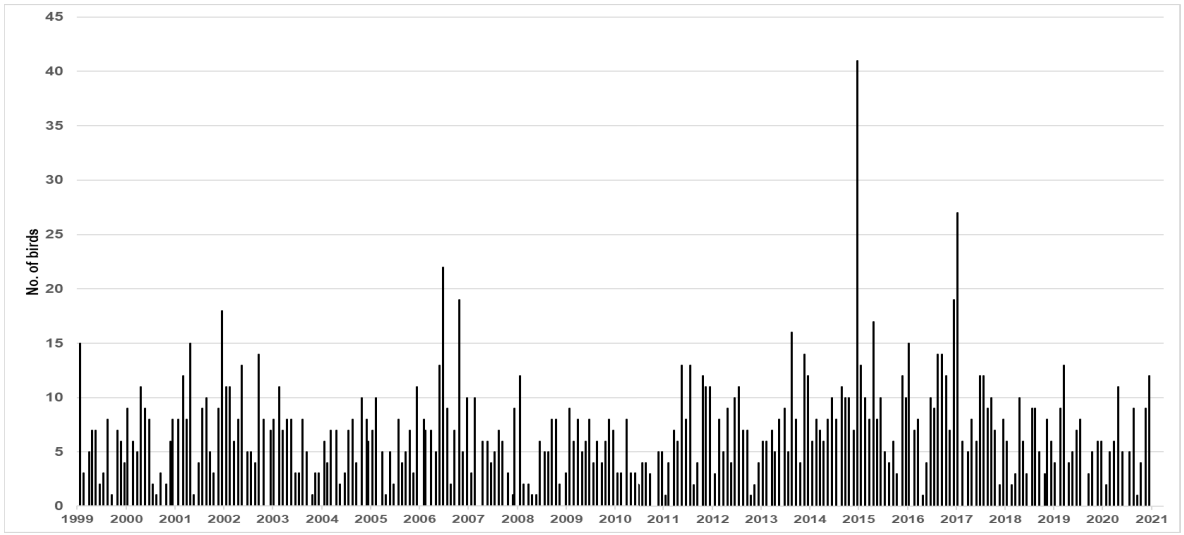


(d) Little Black Cormorant

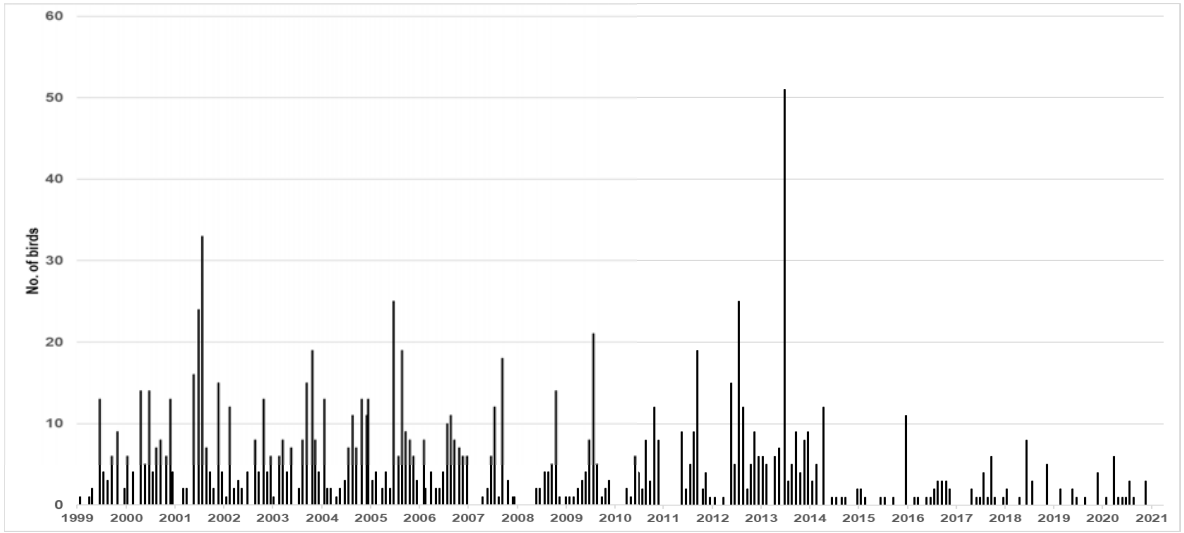
Figure 6. Box and whisker plots for seasonal counts for a) Cattle Egret, b) Australian Pelican, c) Great Cormorant and d) Little Black Cormorant in the Hunter Estuary for two time periods.



(a) Australian Pelican



(b) Little Pied Cormorant



(c) Great Egret

Figure 7. Monthly counts for a) Australian Pelican, b) Little Pied Cormorant and c) Great Cormorant in the Hunter Estuary 1999-2021.

Little Black Cormorant

Birds were regularly recorded, with seasonal mean counts of 24-26 birds but occasionally much greater numbers including four counts of more than 120 birds and a peak count of 151 birds in July 2020 (**Figure 8a**). There were no seasonal differences in the numbers present. In all four seasons there was evidence that the population had increased in the second 11-year time period (see **Figure 6d**), from means of 17-20 birds to means of 27-38 birds. Only the winter change was statistically significant ($P < 0.05$), with the mean rising from 17 birds to 38 birds.

Great Pied Cormorant

Birds were regularly recorded in the estuary, and the population increased over the 22-year period (**Figure 8b**). Prior to July 2014 there were no counts of more than 30 birds, subsequently there were twenty such occurrences. Comparisons of the counts for the first and second 11-year time periods showed that the mean counts had increased for every season (**Figure 9a**). The differences were statistically significant ($P < 0.05$) for summer (mean counts of eleven and 22 birds respectively) and spring (mean counts of nine and 20 birds respectively).

In both of the 11-year periods, numbers for Great Pied Cormorant were greater in summer and spring than in autumn and winter; however, the differences were statistically significant ($P < 0.05$) in the second 11-year period only.

Australasian Darter

Australasian Darter was recorded frequently, usually in counts of 1-4 birds but with occasional spikes including a peak count of 14 birds in April 2013 (**Figure 8c**). There were indications that birds were present in greater numbers in winter (see **Figure 9b**) but the seasonal differences were not statistically significant.

DISCUSSION

Population trends

Increasing populations

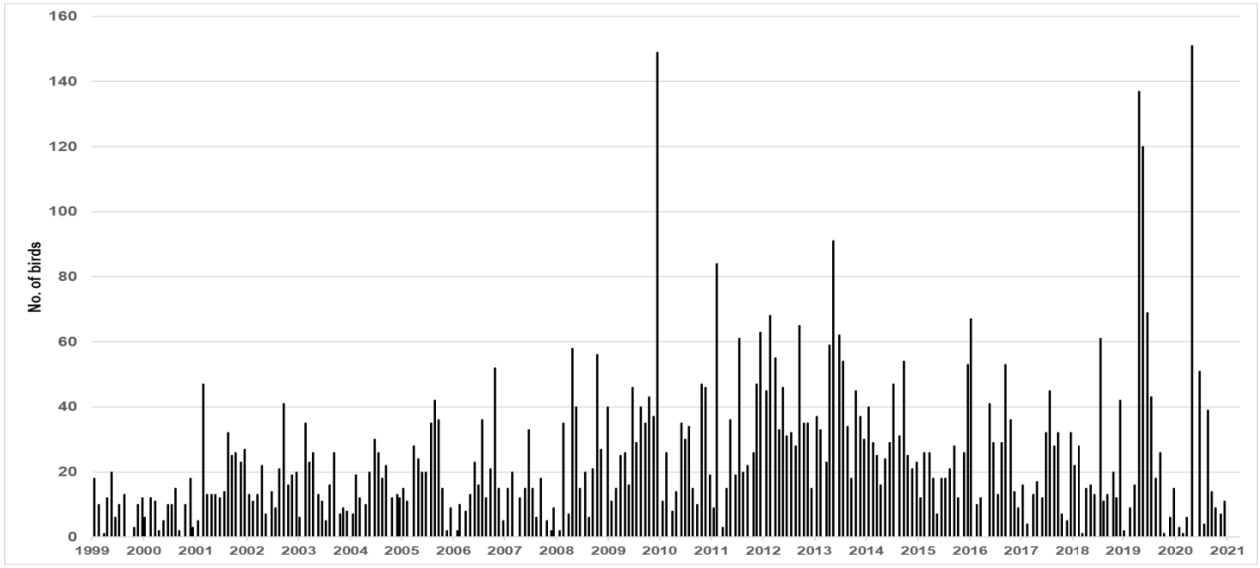
Most of the species were found to have stable populations or the changes over 22 years were modest. The populations of eight species were found to have increased – Black-necked Stork, Royal Spoonbill, Australian White Ibis, Glossy Ibis, White-faced Heron, Great Egret, Little Black Cormorant and Great Pied Cormorant.

