Hunter Estuary surveys: results for waterfowl, grebes, crakes, rails and gallinules

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The Hunter Estuary at Newcastle, New South Wales is a well-known site for migratory shorebirds, but its utilisation by other types of waterbirds is not well understood. This report presents the results for 27 species, representing three families of waterbirds, Anatidae (waterfowl), Podicipedidae (grebes) and Rallidae (crakes, rails and gallinules), from a 22-year study involving monthly surveys of the estuary.

Most of the species were found to have stable populations or the changes over 22 years were modest. The populations of eight species increased - Black Swan *Cygnus atratus*, Australian Wood Duck *Chenonetta jubata*, Pacific Black Duck *Anas superciliosa*, Grey Teal *A. gracilis*, Chestnut Teal *A. castanea*, Australasian Grebe *Tachybaptus novaehollandiae*, Purple Swamphen *Porphyrio porphyrio* and Eurasian Coot *Fulica atra*. These species have benefitted from local rehabilitation projects which have restored tidal flushing to wetlands located at Ash Island, Hexham Swamp and Tomago.

Five species had greater populations in the estuary in summer and/or autumn: Australasian Shoveler *Spatula rhynchotis*, Pacific Black Duck, Grey Teal, Chestnut Teal and Australasian Grebe. The population of Black Swan rose in winter.

Most of the species had fluctuating populations in the estuary. However, five species had notable irruptions interspersed with periods when they were absent or present only in low numbers: Pink-eared Duck *Malacorhynchus membranaceus*, Grey Teal, Hardhead *Aythya australis*, Australasian Shoveler and Eurasian Coot. The populations of Hoary-headed Grebe *Poliocephalus poliocephalus* and three crake species also displayed irruptive tendencies but the peak counts for all of them were relatively low.

The Hunter Estuary was confirmed to be important for Chestnut Teal. At least 1% of its total population was often present and the peak count of 3,856 birds in March 2017 represented almost 4% of the population. All counts exceeding 1,000 birds were in summer or autumn, with the majority of them occurring in autumn.

INTRODUCTION

This is the fourth and final report in a series documenting the results of 22 continuous years of monthly surveys of shorebirds and waterbirds in the Hunter Estuary by members of Hunter Bird Observers Club. Previous reports dealt with shorebirds (Stuart & Lindsey 2021), large waterbirds (Lindsey & Stuart 2021) and gulls and terns (Lindsey & Stuart 2022). In this report we present the results for waterbirds from three families: Anatidae - waterfowl; Podicipedidae - grebes; and Rallidae - crakes, rails and gallinules.

During the surveys all shorebirds and waterbirds observed were counted. Most of the sites monitored were in Hunter Wetlands National Park, the Ash Island section of which is affected by a number of public utilities (Lindsey & Stuart 2021). Some ponds on Kooragang Island on land owned by Newcastle Coal and Infrastructure Group (NCIG) were also surveyed. Because the focus was to ascertain usage by shorebirds, tidally-influenced sites where shorebirds were most likely to be found were chosen. Some sites which were initially important have since disappeared e.g. Big Pond on Kooragang Island (Stuart & Lindsey 2021). Sites monitored included some but not all freshwater wetlands in the lower Hunter Valley. Many of the species mentioned in this article prefer freshwater wetlands. The main omissions were the wetlands around Shortland, which often host considerable numbers of waterbirds (Stuart 2018). In the same time frame (1999-2021) as the surveys analysed in this report, some of the Shortland wetlands were monitored regularly (Stuart 2018), but not all of them and the surveys were not done on the same day as the Hunter Estuary surveys. Thus it is difficult to

merge the results and analyse them together. Other important freshwater wetlands, such as those around Tarro and Woodberry, were surveyed irregularly at best.

METHODS

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

Each month the results from each individual site were entered into Birdata (www.birdata.com.au). The monthly total numbers were also entered into a Microsoft Excel spreadsheet along with general notes (e.g. if any site had not been able to be surveyed that month). We used that spreadsheet as the basis for this report. To analyse the results, we used standard Excel graphing and data analysis tools. When comparing populations for two time periods we assessed if the changes were statistically significant by carrying out two-tailed t-tests assuming unequal variances ($\alpha < 0.05$) and determining the probability P of the change being significant. For P values below 0.05 we classified the differences as significant, and as highly significant for $P < 0.01$. We consider our use of t-tests to be justified as the count data were normally distributed and therefore the data can be treated as continuous; also the standard deviation was known and the sample size was above 30 (https://vitalflux.com/when-to-use-z-test-vs-t-test-differences-examples/, accessed 14 June 2022).

To assess long-term population trends, we compared the counts for two time periods - those for the first 11 years of surveys and those for the subsequent 11 years. For seasonal comparisons, we grouped the data into December-February ("summer"), March-May ("autumn"), June-August ("winter") and September-November ("spring"). We also compared seasonal data for the two 11-year time periods.

RESULTS

There were 263 surveys done in the 22-year period, of the 264 possible. In some surveys not every site was visited, because of access problems on the given day. When we assessed shorebird and gull and tern populations in the estuary (Stuart & Lindsey 2021; Lindsey & Stuart in preparation), some of those surveys were excluded from analysis. However, for the present study we concluded that the total waterbird counts would not have been greatly affected, and thus we have used the results from all 263 surveys.

Twenty-seven species of small waterbird were recorded in the estuary during 1999-2021. **Table 1** lists the species, the number of records for each and their Reporting Rate (RR, the ratio of number of records to number of surveys, expressed as a percentage).

Three species had RRs above 90% - Black Swan *Cygnus atratus*, Pacific Black Duck *Anas superciliosa* and Chestnut Teal *Anas castanea* - and seven other species had RRs above 50%. Status summaries for all 27 species are detailed below. Only the species with more than 60 records were analysed for trends. Results from the two-tailed t-tests for species with complex patterns of occurrence are presented in the **Appendix**.

Table 1. Waterfowl, grebe, crake, rail and gallinule species recorded in monthly surveys of the Hunter Estuary spanning 1999-2021, with their number of records and Reporting Rates (RR).

Species	Times recorded	RR (%)	Max. count
Magpie Goose	9	3.4	36
Wandering Whistling-Duck	10	3.8	18
Blue-billed Duck	5	1.9	4
Musk Duck	116	44.1	12
Pink-eared Duck	66	25.1	338
Freckled Duck	6	2.3	6
Black Swan	255	97.0	429
Australian Shelduck	5	1.9	4
Australian Wood Duck	151	57.4	101
Hardhead	167	63.5	823
Australasian Shoveler	152	57.8	382
Pacific Black Duck	241	91.6	480
Mallard	13	4.9	5
Grey Teal	216	82.1	3659
Chestnut Teal	259	98.5	3856
Australasian Grebe	179	68.1	131
Hoary-headed Grebe	149	56.7	146
Great Crested Grebe	3	1.1	2
Lewin's Rail	6	2.3	2
Buff-banded Rail	35	13.3	4
Australian Spotted Crake	25	9.5	10
Baillon's Crake	12	4.6	4
Spotless Crake	13	4.9	2
Purple Swamphen	191	72.6	149
Dusky Moorhen	102	38.8	36
Black-tailed Native-hen	3	1.1	3
Eurasian Coot	126	47.9	1339

Musk Duck

During 2005-13 there were frequent records of Musk Duck *Biziura lobata* (mainly from Deep Pond) including several of 10-12 birds (see **Figure 1a**). Prior to that, some birds were present during 2000-01. After 2014 there were intermittent records of 1-4 birds. There were no significant seasonal differences.

Pink-eared Duck

There were several influxes of the Pink-eared Duck *Malacorhynchus membranaceus*, when 100 or more birds were in the estuary, and often for periods of many months (see **Figure 1b**). The main influxes occurred in 2005-09, 2013-15, 2017 and late 2018. There were no statistically significant differences in the overall or seasonal results.

Black Swan

Black Swan were absent in only eight of the surveys, and most records were of at least 50 birds (**Figure 1c**). In 2000-01 and in 2014-2021 there were many records of more than 200 birds. Swans were more abundant in winter, with a mean count of 101 birds for the 22 years of winter surveys compared with 62-89 birds for the three other seasons. The differences between winter and summer (mean count of 62 birds) was statistically highly significant ($P < 0.01$) - see **Appendix** for details.

The overall numbers in the estuary rose in the second 11-year time period (**Figure 2a**). For spring the differences for the two time periods were small but for the three other seasons the differences were assessed to be statistically highly significant ($P < 0.01$ in all three cases - see **Appendix** for details). For example, for autumn the mean count rose from 53 to 127 birds.

Australian Wood Duck

Records for Australian Wood Duck *Chenonetta jubata* were infrequent in 1999-2004 but after that birds were present in more than 60% of the surveys. The typical numbers were of 15-30 birds but there were several records of more than 50 birds and two records of *c*100 birds (**Figure 3a**). There were no significant seasonal patterns. For every season, there was an increase in the numbers of birds present between the first and the second 11-year time periods (see **Figure 2b**). For summer and winter, the changes were not significant (although P 0.057 for summer). For autumn and spring, the changes were statistically significant, with the autumn means rising from five to 16 birds across the two time periods and the spring means rising from four to ten birds (see **Appendix** for further detail).

Hardhead

For Hardhead *Aythya australis*, there were no significant seasonal patterns nor any significant long-term population changes. However, there were many shorter-term changes (**Figure 3b**). When present, the typical counts were of 50-100 birds but there were several influxes involving hundreds of birds. In 2005-2007, there were many records of more than 100 birds and the peak counts were 611 birds in May 2005, 550 birds in October 2006 and 823 birds in May 2007. After that the influxes were smaller, but 452 birds were recorded in December 2018. There were very few records during 1999-2004, 2010, 2016 and 2019-2021.

Australasian Shoveler

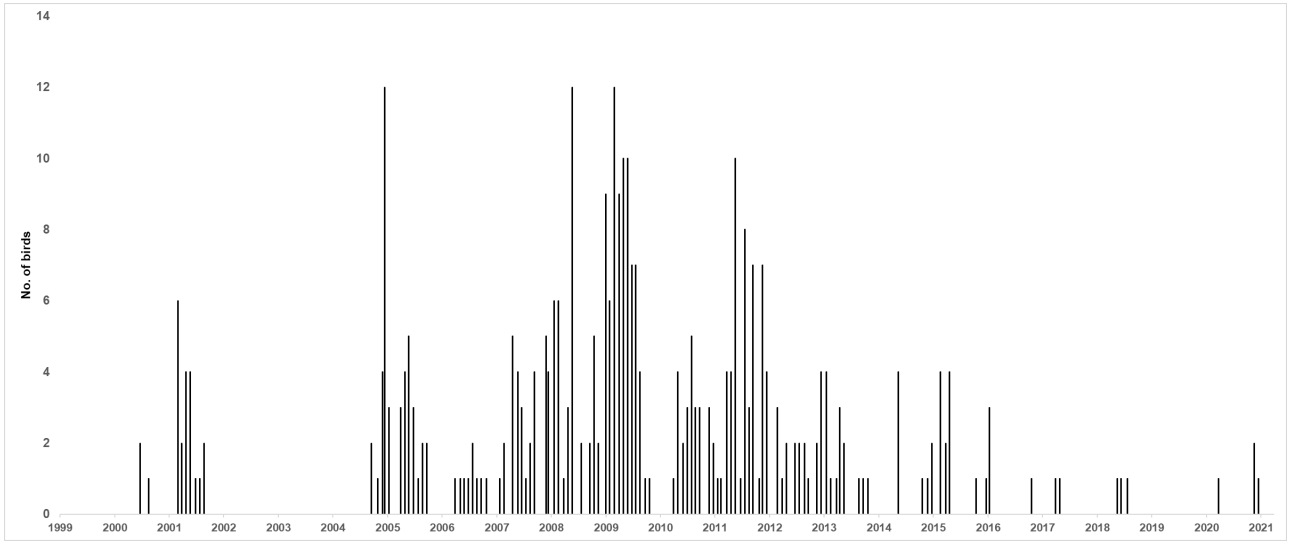
When present, the typical counts for Australasian Shoveler *Spatula rhynchotis* were of 20-50 birds but there were very few records during 1999-2000, mid-2010 to mid-2013 and 2019-2020. There were several influxes involving hundreds of birds, with a peak count of 382 birds in April 2015 (**Figure 3c**).

There were many seasonal differences, as shown in **Figure 2c**. For the full 22-year period, numbers peaked in autumn and the differences in numbers were significantly different for every season except for autumn and winter. However, in the second 11-year period the autumn and winter counts were found to be statistically significantly different but not the summer and winter counts - see **Appendix** for details.

