2022-2023 Annual Waterfowl Quota Report to NSW DPI Hunting, NSW Department of Primary Industries

Steven McLeod

19 August 2022

Table of Contents

Introduction

Ten native duck species can be legally harvested in New South Wales (NSW) for the aim of damage reduction and to support sustainable agricultural management, particularly in the Riverina rice-growing region. DPI Hunting, formerly the Game Licensing Unit (GLU), is required by the *Game and Feral Animal Control Act* 2002 (GFAC Act) to establish annual quotas that limit the number of waterfowl that can be harvested "on the basis of the best scientific knowledge available on the estimated regional population of native game birds 32D(2)(a)." The Vertebrate Pest Research Unit of the NSW Department of Primary Industries is responsible for estimating waterfowl populations s in NSW and recommending an annual quota to DPI Hunting. Additionally, the Vertebrate Pest Research Unit will give DPI Hunting a framework for continuing waterfowl population estimation that can be utilised to determine a sustainable harvest quota.

Although there is no harvest that can be certain to be sustainable, the risk of over-harvest can be reduced with the right monitoring and careful attention to population dynamics. Sources of ambiguity in the decision-making process should be included in harvesting systems that support sustainable practises. Uncertainty comes from a variety of sources, such as monitoring bias, inaccurate estimates of the total number of waterfowl sighted, density-dependent and independent variables that may affect population dynamics, and the impact of harvesting on population viability. Fecundity, mortality (both natural and related to harvest), rates of immigration, and emigration all have an impact on the dynamics of waterfowl populations, which in turn affects how long they can be harvested. There is continuing research into how these factors affect population survival.

We conducted waterfowl surveys in the Riverina region of NSW in June 2022. A helicopter was used to survey smaller farm dams (≤ 4.9 ha in area). To determine an estimate of abundance for each species in the Riverina region, the number of ducks estimated from the sample of dams was extrapolated. Abundance estimates and prescribed quotas for NSW for 2022-23 are presented for nine waterfowl species — the Grey Teal, Pacific Black Duck, Hardhead, Pink-eared Duck, Australian Wood Duck, Australian Shelduck, Blue-winged Shoveler, Chestnut Teal, and Plumed Whistling-Duck.

Methods

For 2022 the survey was restricted to small dams. Small farm dams have the greatest likelihood of occupancy by the three most common species (Australian Wood Duck, Grey Teal and Pacific Black Duck). Large dams, wastewater treatment ponds, wetlands (lakes) and channels were not surveyed this year. The observed and estimated numbers of waterfowl collected from this stratified sub-sample has been extrapolated to the Riverina region to establish an estimate of abundance for each species. Extrapolated abundances were based on small dams only.

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.

