

# Relationships among duck population indices and abiotic drivers to guide annual duck harvest management

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## Summary

Based on literature, practices elsewhere, and earlier recommendations, duck harvest management for Victoria should contain indices that inform on (i) breeding conditions in Victoria, (ii) breeding conditions throughout SE Australia, (iii) current or recent duck population size in Victoria, and (iv) duck population size throughout SE Australia. We propose five indices reflecting elements i-iv. Three of these indices, reflecting breeding condition elements i and ii, use availability of water in the landscape (LANDSAT satellite imagery) across up to 4 regions in SE Australia over 1-3 year intervals. By comparing these indices with actual hunting regulations between 1991-2020, we evaluate their use in advising on future annual hunting arrangement.

## Background<sup>1</sup>

The Victorian Government and its agencies have been considering for some time the potential role of formal population models in decision-making and enhancing public confidence in regulatory performance in setting arrangements for the annual duck hunting season.

In 2009, an expert panel of scientists from Australia, New Zealand and USA was convened to assess whether the approach to sustainable waterfowl harvesting in Victoria could be improved by a more robust scientific approach, and specifically a harvest management model that could be delivered at minimal cost.

The expert panel recommended an adaptive harvest management (AHM) approach be adopted, and developed prototype models of the population dynamics of example game species of waterfowl to inform this approach. Monitoring recommendations and simulation studies using the prototype models were provided in a report published in 2010 (Ramsey et al. 2010). However, the modelling approach recommended in the 2010 report was not implemented by the Victorian government at the time.

In 2016, the Victorian government committed to implementing adaptive harvest management for duck hunting in its Sustainable Hunting Action Plan. In response, the Victorian Game Management Authority (GMA) contracted scientists from the Victorian Arthur Rylah Institute for Environmental Research (ARI) and New South Wales Department of Primary Industries (NSW DPI) in 2017 to review the recommendations in the 2010 report given the passage of time, advances in monitoring technology and further experience in implementing AHM in North America and Europe. The review (Ramsey et al. 2017) recommended a changed approach to modelling and the development of a monitoring program to support implementation of an adaptive harvest management program, amongst other things.

A monitoring program was subsequently designed (Ramsey 2020) and implemented in a trial helicopter survey in November 2020 to test its performance and rigour. Absolute abundance estimates for game ducks in Victoria were inferred and recommendations for further improvements to the monitoring program were included in an evaluation report prepared by Ramsey and Fanson (2021). This report was reviewed by Dr Steve McLeod, NSW DPI (McLeod 2021).

In response to a 2018 election commitment, the Victorian government established an expert panel to review the findings and recommendations contained in the 2017 report. The expert panel report was completed in 2019 (Prowse et al. 2019) and made a series of findings and recommendations. Recommendation 3 was that “a simple harvest management framework be adopted initially, to clearly translate waterfowl monitoring and data on rainfall/wetland availability into harvest recommendations” while ongoing development of the adaptive harvest population model for waterfowl is developed simultaneously as a longer-term goal to assist management

The 2019 expert panel report provided further advice on the recommended harvest management framework:

*“Therefore, consideration should be given to a simple, transparent process for setting harvest regulations which could then be modified or augmented to include modelling results as appropriate at a later date. Given the constraints in currently available scientific information, the panel therefore recommends that, in the short-term, appropriate and adequate information for management can be generated by a conceptually simple and defensible harvest management framework which combines*

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<sup>1</sup> Largely copied from *Request for Quote*

*appropriate measures of spring wetland abundance/rainfall, summer abundance/rainfall, and available waterbird monitoring data to annually generate an abundance ranking for the coming season.*

*This could take a range of forms, such as a “traffic light” system reflecting risk levels (i.e. red light = Low abundance/High risk; orange = Medium abundance/Medium risk; Green light = High abundance/Low risk). The number of abundance/risk levels could be extended as appropriate, and this categorisation could be linked to appropriate management measures.*

*The proposed modelling of historical datasets could evaluate and test the capacity of various indices of rainfall/wetland availability to predict waterfowl population growth rates, and thereby recommend categories of harvesting with definitions based on these indices.”*

With this report, we aim to address the 2019 expert panel recommendations and inform decision making to guide annual harvest management. It was informed and improved by responses from a range of stakeholders on a draft version (provided as *Summary of issues raised in submissions received on the draft proposal* at the end of the document).

## Introduction

Summarizing insights from a large body of literature and knowledge on the drivers for duck abundance and distribution in Australia yields a conceptual model of the driving factors and indices for game management decision-making (Figure 1). Current understanding suggests that duck numbers and distributions are importantly determined by water in the landscape and direct management of ducks, including hunting, with current duck numbers determining future duck numbers, as for any model of changes in abundance. For ducks, density dependence is generally low and environmental variability contributes most to variation in duck numbers (e.g. Pöysä et al. (2016) and citations therein). This is likely due to the typical life history of ducks, characterised by a young age at first reproduction and large clutch sizes. Although our knowledge of waterfowl movement in Australia in relation to spatially and temporally varying resource availability is incomplete, the counting, banding and tracking work available to date indicates that large numbers of waterfowl track resources over vast distances. Duck numbers in Victoria cannot be considered in isolation of duck numbers elsewhere, particularly in SE Australia. Taken together and also following (proposed) practices elsewhere in Australia (SA Dep Environ Water 2020) and overseas (e.g. U.S. Fish & Wildlife Service (2020)), as well as recommendations of the 2019 expert panel (Prowse et al. 2019), a duck harvest management framework for Victoria should contain indices that inform on the following elements:

1. breeding conditions in Victoria;
2. breeding conditions throughout SE Australia;
3. current or recent duck population size in Victoria and;
4. duck population size throughout SE Australia.

Breeding conditions are mainly reflected by water in the landscape, particularly for highly dependent aquatic waterbirds, determining habitat availability.

A conceptually simple management framework should be based on these four elements, but also be transparent and defensible. We propose five indices (Figure 1) and provide analyses supporting their value in reflecting the four elements. Next, by comparing these indices with actual hunting regulations (1991-2020), we evaluate their use in advising on future annual hunting arrangements.

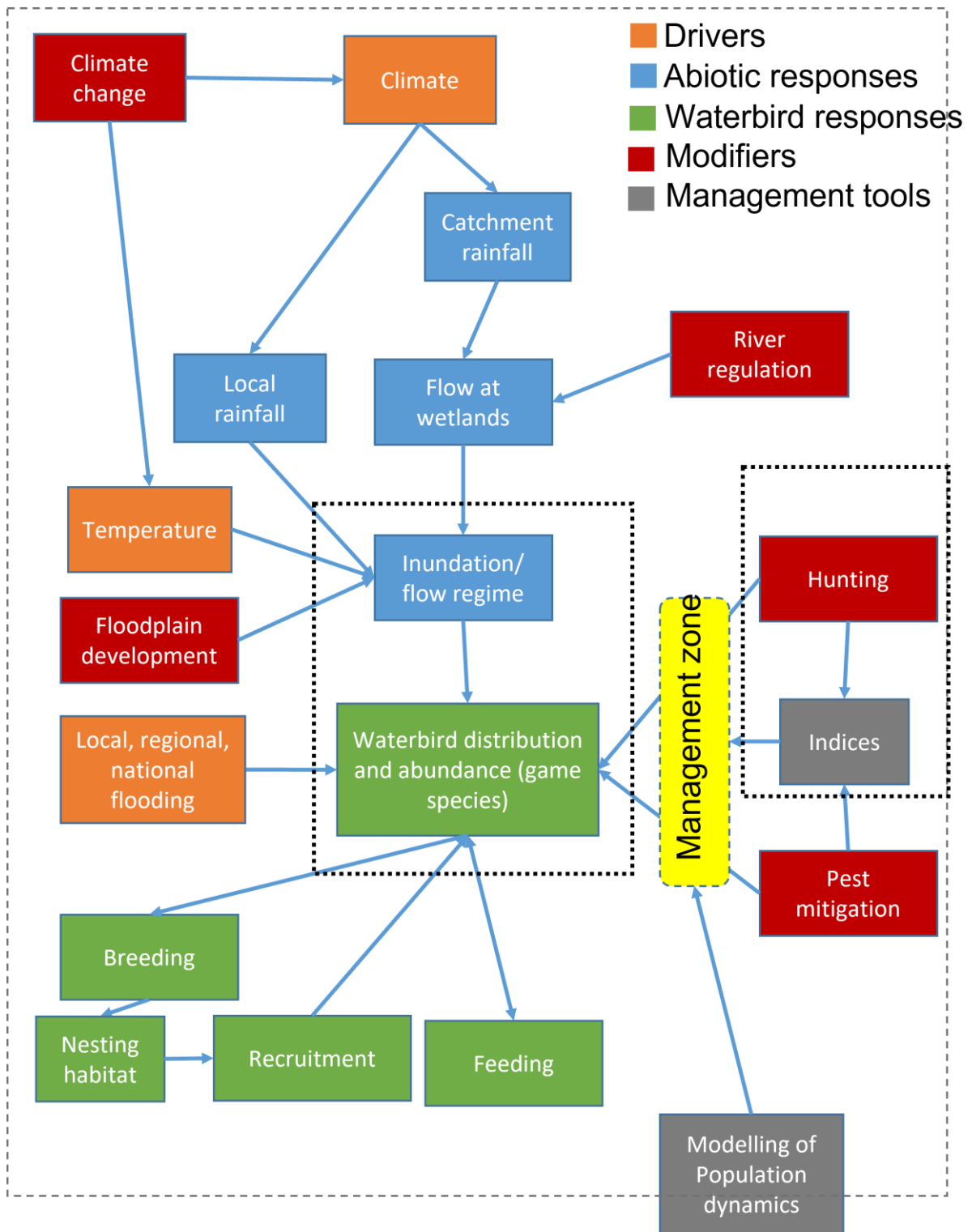


Figure 1. Conceptual model of the drivers of abundance of game species and the decision making space for harvesting ducks, where dotted lines indicate the focus of this report on relationships between flooding and waterbird abundance, linked to indices (adapted from Prowse et al. 2019).