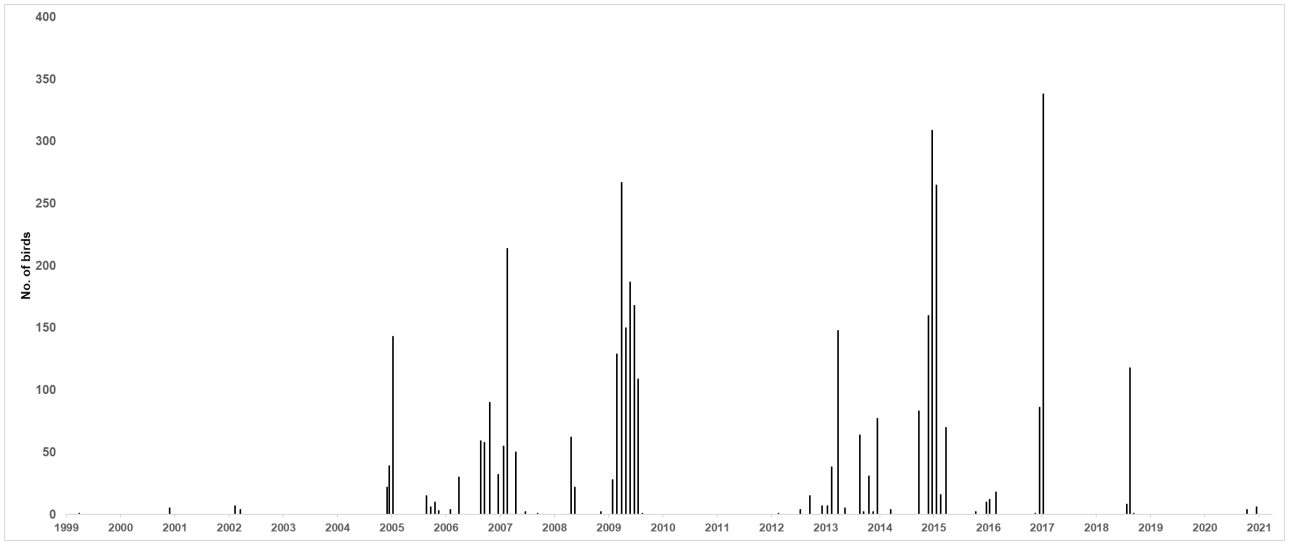
Pacific Black Duck

Of the waterfowl, Pacific Black Duck was the third most commonly recorded species in the estuary over 1999-2021. Prior to 2005 it was recorded only in low numbers; however, the second-highest count, of 447 birds, occurred in March 2005. The highest count was 480 birds in January 2017 and there were several influxes where more than 100 birds were present (**Figure 4a**).

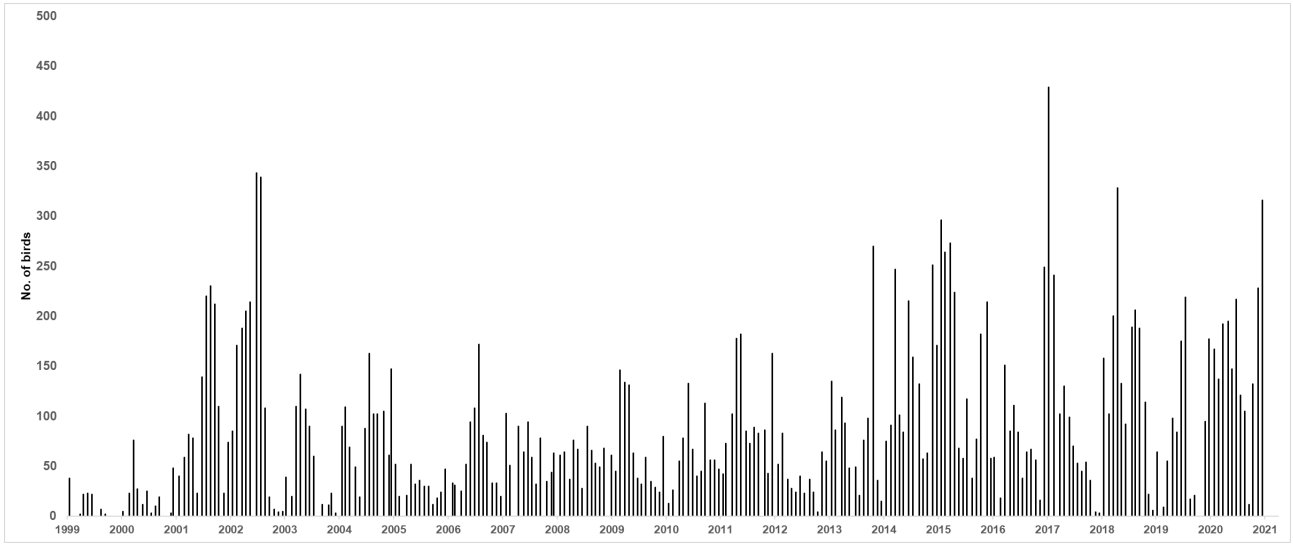
Since 2005, the population has been stable over the long term. However, there have been notable seasonal differences, as **Figure 2d** indicates. Numbers have been greatest in the summer and autumn periods (22-year means of 67-75 birds compared with 31-38 birds, and similar seasonal patterns for the two 11-year time periods). Many of the differences were statistically significant or highly significant (see **Appendix** for details). The summer population was stable across the two 11-



(a) Musk Duck

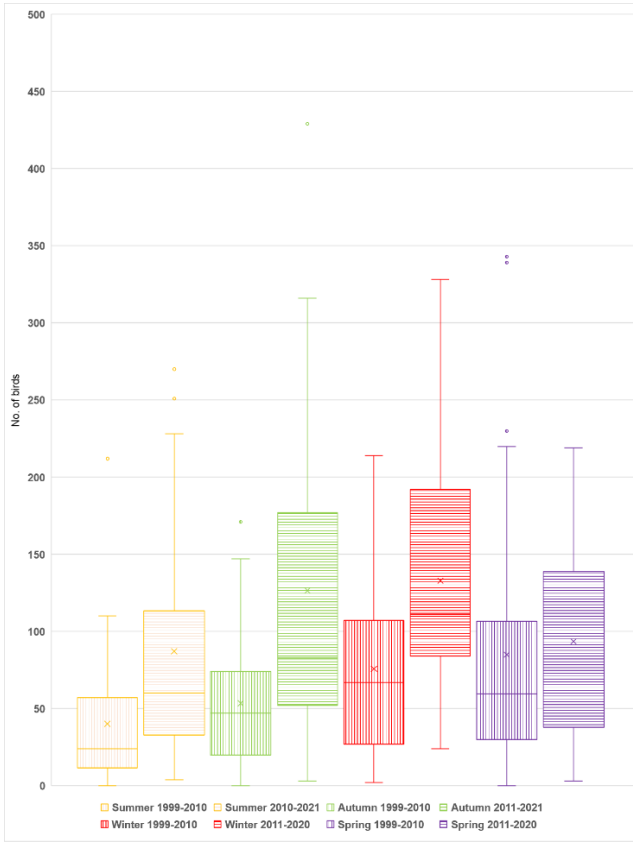


(b) Pink-eared Duck

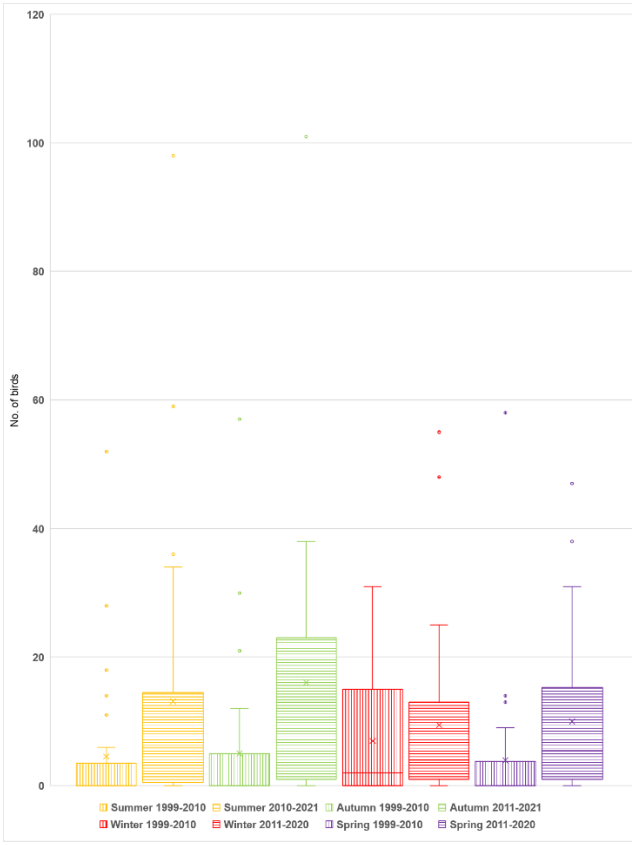


(c) Black Swan

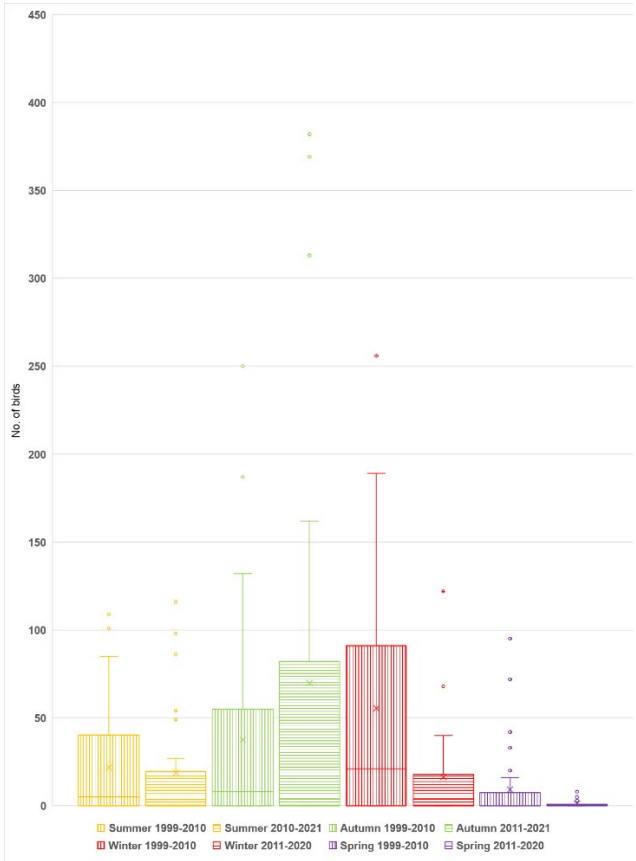
Figure 1. Monthly counts for a) Musk Duck, b) Pink-eared Duck and c) Black Swan in the Hunter Estuary 1999-2021.



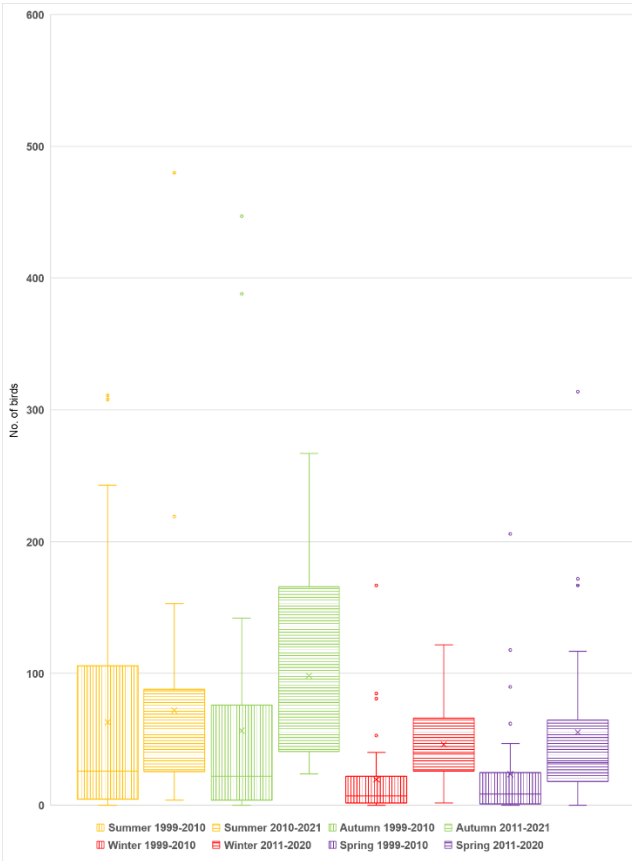
(a) Black Swan



(b) Australian Wood Duck



(c) Australasian Shoveler



(d) Pacific Black Duck

Figure 2. Box and whisker plots for seasonal counts for a) Black Swan, b) Australian Wood Duck, c) Australasian Shoveler and d) Pacific Black Duck in the Hunter Estuary for two time periods: 1999-2010 and 2011-2021.

year time periods but the autumn, winter and spring populations all rose. The differences for winter were statistically significant, and they were highly significant for spring.

