2020-2021 Annual Waterfowl Quota Report to the Game Licensing Unit, NSW Department Primary Industries

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More information

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Cover image: Patrick O’Brien

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Introduction

In NSW, ten native duck species can legally be harvested for the purpose of damage mitigation to promote sustainable agricultural management primarily in the rice growing region of the Riverina. Under the Game and Feral Animal Control Act 2012 (GFAC Act), the Game Licensing Unit (GLU) is required to set annual quotas "on the basis of the best scientific information available of the estimated regional population of native game birds 32D(2)(a)." The role of the Vertebrate Pest Research Unit within the NSW Department of Primary Industries is to assess current methods for establishing population estimates of waterfowl in NSW and to recommend an annual quota to the GLU. In addition, the Vertebrate Pest Research Unit will provide the GLU with a framework for ongoing estimation of waterfowl populations, which can be used to derive a sustainable harvest quota into the future.

No harvest can be guaranteed as being sustainable, but the risk of over-harvest can be minimised with appropriate monitoring and careful consideration of population dynamics. Harvesting strategies that support sustainable practices should include sources of uncertainty in decision making processes. Sources of uncertainty include monitoring bias, lack of precision in estimating total numbers of waterfowl seen, density dependent and independent factors likely to influence population dynamics and the effect harvesting has on population viability. Additional input factors that are important when establishing population models include fecundity, mortality rates (both natural and harvest related), rates of immigration and emigration as well as species responses to these variables are important when establishing population estimates and these factors will be further investigated into the future.

For the 2020-2021 quotas we conducted surveys of waterfowl within the Riverina region of NSW. Unmanned Aerial Vehicles (UAVs) were used to survey larger irrigation dams, wastewater treatment ponds and lakes in May 2020. A helicopter was used to survey small farm dams (<5 ha in size) as well as a small portion of the irrigation channel network in July 2020. The numbers of waterfowl observed from the sample of waterbodies was extrapolated to the Riverina region (Figure 1) to establish an estimate of abundance for each species for the region.

In this report, we present abundance estimates and a suggested quota for nine waterfowl species (Grey Teal, Pacific Black Duck, Hardhead, Pink-eared Duck and Australian Wood Duck, Australian Shelduck, Blue-winged Shoveler, Chestnut Teal and Plumed Whistling-Duck).

Methods

For the 2020-2021 quota, we refined our methodology based on the 2017, 2018 and 2019 surveys. Given the frequent occupancy of smaller farm dams by waterfowl, especially the three most common species (Australian Wood Duck, Grey Teal and Pacific Black Duck), we surveyed 1,412 small farm dams and 63.4 kilometres of channel system across the Riverina region from a helicopter. In addition, we assessed the presence of water in larger dams, wastewater treatment ponds and lakes across the Riverina region and sub-sampled a proportion of these (those holding water) using UAVs and on-ground observation. The observed numbers of waterfowl collected from this stratified sub sample of waterbodies has been extrapolated to the entire Riverina region to establish an estimate of abundance for each species.

Survey region

In NSW, most waterfowl are harvested from the Riverina region (Figure 1), so estimating abundance within this region is important for calculating quotas. There are three separate irrigation districts within the Riverina region, and the large irrigation dams in particular generally fall within these regions (Figure 2).

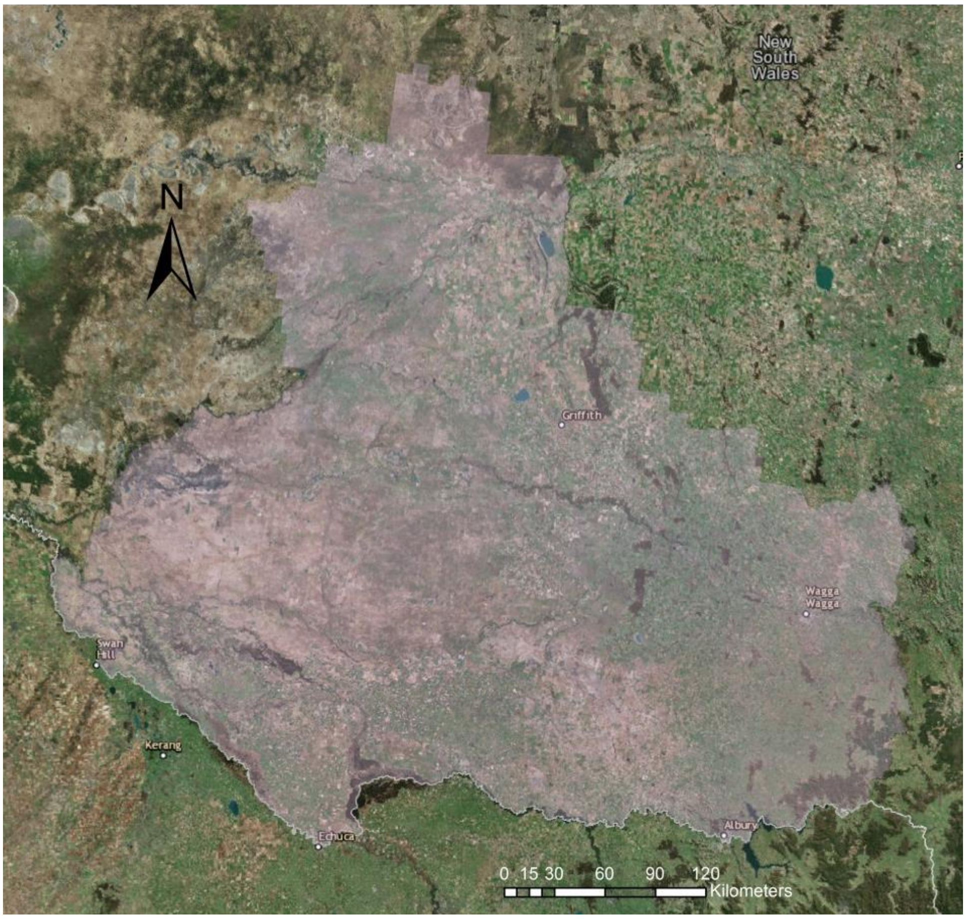

Figure 1: The area defined as the Riverina region as indicated by the Bureau of Meteorology forecast areas (Bureau of Meteorology).

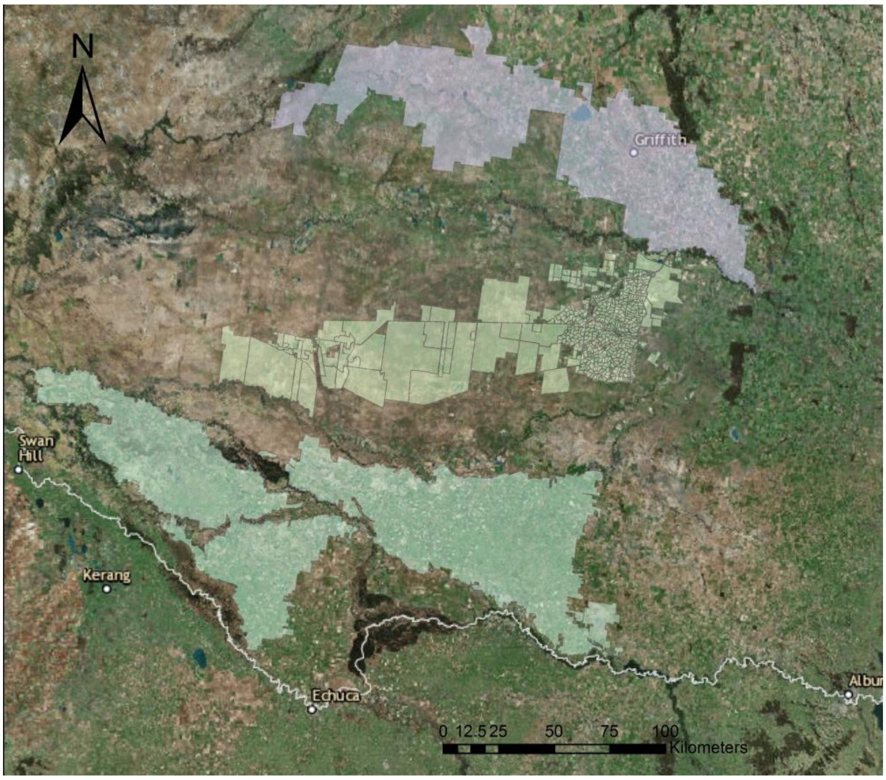

Figure 2: The designated areas of operation for the three irrigation companies located in the Riverina; Murrumbidgee Irrigation (top, pink), Coleambally Irrigation (centre, yellow), Murray Irrigation (bottom, green).

Selection of dams and waterbodies to survey

All waterbodies and dams within the Riverina region were mapped and categorised by size (small 0-4.9 ha, medium 5-9.9 ha, large 10-49.9 ha and extra-large 50+ha) and combined with mapping layers for wastewater treatment ponds, natural lakes and wetlands (Bureau of Meteorology 2013; Kay, Carter *et al.* 2012).

The process for selecting small dams to be surveyed using a helicopter involved stratifying small dams (<4.9 ha in size) into 0.5° longitude x 0.25° latitude grid blocks (Figure 3) across the Riverina region. Within selected blocks we chose a random sample of dams to survey with consideration of proximity to airports for helicopter refuelling stops. For the 2020 helicopter survey, we surveyed 1,412 dams from the 47,510 small farm dams mapped across the Riverina region (2.97% survey effort). We revised the mapped shapefiles for all dam sizes in 2020 to ensure all dams were allocated to the correct size class, to remove dams that had been filled in and to add newly created dams.

To determine which larger irrigation dams in the Riverina region we could survey using UAVs, (with complementary ground surveys), the presence of water within dams (as well as the proportion of dry dams for each size class) was determined using Landsat imagery taken within the preceding month of the survey. From this, we selected a sample of large irrigation dams from three size classes (Medium = 5-9.9 ha, Large = 10-49.9 ha, Extra-large = 50+ha). As a high proportion of dams were dry this year, we surveyed every larger dam we could gain access to.

We selected a range of different sized wastewater treatment ponds across the Riverina region. Following the 2017 survey, we established that there was a correlation (r = 0.89) between the number ducks present on wastewater treatment and surface area of water in ponds. Due to CASA (Civil Aviation Safety Authority) restrictions on flying zones, we excluded wastewater treatment ponds in close proximity to airports from the drone surveys.

