Liberalizing the killing of wolves

State of the science

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Recently, some state governments began pursuing aggressive efforts to reduce wolf populations through programs that include liberalized hunting and trapping seasons, and efforts to incentivize killing (e.g., bounties)[1]. These efforts represent a departure from policies of the recent past, raising the question: *why are states killing wolves*? Herein, we address justifications commonly provided for killing wolves and other large carnivores by reviewing the science on the social and ecological effects of these policies.

I. Increasing human tolerance for wolves

The best evidence indicates that the U.S. public at large has become more positive towards

[1] Wisconsin reduced its population by 27-33% or more in <1 year and then proposed a second wolf-hunt in the same year: A Treves, F.J. Santiago-Ávila, and K. Putrevu, "Quantifying the Effects of Delisting Wolves after the First State Began Lethal Management," *PeerJ* 9 (2021), https://dx.doi.org/10.7717/peerj.11666, A. Louchouarn Treves, N.X., "Uncertainty and Precaution in Hunting Wolves Twice in a Year," *BioRxiv pre-print* (2021), https://dx.doi.org/10.25.465697.; Idaho and Montana planned to reduce their wolf populations by as much as 90%: M. Brown, and Iris Samuels, "Us States Look to Step up Wolf Kills, Pushed by Republicans," *Associated Press* (https://apnews.com/article/donald-trump-wildlife-animals-lakes-billings-5eda7213f2cbec6c3d46897e74dddf80), March 7, 2021, 2021, accessed 10 March 2021, https://apnews.com/article/donald-trump-wildlife-animals-lakes-billings-5eda7213f2cbec6c3d46897e74dddf80. For media and scholarly commentary showing these recent policies are a departure from prior policies, see M. Brown, "Three States Seek to Retain Control of Wolves," *Associated Press*2008, May 7th 2008. and Adrian Treves, and Jeremy T. Bruskotter, "Gray Wolf Conservation at a Crossroads," *Bioscience* 61, no. 8 (2011), https://dx.doi.org/10.1525/bio.2011.61.8.2, J.T. Bruskotter et al., "Gray Wolves Not out of the Woods Yet," *Science* 327 (2010), J. T. Bruskotter et al., "Are Gray Wolves Endangered in the Northern Rocky Mountains? A Role for Social Science in Endangered Species Listing Determinations," *Bioscience* 60, no. 11 (2010), J.T. Bruskotter, S. Enzler, and A. Treves, "Rescuing Wolves from Politics: Wildlife as a Public Trust Resource," *Science* 333, no. 6051 (2011), J.T. Bruskotter, S. Enzler, and A. Treves, "Response to Mech and Johns," *Science* 335, no. 17 (2012).

wolves in recent decades[2], despite some members of some interest groups (especially hunters and livestock owners) in areas with wolves have become more negative[3]. States presumably sought to deal with this by liberalizing killing of wolves via regulated public hunting and trapping seasons. Governments often claim that killing wolves increases public tolerance (or decreases intolerance) for wolves and their conservation[4]. However, the best scientific evidence indicates that programs that liberalize the killing of wolves have not improved tolerance for wolves in either the general public nor among would-be wolf poachers[5]. Rather, it appears that these policies and programs have simply encouraged

[2] A large-sample, repeated cross-sectional study of adult, U.S. residents found that attitudes toward wolves became more positive since the 1970s. The proportion of Americans expressing positive attitudes toward wolves increased by > 40% between surveys conducted in 1978 and 2014. George, K. A., et al. "Changes in attitudes toward animals in the United States from 1978 to 2014," *Biological Conservation*, 201, 237-242 (2016).

[3] Some studies show less tolerance for wolves among urbanites, others among hunters or livestock owners, whereas other studies have examined individual experiences with encounters with wolves or with government policies for compensation or protection. For example, in the E.U., see A. Majic, and A. Bath, "Changes in Attitudes toward Wolves in Croatia," *Biological Conservation* 143 (2010), T.A. Heberlein, and G. Ericsson, "Ties to the Countryside: Accounting for Urbanites Attitudes toward Hunting, Wolves, and Wildlife," *Human Dimensions of Wildlife* 10 (2005), T. A. Heberlein, and G. Ericsson, "Public Attitudes and the Future of Wolves Canis Lupus in Sweden," *Wildlife Biology* 14 (2008), G. Ericsson, and T.A. Heberlein, "Attitudes of Hunters, Locals, and the General Public in Sweden Now That the Wolves Are Back," *Biological Conservation* 111 (2003), G. Ericsson et al., "Support for Hunting as a Means of Wolf *Canis Lupus* Population Control in Sweden," *Wildlife Biology* 10, no. 4 (2004), G. Ericsson, G. Bostedt, and J. Kindberg, "Wolves as a Symbol of People's Willingness to Pay for Large Carnivore Conservation," *Society and Natural resources* 21 (2007), K. Karlsson, and M. Sjöström, "Human Attitudes Towards Wolves, a Matter of Distance," *Biological Conservation* 137, no. 4 (2007).; in Wisconsin, see A. Treves, L. Naughton-Treves, and V.S. Shelley, "Longitudinal Analysis of Attitudes toward Wolves," *Conservation Biology* 27 (2013), L. Naughton-Treves, R. Grossberg, and A. Treves, "Paying for Tolerance: The Impact of Livestock Depredation and Compensation Payments on Rural Citizens' Attitudes toward Wolves," *Conservation Biology* 17 (2003).; and across the U.S. nationally, see JJ.T. Bruskotter, "The Predator Pendulum Revisited: Social Conflict over Wolves and Their Management in the Western United States," *Wildlife Society Bulletin* 37, no. 3 (2013), J.T. Bruskotter et al., "Support for the U.S. Endangered Species Act over Time and Space: Controversial Species Do Not Weaken Public Support for Protective Legislation," *Conservation Letters*;e12595 (2018), https://dx.doi.org/https://doi.org/10.1111/conl.12595.

[4] From the U.S. Fish & Wildlife Service to E.U. member states, many governments have claimed without data that liberalizing wolf-killing will improve tolerance or reduce poaching R. Refsnider, "The Role of the Endangered Species Act in Midwest Wolf Recovery," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: An Endangered Species Success Story*, ed. A. P. Wydeven, T. R. Van Deelen, and E.J. Heske (New York: Springer, 2009), G. Chapron, and A. Treves, "Reply to Comments by Olson Et Al. 2017 and Stien 2017," *Proceedings of the Royal Society B* 284, no. 1867 (2017), Y. Epstein, "Killing Wolves to Save Them? Legal Responses to 'Tolerance Hunting' in the European Union and United States," *RECIEL* 26, no. 1 (2017), Yaffa Epstein, and Guillaume Chapron, "The Hunting of Strictly Protected Species: The Tapiola Case and the Limits of Derogation under Article 16 of the Habitats Directive," *European Energy and Environmental Law Review* June (2018), Y. Epstein et al., "Eu Court: Science Must Justify Future Hunting," *Science* 366, no. 6468 (2019), A. Treves, and J.T. Bruskotter, "Tolerance for Predatory Wildlife," *Science* 344, no. 6183 (2014), J.T. Bruskotter et al., "Removing Protections for Wolves and the Future of the U.S. Endangered Species Act (1973) " *Conservation Letters* 7 (2013).