Grey Teal

The numbers of Grey Teal in the estuary fluctuated considerably. Sometimes birds were absent or were present only in low numbers, but there were also many influxes when 1,000 or more birds were present (**Figure 4b**). More than 2,000 birds were recorded in April 2005 and frequently during 2014-2018.

The seasonal pattern of occurrence changed over time (see **Figure 5a**). In the first 11-year period of surveys, the numbers present in summer, autumn and winter were similar and there was a statistically significant decrease in spring (mean counts of 55 birds for spring compared with 130-260 birds in the other seasons). In the second 11-year period, the counts for every season increased substantially. The differences for autumn, winter and spring across the two 11-year time periods were statistically significant or highly significant - see **Appendix** for details. There was no longer a trend for birds to depart in spring. The lowest counts occurred in summer even though the summer counts had risen. The difference in summer and autumn counts was statistically significant (mean counts of 309 birds for summer compared with 797 birds in autumn).

Chestnut Teal

Chestnut Teal were recorded in all except four of the 263 surveys. Their numbers fluctuated but it was common for at least 500 birds to be present (**Figure 4c**). On 22 surveys, there were more than 1,000 birds, i.e. more than 1% of the estimated south-eastern population of Australia, and the peak count of 3,856 birds in March 2017 represented almost 4% of that population. All of the counts exceeding 1,000 birds were in summer or autumn, with the majority of them occurring in autumn. The differences between the summer and autumn numbers and those for winter and spring were statistically highly significant (22-year mean counts of 453 birds (summer) and 656 birds (autumn) compared with 173 and 123 birds for winter and spring respectively) - see **Appendix** for details.

The mean counts for autumn and spring rose across the two 11-year time periods but only the spring change was statistically significant (see **Appendix**). **Figure 5b** shows the seasonal counts for the two 11-year time periods.

Australasian Grebe

Birds were absent or present in low numbers from 1999 to mid-2005, and in 2010 and 2019-20. At other times, there were periods during which more than 50 birds were often present (**Figure 6a**), in particular mid-2005 to 2009 and 2011 to 2013. The peak count of 131 birds was in May 2012. In general, when there were many birds in the estuary, most of them were at Deep Pond.

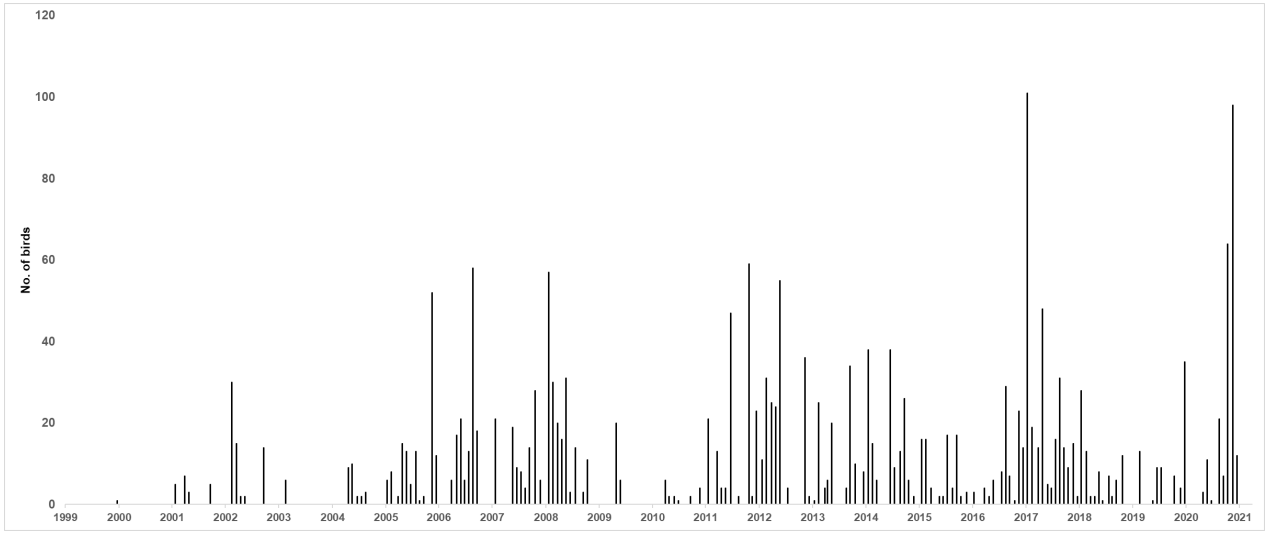
There were fewer birds present in summer than any of the other three seasons (**Figure 5c**). The differences between the summer and either the autumn or winter 22-year means were statistically significant (mean counts of nine birds compared with 18 and 15 birds respectively) - see **Appendix** for details.

For every season, the mean counts for the second 11-year period were greater than for the first 11-year period. However, the changes were only statistically significant for autumn (for which the mean rose from 11 birds to 26 birds) - see **Appendix** for details.

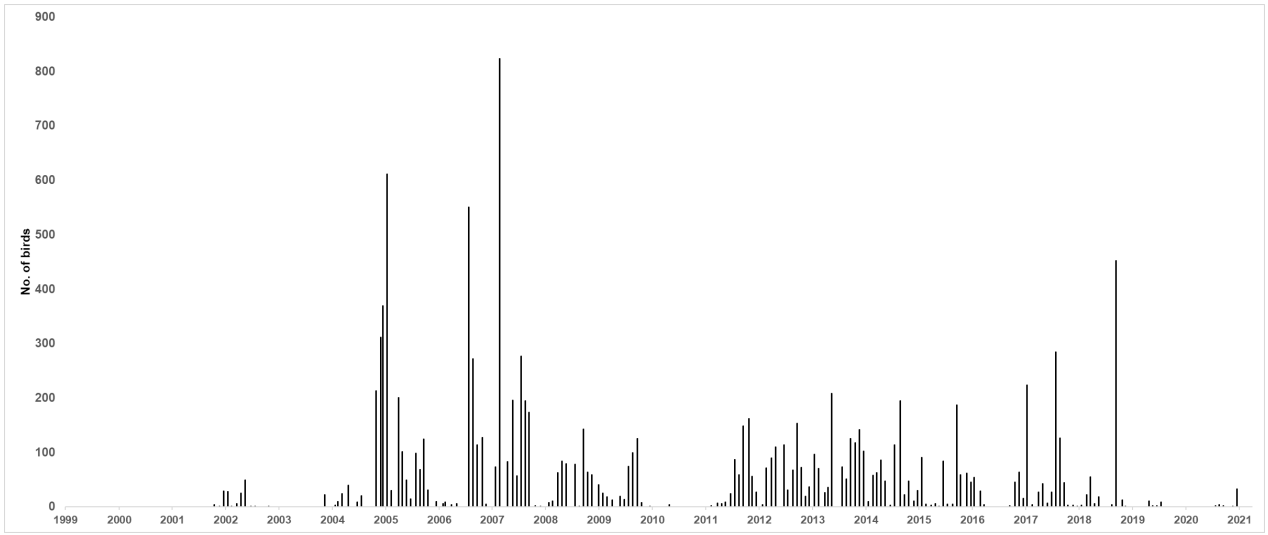
Hoary-headed Grebe

The pattern of records for Hoary-headed Grebe *Poliocephalus poliocephalus* (**Figure 6b**) was broadly similar to that for Australasian Grebe. Birds were absent or present in low numbers from 1999 to mid-2005, and in 2010 and 2019-20, while for 2005 to 2009, 30 or more birds often were present. However, the numbers rose from the beginning of 2005, not from mid-year, and the second period of sustained high numbers spanned 2014 to mid-2017, not 2011-2013 (although some birds had returned by October 2011). In general, when there were many birds in the estuary, most of them were at Deep Pond.

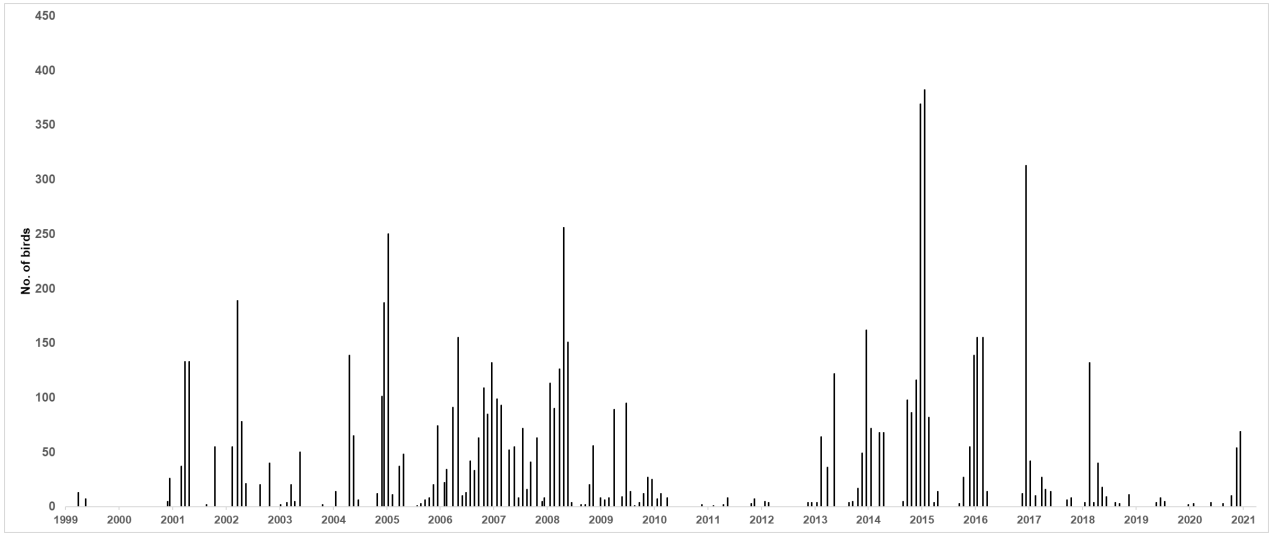
For the first 11-year period there were no significant seasonal differences (**Figure 5d**). In the second 11-year period, the counts rose for autumn and fell for winter and spring. As a result, there was a statistically significant difference to the mean count for autumn (16 birds) compared with either winter or spring (both with means of five birds). Only the changes for spring across the two 11-year periods were statistically significant - see **Appendix** for details.



