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.

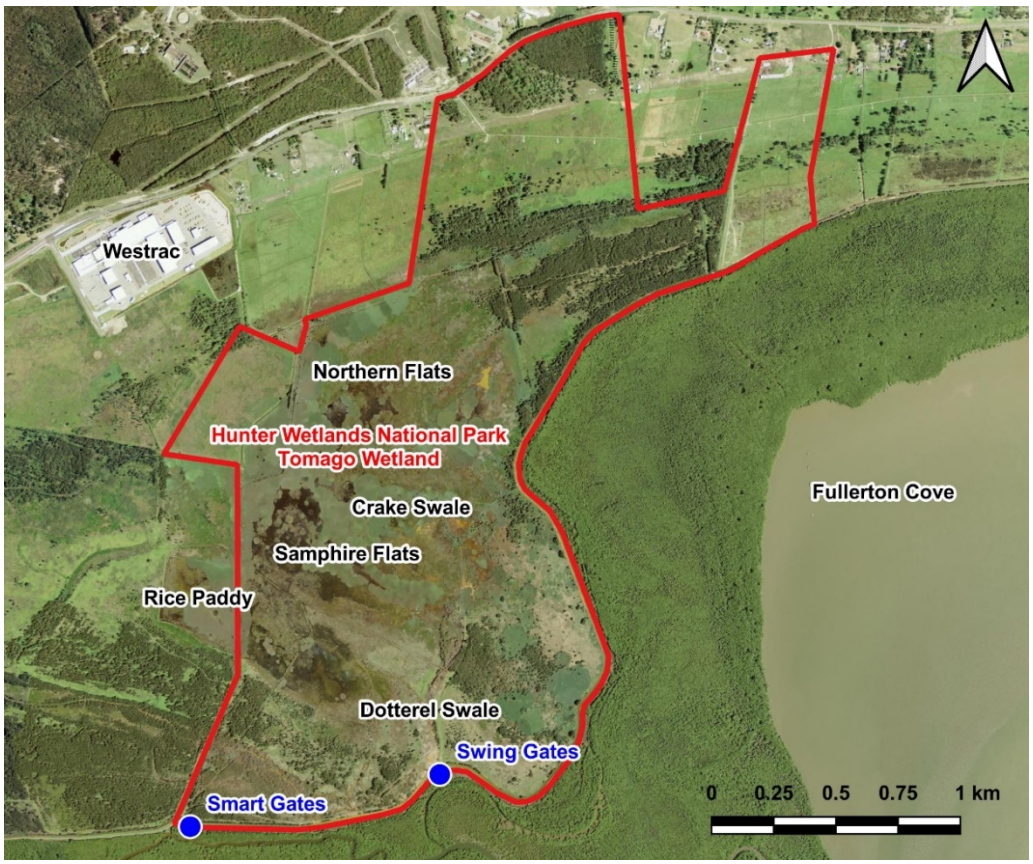

Figure 1. Tomago Wetland precinct of Hunter Wetlands National Park, near Newcastle, NSW.

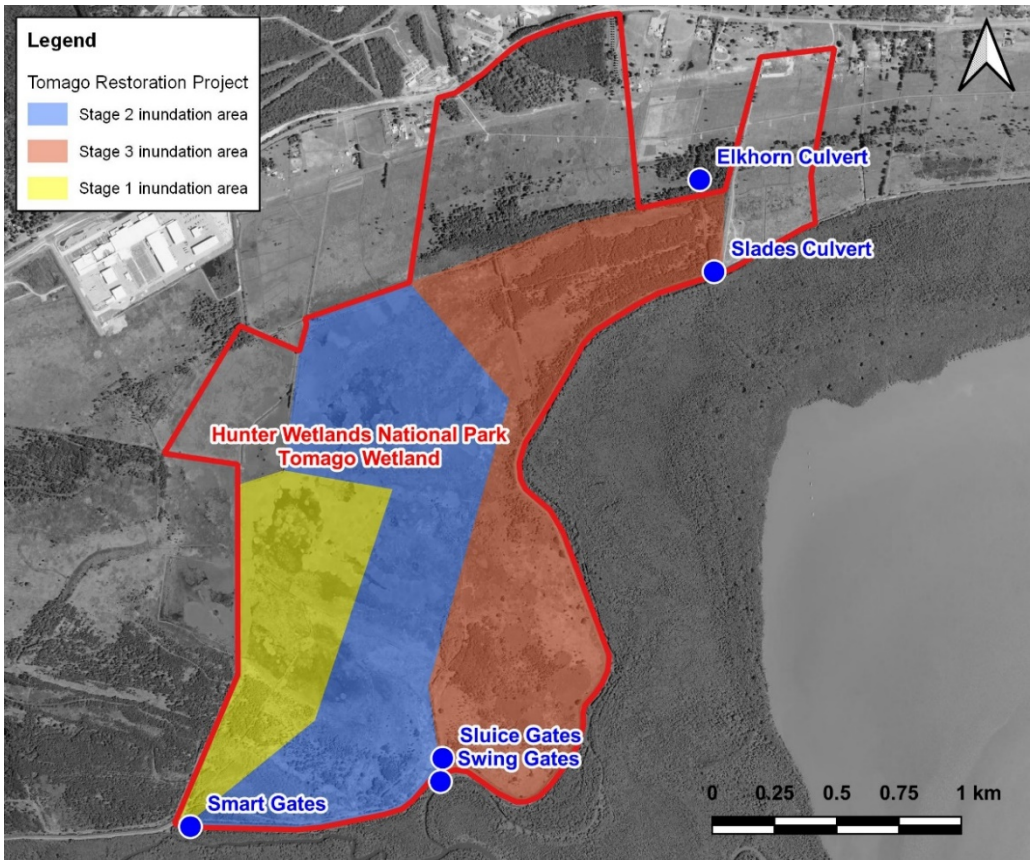

Figure 2. Tomago Wetland Restoration Project, showing the three stages of tidal inundation areas in Hunter Wetlands National Park.

