Game duck AHM review

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Abstract

Since 2020, dedicated aerial surveys of Victorian game ducks have been conducted annually to inform seasonal harvest arrangements. Recent population modelling for key harvested species suggests that proportional harvest quotas of 10–20% of estimated Victorian population sizes should be sustainable. However, proportional quota setting might potentially be improved by: (1) reducing the time lag between the aerial surveys (currently in September/October) and the open season (beginning in March); and (2) estimating game duck abundance beyond Victoria by increasing the spatial extent of the dedicated aerial surveys and/or using data produced by the Eastern Australian Waterbird Survey (EAWS) program. The panel considered these options and made the following recommendations:

1. Although game ducks might emigrate from or immigrate to Victoria between the spring aerial surveys and the open season, these movements pose little risk to the Victorian or eastern Australian populations under a conservative proportional harvest system operating in Victoria only.

2. The sustainability of Victoria's harvest is enhanced by largely unharvested "refuge" duck subpopulations in other states. Expansion of abundance estimation to South Australia and New South Wales would provide useful information on population dynamics over the long-term but is not a priority for Victorian quota setting.

3. Given limitations of the EAWS sampling frame and difficulties estimating correction factors for different habitats, using this program for population size estimation is not recommended.

4. Shifting Victoria's aerial surveys from spring to summer (i.e., closer to the open season) has merit but might also place increased pressure on the staff performing the surveys and subsequent data analysis. Delays in either process might then delay the announcement of the recreational hunting season.
5. The current system involving aerial surveys in spring is largely adequate for the purpose of quota setting. The main conservation risk is above-average duck mortality between the surveys and the open season (e.g., due to drought) and a model-based approach might be developed to quantify this risk and adjust proportional quotas when necessary.

Additionally, using metapopulation simulations for four game duck species, the panel tested the performance of a proportional harvest system in combination with a threshold Victorian population size below which no harvesting was performed. Within the recommended proportional harvest quota range of 10–20%, threshold population sizes required for harvesting had little impact on mean population size or expected minimum abundance for black duck, grey teal or wood duck. However, a high threshold (equivalent to 50% of mean simulated population size without harvesting) produced some population benefit for the rarer, coastal chestnut teal. This result is explained because a high proportion of the eastern Australian chestnut teal population is estimated to reside in Victoria, and because dispersal (i.e., compensatory immigration) is assumed to be more limited in this species. Hence, within the recommended proportional harvest quota range, a harvest threshold may not be required for black duck, grey teal or wood duck, but should be considered for chestnut teal.

Contents

1 Introduction

To increase the transparency of, and confidence in, annual harvest regulations, the Victorian Government is currently shifting towards an Adaptive Harvest Management (AHM) approach for game duck species (Ramsey *et al.*, 2010, 2017). AHM attempts to improve our management of wildlife resources through carefully structured learning by doing. A key component of AHM is the development of quantitative population models, able to be represented mathematically, that are used to learn about and predict how wildlife populations respond to changing environmental conditions and harvest regulations. The performance of different models can then be evaluated over time, by comparing model predictions to real data from wildlife monitoring programs.

The Victorian government has been moving towards implementing adaptive harvest management for setting seasonal harvest arrangements for duck hunting in Victoria. Over the last 15 years, experts have designed an approach to model waterfowl abundance, determine sustainable proportional off-take (within the range of 10–20% of the total Victorian abundance) and, using previous harvest data, determine daily bag limits to achieve the desired level of take. Season length may or may not be varied, however, there seems to be a fixed level of effort by Victorian hunters with little variation year-to-year, despite environmental conditions and regulatory settings. Therefore, manipulation of season length in addition to bag limits may not be necessary.

Currently, harvest arrangements are based on game duck population sizes estimated for Victoria. Dedicated aerial surveys of Victorian game ducks were conducted for the first time in 2020, based upon the survey design considerations of Ramsey (2020), and have been conducted annually since. These surveys are timed to occur in in spring (October) and allow estimation of the total abundance of game ducks as well as species-specific estimates for the most abundant species (Ramsey & Fanson, 2021, 2022, 2023).

