Port Stephens shorebird and waterbird surveys 2004-2020

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Shorebird and waterbird populations in the Port Stephens estuary in New South Wales have been monitored regularly since 2004, using teams in boats to survey sub-sections of the estuary simultaneously. Overall, 23 shorebird species and 31 waterbird species have been recorded in the surveys, which were carried out twice-yearly in most years, as one summer survey and one winter survey.

Sixteen migratory shorebirds were recorded, including 13 species which had regular records. The most abundant shorebird species in Port Stephens was Bar-tailed Godwit *Limosa lapponica*, followed by Far Eastern Curlew *Numenius madagascariensis* and Whimbrel *N. phaeopus*. The numbers of visiting shorebirds have decreased, with average declines of around 2.5% per year having occurred for the above three species since 2004.

There were several records in summer of more than 1% of the total world population of Far Eastern Curlew; Port Stephens is an internationally significant site for that species. In winter, many immature (non-breeding) curlews stay in Port Stephens, with an average winter count of 66 birds and a peak count of 223 birds in 2009.

More than 1% of the total population of the Australian Pied Oystercatcher *Haematopus longirostris* was regularly recorded in Port Stephens, in both the summer and winter surveys and with a peak count of 192 birds. The numbers of Sooty Oystercatcher *H. fuliginosus* increased, such that since 2013 more than 1% of the total population of subspecies *H. f. fuliginosus* has often been present, particularly in summer.

The most abundant waterbirds were Australian Pelican *Pelecanus conspicillatus*, Little Pied Cormorant *Microcarbo melanoleucos*, Little Black Cormorant *Phalacrocorax sulcirostris*, Great Pied Cormorant *P. varius*, Silver Gull *Chroicocephalus novaehollandiae* and Greater Crested Tern *Thalasseus bergii*, all of them having average counts of more than 100 birds in both the summer and winter surveys. The Little Tern *Sternula albifrons* was only recorded in low numbers each summer until 2016. From then, their numbers increased, to a peak count of 304 birds in 2018 and breeding colonies have re-established.

Several waterbird species were present in larger numbers in the winter surveys than in summer. Examples included Little Pied Cormorant, Great Cormorant *P. carbo*, Great Pied Cormorant and Caspian Tern *Hydroprogne caspia*. Conversely, species such as Black Swan *Cygnus atratus*, Silver Gull, and Greater Crested Tern were more abundant in summer than in winter. There was some evidence to suggest that rainfall patterns (El Niño and La Niña events)) affected waterbird numbers.

INTRODUCTION

The Port Stephens estuary (**Figure 1**), situated approximately 200 km north of Sydney, is a popular tourist and recreational area. The area around the south-eastern section of the estuary has experienced substantial development as has the north-eastern section to some extent. However, many parts of Port Stephens are relatively undisturbed. All the Port Stephens waters, to the high-tide shoreline, are part of the Port Stephens-Great Lakes Marine Park.

A substantial portion of the less-disturbed parts of Port Stephens provides suitable foraging or roosting habitat for shorebirds and various waterbirds. This includes two nature reserves – Gir-um-bit National Park (the southern part of the reserve is centred at 32º 42'S, 151º 58'E) and Corrie Island Nature Reserve (32º 40'S, '152º 08'E). Also, there are several islands (see **Figure 1**) that offer foraging or roosting habitat. At low tides, many mudflats and sand banks around the Port, and oyster racks, become exposed; these all offer opportunities for shorebirds and some waterbirds to forage. Many other waterbird species can utilise the extensive areas of open water found in Port Stephens.

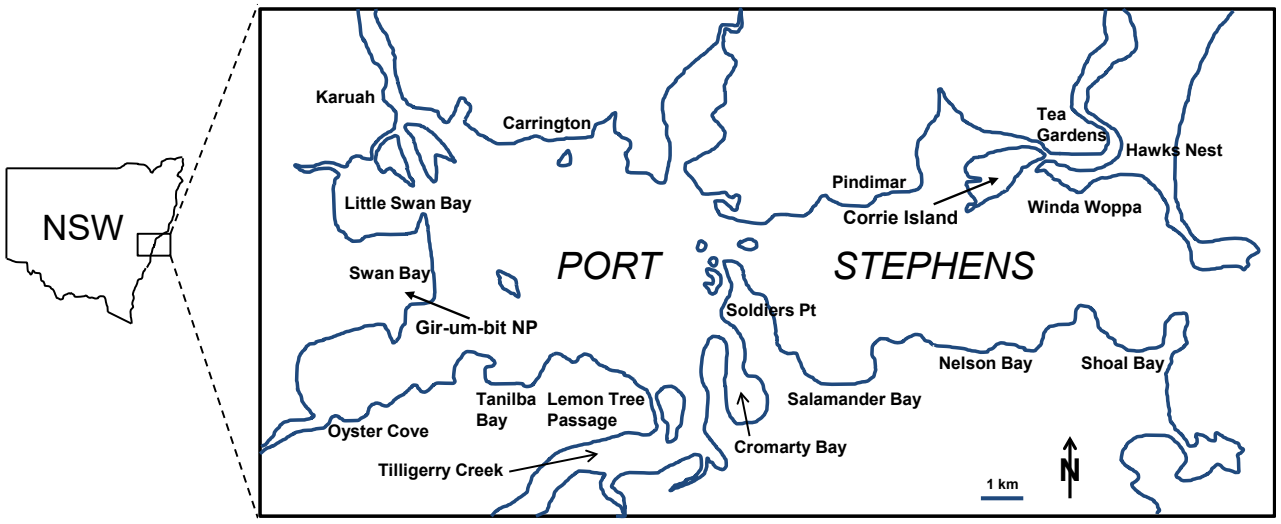


Figure 1. Port Stephens in New South Wales, showing the main towns and topographic features.

Prior to 2004, Port Stephens was sometimes surveyed for shorebirds, particularly in the 1980s, and its importance for certain species was recognised (Lane 1987; Smith 1991; Bamford *et al*. 2008). However, the surveys in general were infrequent, and they were land-based. Being limited to land-accessible locations meant that not all of the now-known roost sites for shorebirds were able to be surveyed, because some of them are only accessible by boat (Stuart 2011). In 2004 I began organising regular boat-based surveys of Port Stephens, with all shorebirds, waterbirds and birds of prey utilising the marine and estuarine habitats of the Port being recorded. For 2004-2007, a survey was carried out every summer, and there have been both summer and winter surveys in most years since 2008.

Some of the results from the post-2004 surveys have been presented elsewhere, namely: the interim findings from the first three years of summer surveys (Stuart 2005, 2007); information about the Australian Pied Oystercatcher in Port Stephens (Stuart 2010; Fraser 2019); data for shorebirds from the 2004-2011 surveys and comparison with pre-2004 shorebird records (Stuart 2011); data for some shorebirds from the 2004-2015 surveys (Roderick & Stuart 2016); and information about the birds of prey in Port Stephens (Stuart 2016). In this report I present and discuss the findings for all shorebird species and the main waterbird species from the 2004-2020 surveys.

METHODS

The general methodology for the surveys has been described previously (Stuart 2011). Four to six teams (for most of the surveys, six teams) in boats simultaneously surveyed sub-areas (sectors) of Port Stephens, following pre-defined standard routes every time. Due to human activity, shorebirds only occasionally use the south-eastern section of the Port Stephens coastline and only in small numbers (AS pers. obs.). Hence that area was not included in the surveys. The teams collectively covered the remainder of the Port Stephens shoreline including all of the contained islands.

Each survey commenced approximately 90 minutes before the predicted time for high tide at Soldiers Point in Port Stephens. The surveys of each sector took *c*. 3 hours to complete, meaning that all the surveys were carried out in high-water conditions when shorebirds usually are congregated at their roost sites (Finn 2007). Port Stephens is often subjected to strong afternoon sea breezes, hence days with early high tides were chosen for the surveys.

Every vessel had a dedicated skipper and 1-2 observers, at least one of whom was an experienced birdwatcher. After the initial set of surveys in 2004, teams were assigned such that at least one of the observers and/or the skipper had surveyed the sector previously and was familiar with the route and its subtleties. Each team recorded the numbers of all shorebird species observed and of all other waterbirds, as well as birds of prey.

A de-briefing session for participants was held after every survey. That session provided the opportunity to eliminate any possible instances of double-counting because of movements of birds out of a sector mid-survey. Such instances were found to be rare.