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

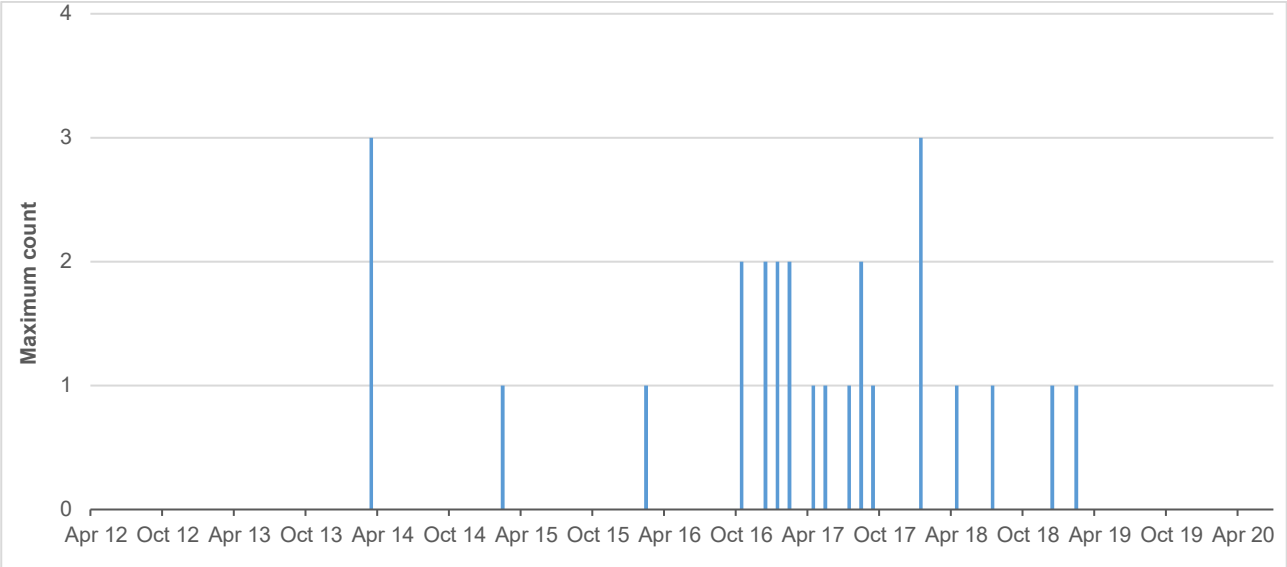

Figure 3. Monthly highest counts of Black-necked Stork at Tomago Wetland.

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.

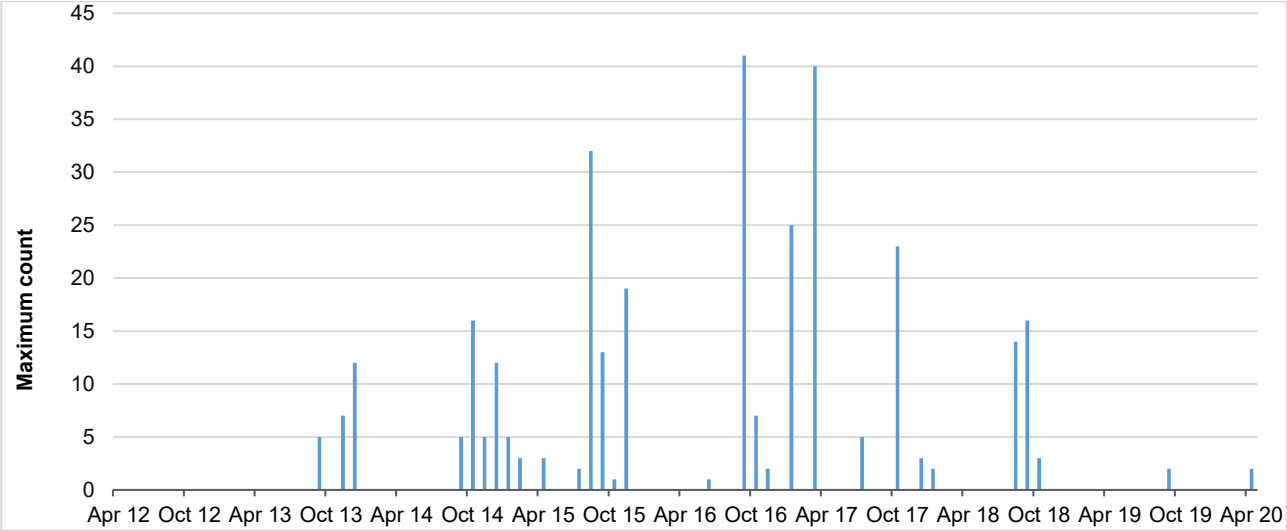

Figure 4. Monthly highest counts of Curlew Sandpiper at Tomago Wetland.

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	

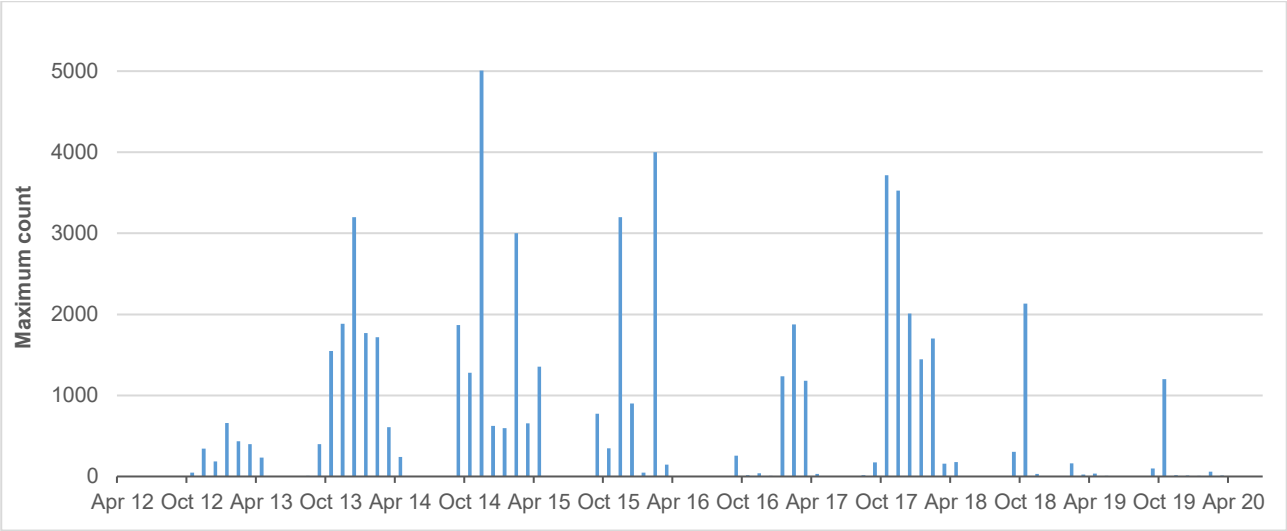

Figure 5. Monthly highest counts of Sharp-tailed Sandpiper at Tomago Wetland.