### Proxies for duck numbers

The number of ducks in Victoria and SE Australia are unknown and, despite the best of efforts and the use of advanced technology, likely also impossible to know with great accuracy. Next-best is a good estimate of duck numbers and status of the landscape informing on their breeding potential. For this the following three data sources come into focus.

- **Victorian hunting bags** during opening weekend have been collected and reported by ARI since 1973 (Menkhorst et al. 2019) and may provide a proxy for the game population when simultaneously considering the seasonal arrangements for duck hunting in every single year (Game Management Authority 2021).
- **Game-duck-species counts across Victoria** which started in 1987, have been conducted in the framework of the Victorian Duck Season Priority Waterbird Counts, which summarises ground-based counts in Victoria, with data collected from a large number of wetlands (100+ annually), mostly taking place a month ahead of the duck hunting season. The approach of the Victorian game counts changed in 2015, when a limited survey was introduced focussing on so-called “priority wetlands”, which are also important duck hunting sites. To avoid bias, our analyses only used data from 37 priority wetlands, counted 20 or more times since 1987. Although not claiming to be an overall count of game across the state, it may serve as a proxy for duck game species in Victoria (Menkhorst et al. 2020). Due to counts being hampered by the COVID-19 outbreak, data from 2020 were incomplete and not considered in the analyses.
- **The Eastern Australian Aerial Waterbird Survey** counts, taking place in October of every year since 1983 forms yet another important data source, with its most southerly transects (bands 1-3) providing a proxy for birds in Victoria, southern NSW and SE SA with bands 4-6 providing a proxy for bird numbers for the remainder of SE Australia, i.e. eastern SA and the whole of NSW and the south of Queensland (from here onwards referred to as VIC and NSW aerial counts, respectively) (Kingsford et al. 2020).

The latter, aerial counts can be directly used as proxies for actual game numbers for Victoria and the whole of SE Australia, given that the survey is conveniently timed, a few months prior to when hunting arrangements for the upcoming hunting season are called and has used a consistent methodology.

The above data series are possibly not the only remarkable duck data series available. Another example is the long-term database on duck counts from Melbourne Water’s Western Treatment Plant (WTP), a permanent wetland bordering Port Philip Bay in Victoria. Based on our analysis of these data we conclude that duck numbers in the WTP increase when conditions in the wider landscape become unfavourable for ducks. This function of the WTP as a refuge for waterfowl is also corroborated with previous analyses in the literature (Loyn et al. 2014, Clarke et al. 2015, Papas et al. 2021). It cautions against assessing duck population sizes across the state from single wetland counts, notably if the hydrology of these wetlands is disconnected from what is happening in the wider landscape.

### Proxies for duck numbers and their relationships with water in the landscape

The four data sources allow for analyses of game numbers of ducks in relation to availability of water in the landscape using LANDSAT satellite imagery. Given that water availability is the key driver of waterbird numbers, we investigate relationships that allow predictions of habitat suitability for ducks from water availability in the landscape over time.

There are inherent uncertainties in every estimate, with observer/ methodological and sampling errors and this holds for water surface estimates, hunting bag estimates as well as on-the-ground and aerial counts. This is also clearly expressed by the authors of the reports from which these data were extracted. This fact cautions against expecting relationships explaining very high proportions of variation and necessitating the use of multiple indices in informing duck hunting arrangements (a multiple lines of evidence approach). These data sets vary in timing in relation to hunting and scale (Fig. 2).

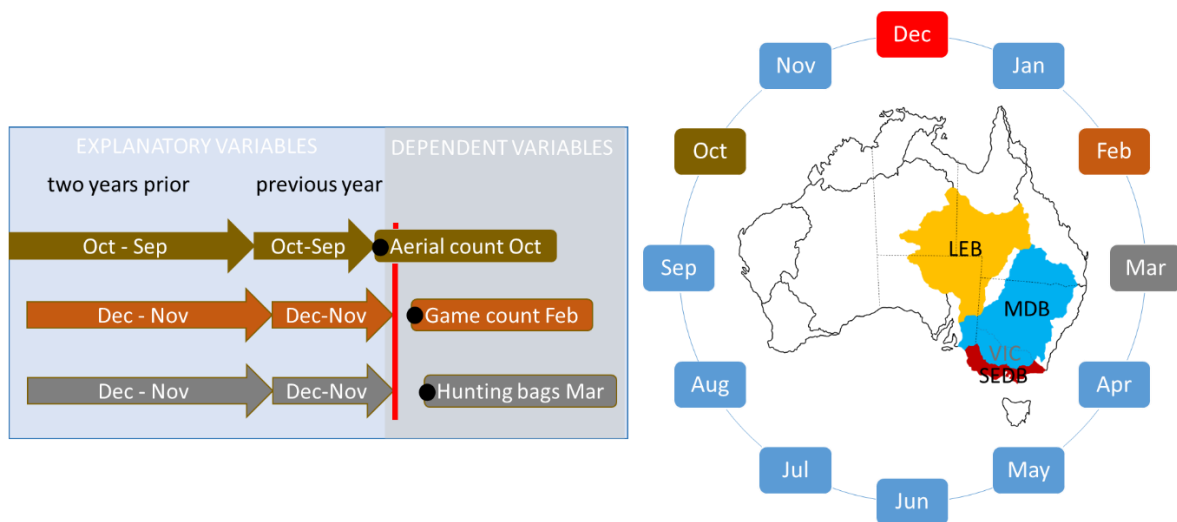


Figure 2. Map with the regions for which water in the landscape was measured, including the Lake Eyre Basin (LEB, mustard), Murray-Darling Basin (MDB, blue) and southeast SEDB (dark red). Victoria (VIC) was also considered a separate region for these analyses. The average water surface area across these regions in the year prior to the aerial counts and the two years prior to that were used as explanatory variables in the statistical analysis of aerial counts. For Game counts and hunting bags these water surface areas were similarly calculated, but using a 3 and 4 month time shift respectively, allowing for models that can generate predictions based on water surface area in the landscape over the preceding 3 years in December of each year.

A detailed account of the methods and results of our analyses, including programming code, is provided in the supplemental html “an analysis of duck proxies and surface water to inform hunting arrangements”, with only an abridged version of methods and results provided here. Monthly water surface areas as % of total surface water area and starting July 1987, were extracted from LANDSAT satellite imagery following Pekel et al. (2016) for Victoria (VIC) Murray-Darling Basin (MDB), SE Australia south of the MDB (SEDB) and the Lake Eyre Basin (LEB) (Figure 2). To investigate the relationships between hunting bags, game counts and aerial survey counts for Victoria and NSW as dependent variables in relation to water surface areas as explanatory variables, we used linear modelling in R. As explanatory variables we used the average water surface area, over the year prior to which the dependent variables, were collected (abbreviated as VIC, MDB, SEDB and LEB, Fig. 2).

Generally, there were good relationships between the four proxies for duck numbers and water in the landscape in the preceding 12 months, notably so for the percentage of water surface area in Victoria and across the entire MDB. Modest time shifts of up to 6 months (i.e., using average water surface areas calculated from 0-12 months prior to the estimate of the dependant variable up to 6-



18 months prior) did not generally impact the fits, somewhat supporting an approach where decision-making on annual duck hunting arrangements is made based on environmental indicators a few months prior to the actual hunting season. These relationships based on 12 months of water surface data represent the availability of habitat for ducks and probably also reflect breeding capability.

To allow for longer-term effects of water availability in the landscape on duck populations, reflecting breeding and recruitment, we created an additional set of explanatory variables that consisted of the average water surface area over the two years prior to the explanatory variables outlined above (abbreviated as *VIC2*, *MDB2*, *SEDB2* and *LEB2*). Thus, in each analysis we used eight explanatory variables. We ignored data on water surface area between the 1<sup>st</sup> of December and the actual game counts and hunting bag assessments, since the aim was the development of models that can predict hunting bags and game counts in December of each year, prior to the actual game counts and assessments of hunting bags during opening weekend.