[5] For measurement of human attitudes before and after policy changes that liberalized wolf-killing or conversely tightened protections for wolves, see two sets of data from Wisconsin collected since 2001 using focus groups or mail-back surveys C. Browne-Nuñez et al., "Tolerance of Wolves in Wisconsin: A Mixed-

more killing of wolves[6]. Specifically, studies conducted before and after the programs were

Methods Examination of Policy Effects on Attitudes and Behavioral Inclinations," *Biological Conservation* 189 (2015), J. Hogberg et al., "Changes in Attitudes toward Wolves before and after an Inaugural Public Hunting and Trapping Season: Early Evidence from Wisconsin's Wolf Range," *Environmental Conservation* 43, no. 1 (2015), Treves, Naughton-Treves, and Shelley, Treves, and Bruskotter, A. Treves et al., "Estimating Poaching Opportunity and Potential," in *Conservation Criminology*, ed. M. L. Gore (New York: John Wiley & Sons, 2017). In particular, Hogberg et al. (2015) used a mail-back survey to resample individuals in 2013 after the inaugural Wisconsin wolf-hunt in 2012 and compared their responses to those of the same individuals measured in 2009. She found the largest declines in individual tolerance among men in wolf range with familiarity with hunting, the target demographic for such claims about tolerance rising after wolf-killing. Likewise, Browne-Nuñez et al. (2015) convened focus groups and analyzed anonymous questionnaires filled out by the same participants to in a mixed-methods approach to understand attitudes to changes in policy that allowed government agents to kill wolves suspected of preying on livestock Browne-Nuñez et al. Focus groups conducted after the change in policy showed increased calls for yet more wolf-killing and no change in tolerance for wolves or inclination to kill wolves illegally among focus group participants drawn from deer hunters, bear hounders, or livestock owners. Similar results of no differences in attitudes come from areas with and without hunting of brown bears in Slovenia P. Kaczensky, M. Blazic, and H. Gossow, "Public Attitudes Towards Brown Bears (Ursus Arctos) in Slovenia," *Biological Conservation* 118 (2004).
A study that is not peer-reviewed to our knowledge from Montana Fish Wildlife & Parks is sometimes cited as counter-evidence. However the only report we could find that was entitled, "Selected results" seemed instead to report that attitudes of hunters *toward state wolf policy* improved when they were allowed to hunt wolves and those self-reports were retrospective recall of the respondents' past attitudes; see: Michael S. Lewis et al., *Selected Results from Four Separate Surveys of Resident Montanans Regarding Montana's Wolf Hunt* (Montana Fish Wildlife and Parks, 2012).. Hogberg et al. (2015) measured both retrospective self-reports of tolerance for wolves and more objective measures of tolerance for wolves at two time points — among the same respondents — and found the two were not always congruent. Individuals whose more objective measures showed a decline in tolerance would often report no change or an improvement in their tolerance Hogberg et al.

[6] For studies of intolerant behavior measured by rates of poaching in relation to policies for liberalizing wolf-killing, see N.X. Louchouarn et al., "Evaluating How Lethal Management Affects Poaching of Mexican Wolves " *Open Science* 8 (registered report) (2021), https://doi.org/10.1098/rsos.200330, F.J. Santiago-Ávila, 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* 10 (2020), https://dx.doi.org//10.1038.. These and other studies have shown that management agencies discarded information on missing radio-collared wolves (A. Treves et al., "Mismeasured Mortality: Correcting Estimates of Wolf Poaching in the United States," *Journal of Mammalogy* 98, no. 5 (2017), https://dx.doi.org/10.1093/jmammal/gyx052 , S.W. Agan, A. Treves, and E.L. Willey, "Estimating Poaching Risk for the Critically Endangered Wild Red Wolf (Canis Rufus)," *PLos ONE* 16, no. 5 (2021), https://dx.doi.org/10.1371.,) which had the effect of biasing their analyses of threats and obscuring the dynamics of poaching. Also, had the agencies understood the dynamics of poaching, they might have detected substantial slow-downs in wolf population growth independent of the number of wolves killed legally, and each time wolf-killing was liberalized G. Chapron, and A. Treves, "Blood Does Not Buy Goodwill: Allowing Culling Increases Poaching of a Large Carnivore," *Proceedings of the Royal Society B* 283, no. 1830 (2016), http://dx.doi.org/10.1098/rspb.2015.2939 , G. Chapron, and A. Treves, "Correction to 'Blood Does Not Buy Goodwill: Allowing Culling Increases Poaching of a Large Carnivore'," *Proceedings of the Royal Society B* Volume 283, no. 1845 (2016), G. Chapron, and A. Treves, "Reply to Comment by Pepin Et Al. 2017," *Proceedings of the Royal Society B* 2016257, no. 1851 (2017), http://dx.doi.org/10.1098/rspb.2015.2939 , Chapron, and Treves, "Reply to Comments by Olson Et Al. 2017 and Stien 2017.", Louchouarn et al.. The most recent studies of this question involve competing risks analyses of incidence of different endpoints (death or disappearance) for

initiated indicate they did not have the intended effect. More importantly, studies that have sought to evaluate the effect of liberalized killing policies on poaching found an increased tendency for radio-collared wolves to disappear whenever governments reduced protections for wolves. Thus, in contrast to promoting tolerance, these policies appear to have had the opposite effect (i.e., they led to increased poaching).

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radio-collared wolves in two populations Louchouarn et al, Santiago-Ávila, Chappell, and Treves. and three additional studies in review (Santiago-Avila, Louchouarn, in review). Collectively, each of these studies shows one or more of the following patterns of human behavior detected by changes in incidence of death or disappearance of collared wolves during periods of liberalized wolf-killing: an increase in cryptic poaching (sensu Olof Liberg et al., "Shoot, Shovel and Shut Up: Cryptic Poaching Slows Restoration of a Large Carnivore in Europe," *Proceedings of the Royal Society of London Series B* 270 (2012).) involving the concealment of evidence, an increase in documented poaching without concealment of evidence, or an increase in both incidences. In addition to the most rigorous analytical methods, the scientific manuscripts were submitted under new Open Science rules for registered reports that reduce publication biases Jeremy Sanders et al., "Transparency and Openness in Science," *Royal Society Open Science* https://doi.org/10.1098/rsos.160979 (2017).. That makes these studies the best available science by the standards of evidence accepted by the global scientific community.