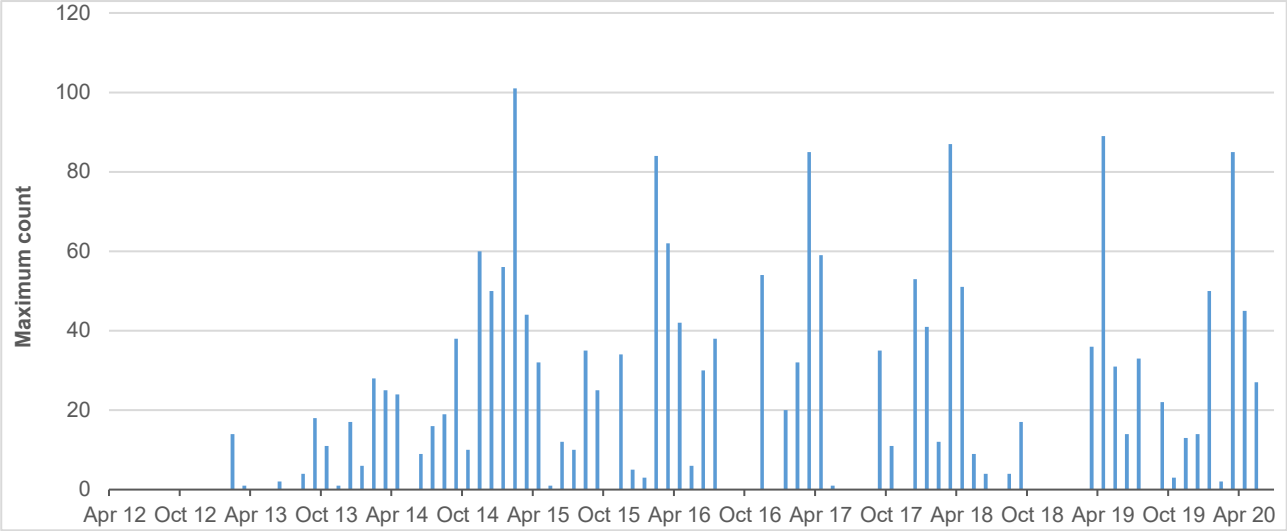

Figure 6. Monthly highest counts of Common Greenshank at Tomago Wetland.

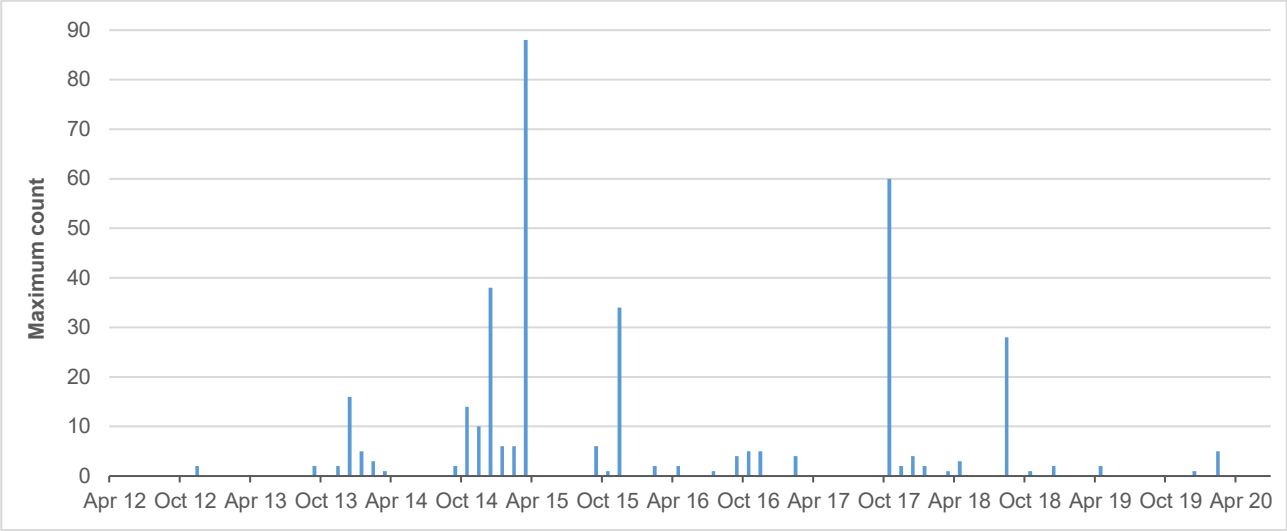

Figure 7. Monthly highest counts of Red-necked Stint at Tomago Wetland.

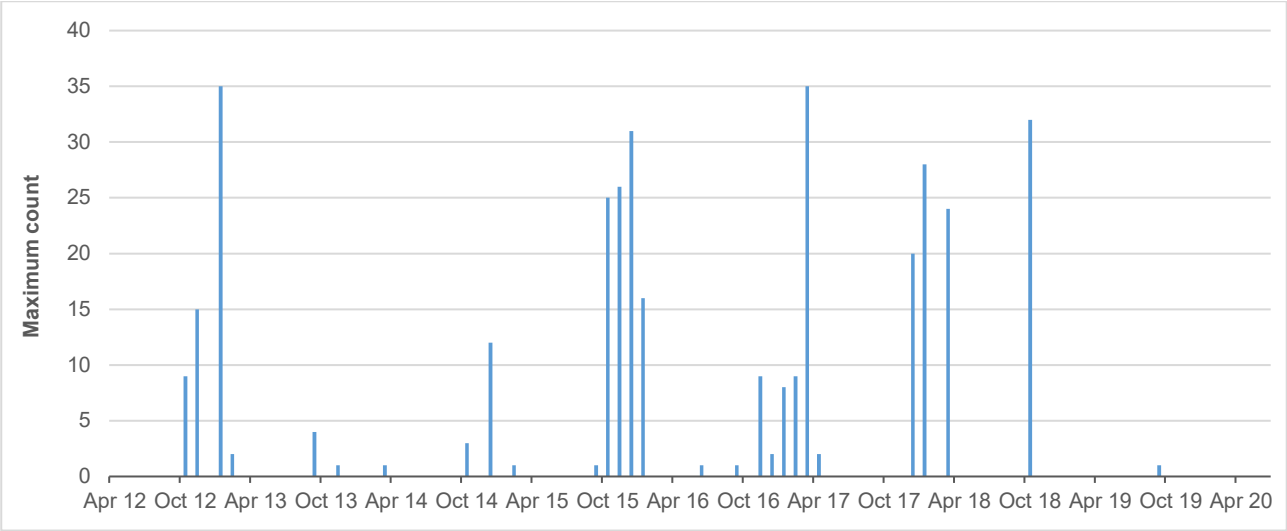

Figure 8. Monthly highest counts of Pacific Golden Plover at Tomago Wetland.