The distributions of game duck species span much of eastern Australia and cross state boundaries. The ecology of these species is also complex: many of the harvested species are highly mobile, can travel long distances to exploit ephemeral wetlands following rainfall events (Roshier *et al.*, 2008a,b), and can breed rapidly when conditions are favourable. Although Victoria's aerial waterfowl surveys are conducted in spring, the Victorian duck hunting open season does not commence until *c.* 5 months later (on the third Saturday in March each year), so there is ample opportunity for emigration or immigration of ducks to occur between the surveys and the season. A 2017 review (Ramsey *et al.*, 2017) of the approach to AHM, and subsequent reviews of that review, have all recognised the mobile nature of several of the key harvested game duck species, and recommended that AHM models be based on monitoring data covering as much of eastern Australia as possible.

One option is to extend the current Victorian helicopter surveys into eastern South Australia, and to align surveys more closely with those currently being conducted in New South Wales. The large-scale Native Game Bird Management program of New South Wales allows landholders, primarily in the Riverina district, to manage native game ducks on agricultural land with the help of licensed hunters. However, aerial waterfowl surveys of the Riverina are conducted over May to July (Dundas *et al.*, 2016; McLeod, 2022) and are not currently used in Victoria's quota setting. The timing of these Riverina surveys is relatively inflexible because the annual harvest quota is set in August. Surveys are timed to precede quota setting so that the estimate of waterfowl abundance is as close to the start of the harvesting season as possible.

For areas north of central NSW, it has been suggested that game duck abundances might be estimated using data from the Eastern Australian Waterbird Survey (EAWS) (Kingsford, 1989; Kingsford *et al.*, 2020). The EAWS monitors waterbird species in eastern Australia using annual aerial surveys flown in September/October along east-west transect bands of 30 km width that are separated by 2° of latitude. Wetlands that contain water and fall within these bands are surveyed via a number of subsampling methods (Kingsford *et al.*, 2020). The waterbird counts generated by the EAWS are not an absolute estimate of game duck abundance for the survey band let alone the survey area (though see Caley *et al.*, 2022, for a discussion) but rather an index of their abundance which is commonly termed "relative abundance". Note, however, that the EAWS monitoring approach could potentially be revised to quantify detectability in different habitats along the EAWS transect lines. For example, double-observer methods for aerial surveys allow estimation of (possibly observer-specific) detection probabilities and allow waterfowl counts to be adjusted for incomplete detection (Koneff *et al.*, 2008). Double-observer waterbird counts could be conducted as part of future EAWS monitoring, either along entire aerial transects or for a sample of different habitat types along these transects, to allow population estimation for regions beyond the scope of dedicated waterfowl surveys.

To achieve the above, either the Victorian government resources the expansion of the sample frame and revised approach to the EAWS, or cooperation and investment would be required from the South Australian and New South Wales governments, and additional resources would be required to be invested in the EAWS (i.e. the inclusion of two double observers). This review details the panel's consideration of five options presented by the Game Management Authority:

1. Victoria takes responsibility for resourcing the expansion of the sampling frame and revision to the EAWS.
2. Victoria partners with SA and NSW to expand the sampling frame and revision to the EAWS.
3. Maintain the current Victorian sampling frame and conduct abundance surveys in January (as close to the start of the season as possible).
4. Move the timing of the Victorian surveys to align with the NSW Riverina surveys and undertake modelling to predict the population of game ducks at the start of the hunting season.
5. Maintain the current system, which involves abundance surveys for Victoria only which are conducted in October.

Finally, this review extends the simulation modelling of Prowse (2023) to consider expected outcomes for game duck populations a proportional harvest was implemented in combination with minimum population threshold (below which no harvesting was allowed).