The Black-necked Stork is listed as Endangered under the NSW *Biodiversity Conservation Act 2016*. Until relatively recently, it was an uncommon species within the estuary. In the Hunter Region Annual Bird Report series (the issues for 1993-2019 are currently available), there were only occasional records from within the estuary between 1993 and 2005 and there were no records for 2006-2008. In mid-January 2009, an immature bird, which had been taken into care in Sydney, was released at HWCA. After an interval of about two weeks with frequent sightings, there were no further records of that bird. However, from October 2009 onwards, records of Black-necked Stork began to become more frequent although they still were intermittent (and none was on a survey date). During 2010-13, most reports were of a single male or female but occasionally a pair were recorded together.

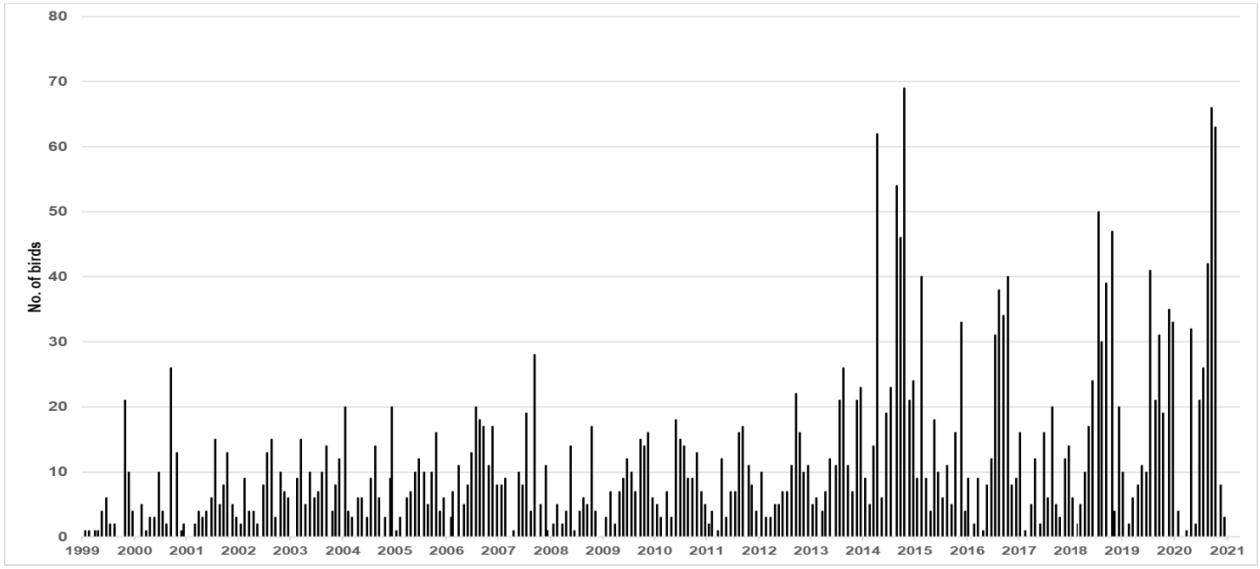
The increase in records in the estuary since 2013 eventually was accompanied by the first documented evidence of local breeding activity. By 2020 there were at least two breeding pairs within the estuary, one pair at Tomago and the other at Hexham Swamp (Lindsey 2019; 2021). The Tomago pair were confirmed to have bred successfully in the 2017 and 2018 seasons and possibly they had also bred there earlier (Lindsey 2019). The only confirmed breeding record for the Hexham Swamp pair was in 2020 but birds possibly bred there, or nearby, in 2014 and 2015 (Lindsey 2020; Stuart 2017).

The increases in Royal Spoonbill population were modest and were mainly associated with greater numbers in autumn. This species, which preferentially feeds on intertidal mudflats (Lowe 1982), is generally considered to be sedentary (Marchant & Higgins 1990).

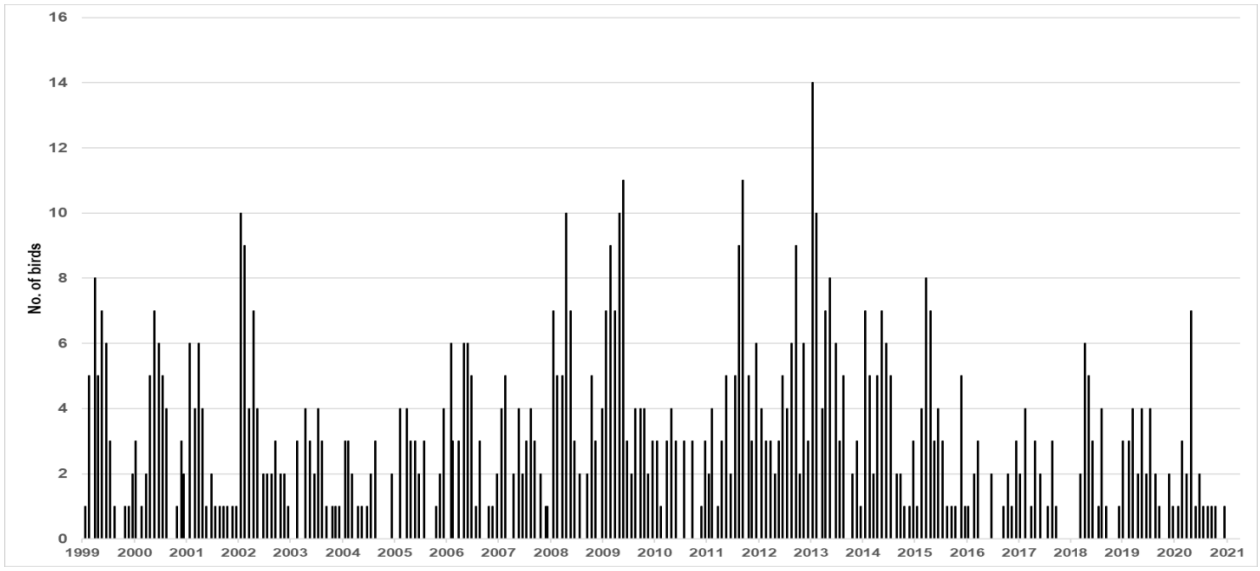
Australian White Ibis is widespread in NSW (Marchant & Higgins 1990; Cooper *et al*. 2014) and is equally at home in saline or freshwater habitats. The rise in numbers in the estuary was unexpected, as there has been a significant decline in numbers in eastern Australia over a 30-year period (Kingsford *et al*. 2017) and there have been fewer nests at a breeding colony at HWCA. Regular breeding at HWCA, mainly over the winter period, commenced in 2003-04 and peaked in 2011-12 with 303 nests