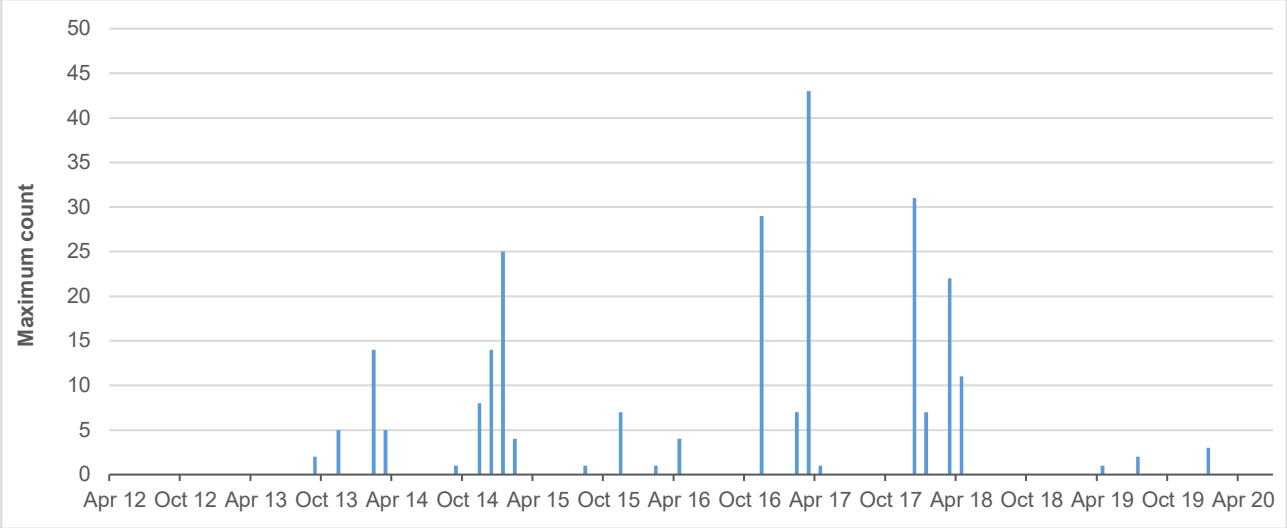

Figure 9. Monthly highest counts of Marsh Sandpiper at Tomago Wetland.

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).

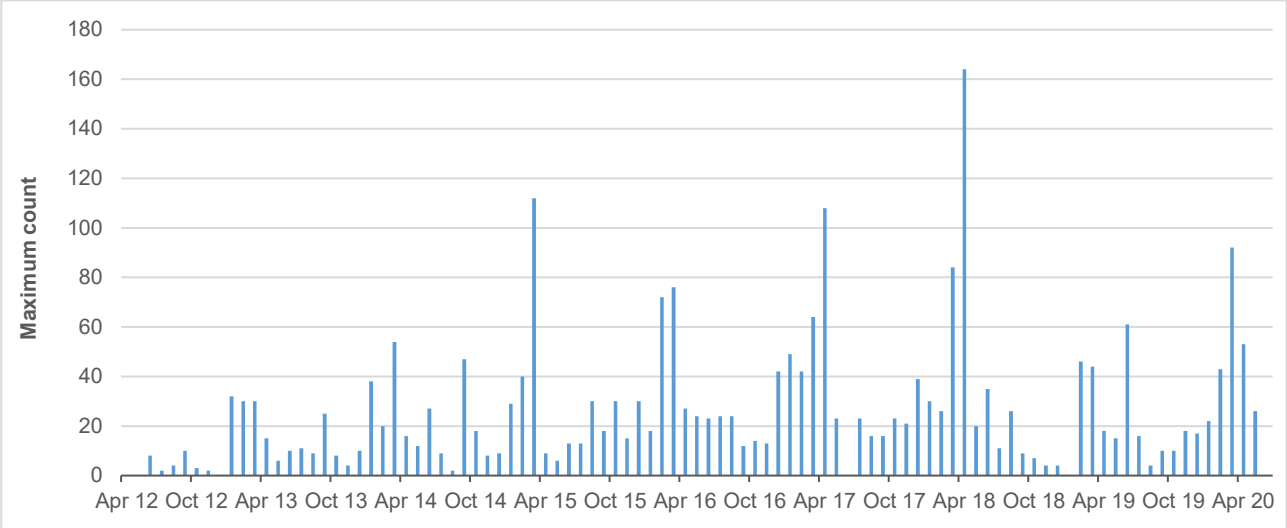

Figure 10. Monthly highest counts of Masked Lapwing at Tomago Wetland.

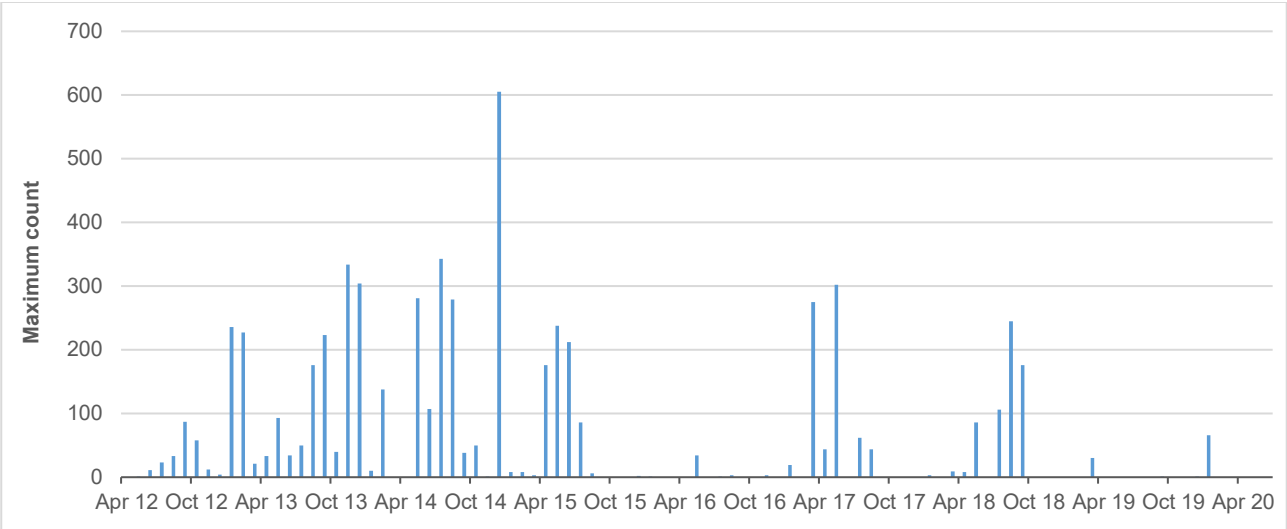

Figure 11. Monthly highest counts of Pied Stilt at Tomago Wetland.