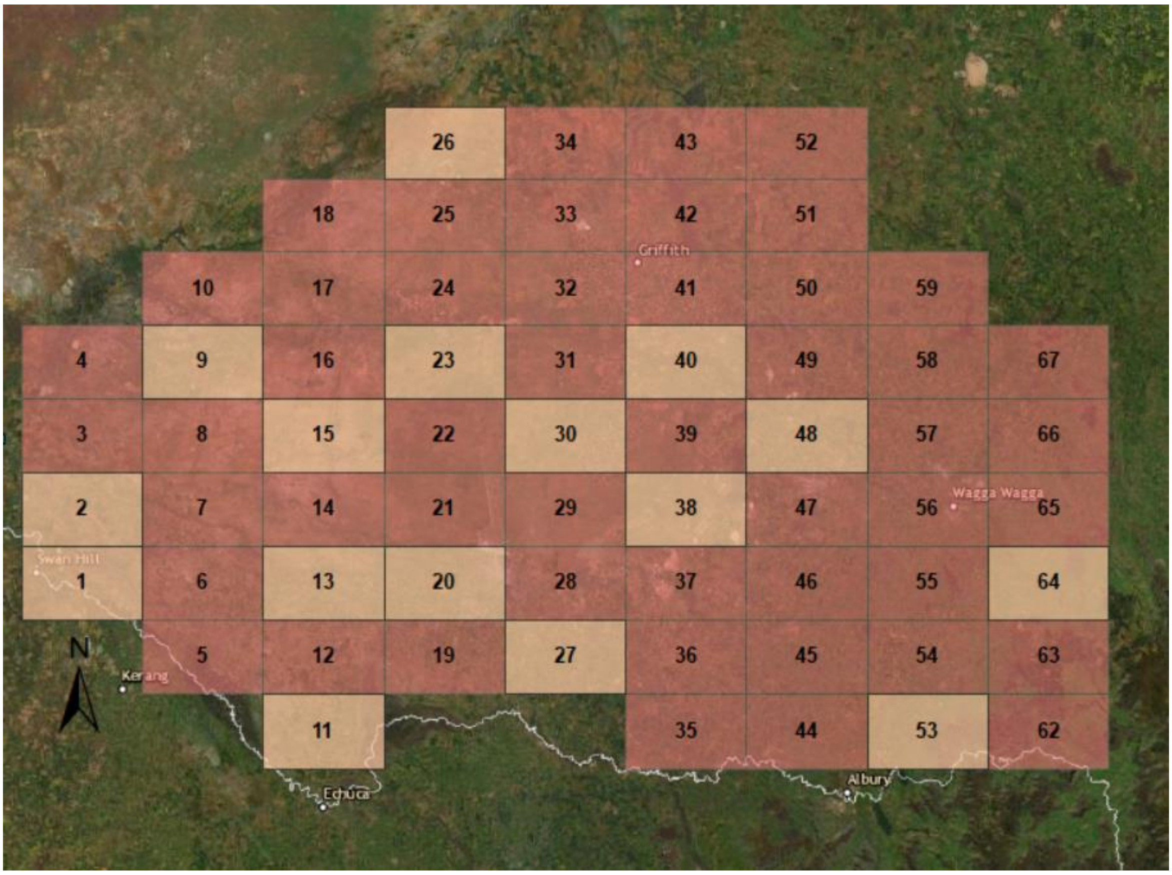

Figure 3: Grid blocks (0.5° longitude x 0.25° latitude) projected across the sampling area. Sixteen blocks were selected to be sampled. A random sample of dams within each block was selected to be surveyed.

We selected three natural lakes within the Riverina region to survey for the 2020 survey. Many of the lakes within the survey region were dry at the time of the survey (Lake Urana, Lake Cullivel and Lake Coolah). We were unable to access Barrenbox Swamp for the survey in 2020. Lake Brewster which is usually dry was holding water this year. Lake Cowal also had some shallow water this year.

We carried out UAV surveys at Lake Cowal, Lake Brewster and Tombullen water storage.

Helicopter surveys

Within each survey block, we randomly selected about 100 dams (Figure 4). The final number of dams per survey block depended on keeping the total transect length to less than 320km or a flight time of<2.5 hours (limited by the fuel capacity of the helicopter). Dams holding no water and those with water but not occupied by waterfowl were noted. For dams with waterfowl, we flew a low circuit around the dam to allow observers to identify and count waterfowl on small dams. For the July 2020 count, we used a Bell 407 helicopter which allows for three observers to be seated on the same side of the helicopter. All aerial operations were conducted with the doors off as this allows for better visibility of ducks for all observers.

Data collected during the helicopter surveys represents a multiple observer count (with two observers, front and back, making simultaneous observations and logging species counts on Xbox controllers and GPS enabled tablets) and a third observer facing backwards between the front and back observers recording covariate data that potentially influences detection probability and the presence of waterfowl (e.g. habitat around dams, presence of livestock). Survey data were analysed using the package `unmarked` (Fiske and Chandler 2011) in the statistical programming language R (R Core Team 2020).

The function `pcount` from the R package `unmarked` was used to estimate abundance of waterfowl using an N-mixture model (Royle 2004). N-mixture models can be used for estimating abundance in closed populations of unmarked individuals and where there is uncertainty in the count process (estimation of abundance) and the detection process. The N-mixture model approach assumed that waterfowl counts represented replicated point-count estimates and that the counting process was a function of covariates that affected detection and could change from one survey to the next (e.g. observer, the presence of glare on the water surface etc) and covariates that were site dependent and were fixed (e.g. the presence of grass, crops or trees etc).

The function `pcount` calculates the probability of detection given that a species is present at a waterbody and an estimate of the mean number of individuals per dam. In addition, the total population size and confidence intervals around the estimate, for the dams surveyed, were calculated using empirical Bayes methods (Fiske and Chandler 2011). Detection probability and mean abundance per dam were estimated from the 'best' model (based on AIC).

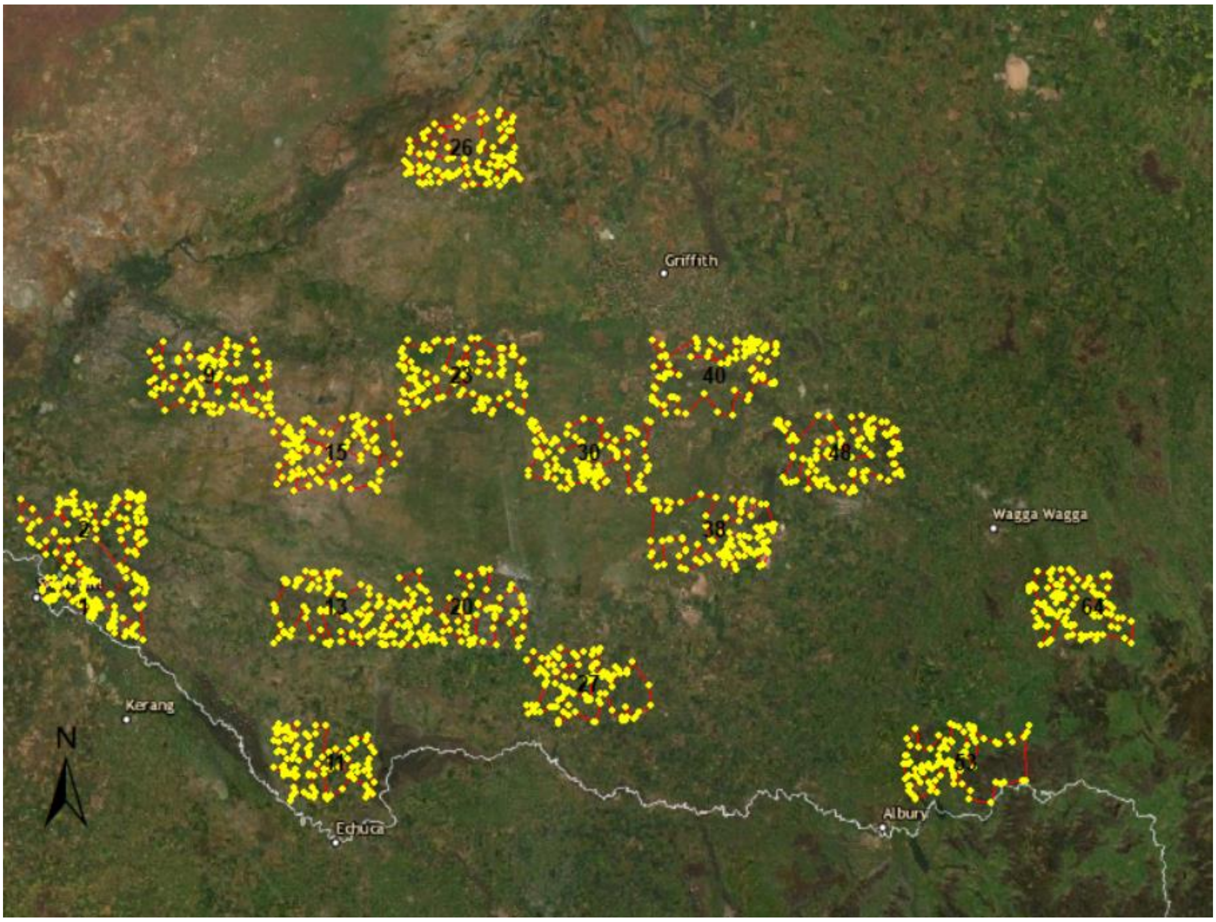

Figure 4: Map of helicopter transects and sample dams, July 2020.

Drone surveys

Unmanned aerial vehicles are particularly suited to sampling medium and large waterbodies (> 4.9 ha surface area). However, there are restrictions on using UAVs, specifically the requirement to have landholder permissions to fly UAVs on private property and the restrictions related to flying UAVs in restricted airspace, especially around airports.

For the 2020 survey, we used a DJI Matrice 210 UAV with an X5S camera. These UAVs have a 20MP camera and can record high resolution video footage in 4K at 60fps which gives us the required resolution to identify ducks to species (Figure 6).

We used the DJI Pilot app to define a survey grid for each surveyed waterbody. For each selected dam or wastewater treatment pond, the UAV was flown in a grid pattern with the aim of surveying all waterfowl present on the dam or pond. For the wastewater treatment ponds, we calculated an average number of each species per ha of surface area surveyed (60ha) and extrapolated this to the total surface area of all wastewater treatment ponds in the Riverina (total of 153 ha of surface water). For natural lakes, we surveyed a sub-sample of the lake with the UAV and calculated the area of the lake covered during the survey. We then extrapolated these counts to the entire lake, taking into account current water level (as determined from recent Landsat images).

We aimed to collect video footage of waterfowl across each dam while they were on the water by flying the UAV as close as possible without causing them to fly away. Depending on the reaction of waterfowl to the drone, the survey height of the drone was varied (20m-35m). Flying at a faster speed (20-25kph) also reduced the amount of disturbance to waterfowl sitting along banks or on water.

We analysed the video using a custom program (Birdtags, Mathworks) using the MATLAB software. For each video, one observer went through all videos manually and extracted videos with waterfowl present. Two observers then went through all sub videos and independently identified and tagged all waterfowl seen. The total area of the dam covered by the footprint of the drone was calculated and the counts were adjusted to represent 100% for each dam. The program then automatically outputs the resulting data into an Excel spreadsheet. In some cases, very few ducks were present on the dams, and these were surveyed by ground counts only, where two observers carried out independent counts using a spotting scope.

