Biological Conservation xxx (xxxx) xxxx

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Letter to the editor

Modelling concerns confound evaluations of legal wolf-killing

Liberg et al. (2020)'s interesting article on the effect of legal killing on poaching and disappearance of wolves continued the seminal work of Liberg et al. (2012). However, our eyes were caught by unusual modeling procedures, so we reanalyzed their population model and found issues with the specification of their individual-level model.

At the population-level, the authors modeled "Disappearance rate in relation to… number of wolf territories" (Fig. 2A) or in relation to "culling rate" (Fig. 2B) using logistic regressions (Table 1). We could not find probability estimates or logistic curves in those data depictions and overall had difficulty interpreting their methods. We think they analyzed annual population-wide disappearance rate (number of wolves that were poached or lost, divided by the number of territories variously referred to as population size or n of wolves at risk/2) as a continuous, not binary, variable. Using the population-level data from their appendix, we quantified the annual absolute number of wolves that disappeared for correlation with the absolute number culled ($n = 17$, $r = 0.69$) and as rates (divided by the annual number of wolves at risk and standardized as the authors did, $r = 0.56$), although the latter is unnecessary because the denominator was the same for both variables. We suggest the authors should have mentioned this positive correlation explicitly, given it is consistent with a hypothesis they tested (Chapron and Treves, 2016). Instead, the authors incorporated population size into their multivariate glm. Population size is collinear with culling rate ($r = 0.86$, variance inflation factor $= 3.9$), raising concerns about the interpretation of the glm. More worrisome, the glm seems to regress y/x against x, where y = the *absolute* number of disappearances divided by x = number of territories to make disappearance *rate*, e.g., "Both **population size** and culling **rate** were included in the top ranked model explaining disappearance **rate** at the population level (Table 1, Fig. 2)." (emphasis added, p.4). Regressions of y/x on x produce negative slope parameters when simulated with random numbers, not a null hypothesis of a zero slope (Treves, 2001). The authors did not point out that culling rate went from a positive correlation with disappearance rate to a negative one after controlling for the much stronger correlation with population size. This oversight seems to favor the hypothesis underlying the government-endorsed policy. We do not believe their result is reliable.

We recommend instead that the authors build a population model including culling using absolute numbers. Liberg et al. (2020) Fig. 1 suggests absolute numbers are important because wolf disappearances rose after the culling policy began in 2010, similar to findings by (Santiago-Ávila, 2019) and reported informally in June 2019 (Treves, 2019). They might try the published model that one of their co-authors discussed at length with Chapron and Treves (2016). We don't understand why the authors ignored the clear positive correlation between disappearances and culling that was independent of population size. Perhaps they were focused more on individual-level modeling.

The authors use Cox proportional hazards in a competing risks framework to model disappearance risk at the individual level. We have some questions about this model and suggestions for a more robust analysis. First, in their analysis of collared territorial wolves the authors used a Kaplan-Meier (KM) estimate of cause-specific survival functions. However, in the presence of competing risks, KM estimators can overestimate the incidence function. When summed, the KM estimates of incidences for individual endpoints will sum to greater than the KM estimate of the cumulative endpoint (Austin et al., 2016). This may explain why Fig. 2B presents the impossible outcome that disappearance rate is > 0 even when culling rate $= 1$. Second, Cox proportional hazard models estimate hazard as a function of survival time and covariates. In their best Cox model (Table 2), the authors included population size and culling rate as covariates, but, in our understanding, both variables were recorded at the end of the monitoring season not after each wolf was 'lost' or born. The problem here is that, in a survival or competing risk framework, both of these variables would *retrospectively* affect hazard and incidence of disappearance within that monitoring season. This does not seem conceptually sound for models that evaluate how the hazard or incidence of an event occurring is affected by current (not future) conditions. Third, while Cox proportional hazard models can help us understand cause-specific risks, their results are most useful in conjunction with competing risk analyses that estimate the cumulative incidence functions (CIF) of an endpoint of interest (in this case disappearance) in the presence of all other competing risks (Austin et al., 2016). CIFs allow for visualizing the effect of covariates on the probability of occurrence of a competing risk event over time, and any potential interactions between competing risks (e.g., between culling and poaching). We suggest that the authors present results of hazard and incidence for all endpoints because these are important for proper and contextual interpretation of their results (Austin et al., 2016).

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

References

Austin, P.C., Lee, D.S., Fine, J.P., 2016. Introduction to the analysis of survival data in the presence of competing risks. Circ. Res. 133, 601–609.

Chapron, G., Treves, A., 2016. Blood does not buy goodwill: allowing culling increases poaching of a large carnivore. Proc. R. Soc. B 283, 20152939.

Liberg, O., Chapron, G., Wabakken, P., Pedersen, H.C., Hobbs, N.T., Sand, H.k., 2012. Shoot, shovel and shut up: cryptic poaching slows restoration of a large carnivore in Europe. Proc. R. Soc. Lond. Ser. B 270, 91–98.

Liberg, O., Suutarinen, J., Åkesson, M., Andrén, H., Wabakken, P., Wikenros, C., Sand, H., 2020. Poaching-related disappearance rate of wolves in Sweden was positively related to population size and negatively to legal culling. Biological Conservation 243.

Santiago-Ávila, F.J., 2019. Survival Rates and Disappearances of Radio-Collared Wolves in Wisconsin. In Nelson Institute for Environmental Studies. University of Wisconsin-Madison (accessed).

https://doi.org/10.1016/j.biocon.2020.108643
Received 10 April 2020; Accepted 24 May 2020

Treves, A., 2001. Reproductive consequences of variation in the composition of howler monkey social groups. Behav. Ecol. Sociobiol. 50, 61–71.

Treves, A., 2019. Peer Review of the Proposed Rule and Draft Biological Report for Nationwide Wolf Delisting. U.S.F.W.S. Department of Interior. Department of Interior, U.S. Fish & Wildlife Service, Washington, D.C.. https://www.fws.gov/endangered/esa-library/pdf/Final%20Gray%20Wolf%20Peer%20Review%20Summary%20Report_053119.pdf (accessed).

Adrian Treves*, Naomi X. Louchouarn, Francisco J. Santiago-Ávila
Nelson Institute for Environmental Studies, University of Wisconsin-Madison, 30A Science Hall, 550 North Park Street, Madison, WI 53706, USA
E-mail address: atreves@wisc.edu (A. Treves).

---

* Corresponding author.