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TRENDS IN EASTERN AUSTRALIAN WATERBIRD SURVEY, GAME DUCK AND WATERBIRD COUNTS

Prepared by: Fisheries and Wetlands Consulting for Select Committee on Victoria's Recreational Native Bird Hunting Arrangements

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This report continues the preliminary analysis done in a previous report for Field & Game Australia:

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Trends in Eastern Australian Waterbird Survey, Game duck and Waterbird Counts.

Executive Summary

- In Victoria, Eastern Australian waterbird Survey (EAS) counts of game duck species show no statistically significant negative or positive trend (1983-2020).
- Autocorrelation is detectable in the Victorian duck count data indicating that time-series analysis is more appropriate than OLS regression. The best fitting time-series model also suggests that the count of Game ducks in Victorian EAS survey bands is stable 1985-2020 with no significant trend over time.
- While there is evidence in the EAS data of highly significant downward trends in waterbird counts (1983-2020) in Victorian and NSW survey bands, most of this effect is due to trends in 66 species of non-game waterbirds and in game-duck species in NSW. After duck hunting was banned in NSW the downward trend ceased but there has been no significant recovery.

DATA AND ASSUMPTIONS

Eastern Australian waterbird Survey (EAS) data was obtained from https://aws.ecosystem.unsw.edu.au/ from 1983 to 2020. Data from 2021& 2022 is not yet published.

Bands 1-2 = Victoria. Bands 3-5 = NSW.

The data set was filtered as follows:

- Game ducks - counts for all eight “game species” of ducks. Non-game ducks were not included. Counts for all eight species were aggregated as a “game duck count”.
- Waterbirds other than ducks - counts for all “not-hunted” waterbirds not-including the eight game duck species were aggregated as “waterbird count”. Counts for 66 species were aggregated.

Count variables were transformed prior to regression analyses to stabilise error variance (square root and 4^{th} root transformed), but it made little difference to the outcomes, so untransformed-variable analysis has been presented here.

INTRODUCTION

While large interstate migrations have been recorded, movement data from banded individuals of Australian game duck species (Appendix 1) suggests that most game ducks move only moderate distances, most of the time. Duck counts among EAS survey bands 1 & 2 (Victoria) and among bands 3 & 4 & 5 (NSW) are well correlated, whereas most (i.e. 5 out of 6) correlations among duck counts between Victorian and NSW survey bands are not significant (Table 1). This justifies examining the time series trends in duck counts separately for bands 1 & 2 from Victoria and for 3 & 4 & 5 from NSW.

Duck species subject to hunting in Victoria and NSW 1981-2020 have been generally managed as a pooled group of species (bag limits, and seasons are applied as if eight species are one group)—with very recent exceptions of species protections for Blue-winged shoveler and Hardhead. It is therefore appropriate that when EAS count data is used to influence decisions on hunting management, trends in abundance should also consider game ducks as an aggregated group of species.

Caveat 1: Statistical significance of trends

- The EAS survey data are time series of counts, not random samples of counts. This distinction is important when statistically testing the data. Time series data has special statistical properties in that the values of adjacent members in the time series may well be correlated. This is termed "serial dependency" of the data. This makes sense for annual animal-counts where animals survive for more than a year and contribute to subsequent abundance.
- Two fundamental assumptions required of the user of Ordinary Least Squared (OLS) models, used in (Porter, Kingsford, Francis, Brandis, & Ahern, 2022) is that (1) data are randomly sampled from a population, and as such are independent of each other and (2) that the data has normally distributed errors around the prediction. Assumption 1 is not satisfied in time-series data such as this and assumption 2 is unlikely to be satisfied in most wildlife count data, so if using OLS models, the statistical significance of linear regression trends may be a poor indicator of patterns. From summary reports of EAS it appears that Kingsford *et al* (2020) and Porter *et al* (2022) used OLS to determine significance of trends and augmented the analyses with data transformations and inspection of autocorrelation plots (to satisfy assumptions). However, the details of compliance with these assumptions are not presented.

Patterns (trends) in the data can also be simply identified using a non-parametric test (Mann-Kendalls test) which makes no assumptions about the data's "normality". The Mann-Kendall statistical test for trend is used to assess whether a set of data values is increasing over time or decreasing over time, and whether the trend in either direction is statistically significant. Minimum sample sizes for Mann-Kendalls test are around 8-10 values, so the EAS count datasets here (~40 values) are sufficient. Although once we start considering subsets of years (e.g., data from "before" NSW duck hunting ban, 1983-1995, 13 values) the sample sizes are getting close to the minimum for any reasonable statistical power.

