Waterfowl Adaptive Harvest Model:
Expert Panel Review

Report to the Department of Jobs, Precincts and Regions

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EXECUTIVE SUMMARY

In July 2019, an Expert Scientific Panel was convened to review the proposed approach to adaptive harvest management for duck hunting in Victoria.

The panel agreed that harvest management models can provide key benefits by reducing uncertainties for hunters and other stakeholders, and that the suggested population monitoring and modelling framework is theoretically sound and appropriate.

However, given the modelling proposed requires additional survey effort, the panel recommends that a desktop study should be conducted initially to:

(1) review available datasets relevant to waterfowl in Victoria and adjacent areas, and identify data deficiencies;
(2) identify survey designs required to estimate the abundance of game duck species with given accuracy and precision; and
(3) undertake modelling of waterfowl relative abundance using historical datasets.

Further, the panel highlights that it will be essential to have strong stakeholder understanding and support for the establishment of an adaptive approach to harvest management that incorporates mathematical models.

The panel therefore recommends that:

(1) a broader harvest management planning framework be developed through a collaborative multi-stakeholder process, within which a conceptual model of waterfowl population dynamics can be discussed and evolved with stakeholders;
(2) the review of existing datasets, and models developed using existing datasets, should be presented to stakeholders, with examples of how model outputs can be operationalised and embedded within a broader management strategy;
(3) a simple harvest management framework be adopted initially, to clearly translate waterfowl monitoring and data on rainfall/wetland availability into harvest recommendations; and
(4) ongoing development of the adaptive harvest model for waterfowl can be pursued simultaneously as a longer-term goal to assist management, noting it will require additional investment in modelling and data collection.

PREAMBLE

Adaptive harvest management attempts to improve our management of wildlife resources through carefully structured learning by doing. The approach acknowledges that our understanding of wild populations will always be imperfect, but with monitoring over time we can better predict the outcome of management interventions and extreme environmental events, and thereby improve management decisions, regardless of knowledge gaps.

When embedded in a robust management framework, mathematical models of populations can be useful tools for learning about and predicting how wildlife populations respond to changing environmental conditions and harvest regulations. The performance of different models can be evaluated over time, by comparing model predictions to real data from wildlife monitoring programs.

Ideally, the models and predictions made using them will improve over time, as the uncertainties associated with the drivers of population dynamics and harvest impacts are uncovered and shrink, increasing confidence in the ability of models to inform harvest regulations.

Victorian Government agencies have been considering for some time the potential role of formal population models in decision-making and enhancing public confidence in regulatory performance. Approximately ten years ago, a panel of scientists 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.

This Scientific Panel recommended an adaptive harvest management 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; hereafter “the 2010 report”).

However, the modelling approach recommended by the 2010 report was never implemented. Given this, the recommendations of the 2010 report were reviewed and revised in 2017 (Ramsey et al. 2017; hereafter “the 2017 report”). The latter report sought to identify a suitable modelling approach and the minimum monitoring requirements that would be needed to support an expanded adaptive harvest management program for waterfowl in Victoria and possibly other states (New South Wales, South Australia and Tasmania).

In July 2019, an Expert Scientific Panel (hereafter “the panel”) was convened by the Department of Jobs, Precincts and Regions to review the approach proposed in 2017 to adaptive harvest management for duck hunting in Victoria.

The panel was asked to respond to the following Terms of Reference:

- **(a) consider the original model prepared in 2010**
- **(b) consider the 2017 review of the model and provide advice on whether:**
  - **(i) the review was adequate;**
  - **(ii) the recommendations are sound given the objective; and**
  - **(iii) the model is fit for purpose, noting that resourcing is a constraint;**
- **(c) advise on any gaps/modifications to the revised model and required data inputs.**

The panel was requested to prepare a concise document, with plain-English findings and recommendations addressing the above.