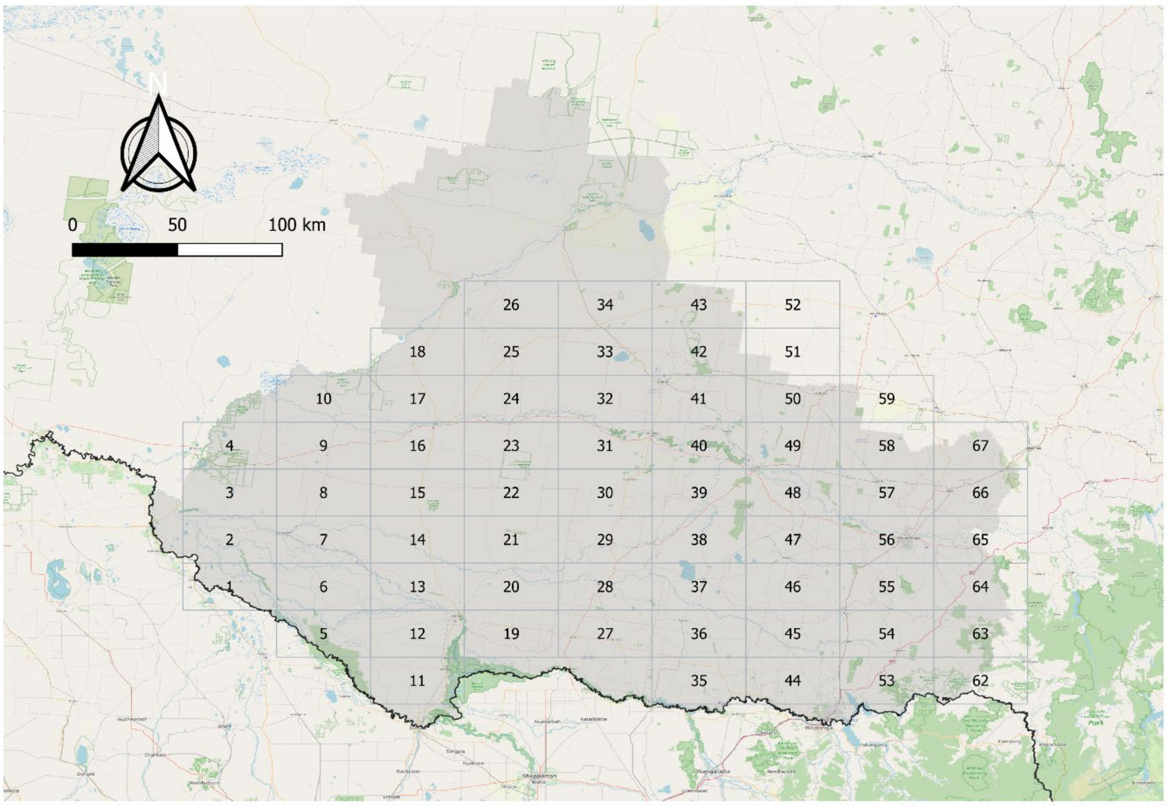

Figure 1: The area defined as the Riverina region as indicated by the Bureau of Meteorology forecast areas (http://www.bom.gov.au/nsw/forecasts/map.shtml). Potential survey blocks are also shown in this figure.

Sampling Strategy

Dams

A stratified random sample of dams ≤ 4.9 ha in size was selected. Sampling units (dams) were selected at random following a two-stage design (Lohr 2019). In stage one, the study site was divided into 62 equal sized sample blocks, with each block's dimensions 0.5° longitude × 0.25° latitude (46.1 × 27.7 km, total area 1279 km^2) (Figure 1), which formed the *sampling frame*. From the sampling frame, a simple random sample of 14 blocks (H) was selected, with each block (h) forming a *sample stratum* (Figure 2). Within each stratum an independent simple random sample of 70 dams was selected from all dams within the stratum, for a total sample size (n) over the sampling frame of 980 dams. Each species was analysed separately. In stratum *h* the number of waterfowl in dam *j* will be $y_{h,j}$, and the total count t_h in stratum *h* will be

$$t_h = \sum_{n=1}^{N_h} y_{h,j}$$

where N_h is the number of sample dams in stratum *h*.

The population total count in the sampled dams and strata will be

$$t = \sum_{h=1}^{H} t_h$$

with an overall mean number of waterfowl ($\bar{y}_U = \lambda$) per dam of

$$\bar{y_U} = \frac{t}{N} = \frac{\sum_{h=1}^{H} \sum_{j=1}^{N_h} y_{h,j}}{N}$$

where *N* is the total number of dams selected from the sampling frame. The variance (S_h^2) tratum *h* is

$$S_h^2 = \sum_{j=1}^{N_h} \frac{\left(y_{h,j} - \bar{y}_{hU}\right)^2}{N_h - 1}$$

Because sampling units were selected independently of other sampling units in different strata, the variance of the stratified estimator is the sum of the individual stratum variances,

$$S_H^2 = \sum_{h=1}^{H} S_h^2$$

The confidence interval for the overall mean number of waterfowl was calculated as

$$\bar{y}_U \pm z\sqrt{S_H^2}$$

where *z* = 1.96 (the approximate value of the 97.5 percentile point of the standard normal distribution).

