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

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

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

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

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

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

INTRODUCTION

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

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

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

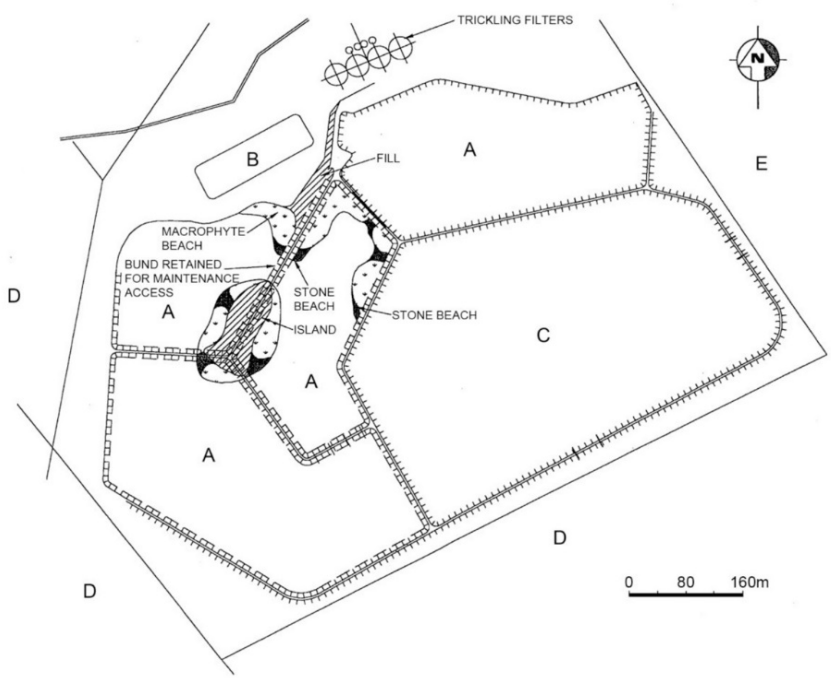

Figure 1. Morpeth Wastewater Treatment Works. (A: ponds with permanent water, B: sludge pond which occasionally dries out, C: ephemeral wetland in bunded area which intermittently floods, D & E: privately owned ephemeral wetlands).