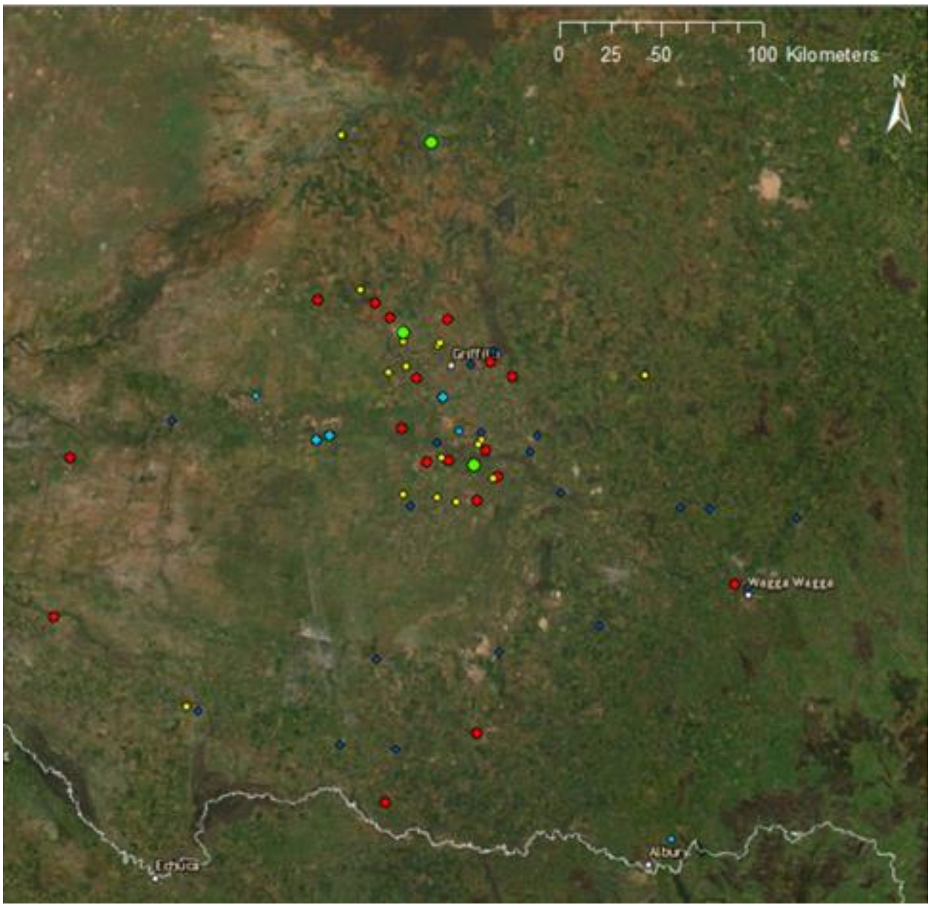

Figure 5: Medium dams 5-9.9 ha (yellow dots), large dams 10-49.9 ha (red dots), extra-large dams 50+ha (light blue dots), natural lakes (green dots) and wastewater treatment ponds (dark blue dots) surveyed using the drone during the July 2020 survey.

Figure 6: Still image example from the UAV survey of ducks. These are primarily Plumed Whistling ducks with some Pacific Black Duck. Videos collected from the UAV are processed using the custom MATLAB Birdtags program.

Water availability in the Riverina

Drought conditions were apparent for 2018 and 2019. Rainfall deciles indicate much of the Riverina region experienced below average rainfall in the past year (Figure 7). The start of 2020 brought rain to the Riverina region with above average and very much above average rainfall deciles (Figure 8). Despite this, many irrigation dams weren't holding water at the time of the survey, as the demand for irrigation water is far less in winter and the system is normally shut off for maintenance. Off allocation water was provided to farmers before and during the helicopter survey in July and many farmers chose to fill their storages to capacity. Despite this, many irrigation dams were dry in May 2020 when we carried out the drone surveys. Additional rain was experienced in the Riverina region in June 2020 (Figure 9).

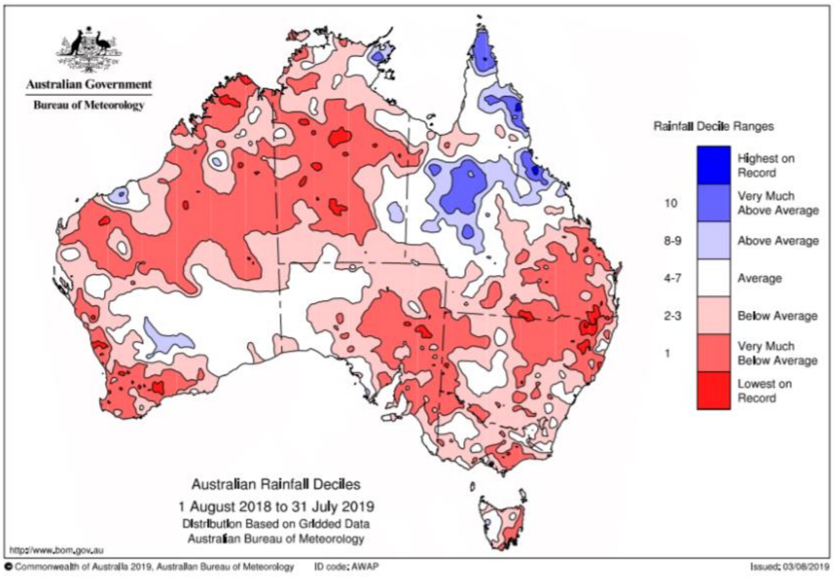

Figure 7: Australian rainfall deciles for 1 July 2019-30 June 2020 (Bureau of Meteorology)

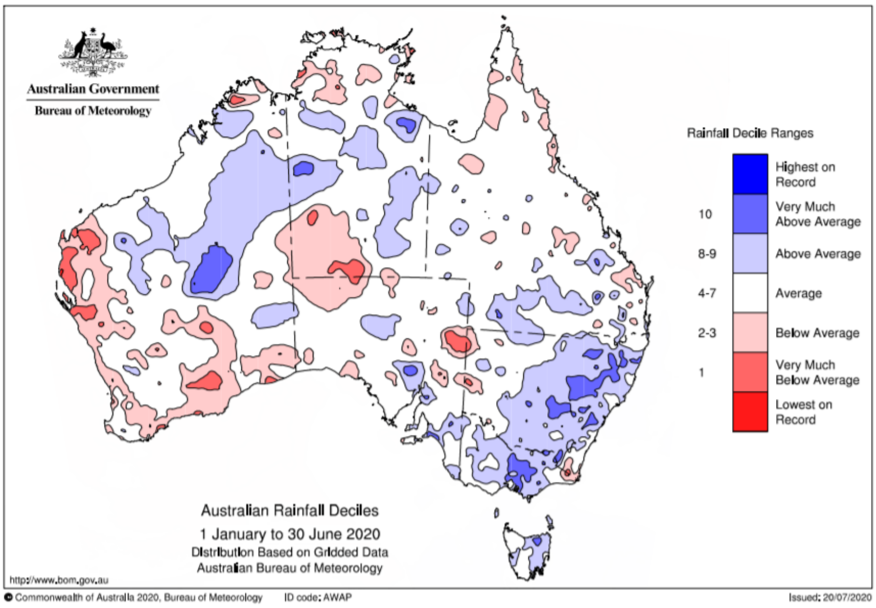

Figure 8: Australian rainfall deciles for last 6 months January 2020 to June 2020 (Bureau of Meteorology)

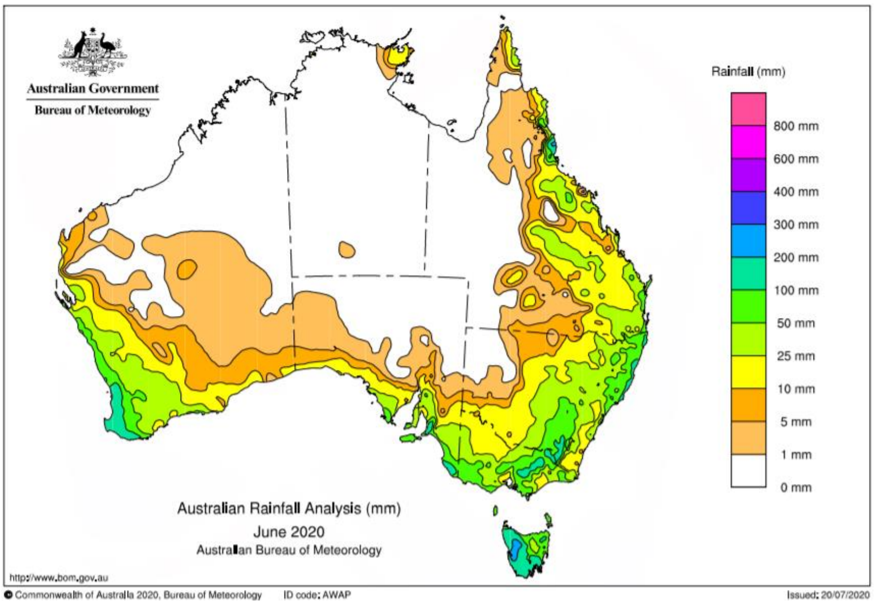

Figure 9: Australian rainfall totals for June 2020 (Bureau of Meteorology)

Many of the large waterbodies in the Riverina were dry during the 2020 survey including Lake Cullivel, Lake Uranagong, Lake Urana and Lake Coolah. We were unable to access Barrenbox Swamp for the 2020 survey, but it was still holding some water and may have been occupied by ducks. (Figure 10). Lake Brewster (Figure 11), Lake Cowal (Figure 12) and Tombullen water storage (Figure 13) were the only major lakes still holding enough water to warrant surveying.

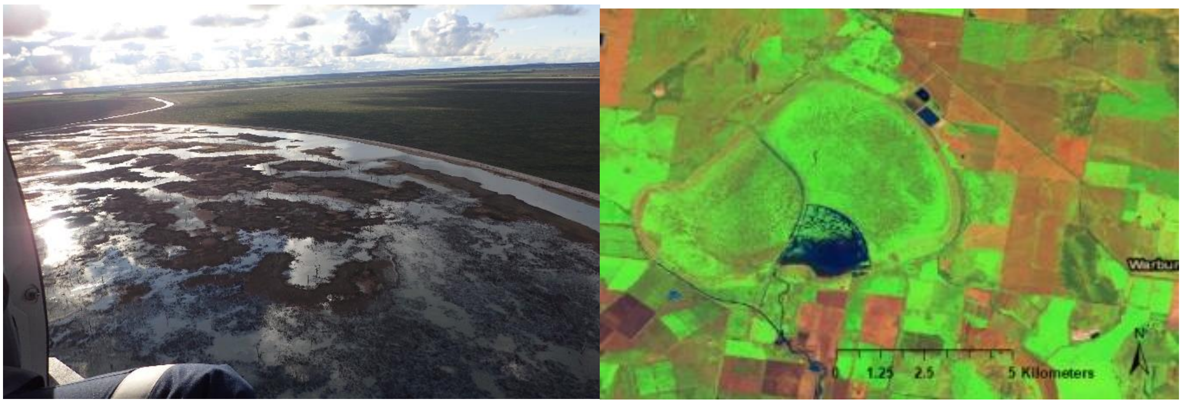

Figure 10: Barrenbox Swamp from the air (12 July 2020) and on a satellite image from 19 July 2020 (blue indicates water present).