Data management

The records for each sector were entered into Birdata as individual Shorebirds 2020 surveys. For each summer and winter overall survey, the aggregated counts for each species from all six sectors were collated in a Microsoft Excel file, from which graphs (annual results and trends, summer/winter comparisons) were generated using standard Excel software tools. Regression

analyses were carried out using Excel's Data Analysis Add-in software.

RESULTS

Surveys

The summer surveys, spanning 2004-2020, were carried out in February, except in 2005 when the originally scheduled date had to be postponed to early March. There were some operational issues during the 2005 survey and only 80-90% of the targeted area was able to be surveyed. The winter surveys have spanned 2008-2020 and all of them were done on a July date, if done at all. In 2016, owing to deteriorating weather conditions during the scheduled survey, not all areas were able to be visited by boat on the chosen date. All the main roost sites that were missed that day were able to be surveyed from land-based visits over the following two days. Extended periods of poor weather conditions prevented the winter surveys in 2015 and 2017 from occurring.

With the above limitations, 17 summer and 11 winter surveys were completed over 2004-2020, overall recording 23 shorebird species and 31 waterbird species. The results are summarised in **Table 1**. It should be noted that, although observers also counted the numbers of Australian White Ibis *Threskiornis moluccus*, Straw-necked Ibis *T. spinicollis* and Cattle Egret *Bubulcus ibis* that they encountered during the survey, those species were excluded from analysis for this report, for reasons discussed later.

Table 1. Summary of Port Stephens surveys 2004-2020

	Summer surveys	Winter surveys	Overall
No. of surveys	17	11	28
Total shorebird species	23	14	23
Total waterbird species	28	28	31

Details of the summer surveys are presented in **Table 2**. Overall, the summer surveys recorded 23 shorebird species and 27 waterbird species; however, for any individual survey there were 8-15 shorebird species and 13-25 waterbird species recorded. In general, there were fewer birds and fewer species recorded in the winter surveys, as summarised in **Table 3**. The winter surveys recorded 14 shorebird species overall (with 8-12 species recorded each survey) and 25 waterbird species (ranging from 13-25 species per survey). The Coefficients of Variation (CV), (which is the ratio of the Standard Deviation (SD) to the Mean) for the results from all surveys have ranged between 7% and 35% (**Tables 2** and **3**).

Table 2. Results from summer surveys in Port Stephens (number of species of shorebirds and waterbirds, total counts of shorebirds and waterbirds, and the overall results).

	Shorebirds		Waterbirds		Overall	
Year	Spp	Birds	Spp	Birds	Spp	Birds
2004	13	2053	23	2387	36	4440
2005	11	689	13	688	24	1377
2006	18	1527	18	1473	36	3000
2007	14	1750	25	1796	39	3546
2008	13	1695	21	982	34	2677
2009	14	1554	16	2235	30	3789
2010	15	1812	22	2280	37	4092
2011	11	1431	19	1072	30	2503
2012	13	1479	19	967	32	2446
2013	10	1147	18	1580	28	2727
2014	11	1230	21	1740	32	2970
2015	13	1327	18	1406	31	2733
2016	13	1419	18	1216	31	2635
2017	8	937	16	1510	24	2447
2018	13	960	18	1970	31	2928
2019	10	1142	19	2584	29	3716
2020	11	1209	19	1539	30	2748
Max.	18	2053	25	2602	39	4440
Mean	12	1374	19	1615	32	2989
SD	2	350	3	547	4	736
CV	17%	25%	16%	34%	13%	25%

Table 3. Results from winter surveys in Port Stephens (number of species of shorebirds and waterbirds, total counts of shorebirds and waterbirds, and the overall results).

	Shorebirds		Waterbirds		Overall	
Year	Spp	Birds	Spp	Birds	Spp	Birds
2008	8	608	22	1219	30	1827
2009	8	738	21	1262	29	2000
2010	8	699	21	674	29	1373
2011	11	544	16	1141	27	1685
2012	10	429	18	885	28	1314
2013	11	630	20	2223	31	2853
2014	12	384	17	1590	29	1974
2016	8	512	18	1570	26	2082
2018	10	368	21	2104	31	2472
2019	9	374	20	2208	29	2582
2020	9	641	16	1381	25	2018
Max.	12	738	22	2223	31	2853
Mean	9	540	19	1478	29	2018
SD	1	136	2	523	2	478
CV	11%	25%	11%	35%	7%	24%

Overview of results for all species

Table 4 summarises the summer and winter results for individual shorebird species, and **Table 5** the analogous results for waterbirds. Six shorebird species were recorded in every summer and winter survey, as were nine waterbird species. The six

shorebirds were Australian Pied Oystercatcher *Haematopus longirostris*, Sooty Oystercatcher *H. fuliginosus*, Masked Lapwing *Vanellus miles*, Whimbrel *Numenius phaeopus*, Far Eastern Curlew *N. madagascariensis* and Bar-tailed Godwit *Limosa lapponica*. The nine waterbirds were White-faced Heron *Egretta novaehollandiae*, Australian Pelican *Pelecanus conspicillatus*, Little Pied Cormorant *Microcarbo melanoleucos*, Great Cormorant *Phalacrocorax carbo*, Little Black Cormorant *P. sulcirostris*, Great Pied Cormorant *P. varius*, Australasian Darter *Anhinga novaehollandiae*, Silver Gull *Chroicocephalus novaehollandiae* and Greater Crested Tern *Thalasseus bergii*.

Sixteen migratory shorebird species were recorded in the surveys, although for three of those species there were only single records. Whimbrel, Far Eastern Curlew and Bar-tailed Godwit were by far the most abundant of the migratory species, but there were regular records of Pacific Golden Plover *Pluvialis fulva*, Ruddy Turnstone *Arenaria interpres*, Red-necked Stint *Calidris ruficollis*, Terek Sandpiper *Xenus cinereus*, Grey-tailed Tattler *Tringa brevipes* and Common Greenshank *T. nebularia* in summer, and of Double-banded Plover *Charadrius bicinctus* in winter.

The threshold for a site to be rated as internationally significant for a migratory species is that it hosts 1% of the total population, which for Far Eastern Curlew is 350 birds based on the current estimated population of 35,000 (Hansen *et al*. 2016). The mean summer count for Far Eastern Curlew in Port Stephens was 310 birds. However, four of the 17 summer surveys recorded more than 350 birds, with the peak count being 649 birds in 2004.

The estimated population of Australian Pied Oystercatcher is 11,000 birds (Delany & Scott 2006). Twenty of the 28 Port Stephens surveys have recorded more than 110 birds (i.e. more than 1% of the total population), with 100-110 birds having been recorded in four other surveys. In only three summer surveys and one winter survey were fewer than 100 birds present.

There were breeding records for Little Tern *Sternula albifrons* in 2018 and 2019; several pulli were observed on both occasions. Prior to 2016, when 80 birds were present, Little Tern were only recorded in low numbers (less than 20 birds and usually, less than ten birds). They were not recorded in any of the winter surveys.

The mean counts for Black Swan *Cygnus atratus* were of 379 birds (in summer) and 131 birds (in winter). However, those results were affected by five surveys in which birds were present in large numbers: 1,056 birds in February 2004; 1,120 birds in February 2010; 651 birds in February 2019; 444 birds in February 2020 (i.e. summer surveys); and 829 birds in July 2019.

Table 4. Summarised data for Port Stephens shorebird species.

	Summer surveys *(n = 17)*				**Winter surveys** *(n = 11)*			
Species	**No. times recorded**	**Max.**	**Mean**	**SD**	**No. times recorded**	**Max.**	**Mean**	**SD**
Bush Stone-curlew *Burhinus grallarius*	1	2	-	-	0	-	-	-
Beach Stone-curlew *Esacus magnirostris*	2	2	-	-	3	4	1	1
Australian Pied Oystercatcher *Haematopus longirostris*	17	192	123	38	11	162	137	21
Sooty Oystercatcher *Haematopus fuliginosus*	17	52	26	15	11	46	25	12
Red-necked Avocet *Recurvirostra novaehollandiae*	2	2	-	-	1	20	-	-
Grey Plover *Pluvialis squatarola*	1	1	-	-	0	-	-	-
Pacific Golden Plover *Pluvialis fulva*	9	38	9	13	3	5	-	-
Red-capped Plover *Charadrius ruficapillus*	12	41	15	13	10	21	8	6
Double-banded Plover *Charadrius bicinctus*	4	3	-	-	8	37	21	14
Lesser Sand Plover *Charadrius mongolus*	7	15	2	4	0	-	-	-

Table 4. Summarised data for Port Stephens shorebird species continued.