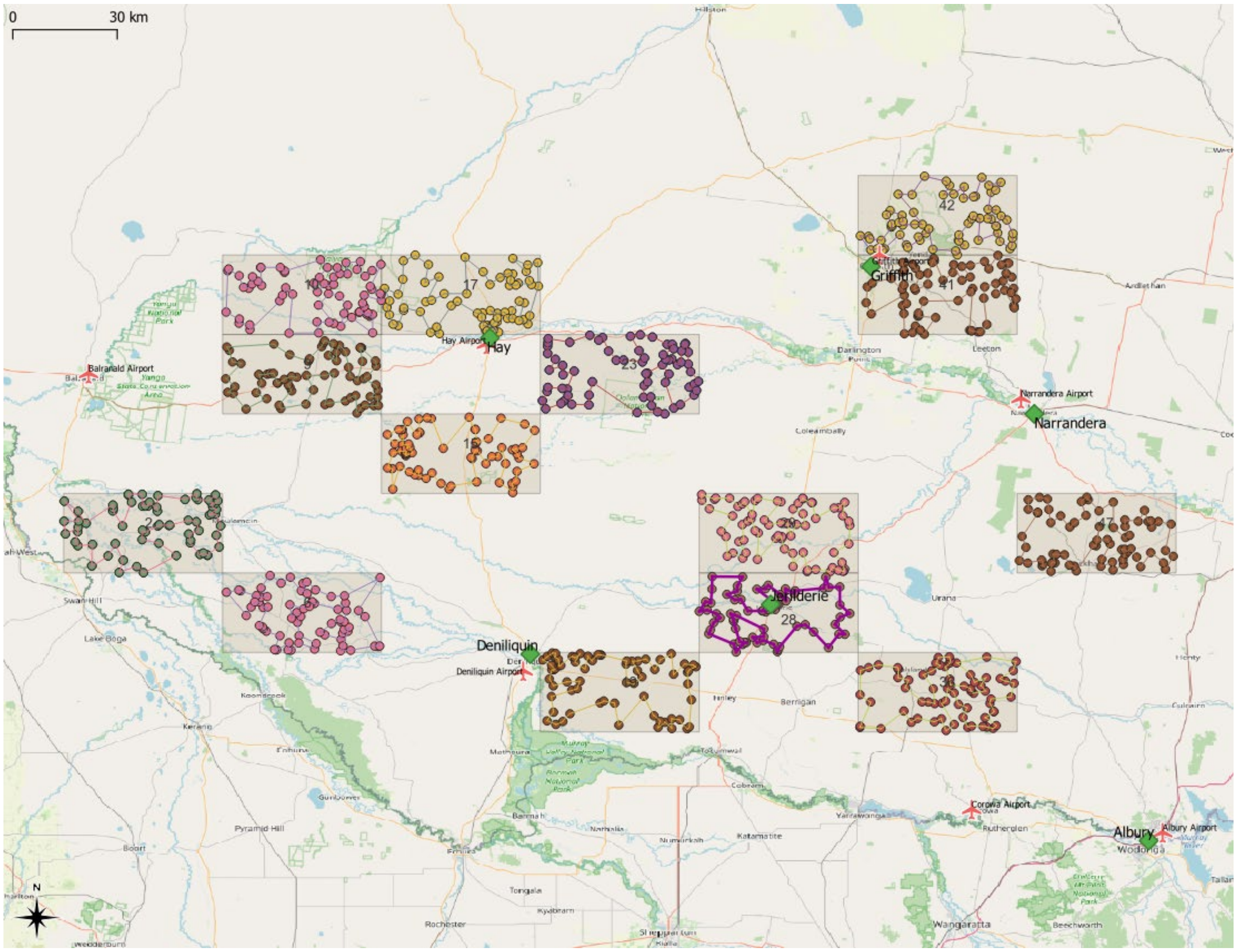

Figure 2: Surveyed small dams per survey block for 2022. In total, 726 small dams were surveyed.

Channels

No channels were surveyed in 2022.

Other waterbodies

No medium, large or extra-large dams, wastewater treatment ponds, wetlands or channels were surveyed.

Helicopter surveys

Within each survey block, we randomly selected 70 dams. 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 hours (limited by the fuel capacity of the helicopter or observer fatigue). Dams holding no water and those with water but not observed to have waterfowl were noted. For dams with waterfowl, we flew a low and slow circuit around the dam (no lower than 18m) and the observers identified and counted all waterfowl. We used a Bell 206 L4 helicopter which allows for three observers to observe on the same side of the helicopter. Aerial operations were conducted without the front and rear doors which allows for better visibility.