The only credible peer-reviewed research suggesting poaching declined when legal wolf-killing was liberalized comes from Scandinavia Olof Liberg et al., "Poaching-Related Disappearance Rate of Wolves in Sweden Was Positively Related to Population Size and Negatively to Legal Culling," *Biological Conservation* 243 (2020), https://dx.doi.org/10.1016/j.biocon.2020.108456., but it has been questioned on statistical grounds of inappropriate survival analyses and inappropriate model specifications A Treves, N.X. Louchouarn, and F. Santiago-Ávila, "Modelling Concerns Confound Evaluations of Legal Wolf-Killing," *Biological Conservation* https://doi.org/10.1016/j.biocon.2020.108643 (2020), https://dx.doi.org/10.1016/j.biocon.2020.108643.. It also did not account for the finding from neighboring Finland that the more legal killing occurred, the lower the risk of poaching because wolves were removed legally before they could be removed illegally J Suutarinen, and I. Kojola, "Poaching Regulates the Legally Hunted Wolf Population in Finland," *Biological Conservation* 215 (2017), http://www.sciencedirect.com/science/article/pii/S0006320717302148, J Suutarinen, and I. Kojola, "One Way or Another: Predictors of Wolf Poaching in a Legally Harvested Wolf Population," *Animal Conservation* 21, no. 5 (2018), https://dx.doi.org/https://doi.org/10.1111/acv.12409.. As Santiago-Ávila and Louchouarn pointed out, when the government preemptively removes wolves suspected of problems before these can be killed illegally, it's difficult to claim tolerance has improved among affected interest groups Louchouarn et al, Santiago-Ávila, Chappell, and Treves..

The latter studies also found that poaching of wolves changed in association with census methods with the pattern apparently being one of lower poaching when more civilian volunteers supported wolf census in Wisconsin Santiago-Ávila, Chappell, and Treves.. And when the federal government liberalized wolf removal but did not alter the hazard or incidence of legal removal by its own agents, the hazard and incidence of disappearances of radio-collared wolves rose 121% Louchouarn et al., which suggests the government may have motivated cryptic poaching. The latter studies support the hypothesis that governments send a signal to would-be poachers that wolves have less value or the government needs the support of poachers to control wolf populations Chapron, and Treves, "Blood Does Not Buy Goodwill: Allowing Culling Increases Poaching of a Large Carnivore.". Independent, corroborating evidence that cryptic poaching carnivore-killing comes from two studies of wolverines *Gulo gulf* in Scandinavia. For one, GPS-collared wolves were less likely to die from illegal kills in a legally hunted population Cyril Milleret et al., "Gps Collars Have an Apparent Positive Effect on the Survival of a Large Carnivore," *Biology Letters* 17, no. 6 (2021), https://dx.doi.org/10.1098/rsbl.2021.0128.. Second, incentive programs that paid for living female wolverines led to higher rates of poaching of male wolverines Jens Persson, Geir Rune Rauset, and Guillaume Chapron, "Paying for an Endangered Predator Leads to Population Recovery," *Conservation Letters* 8, no. 5 (2015)..

II. Decreasing predation on domestic livestock or wild ungulates

A second reason governments give to kill wolves is that it is necessary to protect other animals (both domestic livestock and valued game)[7]. In the case of livestock protection, the best available evidence would come from before-and-after comparisons of interventions with random sampling[8]. No such studies exist but a lower standard of evidence (before-and-after comparisons without random sampling) reveal no protective effect of targeted wolf-killing, in a minority of cases wolf-killing appeared effective for preventing recurrent livestock killing, but an equal or greater number of cases appear to show increase in livestock killing after lethal management[9].

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[7] For livestock, see U.S. Department of Agriculture M.M. Conner et al., "Effect of Coyote Removal on Sheep Depredation in Northern California," *Journal of Wildlife Management* 62, no. 2 (1998), D.B. Ruid et al., "Wolf–Human Conflicts and Management in Minnesota, Wisconsin, and Michigan," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: An Endangered Species Success Story*, ed. A. P. Wydeven, T. R. Van Deelen, and E.J. Heske (New York: Springer, 2009). and U.S. States S. H. Fritts et al., *Trends and Management of Wolf-Livestock Conflicts in Minnesota* (US Fish and Wildlife Service, Resource Publication 181, Washington, DC., 1992), Elizabeth H. Bradley et al., "Effects of Wolf Removal on Livestock Depredation Recurrence and Wolf Recovery in Montana, Idaho, and Wyoming," *Journal of Wildlife Management* 79, no. 8 (2015).; E.U. and Canadian jurisdictions: Jan Darpö, "The Last Say? Comment on Cjeus Judgement in the Tapiola Case (C-674/17)," *Journal for European Environmental & Planning Law* 17, no. 1 (2020), https://dx.doi.org/10.1163/18760104-01701009, Epstein, and Chapron, R. R. Bjorge, and J. R. Gunson, "Wolf Predation of Cattle on the Simonette River Pastures in Northwestern Alberta," in *Wolves in Canada and Alaska: Their Status, Biology and Management.*, ed. L. N. Carbyn (Canadian Wildlife Service, Edmonton., 1983), S. J. Harbo, jr., and F. C. Dean, "Historical and Current Perspectives on Wolf Management in Alaska," in *Wolves in Canada and Alaska: Their Status, Biology and Management*, ed. L. N. Carbyn (Canadian Wildlife Service, Edmonton, 1983), M. Musiani et al., "Seasonality and Reoccurrence of Depredation and Wolf Control in Western North America," *Wildlife Society Bulletin* 33, no. 3 (2005).; for game, see J. C. Reynolds, and S.C. Tapper, "Control of Mammalian Predators in Game Management and Conservation," *Mammal Review* 26 (1996), T.J. Clark, and Mark Hebblewhite, "Predator Control May Not Increase Ungulate Populations in the Future: A Formal Meta-Analysis," *Journal of Applied Ecology* 58, no. 4 (2021), https://dx.doi.org/10.1111/1365-2664.13810, J. B. Theberge, and D. A. Gauthier, "Models of Wolf-Ungulate Relationships: When Is Wolf Control Justified?," *Wildlife Society Bulletin* 13 (1985).

[8] A. Treves, M. Krofel, and J. McManus, "Predator Control Should Not Be a Shot in the Dark," *Frontiers in Ecology and the Environment* 14 (2016), A. Treves et al., "Predator Control Needs a Standard of Unbiased Randomized Experiments with Cross-over Design," *Frontiers in Ecology and Evolution* 7 (2019), https://dx.doi.org/10.3389/fevo.2019.00462, Lily M. van Eeden et al., "Carnivore Conservation Needs Evidence-Based Livestock Protection," *PLoS Biology* l 16, no. 9 (2018), https://dx.doi.org/e2005577, O. Ohrens, C. Bonacic, and A. Treves, "Non-Lethal Defense of Livestock against Predators: Flashing Lights Deter Puma Attacks in Chile.," *Frontiers in Ecology and the Environment* 17, no. 1 (2019), https://dx.doi.org/10.1002/fee.1952.

[9] First it should be stated clearly that none of the research on lethal management of wolves to protect livestock met the highest standard but rather fell between before-and-after comparisons without randomization or lower standard correlational analyses (e.g., A. Fernández-Gil et al., "Conflict Misleads Large Carnivore Management and Conservation: Brown Bears and Wolves in Spain," *PLos ONE* 11, no. 3 (2016), https://dx.doi.org/10.1371/journal.pone.0151541, M. Krofel, R. Černe, and K. Jerina, "Effectiveness of Wolf (Canis Lupus) Culling as a Measure to Reduce Livestock Depredations," *Acta Silvae et Ligni* 95 (2011), Camille Imbert et al., "Why Do Wolves Eat Livestock? Factors Influencing Wolf Diet in Northern Italy," *Biological Conservation* 195 (2016).. Second, among the better studies reviewed in Treves, Krofel, and McManus. and reanalyzing raw data from Krofel, Černe, and Jerina., we find the most careful ones to be F.J. Santiago-Avila, A.