To have explanatory variables for water surface area covering one full year prior to the counts and hunting bag assessments and the two years before that, we time-shifted water surface estimates by 3 and 4 months for these two dependent variables, respectively. By doing so, we thus tried to explain the variation in the two dependent variables with explanatory variables for the four regions containing the average water surface area running from December two years before, until November in the previous year and from December four years ago until November two years ago. For the aerial survey counts across Eastern Australia, in October each year, we did not time shift the data and calculated average water surface areas 0-12 months prior to the October count and 12-36 months prior to the October counts for all four regions. We used function dredge in R to evaluate all possible combinations of the eight explanatory variables in explaining the four dependent variables, using a linear modelling approach.

Out of all these combinations we ultimately selected a model as the most satisfying model explaining the dependent variable using the following criteria: (i) all parameter estimates for the explanatory variables in the model were significantly different and larger than zero, (ii) its AIC ranking was high (i.e. its AIC value needed to be amongst the lowest across all models tested), (iii) the model's adjusted  $R^2$  was amongst the highest of all models tested. The results of this exercise are in Table 1.

*Table 1. Selected predictive models for annual hunting bag size during opening weekend, game counts in Victoria and aerial waterbird surveys for survey bands in Victoria and NSW across the years 1990 – 2020, using the average percentage of surface water over the previous year and the two years before this (i.e. total of three years' worth of surface water information), over four different geographic regions (SEDB, MDB, VIC, LEB). Only previous year's data for VIC and MDB were selected and data for the two years before that for MDB and LEB (i.e. MDB2 and LEB2, respectively).*

| <i>Dependent variable</i> | <i>Model</i>                                   | <i>N</i> | <i>AIC rank</i> | <i>adjusted <math>R^2</math></i> |
|---------------------------|--|----------|-----------------|----------------------------------|
| Bag size                  | 0.430 + 4.792 <i>MDB</i>                       | 25       | 1               | 0.230                            |
| Game counts Victoria      | -23008 + 75433 <i>VIC</i>                      | 26       | 1               | 0.198                            |
| Aerial counts Victoria    | -62400 + 82644 <i>VIC</i> + 108564 <i>LEB2</i> | 31       | 3               | 0.530                            |
| Aerial counts NSW         | -54758 + 75224 <i>VIC</i> + 99745 <i>LEB2</i>  | 31       | 1               | 0.380                            |

For bag size, although measured during opening weekend in Victoria, the preferred model contained water availability over the previous year in MDB rather than Victoria. However, it should be considered that water surface area in the MDB is highly correlated with water surface area in Victoria ( $r = 0.65$ ,  $n=25$ ,  $P < 0.01$ ). Moreover, the number of ducks in Victoria and thus the ease of shooting them, may not only be dependent on water and wetland conditions in Victoria but also elsewhere as we also a priori assumed (see Introduction page 5). The aerial counts for Victoria and NSW also reflect the importance of water in the landscape, although water availability in the landscape across the Lake Eyre Basin, 2-3 years prior to the counts, appears influential on duck numbers. Importantly, correlations between *LEB2* and *MDB2* ( $r = 0.61$ ,  $n=30$ ,  $P < 0.01$ ) and *VIC* and *MDB* ( $r = 0.69$ ,  $n=30$ ,  $P < 0.01$ ) are reasonably high.

### Duck indices

Using the preferred predictive models from Table 1 as well as the two aerial duck counts (i.e. Victoria and NSW), we developed indices that broadly inform on the current population status of ducks in SE Australia and Victoria. We opted not to use bag size predictions from water surface area as an index of duck numbers since bag size may be biased by hunting bag limits imposed during 12 of the 25 years for which data were available. Using linear modelling across hunting bag data from unrestricted seasons only, also dramatically reduced sample size ( $n=13$ ) and yielded no meaningful insights (i.e. insignificant relationships only).

To graphically illustrate the fit of the models to the data, we plotted predicted duck proxies using the remaining three models in Table 1, against observed duck proxies (Figure 3). Additionally, using symbols depicting seasonal bag limits (outside opening weekend and ignoring species-specific limitations imposed in some years and in some species), these graphs also allow identifying thresholds for these proxies above which restrictions were typically not imposed (and conversely below which, limitations to hunting were called). These threshold values for game duck counts in Victoria and aerial surveys for Victoria and NSW were 64000, 56300 and 53500, respectively. These threshold values were used to calculate five duck population indices:

*iPGame*: index of game counts limited to priority wetlands using the game counts predicted by the model in Table 1 divided by the game count threshold of 64,000

*iVic*: index of aerial survey for Victoria using the predicted aerial counts for Victoria (Table 1) divided by the threshold for these counts of 56,300

*iNSWC*: index of aerial survey for NSW using the predicted aerial counts for NSW (Table 1) divided by the threshold for these counts of 53,500

*tfVic*: index or threshold fraction of aerial survey for Victoria using actual counts divided by the threshold for these counts of 56,300

*tfNSWC*: index or threshold fraction of aerial survey for NSW using actual counts divided by the threshold for these counts of 53,500

Index values higher than 1 indicate a good to excellent population status of ducks, while values lower than 1 indicate a poor to good population status. These 5 indices cover the 4 elements mentioned in the introduction as follows:

1. Breeding conditions in Victoria is covered by *iPGame* and *iVic*.
2. Breeding conditions throughout SE Australia is covered by *iPGame*, *iVic* and *iNSWC*.

3. Current or recent duck population size in Victoria is covered by *tfVicC*.
4. Duck population size throughout SE Australia is covered by *tfVicC* and *tfNSWC*.

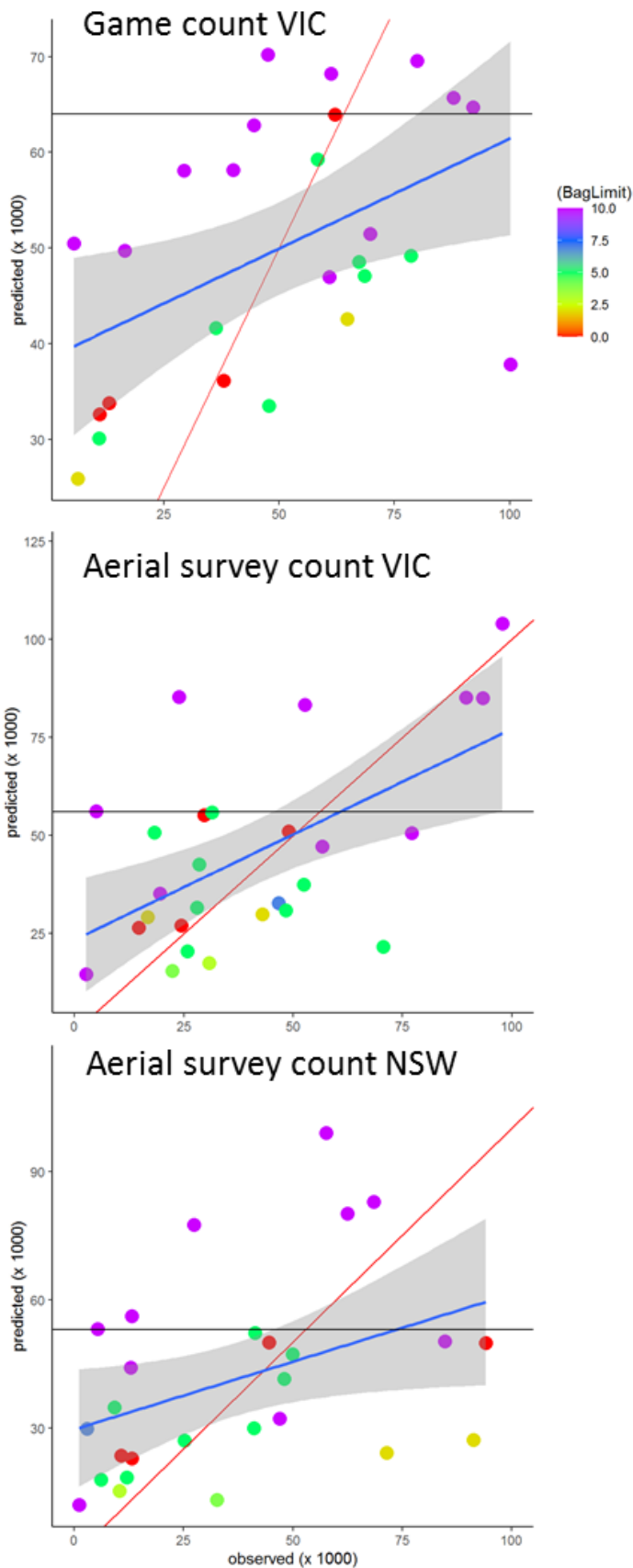


Figure 3. Observations versus model predictions for Game counts in Victoria and aerial waterbird survey counts of Victoria and NSW, with symbol colour reflecting hunting bag limits for the season (not considering potential separate limitations for individual species and special restrictions during opening weekend). Red line depicts observed=predicted, while the blue line is the linear regression relationship with grey shading reflecting the 95% confidence interval of this line. Black horizontal lines are thresholds values for these three dependent variables, reflecting the lower limit above which unlimited seasons were always called.