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

METHODS

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

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

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

RESULTS

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

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

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

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

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

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

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

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

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

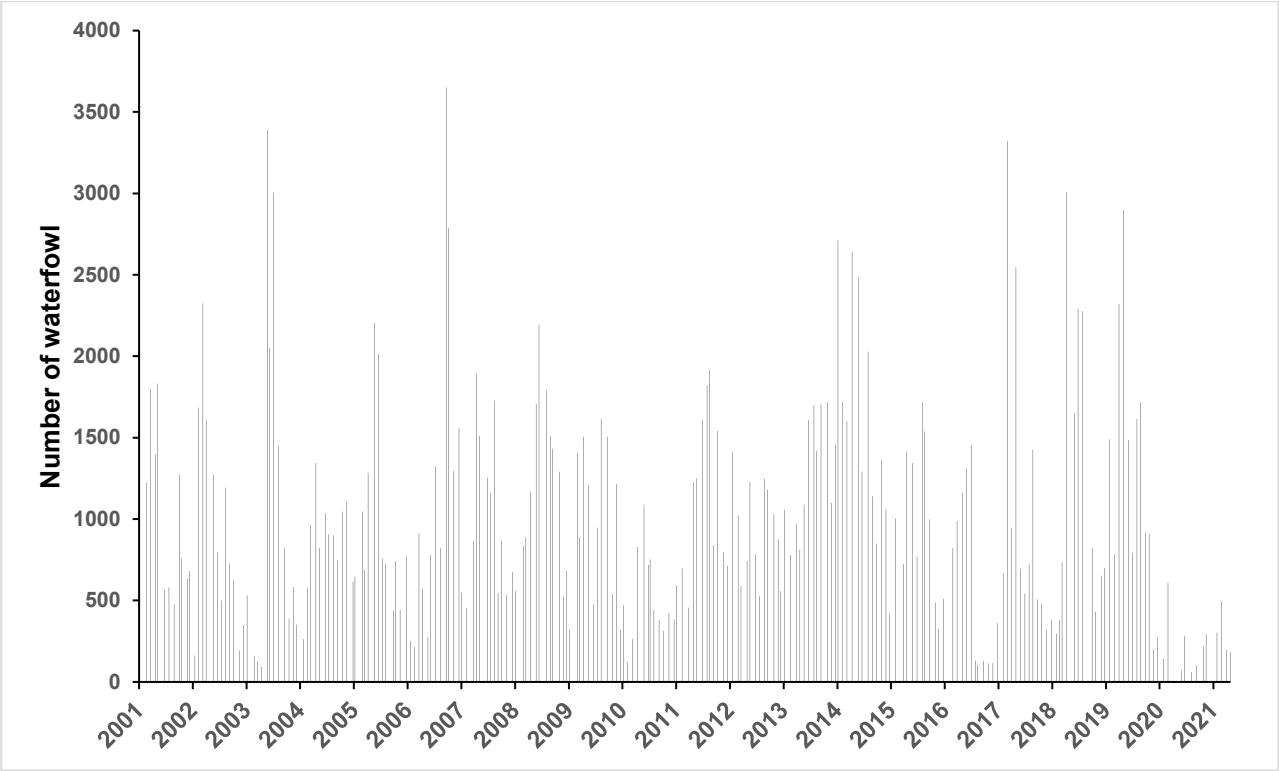

Figure 3. Variation in the number of all *Anatidae* waterfowl present at the Morpeth Wastewater Treatment Works between 2001 and 2021.