	Summer surveys *(n = 17)*				**Winter surveys** *(n = 11)*			
Species	**No. times recorded**	**Max.**	**Mean**	**SD**	**No. times recorded**	**Max.**	**Mean**	**SD**
Masked Lapwing *Vanellus miles*	17	75	41	17	11	54	26	13
Whimbrel *Numenius phaeopus*	17	424	207	86	11	67	22	20
Far Eastern Curlew *Numenius madagascariensis*	17	649	310	134	11	223	66	62
Bar-tailed Godwit *Limosa lapponica*	17	888	574	196	11	424	222	124
Black-tailed Godwit *Limosa limosa*	4	51	4	12	0	-	-	-
Ruddy Turnstone *Arenaria interpres*	12	20	4	5	0	-	-	-
Red Knot *Calidris canutus*	1	1	-	-	0	-	-	-
Sharp-tailed Sandpiper *Calidris acuminata*	1	40	-	-	0	-	-	-
Red-necked Stint *Calidris ruficollis*	14	59	15	17	1	1	-	-
Terek Sandpiper *Xenus cinereus*	10	6	2	2	1	1	-	-
Common Sandpiper *Actitis hypoleucos*	4	1	-	-	0	-	-	-
Grey-tailed Tattler *Tringa brevipes*	16	100	35	25	10	23	9	8
Common Greenshank *Tringa nebularia*	9	15	4	5	0	-	-	-

Table 5. Summarised data for Port Stephens waterbird species.

	Summer surveys *(n = 17)*				**Winter surveys** *(n = 11)*			
Species	**No. times recorded**	**Max.**	**Mean**	**SD**	**No. times recorded**	**Max.**	**Mean**	**SD**
Pink-eared Duck *Malacorhynchus membranaceus*	0	-	-		1	2	-	-
Black Swan *Cygnus atratus*	17	1120	379	313	10	829	131	241
Australian Wood Duck *Chenonetta jubata*	14	41	14	9	10	23	9	7
Pacific Black Duck *Anas superciliosa*	14	35	7	9	4	8	1	3
Grey Teal *Anas gracilis*	4	10	1	3	3	4	-	-
Chestnut Teal *Anas castanea*	17	30	13	11	10	21	11	7
Hoary-headed Grebe *Poliocephalus poliocephalus*	0	-	-	-	1	20	-	-
Little Penguin *Eudyptula minor*	4	4	-	-	0	-	-	-
Royal Spoonbill *Platalea regia*	7	5	1	2	5	13	2	4
Nankeen Night Heron *Nycticorax caledonicus*	4	12	1	2	0	-	-	-
Striated Heron *Butorides striata*	12	11	3	3	8	7	2	2
White-necked Heron *Ardea pacifica*	2	1	-	-	0	-	-	-
Great Egret *Ardea alba*	15	14	7	5	11	23	13	6

Table 5. Summarised data for Port Stephens waterbird species continued.

	Summer surveys *(n = 17)*				**Winter surveys** *(n = 11)*			
Species	**No. times recorded**	**Max.**	**Mean**	**SD**	**No. times recorded**	**Max.**	**Mean**	**SD**
Intermediate Egret *Ardea intermedia*	4	2	-	-	9	8	2	2
White-faced Heron *Egretta novaehollandiae*	17	58	31	14	11	250	86	72
Little Egret *Egretta garzetta*	8	15	1	4	11	18	10	5
Australian Pelican *Pelecanus conspicillatus*	17	213	126	49	11	198	127	36
Australasian Gannet *Morus serrator*	0	-	-	-	6	6	2	2
Little Pied Cormorant *Microcarbo melanoleucos*	17	473	114	101	11	298	190	52
Great Cormorant *Phalacrocorax carbo*	17	55	25	13	11	154	66	58
Little Black Cormorant *Phalacrocorax sulcirostris*	17	475	146	145	11	910	226	253
Great Pied Cormorant *Phalacrocorax varius*	17	458	252	104	11	681	362	232
Australasian Darter *Anhinga novaehollandiae*	14	25	5	7	11	39	16	10
Silver Gull *Chroicocephalus novaehollandiae*	17	449	259	96	11	250	135	76
Little Tern *Sternula albifrons*	14	304	53	87	0	-	-	-
Australian Gull-billed Tern *Gelochelidon macrotarsa*	6	19	2	5	8	21	7	7
Caspian Tern *Hydroprogne caspia*	13	12	4	4	11	51	38	10
White-fronted Tern *Sterna striata*	0	-	-	-	3	3	-	-
Common Tern *Sterna hirundo*	13	122	20	30	0	-	-	-
Greater Crested Tern *Thalasseus bergii*	17	318	148	68	11	76	40	22
Arctic Jaeger *Stercorarius parasiticus*	5	5	-	-	0	-	-	-

Summer and winter variations in abundance

Many species were only recorded in summer. Excluding four species which only had single records, the summer specialists were Lesser Sand Plover *Charadrius mongolus*, Black-tailed Godwit *Limosa limosa*, Ruddy Turnstone *Arenaria interpres*, Common Sandpiper *Actitis hypoleucos*, Common Greenshank *Tringa nebularia*, Little Penguin *Eudyptula minor*, Nankeen Night Heron *Nycticorax caledonicus*, White-necked Heron *Ardea pacifica*, Little Tern *Sternula albifrons*, Common Tern *Sterna hirundo* and Arctic Jaeger *Stercorarius parasiticus*.

A small number of species were only recorded in winter. The winter specialists, excluding two species with one-off records, were Australasian Gannet *Morus serrator* and White-fronted Tern *Sterna striata*.

Summer and winter abundance data were compared for a selection of species which were regularly recorded in medium to high numbers in summer and winter (all of the selected species had mean counts of ten or more birds in summer or winter, or both). Within **Figures 2-13** are presented comparisons of summer and winter numbers for the selected species, using box and whisker plots in which the median counts for each species are represented as horizontal lines between the 25% and 75% interquartile ranges (boxes), and the 1.5 x interquartile ranges are shown as whiskers. Outlier values are presented individually. **Figures 2-9** also show the summer and winter trends for some species, as described later.

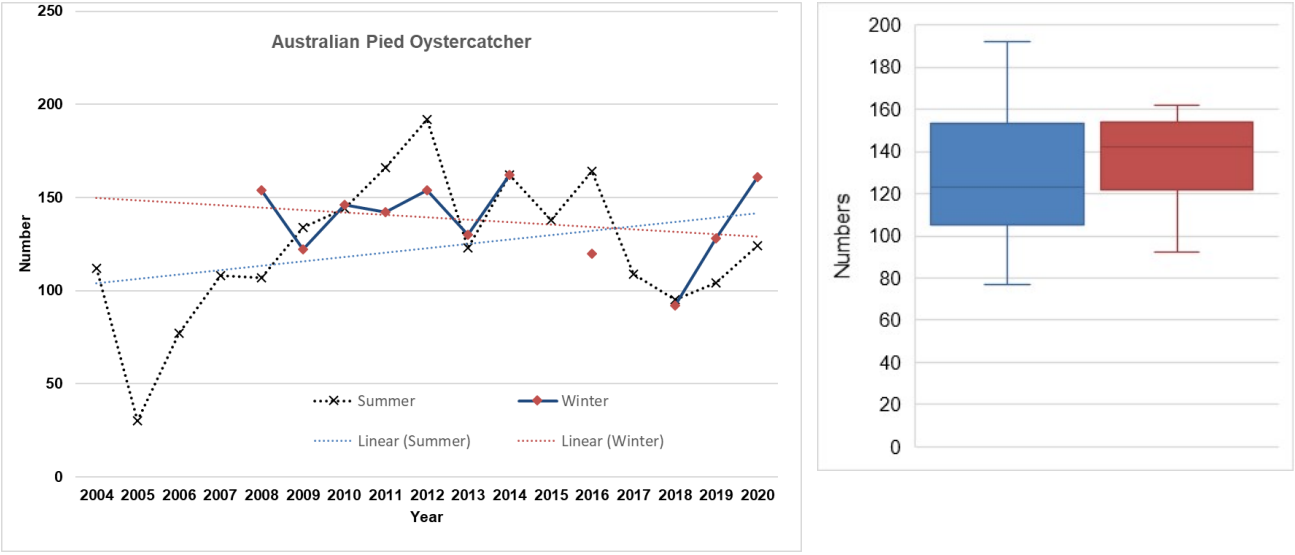


Figure 2. Summer and winter comparisons for Australian Pied Oystercatcher. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