(a) Little Black Cormorant

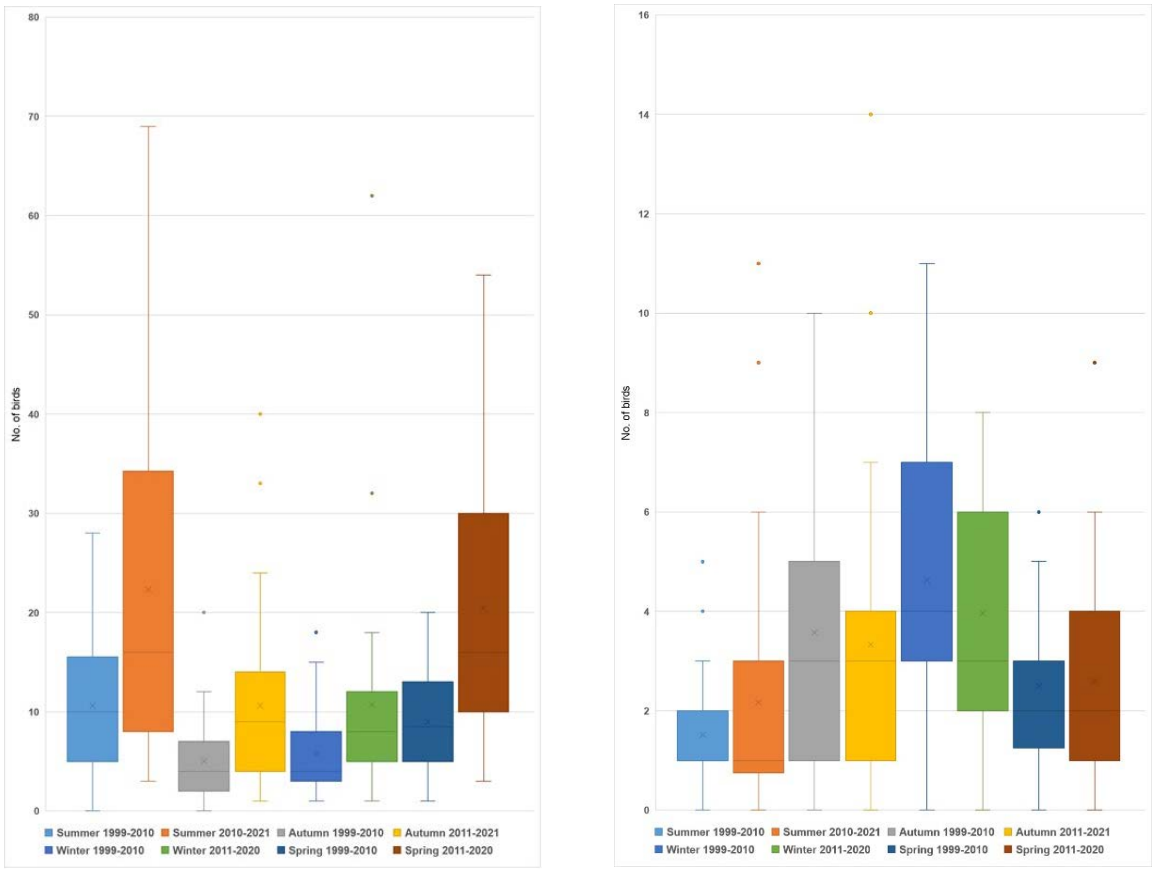


(b) Great Pied Cormorant



(c) Australasian Darter

Figure 8. Monthly counts for a) Little Black Cormorant, b) Great Pied Cormorant and c) Australasian Darter in the Hunter Estuary 1999-2021.



(a) Great Pied Cormorant (b) Australasian Darter

Figure 9. Box and whisker plots for seasonal counts for a) Great Pied Cormorant and b) Australasian Darter in the Hunter Estuary for two time periods.

(Nicholls 2019). There has been a steady decrease in the number of nests since then and there were only 76 nests in July 2020 (G. Nicholls unpublished reports).

In the Hunter Region the Glossy Ibis is an uncommon, irruptive species which occurs in small numbers, mainly on freshwater wetlands (Williams 2020). Its numbers in Australia fell by almost 38% between the two national Atlas surveys in 1977-1981 and 1998-2002. There was a decrease in the reporting of this species from 1986-2006 (Cooper *et al*. 2014). The increased number of records in the estuary since 2013 may be a result of improved habitat as discussed further below (in *Effects from local rehabilitation projects*).

White-faced Heron was one of two species recorded on every survey (the other species with an RR of 100% was the Australian Pelican). Across the two 11-year time periods its numbers increased significantly or highly significantly, depending upon which season was being considered. A combination of dry conditions inland and the effects of local rehabilitation projects probably account for the changes. The recent decrease in numbers of White-faced Heron may have been as a result of the Millennium Drought breaking, with some birds thus able to return to inland wetland sites. The changes observed for Great Egret might be similarly explained (although, see the discussion about *Egrets*, further below).

The increased numbers of Little Black Cormorant and Great Pied Cormorant could be due to a number of factors including changes in portside land use, pollution reduction programs, restoration of natural tidal flows and the rehabilitation of estuarine habitats (Office of Environment and Heritage 2017).

Declining populations

The absence of Australasian Bittern records from the monthly surveys since 2013 suggests that its population may have declined. However it is a cryptic species and there were only four records in the first 14 years. In 2020-21, some birds were recorded occasionally at both Hexham Swamp and Ash Island during targeted surveys (I. Benson pers.

comm.). Nevertheless, there have been some loss of habitat for this species, as discussed below under *Effects from local rehabilitation projects*.

Although there were insufficient records of Nankeen Night-Heron from the surveys for any trends to become apparent, the results confirm that the estuary's population of this species has not recovered since the progressive destruction of the Kooragang Island colony near Stockton Bridge (Maddock 2008). The destruction was complete by 1972. Gosper reported roosting assemblages of up to 300 birds and up to 60 breeding pairs (Gosper 1981). During the 1980s Maddock reported a range of 11-51 birds as semi-permanent residents at HWCA (Maddock 2008). Small numbers continue to be reported from that site (M. & R. Stewart pers. comm.). The only confirmed breeding record in the estuary since the 1970s was from near HWCA in 2009 (Stuart 2010). We speculate that this species leaves HWCA to forage in Hexham Swamp. In October 2012 one bird was seen flying from the direction of HWCA to Hexham Swamp where it landed in the early evening (AL pers. obs.) and in September 2017, seven birds were seen flying from HWCA to Hexham Swamp (www.birdlife.birdata.com). Williams (2020) describes this species as resident and an irruptive visitor to the Hunter Region.

Egrets

The results for the egrets do not reflect the trends occurring for them at the HWCA and Seaham colonial breeding sites, where all four species breed or have bred in the past (Maddock 2008; Nicholls 2019). The monthly survey results suggest that the Great Egret population had increased, that Cattle Egret had decreased although not statistically significantly, and that the Plumed and Little Egret populations had been stable. Maddock (2008) reported declines between the 1981/82 and 2007/08 seasons for the numbers of nests of Great, Plumed and Little Egrets at HWCA and Seaham as being well in excess of 90% and the decline for Cattle Egret nests at both colonies exceeded 70%. The Seaham colony ceased to exist in about 2010. More recent nest counts at HWCA for the 2010/11 to 2018/19 seasons, when compared to the 1995/96 to 2007/08 time period, showed a further decline in the median counts of Great Egret and Plumed Egret nests, an increase in Cattle Egret nests and the same median count for Little Egret nests (Nicholls 2019).

The differences in the trends being seen from the two types of survey may be due, at least in part, to the estuary surveys not providing the full picture for the egrets, all of which have differing habitat preferences. Plumed Egret and Cattle Egret were less commonly recorded during the surveys because the habitat in the surveyed areas of the estuary was not optimal for them. The Plumed Egret prefers freshwater wetlands while Cattle Egret prefers low-lying or poorly drained pasture (Marchant & Higgins 1990). These habitats are not common at the monitored sites. The two other species had RRs above 90% in the surveys but neither species was present in large numbers. The Great Egret uses both saline and freshwater wetlands and forages in open shallow water, while the Little Egret prefers saline wetlands and also forages in open shallow water (Marchant & Higgins 1990). There are many other wetlands in the lower Hunter which provide such required habitats, i.e. the estuary surveys find only a subset of the total local population.

Seasonal population changes

Summer and autumn

Seven species had greater populations in the estuary in summer and autumn: Royal Spoonbill, Australian White Ibis, Glossy Ibis (in summer only), Great Egret, Cattle Egret, Australian Pelican and Great Pied Cormorant.

The Royal Spoonbill breeds in the Hunter Region (Williams 2020) and the higher numbers in autumn may be related to post-breeding dispersal. An analogous situation may apply for the Australian White Ibis. At HWCA it breeds mainly in winter and the rise in its numbers in spring and summer may also be due to post-breeding dispersal to other wetlands in the estuary, particularly to nearby Hexham Swamp. Consistent monitoring in the Sydney region, however, showed that banded juveniles were rarely resighted after leaving the nesting sites and they comprised only 10% of the population (Smith 2009). Juvenile Straw-necked Ibis were likewise infrequently observed after leaving nest sites (Smith 2009). Both species may be benefitting from scavenging opportunities at the waste management facility at Maryland, a suburb on the edge of Hexham Swamp (Maddock 2008).