2 Strategies for recreational quota setting

Proportional harvest quotas (i.e., quotas set equal to a fixed proportion of a population) are sustainable provided that: (1) the population size can be estimated accurately; (2) the harvested proportion is not so high as to overwhelm the maximum population growth rate of any given species; and (3) the quota is conservative enough to account for stochastic (e.g., environmentally driven) variation in the population growth rate. The panel noted that although a proportional quota might be set as an upper limit for each harvested species, the primary mechanism of limiting harvest off-take is through bag limits, and hence translation of a proportional quota into the required bag limits is a separate exercise which is beyond the scope of this review. In other words, this review assumes that proportional harvest quotas can be set and enforced for each game duck species.

Before evaluating the different management options provided, the panel considered that the proportional harvest quota for Victoria could be set using two possible strategies: (1) as a proportion of estimated species population sizes in Victoria, or (2) as a proportion of the estimated species population sizes in eastern Australia. The former strategy was evaluated using spatial population modelling by (Prowse, 2023) and proportional harvest quotas of 10–20% of the Victorian population sizes were deemed sustainable depending on the species. Table 1 details the panel's consideration of these two quota-setting strategies under different game duck movement scenarios.

Table 1: Summary of harvest quota setting strategies and associated risks. Risks assume no adjustment is made to account for migration of ducks between the annual abundance survey and the recreational hunting season.

Harvest Quota Setting Strategy	**Duck movements between abundance survey and harvest season**	**Risks**
Victorian populations only	Net Emigration from VIC	The proportional harvest quotas may be higher than planned for VIC, but there is no risk to the eastern Australian populations.
Victorian populations only	Net Immigration into VIC	The proportional harvest quotas may be lower than planned for VIC and recreational hunters will be prevented from taking advantage of increased abundance due to immigration. There is no risk to the eastern Australian populations.
Eastern Australian Populations	Net Emigration from VIC	The proportional harvest quotas may be higher than planned for VIC, but there is no risk to the eastern Australian populations.
Eastern Australian Populations	Net Immigration into VIC	The proportional harvest quotas may be lower than planned for VIC and recreational hunters will be prevented from taking advantage of increased abundance due to immigration. There is no risk to the eastern Australian populations.

3 Evaluation of Options

3.1 Victoria takes responsibility for resourcing the expansion of the sampling frame and revision to the EAWS

A proportional harvest quota system based solely on the Victorian sampling frame causes some uncertainty regarding the impact of the state's harvest on the eastern Australian population sizes of the game duck species. Hence, expansion of the sampling frame to include key areas of SA and NSW could potentially assist by providing more complete eastern Australian population estimates to inform Victoria's proportion harvest quotas.

The panel, however, considered that proportional harvesting based on Victorian estimates alone poses no serious risks to the wider eastern Australian population sizes. With the exception of some off-take occurring in the NSW Riverina and South Australia, most ducks residing outside Victoria can be considered an 'unharvested' population fraction which increases the resilience of the wider population and the sustainability of any harvesting that occurs. If substantial movement of ducks into or away from Victoria were to occur between the abundance estimation surveys and the hunting season, the actual Victorian harvest might be lower or higher than would be set based on perfect up-to-date information, yet this should produce no risks for the larger eastern Australian populations providing Victorian quotas are set conservatively (Table 1) .

As another consideration, the panel thought it likely that, were the sampling frame expanded, that population sizes outside of Victoria would likely then be included in calculation of the quota set. And, for example, a 20% harvest quota applied to the larger sampling frame would naturally be harsher on the overall population than a 20% harvest applied to Victorian population sizes only. In summary, while expanding the sampling frame would likely help with understanding the population and movement dynamics of these species, it might result in pressure for higher harvests rather than improving the viability of the game duck populations.

Regarding revision of the EAWS methodology, there are three main problems with the EAWS approach which limits application of these data for quota setting: (1) the system produces relative abundance data only, because no attempt has been made to correct for imperfect detectability; (2) unlike the current Victorian survey, the sampled transects are fixed and take no account of wetland inundation (and hence waterbird aggregation) across the survey region (i.e. the transects in a given year may not be representative w.r.t game duck populations and hence the estimate may be biased)(Caley *et al.*, 2022); and (3) the sampling frame by design focuses on larger natural wetlands, and largely ignores smaller artificial water bodies, including farm dams which can house a large proportion of the populations of certain species (e.g., Australian wood duck) (Ramsey & Fanson, 2021, 2022, 2023).

