Preliminary Estimate of Impact of Impact of Recommended DNR Quota on WI Wolf Population

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Introduction

On or about 29 July 2021, the Wisconsin Department of Natural Resources announced its recommendation that the Natural Resources Board set a quota of 130 wolves for the fall Wisconsin wolf hunt starting in November 2021. Soon after I received this recommendation, I worked with my colleagues at the University of Wisconsin-Madison Carnivore Coexistence Lab to construct scenarios to predict the impact that a hunt of this magnitude would have on the Wisconsin wolf population.

I worked as quickly as I could, so as to get these estimates out to the Natural Resources Board before it votes on whether to approve the recommended quota on 11 August 2021. Due to the time constraints, this work has not yet been peer-reviewed, and I reserve the right to amend it after receiving advice as a result of peer review.

My scenarios start from the only published, peer-reviewed estimate of the state wolf population made after the February 2021 hunt (which estimated the population as of April 2021), and the only published, peer-reviewed, estimate of births and pup survival to November. All the scenarios that I constructed were conservative, in that they assumed hunters would not kill any wolves in excess of the quota, would not fail to report any wolves that were lethally injured in the hunt, and that there would be zero additional cryptic poaching as a result of the hunt, beyond that already captured in our estimated annual mortality rate for a population without Endangered Species Act protection. During the February 2021 hunt, 99 wolves were killed in excess of the state-mandated quota, and we estimate an additional 98-105 wolves died in actions related to the hunt and federal delisting.

My first, and primary, conclusion is that the uncertainty about reproduction and pup survival from April 2021 to the present date is so vast that it would be reckless to authorize a November 2021 hunt without gathering more data about the full impact of the February 2021 hunt on the wolf population.

My second conclusion is that the scenarios show a likelihood that the recommended quota level is likely to cause the Wisconsin wolf population to fall below the state population goal of 350 wolves by April 2022, and below the state re-listing level of 250 wolves by summer 2022, triggering statutory relisting of wolves under the state endangered species act.

I make the following additional observations:

- My most likely scenarios suggest that a fall hunt with a quota of 130 wolves will leave Wisconsin with an estimated population of 272-401 wolves outside of reservations by April 2022.
  - 10 out of 18 of the scenarios predict that the recommended quota will put the wolf population below the state population goal of 350 wolves.
  - 4 out of 18 scenarios predict the recommended quota will put the wolf population below the state re-listing threshold of 250 wolves.
- By summer 2022, the wolf population will likely fall below the state re-listing level of 250 wolves.

Given the uncertainty about the current status of the wolf population following the spring/summer 2021 breeding season, the uncertainty level of our predictions is 272%. That high level of uncertainty cautions against authorizing another hunt in November 2021 (or setting the quota at the lowest level allowed by state law), because of the potentially catastrophic impact of hunting at the level of the recommended quota. The numbers suggest the danger that the wolf population numbers could crash if there is poor reproductive success in 2022, which may be likely depending on which wolves are killed in the fall 2021 hunt.

Purpose

To quantify the risk to the state wolf population of the Wisconsin Department of Natural Resources (DNR) recommended quota of 130 wolves for the fall 2021 hunt, with a full accounting of uncertainty, using only peer-reviewed scientific evidence and the latest official data on collared wolf deaths.

Note: These results are preliminary pending peer review and offered to provide the best information available in advance of the 11 August 2021 decision by the Natural Resources Board decision on the fall 2021 wolf hunt.

Methods

Population size estimation
I estimated population growth and decline from 15 April 2021 to 14 April 2022, using the only peer-reviewed published estimate for the state wolf population in April 2021 **[1]**. I used the lower bound of 695 as a precaution, not the high bound of 751, because the latter study judged those values to be maximum possible values based on a set of conservative estimates. I then subtracted 42 wolves living entirely or mostly on tribal reservations [**2**], because these are managed by the co-sovereign tribes whose governments declared wolves protected from public hunts **[3]**. I then subtracted the expected deaths of adults and yearlings in several steps.