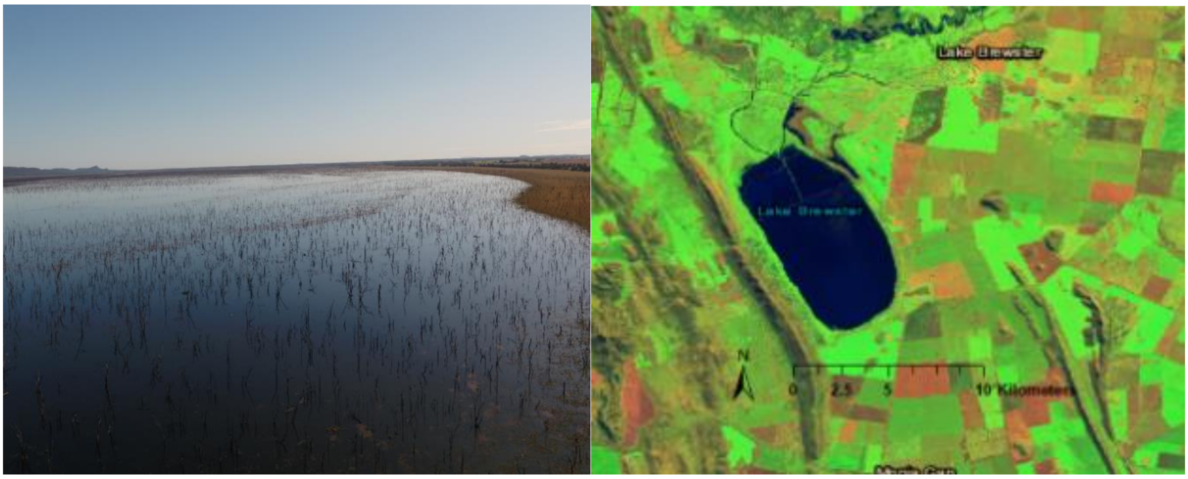

Figure 11: Lake Brewster from the air (surveyed 13 May 2020) and satellite image from 19 July 2020 (blue indicates water present).

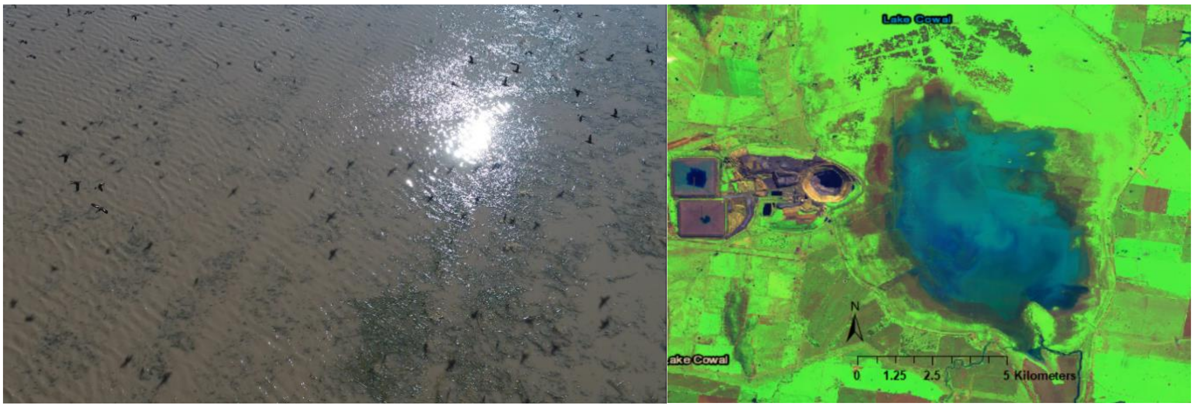

Figure 12: Lake Cowal from the air (surveyed 22 May 2020) and satellite image from 16 July 2020 (blue indicates water present).

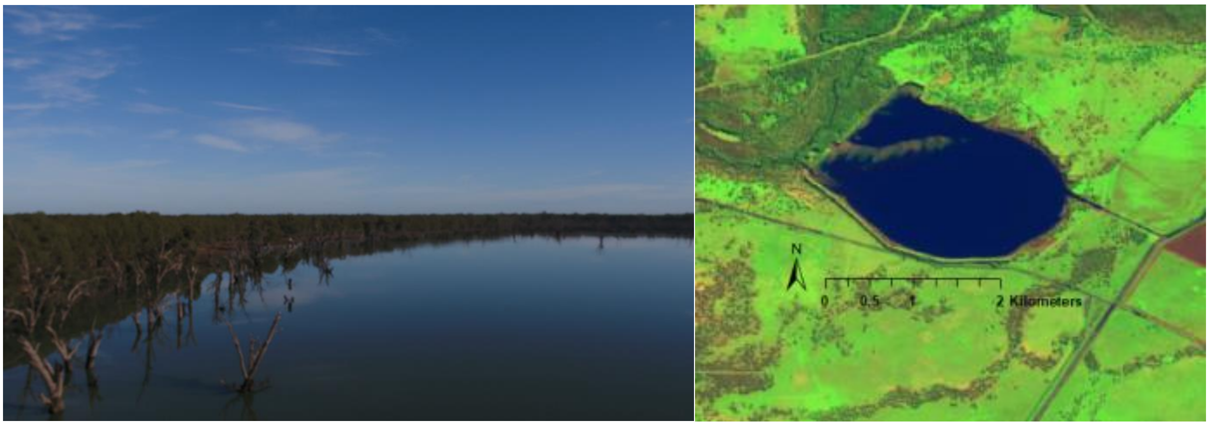

Figure 13: Tombullen water storage from the air (surveyed 12 May 2020) and satellite image from 19 July 2020 (blue indicates water present).

Results

Estimating waterfowl abundance

The helicopter and drone surveys represent a sub-sample of the available waterbodies that waterfowl occupy. To estimate total abundance for all waterfowl species, the observed numbers of waterfowl collected during both the aerial, drone and ground survey are extrapolated to a known number of dams (separated into waterbody type and size classes) in the Riverina region (minus the estimated proportions of dry dams).

Small (<4.9 ha) dams - We mapped 47,510 small dams in the Riverina region. During the July survey, we surveyed 1,412 from the helicopter (Figure 4). A total of 24.4% of small dams were dry at the time of the survey (n = 345 of dams surveyed). For the small dams with water, 67.7% were occupied by at least one duck, while 345 dams that contained water had no ducks.

Medium dams (**5-9.9 ha**) - We mapped 142 medium dams in the Riverina region. During the survey, we surveyed 14 with the UAVs (Figure 5). A total of 69% of medium dams were dry at the time of the survey and 100% of surveyed dams with water were occupied by at least one duck.

Large dams (**10-49.9 ha**) - We mapped 139 large irrigation dams in the Riverina region. During the survey, we surveyed 17 using the UAV (Figure 5). A total of 68% of large dams were dry, while 88% of surveyed dams that had water and were occupied by at least one duck.

Extra-large dams (**50+ ha**) - We mapped 32 extra-large irrigation dams in the Riverina region. During the survey, we surveyed 3 of these using the UAV (Figure 5). A total of 82% of extra-large dams were dry, while 100% of surveyed dams with water and were occupied by at least one duck.

Wastewater treatment ponds – We mapped 38 wastewater treatment ponds in the Riverina and surveyed 19 of these using a UAV (Figure 5). Only 1 surveyed wastewater treatment pond was dry (Hay).

Channels – We surveyed 63.4 km of channel systems in the Riverina region. The mean length of the transects was 2.11 km (n = 30). Approximately 75% of the surveyed channels held water. The estimated total length of channels that held water during the time of the survey was 5851 km.

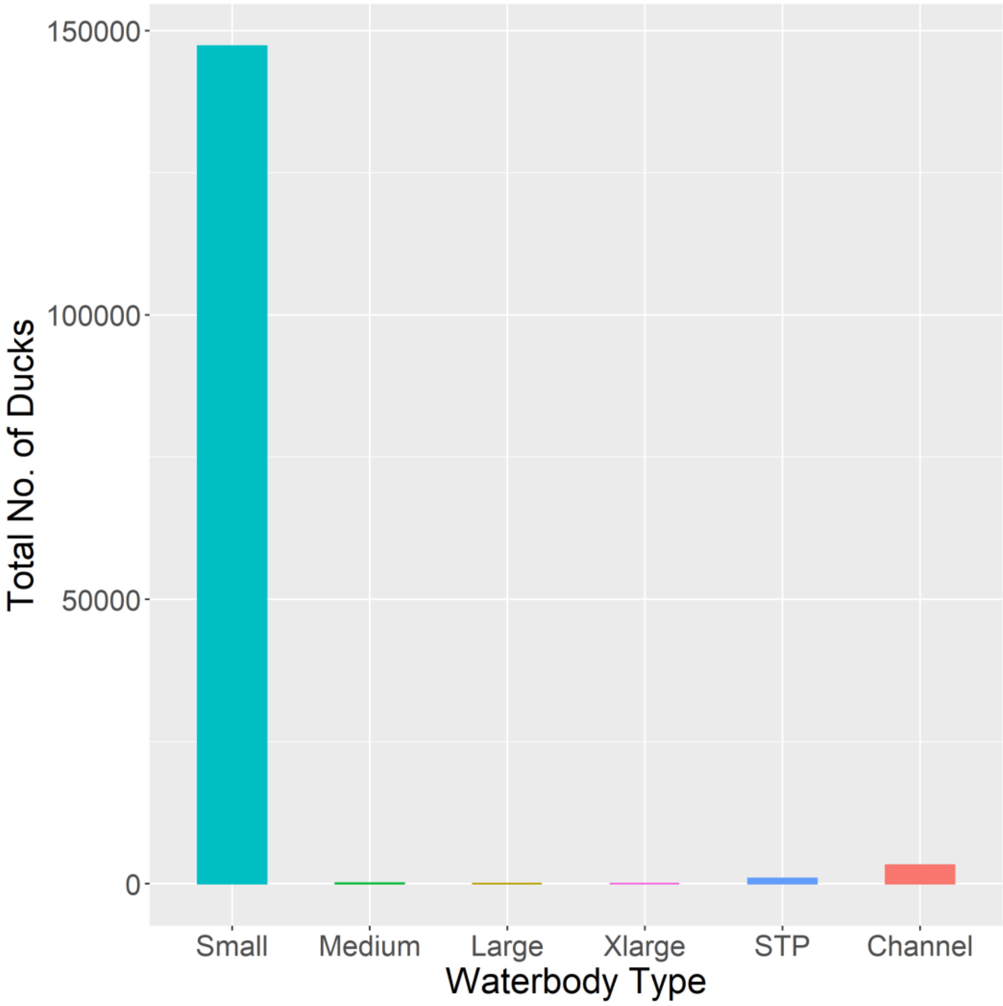

Figure 14: Estimated Grey Teal abundance across the different waterbody types surveyed in 2020 across the Riverina.

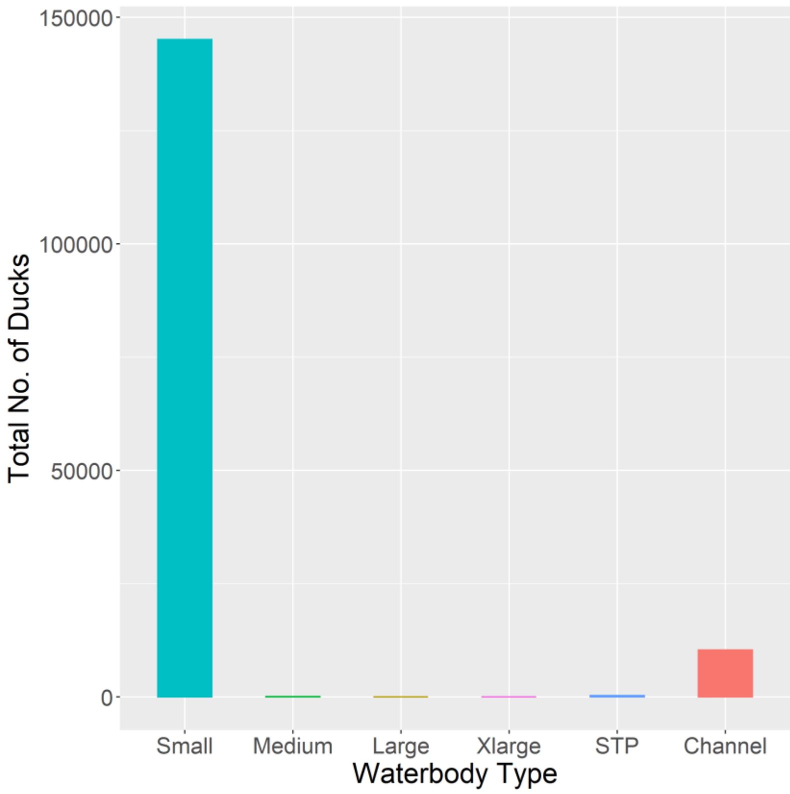

Figure 15: Estimated Australian Wood Duck abundance across the different waterbody types surveyed in 2020 across the Riverina.