The Glossy Ibis is described as migratory with local movements driven by food availability (Marchant & Higgins 1990; Cooper *et al*. 2014) and the pattern of records from the estuary accords with that description. Cattle Egret departs its breeding colonies in March or April, dispersing widely (Maddock 2008), which would account for the fewer numbers in the estuary over winter and early spring. Great Egret (and Little Egret) are also

described as dispersive and possibly migratory (Marchant & Higgins 1990), which may account for the seasonal aspect to the Great Egret records. Cooper *et al*. (2014) noted that there did not seem to be significant regular movements out of NSW.

The reason for the greater numbers of Australian Pelican in summer and autumn is unclear. Cooper *et al*. (2014) found no evidence for regular seasonal movements. This species breeds throughout the year at Wallis Lake, north of Newcastle and thus the seasonal changes do not seem to be related to dispersal after breeding. At Wallis Lake, eggs were present in nests in all months from January through to October although peak laying seemed to be in August-September (Marchant & Higgins 1990). At the colony in 2012, many birds had nests with eggs in August and chicks of varying ages were present in November (Stuart *et al*. 2012).

The seasonal increase in Great Pied Cormorant numbers may be associated with the colony at Shortland where breeding was first recorded in 1998 (Stuart 1999). Foraging presumably becomes more locally focussed in the breeding season whereas at other times of the year, birds are more widely dispersed including when they are foraging at beaches away from Newcastle harbour.

Winter

The numbers for White-faced Heron rose in autumn and peaked in winter. This was also found to be the case in Westernport Bay in Victoria where there was a spring dispersal away from the coast presumably to breed inland and the largest flocks were observed in May and June (Lowe 1983). Gosper (1981) noted that in north-east NSW this species congregates on coastal mudflats during winter. White-faced Heron will also move to coastal estuaries during summer after breeding (Marchant & Higgins 1990). Cooper *et al*. (2014) noted that birds are absent from high-altitude parts of NSW in winter, with a corresponding increase in coastal records.

Very little is known about the movements of Australasian Darter but when not breeding it disperses sometimes over long distances (Marchant & Higgins 1990). Its increased numbers in the estuary in winter may be associated with post-breeding dispersal (Cooper *et al*. 2014).

Irruptions

Several species had short-term irruptions into the estuary, when their numbers briefly were much greater than average. Mostly these irruptions can be accounted for by a combination of inland conditions and conditions within the estuary. When inland wetlands begin to dry out, the birds there disperse to coastal refuges where there is sufficient suitable habitat to sustain them at least temporarily. For example, the irruption of Australian Pelican from October 2002 may have been caused by the intensification of drought conditions inland which started to abate by March 2003 (Bureau of Meteorology 2003).

For another example, we considered the irruptions by White-necked Heron. In NSW this species is more common in the Riverina, Western Slopes and North Coast (Cooper *et al*. 2014). It is known to be affected by water conditions which may lead to irruptions and fluctuations in numbers (Marchant & Higgins 1990). Irruptions in the estuary have been small compared to a report of "hundreds of these herons being seen on Burswood Island" near Perth in 1923 (Pringle 1985). Four irruptions occurred in the estuary between 1999 and 2021, one of which was not on a survey date. These irruptions could be linked to the local and inland NSW water conditions. For instance, in 2006 (when 16 birds were present), 2008 (26 birds – see Lindsey & McNaughton 2012) and January 2014 (30 birds present) the rainfall in the Hunter Region was average to above-average whereas conditions inland were particularly dry. Three heatwaves in January 2014 caused extreme temperatures. (Bureau of Meteorology 2006, 2009, 2014a). Although most of the state had good rainfall in August 2014, there was about double the average rainfall in the coastal regions (Bureau of Meteorology 2014b) which may account for the spike of 22 birds in that month.

Water levels in the estuary were high in April 2017 in the aftermath of Cyclone Debbie the previous month (Bureau of Meteorology 2017) and this may have attracted both Great and Plumed Egret to wetlands in larger than usual numbers.

Some of the other large counts may be associated with chance observations of larger congregations of birds. For example, the peak counts of Australian White Ibis (1,126 birds) and Straw-necked Ibis (965 birds) occurred in February 2020 when a large mixed flock of ibis rose out of dense vegetation at Hexham Swamp and was briefly sighted (AL pers. obs.).

Effects from local rehabilitation projects

The Hunter River has a long history of wetland decline due to interventions commencing in the mid-19th century, which altered the hydrology and

vegetation of the coastal floodplain (Rogers 2016). One of the main changes was that floodgates were installed at Ash Island, Hexham Swamp and Tomago Wetland. The floodgates prevented tidal exchange and created freshwater wetlands, which often were ephemeral. Commencing with the Kooragang Wetland Rehabilitation Project in 1993, reinstatement of tidal flushing was established as a long-term objective for the lower Hunter Estuary in 1998 (Russell *et al*. 2012). Reinstatement of tidal flushing was accomplished at Hexham Swamp between 2008-2013 and at Tomago Wetland between 2012-2015 (Lindsey 2021). A fourth project at Fish Fry Flats on Ash Island known as the Newcastle Coal and Infrastructure Group Shorebird Compensatory Habitat Construction, commenced in 2016 (Reid 2019; Lindsey 2021).

The expansion and improvement in estuarine habitat through the reinstatement of tidal flushing resulted in significant improvement in aquatic species diversity and abundance in Hexham Swamp, for example fish, including eel and prawn species. Monitoring of the prawn populations at Hexham Swamp after staged reintroduction of tidal flushing between 2008 and 2013 found that there was positive recruitment of Eastern King Prawn *Melicertus plebejus a*nd School Prawn *Metapenaeus macleayi* as well as fish including eel species (Boys 2015).

At Westernport Bay, Victoria, the dominant prey for Royal Spoonbill and White-faced Heron were prawn species (Lowe 1982; 1983). The diet of Black-necked Stork includes fish (Clancy 2012). The populations of these three species in the estuary have increased, almost certainly as a result of the rehabilitation projects. It seems reasonable to conclude that most other bird species which forage in estuarine habitat in the Hunter have benefitted from the growing food supply. For example, the four irruptions by White-necked Heron occurred at rehabilitated wetlands (Lindsey 2021).

The several successful breeding events by Black-necked Stork in recent years very likely are a direct result of the improved foraging opportunities for this species. The nests established at Tomago and Hexham were immediately adjacent to the newly-rehabilitated wetlands where food had become abundant.

One species may have been adversely affected by the rehabilitation projects – the Australasian Bittern, which is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999*. Before tidal flushing was reinstated at Tomago Wetland, there were regular records from there and birds possibly were breeding (Lindsey & McNaughton 2012). After the reintroduction of tidal flushing, there have not been any records of bitterns at the surveyed parts of Tomago Wetland. However, there continue to be records from nearby freshwater wetlands and also at Hexham Swamp.

CONCLUSIONS

Twenty-one species of large waterbirds of five families were recorded in systematic surveys commencing in 1999. Of these, 13 species had reporting rates of over 50% and most species were found to have stable populations. The populations of eight species increased and the populations of four species decreased slightly (Cattle Egret, Australian Pelican, Great Cormorant, Australasian Darter). Two resident species, Black-necked Stork and Australasian Bittern, are listed threatened species. The wetlands of the Hunter Estuary form an integrated ecological system of interdependent units. Improvement in water quality and the expansion of estuarine habitat through rehabilitation projects have had a positive effect on aquatic fauna thus providing more food resources for waterbirds.

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The surveys of the Kooragang Dykes have used a boat provided by Hunter Local Land Services (originally, the Hunter and Central Rivers Catchment Management Authority). The boat was donated by PwC Australia, and the main skippers have been Chris Herbert, Tom Kendall and Greg Little.

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Is the Bush Stone-curlew about to become extinct in the Hunter Region?

