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

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On analysing 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).
- 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.

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 4th root transformed), but it made little difference to the outcomes, so untransformed-variable analysis has been presented here.

Duck counts among 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.

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., "before" data 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 *et al.* 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), but have not been completed here due to time constraints.

Caveat 1: Statistical significance of trends

- The EAS survey data is a time series of counts, not a random sample 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.
- A fundamental assumption required of the user of Ordinary Least Squared (OLS) models, such as the linear regressions performed by Microsoft Excel, is that target data are randomly sampled from a population, and as such are independent of each other. This assumption may not be satisfied in time-series data and 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) also used OLS to determine significance of trends and augmented the analyses with data transformations and inspection of autocorrelation plots (to satisfy assumptions).

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 *et al.* 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.

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 wildfowl 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 prepared by Adam Carson (as requested, Field & Game Australia) and also used Mann-Kendall's trend test. Results are summarised in Table 2 and Table 3.

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. Bands 3-5 cover NSW

	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 timeseries (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 less 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	**

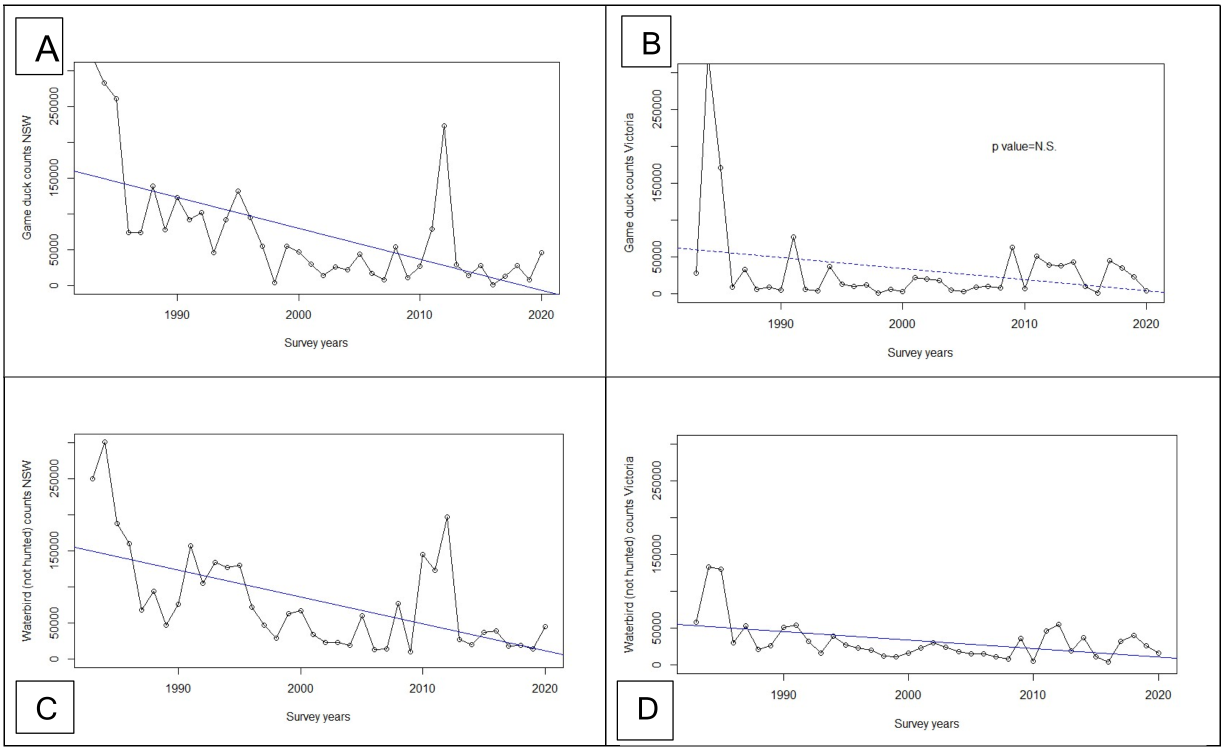

Figure 1. (A) Time series of EAS counts of game duck species for EAS bands 3-5 in NSW. (B) Time series of EAS counts of game duck species for EAS bands 1-2 in Victoria (regression slope is not significantly different from zero, see Table 2). (C) Time series of EAS counts of waterbird species (other than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

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.

Future analyses of EAS (or other) time-series of waterbird counts to identify trends, should take advantage of the recently developed Generalized Linear Modelling approach for time-series of Liboschik *et al* (2017). Such methods are probably the most statistically appropriate to-date when answering questions about trends and effects of management interventions in time-series of count data.

References

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