In contrast, research indicates at least three forms of non-lethal interventions are effective specifically against wolves[10]. Preventative, non-lethal methods are generally preferable over

M. Cornman, and A. Treves, "Killing Wolves to Prevent Predation on Livestock May Protect One Farm but Harm Neighbors," *PLos ONE* 13, no. 1 (2018), https://dx.doi.org/10.1371. and O. Grente, PhD thesis and in review 2021. Both conclude that some effects of lethal management of wolves reduce risk and some raise risk, some effects are neutral. Note that although Bradley et al.Bradley et al. claimed that lethal removal of an entire wolf pack would reduce livestock losses in that territory thereafter, Santiago-Avila et al. Santiago-Avila, Cornman, and Treves. was unable to reproduce their methods let alone their results even after corresponding with the lead authors. Replicating the methods with improved transparency and sharing all the data for Michigan's wolf control program, Santiago-Avila Santiago-Avila, Cornman, and Treves. found risk increased for cattle in neighboring townships. See also O. Grente, PhD thesis and in review 2021 for a study of multiple regions of France showing that the majority of regions showed no effect of wolf-killing on subsequent livestock losses. In the latter studies and every review thus far published on the effectiveness of lethal methods as a way to protect livestock, authors from over a dozen countries report occasional counter-productive effects resulting in higher livestock losses after predator-killing A. Eklund et al., "Limited Evidence on the Effectiveness of Interventions to Reduce Livestock Predation by Large Carnivores," *Scientific Reports* 7 (2017), Igor Khorozyan, and Matthias Waltert, "How Long Do Anti-Predator Interventions Remain Effective? Patterns, Thresholds and Uncertainty," *Royal Society Open Science* 6, no. 9 (2019), https://dx.doi.org/10.1098/rsos.190826, Robert J. Lennox et al., "Evaluating the Efficacy of Predator Removal in a Conflict-Prone World," *Biological Conservation* 224 (2018), Jennifer Miller et al., "Effectiveness of Contemporary Techniques for Reducing Livestock Depredations by Large Carnivores," *Wildlife Society Bulletin* 40 (2016), Darío Moreira-Arce et al., "Management Tools to Reduce Carnivore-Livestock Conflicts: Current Gap and Future Challenges," *Rangeland Ecology & Management* (2018), Treves, Krofel, and McManus, Treves et al, van Eeden et al, Lily M. van Eeden et al., "Managing Conflict between Large Carnivores and Livestock," *Conservation Biology* (2018), https://dx.doi.org/10.1111/cobi.12959, Igor Khorozyan, and Matthias Waltert, "Variation and Conservation Implications of the Effectiveness of Anti-Bear Interventions," *Scientific Reports* 10, (2020), https://dx.doi.org/10.1098/rsos.190826..

[10] (i) Fladry, a Polish word for a visual deterrent, consisting of flagging hog from fence-lines: Sarah J. Davidson-Nelson, and Thomas M. Gehring, "Testing Fladry as a Nonlethal Management Tool for Wolves and Coyotes in Michigan," *Human–Wildlife Interactions* 4, no. 1 (2010), https://dx.doi.org/https://doi.org/10.26077/mdky-bs63. following captive trials and non-randomized before-and-after comparisons M. Musiani, and E. Visalberghi, "Effectiveness of Fladry on Wolves in Captivity," *Wildlife Society Bulletin* 29 (2000), M. Musiani et al., "Wolf Depredation Trends and the Use of Fladry Barriers to Protect Livestock in Western North America," *Conservation Biology* 17: 1538–1547 (2003).. (ii) Livestock-guarding dogs, which are specialized breeds bonded to livestock not people, often in combination with fencing in livestock or using night-time enclosures for livestock Thomas M.; Gehring et al., "Utility of Livestock-Protection Dogs for Deterring Wildlife from Cattle Farms," *Wildlife Research* 37 (2010), http://digitalcommons.unl.edu/icwdm_usdanwrc/1344, T. M. Gehring, K. C. VerCauteren, and J.-M. Landry, "Livestock Protection Dogs in the 21st Century: Is an Ancient Tool Relevant to Modern Conservation Challenges?," *Bioscience* 60 (2010), T. M. Gehring, K. C. VerCauteren, and A. C. Cellar, "Good Fences Make Good Neighbors: Implementation of Electric Fencing for Establishing Effective Livestock Protection Dogs," *Human–Wildlife Interactions* 4 (2010).' also supported by numerous before-and-after comparisons and correlational studies N. Espuno et al., "Heterogeneous Response to Preventive Sheep Husbandry During Wolf Recolonization of the French Alps.," *Wildlife Society Bulletin* 32 (2004).. (iii) low-stress livestock handling practiced by 'range riders' or specially trained herdsmen periodically visiting cattle on public lands open-range pastures (Louchouarn & Treves, in review). Note that many other non-lethal methods have proven effective against other predators and in other conditions, including methods that are likely to work on wolves such as electric fences, but these have not been tested on wolves using high enough standards of evidence four our current discussion Eklund et al, Khorozyan, and Waltert, "How Long Do Anti-Predator Interventions Remain Effective? Patterns, Thresholds and Uncertainty.", Treves, Krofel, and McManus, Treves

post hoc killing of predators because non-lethal methods (a) allow owners to avoid losses as well as associated government reimbursements (thus saving money and time)[11], (b) have not led to those counter-productive increases in livestock losses[12], and (c) avoid removing wolves, which, among other problems, diminish the benefits of wolves and may disrupt social dynamics in ways that lead to additional livestock losses, thereby probably perpetuating a cycle of killing that can spread livestock losses geographically[13].

Although eradication of all predators would, of course, protect livestock from predation[14], less drastic killing can produce variable and unpredictable results. For example, lethal management that left survivors of the same species in a majority of cases resulted in higher livestock losses as summarized on the previous page, as did lethal management that

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et al, van Eeden et al, Khorozyan, and Waltert, "Variation and Conservation Implications of the Effectiveness of Anti-Bear Interventions.", Igor Khorozyan et al., "Studded Leather Collars Are Very Effective in Protecting Cattle from Leopard (Panthera Pardus) Attacks," (2020), https://dx.doi.org/10.1002/2688-8319.12013, N. J. Lance et al., "Biological, Technical, and Social Aspects of Applying Electrified Fladry for Livestock Protection from Wolves (Canis Lupus)," *Wildlife Research* 37 (2010)..