The panel comprised 7 members: Dr Thomas Prowse (Chair), Professor Sue Briggs, Dr Rosie Cooney, Professor Richard Kingsford, Professor Marcel Klaassen, Professor Grahame Webb, and Dr Peter Whitehead; and met three times by remote session (July 11, July 26 and August 19, 2019) as well as conducting extensive discussions by e-mail.

PANEL RESPONSE

(A) Consideration of the original model prepared in 2010

The prototype models in the 2010 report consisted of age-structured, spatial population models for two example waterfowl species, the Grey Teal and the Australian Wood Duck. These models used a mixture of data and expert opinion to parameterise mathematical functions governing how the birth, death and dispersal rates of these species are expected to respond to climate, wetland availability, waterfowl density, and harvesting.

The models were deterministic, meaning that any given set of inputs (i.e., starting values, parameters and environmental drivers) would always produce the same simulated population trajectories. As such, the models assumed that there was no uncertainty about the way in which waterfowl populations would respond to environmental variation. Uncertainty about key mechanisms (i.e., the impact of waterfowl density on survival and fertility rates, and the movement of waterfowl between wetlands) was considered by developing candidate models with no, weak or strong density-dependent and dispersal effects.

Using the prototype models, the 2010 report presented simulation results showing how the population size of the two waterfowl species would be expected to respond to zero harvesting or an annual 20% proportional harvest over a 50-year time period. However, the authors noted that the results of the simulation studies should be interpreted with caution because the model parameterisation was incomplete.

The 2010 report proposed that such models could be used within an adaptive harvest management framework, if they were updated annually based on wetland area, estimated waterfowl abundance, and projected rainfall. The report suggested that over time the models with the greatest predictive accuracy could be identified by comparing model predictions to real data, and given more weight when setting harvest regulations. However, no validation of the 2010 models was attempted; the predicted response of the two waterfowl species to environmental variation and harvest was never tested against real data.

The panel noted that the prototype models in the 2010 report required the estimation of numerous parameters, and may therefore be of more use for scenario testing (e.g., testing different harvest strategies by desktop simulation) rather than for predicting population responses. The panel also noted that some aspects of the 2010 report (such as simulation-based optimisation of harvest strategies given context-specific constraints) are relevant to the model proposed in the 2017 report.

(B) Consideration of the 2017 review and the model proposed

The panel considered the 2017 report in its entirety. Below we address part (b) of the Terms of Reference in framing the six key recommendations made by the 2017 report.

Recommendation 1: Adaptive harvest management framework

The report recommended "triple-loop learning" as a framework for adaptive harvest management of waterfowl, with three annual feedback processes: an update of the harvest model and regulations; a review and update of management objectives and alternative model structures; and a review of stakeholder ownership and governance processes.

The panel noted that triple-loop learning has been discussed in the context of adaptive harvest management of waterfowl in North America, but that the merits of such an approach are yet to be demonstrated. The processes required for triple-loop learning were unclear to the panel, and likely to be unclear to others, which could reinforce the divide between regulators and stakeholders.

Finally, the panel considers that a full annual review of the objectives of the adaptive harvest management program for waterfowl is neither feasible nor desirable, though periodic reassessment at considerably longer timescales could well be appropriate.

The panel considered improved stakeholder engagement essential and provides specific recommendations concerning it (see Section C).

Recommendation 2: A model for duck population dynamics

The 2017 report reviewed existing approaches to adaptive harvest management (AHM) modelling, and methods for stakeholder engagement.

The panel considers the review of AHM modelling approaches, and of the technical challenges involved in modelling populations, was adequate and thorough for population models that attempt to simulate the absolute or true abundance of wildlife.

However, the panel also noted that sound, science-based harvest management does not necessarily require knowledge of absolute population abundance, but does require a reliable (highly precise) measure of relative abundance to inform choice of harvest management measures.