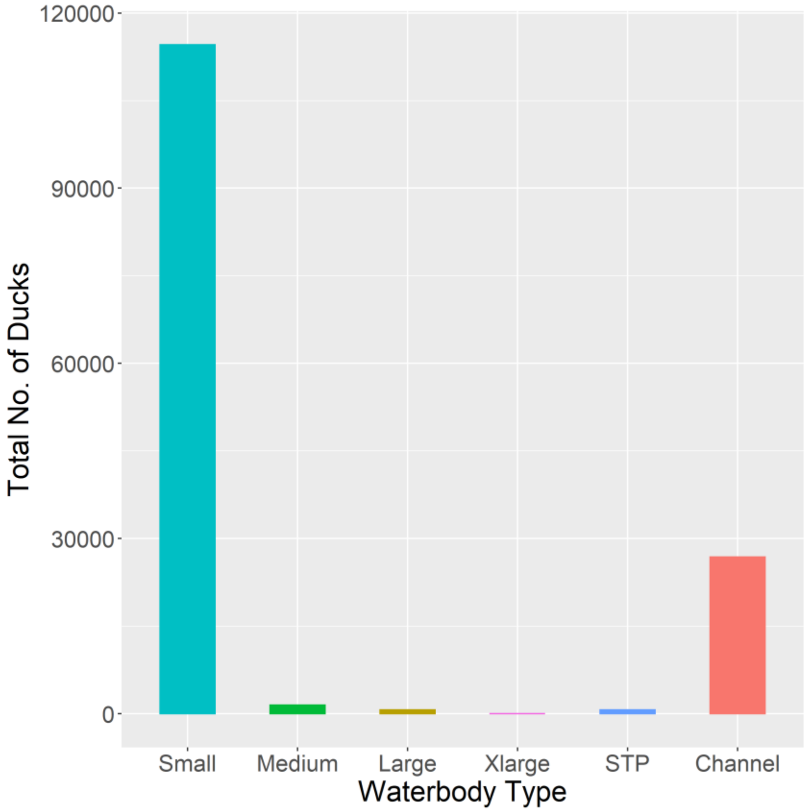

Figure 16: Estimated Pacific Black Duck abundance across the different waterbody types surveyed in 2020 across the Riverina.

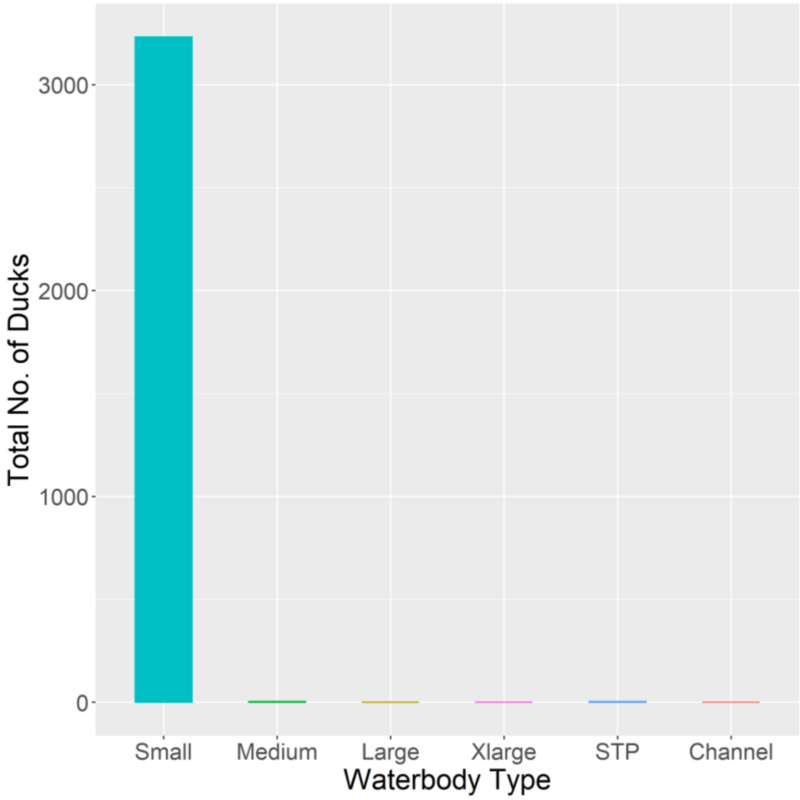

Figure 17: Estimated Hardhead abundance across the different waterbody types surveyed in 2020 across the Riverina.

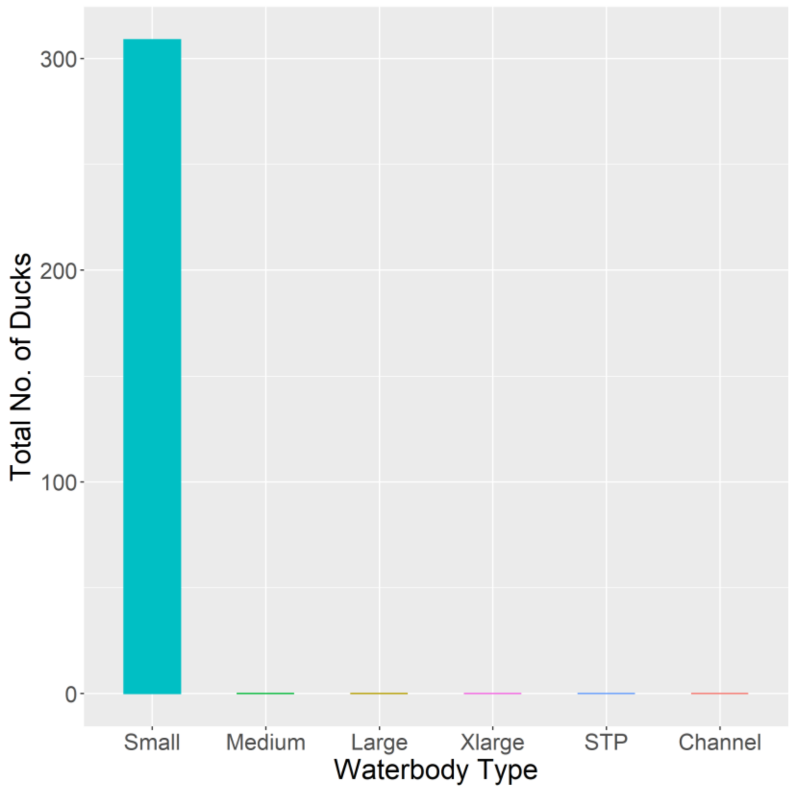

Figure 18: Estimated Pink-eared Duck abundance across the different waterbody types surveyed in 2020 across the Riverina.

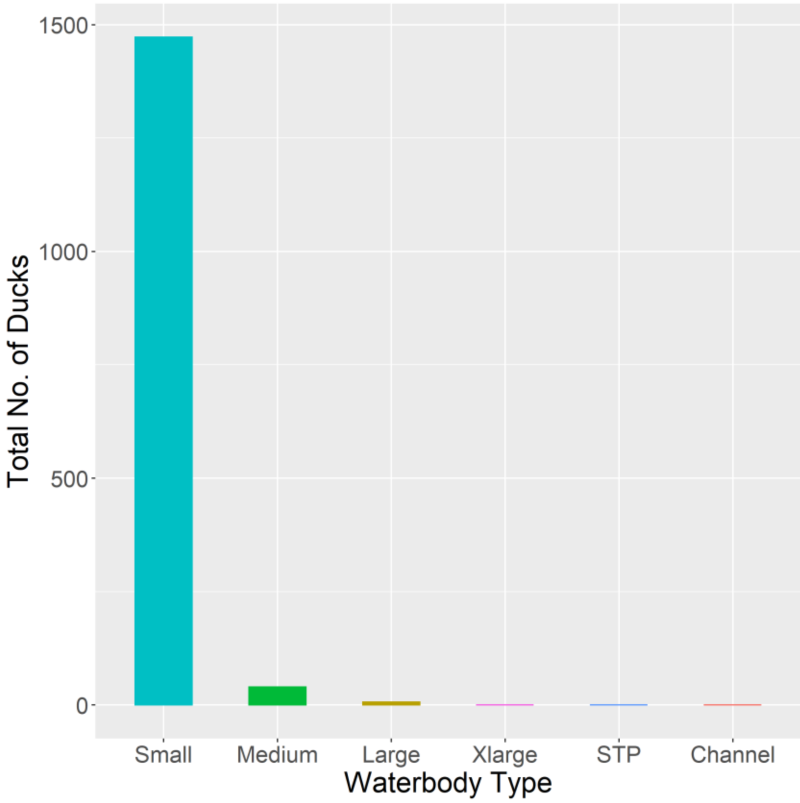

Figure 19: Estimated Blue-winged Shoveler abundance across the different waterbody types surveyed in 2020 across the Riverina.

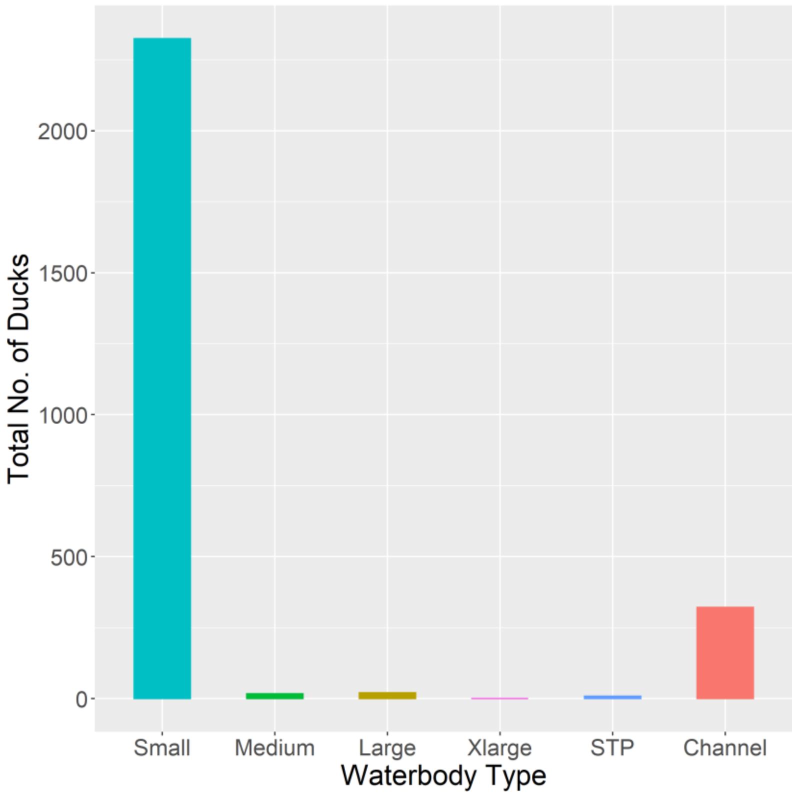

Figure 20: Estimated Australian Shelduck abundance across the different waterbody types surveyed in 2020 across the Riverina.