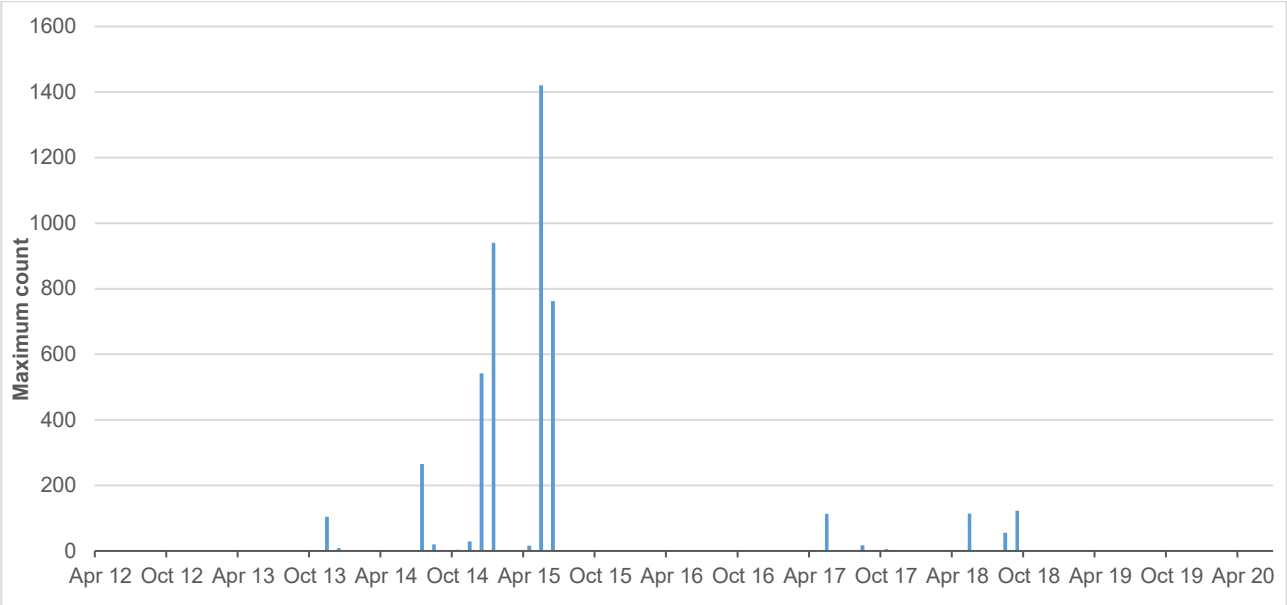

Figure 12. Monthly highest counts of Red-necked Avocet at Tomago Wetland.

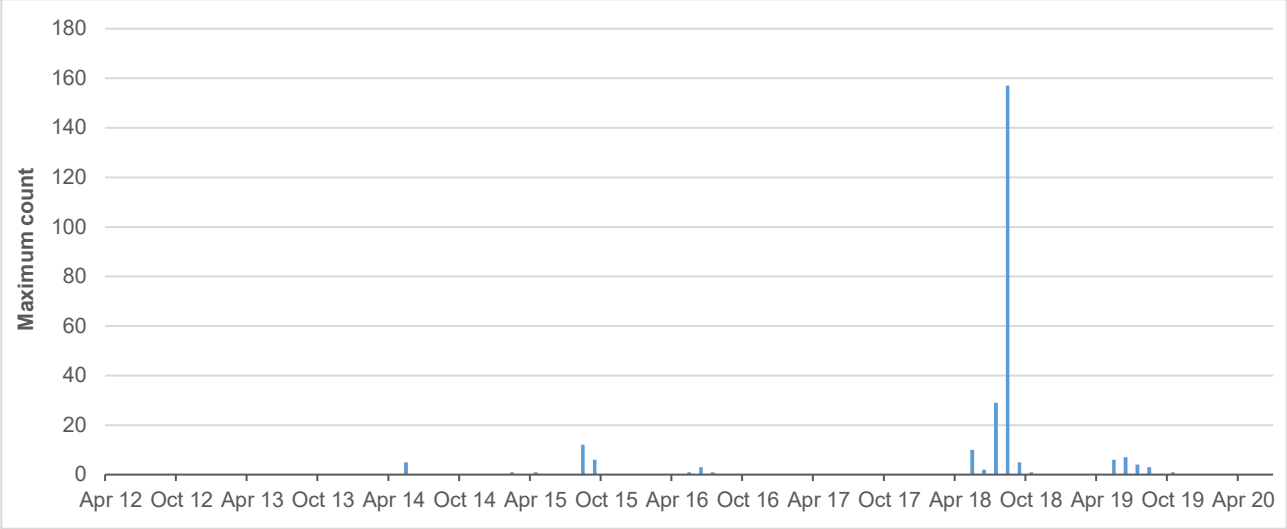

Figure 13. Monthly highest counts of Red-capped Plover at Tomago Wetland.