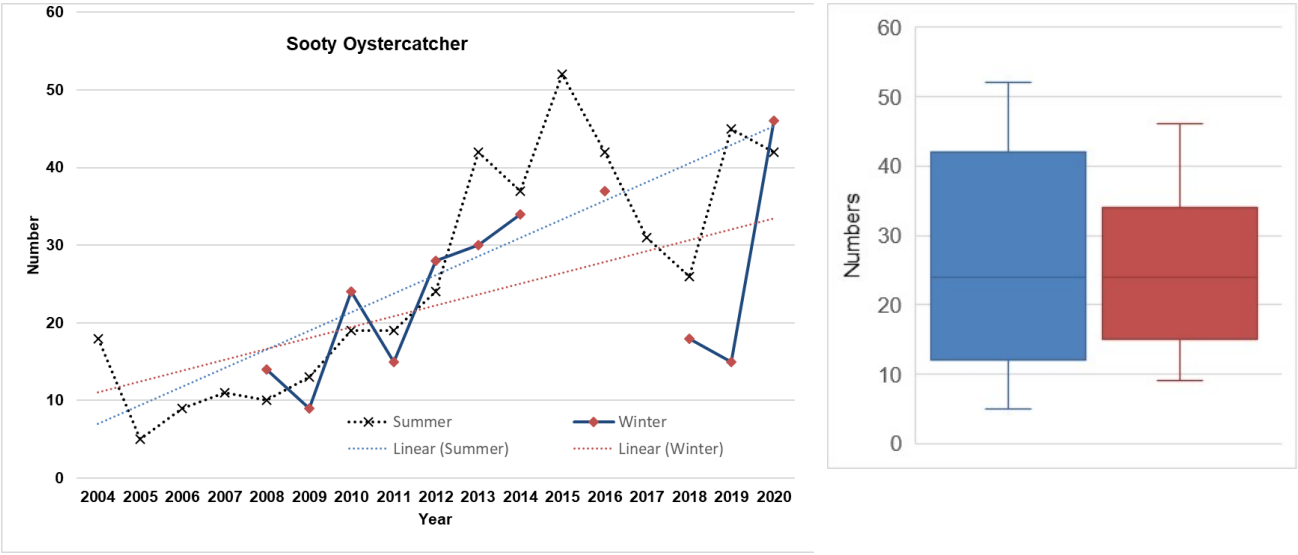


Figure 3. Summer and winter comparisons for Sooty Oystercatcher. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

Australian Pied Oystercatcher and Sooty Oystercatcher numbers exhibited no substantial summer/winter differences **(Figures 2-3)**. However, for the three main migratory shorebirds of Port Stephens (Whimbrel, Far Eastern Curlew and Bar-tailed Godwit), the winter numbers were substantially lower than the summer ones **(Figures 4-6)**. The resident shorebird Masked Lapwing also was present in lower numbers in the winter surveys compared with the summer ones (**Figure 10**).

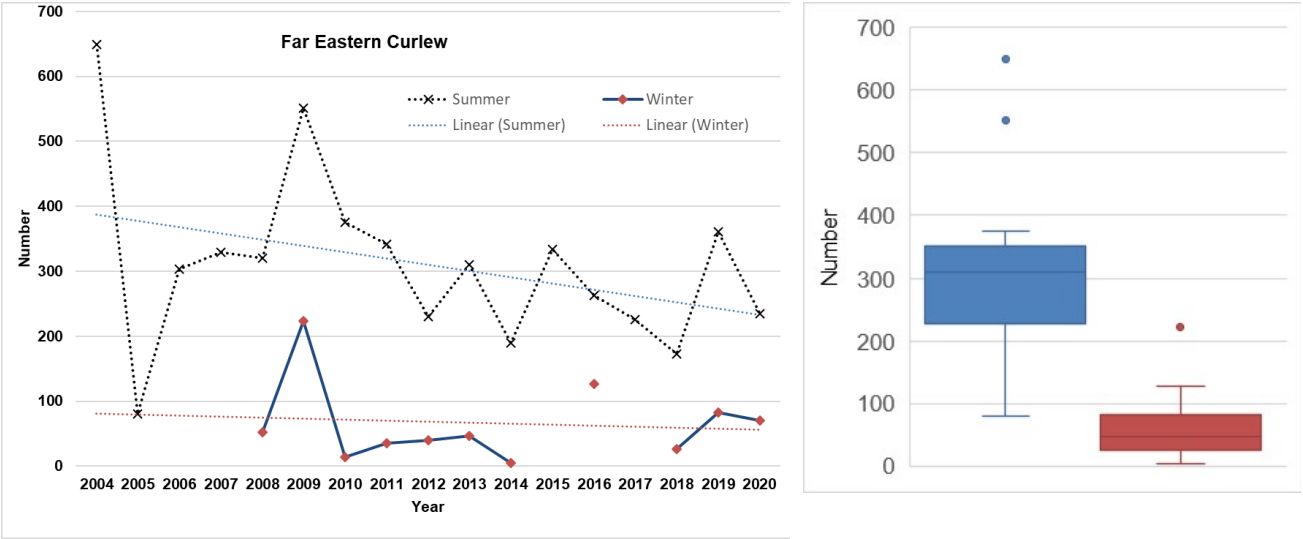


Figure 4. Summer and winter comparisons for Far Eastern Curlew. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

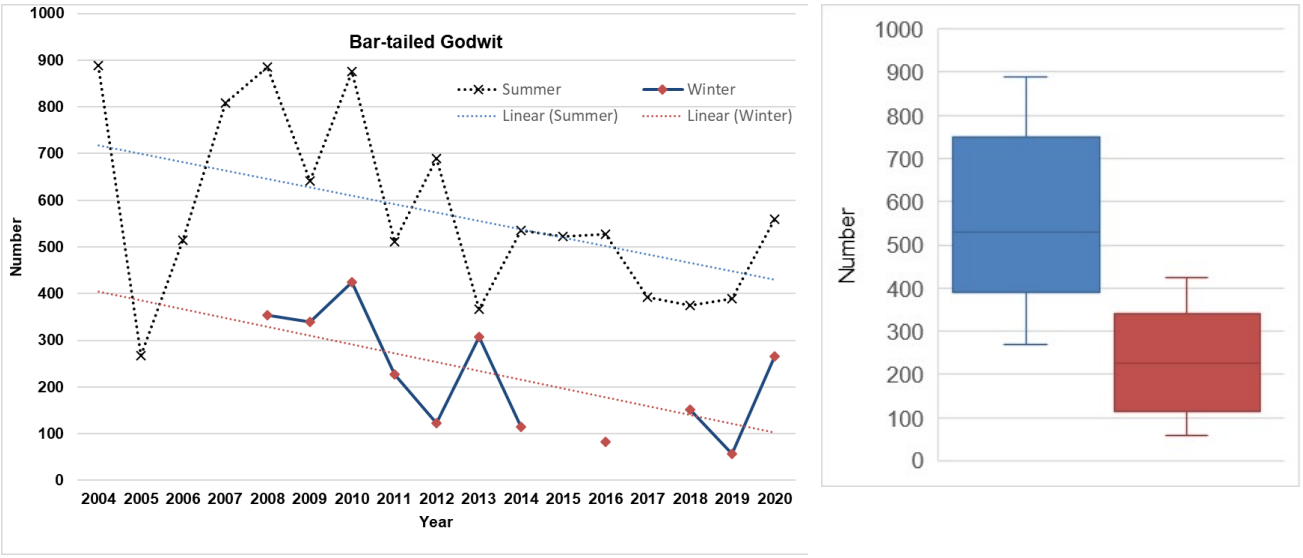


Figure 5. Summer and winter comparisons for Bar-tailed Godwit. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