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 GPS enabled tablets) and a third observer, seated next to the rear observer, recording covariates identified by the front observer that may influence detection probability and habitat suitability for waterfowl (e.g. habitat around dams, presence of livestock). In addition, the third observer recorded duck species after confirmation by both the front and rear observers. Survey data were analysed using the package unmarked (Fiske and Chandler 2011) in the statistical programming language R (R Core Team 2022).

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 state process (true abundance) and the detection process. The N-mixture model approach assumes that the 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 highest ranked model based on AIC.

N-mixture models

N-mixture models were developed to analyse replicated count data and account for imperfect detectability while deriving relationships between populations of animals and their environment (Royle 2004). The basic idea is that r sites are surveyed, and each site contains an expected number of animals λ, such that the number of individuals at the ith site can be described by the equation

$$N_i \backsim Poisson(\lambda)$$

which describes the state process (or true abundance — a latent state) at site i. Each site is surveyed j times (for the waterfowl survey $j = 2$ and counts are conducted simultaneously), and each individual duck has a probability p of being detected, giving

$$y_{i,j}|N_i \backsim Binomial(N_i, p)$$

which described the observation process (or observed count, $y_{i,j}$) as a function of the true abundance, N_i.

The variation in true abundance at sample site i, is modelled as a Poisson distribution with mean λ. The observed counts $y_{i,j}$ (given N_i) at site i and replicate survey j are described by a binomial distribution with sample size N_i and detection probability p. Distributions other than the Poisson were tested, including the zero-inflated Poisson and the negative binomial.

Covariates may affect both the state process (likelihood that waterfowl occupy a dam) and the observation process (the likelihood that waterfowl, if present, are detected). A range of potential covariates were assessed and included in alternative models that were fitted to the data. Models with high levels of support ($\triangle AIC < 2$) were identified using multimodel inference (Burnham and Anderson 2002) and used to estimate mean abundance per dam, λ, and detection probability, p. Covariates tested that potentially influenced detection included: observer (SD, POB); observer position (front, rear); and the presence of glare. Covariates that potentially affected occupancy included: presence of livestock (sheep, cattle); presence of vegetation (grass, crops, trees, unspecified vegetation); presence of vegetation in the water; and the presence of bare ground.

Assumptions of the N-mixture model

There are a few assumptions of N-mixture models, and inference regarding abundance can be sensitive to the assumptions. The assumptions are,

1. Poisson and binomial distributions are true descriptions of state/observation processes
2. Abundance at each site is random and independent of abundance at all other sites
3. Population is closed between surveys
4. Observers do not double count individuals
5. All N individuals have the same detection probability p

Of these five, the last assumption — that there is no unmodeled variation in detection probability — is probably the most likely to influence our counts, and we were confident that deviations from the other assumptions were minor. Violations of assumption 5 may lead to under- or overestimation of average abundance, and consequently, over- or underestimates of total population size, respectively. Unfortunately, it is difficult to identify model mis-specification due to unmodelled heterogeneity in detection probability (Link *et al.* 2018). Alternatives to N-mixture models, likely to involve capture-recapture methods will be examined for future surveys.

For estimating population size, we assumed that violations of any assumptions were minor and did not greatly influence estimated abundances.

Results

Estimating waterfowl abundance

The helicopter 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 the aerial survey are extrapolated to a known number of dams in the Riverina region (minus the estimated proportions of dry dams).

46,026 small dams were previously mapped in the Riverina region. During the survey, we surveyed 726 from the helicopter (Figure 2). A total of 19.8% of small dams were dry at the time of the survey (n = 144 of dams surveyed). For the small dams with water, 307 dams (52.7%) were occupied by at least one duck, while 275 dams (47.3) that contained water were not observed to have any ducks.

The results of the helicopter survey (Table 1 and Table 2) 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 91% of the total number of waterfowl that were surveyed in the Riverina (16.6%, 23.8% and 50.2%, respectively). The only other species estimated to have a population abundance greater than 10,000 individuals was Plumed-Whistling Duck.