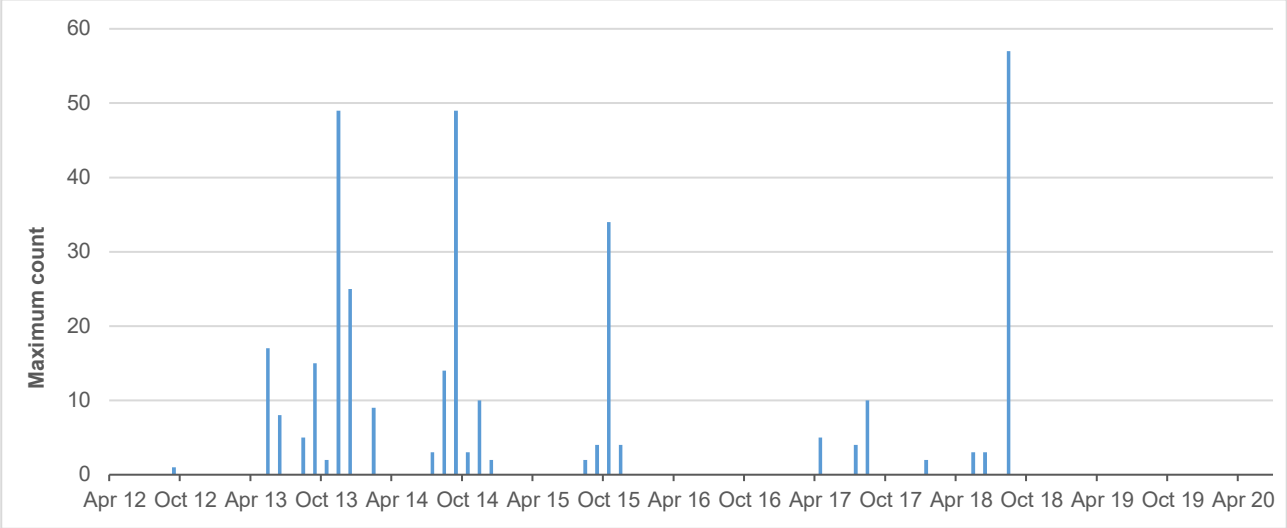

Figure 14. Monthly highest counts of Red-kneed Dotterel at Tomago Wetland.

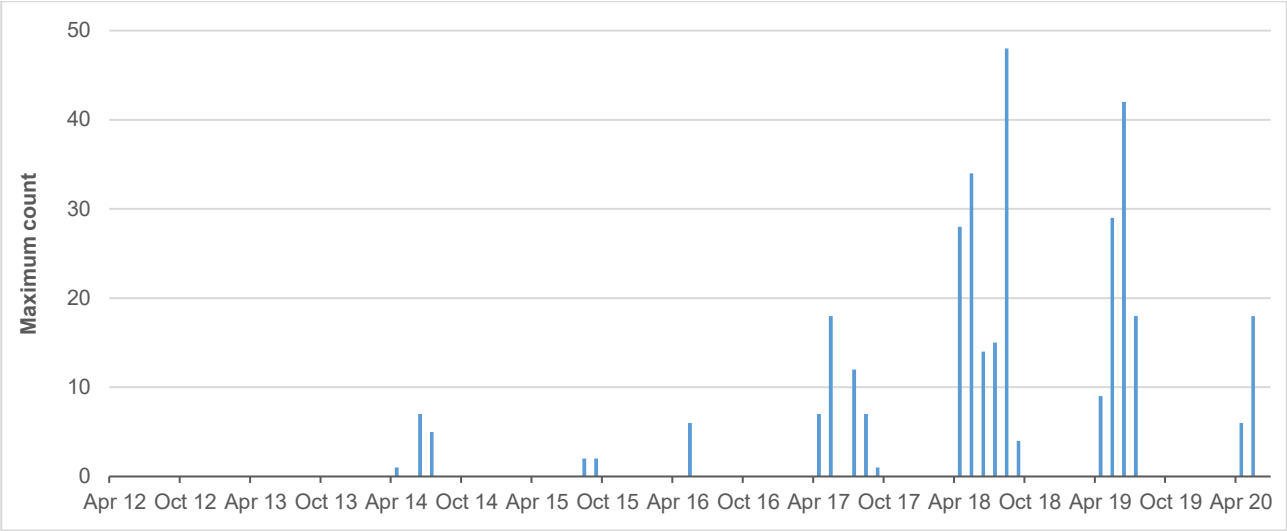

Figure 15. Monthly highest counts of Black-fronted Dotterel recorded at Tomago Wetland.

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

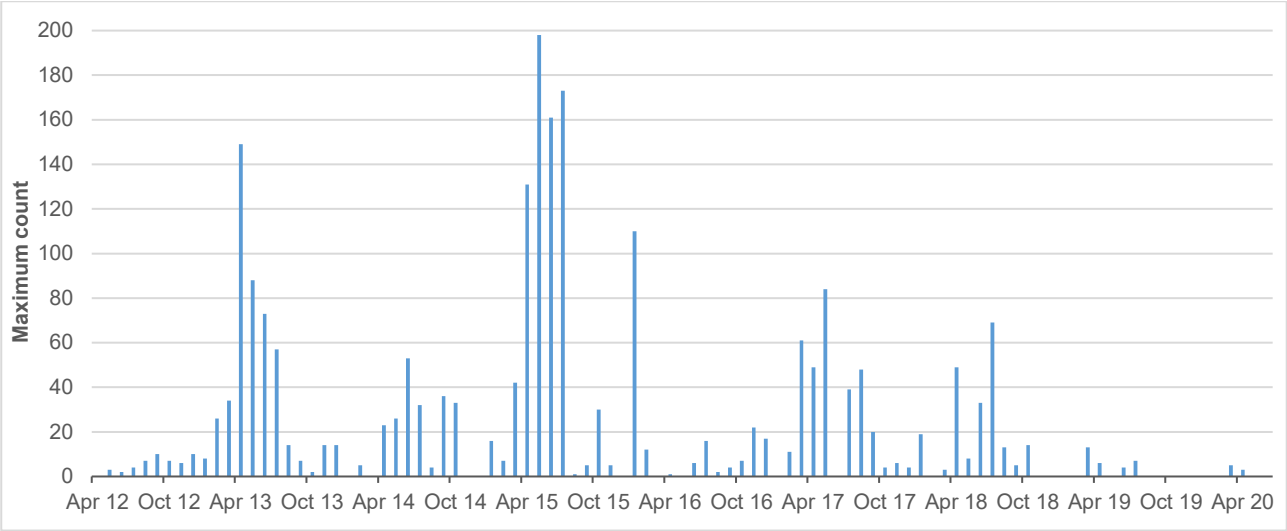

Figure 16. Monthly highest counts of Black Swan at Tomago Wetland.