(a) Australian Wood Duck

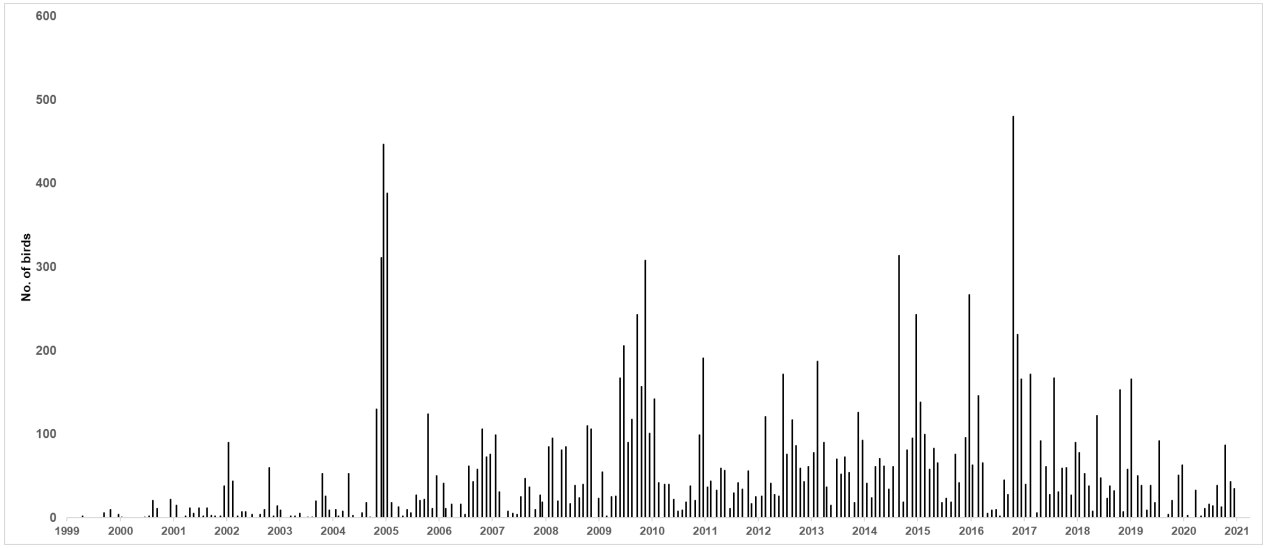


(b) Hardhead

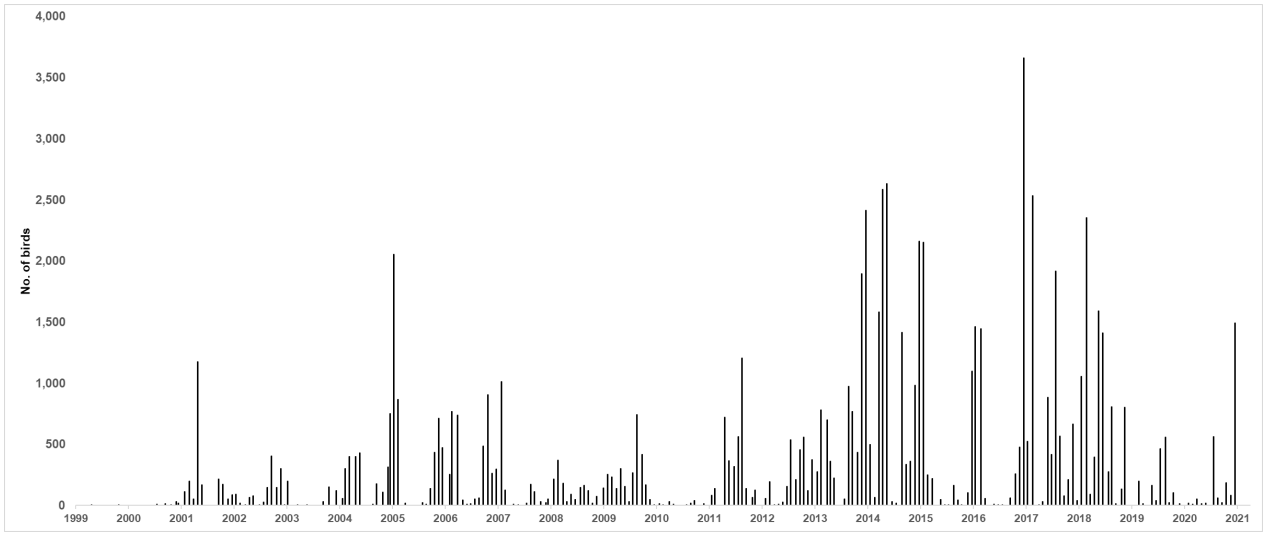


(c) Australasian Shoveler

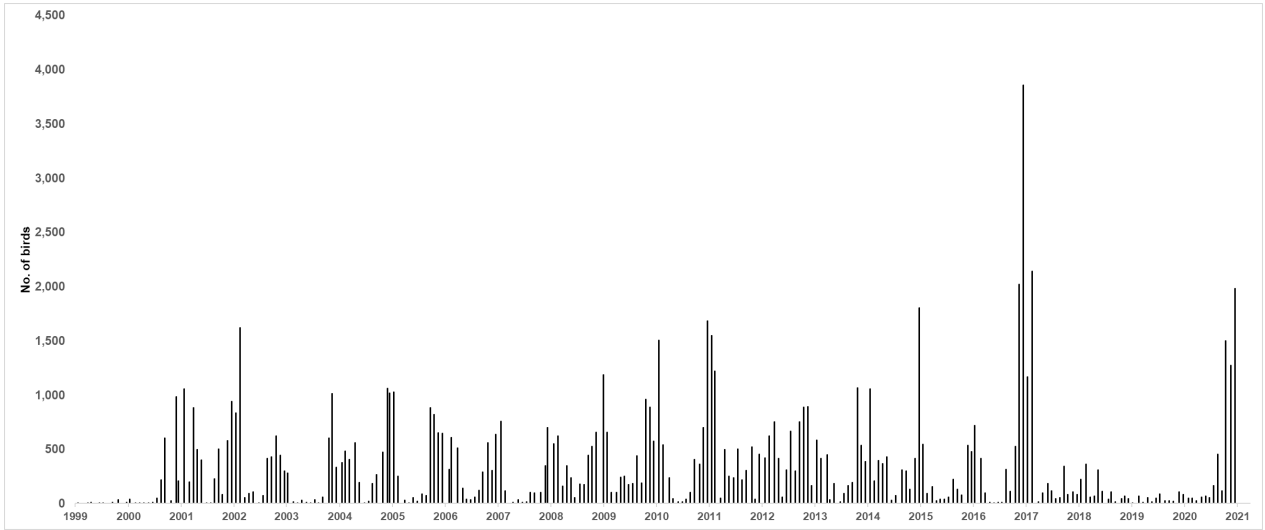
Figure 3. Monthly counts for a) Australian Wood Duck, b) Hardhead and c) Australasian Shoveler in the Hunter Estuary 1999-2021.



(a) Pacific Black Duck



(b) Grey Teal



(c) Chestnut Teal

Figure 4. Monthly counts for a) Pacific Black Duck, b) Grey Teal and c) Chestnut Teal in the Hunter Estuary 1999-2021.

Purple Swamphen

Records of Purple Swamphen *Porphyrio porphyrio* were infrequent prior to 2005. After that, up to 40 birds often were present (**Figure 6c**). During 2011-16 the counts frequently were higher, particularly in 2013-14 which included the peak count of 149 birds in December 2013. There were no statistically significant seasonal differences; however, for every season there was a statistically highly significant increase in numbers for the second 11-year time period compared to those for the first eleven years (as evident in **Figure 7a**; see **Appendix** for details).

Dusky Moorhen

Dusky Moorhen *Gallinula tenebrosa* were recorded less frequently than most of the common waterbirds and usually with fewer than ten birds (**Figure 8**). The peak counts of 36 birds occurred in April 2005 and May 2012. The mean counts for every season were of just 1-3 birds and there were no seasonal trends. The numbers present in any season rose somewhat in the second 11-year period (see **Figure 7b**) but no differences were statistically significant.

Eurasian Coot

Eurasian Coot *Fulica atra* were recorded infrequently until 2012 although with occasional periods of several months where up to c200 birds were present (**Figure 9**). From late 2011 until mid-2016, large numbers were often present including several records of more than 400 birds. The peak count, 1339 birds, was in January 2014. Another influx, of shorter duration, occurred in late 2018 and early 2019.

There were no significant seasonal differences but, for every season the differences in numbers for the first and second 11-year periods were statistically significant or highly significant (**Figure 10**, and see **Appendix** for details). The seasonal means rose from 17-28 birds, to 119-208 birds.

Uncommon waterfowl

Seven of the nine records of Magpie Goose *Anseranus semipalmata* were in summer, with one autumn record (13 March 2021, six birds) and by far the greatest count, of 36 birds, occurring in spring (13 October 2012). All the records were from 2007 onwards.

There were two records of Wandering Whistling-duck *Dendrocygna arcuata* in 2005 (February-March) and one in February 2012; the other seven records spanned 2016-2018. Six of the ten records were in summer months and none were in winter.

A few Blue-billed Duck *Oxyura australia* were recorded in July-September 2005 (the maximum count of four birds was in August) and 2-3 birds were present in July-August 2007.

All six records of Freckled Duck *Stictonetta naevosa* were in summer months, with peak counts of six birds in December 2006, five birds in December 2018 and three birds in January 2006. The three other records were of single birds (in January-February 2014 and December 2017).

Three of the five records for Australian Shelduck *Tadorna tadornoides* occurred in December (one to two birds in 2006 and 2007; four birds in 2020). The other two records were in winter - two birds in May 2012 and a single bird in June 2020.

Of the 13 records for Mallard *Anas platyrhynchos*, eight of them occurred between May 2015 and May 2016 including up to five birds present for May-July 2015. The other five records were of single birds, present intermittently and only briefly each time.

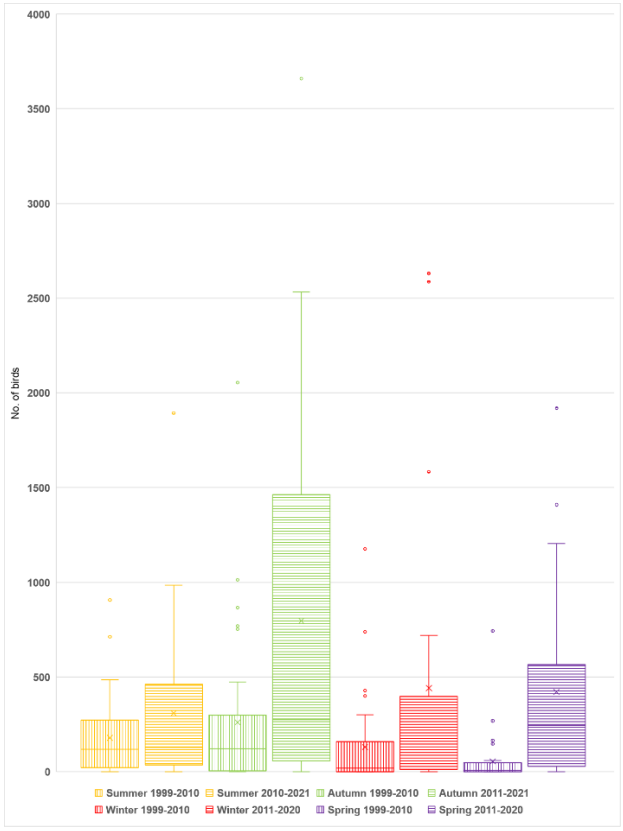
Of the 13 records for Mallard *Anas platyrhynchos*, eight of them occurred in the period from May 2015 to May 2016 including up to five birds present for May-July 2015. The other records were of single birds, present intermittently and each only briefly.

The three records of Great Crested Grebe *Podiceps cristatus* all occurred in late 2007, with two birds present in September-October and one bird in December. All the birds were at Deep Pond.

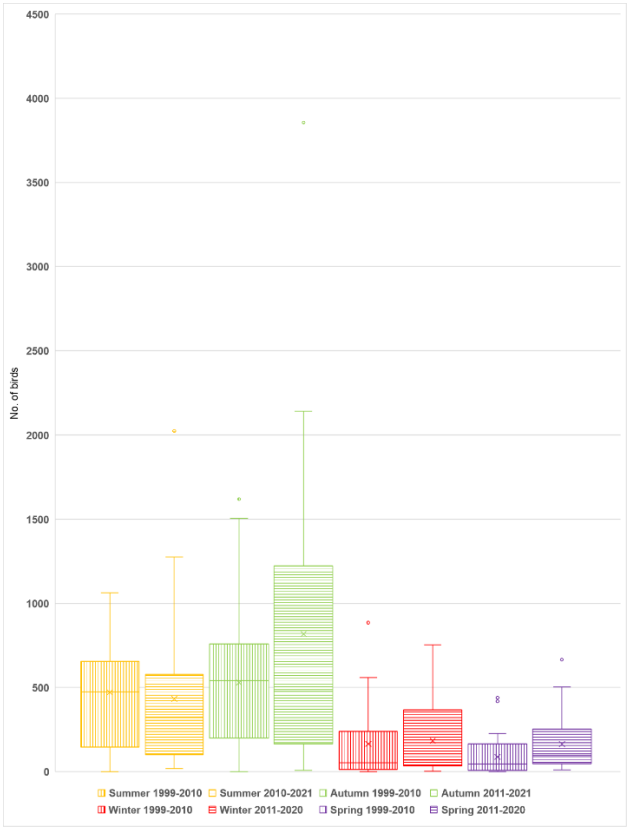
Uncommon crakes and rails

The six records of Lewin's Rail *Lewinia pectoralis* were in spring-summer. They mostly were of single birds; two birds were recorded in January 2021.