The first step estimated wolf deaths during the study period. The second step was to subtract the proposed quota of 130, assuming zero over-kill will occur, zero sub-lethal injuries unreported as legal kills, and assuming zero additional cryptic poaching beyond that already captured in annual mortality rates during periods without ESA protections **[1, 4]**. The most rigorous study of cryptic poaching to date on the endangered Mexican wolf estimated that disappearances of collared wolves in this closely monitored population went up 121% when the wolf was not listed under the Endangered Species Act [ESA], compared to periods of strict ESA protection **[5]**. To be conservative, I did not use that scaling factor, but I note below why high mortality rate estimates may be realistic. The third and final step in population estimation required that I add the surviving pups born in summer 2021 using several scenarios for the number of breeding packs. Note my procedure keeps adults and young of the previous year on a separate accounting from pups and their survival, which assumes adult deaths between April and November have no effect on pup survival and vice versa. I know of no evidence from Wisconsin for or against this assumption.

Deaths
Estimating how many wolves died in the study period is both difficult and controversial, given that DNR asked a limited subset of stakeholder groups to come to consensus on the annual rate of human-caused (non-hunt) mortality, rather than using science to arrive at an estimation of that rate. The rate that DNR came to from this consensus process was 13%, which I dismiss because it is lower than any of the published estimates from prior periods and also lower than the data presented by DNR for 2019-2021, as I explain below.

I used three sources to estimate the annual non-hunt mortality rate and expected number of deaths unrelated to the wolf-hunt proposed for November 2021. Because annual mortality rate is a proportion of living wolves, the order in which I deduct non-hunt deaths is important. It would be conservative to deduct them after the wolf hunt because wolf mortality is highest in the winter, and the resulting deaths would be lower after deducting the hunt. Because my focus here is on precautions, I might argue for subtracting deaths before the wolf hunt. However, I anticipate the differences between the two approaches will produce little variation relative to the uncertainty in the input parameters, as I discuss next.

I derived the first estimate of annual mortality rate from the prior year population report for April 2019-April 2020 based only on collared wolves **[2]**, spanning a period when the wolves were federally protected. That estimate was approximately 0.268 (17 died or disappeared of 76 monitored for a maximum of 64 wolf-years). Because the latter report did not provide time on the air for each wolf, this estimate is necessarily imprecise but may over- or under-estimate. Note this is higher than the estimate of 0.24 for marked wolves only from 1979-2013 but probably within the SD of that estimate **[6]**. However, the announcement of federal delisting on 3 November 2020 affects my study period, unlike the period April 2019-April 2020 when wolves were under ESA protection for the entire period, and there had been five years since last wolf hunt in December 2014. Reducing ESA protections has consistently raised mortality independent of the number legally killed, slowing population growth an average of 5% annually **[7]** and reducing individual collared wolf survival by approximately 10% over a year **[4]**. Therefore, the estimate from April 2019-April 2020 appears too low for my study period.

Furthermore, I have more recent information from a partial report DNR released in April 2021, apparently covering April 2020-April 2021 **[8]**. Although that partial report was unclear about 10 collared wolves that began that year (TABLE 1) and did not report how many collared wolves died of causes other than wolf-hunting, I can nevertheless infer deaths and disappearances if I assume 59 collared wolves survived from the prior year report **[2]**.

Table 1. Wisconsin collared wolves April 2019-April 2021 from two incomplete reports. The 2019-2020 report from **[2]** lacks time on the air, while the 2020-2021 report did not document the outcome for all collared wolves nor time on the air **[8, 9]**.

Category	2019-2020	2020-2021	Notes
Wolves on the air before	51	59	
Wolves added during	25	NA	
Found dead	17	11	<—incomplete report
Disappeared (non-hunt)		17	<—incomplete report
Still transmitting	59	26	
Unaccounted for		9	

By April 2021, there were 50 collared wolves accounted for in the DNR partial report (TABLE 1). Of those 50, 7 were confirmed dead in the wolf-hunt, 17 had disappeared (stopped transmitting), and 26 appeared to be transmitting well or intermittently. I assume the 6 wolves referenced as VHF-collared were part of the 43 transmitting and not an additional 6, otherwise the slide makes no sense by not summing to 43 (TABLE 1). Therefore, 9 of the original 59 wolves were not mentioned, which I assume means they were known to have died of other causes. In a tally of collared wolves killed by human causes, the DNR reported 4 collared wolves illegally killed **[8]**. As neither of the cited sources in this paragraph were complete or clear, I propose the following three scenarios for deaths during my study period.