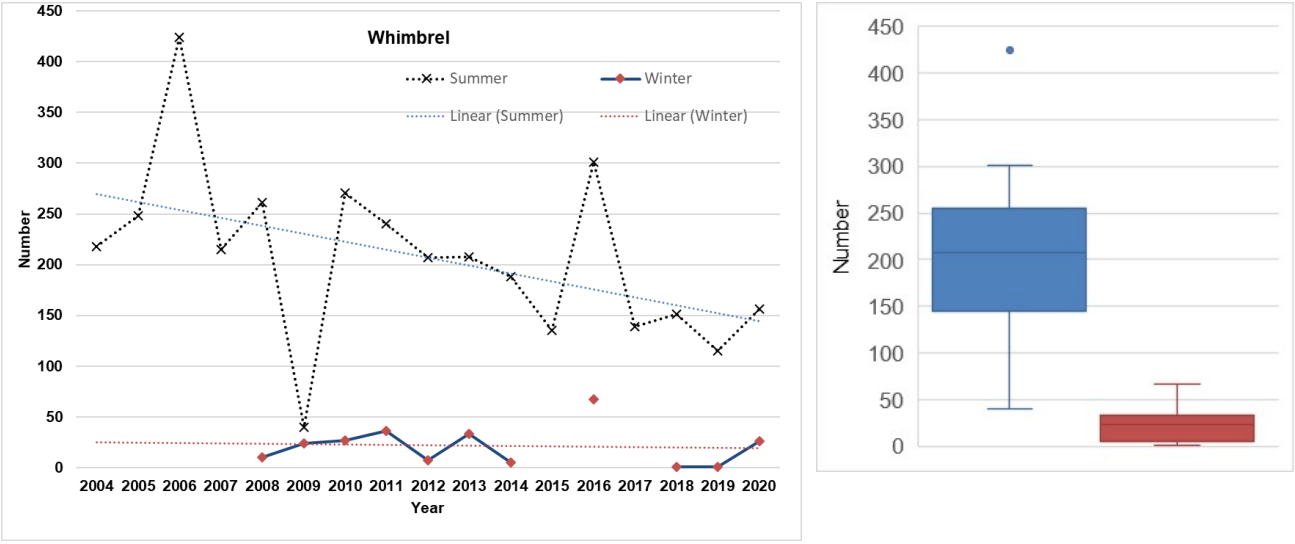


Figure 6. Summer and winter comparisons for Whimbrel. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

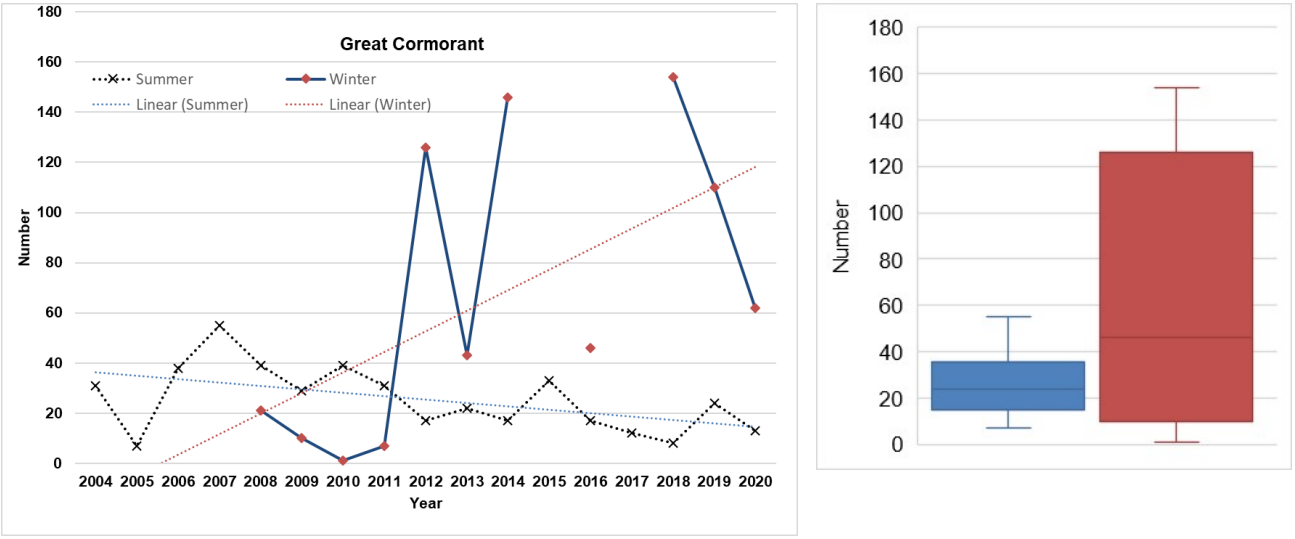


Figure 7. Summer and winter comparisons for Great Cormorant. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

Australian Gull-billed Tern *Gelochelidon macrotarsa* and Caspian Tern *Hydroprogne caspia* were more abundant in winter than in summer as were three cormorant species (Little Pied Cormorant, Great Cormorant, Great Pied Cormorant), Double-banded Plover and White-faced Heron (**Figures 7-12**). Conversely, the counts of Silver Gull, Greater Crested Tern and Black Swan were greater in summer surveys (**Figures 11-12**).

The differences in the summer and winter counts of Far Eastern Curlew, Bar-tailed Godwit, Whimbrel, Double-banded Plover, Great Cormorant, White-faced Heron, Silver Gull, Caspian Tern and Greater Crested Tern were statistically significant (all had $p < 0.05$).

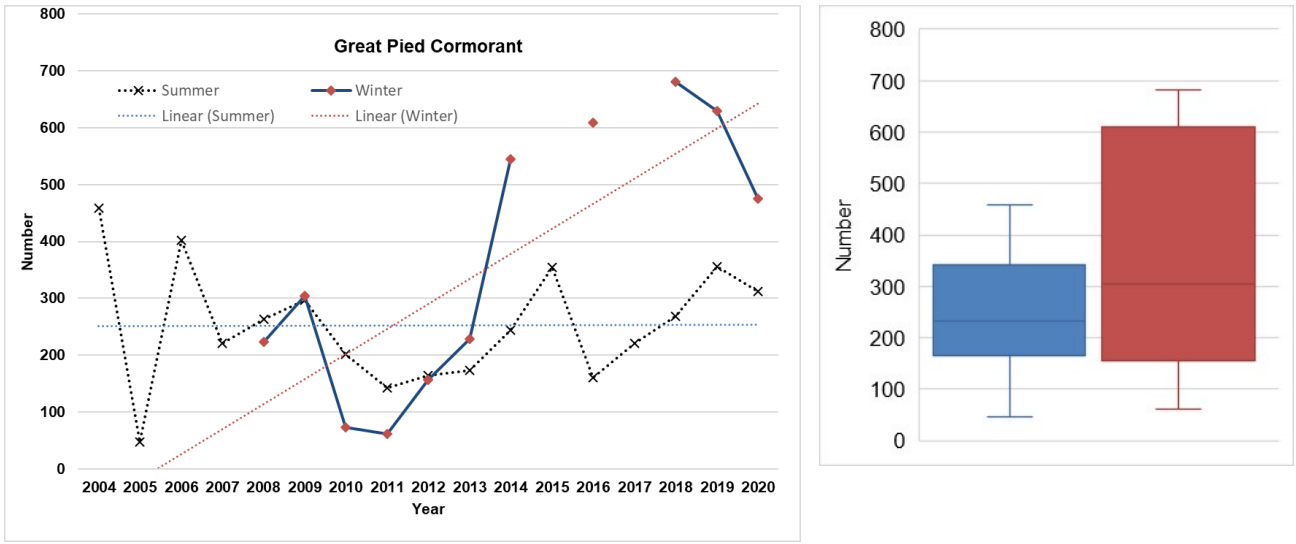


Figure 8. Summer and winter comparisons for Great Pied Cormorant. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