The first of these issues could be addressed by using double-observer counts, thereby allowing the per-individual probability of detection to be estimated, and the conversion of raw counts to abundance estimates for wetlands surveyed by the EAWS after accounting for imperfect detection. However, options for modifying the EAWS monitoring methods to provide an estimate of incomplete detection are limited. Although double-observer methods have been used to estimate the detectability of waterfowl in North America, the analysis was restricted to small groups (usually consisting of 8 waterfowl or fewer) (Koneff *et al.*, 2008). They noted that when many groups were observed simultaneously, it was not possible to reconcile the observations between the two observers. If groups cannot be reconciled between the observers, the results are highly likely to be biased. The group sizes recorded for some species during the EAWS can be large (including 100's or sometimes 1000's of individuals), and reconciling the counts of this many individuals can be very difficult (S. Dundas pers. comm.).

Addressing the second and third issues would require major changes in the operation of the EAWS. Fixed-winged aircraft are unsuitable for surveying small dams. The EAWS exclusively uses fixed-winged aircraft, leaving a large portion of suitable habitat un-surveyed. Overcoming these limitations of the EAWS would require significant investment to produce data fit for quota-setting purposes — changes we consider unlikely to be supported in the short-term at least.

3.2 Victoria partners with SA and NSW to expand the sampling frame and revision to the EAWS

As above, the panel considers there are not clear reasons to expand the sampling frame beyond Victoria, and that revision of the EAWS to allow robust population estimation would be difficult and very costly. It is worth noting there is no guarantee that the external funding and personnel required to maintain (and augment) the EAWS surveys would continue indefinitely into the future. Seeking additional funding partners in SA and NSW would likely complicate this funding situation, and again, maintaining funding across three states for these proposed changes would likely be difficult.

3.3 Maintain the current Victorian sampling frame and conduct abundance surveys in January (as close to the start of the season as possible)

The advantage of this proposal is that abundance estimates for Victoria would be generated *c.* 2 months before the start of the season (rather than *c.* 5 months before hand as with the current October surveys). Given that some game ducks likely emigrate from Victoria in summer to track rains in northern Australia, October surveys might overestimate Victorian population sizes at the start of the hunting season because counts are conducted before northerly movement occurs. In contrast, January surveys might be less likely to overestimate population sizes because some/all of this movement might have occurred prior to the survey period, and hence the Victorian populations might be assumed to be closed between the survey flights and the season commencement.

In reality, although January surveys would be closer to the start of the harvest season, it is still possible for duck movement into or away from Victoria between the surveys and the season commencement, which leads to the same (albeit lessened) uncertainty associated with surveys in October. There may also be logistical challenges with conducting the surveys and data analysis required for generating abundance estimates in January. Such challenges may include difficulty in securing appropriately skilled survey contractors to operate during this time and unforeseen environmental conditions, such as flooding and/or widespread bushfires. Delay in the calculation of abundance estimates and proportional quotas might flow on to delays to the announcement of the recreational hunting season.

3.4 Move the timing of the Victorian surveys to align with the NSW Riverina surveys and undertake modelling to predict the population of game ducks at the start of the hunting season

Given the NSW Riverina surveys cannot be moved to spring or summer, this option would require the Victorian surveys to be shifted to April–May to match the timing of the NSW surveys. Unfortu- nately, this would place the Victorian surveys within the open season, meaning proportional harvest quotas would be based on data collected a full year prior. This longer delay between surveys and the hunting season would allow extra time for the Victorian population size to deviate from that surveyed due to immigration, emigration or extreme environmental variation (e.g., drought). Modelling these deviations might prove difficult due to the long time lag involved.