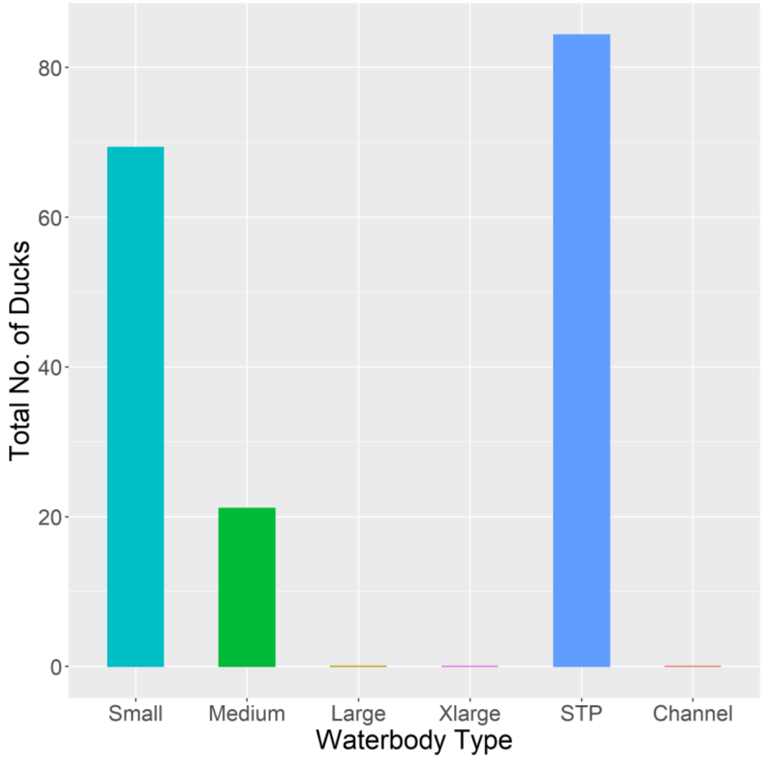

Figure 21: Estimated Chestnut Teal abundance across the different waterbody types surveyed in 2020 across the Riverina.

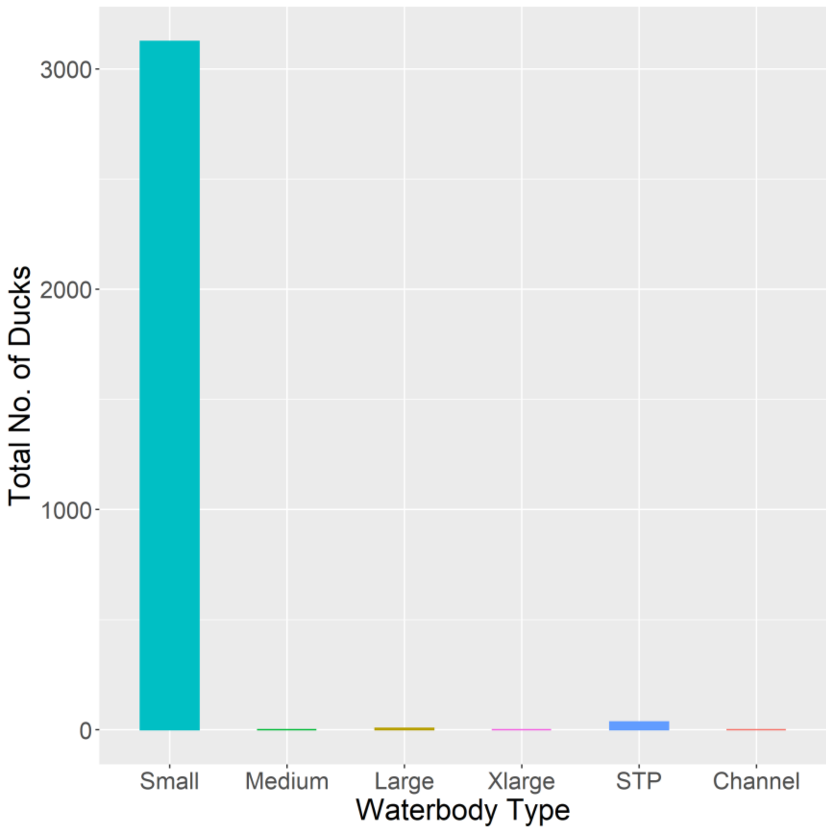

Figure 22: Estimated Plumed Whistling-Duck abundance across the different waterbody types surveyed in 2020 across the Riverina.

The trends in waterfowl numbers between 2019 – 2020 indicate that there has been a slight increase in the number of Australia Wood Duck in the last year, while the numbers of Grey Teal and Pacific Black Duck have remained relatively stable (Figure 23). Other species have remained in relatively low abundance in comparison to the three most numerous species.

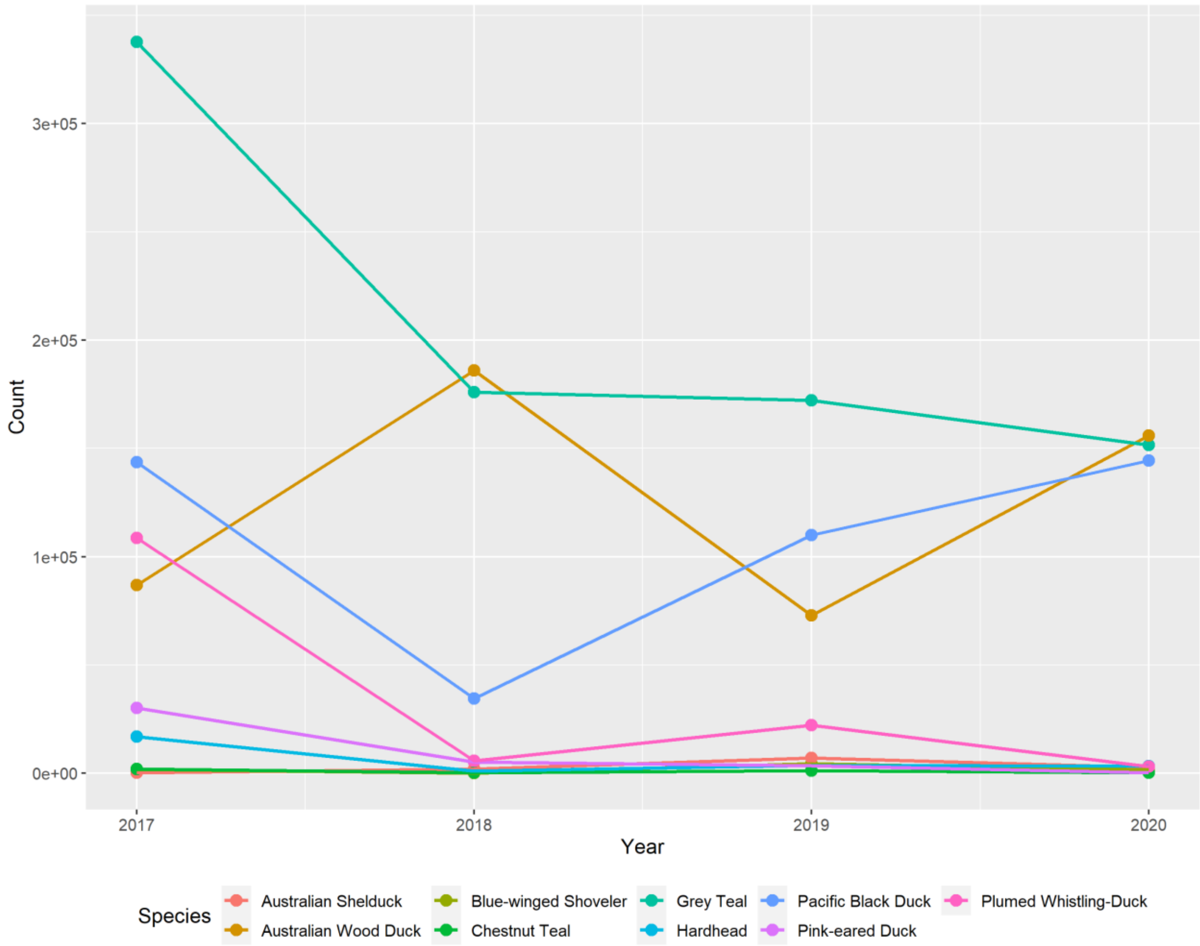

Figure 23: Time series of estimated waterfowl abundances in the Riverina, 2017—2020.

The results of the helicopter survey (Table 1) and UAV data analyses indicated that common species such as Pacific Black Duck, Grey Teal and Australian Wood Duck were most likely to be found on small dams. These three species make up 97.6% of the total number of waterfowl that were surveyed in the Riverina (31.2%, 32.8% and 33.7%, respectively). Of the remaining species, Plumed Whistling-Ducks were most commonly observed on small dams. Chestnut Teal were observed on wastewater treatment ponds in addition to smaller numbers on small and medium dams. Hardhead were most commonly found on small dams. A small number of Blue-winged Shovelers were observed on small, medium and large dams. Australian Shelduck were most commonly observed on small dams and channels. Pink-eared Ducks were only seen in low numbers. This species often travels long distances to opportunistically take advantage of macroinvertebrates in stagnant flood waters (Frith 1959; Martin, Jarrett et al. 2007).

Table 1: The mean group size per dam (on occupied dams) estimated from analysis of the helicopter survey multiple observer data. Only small dams (<4.9 ha) were surveyed by helicopter. Chestnut Teal were detected at too low an encounter rate (most dams were unoccupied by these species) and at too low a detection probability to reliably estimate mean group size per dam. Pink-eared, Blue-winged Shoveler and Plumed Whistling-Duck were observed in very low numbers.

Species	Estimated number per dam	Lower 95% CI	Upper 95% CI	Detection probability (λ)	SE detection probability
Grey teal	4.10	3.63	4.87	0.75	0.015
Australian Wood Duck	4.04	3.09	5.37	0.39	0.080
Pacific Black Duck	3.19	2.60	4.42	0.52	0.079
Australian Shelduck	0.0647	0.0639	0.0686	0.54	0.126
Hardhead	0.090	0.080	0.108	0.153	0.070
Blue-winged Shoveler	0.041	--	--	0.654	0.0696
Pink-eared Duck	0.0086	--	--	0.0071	0.252
Plumed Whistling-Duck	0.087	0.0867	0.0887	0.163	0.143

Recommended quotas for waterfowl in NSW

Quotas are set using the best scientific information available and separate quotas are set for each species. The quotas set the upper limits to the number of waterfowl of a particular species that can be sustainably harvested in a year. Given the uncertainties in the drivers of the population dynamics of ducks and the impacts that harvesting has on duck population viability, we recommend that low risk, conservative quotas are set for all duck species hunted in NSW. If new information becomes available, quotas may be revised.