### Past performance of the indices

In Table 2 we present the predictions for the five indices, calculated for all years where we have complete sets of data available to allow these calculations (i.e. from 1991-2020). In this table, years are ranked from years with the most to the least restrictive hunting regulations (i.e. they are ranked by seasonal bag limit ranging between 0-10 ducks, not considering any opening-weekend or species-specific hunting regulations, 1995, 2003, 2007 and 2008 being the most restrictive). The index values are colour coded with dark colours indicating high and light colours indicating low population status. The same data are also presented graphically (Figure 4), where boxplots show all five indices as well as their median value across three categories of hunting season: unrestricted, somewhat restricted and cancelled hunting seasons. For these three categories, it is expected that indices should show high, intermediate, and low values, respectively. Although there is a clear tendency for this to occur, there is considerable variation both within and across indices.

Firstly, there is a need to reiterate that all proxies, as well as estimates of water in the landscape are prone to error. Also, the decisions in relation to setting of annual duck hunting regulations and seasons may be influenced by a range of factors. Thus, we should caution against naively expecting highly clear-cut patterns of index values for the various bag-limit categories.

Table 2. The five predicted duck population indices for the years 1991-2020 where years are ranked from most (BagLimit = 0) to least (BagLimit = 10) restricted hunting seasons (values are not considering opening weekend and species-specific regulations; data from Game Management Authority (2021)). The index values are colour coded with dark colours indicating good and light colours indicating poor population status. Indices in white font (body of the table) relate to proxies from Victoria whereas indices in yellow font (body of the table) relate to proxies from NSW. In the final column the proposed hunting arrangement for each season is presented based on all five indices using an aggregate point system (aPS; see text below under "Annual duck hunting arrangements").

| Year | BagLimit | using water surface |       |       | using aerial counts |        | aPS |
|------|----------|---------------------|-------|-------|---------------------|--------|-----|
|      |          | iPGame              | iVicC | iNSWC | tfVicC              | tfNSWC |     |
| 2007 | 0        | 0.53                | 0.48  | 0.50  | 0.43                | 0.20   | 1   |
| 2008 | 0        | 0.51                | 0.52  | 0.55  | 0.26                | 0.25   | 3   |
| 2003 | 0        | 0.56                | 0.53  | 0.55  | 0.53                | 0.83   | 5   |
| 1995 | 0        | 1.00                | 0.90  | 0.90  | 0.87                | 1.76   | 7   |
| 2009 | 2        | 0.40                | 0.39  | 0.42  | 0.30                | 1.34   | 2   |
| 2004 | 2        | 0.67                | 0.37  | 0.39  | 0.76                | 1.71   | 4   |
| 2020 | 3        | 0.57                | 0.19  | 0.22  | 0.55                | 0.19   | 2   |
| 2016 | 4        | 0.59                | 0.26  | 0.29  | 0.40                | 0.61   | 2   |
| 2019 | 5        | 0.52                | 0.32  | 0.34  | 0.86                | 0.47   | 2   |
| 2005 | 5        | 0.64                | 0.59  | 0.60  | 0.46                | 0.22   | 3   |
| 2015 | 5        | 0.65                | 0.28  | 0.31  | 0.93                | 0.17   | 3   |
| 2010 | 5        | 0.47                | 0.63  | 0.64  | 1.25                | 0.11   | 4   |
| 2000 | 5        | 0.74                | 0.56  | 0.58  | 0.32                | 0.93   | 5   |
| 2001 | 5        | 0.77                | 1.00  | 1.00  | 0.50                | 0.77   | 6   |
| 2002 | 5        | 0.76                | 0.98  | 0.99  | 0.56                | 0.77   | 7   |
| 1998 | 5        | 0.93                | 1.00  | 1.00  | 0.51                | 0.90   | 8   |
| 2006 | 7        | 0.62                | 0.49  | 0.51  | 0.83                | 0.05   | 3   |
| 2017 | 10       | 0.59                | 0.84  | 0.85  | 0.05                | 0.02   | 3   |
| 2018 | 10       | 0.73                | 0.55  | 0.57  | 1.01                | 0.24   | 5   |
| 1999 | 10       | 0.80                | 0.90  | 0.91  | 0.09                | 0.10   | 5   |
| 2011 | 10       | 0.78                | 1.84  | 1.82  | 0.35                | 0.88   | 6   |
| 1997 | 10       | 1.10                | 0.76  | 0.77  | 1.79                | 0.25   | 6   |
| 2014 | 10       | 0.79                | 0.67  | 0.68  | 0.93                | 0.51   | 6   |
| 1994 | 10       | 1.09                | 0.91  | 0.91  | 0.43                | 1.28   | 8   |
| 2012 | 10       | 0.98                | 2.16  | 2.12  | 1.74                | 1.08   | 10  |
| 1996 | 10       | 1.07                | 1.00  | 1.00  | 1.37                | 1.58   | 10  |
| 1991 | 10       | 1.03                | 1.87  | 1.84  | 1.66                | 2.67   | 10  |
| 1993 | 10       | 0.91                | 1.51  | 1.49  | 1.59                | 1.17   | 10  |
| 2013 | 10       | 0.91                | 1.48  | 1.47  | 3.00                | 2.95   | 10  |
| 1992 | 10       | 1.01                | 1.51  | 1.50  | 2.45                | 2.30   | 10  |

Next, we must consider that indices that rely on many (independent) estimates over considerable periods of time are less prone to error than indices relying on much fewer data. The indices based on water surface area, which are calculated based on monthly water surface estimates over 1-3 years, are thus expected to fluctuate less due to chance compared to the indices based on annual aerial counts, based on a single set of counts over a relatively short period of time. Indeed, *iPGame*, *iVicC* and *iNSWC* show clearer patterns across the three hunting restrictions categories in Figure 3 than *tfVicC* and *tfNSWC*. For the latter two indices, we observe generally more variation within the bag limit categories and more overlap between bag limit categories. The latter is notably the case for *tfNSWC*. However, for this index it should also be considered that it is based on counts entirely outside of Victoria, which may also be cause for a weaker correlation with annual hunting arrangements.