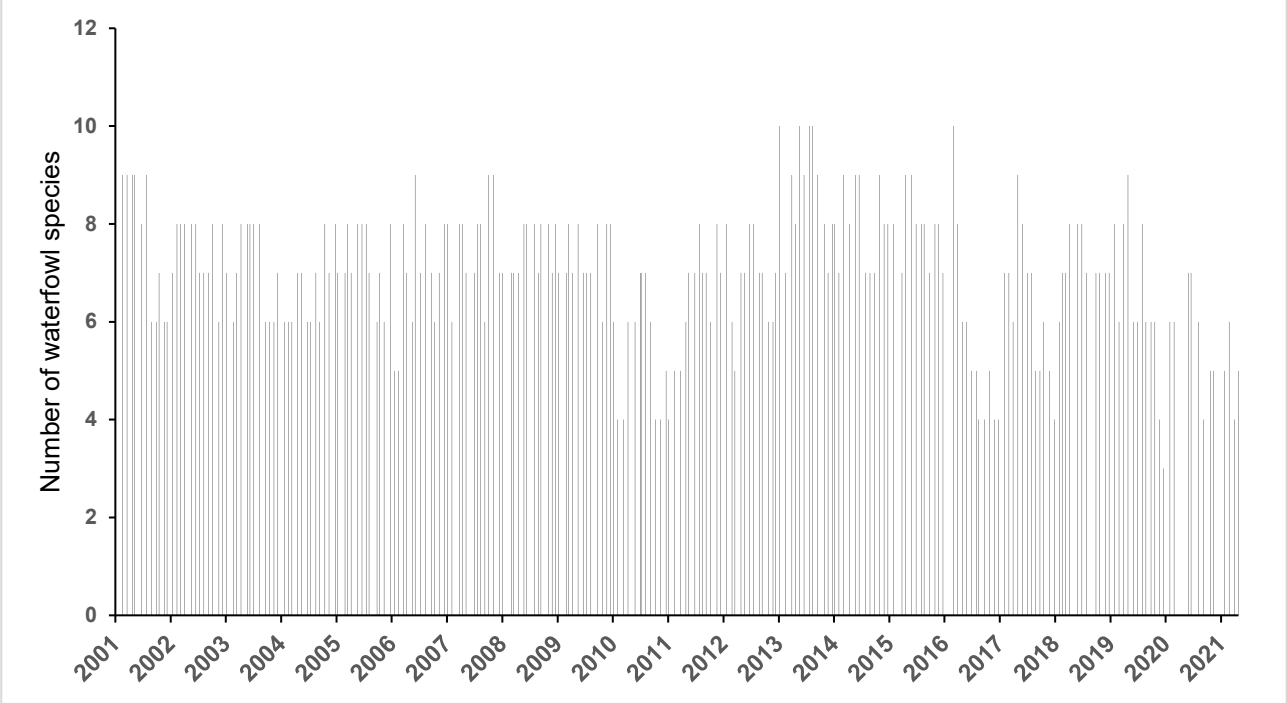

Figure 4. Variation in the number of *Anatidae* waterfowl species present at the Morpeth Wastewater Treatment Works between 2001 and 2021.