For species whose population dynamics respond predictably to changes in climate (as determined from previous analyses using the Eastern Australian Aerial Waterbird Survey data e.g. Pacific Black Duck, Grey Teal, Hardhead and Australian Wood Duck), we recommend that a management quota is set at 10% of the estimated population size (Table 2). The population dynamics of the other species (i.e. Pink-eared Ducks, Plumed Whistling-Ducks, Blue-winged Shoveler, Chestnut Teal and Australian Shelduck) do not respond predictably to changes in climate and consequently we recommend that reactive quotas only are set for these species.

Table 2: Estimated population sizes within the Riverina region, management quotas and reactive quotas for hunted duck species in NSW 2020-21. Management quotas are recommended for Grey Teal, Pacific Black Duck, Australian Wood Duck and Hardhead. Reactive quotas (†) are recommended for Pink-eared Duck, Plumed Whistling-Duck, Blue-winged Shoveler, Australian Shelduck and Chestnut Teal. Wandering Whistling-Ducks were not observed in the Riverina during the 2020 survey.

Species	Estimated abundance in the Riverina region	Quota for 2020-2021 (assuming 10% harvest rate)
Grey Teal	151,653	15,165
Australian Wood Duck	155,974	15,597
Pacific Black Duck	144,311	14,431
Hardhead	3,242	324
Pink-eared Duck†	309	31
Blue-winged Shoveler†	1,519	152
Australian Shelduck†	2,694	269
Chestnut Teal†	175	18
Plumed Whistling-Duck†	3,168	317

† Reactive quota recommended for these species

Management quotas are set for species with lower risk of overharvest. The population dynamics of these species react predictably to changes in the environment and—with the exception of Hardhead—they have relatively high population size. Reactive quotas are set for species with a higher risk of overharvest, due to low population size and dynamics that are less predictable. We recommend that allocations from reactive quotas should only be provided if a property is both; 1) prone to damage from those species; and 2) can demonstrate that damage is occurring or very likely to occur.

Satellite tracking of waterfowl in the Riverina

Introduction

In November 2019, we fitted solar powered GPS transmitters attached to a harness to ducks from three common species; Australian Wood Duck, Pacific Black Duck and Grey Teal. The purpose of this portion of the waterfowl project is to observe duck movements so we can better inform population models by taking into account spatial movements of species in and out of the survey region. Some individuals are recognised as being more sedentary and will remain within a smaller home range area, irrespective of water availability elsewhere. Conversely, the movements of other individuals is driven by water availability in a broader region.

Methods

Trapping

In October/November 2019, most of NSW had been in drought for more than 12 months which limited the availability of suitable duck trapping sites. Initially, we conducted pre-baiting and trapping at Barrenbox swamp but the water quickly receded and we had no luck capturing ducks as they moved on to other locations. Subsequently, we decided to trap at wastewater treatment ponds (STP) which still held water and were being used as drought refuges by large numbers of ducks. Australian Wood Duck were only reliably present at Yanco STP. We captured Pacific Black Ducks and Grey Teal at Deniliquin STP and Leeton STP which is positioned next to Fivebough swamp (although the swamp wasn't holding water when we conducted trapping).

Ducks were captured in floating cage traps with funnel entrances (Figure 24). Traps are designed with a funnel entrance which ducks can walk through to get into the trap but are far less likely to be able to get out. The trap can be disabled by removing the funnels so ducks can easily get into and out of the traps. The traps had a plywood feeding platform so we could add wheat as bait. Bread also proved to be an effective bait to entice ducks into the traps. We constructed the trap with plastic mesh to reduce the potential for injuries to ducks while they were in the trap.

Pre-feeding using grain in and around the trap for at least 2 weeks beforehand proved to be an important step when acclimatising ducks to the traps. We used remote cameras on traps to determine if ducks were entering the traps and feeding on the grain and when they were most active. We found the best times for trapping ducks is dawn and dusk. Therefore, we set traps ~30 minutes before dawn and dusk. Set traps had to be monitored at all times from a distance when set to prevent possible predation by birds of prey and foxes.

Figure 24: Floating funnel trap used for trapping ducks at the Deniliquin wastewater treatment plant.

Tagging and tracking

Trapped ducks were measured, weighed and sexed by cloacal examination. All captured ducks were fitted with an individually numbered leg band as part of the Australasian Bird and Bat Banding Scheme under the guidance of an A-class bander. Suitable ducks from three species and representing both sexes were fitted with solar powered, GPS satellite transmitters (Figure 25). The satellite tags were fitted with a thin Teflon ribbon harness, as described by Roshier & Amus (2009). The teflon material is ideal for using on waterbirds as it does not wick water and sits neatly under the feathers without rubbing. Once the tag and harness has settled on the duck, the tag and antenna is the only visible part. We observed a number of our tagged ducks at the capture sites and all were behaving normally. The satellite tags have a solar panel which recharges the battery but the size of the battery limits the number of GPS points that can be collected per day. Tags were programmed to ping the satellite every 4 hours, 24 hours a day, as ducks are known to move at night. The tags are linked to the Argos satellite system and data from each functioning tag is uploaded to the satellite weekly.

Figure 25: a. Pacific Black Duck and b. Australian Wood Duck with 17g Microwave Telemetry transmitters. c. Grey Teal with smaller 12g GeoTrak transmitter.

Results

Table 3: Ducks fitted with solar powered GPS transmitters in the Riverina region in November 2019.

Species	Sex	ID	Capture site	Tag type	Days tracked	Distance moved between points (km)	Average movement (km) per day	Movement type	Home range (100% minimum convex polygon in sq km^{-2})
Pacific Black Duck	F	180354	Yanco STP	Microwave Telemetry 17g	49^	236.36	4.82	Sedentary<12km	47.43
Pacific Black Duck	F	180355	Leeton STP	Microwave Telemetry 17g	68^	217.37	3.20	Sedentary<15km	62.94
Pacific Black Duck	M	180356	Deniliquin STP	Microwave Telemetry 17g	50^	186.44	3.73	Sedentary<20km	113.67
Pacific Black Duck	M	180357	Deniliquin STP	Microwave Telemetry 17g	32^	9.92	0.31	Sedentary<2km	0.40
Pacific Black Duck	F	180358	Leeton STP	Microwave Telemetry 17g	8*	1.30	0.16	Sedentary<0.5km	0.02
Pacific Black Duck	F	180359	Leeton STP	Microwave Telemetry 17g	32^	98.88	3.09	Sedentary<25km	22.59
Pacific Black Duck	F	180360	Leeton STP	Microwave Telemetry 17g	137^	253.37	1.85	Sedentary<20km	89.49
Pacific Black Duck	F	180361	Leeton STP	Microwave Telemetry 17g	55^	249.52	4.54	Sedentary<15km	34.95
Australian Wood Duck	M	180347	Yanco STP	Microwave Telemetry 17g	197^	738.14	3.75	Sedentary<25km	164.26
Australian Wood Duck	F	180348	Yanco STP	Microwave Telemetry 17g	84^	103.55	1.23	Sedentary<10km	8.20
Australian Wood Duck	M	180349	Yanco STP	Microwave Telemetry 17g	263+	767.51	2.92	Sedentary<45km	583.76
Australian Wood Duck	M	180350	Yanco STP	Microwave Telemetry 17g	203^	978.77	4.82	Nomadic>350km	13,760
Australian Wood Duck	F	180351	Yanco STP	Microwave Telemetry 17g	91^	211.01	2.32	Sedentary<15km	26.98

Australian Wood Duck	F	180352	Yanco STP	Microwave Telemetry 17g	251+	397.32	1.58	Sedentary<10km	21.87
Australian Wood Duck	F	108353	Yanco STP	Microwave Telemetry 17g	251+	1300.79	5.18	Sedentary<20km	157.48
Grey Teal	F	184215	Leeton STP	GeoTrak 12g	90^	23.45	0.26	Sedentary<5km	0.08
Grey Teal	M	184216	Leeton STP	GeoTrak 12g	261+	1920.95	7.36	Nomadic>400km	98,700
Grey Teal	F	184217	Leeton STP	GeoTrak 12g	260+	438.19	1.69	Sedentary<20km	21.64
Grey Teal	M	184218	Leeton STP	GeoTrak 12g	258+	1467.64	5.69	Nomadic<400km	13,500

* Likely transmitter malfunction

+ Still being tracked

^ Most likely deceased

Figure 26: GPS tracks for Pacific Black Duck fitted with 17g solar satellite transmitters

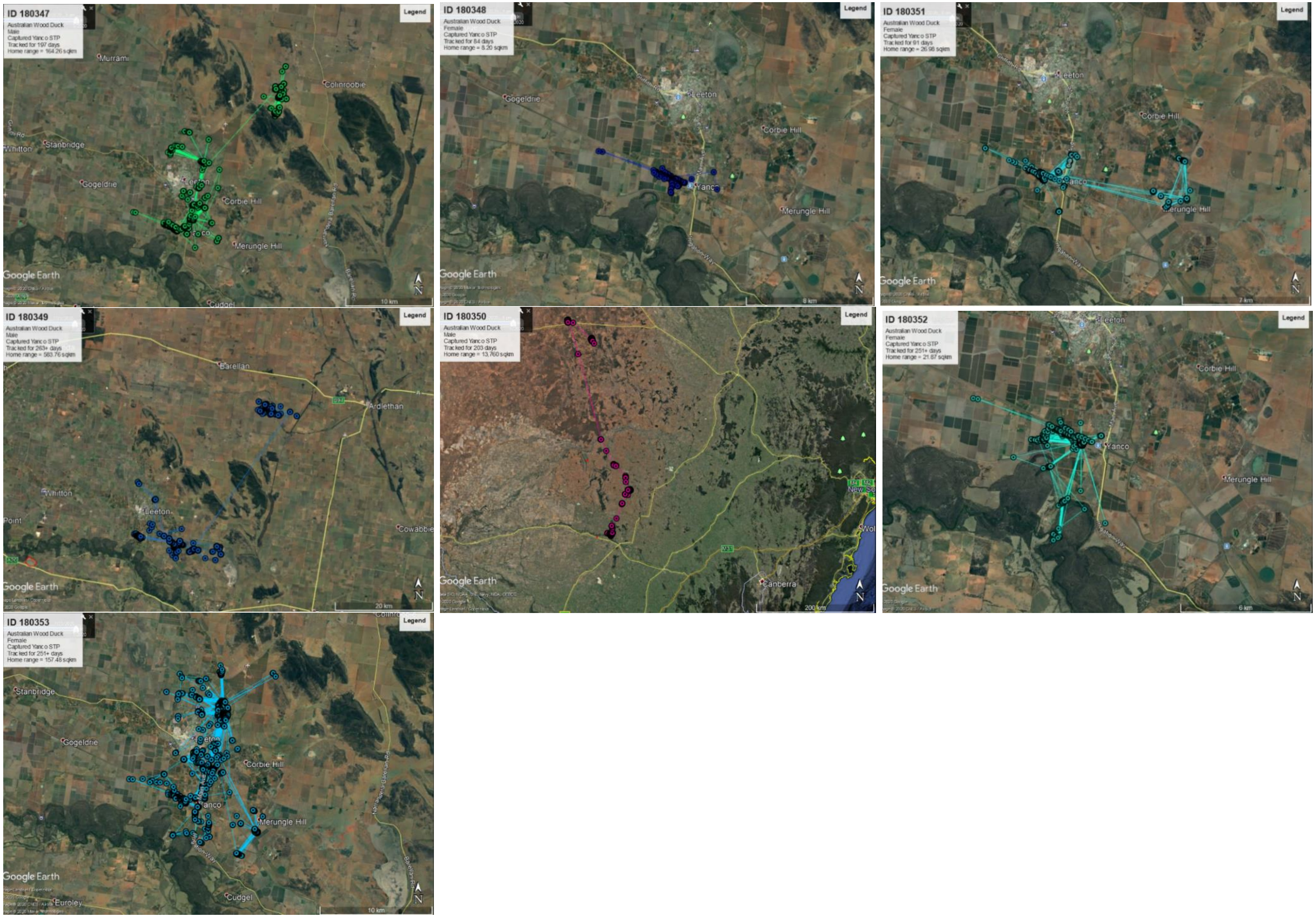

Figure 27: GPS tracks for Australian Wood Duck fitted with 17g solar satellite transmitters