[11] For research on post-loss reimbursement method for compensation for property damage by wolves and the time and costs experienced by recipients, see Naughton-Treves, Grossberg, and Treves, A. Treves et al., "The Price of Tolerance: Wolf Damage Payments after Recovery," *Biodiversity and Conservation* 18 (2009), J. Montag, "Compensation and Predator Conservation: Limitations of Compensation," *Carnivore Damage Prevention News* 6 (2003), J. Montag, M.E. Patterson, and B. Sutton, *Political & Social Viability of Predator Compensation Programs in the West* (Missoula, MT: School of Forestry, University of Montana, 2003), A. Treves et al., "Wolf Depredation on Domestic Animals: Control and Compensation in Wisconsin, 1976-2000," *Wildlife Society Bulletin* 30 (2002), https://www.jstor.org/stable/3784658.. For research on other carnivores, focused on differences between monetary incentives paid before losses occur and those that reimburse losses, see Montag, *The Coalition Fo Wisconsin Wolf Trackers (Cwwt): Testimony by 28 Volunteer Wolf Census-Takers Declaring Opposition to State Wolf Policy*, 7 July 2012, 2012, A. Zabel, and K. Holm-Muller, "Conservation Performance Payments for Carnivore Conservation in Sweden," *Conservation Biology* 22, no. 2 (2008), K. Schwerdtner, and B. Gruber, "A Conceptual Framework for Damage Compensation Schemes," *Biological Conservation* 134 (2007)..

[12] Note that at least one non-lethal method (Foxlights®) were associated with increases in predation by carnivores other than wolves and so resulted in more livestock losses under particular circumstances, i.e., effective against pumas but not Andean foxes in Chile Ohrens, Bonacic, and Treves. and counter-productive against foxes in Australia K. Hall, and P. A. Fleming, "In the Spotlight: Can Lights Be Used to Mitigate Fox Predation in a Free-Range 4 Piggery?," *Applied Animal Behaviour Science* 2 (2021).. Also, sub-lethal methods such as translocation result in higher mortality of the translocated wolves and perhaps recurrent livestock losses following such removals S. H. Fritts, W. J. Paul, and L. D. Mech, "Can Relocated Wolves Survive?," *Wildlife Society Bulletin* 13 (1985)..

[13] Santiago-Avila, Cornman, and Treves.

[14] Erlend B. Nilsen et al., "Wolf Reintroduction to Scotland: Public Attitudes and Consequences for Red Deer Management " *Proceedings of the Royal Society B* 274 (2007), S.J. Riley, G.M. Nesslage, and B.A. Maurer, "Dynamics of Early Wolf and Cougar Eradication Efforts in Montana: Implications for Conservation," *Biological Conservation* 119, no. 4 (2004), U. Breitenmoser, "Large Predators in the Alps: The Fall and Rise of Man's Competitors," *Biological Conservation* 83 (1998), Treves et al, A. Treves, and L. Naughton-Treves, "Evaluating Lethal Control in the Management of Human-Wildlife Conflict," in *People and Wildlife, Conflict or Coexistence?*, ed. R. Woodroffe, S. Thirgood, and A. Rabinowitz (Cambridge, UK: Cambridge University Press, 2005).

eliminated one species but left another species of predator[15]. The counter-productive increase in property damage or losses of game after lethal management have been reported anecdotally for over half a century[16]. Such anecdotes have been corroborated by systematic scientific studies of coyote-killing[17] and more recently by systematic scientific studies of wolf killing in several countries as summarized in the previous page. Given that societies globally have outlawed programs of eradication of native predators[18], we conclude from the scientific evidence that non-lethal methods are the more useful alternative.

Relatedly, governments have for a century or more justified killing wolves as a means to

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[15] Consider the eradication of the Tasmanian thylacine *Thylacinus cynocephalus* C. Sillero-Zubiri, R. Sukumar, and A. Treves, " Living with Wildlife: The Roots of Conflict and the Solutions," in *Key Topics in Conservation Biology*, ed. D. MacDonald and K. Service (Oxford: Oxford University Press, 2007). that left dingoes (*Canis familiars dingo*) and red foxes (*Vulpes vulpes*) meso-predators to become the dominant livestock predators of Australia and Tasmania T.M. Newsome et al., "Top Predators Constrain Mesopredator Distributions," *Nature Communications* 8 (2017), L.R. Allen, and E.C. Sparkes, "The Effect of Dingo Control on Sheep and Beef Cattle in Queensland," *Journal of Applied Ecology* 38 (2001), C. Greentree et al., "Lamb Predation and Fox Control in South-Eastern Australia," *Journal of Applied Ecology* 37 (2000).. Or consider the expansion of range by coyotes *Canis latrans* in the wake of extermination of red and gray wolves across many U.S. States and Canadian provinces Joseph W. Hinton et al., "Effects of Anthropogenic Mortality on Critically Endangered Red Wolf Canis Rufus Breeding Pairs: Implications for Red Wolf Recovery," *Oryx* doi:10.1017/S0030605315000770 (2016), M. E. Gompper, "Top Carnivores in the Suburbs? Ecological and Conservation Issues Raised by Colonization of North-Eastern North America by Coyotes " *BioScience* 52, no. 2 (2002).. Those and other rmeso-predator interactions suggest that eradication of a large predator like the wolf will have varied effects on other animals including domestic ones Benjamin L. Allen et al., "Does Lethal Control of Top-Predators Release Mesopredators? A Re-Evaluation of Three Australian Case Studies," *Ecological Management & Restoration* 15, no. 3 (2016), doi: 10.1111/emr.12118, K. R. Crooks, and M.E. Soulé, "Mesopredator Release and Avifaunal Extinctions in a Fragmented System," *Nature* 400 (1999), M. Krofel et al., "Golden Jackal Expansion in Europe: A Case of Mesopredator Release Triggered by Continent-Wide Wolf Persecution? ," *Hystrix* 28, no. 1 (2007), https://dx.doi.org/10.4404/hystrix-28.1-11819, N. Nattrass et al., "Culling Recolonizing Mesopredators Increases Livestock Losses: Evidence from the South African Karoo," *Ambio* (Nov 2 2019), https://dx.doi.org/10.1007/s13280-019-01260-4, Newsome et al, L.R. Prugh et al., "The Rise of the Mesopredator," *Bioscience* 59, no. 9 (2009), L Minnie, A Gaylard, and GIH Kerley, "Compensatory Life-History Responses of a Mesopredator May Undermine Carnivore Management Efforts " *Journal of Applied Ecology* 53 (2016), https://dx.doi.org/10.1111/1365-2664.12581, LM Elbroch et al., "Reintroduced Wolves and Hunting Limit the Abundance of a Subordinate Apex Predator in a Multi-Use Landscape," *Proceedings of the Royal Society B* 287 (2020), http://dx.doi.org/10.1098/rspb.2020.2202..

[16] F. Newby, and R. Brown, "A New Approach to Predator Management in Montana," *Montana Wildlife* 8 (1958), G. C. Haber, "Biological, Conservation, and Ethical Implications of Exploiting and Controlling Wolves," *Conservation Biology* 10 (1996).

[17] Virtually all coyote predation on sheep is done by mated pairs with pups to feed, so most lethal management kills coyotes that have not killed and will not kill sheep F. F. Knowlton, E. M. Gese, and M. M. Jaeger, "Coyote Depredation Control: An Interface between Biology and Management," *Journal of Range Management* 52 (1999).; also see A.D. Wallach, D. Ramp, and A. J. O'Neill, "Cattle Mortality on a Predator-Friendly Station in Central Australia," *Journal of Mammalogy* 98, no. 1 (2017), DOI:10.1093/jmammal/gyw145. for counter-productive effects of killing dingoes on an Australian cattle ranch.