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Records of Bush Stone-curlew *Burhinus grallarius* in the Hunter Region were reviewed and population trends established for the period 1998-2021. A small population was previously widely dispersed across a broad area of near-coastal habitat in the region. Peak numbers were 20-23 birds in 2010-11 which corresponded with the implementation of a recovery plan. Since then, numbers have declined rapidly and in 2021 only six birds could be accounted for – five around Port Stephens and one at Dora Creek. Only one pair is known to have bred in 2020. Many eggs, most chicks and pre-adult birds appear to have been predated. Foxes are considered to be the main predator. The surviving birds are in sub-optimal habitat with no recovery or protection programs. There is no evidence of successful dispersal of locally fledged birds to form new breeding pairs or recruitment of birds from external populations to the region. This small population is unsustainable and faces extinction in the foreseeable future.

INTRODUCTION

The Bush Stone-curlew *Burhinus grallarius* is a large, slim, mainly nocturnal, ground-dwelling bird endemic to Australia. In the early 1900s it was widely distributed over most areas of the continent, except for central inland areas (Matthews 1913-1914). Since then, the abundance and range of the species has declined by over 50% (Garnett & Crowley 2000). In southern and eastern Australia this appears to correlate with the distribution of the European Red Fox *Vulpes vulpes* (Robinson 1998) and the conversion of large areas of native vegetation to intensive agricultural practices and urban landscapes (Marchant & Higgins 1993).

Historically, in New South Wales (NSW) the Bush Stone-curlew was widespread and reasonably common in areas of suitable habitat, from Queensland to the Victorian border (Marchant & Higgins 1993). It remains widely distributed in the state but in very low densities. It is locally extinct from many areas of its former range (Blakers *et al*. 1984; Marchant & Higgins 1993; Barrett *et al*. 2003; Davey 2005).

There are widespread records from the Hunter Region for the first half of the last century. Early records of the species in the Upper Hunter are provided by the egg collection of Eric McPhee from the periods 1918-1921 and 1927-1928 (Stuart & Newling 2009). McPhee collected principally around Belltrees, Moonan Flat, Stewarts Brook and Broke. Hordern & Hordern (1931) reported the species in scrub around the Myall Lakes. Birds were seen and heard on the south side of the Comboyne Plateau (Chisholm 1934). Chisholm stated they had a poor chance of survival due to predation by foxes and dingo. A pair was often seen at Barrington (Hyem 1936). Hyem reported that foxes have practically exterminated the species in the area, taking both eggs and chicks. At West Maitland birds were seen in a local garden and heard from nearby lucerne paddocks (Enright 1939). The species was recorded on a list of birds of the Paterson District in 1952.

The species is listed as endangered in NSW under the *Biodiversity Conservation Act 2016.* It has been listed since 1995. This listing reflects the decrease in abundance and reduction in range across the state. The main threat is predation by introduced species (foxes and cats). Other threats include clearing of habitat for agriculture and urban development, modification of its preferred woodland habitat through removal of litter and fallen timber, disturbance in the vicinity of nest sites, high-intensity grazing, introduction of exotic grasses, inappropriate fire regimes and insecticide use (NSW Office of Environment and Heritage 2018). This report noted that numbers have declined greatly over the last century and there are concerns that in 10 or 20 years it will be too late to prevent the species from becoming extinct in NSW. The Red Fox is also identified as the principal current threat to the species in Victoria (Victorian Depart-

ment of Environment and Sustainability 2004) and on mainland South Australia (Gates & Paton 2005).

Birdata records in NSW since 1980 reveal the majority of the remaining population is clustered around three coastal areas: the Tweed, Byron and Ballina Shires; around Port Stephens; and the Central Coast. The Birdata average annual Reporting Rate (RR) for NSW and the ACT from 1998-2020 is 0.12%. In contrast to the rest of the state, a larger population is present in the Tweed, Byron and Ballina Shires. Here, monitoring since 2009-2010 has shown a considerable increase in population and the number of breeding pairs (Tweed Shire Council 2019; Charley 2020). This population is the southern extension of a relatively secure Queensland population and is not considered to be under threat. The average Birdata RR for this region for 2009-2020 is 2.19%.

A Recovery Plan for the species in NSW was approved in 2006 (Department of Environment and Conservation 2006). At that time the state population was estimated at around 1,000 breeding pairs and declining. The plan recorded a number of small coastal populations sporadically present from Sydney to the Queensland border. This included a population at Pindimar, Port Stephens. Following the release of the plan, there was a concerted effort by NSW National Parks and Wildlife Service (NPWS) and volunteer groups to implement recommendations and monitor the species. Activities conducted by NPWS to implement the plan locally included extensive community consultation and engagement, installation of temporary fencing to protect breeding sites, deploying remote cameras to monitor activity and maintaining vegetation to provide optimal habitat (S. Callaghan pers. comm.).

In 2016 NSW introduced the Saving our Species Program which included management of Bush Stone-curlew. Under this program, the birds are managed at a landscape scale and the Hunter Region is recognised as a priority landscape. However, no management sites have been established to date due to a lack of local interest (S. Callaghan pers comm.). The status of Bush Stone-curlew in the Hunter Region is uncertain (Williams 2019).

The objectives of the present study were to review records of Bush Stone-curlew in the Hunter Region, identify breeding events and evaluate the population trend of the species.

The Hunter Region is defined by Williams (2019) as the area managed by Local Governments of Newcastle, Lake Macquarie, Maitland, Cessnock, Port Stephens, Dungog, MidCoast, Muswellbrook, Scone, Singleton and the area formerly managed by Local Governments of Merriwa and Murrurundi. It also includes the ocean within 100km of the coastline.

METHODS

All available records were extracted from the BirdLife Australia Birdata portal (https://birdata.birdlife.org.au), the Cornell Lab of Ornithology eBird Australia portal (https://ebird.org/australia/home) and the NSW Department of Environment and Heritage BioNet Atlas (http://www.bionet.nsw.gov.au/). Records were also extracted from Annual Bird Reports for the Hunter Region (https://www.hboc.org.au/publications/annual-bird-report/) for years 1993-2019 and from a spreadsheet of early records (1979-1993) for the region (A. Stuart pers. comm). Records were consolidated by year and the number of birds present each month was determined. Banding, breeding and predation data was also extracted from these sources. Annual RR for the Hunter Region for years 1998-2020 for all survey types was downloaded from the Birdata portal.

To confirm the current status, a limited amount of playback surveying was done in August 2021 in known locations around Port Stephens, and requests for reports of the species were posted on websites of the Port Stephens Econetwork, the Soldiers Point - Salamander Bay Landcare Group and the Myall Koala and Environment Group.

RESULTS

The following were downloaded from online databases: Birdata, 103 records, 1980-2021; eBird, 25 records, 2006-2021; BioNet, 43 records, 1952-2019. Records from HBOC Annual Bird Reports for 1993-2019. Six records were obtained from HBOC early bird records from 1979-1993. There was considerable duplication between the sources.

No responses were obtained from the August 2021 playback surveys and no reports were received from the online requests for information.

Most of the records were from one of three local districts – Port Stephens, Northern Hunter and Lake Macquarie – with a handful of others from other isolated locations within the region. The records are summarised in **Table 1**. The majority were from Port Stephens, from 11 locations, mainly Bobs Farm, Carrington/ Tahlee, Karuah, Little Swan Bay

and Lemon Tree Passage. There were records from 11 locations in the Northern Hunter and seven locations around Lake Macquarie.

Annual population numbers were determined for the period 1998-2021, together with an estimate of possible additional birds identified by calls only, and are charted in **Figure 1**. Breeding records for districts were summarised and are shown in **Table 2**. The annual Birdata RRs for the Hunter Region for the years 1998 to 2020 are shown in **Figure 2.**

Population trend

The annual population numbers for 1998-2021 are shown in **Figure 1**. The maximum numbers, of 20-23 birds, were recorded in 2010-2011 and numbers have declined rapidly since then. There are only six birds present within the Hunter Region in 2021; a pair at Little Swan Bay and single birds at Tahlee/Carrington, Karuah, Salamander Bay and Dora Creek. The pair that have bred at Bobs Farm since 2005 did not return in 2021. A single bird at Salamander Bay in January 2021 is the first known record from that area.