The 2017 report proposed a general state–space modelling framework for modelling waterfowl populations subject to environmental variability and harvesting. The panel noted that this approach in the 2017 report differed from that taken by the 2010 report in three primary ways:

(1) The model (or a set of candidate models) would be developed using time-series data on waterfowl abundance from monitoring programs. Such models are likely to have better predictive capacity than the first-principles models developed in the 2010 report.
(2) The 'unstructured' state-space models proposed in the 2017 report are simpler (require fewer parameters) than the models proposed in the 2010 report, and would model the population growth rate of waterfowl (rate of increase, *r*) as a function of environmental variables and/or harvest pressure.
(3) The state-space modelling framework proposed in 2017 allows uncertainties to be fully explored. The approach explicitly acknowledges process uncertainty (i.e., uncertainty in our understanding of the mechanisms driving population size changes each year) and observational uncertainty (i.e., uncertainty in the true number of waterfowl per sampling unit). The latter uncertainty contains possible elements of inaccuracy (e.g., some individuals are not counted or counts are inflated) and statistical error (e.g., precision will be low if there is high variation in the counts obtained between different sampling units). Since these uncertainties would be incorporated during the model-fitting process, predictions from the models would consist of estimates of waterfowl abundance along with appropriate uncertainty bounds around those estimates.

The panel considered that the state-space modelling approach proposed in the 2017 report is theoretically sound and appropriate.

The unstructured model proposed as a starting point should be relatively straightforward to explain to stakeholders, at least conceptually. Importantly, this modelling approach is readily updateable (as new data become available) and could be extended to more complex age- or sex-structured formulations (if required, and if new data were collected).

However, the panel also noted that:

(1) No state-space modelling of Victorian waterfowl populations has yet been done, so the models need to be developed and validated before they could be used to inform an adaptive harvest management program;
(2) Although the proposed modelling approach allows structural, process and some observational uncertainties to be considered appropriately, the contribution of these uncertainties to prediction reliability still needs to be evaluated once the model(s) are developed;

(3) Environmental variables (e.g., rainfall, wetland availability) that are widely accepted by regulators and hunters as being major influences on duck numbers and densities (through breeding, survival and habitat availability in dry times) should be given a more explicit treatment to make it clear to stakeholders what environmental drivers are likely to be important;
(4) It is unclear from the report whether multiple species-specific models, or a single multi-species model, are planned; and
(5) The 2017 report also identified minimum data requirements for developing models which involves additional monitoring effort (see below). If this approach is taken, there will be a significant lag between the data collection and modelling phases.

The panel recommends:
(i) that all existing datasets be collated first, and be used for fitting models for individual duck species in Victoria, and possibly for regions outside Victoria, where possible; and
(ii) a transition period during which harvest regulations are set using a decision matrix approach, to allow time for the model development and validation (see Section C below).

<u>Recommendation 3: Waterfowl monitoring data and a desktop study</u>

The 2017 report recommended that the abundance of game duck species should be estimated in October of each year within a set of predefined bioclimatic regions, which would require suitable monitoring data for each region.

To achieve this, the report proposed simultaneous ground counts and aerial (fixed-wing and helicopter) surveys should be conducted at a subset of wetlands to determine visibility correction factors for different survey methods, which could then be used to correct survey counts upwards to estimate absolute abundance at that wetland.

Finally, a desktop study was proposed to:
(1) identify the optimal combination of aerial (fixed-wing and/or helicopter) and ground-based surveys that would be required to provide estimates of waterfowl abundance in different sub-regions; and
(2) examine the utility of existing survey data sources (e.g., the Eastern Australian Aerial Waterfowl Count, additional aerial transects, and citizen science bird surveys) for minimising the amount of extra survey effort required in each region.

The panel considers that a desktop study to examine optimal survey design to estimate the abundance of game duck species with given accuracy and precision is warranted.