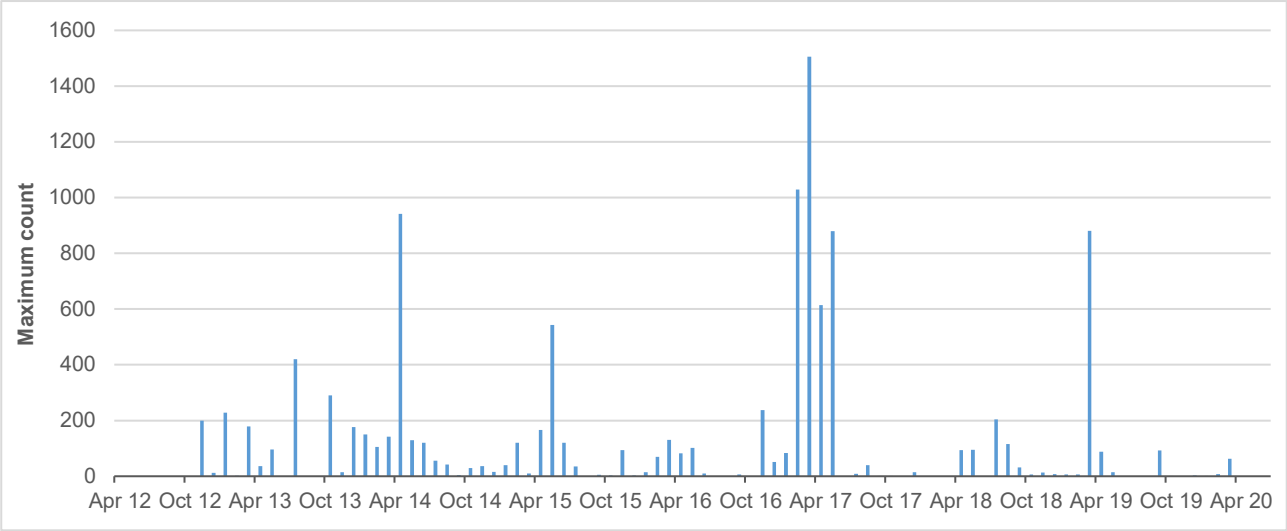

Figure 17. Monthly highest counts of Chestnut Teal at Tomago Wetland.

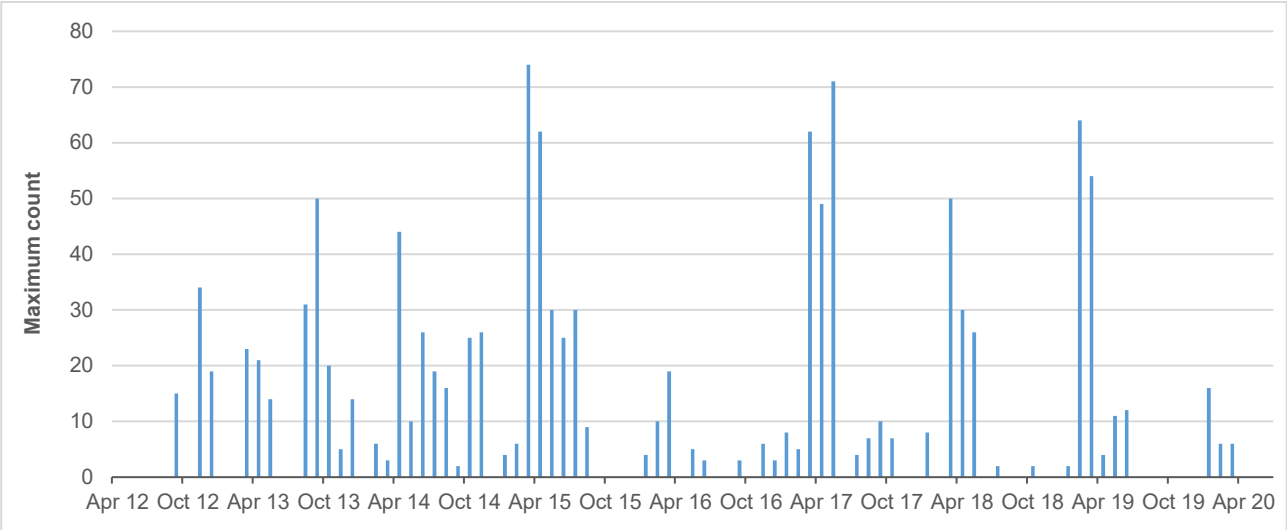

Figure 18. Monthly highest counts of Pacific Black Duck recorded at Tomago Wetland.

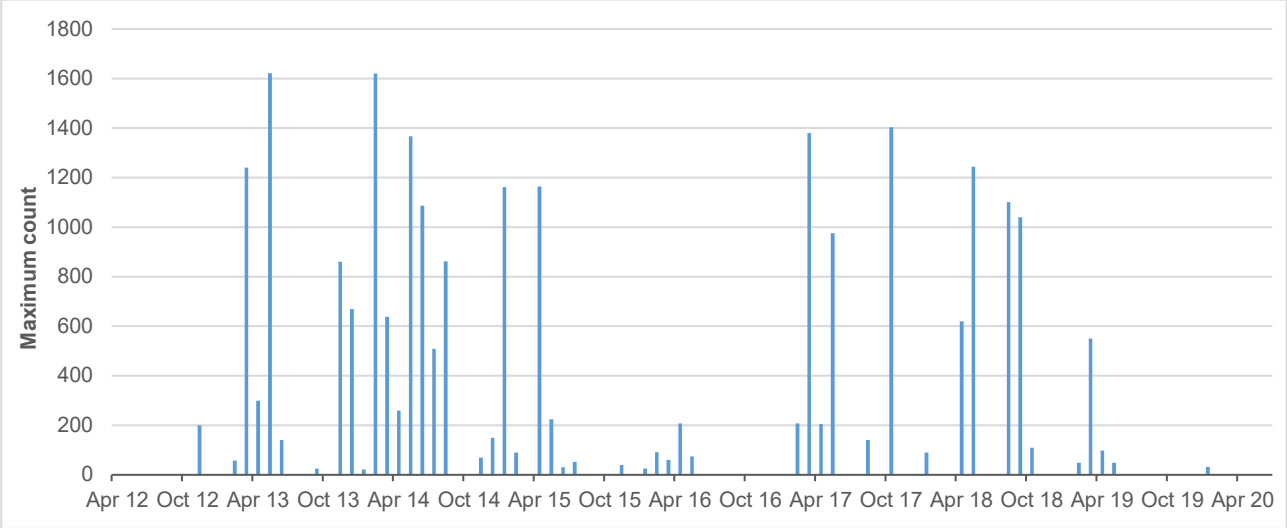

Figure 19. Monthly highest counts of Grey Teal at Tomago Wetland.