The annual Birdata RR for the Hunter Region from 1998-2020 had a maximum of 0.29% in 2004 and declined to 0.07% in 2020 (see **Figure 2**)**.** The average RR over the period was 0.11%. A similar trend was evident for NSW and the ACT for the period 1986-2006 (Cooper *et al*. 2014).

Information from banding studies

Chicks were banded at four nesting sites as part of the NPWS Recovery Plan from 2004 to 2009:

- Bobs Farm: Chicks were banded in November 2008, November 2009, January 2010, with subsequent observations in January 2009, February 2009, January 2010.
- Fenninghams Island: Chicks were banded in January 2009.
- Lemon Tree Passage: Chicks were banded in December 2005, December 2006, November 2008, with subsequent observations in September 2010, December 2010.
- Little Swan Bay: Chicks were banded in March 2009.

Three adult birds were taken into care at public locations, banded and released elsewhere:

- February 2010: Single bird captured at Horseshoe Beach and released at Fenninghams Island.
- February 2011: Single bird captured at Newcastle Airport and released at Karuah.
- March 2011: Single bird captured at Kooragang Island and released at Karuah.

Two banded birds dispersing from elsewhere were recorded:

- August 2006: A single banded adult bird was at Balickera.
- August 2006: A single banded adult bird was at Swansea. This bird had been banded at St Huberts Island, Brisbane Water in February 2006.

The data indicate that the majority of banded chicks and pre-adult birds were probably predated. Only one banded bird dispersed and survived in the region for longer than one year – a bird which had been banded at Bobs Farm in November 2009 was recorded several times at Carrington/Tahlee between April 2014 and August 2016. Only one confirmed bird from outside the Hunter Region was recorded. It did not remain in the region.

Breeding records

A summary of breeding records is presented in **Table 2**. Breeding was not recorded in every year over the intervals shown. There were seven locations with breeding records between 1980 and 2020, all around the shores of Port Stephens. The longest set of records were from Bobs Farm (2005-2020) and Lemon Tree Passage (1980-2014). However, since 2000, the number of breeding pairs has declined. After 2002 there were only four active breeding pairs and after 2010, only one. The pair at Bobs Farm did not return to breed in 2021 (V. Diemar pers. comm.) and the pair at Little Swan Bay were last reported nesting in 2018. One instance of possible successful dispersal was recorded at Bobs Farm in 2017 when the resident breeding female was joined by a new male bird (V. Diemar pers. comm.). It is not known where the new bird had dispersed from but the only other active breeding pair in the region at that time was at Little Swan Bay. The distance between the two sites is 9.4 km. Records from BioNet indicate that breeding pairs in the region usually laid two clutches of two eggs each breeding season, but that chicks rarely survived more than 1-2 months.

Table 1. Bush Stone-curlew records for the Hunter Region 1952-2021.

District	Location	Date of record and number of birds
Port Stephens	Bobs Farm	2005-2020 (p), Nov 2008 (4), Aug 2009 (2), Oct-Dec 2009 (4), Jan 2010 (3), Aug 2010 (2), Dec 2010 (3), Jan 2011 (3), Apr 2011 (3), Sep 2011 (2), Nov 2011 (2), Sep-Oct 2012 (3), Nov 2012 (3), Oct-Nov 2013 (2), Oct 2016 (2), Oct 2019 (2), Oct 2020 (3)
	Bull Island	Jun 1980 (p), Nov 1980 (2)
	Fenningham's Island/ Taylor's Beach	Dec 1979 (p), Jun 1980 (2), Nov 2000 (p), Sep 2005 (1), Sep 2008 (2), Jan-Feb 2009 (2), Sep 2009 (2), Nov 2009 (2), Feb-Mar 2010 (1) (relocated from Horseshoe Beach)
	Carrington/Tahlee	Apr 2014 (2), Jan 2015 (1), Jul 2015 (2), Oct 2015 (p), Nov 2015 (2), Feb-Apr 2016 (2), Jul 2016 (2), Mar 2017 (2), May-Jul 2017 (2), Sep 2017 (3), Jan 2018 (1), Apr 2018 (1), Jul-Aug 2018 (1), Oct 2018 (1), Jun-Jul 2020 (1), Sep-Dec 2020 (1), Jan-Feb 2021 (1), Jun 2021 (1)
	Karuah	Jun 1989 (1), Nov 1998 (2), Jul 1999 (2), Nov 1999 (2), Aug 2005 (p), Nov 2005 (2), Sep 2008 (2), Aug-Sep 2010, Nov 2010 (2), Feb 2011 (1) (relocated from Newcastle Airport), Mar 2011 (1) (relocated from Kooragang Island), Jan 2012 (2), Feb 2015 (2), Apr 2015 (1), Jun 2021 91), Oct 2021 (1)
	Little Swan Bay	Oct 2000 (1), Dec 2004 (4), Sep 2007 (3), Sep 2008 (2), Dec 2008 (2), Mar 2009 (3), Sep-Nov 2009 (3), Feb 2014 (2), Feb 2017 (3), Dec 2017 (2), Jan 2018 (2), Oct 2018(2), Jul 2018 (3), Aug 2019 (4), Feb 2021 (2)
	Lemon Tree Passage	1980-1992 (p), Jan-Mar 1993 (p), Oct 1996 (4), Oct 2000 (p), Nov 2002 (p), Nov 2003 (p), Sep 2004 (p), Dec 2004 (p), Dec 2006 (3), Nov 2007 (p), Jan 2008 (2), Sep-Dec 2010 (3), Oct 2014 (2)
	Medowie	Jan 2010 (1)
	Pindimar/ North Arm Cove	1998 (4), 1999 (4), 2000 (2), 2001 (2), 2003 (1), 2004 (2), 2005 (p), Sep 20011 (1), Feb 2017 (1)
	Tanilba	2001 (2), 2003 (2), Oct 2006 (p), Sep 2008 (2), Aug 2011 (1)
	Salamander Bay	Jan 2021 (1), Oct 2021 (1)
	Wallaroo NP	Aug 2006 (1)
Northern Hunter	Harrington	Apr 1991 (1), Apr 1998 (1), Jul-Aug 2006 (1), Mar 2011 (1), Jul 2007 (2), Aug 2011 (3)
	Old Bar	Mar 1993 (4), Jan 2007 (p), Jul 2011 (3), Nov 2018 (1)
	Crowdy Head	Jul 2002 (1)
	Crowdy Head NP	Mar 2003 (2)
	Diamond Head	Oct 2019 (1)
	Green Point	Dec 2005 (1)
	Bungwahl	2008-2009 (2), Jan-Feb 2010 (1)
	Knappinghat NP	Mar 2013 (2)
	Black Head Reserve	Oct 2019 (1)
	Coorabakh NP	Oct 2000 (2)
	Wang Wauk NP	Aug 2001 (1)
Lake Macquarie	Wyee	Feb 1998 (1)
	Warners Bay	Jan 2003, Nov 2004 (2)
	Swansea South	Aug 2006 (1)
	Jewell's Swamp	Mar 2007 (1)
	Dora Creek	Jan 2011 (1), Jul-Dec 2012 (1), Oct 2021 (1)
	Eraring	Jan-Mar 2013 (1)
	Fennal Bay	Feb 2015 (1)
Other Records	Paterson	1952 (p)
	Allyn River	May 1980 (1)
	Stockton Sandspit	Sep 1988 (1)
	Muswellbrook	Oct 1999 (2)