Quite recently, stronger methods have been developed specifically for the analysis of count time series following Generalized Linear Models (Liboschik, Fokianos, & Fried, 2017). This is a flexible class of models which can describe serial correlation in a parsimonious way. These methods are more appropriate than basic OLS regression used here and by the UNSW group (e.g., Porter et al, 2018 & 2022), and have been completed here only on the Victorian game duck count here due to time constraints.

Caveat 2: Outliers: To include, or not include.

- The first three years of data (1983-1985) may statistically be outliers, but unless there is evidence to show that this is an artifact, "ecologically" it may be unwise to exclude them. An artifact would be for example, if there were methodological differences in the EAS during these three years. Extreme values also exist later in the time series associated with what we know to be wetter-than-average climate-conditions, so it's likely that this is a natural phenomenon. It is true than the UNSW group have themselves trialled omitting 1983 & 1984 from their overall (all bands) counts analyses and although it weakens the trends reported in most cases the statistical significance of trends doesn't change (Porter, Kingsford, & Brandis, 2018). In the analyses that follow, I have included the data from 1983–1985, although it is likely that trend-results are strongly influenced by the outliers in the first 2-3 years of data. The exception being where time-series predictors are calculated on lags of up to two years, which omits the first two years as missing values, and the time series becomes 1985-2020.

This basic analysis of EAS data examines two questions.

- *Does the banning of duck-hunting in NSW in 1995 have an observable effect on duck counts in EAS survey bands 3-5; and if so, how does that compare with duck counts in Victoria over similar time frames.*
- *Do trends in NSW and Victoria in hunted waterfowl differ from those species that are not hunted i.e., game ducks -vs- water birds other than game ducks.*

All analyses carried out using statistical software package R (R Development Core Team, 2023). Notwithstanding the caveats above, I have completed basic OLS regression analysis to compare with and based on analysis described in Porter *et al* (2022) and also used Mann-Kendall's trend test. Results are summarised in Table 2 and Table 3.

Autocorrelation was detected in the Victorian duck count data and therefore time series generalised linear modelling was used with either Poisson or Negative Binomial error distributions as appropriate. Additional predictor variable were generated from the data set for lagged variables and past-mean variables and model selection used Akaikes Information Criterion to select the most appropriate time series model (Liboschik et al., 2017). Time-series model simplification using likelihood ratio tests reduced the model to its most parsimonious form and assessed which predictors made a significant contribution to the model's explanatory power.

OUTCOMES

1. Spearmans correlation coefficients calculated for pairs of survey bands show that counts of game-ducks were significantly correlated in Bands 1 & 2 (Victoria) and in Bands 3 & 4 & 5 (NSW), but correlations among pairs of bands between Victoria and NSW were mainly not significant with a single exception between band 2 and band

Table 1. Correlation structure among EAS survey bands. Bands 1& 2 cover Victoria (green). Bands 3-5 cover NSW (blue)

	Significance				
Spearman's rho	*Band 1*	*Band 2*	*Band 3*	*Band 4*	*Band 5*
Band 1	1.00	**	ns	ns	ns
Band 2	0.50	1.00	ns	*	ns
Band 3	-0.07		1.00	**	*
Band 4	0.17	0.38	0.48	1.00	**
Band 5	0.31		0.36	0.42	1.00

Count data is plotted for aggregated game-ducks (Figure 1 A & B), and waterbirds other-than-game-ducks (Figure 1 C & D) in NSW and Victorian bands of the EAS.

2. For Bands 1-2 from Victoria overall, OLS regression shows there is no statistically significant positive or negative trend in counts of ducks in the EAS time series from 1983 to 2020 (p=0.08) (Table 2) The Mann-Kendall test statistic (tau = -0.0327, 2-sided p=0.7821) also suggests that we cannot reject the null hypothesis and must conclude there is no trend in the data. So, there is no evidence of either a "decline" or a "recovery" in game ducks in Victoria.