However, we also suggest that, before funding is committed for additional survey effort, this study should be expanded to:

(1) Conduct a thorough data audit of all relevant and available data on waterfowl for Victoria and adjacent regions in South Australia and New South Wales, including the possibility of additional waterfowl monitoring data for the River Murray and for other parts of Victoria through the Murray-Darling Basin Authority, along with data available from BirdLife Australia and catch-per-unit-effort (i.e., hunter CPUE) data.
(2) Investigate harvest offtake and harvest regulations used by adaptive harvest management programs for similar species elsewhere, such as for waterfowl in North America;
(3) Examine the relationship between bag sizes/season lengths and harvest numbers, which could be achieved by an analysis of the data from the Victorian mail/telephone surveys of hunters, and could inform simulation modelling of impact of different harvest regulations;
(4) Fit models for sample species/regions using available data, and explore the sensitivity of model predictions to structural and parameter uncertainties;
(5) Use simulation studies to:
    (a) test different monitoring regimes to demonstrate how the various proposed improvements in accuracy and precision of inputs individually and collectively affect predictions and levels of uncertainty; and
    (b) show how varying waterfowl management settings within presently accepted bounds (and plausible additions) influence predicted population responses given other sources of uncertainty;
(6) Illustrate, with quantitative examples, how model predictions can be used in conjunction with other existing and proposed information to improve decision-making;
(7) Indicate how stakeholders can participate in understanding and assisting the analyses, and in framing recommendations to decision-makers, and why this level of participation is expected to reduce contention; and
(8) Suggest indicative costings for the various enhancements (e.g., additional data collection), so that decision-makers can make properly informed judgements.

The panel recognises that currently available data may not be sufficient for fitting state-space models, and that a simpler population modelling approach might be required. However, developing models of waterfowl relative abundance from existing data would speed up the modelling process (rather than a significant lag before a new monitoring time-series becomes available for analysis), and help establish and demonstrate the utility of the approach to stakeholders.

As part of this process, it would become clearer whether there are data deficiencies, including unsurveyed regions where additional monitoring might be needed. Further, modelling using historical datasets would allow consideration of the strength of the relationships between waterfowl abundance indices and environmental variables (rainfall, wetland availability). Sensitivity analyses could also be conducted on these models to identify the most important parameters to focus further research.

Recommendation 4. Water occurrence data

The 2017 report recommended that accurate maps of water availability be assembled from satellite imagery annually to estimate wetland area/shoreline length available for breeding by ducks, along with surrogates of water availability (e.g., the standardised precipitation evapotranspiration index).

The panel agrees that water availability/wetland area is a critical driver of waterfowl population dynamics, and that these temporal and spatial data should be collated and their usefulness for explaining waterfowl population growth rates explored.

Recommendation 5. Harvest data

The 2017 report considered that current arrangements for estimating harvest offtake for the game species of ducks in Victoria using telephone surveys were adequate for the purposes of adaptive harvest management, but also recommended that:

(1) additional data are required on the harvest regulations that were in operation during the years when telephone surveys were implemented, to identify relationships between regulations and offtake, which would assist with model predictions and simulation studies;
(2) telephone surveys should be implemented in both NSW and South Australia to provide a representative sample for estimating the size of the harvest; and
(3) further work should be conducted to estimate reporting biases (i.e. over- or under-reporting of harvest numbers) inherent in the telephone surveys.

The panel supports the first point and, as detailed above, recommends that an analysis of the impact of harvest regulations on harvest offtake should be conducted as part of the desktop study.

However, the panel considers that additional surveys in the other states and information on reporting biases are not essential. Co-ordinating telephone surveys in NSW and South Australia could prove logistically difficult, given wildlife management is the responsibility of the different state jurisdictions.

Expert opinion could be used to consider/estimate reporting biases that might affect the Victorian situation, and this information could be incorporated within the context of sensitivity analyses (i.e., the impact of varying these parameters could be considered through simulation modelling).

Recommendation 6. Additional data required to increase predictive power of adaptive harvest management models

The 2017 report recommended more information on age/sex structure and dispersal could improve the predictive accuracy of population models, and specifically that:

(1) a new harvest bag survey be designed to provide unbiased and precise estimates of age ratios for each of the game species within bioclimatic regions; and
(2) satellite/GPS telemetry be conducted for individual ducks, for estimating age- and sex-specific survival rates as well as movement between each of the bioclimatic zones, potentially supplemented by duck-banding programs.