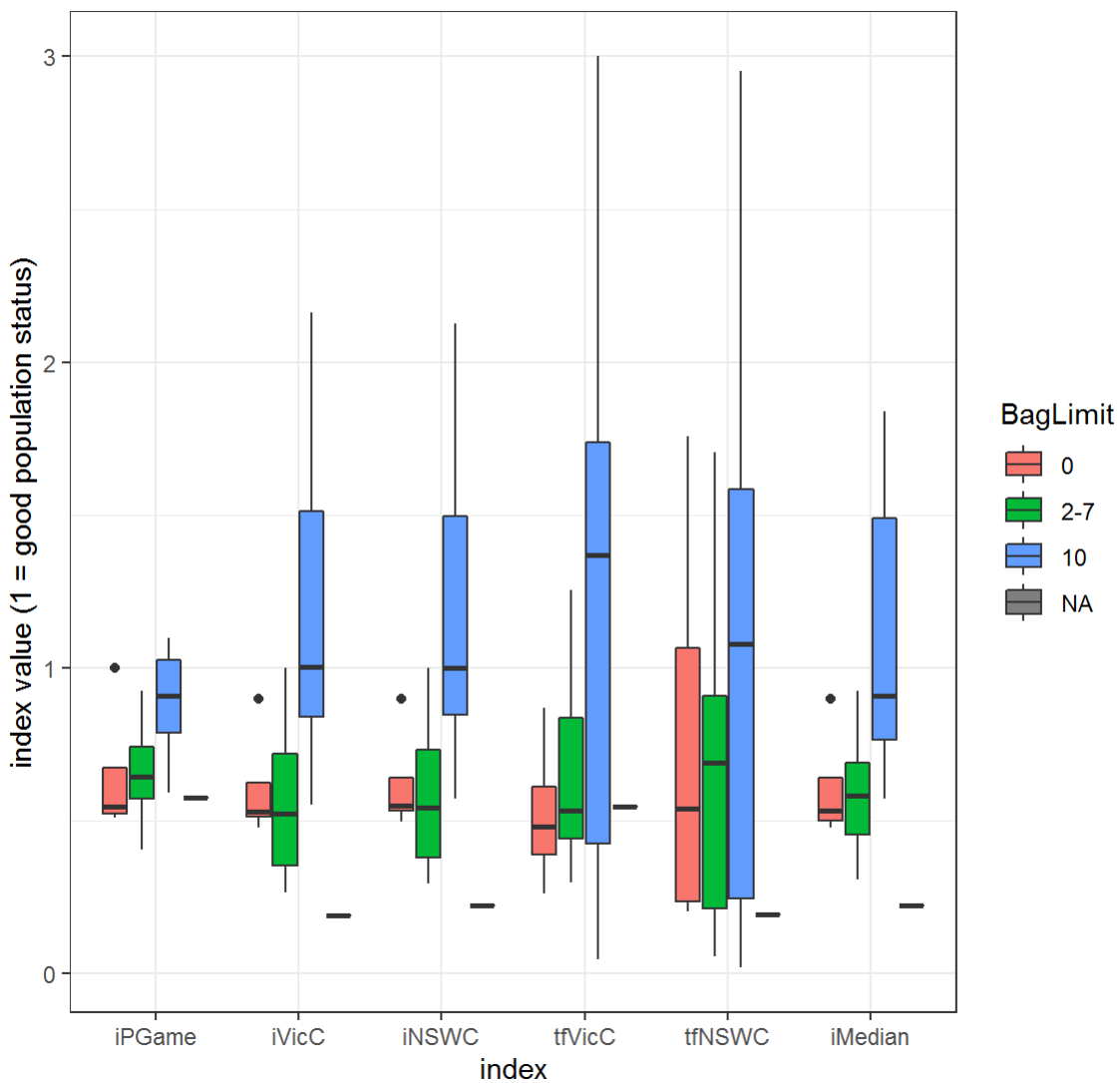


Figure 4. Boxplots (depicting minimum, 25 percentile, median, 75 percentile and maximum) for the five duck-population indices, as well as their median for unrestricted hunting seasons (bag limit = 10, blue) cancelled hunting season (bag limit = 0, red) and hunting seasons with restrictions (bag limit = 2-7, green).

Finally, while for many indices the unrestricted seasons truly stand out, there is striking overlap for all indices for the years where hunting was banned or restricted. We consider that the most prudent way forward is to use these indices to help set annual duck hunting arrangements. We consider this warranted given the indices' theoretical as well as empirical support, as outlined in introduction and results presented above using historic data and annual duck hunting arrangements over the years 1991-2020.

### Annual duck hunting arrangements

Although some indices are less prone to error than others, collective use of these indices should adequately address the four key elements that should form part of a decision model as outlined in the introduction. Furthermore, there is no sound basis for weighting these indices differentially. We thus propose to include all five indices in a highly straightforward and transparent manner in guiding decision-making for annual hunting arrangement of which seasonal bag limits form an important part.

We propose to do this using an aggregate point system (*aps*). In this system, each index with a value between 0.5 and 0.9 attracts 1 point and a value over 0.9 attracts 2 points. With all 5 indices the maximum number of points amounts to 10, when all indices are >0.9. This aggregate point system thus provides a valuation of the overall population status of game ducks in Victoria on a scale from 0-10 (last column of Table 2). Conveniently, this aggregated point system does not deviate much from the actual bag limits between 1991 and 2020 (5.5 versus 6.3), with generally good agreement between actual bag limits and aggregated point system over this period (Figure 5). There are, however, also marked outliers, with notably 1995 and 2017 demanding explanation.

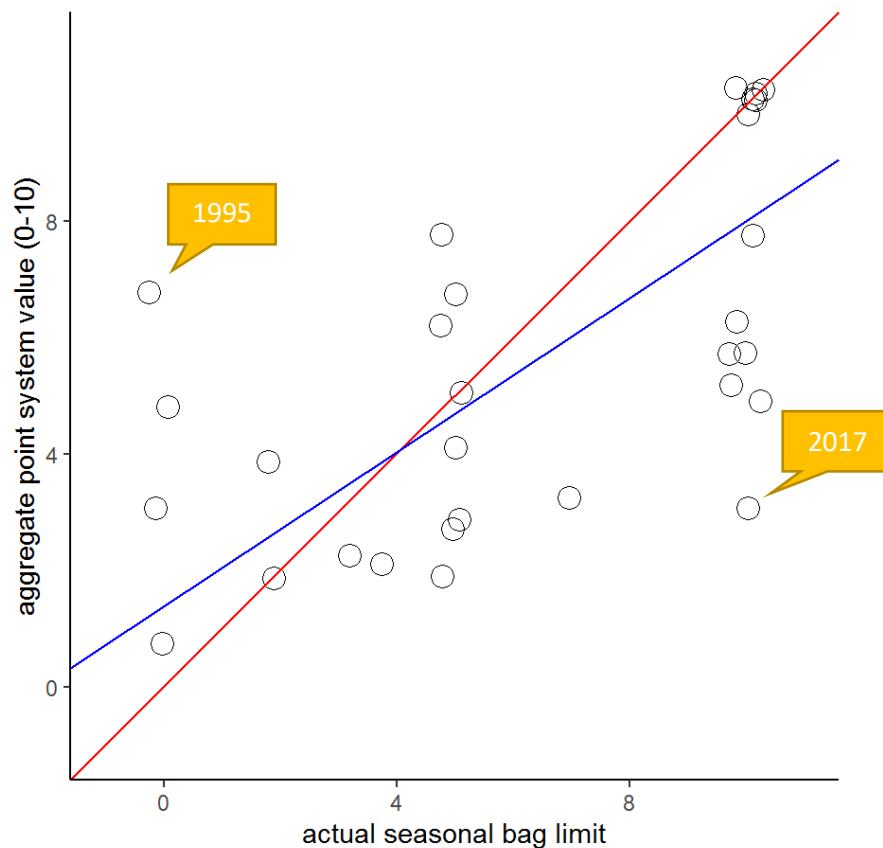


Figure 5. Actual bag limits versus the aggregate point system (aPS) proposed bag limits as calculated from the five duck population indices for the years 1991-2020. Red line depicts actual=aPS, while the blue line is the major axis regression. A small amount of random variation has been added to otherwise overlapping data points to improve data presentation.

### Final caveats

We were asked to advise on the social, economic and ecological costs and benefits associated with reducing either season length or bag limits in relation to reductions in harvest. We have neither the expertise nor data to comment on the social or economic costs/benefits or the ecological cost/benefits in relation to hunting arrangements. Although changes in season length have an effect (Sunde and Asferg 2014, Madsen et al. 2016) it is limited. A phenomenon that may be due to recreational hunters either investing a fixed effort or aiming for a specific yield within a given season (Sunde and Asferg 2014). Data from GMA collected between 2009 and 2019 corroborate this with the number of days hunted in the season varying only little (3.3-4.6) across the 11 hunting season between 2009 and 2019 (Game Management Authority 2020). If recreational hunters aim for a fixed seasonal effort that would translate into a fixed number of days of hunting in each year, as suggested by the data available to date, limiting daily bags rather than season length might be more effective.

Our analyses and advice have not differentiated the eight different duck game species that all have their own specific life histories and ecology. Although species-specific game and aerial count data are available and we are in principle able to make species-specific indices, such approach would inflate error rates and likely reduce the confidence of the aggregate point system here applied.

We advocate that the model here presented be used as a tool to inform decision making for hunting arrangements; it should not be used to set hunting arrangements without due diligence. This means

that the aPS or daily bag limit recommendation, is considered in the broader context. For instance, it should be realised that this is a statistical model, which means that predictions are based on past events. This also means that if any of the input would be truly extreme (and nothing like we have seen over the past 30 years) one should be mindful of that when using the model outcome.

We also encourage the use of the model as an “adaptive interim harvest model”, where the model is (annually) updated when additional data or even completely new sets of data (e.g. helicopter counts) become available. Using the proposed model as an adaptive model critically requires a continued and standardised effort in aerial surveys and game counts.

Three of the five indices presented importantly rely on surface water data extracted from LANDSAT satellite imagery. We should consider further investigating the possibility for increasing their accuracy, as well as their potential to inform even more accurately on the status of duck populations over time.

Knowledge on movements and population dynamics are crucial to assess species’ vulnerability to hunting and environmental fluctuations and change, requiring our ongoing attention. Notably in the Australian context, there is a need to understand how and when widespread drying conditions north of Victoria may affect numbers. Such knowledge is particularly needed for species that are not numerous and widespread in Victoria. As a first step, reanalysis of available banding data should be considered. Such analysis could be of importance for designing future banding projects to (i) provide explanations for the relationships on which the indices are based, (ii) potentially construct better indices and (iii) inform a future adaptive harvest model. Such analyses may also help updating our knowledge on movements to and from non-breeding and breeding areas, and between river basins and wetlands across SE Australia, as potential key drivers of fluctuations in abundances across this vast area. Importantly, such analysis may also help identify key caveats in our understanding of duck movements, assisting in designing future banding and tracking studies.

There is a need to better understand breeding and recruitment and relevant drivers across different scales as this is critical for hunting and management of species. This could be done by focused studies on breeding and recruitment in relation to flooding and flow and rainfall regimes. There may also be relevant data already available that is collected during hunting bag collection.