3. Over the whole time series (1983-2020) on average there were nearly 4400 fewer ducks per year counted in the NSW bands which is a highly significant downward trend in both the regression (p=0.00004) and the non-parametric test (p=0.00007) (Table 2). Most of the signal in this trend is prior to the banning of duck hunting in NSW. OLS regression shows that there was a slightly significant downward linear trend of approximately 16,000 fewer ducks per year counted in NSW before duck hunting was banned in 1995 (p=0.0104) (Table 2). However, the Mann-Kendall test for this period (tau = -0.308, 2-sided p =0.16056) suggests that we cannot reject the null hypothesis of the test and must conclude that no 'real' trend exists in the "before" data.
4. Considering just the period after duck hunting was banned in NSW (1996-2020) there was still no significant positive or negative trend (p=0.681) despite there being on average approximately 500 fewer ducks per year counted. Again, the Mann-Kendall test statistic (tau = -0.193, 2-sided p=0.18311) suggests that we cannot reject the null hypothesis of the test and must conclude that no trend exists in the data (Table 2). So, there is no evidence of any "recovery" in NSW following the banning of duck hunting although the negative trend ceases.

*Table 2. OLS regression slope statistics and Mann-Kendall's trend analysis for timeseries of game duck counts in NSW (EAS survey bands 3-5) and Victoria (EAS survey bands 1-2). Time periods before and after the banning of duck hunting in NSW (1985) are also considered. ns= non-significant, * p<0.05, ** p<0.01, *** p<0.001*

Time series	Slope Estimate (Mean change in count per year)	Standard Error	*t* value	*P* value	*Significance*	*Tau*	*2-sided P value*	*Significance*
Vic 1983-2020	-1491	830	-1.797	0.0808	ns	-0.038	0.7821	ns
Vic 1983-1995	-11618	6317	-1.839	0.0930	ns	-0.308	0.16056	ns
Vic 1996-2020	914	472	1.938	0.0650	ns	0.173	0.23361	ns
NSW 1983-2020	-4355.4	936.1	-4.653	0.00004	***	-0.511	0.00007	***
NSW 1983-1995	-15599	5060	-3.083	0.0104	*	-0.308	0.16056	ns
NSW 1996-2020	-528	1268	-0.416	0.6810	ns	-0.193	0.18311	ns

5. If we look in bands 1-2 (Victoria) at the same time-periods as the NSW-analysis above; again, there is no significant trend in Victorian duck counts 1983-1995 (despite there being approximately 12,000 fewer ducks counted per year), and no trend 1995-2020 (despite there being approximately 900 more ducks counted per year after 1995 (Table 2)).
6. The not-hunted waterbird counts in both Victorian and NSW survey bands show highly significant downward trends between 1983 and 2020 (Table 3). On average over this period there were 3700 fewer waterbirds counted each year in NSW and 1200 fewer each year in Victoria.

Table 3. OLS regression slope statistics and Mann-Kendall's trend analysis for timeseries of water bird counts (66 species) omitting game-duck counts in NSW (EAS survey bands 3-5) and Victoria (EAS survey bands 1-2)

	Slope Estimate (Mean change in count per year)	Standard Error	*t* value	*P* value	*Significance*		*Tau*	*2-sided P value*	*Significance*
NSW 1983-2020	-3728	862	-4.323	0.0001	***		-0.471	0.00003	***
Vic 1983-2020	-1161	372.7	-3.115	0.0036	**		-0.309	0.00662	**

7. Autocorrelation was statistically detectable in counts of Victorian game ducks (Lag 1 >5% significance level) and the best fitting time series model is shown to contain predictor variables of – the previous 2-years counts (Vic2), the expected mean counts of two previous years (VicM2) and assumed a negative binomial error distribution (Figure 2). The best fitting model can be simplified further by omitting the predictor variables Vic2 and Year. There is no significant trend over time as the variable "Year" made no significant contribution to this model. i.e., Models with or without "Year" and "Vic2" were not significantly different when a likelihood-ratio test was applied (Chi-sqd=0.29, p-value= 0.6) (Table 4).

Table 4. Time series GLM regression summary table with addition of Likelihood ratio test results for model simplification indicating retention of which predictors make a significant difference to the model.

Predictor	Estimate	Std. Error	z value	Pr(>|z|)	Significance from LR test
(Intercept)	-7.544	33.740	-0.224	0.823	
Year	0.009	0.017	0.515	0.607	n.s.
Vic2	-0.000007	0.000005	-1.431	0.152	n.s.
VicM2	0.000012	0.000006	1.904	0.057	0.008

8.