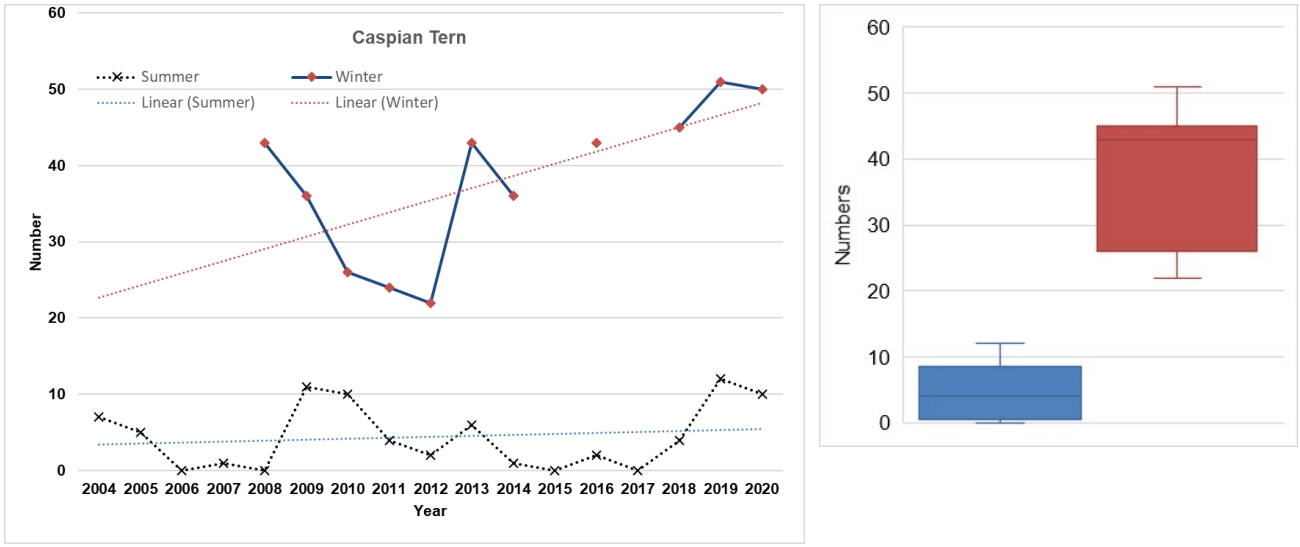


Figure 9. Summer and winter comparisons for Caspian Tern. Left-hand side: Results from individual summer and winter surveys, and trend lines. Right-hand side: Box plots summarising the overall results (summer data in blue, winter data in red), with medians represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers).

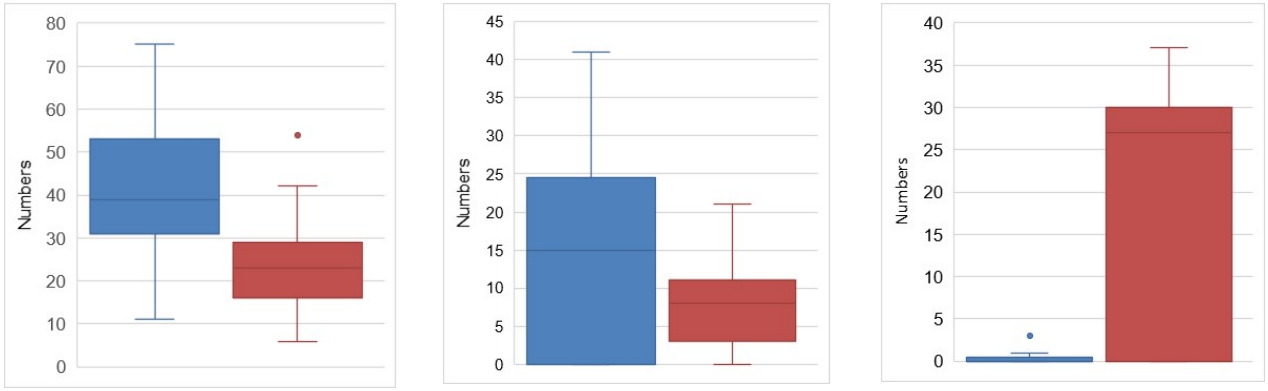


Figure 10. Shorebird summer and winter abundance comparisons for Masked Lapwing, Red-capped Plover and Double-banded Plover (summer data in blue, winter data in red). Medians are represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

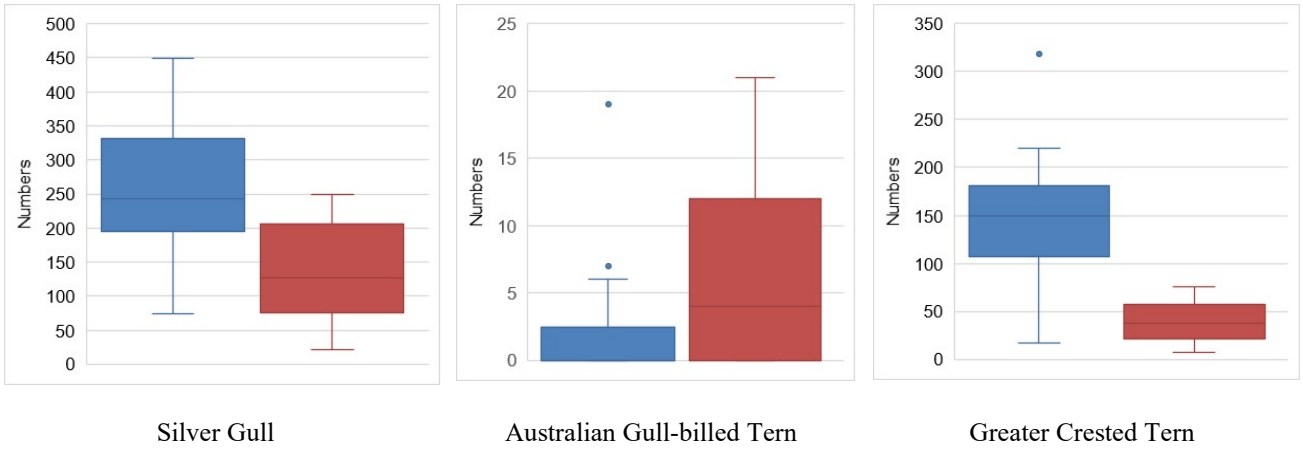


Figure 11. Shorebird summer and winter abundance comparisons for Silver Gull, Australian Gull-billed Tern and Greater Crested Tern (summer data in blue, winter data in red). Medians are represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

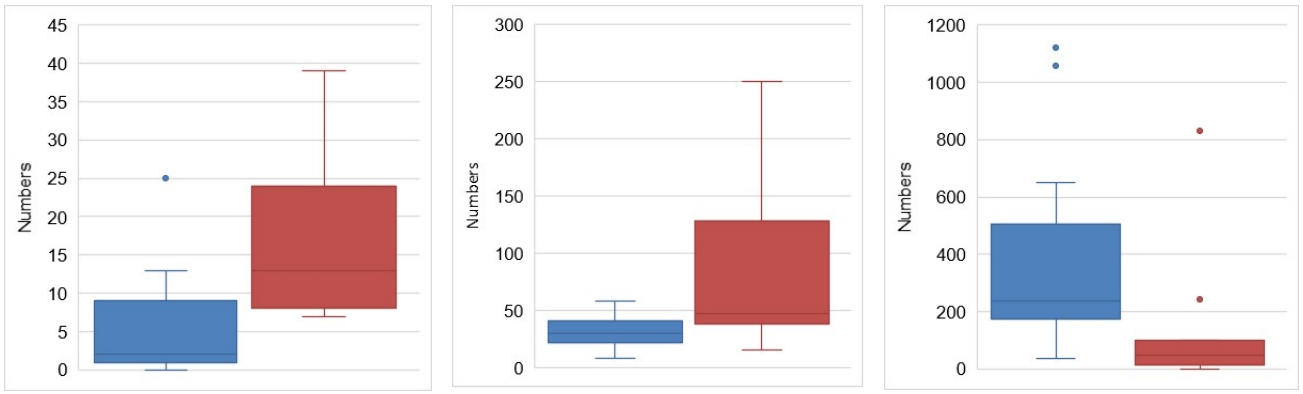
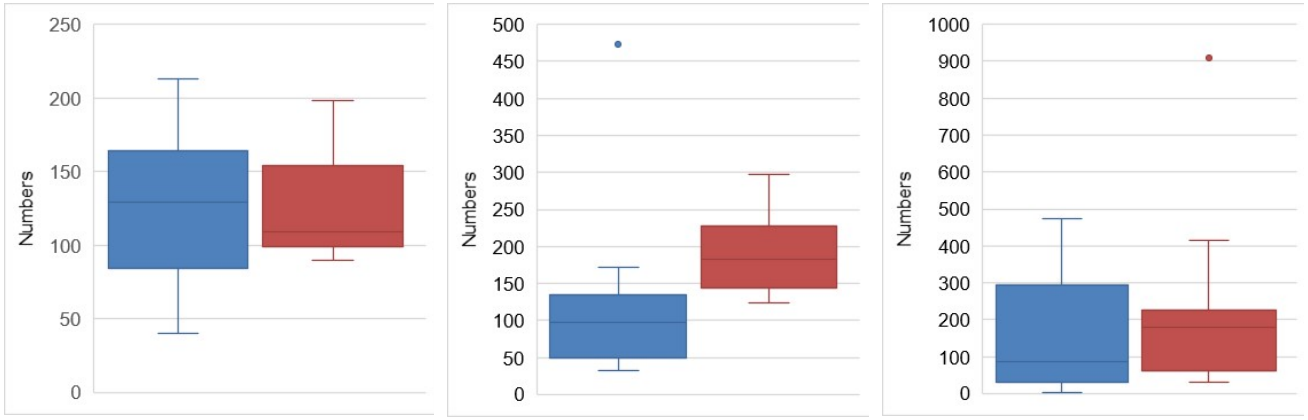


Figure 12. Shorebird summer and winter abundance comparisons for Australasian Darter, White-faced Heron and Black Swan (summer data in blue, winter data in red). Medians are represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).