### Acknowledgements

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## Summary of issues raised in submissions received on the draft proposal

The table below provides a summary of points made in submissions received from stakeholder groups. It includes only issues directly relevant to the model itself, rather than duck hunting per se. Ten submissions were reviewed, from each of the following organisations:

AA – Animals Australia

ADA – Australian Deer Association

BLA – BirdLife Australia

CADS – Coalition Against Duck Shooting

DELWP

FGA – Field and Game Australia

GMA

RSPCA Victoria

RVOTDS – Rural Victorians Opposed To Duck Shooting

SSAA VIC – Sporting Shooters Association of Australia, Victorian Branch

The table below does not indicate whom raised the various points. The authors response to all points raised is provided in the final column. Although the feedback provided did ultimately neither result in major changes to our approach nor the outcome, it did result in considerable alterations in the analyses (e.g. in the estimation of threshold values and the way the Victorian Game Count data have been integrated in the modelling) and improvements, notably clarifications, in the main text.

| Issue   | Sub-issue        | Stakeholder comment  | Response   |
|---|------------------|--|--|
| <p><b>Modelling as a tool for decision making</b></p> |                  | <ol style="list-style-type: none"> <li>Can be useful for highlighting relationships or trends but is dangerous when used definitively to determine fate of declining species.</li> <li>Welcome the attempt to widen consideration of relevant environmental factors, but urge caution</li> <li>The establishment of a robust total population estimate could also be an appropriate way to determine an appropriate annual offtake, as an interim measure</li> </ol> | <ol style="list-style-type: none"> <li>This is not a population model. Rather the model tracks overall game duck numbers in Victoria over time in relation to predictor variables related to abundances. We advocate that the model be used as a tool to inform hunting arrangements only. We will stress this is a tool to inform decision making. It should not be used to set hunting arrangements without due diligence.</li> <li>As above.</li> <li>As yet problematic. The tool provides an overall index summarising the population status of all game ducks rather than providing an estimate of duck numbers present or harvestable.</li> </ol> |
| <p><b>The indices</b></p>                             |                  |  |  |
|   |                  | <ol style="list-style-type: none"> <li>The parameters in the indices are sensible.</li> </ol>  | <ol style="list-style-type: none"> <li>Noted.</li> </ol>   |
|   | <p>Weighting</p> | <ol style="list-style-type: none"> <li>Need further justification for equal weighting given to the 5 indices.</li> <li>Why not give greater weighting to the statistical relationships that appear stronger – goodness of fit?</li> </ol>  | <ol style="list-style-type: none"> <li>Possibly one of the best arguments against weighting is that we a priori define a number of elements that should be integral to the interim harvest model and are of equal importance. Each of these indices addresses other elements and should thus all count equally to the ultimate “aggregate Point System”</li> <li>Following on from the above: since each index covers a different aspect of the elements that should collectively inform on the population status of all game ducks. Weighting some indices (and thus elements) more than others is not advisable.</li> </ol>                            |

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|  | SWC/DSPWC  | <ol style="list-style-type: none"> <li>1. Data is unsuitable for inclusion in model – inconsistent effort and coverage between years.</li> <li>2. Should not be included in model because ‘not in tune’ with the other 4 indices. Rather, remove iGame and upscale the other 4 indices by 5/4 to retain a maximum bag limit of 10 [but they then admit that this would remove the only index that specifically relates to surface water in the MDB].</li> <li>3. If the proposed framework is adopted, the number of wetlands surveyed in DSPWC will need to be increased.</li> </ol> | <ol style="list-style-type: none"> <li>1. This is a fair criticism and we have reanalysed the Victorian Game Count data focussing on wetlands that have been generally counted consistently across years, which should make the years more comparable with respect to effort; 2020 was removed from the analyses as due to COVID-19 few wetlands were counted. The outcomes of this new analysis are similar to those presented earlier.</li> <li>2. See above. This index is as good as the other indices.</li> <li>3. Future game counts have in principle no influence on the outcome of the model, unless the model is used as an “<u>adaptive</u> interim harvest model”, where the model is regularly updated with additional data or even completely new sets of data (e.g. helicopter counts). Using the model as an <u>adaptive</u> model is a realistic possibility.</li> </ol> |
|  | Addition of Vic aerial count [the ‘helicopter survey’] | <ol style="list-style-type: none"> <li>1. Why not included? Some stakeholders will find it difficult to accept that the significant investment in helicopter surveys is not being utilised in the interim model.</li> <li>2. Should use Vic aerial count data rather than EAWS.</li> <li>3. It is imperative that the helicopter surveys from SE Australia eventually are built into the modelling.</li> <li>4. The AEGD [Vic aerial count] should provide robust data and allow for a comparison of the proposed arrangements with a set population take. A comparison is</li> </ol> | <ol style="list-style-type: none"> <li>1. Likely to be included in future when fully standardised and deemed adequate (see also former point that the model is in principle adaptable) and there are sufficient long-term data.</li> <li>2. Partially agree. It should be included (in future) but not replace VIC EAWS data.</li> <li>3. Agree (see above).</li> <li>4. Modelling of the AEGD will only be possible after a considerable number of years (e.g. 6). Using it as an index could be achieved after fewer years if we can settle on a threshold/reference number of animals to calculate the index with.</li> </ol>  |

|  |             |   |  |
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|  |             | <p>considered important to give stakeholders confidence that the indices and modelling estimates are delivering reasonable outcomes.</p> <p>5. Is there a role for results of Vic aerial surveys in the interim framework, or to complement outputs from the framework?</p>   | <p>5. Not as yet, but definitely in future years.</p>  |
|  | <p>EAWS</p> | <ol style="list-style-type: none"> <li>1. EAWS data is the best available and has been ignored.</li> <li>2. Disregarding EAWS data from Qld has not been justified.</li> <li>3. Reliance on EAWS remains an issue (poor coverage in Vic) and it is the main input to 2 of the 5 indices.</li> <li>4. EAWS was never designed as a tool for game management or game season setting.</li> </ol> | <ol style="list-style-type: none"> <li>1. This is a misinterpretation since 3 of the 5 indices rely on EAWS data.</li> <li>2. It is imperative that hunting arrangements within Victoria should also consider ducks elsewhere in SE Australia, but within limits. Including parts of the Australian duck populations that have limited chance to impact duck numbers in Victoria will make the model less informative. Bands 1 (southern Victoria) to 6 (southern Queensland) of the EAWS have been included in the analyses.</li> <li>3. The issue of “error” and the limitations of the data are amply addressed. We need to do with what is available. We highlight that the model is a tool and that needs to inform the ultimate decisions.</li> <li>4. The EAWS was actually designed to learn more about game duck populations and monitor abundance, distribution and habitat availability to ensure sustainable hunting (Braithwaite et al. 1986). Still, none of the inputs was designed for setting game management seasons in the here employed fashion, but that does not make them necessarily inadequate or less suitable.</li> </ol> |

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|                        | Surface water area         | <ol style="list-style-type: none"> <li>1. Agree is a useful proxy for habitat but should be used as a guide not a definitive tool.</li> <li>2. In a concerning development, the 2020 EAWS found that longstanding link between surface water area and waterbird breeding had broken.</li> <li>3. Should not be a replacement for consideration of all relevant environmental data.</li> <li>4. Surface water includes some wetlands that are poor duck habitat – saline, deep impoundments</li> <li>5. Support indices incorporating the spatial and temporal fluctuation of water in the landscape.</li> </ol> | <ol style="list-style-type: none"> <li>1. Surface water area is guiding 3 of the 5 indices. We highlight that the model is a tool and that needs to inform the ultimate decisions.</li> <li>2. This is not necessarily correct. There is a need for more than a year to assess the relationships between waterbird breeding and water. Our analyses underlying the ultimate model are novel, investigating the relationship between different parts of the EAWS counts (VIC and NSW) with a set of 8 different water surface variables spanning 3 years prior to each count. Their outcome is only partly comparable with earlier analyses relating surface water area and bird numbers.</li> <li>3. See point 1.</li> <li>4. In the analyses it not so much the absolute amount of water in the landscape but the relative changes in the amount of water in the landscape that matter. This means that these areas with stable water levels (e.g. large dams) will remain static over time. As long as the directions of annual change in suitable and unsuitable duck habitat is the same, it is of little concern when unsuitable water bodies are included in the analyses.</li> </ol> |
|                        | Satellite imagery in 1990s | <ol style="list-style-type: none"> <li>1. Was it any better than the 1980s data which was not modelled?</li> </ol>  | <ol style="list-style-type: none"> <li>1. Adequate imagery for this purpose only became available in 1987.</li> </ol>   |
|                        | Figure 3 - caption         | <ol style="list-style-type: none"> <li>1. Does Figure 3 refer to all waterbirds or just the Victorian game duck species?</li> </ol>   | <ol style="list-style-type: none"> <li>1. Game waterbirds.</li> </ol>   |
| <b>Model structure</b> |                            |   |   |
|                        | Aims of the model          | <ol style="list-style-type: none"> <li>1. Is the aim of the model to determine maximum</li> </ol>   | <ol style="list-style-type: none"> <li>1. The model is not a population model. The model</li> </ol>   |