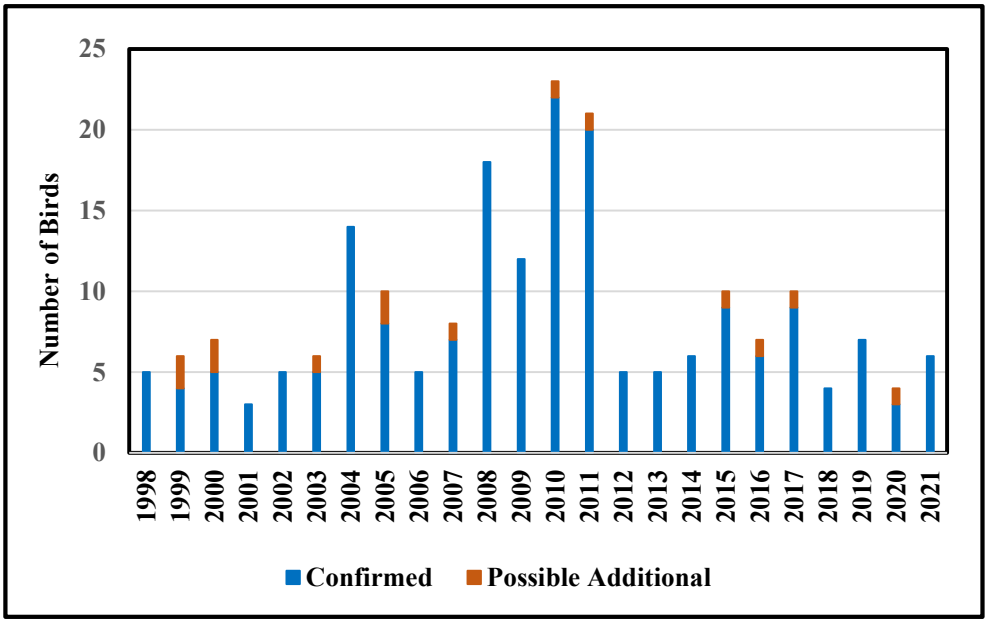

Figure 1. Total annual number of Bush Stone-curlew recorded in the Hunter Region, 1998-2020.

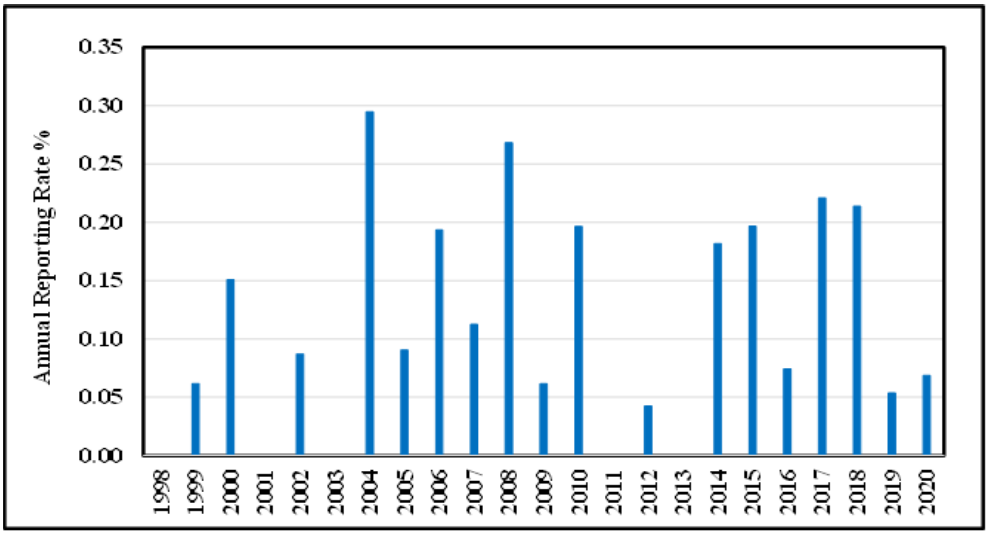

Figure 2. Annual Reporting Rate for Bush Stone-curlew in the Hunter Region, 1998-2020.

Table 2. Breeding locations, intervals and number of records for Bush Stone-curlew, Hunter Region, 1980-2020.

Location	Breeding Records	
Bobs Farm	2005 - 2020	15
Fenninghams Island	2001-2002	2
Karuah	2005	1
Lemon Tree Passage	1980 - 2014	10
Pindimar	1998 - 2002	4
Little Swan Bay	2007 - 2018	6
Tanilba Bay	2001 - 2002	2

Predation

Many eggs and most young chicks were lost to predation. At Bobs Farm, predation of chicks by Southern Boobook *Ninox boobook* and Laughing Kookaburra *Dacelo novaeguineae* was observed and a fox was recorded taking eggs (V. Diemar pers. comm.). At Lemon Tree Passage, two two-day-old chicks were predated by a Laughing Kookaburra in December 2007 (Stuart 2008).

DISCUSSION

The long-term security of an organism depends largely on the extent of its geographical range, the number and extent of habitats it can occupy and its average density within these habitats, which together determine its overall numbers (Newton 1998). Prior to European settlement, Bush Stone-curlew had a large range, occupied a number of different habitats and was relatively common. The species was well adapted to low level of predation from other endemic species. Today in the Hunter Region, the species has a small range around Port Stephens, occupies limited habitats and has very low density. This, according to Newton (1998), puts the species in the most-at-risk category for extinction.

The 2006 Recovery Plan for Bush Stone-curlew identified Red Fox as the major threat to the survival of the species, although other factors such as loss of habitat also had a role. The fox is now a successful apex predator. In NSW it favours fragmented landscapes and coastal forests where densities are around 1-2/km^2. Populations are well established in peri-urban and urban areas where food is abundant and where densities may be as high as 12/km^2 (Agriculture Victoria 2021; NSW Department of Primary Industries 2018). The 2016 Saving our Species program also recognised predation by Red Fox as a Key Threatening Process for Bush Stone-curlew.

Bush Stone-curlew live for up to 30 years and are believed to form long-term pair-bonds. Breeding begins at 2-3 years of age and a breeding pair will usually lay two clutches, usually of two eggs, within a breeding season. The birds exhibit nest-site fidelity (Marchant & Higgins 1993). This life strategy successfully maintained the species' population prior to European settlement. It has a vigorous anti-predator response to protect its nest and chicks, involving a mantling display and distraction behaviour. In other instances when confronted with a predator, the birds will run to escape rather than fly (Marchant & Higgins 1993). These behaviours evolved in response to threats from endemic predators but are not effective in deterring introduced foxes. The predictions of Chisholm (1934) and Hyem (1936) have been borne out by the absence of reports from the Western Hunter Region since the early 1950s.

The NPWS Fox Threat Abatement Plan (Fox TAP) ranks the Bush Stone-curlew highly as a species which suffers population level impacts from fox predation. However, because of the widespread and isolated distribution of Bush Stone-curlew, no Fox TAP programs specifically targeting Bush Stone-curlew populations have been implemented. The impact of foxes on Bush Stone-curlew mortality has not been measured experimentally, but anecdotal evidence demonstrated that foxes can kill adult Bush Stone-curlews as well as chicks (Department of Environment and Conservation NSW 2006). A search of the NSW Department of Environment and Heritage BioNet Atlas from 1980 to the present, reveals foxes have been reported in all the areas where Bush Stone-curlew were breeding around Port Stephens. Focussed Fox TAP programs conducted by NPWS in national parks in the region to reduce the threat to other high priority species (National Parks and Wildlife Service 2001) are likely to have only indirectly assisted Bush Stone-curlew.

While evidence of decline due to fox predation is largely anecdotal, populations on coastal islands such as Coochiemudlo Island and Magnetic Island in Queensland (Cannard & Milton 2012; Coleman *et al*. 2021) and Kangaroo Island in South Australia (Gates & Paton 2005), which are fox free, are flourishing. These authors have suggested Bush Stone-curlew have adapted successfully to the peri-urban and urban environment on these islands and their populations are supported by some elements of urban infrastructure.

A GIS study of habitat preferences of Bush Stone-curlew on the NSW Central Coast and Port Stephens (Murialdo *et al*. 2015) showed that the birds observed around Port Stephens were more likely observed in dry sclerophyll forests and saline wetlands. As these habitats are widespread throughout Port Stephens, it is unlikely that a lack of suitable habitat is a factor in the species' decline.

It is probable that the higher numbers of Bush Stone-curlew in the Hunter Region reported from 2004-2011 resulted from increased conservation activity by NPWS and volunteer groups to implement recovery strategies and monitor numbers following the development of the Recovery Plan. However, since 2011 these activities have declined and the effectiveness of

the program has diminished. This was due to a number of factors: NPWS decided to focus more on threatened species within National Parks; key personnel left the program; and some detrimental management efforts resulted in a loss of support from local landholders (S. Callaghan pers. comm.). At McCann Park, Lemon Tree Passage for example, the fenced breeding site was not maintained and the ensuing dense, rank vegetation rendered the site unsuitable. There were no further nesting attempts after 2010 and no records from the site after 2011. The fate of the birds that had nested there is unknown.