Regarding only April 2020-April 2021, if I sum the 9 unaccounted and the 17 accounted (TABLE 1), 26 of the 59 wolves died or disappeared, excluding the 7 killed in the wolf-hunt. In the past, approximately 5-7% of collared wolves (mainly VHF) that disappeared were not in fact dead when the collar stopped transmitting **[4, 6, 10]**, so if I assume one of the 17 disappearances was still alive in April 2021, then the previous year's annual rate of death and disappearance was 0.424 (26 of 59). I define this as my medium mortality scenario. My medium mortality rate is consistent with two separate estimates using different methods for adult wolves from 1979-2012. For collared wolves only, the cumulative incidence of all endpoints for collared wolves at 365 days since collaring was 0.42-0.52 depending on ESA listing status **[4]** and a weighted average of collared and uncollared adult wolves of 0.38-0.41 **[10].**

The latter study reported uncollared wolves experienced an annual average mortality rate of 0.47 **[10]**. Similarly, **[11]** reported higher mortality rates for uncollared Alaskan gray wolves. If uncollared wolves experience higher annual mortality than collared ones, as I suspect, then the relative proportion of collared to uncollared wolves should be considered when evaluating mortality scenarios. On average from 1979-2012, collared wolves represented 13% of the population, but in 2020 they represented 5-7% of the population. Given the evidence cited above for higher rates of annual mortality among uncollared wolves, the medium and high mortality rates cannot be dismissed without more evidence. Moreover, a higher annual mortality rate for collared wolves can also be justified. Given that from April 2020-April 2021, the denominator of 59 might instead have been 52 (59 minus the 7 killed in the wolf-hunt), which I used as my high mortality scenario with a rate of 0.481 (25/52).

Likewise, one can envision a lower annual mortality rate if one reasons that the annual mortality rate from April 2019-2020 represented a good year in the sense that the population had grown 13% **[2]**, the entire year was under ESA protections, and >5 years since the last wolf-hunt in December 2014. Therefore, I averaged the latter good year with the April 2020-2021 year of higher mortality (April 2019-April 2022). To do so, I estimated the time on the air for 51 wolves already collared before April 2019 (treating these as 24 months on the air on average, which is an under-estimate given some collared wolves have been on the air for >2 years in this population), pooled with 25 additional wolves collared before April 2020 (treating these as 18 months on the air on average) as reported by **[2]** and in Table 1. The weighted average of those two sets of wolves was 21 months for each collared wolf. Given no evidence that new wolves had been collared between April 2020 and April 2021, I then summed all deaths and disappearances from the two-year period excluding the February 2021 wolf-hunt, resulting in 38 deaths and disappearances over an average time on the air of 21 months for 76 wolves. That translates to an annual mortality rate of 0.323 for collared wolves, which I designated as the low mortality estimate.

In sum, three annual mortality rate estimates without wolf-hunts range from 0.323-0.481. That is nearly 50% uncertainty (maximum estimate – minimum estimate divided by the latter), which will "stack" with uncertainty about births and pup survival in the text below. Also note how much higher this is than the DNR "consensus" estimate of 13% + approximately 9% nonhuman-caused **[8].** Yet, my estimate is scientifically defensible, based on evidence and peer-reviewed studies. In that way, I avoid the pitfall envisioned by Curtis, "The very basis of the Precautionary Principle is to imagine the worst without supporting evidence... those with the darkest imaginations become the most influential." **[12]**. We have supporting evidence for my precautionary approach.

Births

I began with an estimate for the statewide number of packs that produced pups in summer 2021. That number might have been strongly affected by the February 2021 wolf hunt that took place during the breeding season and used methods (hounds, snowmobiles, night-time tracking) that might have made breeders more vulnerable than in prior wolf hunts.

I developed spatial scenarios for estimating the number of wolf packs whose breeding was interrupted by the February 2021 wolf-hunt. I assumed the maps of hunted areas and pack areas were accurate, every pack near to a hunted area would potentially be affected by the hunt, reservation packs and packs outside of hunted counties would be unaffected by the hunt. I assumed a pack affected by hunting did not reproduce in summer 2021.

With two plausible estimates for the number of packs that bred in summer 2021, I multiplied that number by the average value for the following birth rate parameters. I used the only peer-reviewed published study of reproductive success before November conducted among Wisconsin wolves **[13].** I did not use another commonly cited summary **[14]** because it aggregated breeding data at the end of the wolf-year in April and I needed an estimate for November. Also, we have previously explained why winter estimates of pack size might be confounded with estimates of breeding at that time **[15]**.