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|  |                                | <p>sustainable yield or a more conservative take?</p> <ol style="list-style-type: none"> <li>2. Fails to translate into management measures – need clarification on how aPS relates to the level of risk.</li> <li>3. The stated objective of providing five seasonal arrangement options to government would suggest that opinion-based decision-making may continue to play a significant part in the duck season setting process - in deciding which of the 5 possible arrangements to adopt.</li> </ol> | <p>produces an index extrapolating past practice into the future, founded on the best available data, without providing an estimate of population size and a proposed harvest limit.</p> <ol style="list-style-type: none"> <li>2. The model provides an overall index (aPS) summarising the population status of all game ducks rather than providing an estimate of duck numbers present or harvestable. The aPS thus also informs on the risk of hunting to game duck populations if no hunting arrangements would be in place. The aPS can be used to inform hunting arrangements and we provide a suggestion on to directly translate aPS into specific hunting arrangements.</li> <li>3. This was part of the original brief but we have now provided a suggestion for translating aPS directly into bag limits. Nevertheless, the model should still be used as a tool to <u>inform</u> hunting arrangements not to set it. The approach uses multiple lines of evidence for management decisions, which do not reflect opinion-based decision-making.</li> </ol> |
|  | <p>Aggregated points score</p> | <ol style="list-style-type: none"> <li>1. Why is threshold 0.9 rather than 1.0?</li> <li>2. Rounding of the aPS is suspect, is it rounded up or down?</li> <li>3. Decision to ‘round off’ to an even number is a tacit admission that the model has considerable limitations.</li> <li>4. Why does aPS scale allocate a max score of 2 when the index is &gt;0.9 rather than <math>\geq 1.0</math>? This</li> </ol>   | <ol style="list-style-type: none"> <li>1. The index brackets are somewhat arbitrary. Importantly, the settings of these brackets yield outcomes that are by and large comparable with decisions for hunting arrangements made in previous years. There is neither a more liberal nor a more restrictive outcome from the model compared to previous years. The model provides an overall index</li> </ol>  |



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|  |  | <p>effectively liberalises the criterion for a full season by 10% at a time when sustainability is most at risk.</p> <ol style="list-style-type: none"> <li>5. Rules for rounding need clarification.</li> <li>6. The aPS table could provide a simple basis for allocating a daily bag limit.</li> <li>7. Scaling and assumptions made to establish the aPS are not appropriate – the model should be set to achieve a 10-bird bag limit in an average season.</li> <li>8. Clarify how aPS relates to bag limit, season length, species conservation, season closures, i.e., to sustainable management.</li> <li>9. How do the aPS scores (0-10) relate to management settings?</li> </ol>                             | <p>(aPS) summarising the population status of all game ducks rather than providing an estimate of duck numbers present or harvestable.</p> <ol style="list-style-type: none"> <li>2. This was related to the original brief requesting a 5 tier system. This has now been abolished.</li> <li>3. Unfounded comment.</li> <li>4. See 1.</li> <li>5. See 2.</li> <li>6. Correct. We provide a suggestion for translating aPS directly into bag limits. <b>Nevertheless, the model should still be used as a tool to inform hunting arrangements not to set it without due diligence.</b></li> <li>7. See above.</li> <li>8. See above.</li> <li>9. See above.</li> </ol>  |
|  | <p>Consideration of individual species</p> | <ol style="list-style-type: none"> <li>1. Is lacking. How would declining spp and listed threatened spp be handled?</li> <li>2. How to handle species with a low count in the aerial survey [not sure if this means EAWC or ‘new’ Vic count].</li> <li>3. Does not address the need for species specific management.</li> <li>4. Species-specific indices should be determined and published with appropriate discussion of limitations.</li> <li>5. The model cannot account for particular species at risk. Hence protections, or lack of them, will be subjective assessments. E.g., failure to protect Hardhead, now listed for Vic as Vulnerable.</li> <li>6. A model based on long-term (30-year) data</li> </ol> | <p>1-6. Irrespective of practicalities regarding implementation into hunting arrangements, we acknowledge that it would be desirable to have species-specific indices of population status. However, it should be understood that <b>all game duck count estimates are prone to error</b> (i.e. uncertainty in the data) and that the impact of that error will be magnified if we are further sub-setting the data (e.g. by species or by region within Victoria). Individual species models are likely to be less robust if there is high variability or even low numbers of a particular species. Sub-setting will thus lead to increasingly weaker relationships since the error will become more dominant. Thus, <b>with the data at hand we cannot, at least not yet,</b></p> |

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|  |                             | <p>patterns will likely mask shorter-term precipitous declines, as currently happening for Pink-eared Duck, for example.</p>  | <p>meaningfully generate species-specific models. Also with respect to this point, we again like to highlight that the model should be used to inform hunting arrangements not to set it without due diligence. It should be used as multiple lines of evidence approach.</p>   |
|  | Decision date of 1 December | <ol style="list-style-type: none"> <li>1. Too early relative to season opening, doesn't allow for inclusion of recent [current summer] seasonal data on climate and bird numbers.</li> <li>2. Decisions on duck shooting should be deferred as late as possible to assess how the ducks and their habitat survive the blast of summer. 1 December date needs justification.</li> <li>3. Artificially imposed date will undermine public confidence in future adaptive harvest models</li> </ol> | <p>1-3. Part of brief.</p>  |
|  | Bag limits                  | <ol style="list-style-type: none"> <li>1. Bag limits flowing from the framework should be treated with caution.</li> <li>2. Currently there are 11 options for bag limit (0-10). Would there be value in reducing to 4 or 5, for example? Would this simplify communication? What would be impact on harvest levels?</li> </ol>   | <ol style="list-style-type: none"> <li>1. In the current version we propose a straightforward translation of the aPS into bag limits, yielding outcomes that are by and large comparable with decisions for hunting arrangements made in previous years. Nevertheless, the model should still be used as a tool to inform hunting arrangements not to set it without due diligence.</li> <li>2. We originally had 5 tiers, but we have now moved to suggesting a continuous, straight-forward scale from 0-10.</li> </ol> |
|  | Season length               | <ol style="list-style-type: none"> <li>1. Do not agree that season length can be excluded from the management options.</li> </ol>   | <ol style="list-style-type: none"> <li>1. Research (including analyses of hunters' behaviour in Victoria) indicates that manipulating season length is less effective than modifying</li> </ol>   |

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|  |  | <ol style="list-style-type: none"> <li>2. Model does not consider advantages of a shorter season length, such as reduced ecological damage and easier enforcement load. Nor does it recognise that historically seasons were shorter.</li> <li>3. Need to consider the combined effects of bag limit and season length, rather than dismissing season length.</li> <li>4. Vic data on season length and total days hunted supports the contention that season length is not a good management lever to control harvest.</li> </ol> | <p>bag limits. But that indeed does not invalidate it as a management option. To be effective season length will have to be drastically modulated.</p> <ol style="list-style-type: none"> <li>2. Modulating season length appears to have limited impact of hunters' behaviour and therewith on total number of ducks hunted and total "ecological damage". The point regarding enforcement load is valid.</li> <li>3. See above.</li> <li>4. Correct. See 1.</li> </ol> |
|  | <p>Level of sustainable take</p>             | <ol style="list-style-type: none"> <li>1. The suggested 10% take likely to be challenged.</li> <li>2. The actual percentage figure would need to be established, but a reasonable take would be expected to be 20% of the population</li> </ol>  | <p>1-2. This is not a population model. The model provides an overall index (aPS) summarising the population status of all game ducks rather than providing an estimate of duck numbers present or harvestable. We propose a straightforward approach to translating aPS into bag limits extrapolating past practice.</p>  |
|  | <p>Threshold values for game duck counts</p> | <ol style="list-style-type: none"> <li>1. Arbitrarily selected – need further explanation and clarification, including the process of expert appraisal.</li> <li>2. Threshold values are vulnerable to manipulation by vested interests</li> <li>3. Re the 'arbitrary threshold values' for game duck counts in Vic – is arbitrary the most appropriate word given that some thought and evidence was used to produce the numbers?</li> </ol>  | <p>1-3. The wording ("arbitrarily selected") was unfortunate and incorrect and the criteria for setting the thresholds was too loosely defined. This has been corrected, which has led to more objective threshold settings.</p>   |