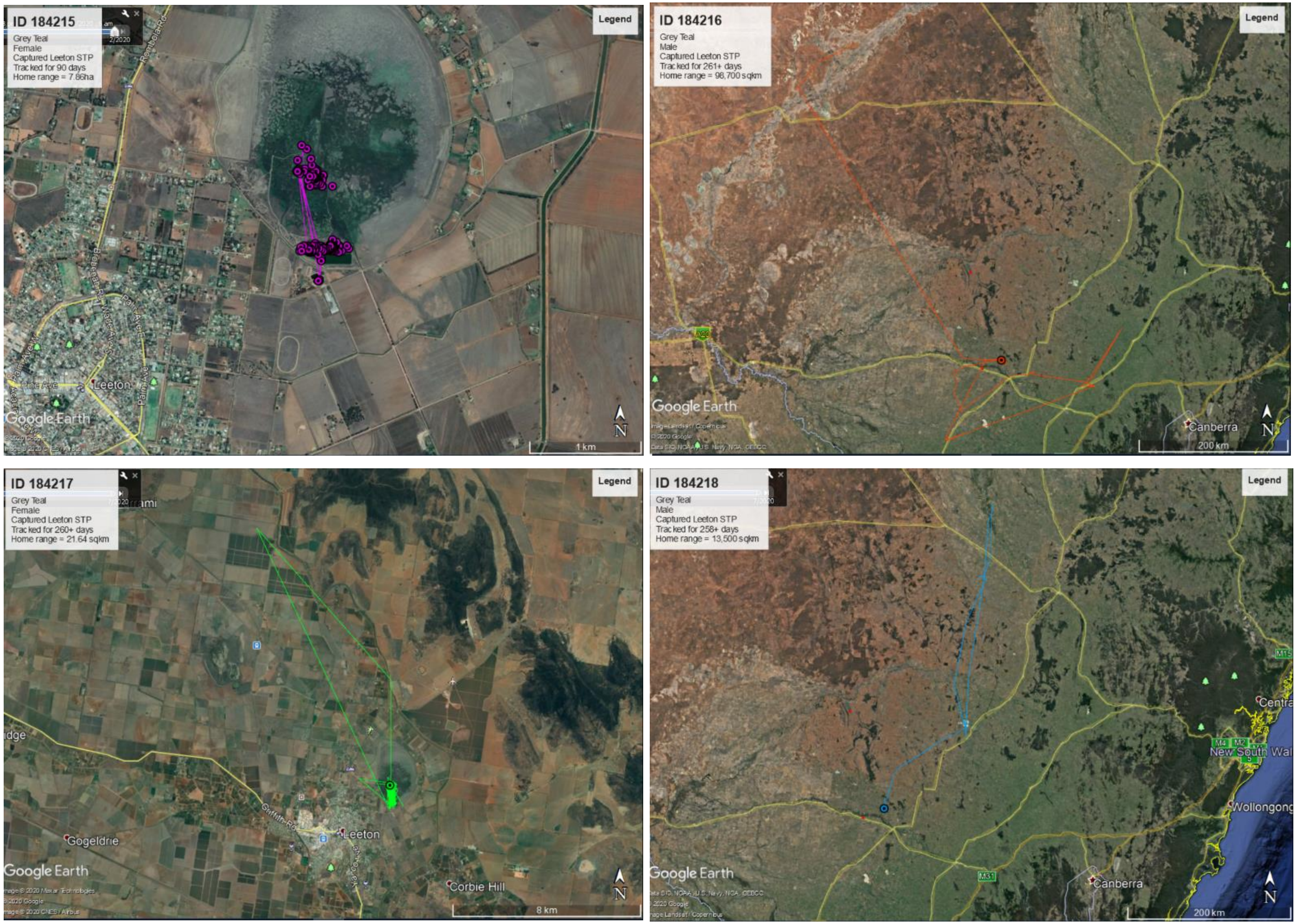

Figure 28: GPS tracks for Grey Teal fitted with 12g solar satellite transmitter

Discussion

We found the use of transmitters is an effective method to establish movement patterns for waterfowl (Table 3, Figures 26, 27, 28). We found similar results to other studies with species not necessarily behaving in a predictable manner with a range of individualistic behaviour observed between birds of the same species. This was evident for Pacific Black Ducks tagged and released in arid Australia (McEvoy, Roshier *et al.* 2015) and Grey Teal tagged and released in arid and agricultural landscapes (Roshier, Doerr *et al.* 2008). Tagged ducks were moving on average 3.24 ± 1.9km per day across a home range that varied from 0.02 – 98,700 $sqkm^{-1}$ (Table 3). For such variable data, further tracking work will require a greater number of replicates.

Initially after release, all ducks remained close to the site of capture. Three ducks were observed moving longer distances away from the site of capture (180350; male Australian Wood Duck, 184218; male Grey Teal and 184216; male Grey Teal). Grey Teal 184216 (Figure 28) started moving in mid to late January 2020 which coincided with good rainfall in January 2020, following a very dry December 2019. This male Grey Teal headed out north-west from the Leeton STP capture site in mid May 2020 after above average rainfall during April 2020. He took advantage of flood waters in the Paroo-Darling National Park near White Cliffs. Grey Teal 184218 (Figure 28) started moving west in early April 2020, again probably in response to higher than average rainfall during this month. This Grey Teal headed to Lake Cowal in April 2020, where low levels of water are currently present. After travelling further north near Nyngan, this Grey Teal headed south again to Lake Cowal where he is currently located. Australian Wood Duck 180350 starting moving mid-February 2020 (Figure 27). He headed north to Cobar and moved between a few dams from mid-March to the start of June 2020 when the transmitter signal was lost. For all the nomadic ducks, it was clearly evident the ducks were moving between small farm dams across the landscape. These are the small farm dams surveyed as part of the helicopter surveys.

A few ducks were very clearly sedentary and showed strong site fidelity. Australian Wood Duck female 180352 has been tracked for 251 days (and is still being actively tracked) and hasn't moved more than 10km from the Yanco STP where she was captured (Figure 27). Grey Teal female 184217 (Figure 28) has been tracked for 261 days (and is still being actively tracked) and unlike the other two tracked male Grey Teal, she hasn't moved more than 20km from the site she was captured and tagged at Leeton STP. Both these ducks have been regularly sighted on the water at Yanco STP and Leeton STP. Australian Wood Duck female 180352 was captured at Yanco STP (Figure 27) and is still being tracked after 251 days. She has stayed within a 20km radius of the capture site and is regularly visiting Fivebough swamp in Leeton. Some ducks (male Australian Wood Duck 180347 and male Australian Wood Duck 180349) made short distance movements away from the capture site but still no further than a 40km radius in mid to late March 2020.

Pacific Black Ducks were tracked for 8 to 137 days (Table 3). One tag (180358) most likely experienced a malfunction. Unfortunately there is nothing that can be done about preventing malfunctions as all tags were tested multiple times before being attached to ducks and no issues were identified. The remaining Pacific Black Ducks stayed within a 25km radius of their capture site (Figure 26). Pacific Black Duck male 180357, was tracked for 32 days and stayed at the Deniliquin STP for this time. He most likely moulted flight feathers after being tagged and predation is a potential explanation for the loss of this tag.

Challenges

Initially we had difficulties capturing ducks to attach the transmitters as NSW was experiencing a long period of drought. It was not feasible to capture ducks at smaller dams as the presence of someone baiting and opening a trap is enough to scare ducks away. Trap locations needed to be well populated with ducks with no other sites close by for ducks to move to when they were disturbed by people baiting and opening traps.

Some tagged ducks we caught on a later day after being tagged were going through a moulting period. Waterfowl replace all primary flight feathers at once so can't fly for approximately a month while the new feathers grow in. Many of the Grey Teal and Pacific Black Duck at the trapping sites were going through moult. During this time, they can be more vulnerable to predation, although both Leeton STP and Deniliquin STP have dense rushes around the edges of the ponds to provide shelter to ducks. Despite this, we had a number of Pacific Black Duck tags go offline within the early stages of being tagged. Predation of moulting ducks is one possible explanation for the limited life of tagged Pacific Black Duck compared to the other species. We also can't rule out the possibility that there was an issue with the harness that was more of a problem for Pacific Black Duck given some Grey Teal and Australian Wood Duck have retained the tag for 250+ days. Previous studies involving satellite tagged Pacific Black Ducks used transmitters almost double the size of the transmitters we used (30g versus 17g) with the same Teflon ribbon harness attachment (McEvoy, Roshier *et al.* 2015). They reported losses of 50% of tags after less than 100 days and a further 20% of tags were lost before 200 days. This will require further investigation before more Pacific Black Ducks are tagged.

Another significant challenge is knowing the fate of ducks once the transmitter stops transmitting. A tag that has stopped transmitting can mean the duck has died or it could be a transmitter malfunction issue. There is no easy way to determine which it is when ducks can't be recovered. We conducted extensive searches in the last known location of tracked ducks but have been unable to locate any evidence of ducks or transmitters. There is also a 4 hour gap between locations, which means the last upload may not have been the last location of the duck. Another issue was that the last known location was often in a body of water with no chance of recovery. We have been conducting regular surveys of ducks at wastewater treatment ponds to search for tagged ducks – both those still transmitting and those that may have malfunctioned and may still be attached to a living duck. We have seen two of the tagged Grey Teals at Leeton STP and one of the Wood Ducks at Yanco STP.

Recommendations

Satellite tracking provided data that would not have been possible to collect by any other means. Based on the results, we recommend the smaller 12g tags would be worth investing in regardless of the duck species. A lighter payload will reduce any potential negative effects of placing additional weight on a flying animal. The major limiting factor to additional replicates is cost with each tag priced at ~$5,500 in addition to Argos costs per active tag per month costing $51.00 (weekly data uploads). Despite this, these data, even for ducks tracked for short periods, is invaluable and worth the investment.

Conclusions

The low numbers of ducks is likely due to greater availability of standing water across a wider region beyond the Riverina region resulting in dispersal of ducks across the landscape. The targeted surveys within the Riverina covering the range of waterbody types know to be used by ducks allowed us to derive a representative population estimate for nine waterfowl species in the region. However, it should be noted that these are still only an estimate of total abundance with the Riverina, which has been derived from a sub-sample of the entire region. A small fraction of the irrigation channel network was surveyed in 2020. Ongoing refinement of our techniques and sampling intensity will improve confidence in the estimated numbers, such as greater incorporation of the irrigation channel network into the survey for 2021 survey.

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Reference datasets and layers

Geoscience Australia National Wastewater Treatment Plants Database