From **[13]**, I collected the mean ± 1 SD for each of the following input variables: percent of packs breeding successfully, number of pups emerging from dens in summer, and survival of pups to 3-9 months. I then multiplied those parameters by two values for the number of packs that bred in summer 2021 in two scenarios.

I assumed no compensatory increases in birth or pup survival other than those encompassed by the range of values I used for a period with ESA protections and a population recolonizing vacant range, i.e., reproductive performance in good years measured by **[13].** I do not ignore or dismiss claims of Allee effects, compensation or negative density-dependence **[6, 16, 17],** but await replies to my published questions about the methods behind their findings **[18-20]** and my latest questions (http://faculty.nelson.wisc.edu/treves/archive_BAS/Treves%20public%20comment%20NRB%203%20Aug%202021.pdf), before I complicate predictions about reproductive performance with non-linear effects. In the meantime, I assume the good conditions studied by **[13]** encompass any nonlinear effects for wolves in an environment with fewer competitors than before.

The data from **[13]** produce estimates of pups surviving to November that range from 0.15-4.32 per pack which generates uncertainty of 278% calculated as in the prior section on deaths. That emphasizes how uncertainty about births is greater than about deaths, even without considering the uncertainty about the number of packs breeding. I assumed no net migration during the study period at a rate relative to deaths or births substantial enough to affect my results, as in prior work by others.

I assumed reproductive output dropped to zero when affected by hunting either directly through death of breeders or indirectly through stress, loss of adult wolf helpers, wounding, poaching, or other factors. That assumption allowed us to narrow the bounds of uncertainty on the unmeasured variable of number of wolf packs producing pups in summer 2021.

I schematically depict uncertainty and precaution and their relationship in **Figure 1.**

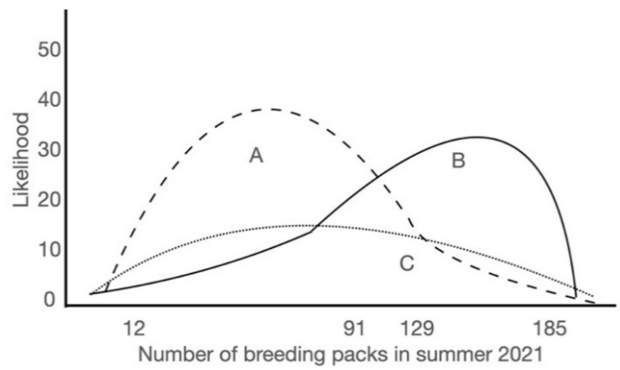

Figure 1. Uncertainties and precautions about the number of breeding wolf packs in Wisconsin in the summer of 2021 (x axis) and three hypothetical curves (A-C) for the probability distributions of x values. I do not know the shape of the distributions because I lack data on disruption of breeding by the February 2021 wolf hunt. Curves such as A (dashed line) lean left to lower values of x (precautionary) but convey more certainty (narrower peak) then curves such as B (solid line) that lean toward higher values of x (riskier) but convey less certainty with a flatter profile across a broader range of x values (uncertain). The flattest distributions (e.g., C dotted line) conveys little or no confidence in any particular x axis value and leaves any precautions to the observer. A curve (not shown) that would lean right and peak narrowly are least precautionary with highest confidence, which are not supported by data in my case study. The tails of all distributions are shown as identical to signify extremely unlikely x values.