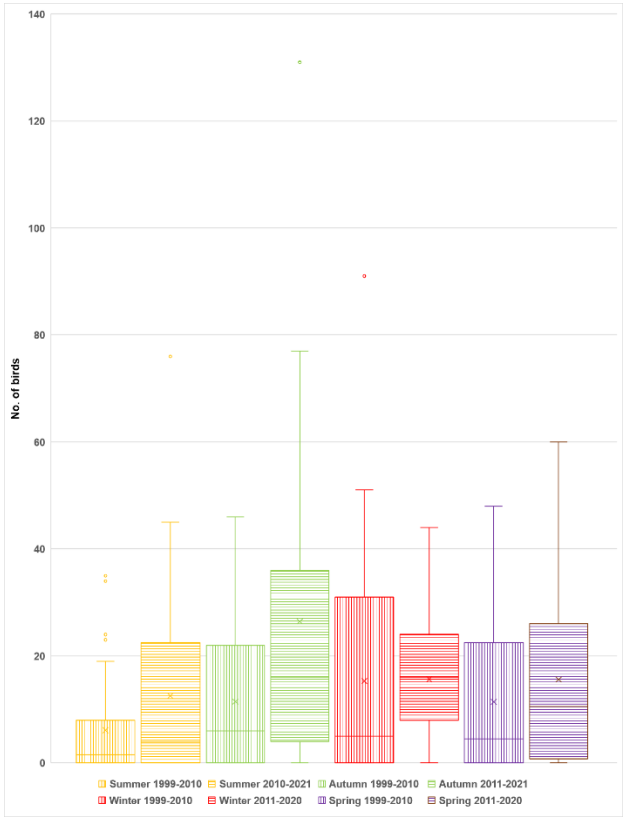
There were 35 records of Buff-banded Rail *Hypotaenidia philippensis*, usually of one to two birds but four birds were recorded in December 2011. There were about twice as many records in summer (with 15 records compared with 6-7 records for any other season). That was also the case for Australian Spotted Crake, with ten of the records being for summer and 4-6 records in each of the other seasons. Sometimes this species was recorded in relatively high numbers, with ten birds found in July 2014 and six birds in September 2014; there were five additional records of three to four birds.



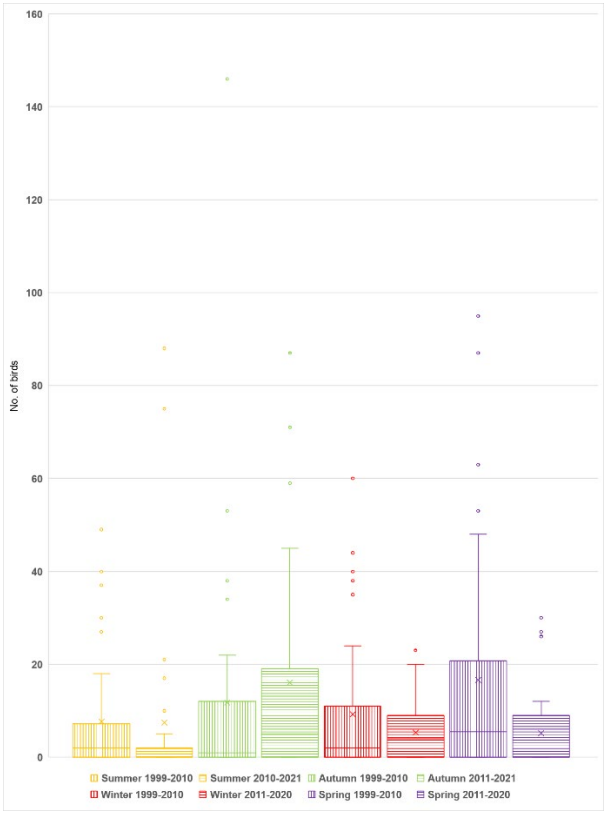
a) Grey Teal



b) Chestnut Teal

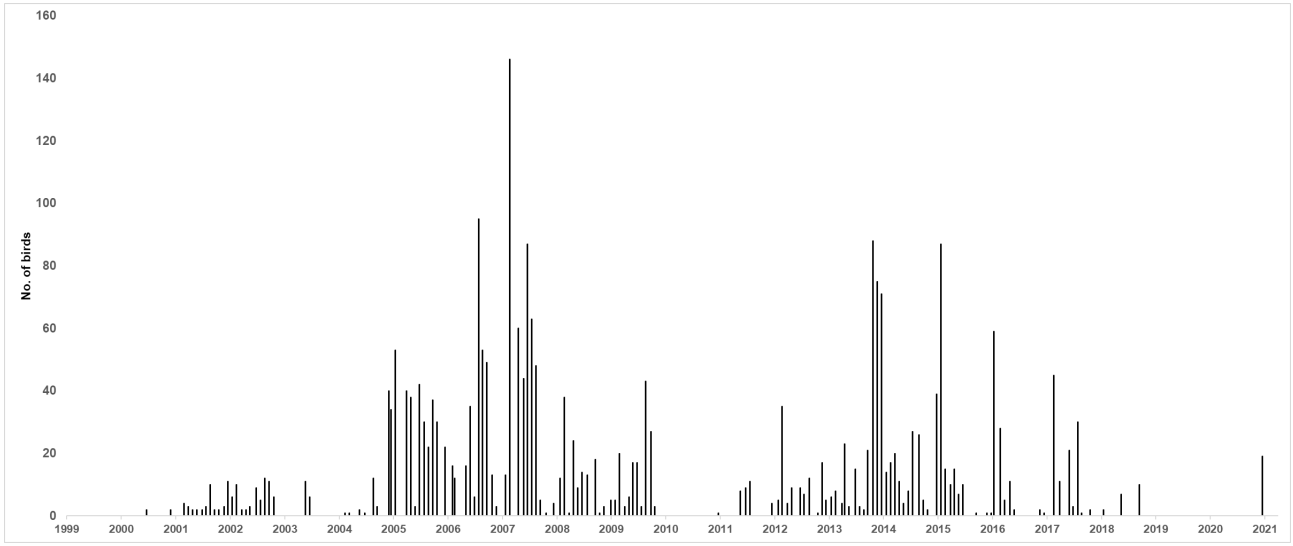


c) Australasian Grebe

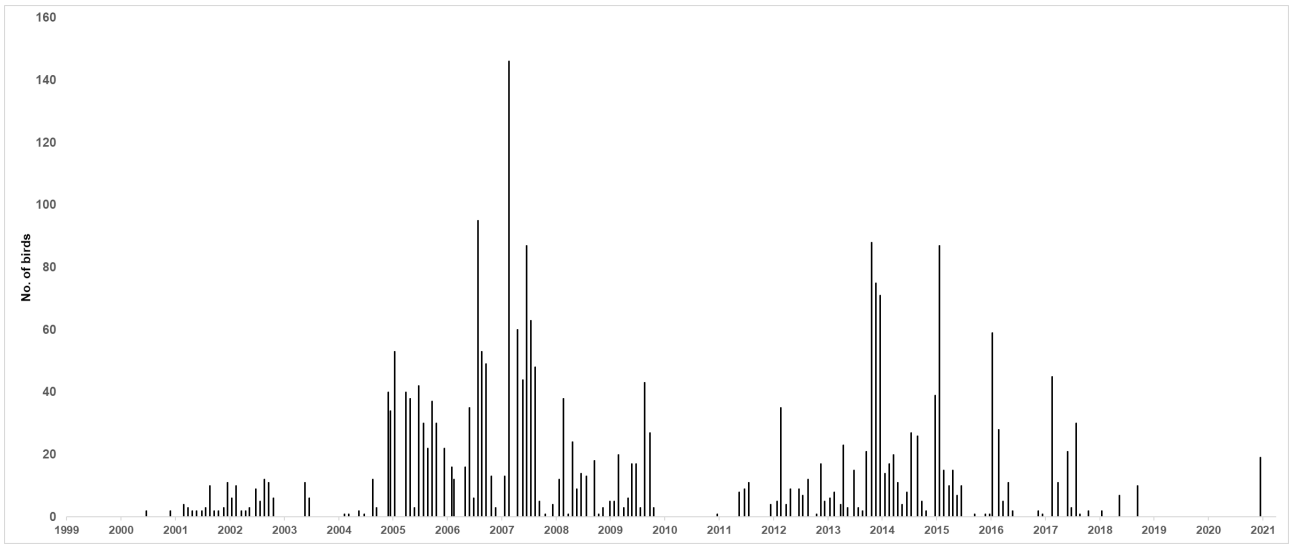


d) Hoary-headed Grebe

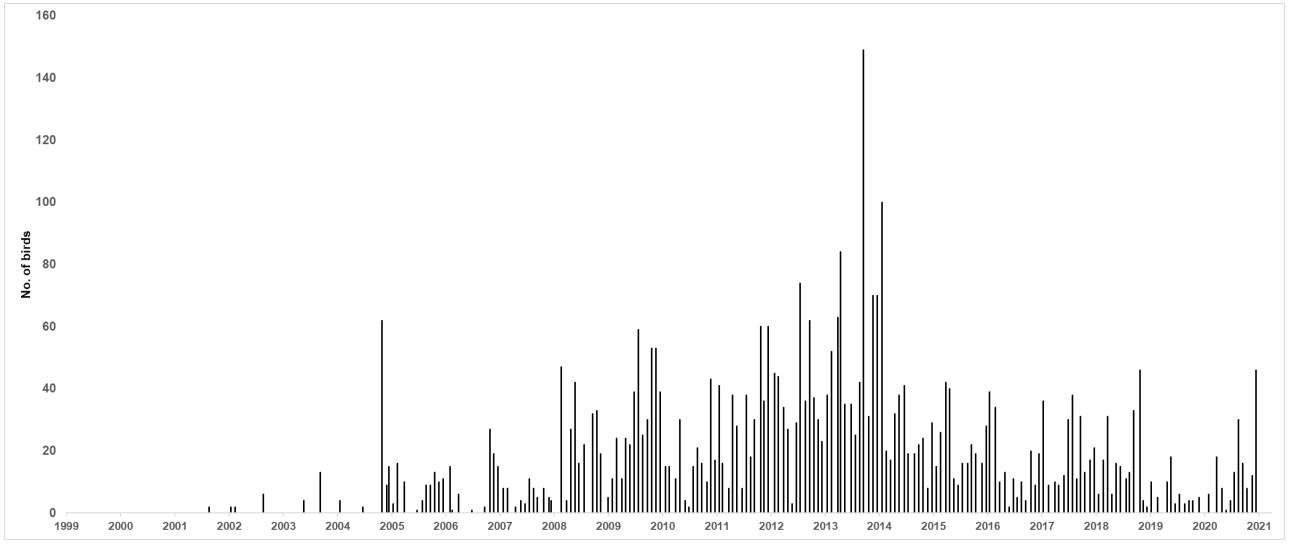
Figure 5. Box and whisker plots for seasonal counts for a) Grey Teal, b) Chestnut Teal, c) Australasian Grebe and d) Hoary-headed Grebe in the Hunter Estuary for two time periods.



(a) Australasian Grebe



(b) Hoary-headed Grebe

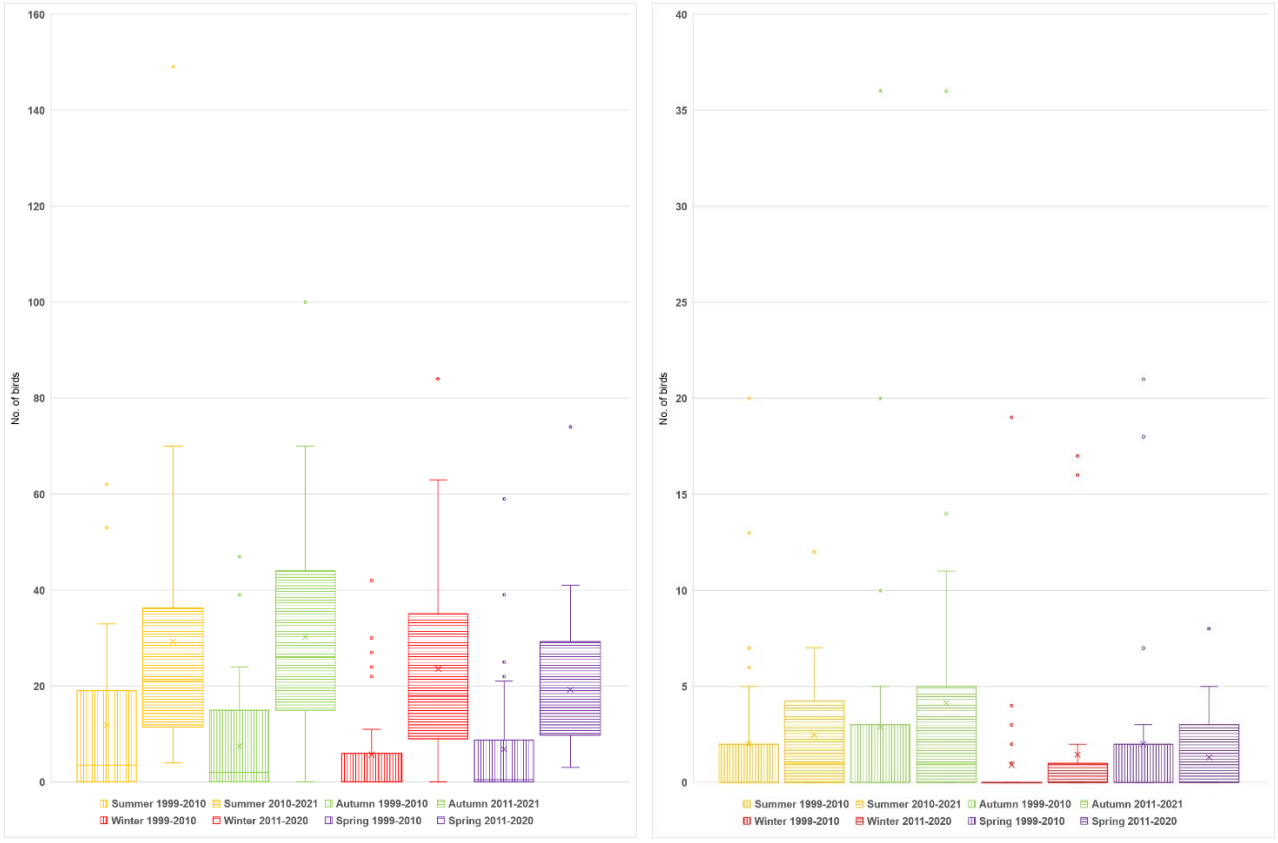


(c) Purple Swamphen

Figure 6. Monthly counts for a) Australasian Grebe, b) Hoary-headed Grebe and c) Purple Swamphen in the Hunter Estuary 1999-2021.