The panel considers that these additional data may not be required (or feasible) for informing the development of the adaptive harvest management models.

Ageing of most species of ducks beyond the early juvenile stage, and notably after their first full flight-feather moult (i.e., at approximately 1 year of age), is difficult. Although a sophisticated harvest bag survey could provide some information on the ratio of first year to adult birds (and thus on annual recruitment), this age information is unlikely to have a strong influence on population dynamics, because ducks reproduce in their first year of life.

Although telemetry data would produce useful information on the dispersal of waterfowl across the landscape (potentially including the redistribution of populations in response to environmental conditions, and interstate movements), it is unlikely that such studies would be sufficient to estimate mortality rates and to parameterise the dispersal matrices required to specify species-specific probabilities of dispersal between individual wetlands.

Banding studies are unlikely to be useful for providing mortality data on waterfowl because the recovery rates of banded ducks are typically very low. The effort required for comprehensive, long-term banding studies may be prohibitive.

(C) GAPS/MODIFICATIONS TO THE PROPOSED APPROACH

The panel agrees that harvest management models can provide key benefits by reducing uncertainties for both hunters and other stakeholders. However, the benefits of an adaptive harvest management model, over and above the current framework for setting harvest regulations, may not be clear to stakeholders. The panel therefore recommends the following approach to developing the adaptive harvest management framework and models.

It is essential to have strong stakeholder understanding and support for the establishment of a sound, transparent, science-based and adaptive approach to harvest management. This is a key lesson from experiences with adaptive harvest management in the USA and Europe, and from wildlife management more broadly. It is therefore critical that stakeholders understand the potential of mathematical modelling to reduce uncertainties about waterfowl management (Fig. 1), and that they contribute to a conceptual model of waterfowl population dynamics and its evolution over time.

The panel agreed that modelling of historical datasets, even where data limitations necessitate modelling of relative abundance (e.g., waterfowl counts per transect segment) rather than absolute abundance, could provide useful and rapid information on waterfowl population dynamics and also be a tool for encouraging stakeholder engagement.

Simple model predictions could be discussed with stakeholders, to facilitate understanding of how models are used, putative environmental drivers are tested, and especially how model predictions can be used in conjunction with other existing and proposed information to enhance decision-making.

Discussing how models can partition environmental and harvest effects on populations, and how they can predict variation in duck populations and densities as a function of rainfall and wetland area (i.e., population abundance trajectories), is the essence of improved engagement.