Results

Births

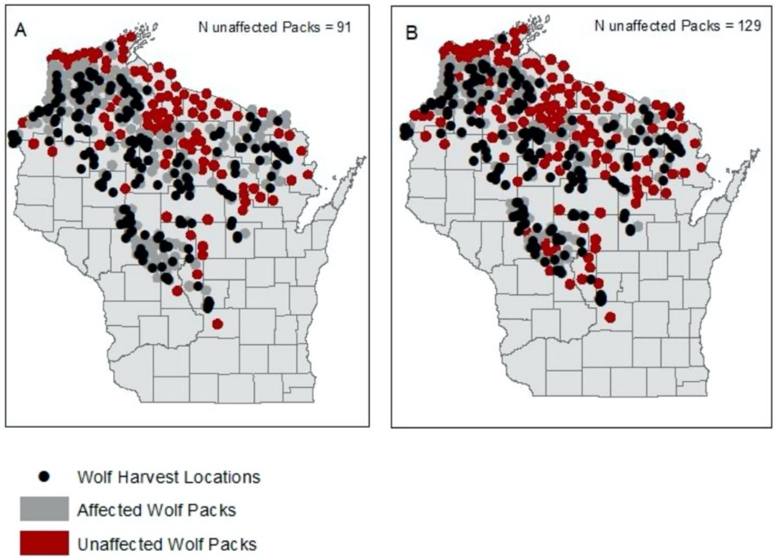

Figure 2. Scenarios for estimating the number of wolf packs in Wisconsin affected by the February 2021 wolf hunt. Scenario A assumes any hunter-reported wolf-kill location within one diameter of an average wolf pack territory would affect the nearest wolf pack. Scenario B assumes any hunter-reported wolf-kill location within the wolf pack territory affects that wolf pack. These scenarios seem plausible compared to extreme ones, such as an optimistic one that speculates that a wolf pack only stops breeding if an alpha female was killed; or alternately a precautionary scenario that speculates that all wolf packs except those in reservations or outside of the counties with hunter-reported kill locations would reproduce successfully.

Table 2. From scenarios A and B in Figure 2 and reproductive estimates from Thiel et al. 2009, I estimate the following numbers of pups surviving to November 2021.

Scenarios	N of packs breeding	Low reproduction & pup survival	Mean reproduction & pup survival	High reproduction & pup survival
High number of packs breeding	129	11	89	496
Low number of packs breeding	91	8	63	350

Deaths

My low, medium, and high annual mortality rates added to the recommended quota of 130 wolves killed in the hunt summed together for estimates of deaths of 341, 418, and 444 by April 2022.

Population change

When I combine my three estimates of births with my three estimates of deaths and my two scenarios for number of breeding packs (Figure 2), I find 18 results I consider plausible (Table 2).

Table 3. Plausible values for two scenarios of 9 combinations of birth and deaths for Wisconsin wolves April 2021-April 2022.

Scenario	Low births, high deaths	Low births, medium deaths	Low births, low deaths	Medium births, high deaths	Medium births, medium deaths	Medium births, low deaths	High births, high deaths	High births, medium deaths	High births, low deaths
High number of packs breeding	220	246	323	298	324	401	705	731	808
Low number of packs breeding	217	243	320	272	298	375	559	585	662

Table 2 presents values ranging from 217-808 (272% uncertainty or the uncertainty is greater than three-quarters of the values) with a median value at 323-324.

Overall, 10 out of 18 (56%) of scenarios falling below the state population goal of 350. Four out of 18 (22%) lie below the state listing threshold of 250 wolves (Table 2). Therefore, the majority of scenarios produce an undesirable result by state policies and almost a quarter are undesirable legally. Another poor reproduction in summer 2022 could lead to population crash, therefore.

Finally, the levels of uncertainty associated with the number of breeding packs leading to highly uncertain pup survival and the extremely uncertain Table 2, placing the burden of proof on those painting a more optimistic picture of the effects of the recommended fall 2021 quota, especially because I assumed no legal over-shooting of the quota and no unreported death resulting from the hunt.

These results are preliminary pending peer review and offered to support a precautionary approach to the fall 2021 wolf hunt, in advance of the 11 August 2021 decision by the Natural Resources Board.