Table 1 Estimated abundance and annual quotas for nine species of waterfowl in NSW Riverina region, July 2022. Estimates were made using an N-mixture model and surveys were restricted to small dams. (lcl = 95% lower confidence level, ucl = 95% upper confidence level).

	Pacific Black Duck	Grey Teal	Australian Wood Duck	Pink-eared Duck	Chestnut Teal	Hardhead	Australian Shelduck	Plumed-Whistling Duck	Blue-Winged Shoveler
Small dams	159800 (lcl: 111100 ucl: 208560)	229200 (lcl: 144330 ucl: 314500)	483560 (lcl: 394970 ucl: 572150)	317 (lcl: 0 ucl: 923)	185 (lcl: 0 ucl: 480)	5832 (lcl: 0, ucl: 12920)	9450 (lcl: 0 ucl: 22370)	75300 (lcl: 2880 ucl: 147650)	258 (lcl: 0 ucl: 738)
Total	159800	229200	483560	317	185	5832	9450	75300	258
Quota	15,980	22,920	48,356	31	18	583	945	7,530	25

Table 2 Average abundance per small dam for nine species of waterfowl in NSW Riverina region, July 2022. λ = mean abundance per dam, lcl = 95% lower confidence level, ucl = 95% upper confidence level, p = detection probability. Detection probability could not be estimated for waterfowl that have "—".

Species	λ	lcl	ucl	*p*
Pacific Black Duck	4.33	3.01	5.65	0.529
Grey Teal	6.21	3.91	8.52	0.481
Australian Wood Duck	13.1	10.7	15.5	0.355
Chestnut Teal	0.005	0	0.013	—
Australian Shelduck	0.256	0	0.606	0.912
Pink-eared Duck	0.0086	0	0.025	—
Hardhead Duck	0.158	0	0.35	0.393
Plumed-whistling Duck	2.04	0.078	4.00	0.705
Blue-winged Shoveler	0.007	0	0.020	1

Recommended quotas for waterfowl in NSW

The best scientific data are used to calculate quotas, and different quotas are set for each species. The quotas determine the maximum number of a certain species' of waterfowl that can be sustainably harvested in a given year. We recommend that low risk, conservative quotas be set for all duck species hunted in NSW due to some of the uncertainties in the factors influencing duck population dynamics and the effects that harvesting has on the survival of duck populations. Quotas may be revised if further information becomes available.

We recommend that a management quota be set at 10% of the estimated population size for species whose population dynamics respond predictably to climatic changes and are in high abundance, e.g. Pacific Black Duck, Grey Teal, and Australian Wood Duck. We advise that reactive quotas be set only for these species because the population dynamics of the other species (such as Pink-eared Ducks, Plumed Whistling-Ducks, Blue-winged Shoveler, Chestnut Teal, Hardhead, and Australian Shelduck) have not shown to respond predictably to changes in climate or only occur in low abundance.

Management quotas are established for species where there is less risk from exploitation. These ducks have relatively large populations, and some data suggests that their population dynamics respond predictably to environmental changes. For species with a higher risk of overharvesting due to smaller populations and/or uncertain dynamics, reactive quotas are recommended. Unless a property is either (1) vulnerable to damage from certain species or (2) able to demonstrate that damage has happened or is extremely likely to do so, we advise against allocation of quota from species with reactive quota.

References

Burnham, K. P., and Anderson, D. R. (2002). 'Model Selection and Inference: A Practical Information-Theoretic Approach.' 2nd edition. (Springer: New York.)

Fiske, I. and R. Chandler (2011). "unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance." 2011 **43**(10): 23.

Link, W. A., Schofield, M. R., Barker, R. J., and Sauer, J. R. (2018). On the robustness of N-mixture models. *Ecology* **99**, 1547–1551. doi:10.1002/ecy.2362

Lohr, S. (2019). 'Sampling: Design and analysis.' Second Edition. (CRC Press: Boca Raton, Florida.)

R Core Team (2022). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing: Vienna, Austria. Available at: https://www.R-project.org/.

Royle, J. A. (2004). "N-mixture models for estimating population size from spatially replicated counts." Biometrics **60**(1): 108-115.