The majority of the records from the Hunter Region from 1979-2021 are from semi-rural, peri-urban and urban locations. There are relatively few records from areas of open forest in regional National Parks. The few remaining Hunter Region sites are all located on small semi-rural holdings, none of which are conducting activities that support Bush Stone-curlew recovery. Fox baiting is unlikely to be undertaken on these properties due to the risk to residents and domestic animals. The habitat on these small landholdings is at risk of being cleared for agriculture and residential purposes, and any remaining woodland habitat modified through removal of litter and fallen timber. Exposure to agricultural chemicals is also more likely on these properties.

It is apparent that the majority of eggs, chicks and pre-adult birds in the Hunter Region are being predated and that dispersal to form new breeding pairs is not occurring. There also is no evidence that the breeding population in the Hunter Region has been subject to recruitment from the Central Coast population, although a bird from that population was briefly present in the Lake Macquarie area in 2006. A 15-year study (2003-2018) of the Brisbane Water population on the NSW Central Coast concluded that the population is effectively isolated. No banded birds have been observed north of Brisbane Water in company with unbanded birds (Price *et al*. 2018). A single bird at Dora Creek in October 2021 was probably a Brisbane Water bird displaced by breeding parents (A. Morris pers comm.).

CONCLUSIONS

A small population of Bush Stone-curlew was previously widely dispersed across a broad area of near-coastal habitat in the Hunter Region. Peak numbers in the past 50 years were 20-23 birds around 10 years ago that corresponded with the implementation of a Recovery Plan and increased survey effort. In the past 10 years numbers have rapidly declined and in 2021 only six birds were known – five in the Port Stephens area and one at Dora Creek. Only one pair is known to have bred in 2020. Many eggs, most chicks and pre-adult birds appear to have been predated. Anecdotal evidence indicates foxes are the main predator.

The surviving birds are located on properties where active recovery or protection activities are not being undertaken, significant habitat modification has been undertaken and human disturbance is common. There is no evidence of successful dispersal of locally fledged birds to form new breeding pairs or recruitment of birds from external populations in the region. The inevitable outcome for the species is regional extinction in the foreseeable future.

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The *Whistler* – Instructions to Authors

The *Whistler* is an occasional publication of the Hunter Bird Observers Club Inc. (HBOC), which is based in Newcastle. HBOC members are active in observing birds and monitoring bird populations in the Hunter Region. This journal-style publication is a venue for publishing these regionally significant observations and findings. The journal publishes three types of articles:

1. **Contributed Papers**
2. **Short Notes**
3. **Book Reviews**

Authors should consider the appropriateness of their study to this publication. The publication is suitable for studies either geographically limited to the Hunter Region or with obvious relevance to it. Papers attempting to address data and issues of a broader nature should be directed to other journals, such as *Corella, Australian Field Ornithology* and *Emu*. Contributed papers should include analyses of the results of detailed ecological or behavioural studies, or syntheses of the results of bird monitoring studies. These may include comprehensive annotated species lists of important bird areas and habitats. Such data would then be available for reference or further analysis in the many important issues of bird conservation facing the Hunter Region.

Communication of short notes on significant bird behaviour is also encouraged as a contribution to extending knowledge of bird habits and habitat requirements generally. Reviews of bird books are also solicited, with the intention of providing a guide for other readers on their usefulness regionally and more broadly.

General Instructions for Submission

Manuscripts should be submitted electronically; please attach your manuscript to an email as a Microsoft Word document. Charts should be submitted as an Excel file. Authors should adhere to the instructions for each type of submission:

Contributed Papers

- Manuscripts should be up to 12 pages in length (longer in exceptional circumstances) and of factual style.
- They should include a summary (abstract) of approximately 250 words.
- An 'Introduction' or 'Background' section introduces the aims of and rationale for the study and cites any other work considered essential for comparison with the study.
- A section on 'Methods' describes the location of the study, citing map co-ordinates or including a map, and describing how observations were made and data were collected and analysed.
- A section on 'Results' includes description and/or analysis of data highlighting trends in the results; this may be divided into subsections if more than one body of data is presented; use of photos, drawings, graphs and tables to illustrate these is encouraged.
- A section headed 'Discussion' should attempt to set the results in a wider context, indicating their significance locally and/or regionally; comparison with national and international work is optional, as is the discussion of possible alternative conclusions and caveats; suggestions for future extension of the work are encouraged.
- A final section headed 'Conclusion[s]' gives a concise summary of findings, usually without introducing any new data or arguments.
- Appendices of raw data and annotated lists of bird species and habitats may be included in tabular form at the end of the submitted article. Usually these will be published on-line and not appear in the hard copy print.
- References should be cited in brief within the text of the article, and full references should be listed at the end of the text after any Acknowledgements. References should be formatted as per the formatting instructions below.
- The preferred layout described above can be modified at the Editors' discretion.

Short Notes

- Should be no more than 4 pages of descriptive or prosaic style.
- Should provide an adequate description of the location of observations, a brief rationale for documenting the observations, and a cogent description of observations; similar relevant observations should be cited with references if appropriate.

- References should be cited and listed as for contributed papers.

Book Reviews

- Should be approximately 2 pages of critical assessment and/or appreciation.
- Should introduce the topics and aims of the book as the reviewer understands them, comment on the thoroughness and rigour of content, and conclude with comments on the effectiveness and originality of the book in meeting its aims, particularly for birdwatchers in the Hunter Region area if appropriate.
- References should be cited and listed as for contributed papers.

Formatting Instructions

Formatting of an article for publication is the responsibility of the Whistler production team and is done after the submitted manuscript has been finalised and accepted. Authors are requested to note the following requirements when submitting a manuscript:

1. A4 size pages using portrait layout except for large tables or figures. Margins 2cm all sides.
2. Title of article at top of first page
3. Names and the affiliations or addresses of all authors are to be listed next, with at least one email address included. Each author's preferred first name is to be indicated.
4. The author for correspondence is to be clearly indicated.
5. Typescript for manuscripts is Times New Roman 11 pt.
6. Figures and Tables are to be included at the end of the document, in Times New Roman 11 pt. Each Figure and Table is to have a title that clearly describes the content.
7. Nomenclature and classification of bird species shall follow the current version of BirdLife Australia's "Working List of Australian Birds" (download from: http://birdlife.org.au/conservation/science/taxonomy). The scientific names of all bird species shall be shown in italics after the first mention of their English name in both the text and summary (abstract) and not thereafter.
8. References should be cited in the text in parenthesis as close as possible to the information taken from the paper: for one author (Smith 2000), two authors (Smith & Jones 2001b) and more than two authors (Smith *et al*. 2002) with the authors listed in the same order as the original paper.
9. References shall be listed in alphabetical order and secondarily by year of publication; if published in the same year then in alphabetical order with a, b, or c etc after the year to indicate which paper is being cited in the text (see example below). Each reference shall form a separate paragraph.

Reference Format

Journal articles:
Jones, D.N. and Wieneke, J. (2000a). The suburban bird community of Townsville revisited: changes over 16 years. *Corella* **24**: 53-60.

Edited book Chapters:

Lodge, D.M. (1993). Species invasions and deletions: community effects and responses to climate and habitat change. In 'Biotic interactions and Global change' (Eds. P.M. Karieva, J.G. Kingsolver and R.B. Huey) Pp. 367-387. (Sinauer Associates, Sutherland, MA.)

Books:

Caughley, G. and Sinclair, A.R.E. (1994). 'Wildlife Ecology and Management'. (Blackwell, Cambridge, MA.)

Theses:

Green, R. (1980). 'Ecology of native and exotic birds in the suburban habitat'. Ph.D. Thesis, Monash University, Victoria.

Reports:

Twyford, K.L., Humphrey, P.G., Nunn, R.P. and Willoughby, L. (2000). Investigations into the effects of introduced plants and animals on the nature conservation values of Gabo Island. (Dept. of Conservation & Natural Resources, Orbost Region, Orbost.)

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Please submit all manuscripts to:

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