[18] William J. Ripple et al., "Status and Ecological Effects of the World's Largest Carnivores," *Science* 343, no. 6167 (2014), William J. Ripple et al., "Conserving the World's Megafauna and Biodiversity: The Fierce Urgency of Now," *Bioscience* 67, no. 3 (2017), W. J. Ripple et al., "World Scientists' Warning to Humanity: A Second Notice," *Bioscience* 67, no. 12 (2017).

increase hunting opportunity for hunters seeking wild ungulates such as elk and deer[19]. Yet, while the best scientific evidence shows that wolves are capable of reducing wild ungulate densities[20], wolves' ability to limit ungulate populations likely depends on other factors (e.g., winter severity).[21] Moreover, the most recent meta-analysis indicates that, counterintuitively, predator control can actually lead to reductions in wild ungulate abundance, juvenile survival, and adult survival.

Also, reports from all states with wolf populations indicate that opportunities to hunt wild ungulates have not been diminished by increased wolf populations[22]. Indeed, recent records from Idaho, Montana, and Wyoming indicate that the number of elk killed by hunters in recent years is stable to increasing in those three states, as are elk populations[23]. In Wisconsin, the thirty-year period 1980-2010 saw the state white-tailed deer population double from 800,000 to 1.6 million while the wolf population went from a handful to 700 wolves. Additionally, hunters took 200,000 deer in the 1980s to 500-600,000 in the 2000s[24]. Collectively, these data and the scientific studies suggest that efforts to kill wolves to increase wild ungulate abundance should be undertaken rarely and that the potential for opposite, counterproductive effects be considered. Such

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[19] Theberge, and Gauthier, A. Leopold, *Game Management* (New York: Scribner 1933 and Madison, WI: Unievrsity of Wisconsin Press 1986, 1933 reprinted 1986), A. Leopold, *A Sand County Almanac: And Sketches Here and There* (Oxford University Press, 1949).

[20] William J. Ripple and Robert L. Beschta. "Large predators limit herbivore densities in northern forest ecosystems." *European Journal of Wildlife Research* 58, no. 4 (2012): 733-742.

[21] Clark, and Hebblewhite.Peterson, Rolf O., John A. Vucetich, Joseph M. Bump, and Douglas W. Smith. "Trophic cascades in a multicausal world: Isle Royale and Yellowstone." Annual Review of Ecology, Evolution, and Systematics 45 (2014): 325-345.

[22]Clark & Hebblewhite (2021) concluded that "…it is unknown how effective predator removal is in decreasing predation on ungulates due to a lack of quantitative synthesis, despite the long history of implementation in North America… from 47 publications. We then conducted a meta-analysis to determine the overall effect size and factors which increased ungulate demography during predator removal. Lastly, we tested for evidence of publication bias and experimental rigour for these experiments… Focusing just on management removals, ungulate demographic responses increased only by 7.8% (95% PI = −32% to 72%)… The low and variable effectiveness of predator removal for ungulate populations might be linked to ungulates' slow life history and the compensatory mortality of carnivores on ungulates, though effects were stronger on endangered prey. We identified the experimental design factors that led to greater uncertainty in ungulate responses to predator removal, including lack of randomization, low replication and short temporal length. Lastly, we found evidence of publication bias, where experiments with poor rigour and negative effects (i.e. reduced ungulate demography following predator removal) were under-reported." Clark, T.J. and M. Hebblewhite, *Predator control may not increase ungulate populations in the future: A formal meta-analysis.* Journal of Applied Ecology, 2021. **58**(4): p. 812-824. https://doi.org/10.1111/1365-2664.13810.

[23] Data from Idaho, Montana and Wyoming were aggregated by Colorado State University Extension; a summary is available here: https://extension.colostate.edu/topic-areas/people-predators/wolves-big-game-and-hunting-8-001/

[24] Also from 1975-2020, the state deer population grew from 600,000 to 1.61 million in post-hunt (Source https://www.researchgate.net/figure/Wisconsin-Prehunt-and-Posthunt-Deer-Population-Estimates-and-Goal-1960-2010-Source_fig5_324135601) during a similar period the wolf population grew from zero to 1034 in late winter counts BUREAU OF WILDLIFE MANAGEMENT, *Wisconsin Gray Wolf Monitoring Report 15 April 2019 through 14 April 2020*, by J.E. Wiedenhoeft et al. (Madison, Wisconsin: Wisconsin Department of Natural Resources, 2020)..

predator control should only be implemented with scientific understanding and caution.

III. Increasing human safety

A final reason governments have given to kill wolves is to increase human safety[25]. Although wolves can and do occasionally attack people, such encounters are extremely rare. While attacks are often linked with rabies, predatory attacks also occur. However, as a recent review concluded, "…these have been associated with a special set of environmental circumstances (absence of wild prey, heavily modified landscapes, high density of humans engaged in vulnerable activities) that are no longer present…"[26] and consequently, "the risks of wolf attacks are currently very low", at least in North American Europe.[27]

In those rare cases where wolves exhibit behavior that has led to attacks on humans in the past (e.g., food-conditioning), it may be prudent to kill those specific animals that appear to be an
imminent threat to safety. However, there is simply no evidence that such behavior is widespread, nor is there a reason to believe that the aggressive killing programs proposed by U.S. states would lead to a meaningful reduction of risk. Indeed, given that zero people have been killed by wild wolves in the lower 48 states in the last 50 years[28], attempting to justify widespread killing based upon concern for safety appears disingenuous at best.

IV. Humans, wolves, and maximizing benefits minus costs of coexistence

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[25] During European history, wolf attacks were more common but were associated in a majority of incidents with rabies or starving wolves apparently J. D. C. Linnell, and T. Bjerke, "Frykten for Ulven. En Tverrfaglig Utredning. (Fear of Wolves: An Interdisciplinary Study.)," *Norsk Institutt for Naturforskning. Oppdragsmelding* 722 (2002).; see also case studies in VE; Sidorovich, LL; Tikhomirova, and B. Jedrzejewska, "Wolf Canis Lupus Numbers, Diet and Damage to Livestock in Relation to Hunting and Ungulate Abundance in Northeastern Belarus During 1990-2000," *Wildlife Biology* 9, no. 2 (2003), K. S. Rajpurohit, "Child Lifting Wolves in Hazaribagh, India," *Ambio* 28 (1998).. Other precipitating conditions may include food provisioning that habituates wild wolves to finding food near people M. E. McNay, "Wolf-Human Interactions in Alaska and Canada: A Review of the Case History," *Wildlife Society Bulletin* 30 (2002).. Given the recovery of many wild prey populations eaten by wolves and wider acknowledgment of the problem associated with supplemental feeding of wild carnivores, the conditions for wolf attacks on people have accordingly diminished. It's unclear to us if rabies or other zoonotic diseases have changed in incidence among wild wolves, but the bidirectional nature of transmission of some of these diseases suggests that we not only need study of incidence in wild wolves but also study of their incidences in domestic animals ranging in wild habitat, if we wish to control the transmission of disease to wolves near people.

[26] Linnell, John DC, and Julien Alleau. "Predators that kill humans: myth, reality, context and the politics of wolf attacks on people." In *Problematic wildlife*, pp. 357-371. Springer, Cham, 2016.