References cited

1. Treves, A., F.J. Santiago-Ávila, and K. Putrevu, *Quantifying the effects of delisting wolves after the first state began lethal management.* PeerJ, 2021. **9**: p. e11666. 10.7717/peerj.11666. https://doi.org/10.7717/peerj.11666.
2. Wiedenhoeft, J.E., S. Walter, M. Gross, N. Kluge, S. McNamara, G. Stauffer, J. Price-Tack, and R. Johnson, *Wisconsin gray wolf monitoring report 15 April 2019 through 14 April 2020*, B.O.W. MANAGEMENT, Editor. 2020, Wisconsin Department of Natural Resources: Madison, Wisconsin. https://dnr.wisconsin.gov/sites/default/files/topic/WildlifeHabitat/wolfreport2020.pdf.
3. Sanders, J.D., *Wolves, lone and pack: Ojibwe treaty rights and the Wisconsin wolf hunt.* Wisconsin Law Review, 2013. **2013**: p. 1263-1294.
4. Santiago-Ávila, F.J., R.J. Chappell, and A. Treves, *Liberalizing the killing of endangered wolves was associated with more disappearances of collared individuals in Wisconsin, USA.* Scientific Reports, 2020. **10**: p. 13881. /10.1038. | https://doi.org/10.1038/s41598-020-70837-x.
5. Louchouarn, N.X., F.J. Santiago-Ávila, D.R. Parsons, and A. Treves, *Evaluating how lethal management affects poaching of Mexican wolves* Open Science, 2021. **8 (registered report)**: p. 200330. https://doi.org/10.1098/rsos.200330.
6. Stenglein, J.L., A.P. Wydeven, and T.R. Van Deelen, *Compensatory mortality in a recovering top carnivore: wolves in Wisconsin, USA (1979–2013).* Oecologia, 2018. **187**(1): p. 99–111. 10.1007/s00442-018-4132-4. https://doi.org/10.1007/s00442-018-4132-4.
7. Chapron, G. and A. Treves, *Correction to 'Blood does not buy goodwill: allowing culling increases poaching of a large carnivore'.* Proceedings of the Royal Society B, 2016. **Volume 283**(1845): p. 20162577.
8. Natural Resources Board, *Request approval of the fall 2021 wolf season harvest quota*, W.D.o.N. Resources, Editor. 2021, Wisconsin Department of Natural Resources: Madison, WI.
9. WDNR, *Presentation by J. Price Tack to Wolf Harvest Committee 8 Aprl 2021*, D.o.N. Resources, Editor. 2021: Madison, WI.
10. Treves, A., J.A. Langenberg, J.V. López-Bao, and M.F. Rabenhorst, *Gray wolf mortality patterns in Wisconsin from 1979 to 2012.* Journal of Mammalogy, 2017. **98**(1): p. 17-32. 10.1093/jmammal/gyw145. http://doi.org/10.1093/jmammal/gyw145
11. Schmidt, J.H., D.S. Johnson, M.S. Lindberg, and L.G. Adams, *Estimating demographic parameters using a combination of known-fate and open N-mixture models.* Ecology, 2015. **56**(10): p. 2583–2589. http://dx.doi.org/10.1890/15-0385.1.
12. Curtis, A., *The Power of Nightmares*. 2004, BBC.
13. Thiel, R.P., W. Hall, E. Heilhecker, and A.P. Wydeven, *A Disjunct Gray Wolf Population in Central Wisconsin*, in *Recovery of Gray Wolves in the Great Lakes Region of the United States: an Endangered Species Success Story*, A.P. Wydeven, T.R. Van Deelen, and E.J. Heske, Editors. 2009, Springer: New York. p. 107-118.
14. Wydeven, A.P., J. Wiedenhoeft, R.N. Schultz, R.P. Thiel, R.R. Jurewicz, B. Kohn, and T.R. Van Deelen, *History, population growth and management of wolves in Wisconsin*, in *Recovery of Gray Wolves in the Great Lakes Region of the United States: an Endangered Species Success Story*, A.P. Wydeven, T.R. Van Deelen, and E.J. Heske, Editors. 2009, Springer: New York. p. 87-106.
15. Wydeven, A.P., A. Treves, B. Brost, and J.E. Wiedenhoeft, *Characteristics of wolf packs in Wisconsin: Identification of traits influencing depredation*, in *People and Predators: From Conflict*

to Coexistence, N. Fascione, A. Delach, and M.E. Smith, Editors. 2004, Island Press: Washington, D. C. p. 28-50.

16. Stenglein, J.L., J. Zhu, M.K. Clayton, and T.R. Van Deelen, *Are the numbers adding up? Exploiting discrepancies among complementary population models.* Ecology and Evolution, 2015. **5**(2): p. 368-376.
17. Stenglein, J.L. and T.R. Van Deelen, *Demographic and Component Allee Effects in Southern Lake Superior Gray Wolves.* PLOS ONE, 2016. **11**(3): p. 10.1371/journal.pone.0150535
18. Chapron, G. and A. Treves, *Reply to comments by Olson et al. 2017 and Stien 2017.* Proceedings of the Royal Society B, 2017. **284**(1867): p. 20171743.
19. Treves, A., *Peer review of the proposed rule and draft biological report for nationwide wolf delisting*, U.S.F.W.S. Department of Interior, Editor. 2019, 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.
20. Treves, A., P.C. Paquet, K.A. Artelle, A.M. Cornman, M. Krofel, and C.T. Darimont, *Transparency about values and assertions of fact in natural resource management.* Frontiers in Conservation Science: Human-Wildlife Dynamics, 2021. **2**: p. e631998. 10.3389/fcosc.2021.631998. https://doi.org/10.3389/fcosc.2021.631998