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

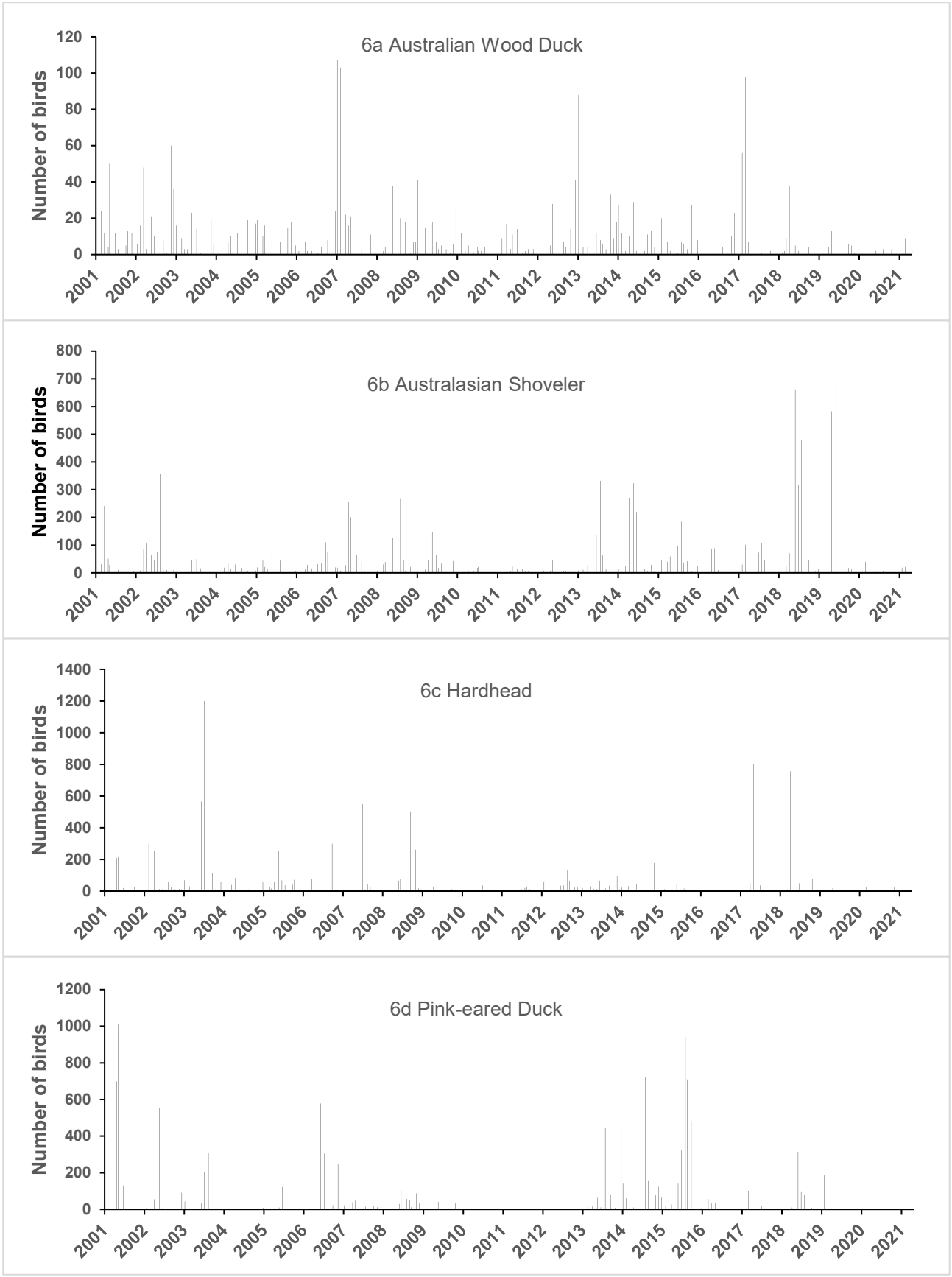

Figure 6. Variation in the numbers of four waterfowl species recorded, either regularly in modest numbers (a) Australian Wood Duck and (b) Australasian Shoveler, or intermittently in considerable numbers (c) Hardhead and (d) Pink-eared Duck for surveys conducted at the Morpeth Wastewater Treatment Works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

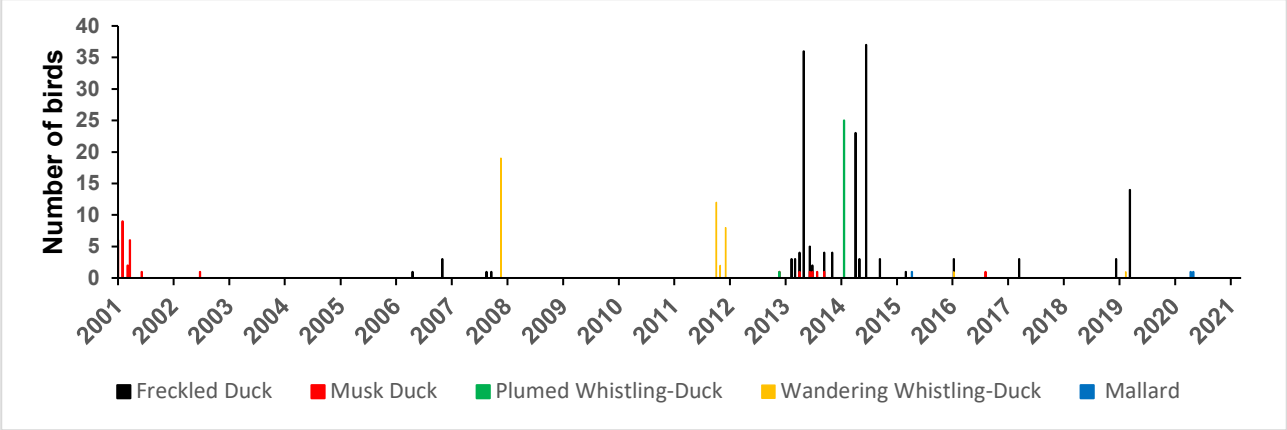

Figure 7. Variations in the numbers of five species of duck which were recorded occasionally during surveys conducted at the Morpeth Wastewater Treatment Works between 2001 and 2021.

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

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

Breeding

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

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

Predator response

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

DISCUSSION

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

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

Changes in habitat at Morpeth Wastewater Treatment Works

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

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

Changes in the Hunter Estuary external to Morpeth Wastewater Treatment Works

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

Common residents

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

Chestnut Teal

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

Pacific Black Duck

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

Black Swan

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

Australian Wood Duck

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

Episodic species

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

Pink-eared Duck

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

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

Hardhead

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

Australasian Shoveler

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

Grey Teal

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

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

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

Uncommon visitors

Musk Duck

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

Freckled Duck

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

Mallard

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

Duration and timing of peak numbers

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

Population trends

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

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

Maintenance as wetland habitat

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

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

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

CONCLUSIONS

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

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

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

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

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