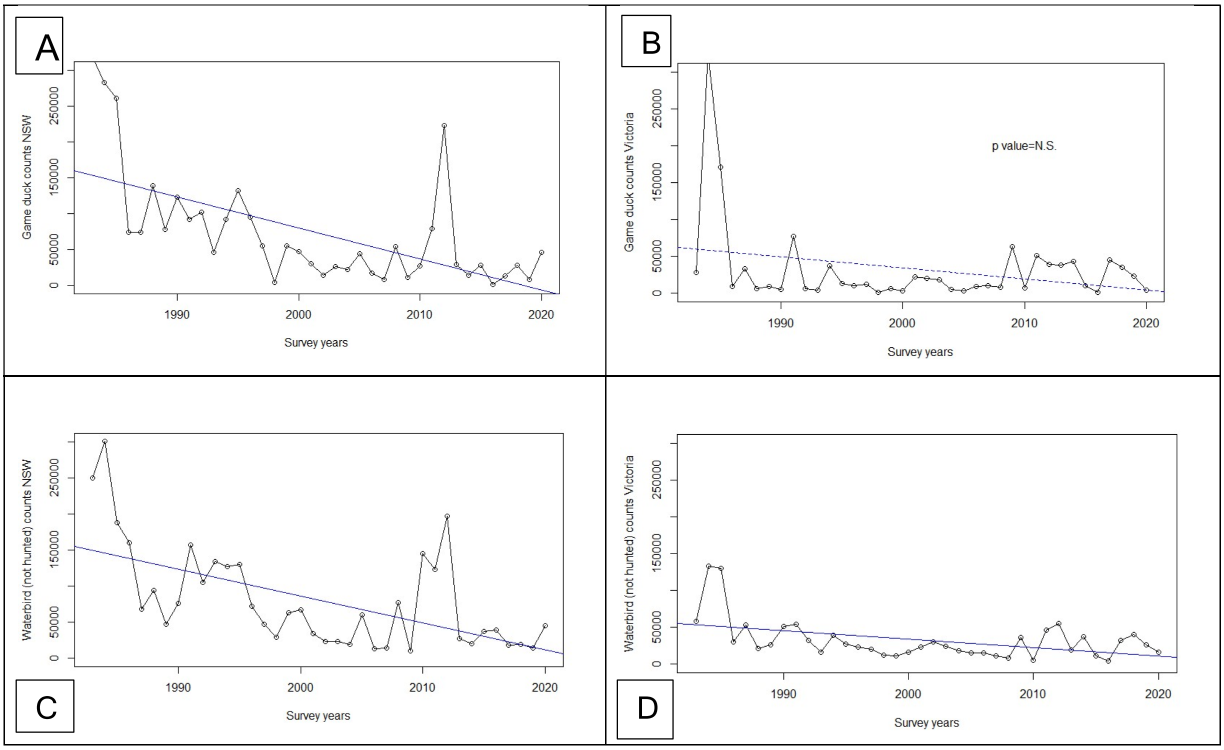

Figure 1. (A) Time series of EAS counts of game duck species for EAS bands 3-5 in NSW. (B) Time series of EAS counts of game duck species for EAS bands 1-2 in Victoria (regression slope is not significantly different from zero, see Table 2). (C) Time series of EAS counts of waterbird species (other than game ducks) for EAS bands 3-5 in NSW. (D) Time series of EAS counts of waterbird species (other than game ducks) for EAS bands 1-2 in Victoria.