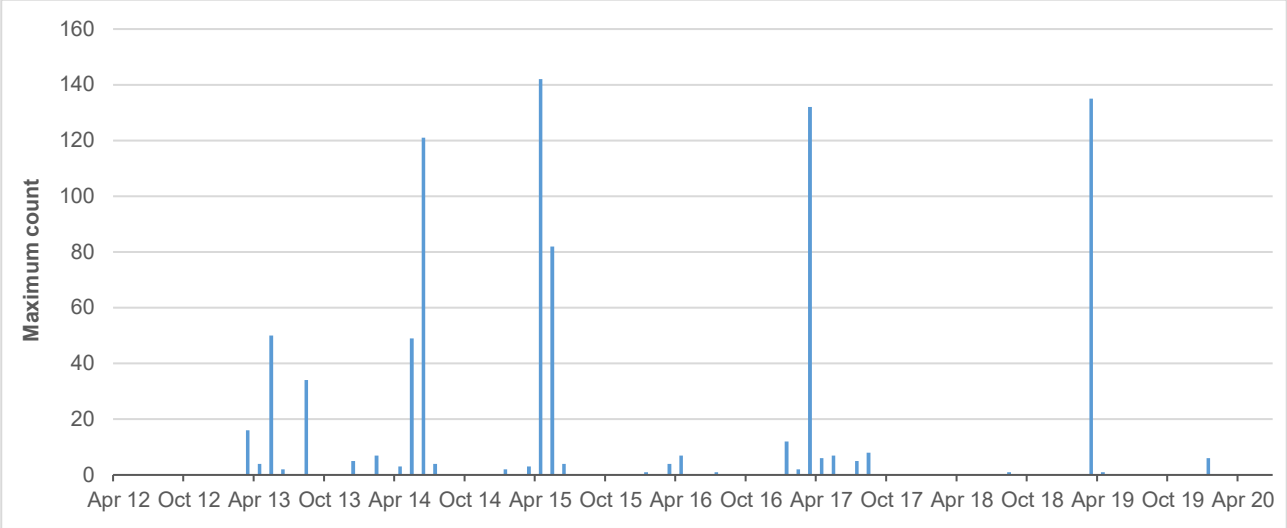

Figure 20. Monthly highest counts of Australasian Shoveler at Tomago Wetland.

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

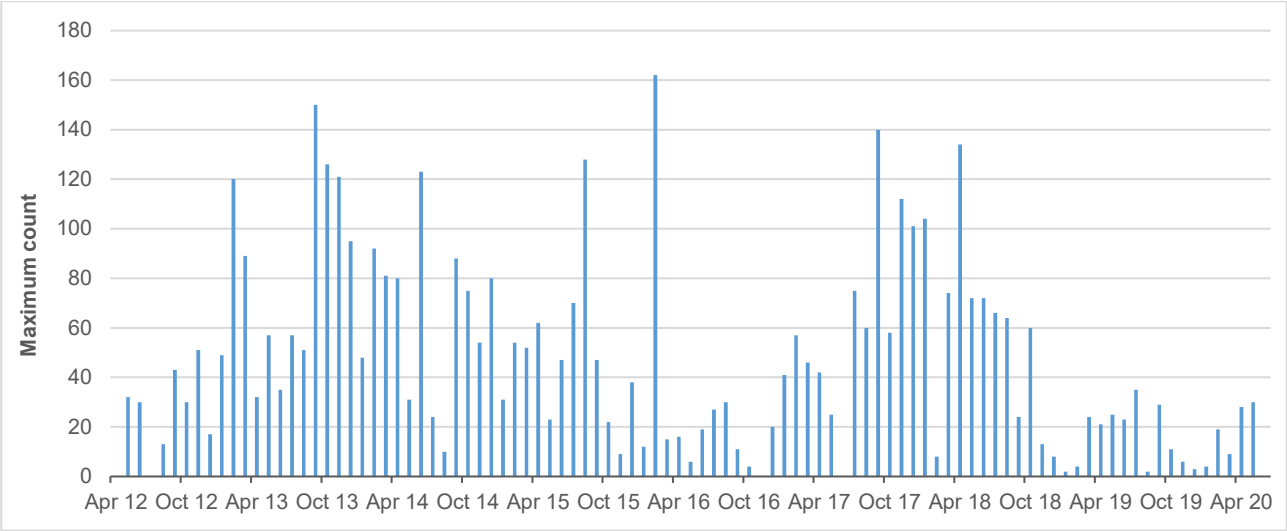

Figure 21. Monthly highest counts of White-faced Heron at Tomago Wetland.

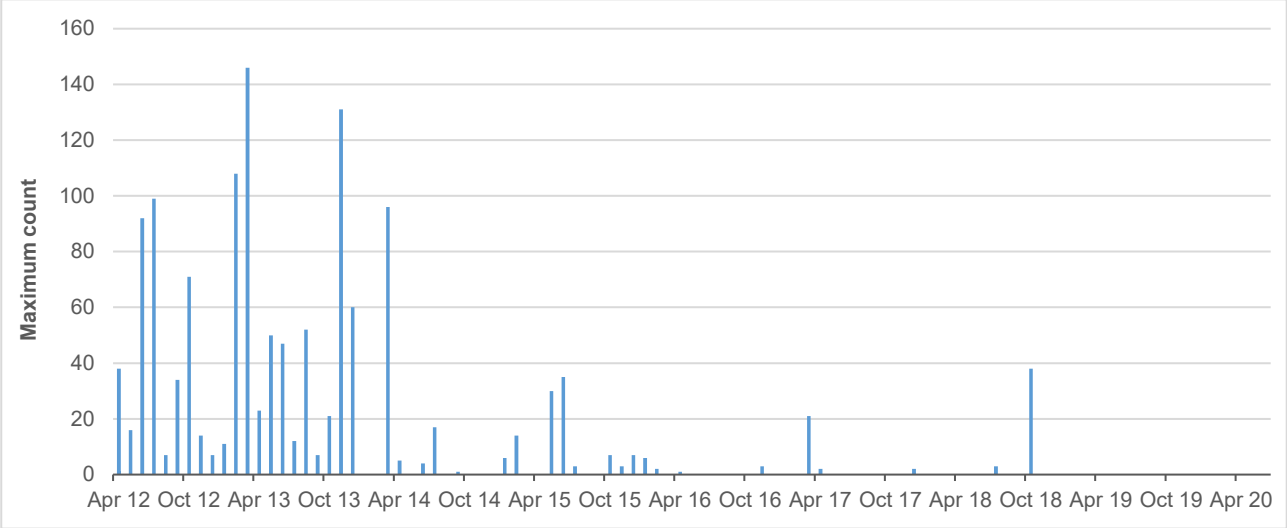

Figure 22. Monthly highest counts of Purple Swamphen at Tomago Wetland.

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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