Australian Pelican | Little Pied Cormorant | Little Black Cormorant

Figure 13. Shorebird summer and winter abundance comparisons for Australian Pelican, Little Pied Cormorant and Little Black Cormorant (summer data in blue, winter data in red). Medians are represented as horizontal lines between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

Trends

Although numbers fluctuated for all species from survey to survey, for most species the fluctuations appeared to be random and there was no obvious trend for change occurring (except for when there were differences between the summer and winter numbers, as described above). However, the numbers for three species have been declining, and for three other species they appear to have been increasing.

Summer counts of Far Eastern Curlew *Numenius madagascariensis* have been decreasing (see **Figure 4**), from peak counts of 649 birds in 2004 and 551 birds in 2009 down to counts of 200-250 birds in recent years. The decline trend was statistically significant (p 0.015) if the result for 2005 was excluded from regression analysis. The low count for 2005 was because their main roost site at Gir-um-bit NP was not able to be surveyed. The winter counts (which were of immature birds that had not returned to the breeding grounds) did not show any clear trend, particularly if the anomalously high counts for 2009 (223 birds) and 2016 (127 birds) were excluded from analysis.

The Bar-tailed Godwit *Limosa lapponica* is a common bird in Port Stephens but the numbers have been decreasing in both the summer and the winter surveys, at similar rates (**Figure 5**). There were several summer records of 800-900 birds during 2004-2010, whereas fewer than 400 birds were recorded in the 2017-2019 summer surveys. There were 559 birds in the 2020 summer survey, the first positive result for some time. The declining trend in summer was statistically highly significant (p 0.002) if the result for 2005 was excluded from the regression analysis. The low count for 2005 was because Gir-um-bit NP was not able to be surveyed. The declining trend in winter was statistically significant (p 0.029).

The numbers of Whimbrel *Numenius phaeopus* in summer also have decreased (**Figure 6**), although the extent of the decline perhaps is exaggerated by an anomalously high count in 2006 (424 birds) and an anomalously low count in 2009 (40 birds). Nevertheless, 220-280 birds usually were recorded in 2004-2010 whereas recent counts have mostly been of *c*. 150 birds. The declining trend was statistically significant (p 0.012) if the anomalous results for 2006 and 2009 were excluded from the regression analysis (p 0.009 when only the 2009 result was excluded from analysis). The winter counts for Whimbrel were more consistent (**Figure 6**).

The linear trends for Far Eastern Curlew, Bar-tailed Godwit and Whimbrel in the summer surveys all correspond to declines of *c*. 2.5% each year for each species.

The numbers of Sooty Oystercatcher *Haematopus fuliginosus* in Port Stephens have been increasing, from ten or so birds recorded in the early years to recent summer counts of more than 40 birds and a peak count of 52 birds in February 2015 (**Figure 3**). The increase in summer was statistically highly significant (p 0.002). The winter trend was similar, although there were fewer birds present in the 2018 and 2019 winter surveys and the trend in winter was not statistically significant. All of the birds recorded in all the surveys were the subspecies *H. f. fuliginosus*.

The winter counts of Great Cormorant *Phalacrocorax carbo* and Great Pied Cormorant *P. varius* have been increasing (**Figures 7-8**). Fewer than 25 Great Cormorant were recorded in the 2008-2011 winter surveys, but since then, more than 100 birds have been present in four of the seven winter surveys. The trend for Great Cormorant was statistically significant (p 0.048). The counts for Great Pied Cormorant between 2008 and 2013 were of fewer than *c*. 300 birds (and usually, of less than 150 birds); all five winter surveys since 2014 recorded more than 500 birds with a peak count of 681 birds in July 2018. The trend for Great Pied Cormorant was statistically highly significant (p 0.006).

The winter counts of Caspian Tern have also been increasing (**Figure 9**). The trend was statistically significant (p 0.049).

DISCUSSION

Although Australian White Ibis, Straw-necked Ibis and Cattle Egret were sometimes encountered during a survey, all three species are land-based foragers (albeit that Australian White Ibis does also forage in the inter-tidal zone) and records of them during a boat-based survey were considered likely to be opportunistic and unpredictable. Hence those three species were excluded from the analyses in this report, which is focused on birds that are dependent on the marine or estuarine habitat of Port Stephens. Records for Australian Wood Duck *Chenonetta jubata* were included, although arguably they fall into the same category as the other three species.

Shorebirds

Port Stephens has long been known for its importance to the Australian Pied Oystercatcher (Stuart 2010). That continues to be the situation, with many records of 120-150 birds and a peak count of 192 birds in February 2012. In recent years, their numbers have been increasing at the nearby Worimi Conservation Lands, with many counts since 2018 of 80 or more birds and occasionally of more than 100 birds (Fraser & Lindsey 2018; N. Fraser & A. Lindsey pers. comm.). However, high numbers continue to be recorded within Port Stephens (for example, 161 birds in July 2020). The combined total numbers at both sites (Port Stephens and Worimi Conservation Lands) is now typically in the range of 220-250 birds (i.e. more than 2% of the total population). As well, there are increasing numbers of breeding records at the two sites (Fraser & Lindsey 2018; Fraser 2019). The Australian Pied Oystercatcher is flourishing in those parts of the Hunter Region.

Wooding (2019) recognised Port Stephens as an important local site for the Sooty Oystercatcher. The twice-yearly boat-based surveys confirm that to be the case and show that numbers have been increasing. Since 2013, five summer surveys and one winter survey have recorded more than 40 birds, which is 1% of the estimated total population of subspecies *fuliginosus* (Wooding 2019). The peak count, of 52 birds in February 2015, corresponds to 1.3% of the total population of the subspecies.

In a review of the Far Eastern Curlew in Port Stephens, using results from the boat-based surveys as well as from land-based surveys at the Gir-um-bit National Park high-tide roost site, the decrease in numbers was found to be statistically significant, and with very significant decreases occurring at the high-tide roost site and in areas around Corrie Island (Griffin & Williams 2019). The current estimated total population of Far Eastern Curlew is 35,000 birds (Hansen *et al*. 2016). Based on that estimate, Port Stephens still can be considered internationally significant for the species – for example, 361 birds were recorded in February 2019. However, it should be noted that the population estimate is likely to be revised downwards, by some 4,000 birds, because of continuing decline mainly arising from threats at coastal stopover locations in the East Asian – Australasian Flyway (Lilleyman *et al*. in preparation). Thus, Port Stephens continues to be an important site internationally for Far Eastern Curlew.

Bar-tailed Godwit numbers have decreased in Port Stephens since the surveys commenced, and probably the Whimbrel numbers as well. The trend is less certain for Whimbrel because of two anomalous counts, in 2006 and 2009. The main decline for Bar-tailed Godwit occurred between 2004 and 2013, when the summer counts dropped from 888 birds to just 366 birds. Similarly, between 2008 and 2012 the winter numbers decreased from 350-400 birds to *c*. 100 birds. However, the situation may now have stabilised. For the period 2014-2020, the average summer count was 471 birds, with SD of 81 birds. The relatively low CV (17%) suggests moderate stability. The winter pattern since 2013 is less clear, especially as there were two years without a winter survey. There have been two winter counts of *c*. 300 birds, in 2013 and 2020, and with 100±20 birds in the other four years.