[27] Linnell, John DC, and Julien Alleau. "Predators that kill humans: myth, reality, context and the politics of wolf attacks on people." In *Problematic wildlife*, pp. 357-371. Springer, Cham, 2016.

[28] In a recent review, John Linnell and Colleagues identified just two fatal attacks in all of North America and Europe over the past 18 years (in Alaska and Canada). We stress, as they did, that wolves do attack and kill people, but fatal attacks are exceedingly rare. Linnell, John DC et al. "Wolf attacks on humans: an update for 2002–2020." NINA Report 1944. Norwegian Institute for Nature Research.

Public policy debate often focuses on population size without considering individuals[29]. Behavioral and cognitive scientists have shown that wolves are intelligent, cooperative individuals with personalities, complex social relationships, and cultures in their families and networks of packs[30]. Genetic evidence is increasingly pointing to small demographic units such as packs and even individuals as vital repositories of unique genetic information [31], challenging the idea that management should be concerned only with populations (as opposed to individual animals). This value judgment[32]--that wildlife management should not be concerned with individuals-- has deep roots in American game management, which has historically been focused on the production of game for hunting and trapping opportunities[33]. Recent research showing relative homogeneity (in terms of values) in state wildlife agencies[34] is likely promoting resistance to recognizing the importance of smaller demographic units. One means of reducing such bias is to make agency decision processes more inclusive—that is, involving individuals trained in different traditions, and representing broad interests[35].

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[29] F.J. Santiago-Avila, W. S. Lynn, and A. Treves, "Inappropriate Consideration of Animal Interests in Predator Management: Towards a Comprehensive Moral Code," in *Large Carnivore Conservation and Management: Human Dimensions and Governance*, ed. T. Hovardos (New York: Taylor & Francis, 2018), J. A. Vucetich, and M. P. Nelson, "Wolf Hunting and the Ethics of Predator Control," in *Political Science, Comparative Politics, Political Theory* (Oxford, UK: Oxford Handbooks Online, 2014), F.J. Santiago-Ávila, A. Treves, and W.S. (equal co-authors) Lynn, "Just Preservation, Trusteeship and Multispecies Justice," *Animal Sentience: Response to Commentary on Treves et al. on Just Preservation* 27, no. 27 (2020), https://dx.doi.org/10.51291/2377-7478.1665, F.J. Santiago-Avila, and W. S. Lynn, "Bridging Compassion and Justice in Conservation Ethics," *Biological Conservation* 248 (2020), A. Treves, F. Santiago-Ávila, and W.S. Lynn, "Just Preservation," *Biological Conservation* 229 (2018), https://dx.doi.org/10.1016/j.biocon.2018.11.018, A. Treves, and F. J. Santiago-Ávila, "Myths and Assumptions About Human-Wildlife Conflict and Coexistence," *Conservation Biology* 34, no. 4 (2020), https://dx.doi.org/10.1111/cobi.13472.

[30] B. Hare, and M. Tomasello, "Human-Like Social Skills in Dogs?," *TRENDS in Cognitive Sciences* 9, no. 9 (2005), Evan L. MacLean, and B. Hare, "Dogs Hijack the Human Bonding Pathway," *Science* 348, no. 6232 (2015), Sarah Marshall-Pescini et al., "Importance of a Species' Socioecology: Wolves Outperform Dogs in a Conspecific Cooperation Task," *Proceedings of the National Academy of Sciences* 114, no. 44 (2017), https://dx.doi.org/10.1073/pnas.1709027114, Santiago-Avila, Lynn, and Treves, in *Large Carnivore Conservation and Management: Human Dimensions and Governance*, Santiago-Ávila, Treves, and Lynn, Santiago-Avila, and Lynn.

[31] C. Carroll et al., "Wolf Delisting Challenges Demonstrate Need for an Improved Framework for Conserving Intraspecific Variation under the Endangered Species Act," *Bioscience* 71, no. 1 (2021), https://dx.doi.org/doi:10.1093/biosci/biaa125.

[32] A. Treves et al., "Transparency About Values and Assertions of Fact in Natural Resource Management," *Frontiers in Conservation Science: Human-Wildlife Dynamics* 2 (2021), https://dx.doi.org/10.3389/fcosc.2021.631998, F.J. santiago-Ávila, "Muddled Facts and Values: Positivism, Egoism, and Anthropocentrism in the Anthropocene," *Animals and Society* (2020), https://dx.doi.org/10.1163/15685306-bja10020.

[33] Leopold, Aldo. *Game Management.* Madison: University of Wisconsin Press, 1933.

[34] Manfredo, Michael J., Tara L. Teel, Andrew W. Don Carlos, Leeann Sullivan, Alan D. Bright, Alia M. Dietsch, H. Bruskotter, and David Fulton. "The changing sociocultural context of wildlife conservation." Conservation Biology 34, no. 6 (2020): 1549-1559.

[35] For example, Schulz-Hardt et al. (2002) show that more heterogenous groups can reduce biased information seeking, leading groups to consider a broader range of information. Schulz-Hardt, Stefan, Marc Jochims, and

Research documenting changes in social values suggests that management that ignores welfare outcomes for individual animals is likely to be increasingly out of step with U.S. values and expectations for wildlife management[36]. Moreover, the common conflation of animal rights and individual animal worth or individual intrinsic values is an error in defining one's terms that all scientists should work to rectify. Research shows that majorities of people appreciate wolves[37]. and that the benefits people appreciate from wildlife such as wolves are both financial and non-financial. That research also shows that the U.S. public prefers non-lethal methods to lethal ones, a trend intensifying over time.[38] Such views are under-represented in U.S. wildlife agencies currently[39].

Beyond these aesthetic and economic benefits, many studies suggest wolves can elicit broader ecological benefits through their effect on their prey, associated scavengers, and vegetation[40]. Though these benefits are likely dependent upon certain conditions, and therefore cannot be anticipated in all cases, research suggests wolves can enhance biodiversity by direct and indirect pathways begun by limiting ungulate herbivory or by altering the competition between prey species or their relative abundances. Although more research is needed, hundreds of studies in many systems indicate that top predators play such roles in their ecosystems[41].

Moreover, the ecological effects of wolves have the potential to benefit humans indirectly. Indeed, one study found where wolf packs hunt there are fewer deer-vehicle collisions[42].

Dieter Frey. "Productive conflict in group decision making: Genuine and contrived dissent as strategies to counteract biased information seeking." *Organizational Behavior and Human Decision Processes* 88, no. 2 (2002): 563-586.

[36] Manfredo, Michael J., Tara L. Teel, Richard EW Berl, H. T. Bruskotter, and Shinobu Kitayama. "Social value shift in favour of biodiversity conservation in the United States." *Nature Sustainability* 4, no. 4 (2021): 323-330.

[37] Bruskotter et al, M. J. Manfredo et al., "The Changing Sociocultural Context of Wildlife Conservation," *Conservation Biology* (Mar 4 2020), https://dx.doi.org/10.1111/cobi.13493.

[38] Reiter, D.K., M.W. Brunson, and R.H. Schmidt, "Public attitudes toward wildlife damage management and policy." Wildlife Society Bulletin, 1999. **27**(3):746-758.