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|                          | Threshold for aPS     | <ol style="list-style-type: none"> <li>1. We are concerned that the aPS score is the maximum value of 2, even when the index is below that threshold (for any index value exceeding 0.9).</li> <li>2. A lower set threshold will result in more full seasons because it will increase index values giving higher aPS.</li> </ol>   | See response to comments raised under “ <i>Aggregated points score</i> ” above.   |
|                          | Other sources of data | <ol style="list-style-type: none"> <li>1. Is it appropriate to consider other sources of data, and in exceptional circumstances use this additional information in reaching a final decision?</li> <li>2. Data from the annual telephone surveys of hunter activity and success could be used to examine impacts of different harvest settings.</li> </ol>                                     | <ol style="list-style-type: none"> <li>1. Yes. We advocate that the model be used as a tool to <u>inform</u> hunting arrangements not to set it without due diligence.</li> <li>2. That is worth considering but is likely to have a similar issue as the bag limit analysis conducted for this report. When limiting the data to years where there were no bag limits implemented, very few years (n =13) remained. This dramatically reduced the power of the analysis and also resulted into discarding these data for ultimate use in the model.</li> </ol> |
| <b>Data used</b>         |                       |  |   |
|                          | 2021 data             | <ol style="list-style-type: none"> <li>1. Why was data for the 2021 season not used?</li> </ol>  | <ol style="list-style-type: none"> <li>1. Because of limited availability of data.</li> </ol>   |
|                          | 2020 data             | <ol style="list-style-type: none"> <li>1. In Table 2 the bag limit was 3, not 5 as shown. All input data needs to be double-checked.</li> </ol>  | <ol style="list-style-type: none"> <li>1. Corrected.</li> </ol>   |
| <b>Model performance</b> |                       |  |   |
|                          | Predictive power      | <ol style="list-style-type: none"> <li>1. Model is not a good fit for the actual data – wide error range. Scatterplots suggest very weak positive relationships with many points outside the CIs.</li> <li>2. Line of best fit shows the predicted values are too low in good seasons and too high in dry years, risking over-estimating abundance during drought, leading to over-</li> </ol> | <ol style="list-style-type: none"> <li>1. These are in fact very strong relationships for ecological studies, notably when taking into account that the data on which the analyses rely are not integral estimates but samples and prone to considerable error. The ultimate outcome of the models are further buffered against a large ultimate error by integrating as 5 independent indices.</li> </ol>  |

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|  |                               | <p>generous bag limits at critical times.</p> <ol style="list-style-type: none"> <li>3. The peculiar result of no relationship between NSW EAWC data and MDB surface water, but rather with surface water outside NSW, should ring alarm bells. Therefore, there are problems with 3 of the regression relationships and thus with 3 of the indices.</li> <li>4. Explanatory values are quite low. Relationships could be spurious – describing noise in data rather than actual relationships.</li> <li>5. The indices and aPS system ‘perform quite well’ in highlighting the years of poor, moderate and good duck numbers. Use should help prevent poor decisions, as seen in the past.</li> <li>6. The fit of the model will vary between environmental conditions in any given year. <b>Old relationships may eclipse new relationships as the weight of years influence coefficients in the formulae. This is especially problematic in times of rapid change such as under climate change and current changes in land use.</b></li> </ol> | <ol style="list-style-type: none"> <li>2. In Fig. 5 we have now replaced the linear regression line with, given the nature of the data which are both prone to error, a more appropriate reduced major axis line, showing that there is no such bias.</li> <li>3. That some counts in certain areas show a (slightly) stronger relationships with other but the local water surface area is not unexpected and not worrying for two reasons. Firstly, the 8 water surface areas are, as might be expected, highly correlated (see supplemental html file with details on the analyses). Secondly, it confirms that ducks move and that a wider but a local geographic scale should be considered.</li> <li>4. The relationships cannot describe noise as long as the noise is random, which is a defensible assumption. Indeed, the noise does result in less predictive power. See also 1 above.</li> <li>5. Indeed, it is important to consider that “error” is possibly also present in past hunting arrangement decisions. Using a multi-pronged approach as here advocated integrating 5 independent indices harnesses against (grossly) incorrect decisions.</li> <li>6. <b>Highly valid point</b>, calling for the presented approach as an <u>adaptive model</u>, which is also a realistic possibility.</li> </ol> |
|  | <p>Retrospective analysis</p> | <ol style="list-style-type: none"> <li>1. Model appears to have potential for retrospective check on quality of decisions on season controls.</li> </ol>  | <ol style="list-style-type: none"> <li>1. Noted.</li> <li>2. As stated under point 1, the model has flagged years where counts and environmental conditions do not corroborate the ultimate</li> </ol>  |

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|                          |                                  | 2. Request for advice on how the 2 aberrant decisions (1995 & 2017) can be dealt with objectively. Could the decision framework be adjusted to account for them?   | decision made. It would require detailed analyses of the decision making process (including meeting notes) to understand the discrepancy between model outcome and ultimate decisions made in those two years.   |
|                          | Retrospective application        | 1. Model would have recommended 4 closed seasons since 1990, the same number that were actually imposed. Since duck populations are declining this is not acceptable.  | 1. Indeed, the model ultimately extrapolates past decisions into the future, yet based on objective indices describing the population status of game ducks. There is currently no scientific basis to amend this either upward or downward.  |
|                          | Model based on past arrangements | <ol style="list-style-type: none"> <li>1. A model based on past flawed, unscientific process will likely perpetuate past policies and the flawed outcomes they produced.</li> <li>2. If the threshold is set at a level to replicate past decisions, we are simply enshrining past mistakes for posterity. "More of the same" ignores on-going declines and puts species at further risk.</li> <li>3. Concerned that arbitrary values for indices have been selected to retrofit the new model to account for previous season settings which were not based on science.</li> <li>4. Fig 4 boxplots for the indices should not be used to distinguish the merit of those indices because decisions over the past 30 years were based on a range of influence, not all being rational/evidence-based.</li> </ol> | <ol style="list-style-type: none"> <li>1. The model indeed extrapolates past decisions into the future, assuming that past decisions on hunting arrangements were (at least on average) correct. The crucial difference between the advocated approach and the process used in the past is that the model outcome is based on objective indices describing the population status of game ducks.</li> <li>2. Thresholds are objectively set. We indeed assume that past decisions on hunting arrangements may have been prone to error but were at least on average made correctly.</li> <li>3. We apologise for earlier wording used in the draft report but there is no arbitrariness in the values used in generating the indices. See also 2 above.</li> <li>4. See above.</li> </ol> |
| <b>Management levers</b> |                                  |  |  |
|                          | Cancellation of season           | 1. How will the framework be used to determine if and when a season  | 1. The model, with the aPS providing a clear guide, can  |

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|                          |                              | cancellation should take place? Need clear decision framework.  | be used to inform decision making.  |
|                          | Bag limits                   | <ol style="list-style-type: none"> <li>1. Framework outcomes need to be considered with caution.</li> <li>2. A bag limit of 10 birds should apply in an average season, not only in the best seasons.</li> </ol>  | <ol style="list-style-type: none"> <li>1. We advocate that the model be used as a tool to inform hunting arrangements not to set it without due diligence.</li> <li>2. The suggested and straightforward translation of aPS into bag limits is based on past hunting arrangements. There is no noticeable upward or downward correction implemented.</li> </ol>   |
|                          | Bag limits and season length | <ol style="list-style-type: none"> <li>1. Need to incorporate the option of exceeding the current 10 bag limit and 87-day season length in good years.</li> <li>2. Support emphasis on adjustment of bag size rather than season length.</li> </ol>   | <ol style="list-style-type: none"> <li>1. We provided a suggestion on how the aPS can be translated into bag limits, departing from past hunting arrangements, including a maximum bag of 10. We feel it is not prudent to increase this and that there is also no scientific basis for lowering it.</li> <li>2. Noted.</li> </ol>  |
| <b>Public acceptance</b> |                              |   |   |
|                          |                              | <ol style="list-style-type: none"> <li>1. Model is <u>not</u> conceptually simple – difficult to ‘sell’ to public.</li> <li>2. Explanation of the model needs to be simplified in order to gain acceptance amongst hunters.</li> <li>3. Proposed interim arrangements do not provide clarity and transparency on how seasons and bag limits will be set.</li> <li>4. Needs a clear decision-making matrix – currently no clear relationship between model outputs and season settings.</li> <li>5. The framework achieves the objective of being conceptually simple, transparent and defensible. Report provides an excellent detailed explanation.</li> </ol> | <ol style="list-style-type: none"> <li>1. This report is not written to inform the general public and should allow for detailed scrutiny of the analyses. This inherently results in some level of unavoidable complexity. We feel that the essence of the analysis is straightforward and can very easily be conveyed to the general public.</li> <li>2. See 1.</li> <li>3. In the current version we propose a straightforward translation of aPS into bag limits, which hopefully mollifies this earlier shortcoming.</li> <li>4. Although the brief was proposing a decision matrix, where to set the cut-off points for the various rows/categories in the matrix will lead to a lot of discussion (exemplified by the feedback</li> </ol> |

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|  |  |  | received and summarised here). We thus opted for a continuous aPS scale rather than a “decision matrix”.<br>5. Noted. |
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