3.5 Maintain the current system, which involves abundance surveys for Victoria only which are conducted in October.

Maintaining the current system leaves a *c.* 5-month lag between abundance surveys and the hunting open season. As detailed in Table 1, movement of game ducks away from Victoria during this period is unlikely to compromise the viability of eastern Australian populations because: (1) if there is net emigration, the proportional harvest quotas will be higher than planned for Victoria, but emigrating ducks will be safe from harvesting; and (2) if there is net immigration, the proportional harvest quotas will be lower than planned for Victoria so there is no conservation risk (but note that recreational hunters will be prevented from taking advantage of increased abundance due to immigration). However, if some information on likely duck population sizes outside Victoria was desired, a model-based approach to estimating population sizes in SA and NSW (e.g., based on satellite observation of wetland filling and drying) could potentially be used.

The primary risk associated with maintaining the current system is a decline in population size due to high duck mortality between the spring surveys and autumn harvest season. For example, drought conditions in Victoria or eastern Australia more generally, such as might occur during El Niño periods, could increase natural mortality rates and decrease population sizes locally or regionally. A disease epidemic (e.g., high pathogenicity avian influenza) could have a similar effect. Hence, unusually high mortality between the spring surveys and autumn harvest poses some risk because the Victorian proportional harvest quota would be set higher than the target proportion and the increase in harvest-induced mortality would not be balanced by improved survival rates elsewhere. To a large extent, conservative harvest quotas (10–20% of estimated population size) are designed to allow for environmental variability, particularly variation in water availability, and additional harvest-induced mortality due to wounding (Prowse, 2023). However, a modelling approach could be developed to estimate change in the Victorian population size between the surveys and the harvest season, potentially incorporating both dispersal and natural mortality over this period.

4 Evaluation of a proportional harvest strategy with threshold

By extending the model developed in Prowse (2023), we tested the performance of proportional harvesting strategies for game ducks, in combination with a threshold Victorian population size below which no harvesting occurred, under a climate change scenario. Metapopulation simulations were conducted for two highly mobile species (black duck and grey teal) and two more sedentary species (chestnut teal and Australia wood duck) over a 50-year simulation time frame. The proportional harvest quota was varied between 0 and 50%, while species-specific harvest thresholds ranging up to 50% of mean population size (in the absence of harvesting) were also tested (Figures 1 and 2).

Within the recommended proportional harvest quota range of 10 – 20%, threshold population sizes required for harvesting had little impact on mean population size or expected minimum abundance for black duck, grey teal or wood duck (Figures 1 and 2). However, a high threshold (set at approximately 18,000 individuals, equivalent to 50% of mean simulated population size without harvesting) produced some population benefit for the rarer, coastal chestnut teal (Figure 2). This result is explained because a high proportion of the eastern Australian chestnut teal population is estimated to reside in Victoria, and because dispersal (i.e., compensatory immigration) is assumed to be more limited in this species. For simulated proportional harvests exceeding 20%, implementation of a high threshold (approximately 50 % of unharvested population size) yielded benefits for all species because higher harvesting pressure reduced population sizes and hence application of the threshold was simulated to occur more frequently.

In summary, these results suggest that, within the recommended proportional harvest quota range of 10 – 20%, a harvest threshold may not be required for black duck, grey teal or wood duck, but should be considered for chestnut teal. One caveat to note is that this metapopulation model assumes a relationship between water availability and the carrying capacity of the landscape for game ducks, based on a statistical relationship between the Standardised Precipitation Evapotranspiration Index (SPEI) and the relative abundance of duck species from the EAWS. This modelled relationship influences the frequency at which simulated population sizes are 'naturally' reduced to low levels, and therefore also influences expected outcomes from applying a threshold. As the time series of annual game duck estimates for Victoria lengthens over the coming years, the relationship between environmental conditions and carrying capacity could be re-evaluated.