For Baillon's Crake *Zapornia pusilla* there *was* one winter record (in mid-August 2015). All other records were from spring or summer, with four birds recorded in December 2006 and one to two birds in all other records. For the Spotless Crake *Zapornia tabuensis*, there was one summer record, of a single bird in January 2018, and one winter record, of two birds in July 2014. All other records, which were of one to two birds were from autumn (six records) and spring (five records).

The three records of Black-tailed Native-hen *Tribonyx ventralis* involved two occurrences at Ash Island - three birds in May 2005 and a single bird during November-December 2009.



a) Purple Swamphen b) Dusky Moorhen

Figure 7. Box and whisker plots for seasonal counts for Purple Swamphen and Dusky Moorhen in the Hunter Estuary for two time periods.

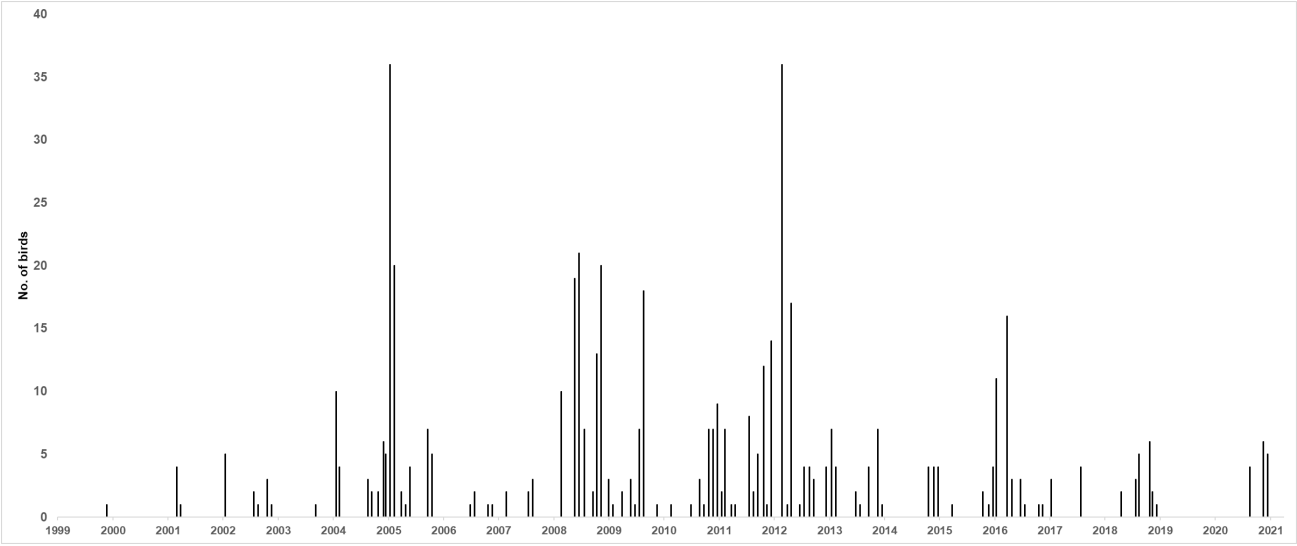


Figure 8. Monthly counts for Dusky Moorhen in the Hunter Estuary 1999-2021.

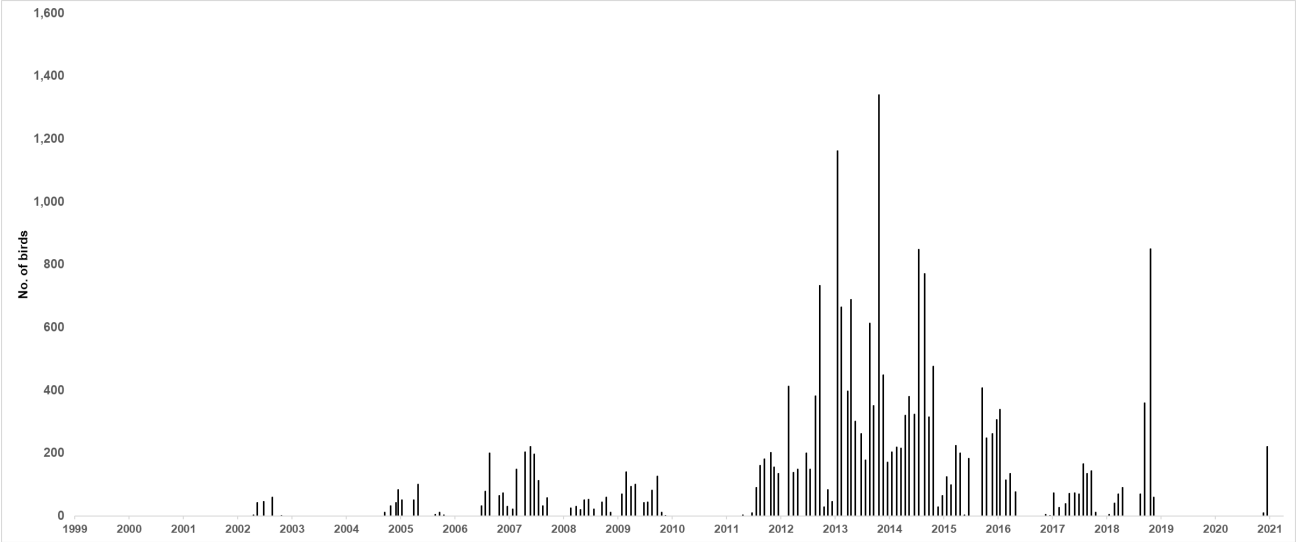


Figure 9. Monthly counts for Eurasian Coot in the Hunter Estuary 1999-2021.

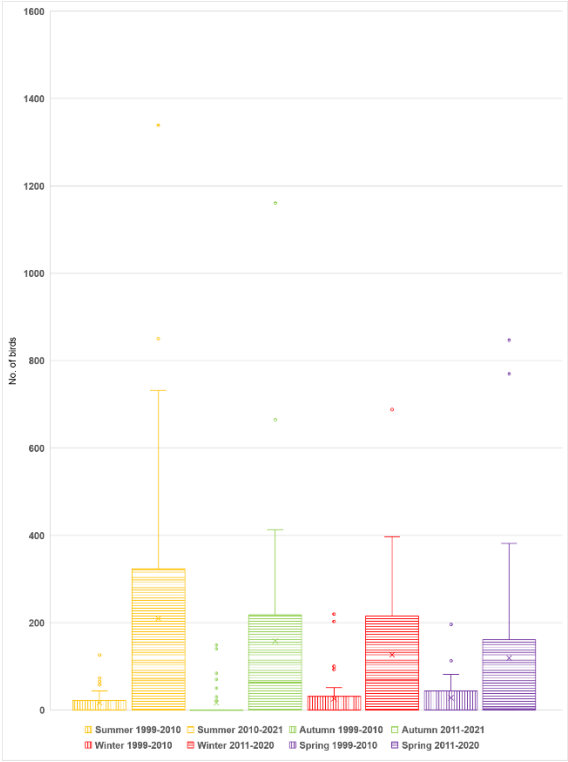


Figure 10. Box and whisker plots for seasonal counts for Eurasian Coot in the Hunter Estuary for two time periods.

Combined results

For the waterfowl, grebe, crake, rail and gallinule species considered in this report, it was common for there to be 500-1,000 birds in total in the estuary and there were many records of considerably more than 1,000 birds. The counts exceeded 4,000 on six occasions, with the peak count being 8,385 birds in March 2017.

Seven species dominated the records. They were Black Swan, Australasian Shoveler, Australian Wood Duck, Pacific Black Duck, Chestnut Teal, Grey Teal and Eurasian Coot. Australasian Shoveler and Eurasian Coot were the least important of those seven species, although still recorded in relatively high numbers (at times) compared with the 20 less abundant species. **Figure 11** is a histogram showing how those seven species dominated the records: for example, on 219 occasions (from 263 surveys) they comprised more than 80% of the total numbers of the waterfowl, grebe, crake, rail and gallinule species recorded in the estuary on that day.

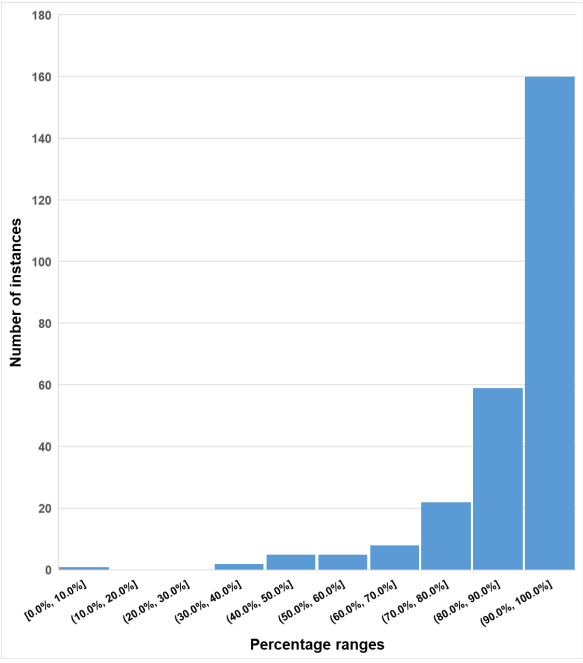


Figure 11. Histogram of records of the seven most abundant waterfowl, grebe, crake, rail and gallinule species in the Hunter Estuary as a percentage of the total numbers of all such species in the estuary, per month.

Seasonal differences

Figure 12 shows the monthly counts for all waterfowl, grebe, crake, rail and gallinule species, for each season. The summer counts were mostly of 500-1,500 birds, with lows in 1999/2000, 2007/08 and 2019/20 and highs (of more than 2,000 birds) in 2004/05, 2006/07, 2012/13-2014/15 (i.e. three summers in a row), 2016/17 and 2020/21. The autumn counts were generally of 1,000-2,000 birds, with low counts in 1999-2000, 2003-04 and 2019-20 and highs (of more than 3,000 birds) in 2005 and 2014-17 (i.e. three autumns in a row). Around half of the winter counts were of 500-1,500 birds but there were seven years with fewer than 500 birds recorded; conversely in five years there were more than 1,500 birds present and the peak winter counts in 2014 were of more than 3,000 birds. Similarly, in nine spring years there were fewer than 500 birds recorded while in six other years the counts exceeded 1,500 birds, peaking at 3,216 birds for spring 2014.

There was a strong bias towards autumn records, as the box and whiskers plots in **Figure 13** show. The autumn means for all waterfowl, grebe, crake, rail and gallinule species, over 22 years, were of 1,583 birds compared with means of 1,069 birds (summer) and 649-775 birds in winter and spring. All of the seasonal differences in means were assessed as being statistically significant or highly significant (see **Appendix** for details). For the first 11-year period the pattern was for summer and autumn counts to be high compared with the winter and spring counts (**Figure 14**). In the second 11-year period the autumn numbers rose substantially. The numbers for the other three seasons also rose but not to the same extent as those for autumn. The differences for autumn in the two 11-year periods were statistically highly significant (see **Appendix** for details).