Most other shorebirds were recorded in low numbers; Port Stephens does not host large numbers of small and medium-sized waders, as has previously been noted (Stuart 2011). The Grey-tailed Tattler can be present in moderate numbers (up to 100 or so birds at times) but it has been shown that boat-based surveys are less effective at finding them than are land-based surveys, owing to the often-cryptic nature of their roosting behaviour (Wooding & Stuart 2013). Red-capped Plover *Charadrius ruficapillus* was recorded in many surveys, more often in the winter surveys although in lower numbers than for summer. Pacific Golden Plover *Pluvialis fulva* was recorded in nine summer surveys and three winter surveys. The winter migrant Double-banded Plover *Charadrius bicinctus* was recorded in all bar one of the winter surveys, with a mean count of 21 birds; occasionally in the February surveys some early-returning birds were present. Red-capped Plover and Double-banded Plover usually were found close together, with their preferred locations being around Corrie Island and Winda Woppa.

There were no breeding records from the surveys for any shorebirds. However, the focus during the surveys is on finding and counting birds and it is possible that some instances of breeding activity may have been overlooked. For example, it seems plausible that Red-capped Plover would breed in Port Stephens. There are breeding records for Beach Stone-curlew *Esacus magnirostris* and Australian Pied Oystercatcher at other times of the year (Fraser & Lindsey 2018; Fraser 2019; Murray 2019).

Waterbirds

Usually, there were many waterbirds in Port Stephens. The average summer and winter counts were of 1,615 birds and 1,478 birds, respectively; however, there were several surveys in which more than 2,000 waterbirds were present. The main species, comprising 1,000 or more birds in total on most surveys, were Black Swan, Australian Pelican, the four cormorants, Silver Gull and Greater Crested Tern. The counts for all of those species and for other waterbirds varied considerably from survey to survey. The most stable numbers were for Australian Pelican, with CV 39% in the summer surveys and 29% in the winter ones. The relatively high CVs for most waterbird species (in general, the CVs were in the range 50-100%, if not higher) is an indicator of the variability in their abundance across the surveys.

Little Tern in Port Stephens usually start to breed in the November/December period (Fraser 2019). The few breeding records for them from the boat-based summer surveys possibly reflects that the breeding season was over or nearly over by the time of the survey, which sometimes was carried out in the latter half of February. It seems unlikely that Little Tern bred in Port Stephens in the period 2005-2015, because the numbers present in those years were quite low, mostly less than ten birds. There are records of Little Tern breeding on Corrie Island and Winda Woppa during the period 1958-1990 (Fraser (2017).

There were no breeding records from the surveys for any waterbirds other than Little Tern. However, as commented above for shorebirds, some instances of breeding activity may have been overlooked.

Threatened species

Eleven threatened species were recorded in the surveys, the majority of those being shorebirds. They are listed in **Table 6**, which also shows the species' classification under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and the NSW *Biodiversity Conservation Act* 2016 (BC Act). Also, Great Knot *Calidris tenuirostris* (EPBC Critically Endangered, NSW Vulnerable) was recorded occasionally on Corrie Island outside of the scheduled surveys (AS pers. obs.).

Table 6. Threatened shorebird and waterbird species recorded in the Port Stephens surveys and their Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and NSW *Biodiversity Conservation Act* 2016 (BC Act) classifications.

Species	EPBC Act	BC Act
Bush Stone-curlew	-	Endangered
Beach Stone-curlew	-	Critically Endangered
Aust. Pied Oystercatcher	-	Endangered
Sooty Oystercatcher	-	Vulnerable
Lesser Sand Plover	Endangered	Vulnerable
Far Eastern Curlew	Critically Endangered	-
Bar-tailed Godwit	Vulnerable	-
Black-tailed Godwit	-	Vulnerable
Red Knot	Endangered	-
Terek Sandpiper	-	Vulnerable
Little Tern	-	Endangered

Drought

Eastern Australia was in drought in 2001-2009 and 2016-2019, with a high rainfall La Niña event occurring in 2010-2011 (Wikipedia 2020). The changing conditions could be expected to have affected waterbird numbers. For the cormorants, the link with rainfall pattern was not strong. Cormorant numbers were at their lowest in 2010-2011 which might reflect dispersal of birds to inland wetlands during the La Niña event. Numbers then began to rise, but for Great and Great Pied Cormorant that increase in numbers began in 2013 i.e. before drought conditions had re-established. Then, over 2019-2020 when the drought was dominant, their numbers in Port Stephens decreased. The pattern for cormorant species 2004-2009 was less clear, particularly as the 2005 survey may have under-estimated the numbers present. However, above-average numbers of Great Pied Cormorant were present in 2004 and 2006.

Three of the peak counts for Black Swan occurred in the three consecutive surveys between February 2019 and February 2020. By July 2020, most of those birds had departed. The pattern fits with birds having moved to Port Stephens from drying areas elsewhere, during the final stages of the 2016-2019 drought. However, the peak counts in February 2004 and February 2010, both involving more than 1,000 birds, occurred when most of NSW had experienced average or above-average rainfall in the preceding three months (Bureau of Meteorology 2020).

Summer and winter differences

There were many differences in the results from the summer and winter surveys. Partly, those differences were associated with known migratory species such as the shorebirds which breed in the northern hemisphere in the austral winter. Those migratory shorebirds were absent in the winter surveys, or else recorded in much lower numbers than in the summer surveys. For the winter-visiting Double-banded Plover, that situation was reversed. The Masked Lapwing *Vanellus miles* was present in every summer and winter survey; however, it too was recorded in lower numbers in the winter surveys.

The migratory Arctic Jaeger *Stercorarius parasiticus* also was absent in winter, and Little Penguin *Eudyptula minor* was not recorded in winter (i.e. in their non-breeding season).

The numbers of Silver Gull, Greater Crested Tern and Black Swan were substantially lower in the winter surveys. Conversely, more White-faced Heron, Little Pied Cormorant, Great Cormorant, Great Pied Cormorant and Caspian Tern were present in winter than in summer. For several other species, such as Australian Gull-billed Tern, there were insufficient data to draw firm conclusions.

CONCLUSIONS

Port Stephens is an important area for many shorebird and waterbird species. Twenty-three shorebird species and 31 waterbird species were recorded in systematic surveys of Port Stephens since 2004. Although some of those species may be considered to be vagrants, at least 12 shorebirds and at least 19 waterbirds frequently were present in the estuary. For three species, Far Eastern Curlew, Australian Pied Oystercatcher and Sooty Oystercatcher, many of the records have been of more than 1% of the total population of the relevant species or subspecies. High numbers of Bar-tailed Godwit continue to be present, despite a population decline having occurred for that species as well as for other migratory shorebirds. The Port Stephens estuary also hosts several hundred non-breeding migratory shorebirds each winter.

The Australian Pied Oystercatcher population seems stable, while Sooty Oystercatcher numbers have risen in recent years. Large numbers of waterbirds were recorded in every survey of Port Stephens, although for individual surveys there was considerable variability in the numbers of each species. Some waterbird species were present in greater numbers in summer than in winter, while for other species the reverse situation occurred.

This study has identified several changes in species' abundance. Understandings about the causes of those changes are speculative and require closer analysis, done on an individual species basis and comparing the changes with patterns occurring in other parts of the Hunter Region and more widely. For example, there was some evidence of rainfall patterns (El Niño and La Niña events) affecting waterbird numbers. However, the evidence requires further examination.

ACKNOWLEDGEMENTS

Each survey involved 12-14 volunteers from the Hunter Bird Observers Club, with a total of 61 people having participated in at least one survey. Ten of the volunteers assisted in at least half of the surveys, and 35 people

assisted in three or more of them. The surveys were organised jointly with the Hunter Coast Area of the NSW National Parks and Wildlife Service (NPWS); their Rangers arranged most of the boats and skippers. Over the years, the prime organisers on behalf of NPWS have variously been Laurence Penman, Susanne Callaghan, Duncan Scott-Lawson and Richard Ghamraoui. Other organisations which have provided boats and/or skippers are Hunter Local Land Services (per the Kooragang Wetlands Rehabilitation Project), Marine Rescue Port Stephens, Marine Rescue Lemon Tree Passage, the Port Stephens-Great Lakes Marine Park Authority and the owners of MV Koala. Robyn Stuart provided guidance in statistical analysis.

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