5 Acknowledgments

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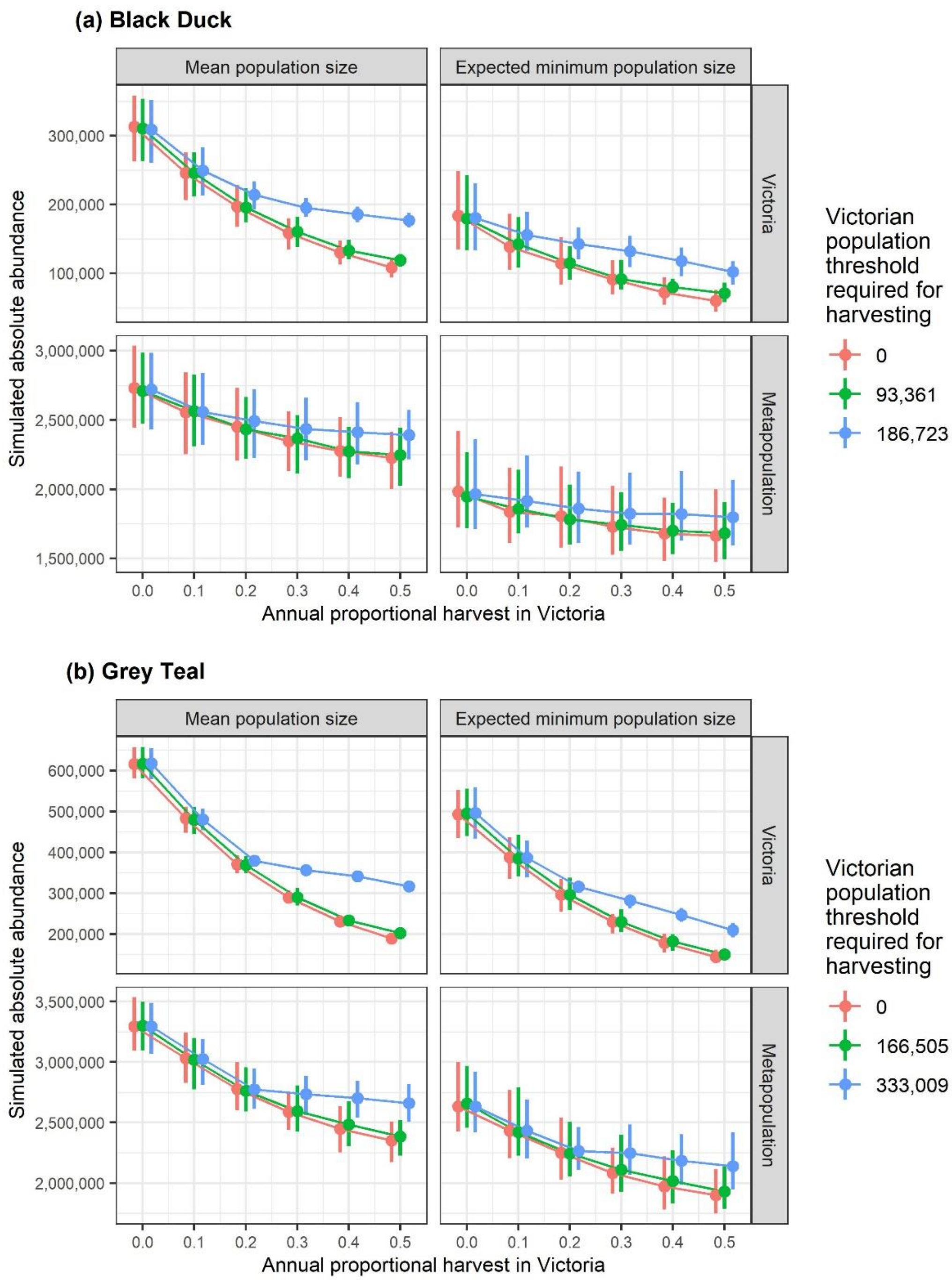

Figure 1: Summary of simulation results for the two highly mobile species, black duck and grey teal. Mean population size and expected minimum population size are shown and were calculated over a 50-year simulation period, for different Victoria proportional harvest rates and threshold population sizes (below which harvesting as assumed not to occur). Error bars represent 95% confidence intervals derived by simulation. Note the different y-scales for the two species plotted.