DISCUSSION

An important consideration relates to the value of the information collected about this group of waterbirds in the Hunter Estuary surveys. Several freshwater wetlands which are known to be important for at least some of those species were not surveyed, e.g. the Hunter Wetlands Centre at Shortland (Lindsey & Stuart 2021). Thus, the data do not present a complete picture about the status of those waterbird species assessed in this paper in the Hunter Estuary. This issue seems more important for these guilds of birds than for the other guilds previously assessed (Stuart & Lindsey 2021; Lindsey & Stuart 2021; Lindsey & Stuart 2021). However, the data were collected systematically and for a well-defined area. Thus, it seems valid to identify trends and compare seasonal and longer-term results, all the while recognising that the information paints a picture about the status of small waterbirds within a subset of their overall habitat mosaic in the lower Hunter Valley.

Threatened species

Three species listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* were recorded in the surveys - Magpie Goose, Blue-billed Duck and Freckled Duck. All were uncommon species in the estuary. The two duck species are uncommon anywhere in the Hunter Region but there is a resident population of about 100 Magpie Goose in the lower Hunter Valley, found mainly at wetlands around Shortland (Williams 2020). This species prefers freshwater wetlands (Marchant & Higgins 1990) and most of the records from the surveys have been of birds at some freshwater swales on Ash Island. Eight of the records were in summer (December to February); however, six birds were recorded in mid-March in 2021 (at Deep Pond).

Population Trends

None of the species analysed were found to have decreasing populations, while seven species significantly increased in number over the course of 22 years of monitoring. These were: Black, Swan, Australian Wood Duck, Pacific Black Duck, Grey Teal, Chestnut Teal, Purple Swamphen and Eurasian Coot. All the increases appeared to be associated with the availability of newly-restored tidal wetlands at Hexham Swamp and Tomago Wetland, and to a lesser extent, at Ash Island, as discussed in the section *Effects of local rehabilitation projects*. However, inland rainfall patterns may also have had an effect, as is also discussed further below.

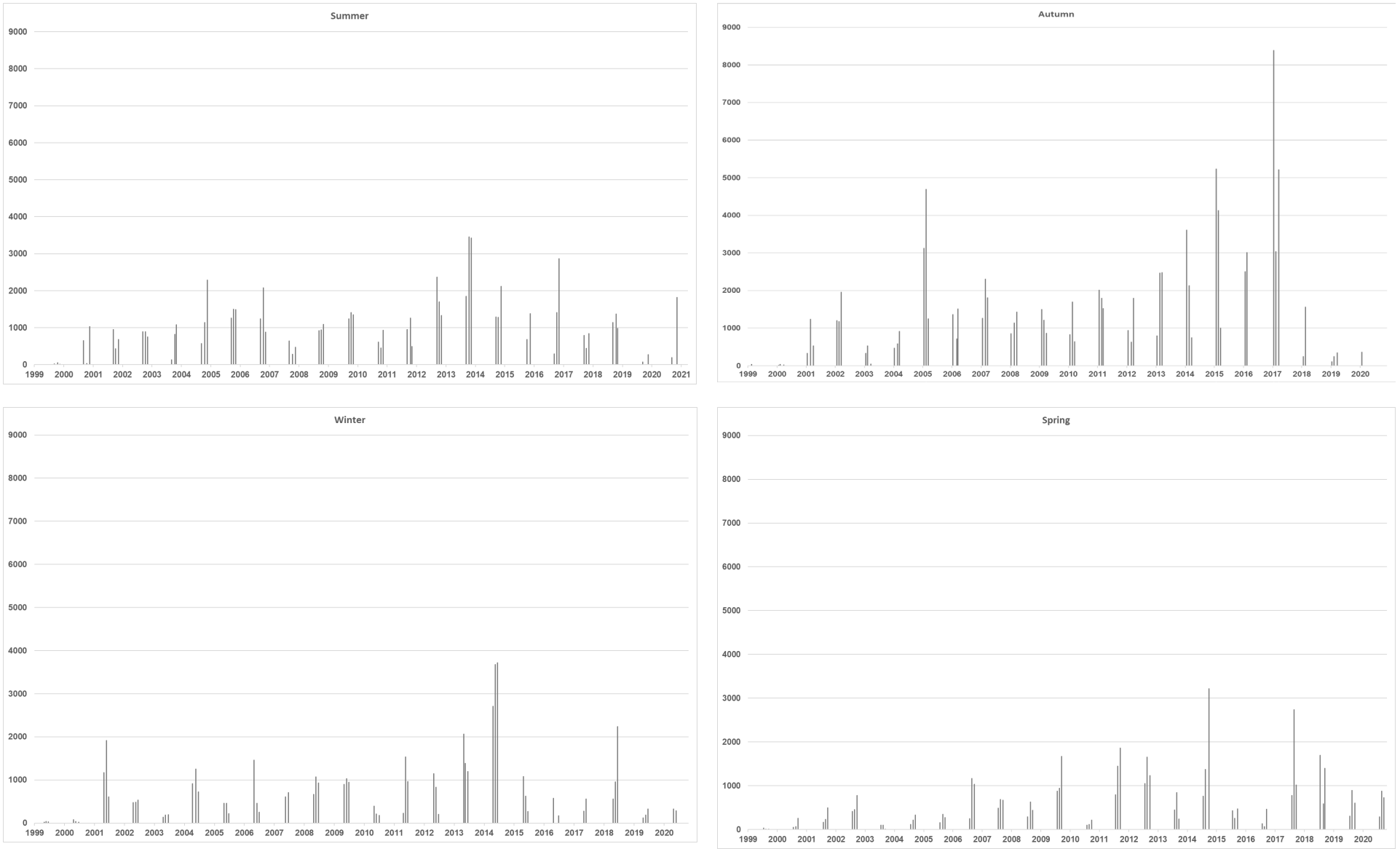


Figure 12. Monthly counts of waterfowl, grebe, crake, rail and gallinule species in the Hunter Estuary for each season.

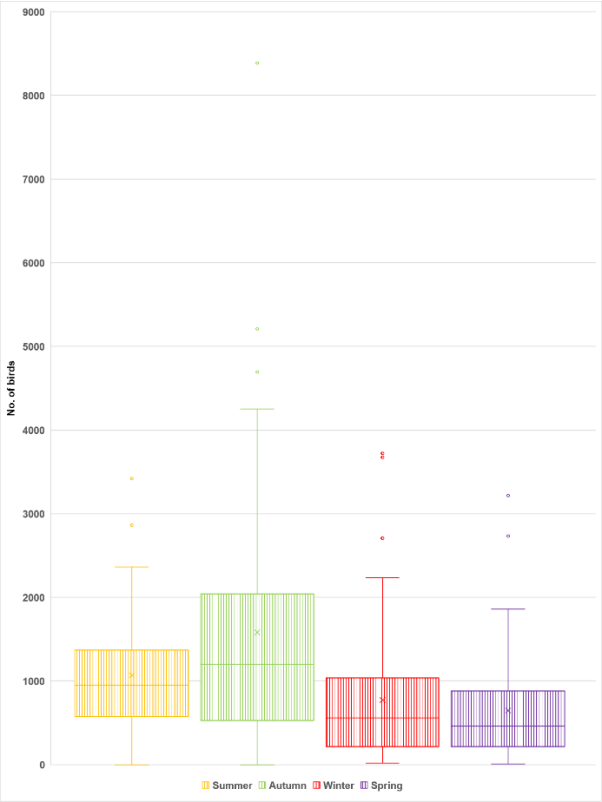


Figure 13. Box and whiskers plots showing the distribution of counts for waterfowl, grebe, crake, rail and gallinule species in each season.

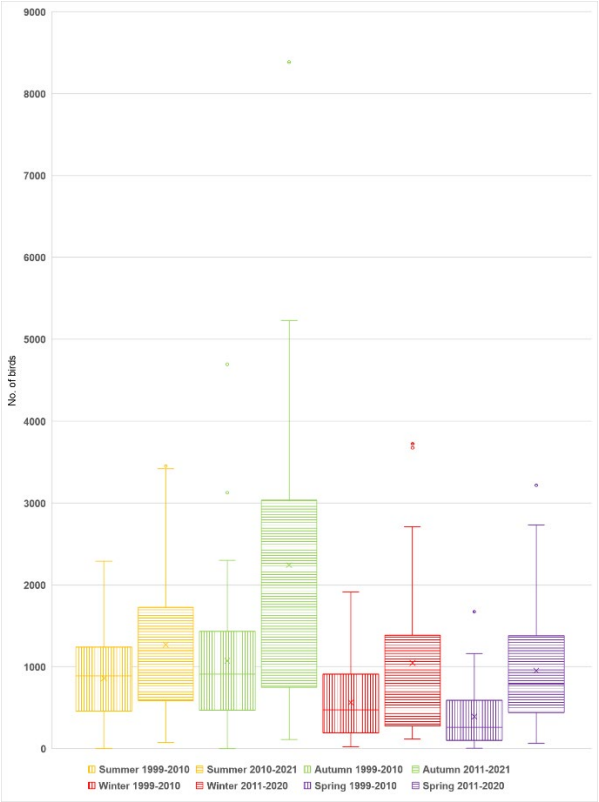


Figure 14. Box and whiskers plots showing the distribution of counts for waterfowl, grebe, crake, rail and gallinule species in each season for two successive 11-year time periods.

Seasonal Population Changes

Seven species exhibited significant seasonal changes in their populations in the estuary, as summarised in **Table 2**. Australasian Grebe numbers declined in summer, but only in the first 11-year period of the surveys, and the counts for Australasian Shoveler were much lower in spring. Five species had highest numbers in autumn (the Pacific Black Duck numbers were higher in summer as well) while Black Swan numbers peaked in winter. The presence/absence patterns have changed over time for Australasian Shoveler, Grey Teal and Australasian Grebe. Grey Teal had no strongly seasonal distribution pattern in the first 11-year period, then in the second 11-years its numbers rose in autumn. In the first eleven years the summer counts for Australasian Grebe were slightly lower than the counts for the other seasons, but in the second 11-year period the differences became statistically significant. The changes for Australasian Shoveler were discussed earlier.

Table 2. Species with significantly different seasonal populations. Symbols ✓ in the table indicate seasons where the population for that species increases significantly. Symbols X indicate seasons where there is a significant decrease.

	Summer	Autumn	Winter	Spring
Black Swan			✓	
Australasian Shoveler		✓		X
Pacific Black Duck	✓	✓		
Grey Teal		✓		
Chestnut Teal		✓		
Australasian Grebe		✓		
Hoary-headed Grebe	X			

The autumn peak for Australasian Shoveler aligns with the results from a two-year study at Western Treatment Plant in Victoria, where there was a tendency for the highest numbers to occur in late summer to early autumn (Hamilton & Taylor 2004). Gosper (1981) noted that there was a seasonal influx

of Pacific Black Duck into the Hunter and Richmond valleys but he found the greater numbers were in the autumn and winter populations rather than the summer and spring ones.

Black Swan are known to breed on the coast between mid-May and October (Cooper *et al.* 2014) and it is possible that the increase in the estuary is due to birds arriving in search of breeding opportunities. However, a study of breeding at two lagoons on the New England Tableland suggested that breeding may be as much about opportunity as about season (White 1986).

Effects of local rehabilitation projects

Habitat for waterbirds is comprised of wetlands and their surrounding edges and these are among the most threatened ecosystems in the world. In common with many countries, Australia has lost extensive areas of wetland habitat (Kingsford *et al*. 2003). In NSW there has been an excessive loss of coastal swamps, and inland swamps are affected by intense grazing by stock (Cooper *et al.* 2014). To address the problem of loss of wetlands, the Ramsar Convention on Wetlands 1971 was established, the broad aim of which was to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain (https://www.awe.gov.au/water/wetlands/ramsar). A part of the Hunter Estuary was declared a Ramsar wetland in 1984. The estuary is in a fortunate position in that, from the 1990s, three significant rehabilitation projects commenced.

The Kooragang Wetland Rehabilitation Project (KWRP) was launched in 1993. Its vision was for:

"an estuary in which healthy, restored fisheries, shorebird, threatened species and other wildlife habitat is in balance with a thriving port, the whole providing opportunities for research, education and recreation" (Svoboda 2017).

As part of this project three sites for rehabilitation were chosen – Stockton Sandspit, Ash Island and Tomago Wetland. The latter became the Tomago Wetland Rehabilitation Project and was managed by National Parks and Wildlife Service. The third major project was the Hexham Swamp Rehabilitation Project which revolved around restoring wetlands on Hexham Swamp.

Although the projects focussed on the reintroduction of tidal flushing and the expansion of estuarine habitat, the major part of the vegetation continued to be influenced by freshwater. For example of the approximately 2000 ha of habitat at Hexham Swamp, only 443 ha reverted to estuarine habitat (Baer 2017). Reinstatement of tidal flushing at selected areas was accomplished at Hexham Swamp between 2008 and 2013 and at Tomago Wetland between 2012 and 2015 (Lindsey 2021).