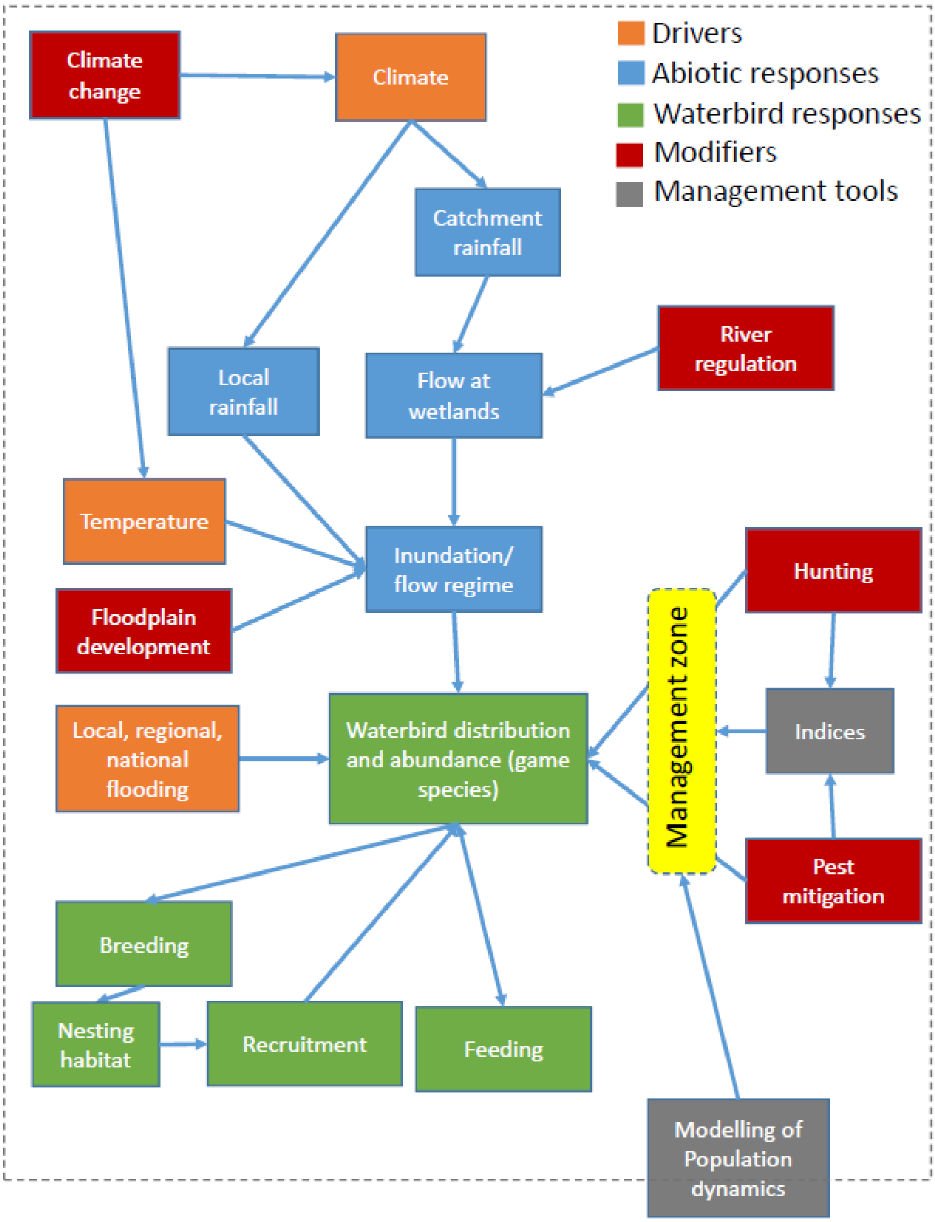

Figure 1. *A conceptual model of the factors affecting waterbird distribution and abundance.*

To date, little specific information has been provided on how harvest management models will be operationalised and embedded within such a broader strategy, but the Panel views this as an important priority. Development of a comprehensive management plan for game ducks through a consultative process would allow stakeholders to:

- Review, comment on, and contribute to formulating the objectives of harvest management (noting that different stakeholders may legitimately hold different objectives for management);
- Review, comment on and discuss conceptual approaches to linking scientific data to harvest measures;
- Engage as active participants in effective management (e.g., through gathering of relevant information and monitoring data, and advising on important environmental drivers and regions); and
- Participate in determination of an appropriate method to operationalise an adaptive harvest management approach.

On the last point, the panel understands that the authors of the 2017 report considered that the modelling and monitoring system recommended could be used in two ways:

(1) to identify optimal harvest policies, using simulation studies and by testing the performance of a set of adaptive harvest policies; and
(2) to generate one-year-ahead predictions of waterfowl population size, under different harvest regulations and environmental scenarios.

It is currently unclear how these two potential outputs would be translated into harvest regulations each year that specify bag limits and harvest season lengths, and potentially close certain wetlands or all wetlands to harvesting in some years.

Further, given no data-driven models have yet been produced, the predictive performance of any modelling is still unknown. 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 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.

Simultaneously, modelling population dynamics of waterbirds can be pursued as a longer-term goal to assist management, noting it will require considerable investments in modelling and data collection.