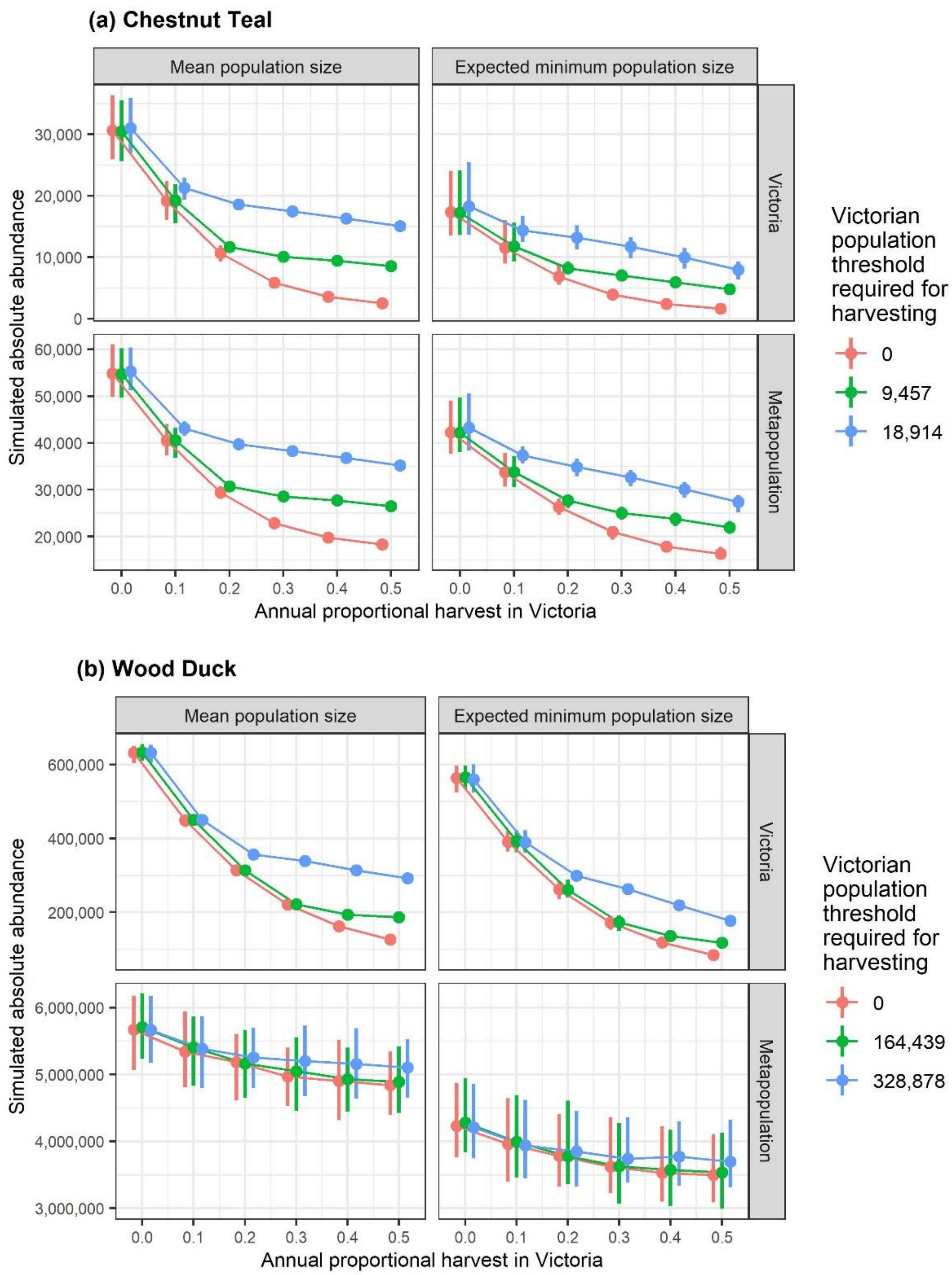

Figure 2: Summary of simulation results for the two more sedentary species, chestnut teal and wood duck. Mean population size and expected minimum population size are shown and were calculated over a 50-year simulation period, for different Victoria proportional harvest rates and threshold population sizes (below which harvesting as assumed not to occur). Error bars represent 95% confidence intervals derived by simulation. Note the different y-scales for the two species plotted.

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