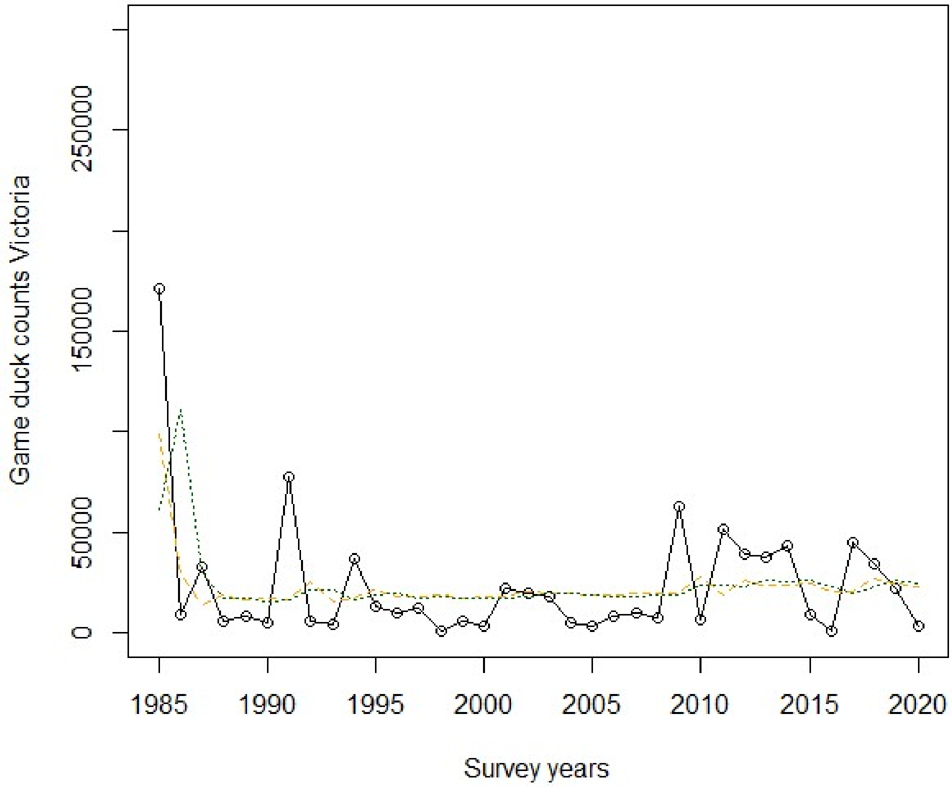

Figure 2. Victorian Game duck counts 1985-2020 (points) with best fitting time series model (dashed line) assuming (1) a negative binomial error distribution and (2) autocorrelation from the expected mean of counts at two years prior to each year. The addition of a predictor for "Year" makes no significant difference the fit of the model to the data (dotted line).

Recommendation

Duck species that have been subject to hunting in Victoria and NSW during this study period have been generally managed as a pooled group of species (bag limits, and seasons are applied as if eight species are one group)—with very recent exceptions of species protections for Blue-winged shoveler and Hardhead. It is therefore appropriate that when EAS count data is used to influence hunting management and in consideration of the effects of hunting, trends in abundance should also consider game ducks as an aggregated group of species.

Ordinary Least Squares (OLS) regression has limited application for wildlife count data where autocorrelation is detectable in the dataset. Future analyses of EAS (or other) time-series of waterbird counts to identify trends, should take advantage of the Generalized Linear Modelling for Time Series approach (see, Liboschik *et al* (2017)). Such methods are the most statistically appropriate when answering questions about trends and effects of management interventions in time-series of wildlife count data.

However, the select committee should note that:

- In Victoria, Eastern Australian waterbird Survey (EAS) counts of game duck species show no statistically significant negative or positive trend (1983-2020), and
- the best fitting time-series model to the Victorian game duck count data from the EAS was stable from 1985-2020 with no significant trend over time.

References

Kingsford, R. T., Porter, J. L., Brandis, K. J., & Ryall, S. (2020). Aerial surveys of waterbirds in Australia. *Scientific Data*, *7*(1), 1–6. https://doi.org/10.1038/s41597-020-0512-9

Liboschik, T., Fokianos, K., & Fried, R. (2017). Tscount: An R package for analysis of count time series following generalized linear models. *Journal of Statistical Software*, *82*(Bollerslev). https://doi.org/10.18637/jss.v082.i05

Porter, J. L., Kingsford, R. T., & Brandis, K. (2018). Aerial Survey of Wetland Birds in Eastern Australia - October 2018 Annual Summary Report, (October), 1–23.

Porter, J. L., Kingsford, R. T., Francis, R., Brandis, K., & Ahern, A. (2022). *Eastern Australian Waterbird Aerial Survey -October 2022 Annual Eastern Australian Waterbird Aerial Survey - October 2022 Annual Summary Report*.

R Development Core Team. (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. Retrieved from http://www.r-project.org/.

Appendix 1. Banded duck recoveries for Australian species with statistics on distance moved and elapsed time (Bird and Bat Banding Database, Australian Government Department of Climate Change, Energy, the Environment and Water, accessed 8-April-2023)

Species	Total recoveries	Average distance (km)	Maximum distance (km)	Average elapsed (Months)	Maximum Elapsed (Months)
Chestnut teal	296	33	1095	11.1	77.4
Grey teal	6236	149	3184	6.8	380.3
Pacific black duck	8280	87	2677	10.8	325.7
Hardhead	75	122	1520	5.6	58.1
Australian wood duck	2262	36	1720	4.5	177.6
Australian shelduck	1981	68	1106	7.2	157.4