Overall improvement in habitat may have had positive outcomes for some species such as gallinules and coot and some species of waterfowl such as Black Swan, Pacific Black Duck and Chestnut Teal. Dusky Moorhen, Eurasian Coot, Purple Swamphen and Black Swan showed an overall increase in numbers in the second time period and Black Swan, Chestnut Teal and Pacific Black Duck had reporting rates of over 90%.

There were insufficient sightings of the crakes and rails to draw any conclusions about the effect of the projects on these species. Australian Spotted Crake seems to have disappeared from the areas which received tidal flushing at Tomago Wetland as none has been recorded since 2014. However, it continues to be recorded at Hexham Swamp even in areas which received regular tidal flushing. Lewin's Rail and Spotless Crake continue to be recorded occasionally at Ash Island and Hexham Swamp and Buff-banded Rail is still recorded at all three wetlands. All species are secretive and hard to detect (Marchant & Higgins 1993; Cooper *et al*. 2014) and are recorded more often in the warmer months (Cooper *et al*. 2014). Movements are largely unknown although it has been speculated that Baillon's Crake may undertake a northwards migration in winter (Cooper *et al.* 2014). These species are considered to be irruptive visitors in the Hunter Region and the records for the estuary are in keeping with other reports in NSW.

Some other regularly-monitored areas were not affected by rehabilitation projects e.g. five small freshwater ponds on Kooragang Island which is the industrial portion of the Ash Island/Kooragang Island complex. Of these the now-bisected Deep Pond is the largest. The majority of records for Hoary-headed and Australasian Grebes and Musk Duck are from these freshwater ponds especially from Deep Pond.

Irruptions

Waterbirds respond to changes in wetland availability at the local scale, at the scale of the catchment, and at scales that extend beyond that of individual catchments (Roshier *et al.* 2002). Therefore it is unsurprising that the populations of all waterbirds in the estuary varied considerably.

However, several species had notable irruptions interspersed with periods when they were absent or present only in low numbers. The most obviously irruptive species were Pink-eared Duck, Grey Teal, Hardhead, Australasian Shoveler and Eurasian Coot. The populations of Hoary-headed Grebe and the three crake species also displayed irruptive tendencies but the peak counts for all of them were relatively low.

Pink-eared Duck are highly nomadic and will often rapidly move vast distances to find suitable conditions. They are generally regarded as birds of the interior but will adopt coastal areas in dry conditions (Cooper *et al*. 2014). Influxes to the estuary were modest compared with some inland congregations; e.g. over 29,000 birds were counted on the Bulloo Overflow in 1990 (Cooper *et al*. 2014). The preferred sites within the estuary were freshwater and brackish ponds. The main influxes broadly coincided with influxes at Morpeth Wastewater Treatment Works (Newman 2012, Newman *et al*. 2021). Higher numbers were usually recorded at Morpeth; for instance, over 1,000 birds were present in May 2001 (Newman *et al*. 2021) but none was in the estuary at that time. However, it is likely that birds utilised both areas at different times during the periods when they were present in the lower Hunter. In 2017-2018 large numbers of Pink-eared Duck were recorded at wetlands attached to Shortland Waters Golf Course, peaking at 755 birds in August 2017 and *c* 1,500 birds in September 2018, but no birds were recorded at any sites within the rest of the estuary during either of those irruptions (Stuart 2018; Williams 2019).

Grey Teal has a nomadic existence exploiting the shallow swamps created by local flooding in the inland and then dispersing across the continent when these swamps evaporate. (Conservation, Natural Resource Management & Protected Area Policy Branch Parks and Regions 2018). In a study of their movements it was found birds moved a large distance (up to 343 km) between occupied sites in a short period (hours), and remained in the vicinity of those sites for extended periods, often months (Roshier *et al*. 2006). Irruptions into the estuary may be connected with heavy rainfall events as a result of, for example, East Coast Lows in 2014 and the remnants of Cyclone Debbie in March 2017 in years of otherwise persistent hot, dry conditions. Conversely in March 2011, when there were good conditions inland, there were almost no Grey Teal in the estuary (Lindsey & Roderick 2011).

The Hardhead is a diving duck which prefers deep, permanent lakes and swamps, many of which have been eliminated through flood mitigation works, particularly on the coast (Cooper *et al.* 2014). There is evidence from earlier writers that until 1900 this species outnumbered all other species on the coasts of New South Wales and Victoria (Pringle 1985). The irruptions into the estuary in 2005-2007 and 2019 were towards the end of extended periods of drought when many inland wetlands had dried out.

Irruptions by Eurasian Coot appear to be more complex. This species was recorded in relatively low numbers prior to 2011, and only occasionally was present. However, in the period 2012-16 it was almost continually present and often in numbers of 600-800 birds, peaking in 2013-14 at more than 1,000 birds. These high counts for four years occurred at a time when there was inland drought plus the newly-rehabilitated wetlands in the estuary had become available. That should explain the irruption, yet conditions in the following three years were broadly similar but the coot numbers dropped substantially. The numbers rose again in late 2018 towards the end of the long drought.

The pattern for Australasian Shoveler also appear to be complex. It is a dabbling duck which prefers large permanent freshwater lakes and swamps (Marchant & Higgins 1990). There were frequent records of large numbers (100-250 birds) between 2001 and 2008 which could be considered as irruptions; however, the pattern also fits for an autumn/winter visitor with fluctuating numbers. The highest counts occurred in winter in those years. In the following four years very few birds were recorded in the estuary – this time period corresponded with the breaking of the Millennium Drought and better conditions inland. During 2013-18, with another inland drought underway, birds returned to the estuary in higher numbers; the peak counts of 300+ birds were within that period. Very few birds were recorded in 2019-20 but *c* 50 birds were present in February-March 2021. Overall the pattern could be interpreted as irruptive but it also fits for an autumn visitor with fluctuating numbers. It is notable that the winter numbers were much lower than for 2001-08. Overall it seems that there has been considerable change in the patterns of occurrence of Australasian Shoveler in the estuary, probably arising from a combination of conditions locally and conditions elsewhere in Australia.

Some species accounts

Australian Wood Duck

This is a grazing species and the most widespread duck in NSW. It is associated with most freshwater habitats (Cooper *et al*. 2014) although water is less important to this species than fresh green grass and herbs (Pringle 1985). It is increasingly using small farm dams as breeding and roosting habitat (Caley *et al*. 2022). The increase in numbers in summer and autumn may be the result of its habit of forming post-breeding flocks in late summer (Cooper *et al*. 2014). The increases in numbers for the second 11-year time period, although found to be statistically significant for autumn and spring, were relatively minor and the differences probably were not due to the rehabilitation projects as this species distribution in the Hunter Estuary is largely confined to freshwater sites on Ash Island, Kooragang Island and the pasture land at Fullerton Cove (https://birdata.birdlife.org.au/ accessed 14 March 2022).

Chestnut Teal

Chestnut Teal are widespread in NSW, normally associated with freshwater habitats but they also utilise estuarine wetlands (Cooper *et al.* 2014). In the Hunter Estuary surveys they were regularly recorded at fresh, brackish and fully estuarine sites, and with many breeding records. Birds are regularly found in hundreds in thick mangroves on Ash Island (AL pers. obs.), confirming the utilisation of estuarine habitat by this species.

In Victoria at the Western Treatment Plant there was no discernible seasonal pattern for Chestnut Teal (Hamilton & Taylor 2004). However, in NSW they are reported to congregate in estuaries during autumn and winter and disperse in spring (Cooper *et al.* 2014). The results for the Hunter Estuary are in accordance with the latter observation (although the large numbers of them regularly present in the estuary probably strongly contributed towards shaping the overall NSW outlook).

There were 22 instances of more than 1,000 Chestnut Teal being recorded during the surveys, spanning eleven distinct time periods. Within any of those time periods 800+ birds often were recorded on some other surveys. The estimated population of Chestnut Teal in south-eastern Australia is 100,000 birds, with another 5,000 birds as a south-western population (Wetlands International 2022). Thus, the estuary regularly supports more than 1% of the total population. This meets criterion number six for identifying wetlands of international importance under the Ramsar Convention (https://www.awe.gov.au/water/wetlands/ramsar/criteria-identifying-wetlands). Chestnut Teal was also one of the species listed to support the nomination of the Hunter Estuary as a Key Biodiversity Area, on the basis of the estuary supporting 1% of its total population (Dutson *et al.* 2009; BirdLife Australia 2017). Undoubtedly, the estuary is important for Chestnut Teal. It should also be noted that when high numbers are present in the estuary there are only small numbers of birds at freshwater wetlands elsewhere in the lower Hunter Valley. For example, a survey in March 2011 (Lindsey & Roderick 2011) recorded 4,497 Chestnut Teal, 93% of which were in the estuary (including the freshwater site at Deep Pond).

Grebes

All three species of grebes, Australasian, Hoary-headed and Great Crested, are found throughout NSW and all form flocks from late summer to late winter (Cooper *et al*. 2014). Of the three species Hoary-headed and Great Crested are more likely to be found on more open, deeper water bodies than Australasian Grebe and the latter is less likely to be reported from saline wetlands (Cooper *et al*. 2014). In the lower estuary, however, all three are recorded on both freshwater and saline ponds.

The presence of Australasian Grebe in the estuary is consistent with this general statement with fewer birds in summer than during the other seasons over the 22 years of this study. The greater mean counts for the second 11-year period also support a conclusion that this species is likely to have recovered since the wet years of 2010 and 2011. (Cooper *et al*. 2014).

The majority of records for Hoary-headed and Australasian Grebes were from freshwater ponds on Kooragang Island. Although Great Crested Grebe was recorded only three times during the monthly surveys, there were six additional sightings recorded in Birdata all of which were from Ash Island (https://birdata.birdlife.org.au/ accessed 6 February 2022). It is intriguing to note that the first NSW record of this species with a specific locality documented was from Ash Island. It was registered into the Australian Museum collection in 1875 (Cooper *et al*. 2014).

Local and inland rainfall patterns

The long-term trends for all species analysed indicated that they had stable or increasing

populations. Several species displayed regular seasonal movements. However, all species had shorter-term fluctuations in their numbers. A detailed study comparing local and inland conditions and any resultant effects on bird populations is beyond the scope of the present study. Difficulties in attempting such comparisons include that it is not generally known where birds move to or from, and there are few reliable estimates of inland populations for any given place and time. However, some examples taken at random do point to the importance of the trade-off between local coastal and inland conditions. For example, the peak counts for both winter and spring were in 2014 after a series of East Coast Lows brought heavy rain to the coast, while the peak count for autumn was associated with rain brought by Cyclone Debbie in March 2017. At that time, it had been estimated that the population of waterbirds in eastern Australia had fallen by 90% (ABC News 2019).

The summer counts had the least variability, particularly after the rehabilitated wetlands had become available. The exceptionally low counts for 2019/20 coincided with the final summer of a severe drought which affected all of south-eastern Australia and which was accompanied by a series of devastating bushfires.

Other examples include the low counts for winter and spring in 2010 - this was immediately after the Millennium Drought had broken. Presumably most waterbirds had moved to inland wetlands then and had commenced breeding.

Fullerton Cove

The shorebird species which feed in Fullerton Cove were found to have decreasing populations and we speculated that a reason for that might be the contamination of the benthic substrate by chemicals used for firefighting, with resultant effects on the food chain (Stuart & Lindsey 2021). Those chemicals were used at Williamtown Airport for several decades. None of the species considered in this report forage regularly at Fullerton Cove and the contamination seems to have had no discernible effects on their populations.

CONCLUSIONS

Twenty-seven species from three families of waterfowl, grebe, crake, rail and gallinule species were recorded in systematic surveys commencing in 1999. Of these, ten species had reporting rates of over 50% and seven of those ten species usually accounted for at least 80% of the total numbers present in the estuary in any month.

Most species were found to have stable, albeit fluctuating, populations while the populations of eight species increased. The expansion of wetland habitat through rehabilitation projects has had a positive effect. Three species, Magpie Goose, Blue-billed Duck and Freckled Duck, are listed threatened species - all three were uncommon in the estuary. Five species had greater populations in the estuary in summer and/or autumn, while the population of Black Swan rose in winter.

The monthly surveys do not cover all the freshwater wetlands in the lower Hunter Valley. Many of the species mentioned in this article utilise freshwater wetlands, and some of the species prefer such habitat. To obtain a clearer picture of the population changes of species within this grouping, the monthly surveys should be expanded to include the main freshwater wetlands of the lower Hunter Valley.

ACKNOWLEDGEMENTS

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