[39] Clark, S.G. and C. Milloy, "The North American Model of Wildlife Conservation: An Analysis of Challenges and Adaptive Options", in *Large Carnivore Conservation: Integrating Science and Policy in the North American West*, S.G. Clark and M.B. Rutherford, Editors. 2014, The University of Chicago Press: Chicago. p. 289-324.

[40] Among ecological benefits wolves may contribute to reducing the incidence or transmission of zoonotic and wildlife diseases M.A. Wild et al., "The Role of Predation in Disease Control: A Comparison of Selective and Nonselective Removal on Prion Disease Dynamics in Deer," *Journal of Wildlife Diseases* 47, no. 1 (2011), E. Tanner et al., "Wolves Contribute to Disease Control in a Multi-Host System," *Scientific Reports* 7940 (2019)., improve scavenger diversity D. W. Smith, R. O. Peterson, and D. B. Houston, "Yellowstone after Wolves," *Bioscience* 53, no. 4 (2003). and reduce deer damage to vegetation Jean-Louis Martin, Simon Chamaillé-Jammes, and D. M. Waller, "Deer, Wolves, and People: Costs, Benefits and Challenges of Living Together," *Biological Reviews* 95, no. 3 (2020), https://dx.doi.org/10.1111/brv.12587..

[41] James A. Estes et al., "Trophic Downgrading of Planet Earth," *Science* 333, no. 6040 (2011).

[42] From Wisconsin, preliminary findings suggest that where wolf packs hunt, counties report fewer deer-vehicle collisions with associated protection of human life and associated financial savings totaling in the millions of dollars Jennifer L. Raynor, Corbett A. Grainger, and Dominic P. Parker, "Wolves Make Roadways Safer, Generating Large Economic Returns to Predator Conservation," *Proceedings of the National Academy of*

Several studies in Wisconsin show benefits of wolves for forest diversity and resilience, and others suggest that wolves may lower the risk of zoonotic disease.

Collectively, the literature documenting the broad risks and benefits associated with wolves makes it difficult for scientists to understand the fact claims used by states to justify the current aggressive efforts to kill wolves. The risks associated with wolves (i.e., attacks on livestock, pets or humans; diminished hunting opportunity) is likely to be exceedingly small. At the population level, these costs are inconsequential relative to other non-wolf risks to those human interests[43]. Although society must make the value judgment not scientists, it behooves s to point out that programs of lethal management of wolves are not cost-free so the use of public funds for wolf killing should be weighed against the benefits-costs of wolves protected from such programs and the need for public funds for other priorities.

Sciences 118, no. 22 (2021), https://dx.doi.org/https://doi.org/10.1073/pnas.2023251118.), rare understory plants fare better near the center of wolf pack territories Ramana Callan et al., "Recolonizing Wolves Trigger a Trophic Cascade in Wisconsin (USA)," *Journal of Ecology* 101 (2013), https://dx.doi.org/https://doi.org/10.1111/1365-2745.12095., and forests were more biodiverse in wildlife and plants, were more mature, had higher tree volumes, showed higher regeneration rates, and experienced fewer invasive species population explosions D. M. Waller, and N.J. Reo, "First Stewards: Ecological Outcomes of Forest and Wildlife Stewardship by Indigenous Peoples of Wisconsin, USA," *Ecology and Society* 23, no. 1 (2018), https://doi.org/10.5751/ES-09865-230145.. These recent results have not yet been formally compared to the economic costs long attributed to wolves, so we call for such a formal analysis by economists.

[43] For example, in Wisconsin, livestock losses to wolves affected <!% of farms and a tenth of one percent of livestock, while at the same time being highly predictable in space so one might attempt to prevent even those few losses Treves et al, A. Treves et al., "Forecasting Environmental Hazards and the Application of Risk Maps to Predator Attacks on Livestock," *Bioscience* 61 (2011), A. Treves, and M.F. Rabenhorst, "Risk Map for Wolf Threats to Livestock Still Predictive 5 Years after Construction," *PLos ONE* 12, no. 6 (2017), https://dx.doi.org/http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0180043.. Also, wolf-dog interactions suffer from reporting biases and notable instances where dog owners failed to take preventive precautions despite being informed of where the risks lay E.R. Olson et al., "Landscape Predictors of Wolf Attacks on Bear-Hunting Dogs in Wisconsin, USA," *Wildlife Research* 41 (2014), A. P. Wydeven et al., "Characteristics of Wolf Packs in Wisconsin: Identification of Traits Influencing Depredation," in *People and Predators: From Conflict to Coexistence*, ed. N. Fascione, A. Delach, and M. E. Smith (Washington, D. C.: Island Press, 2004).. The Wisconsin public expected domestic animal owners to follow best management practices and responsible husbandry, seemingly to avoid the moral hazards that can accompany compensation programs Naughton-Treves, Grossberg, and Treves, Treves et al.. Instead, compensation rules became more lax and more generous under political pressure from powerful interest groups Treves et al.. At the same time, in other regions, concerns rose about the accuracy of verification of wolf predation and the reliability of compensation programs suggest that an important remedy would be third-party scrutiny of methods used and data collected by agencies José V. López-Bao et al., "Building Public Trust in Compensation Programs through Accuracy Assessments of Damage Verification Protocols," *Biological Conservation* 213 (2017), M. Agarwala et al., "Paying for Wildlife. Compensation Policy and Practice for Wolves in Solapur, India and Wisconsin, USA," *Biological Conservation* 143, no. 12 (2010), Liivi Plumer et al., "Assessing the Roles of Wolves and Dogs in Livestock Predation and Suggestions for Mitigating Human-Wildlife Conflict and Conservation of Wolves," *Conservation Genetics* https://doi.org/10.1007/s10592-017-1045-4 (2018).. The increased scrutiny of compensation programs worldwide has led to population-wide economic analyses of wolf predation on livestock. Many studies show that other causes of morbidity and mortality in livestock such as disease, weather, and accidents are far more serious, especially in systems where owners have left livestock unsupervised for long periods J. D. C. Linnell, and H. Broseth, "Compensation for Large Carnivore Depredation of Domestic Sheep," *Carnivore Damage Prevention News* 6 (2003), Allen, and Sparkes, Wallach, Ramp, and O'Neill..

Moreover, it is not at all clear that aggressive killing of wolves is likely to significantly reduce these risks as we summarized in section II. Conversely, it is likely that the large-scale killing of hundreds of wolves as proposed by some states will substantially diminish the benefits associated with their presence as we summarized in the latter section.

V. Why are states aggressively killing wolves?

The scarcity of scientific evidence justifying lethal management of wolves leads to an obvious question: why are state governments promoting aggressive killing programs? Are these programs simply misguided attempts to promote the outcomes—increased safety, increased hunting opportunity, decreased livestock predation— that politicians have provided as justification? Or alternatively, are such justifications merely post-hoc rationalizations meant to make these programs more palatable to a largely skeptical, but uninformed public? And if so, what is it they truly seek to accomplish with such policy? Of course, we cannot know until policy-makers state their values and ethical reasoning more plainly.

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Bruskotter, J. T., E. Toman, S. A. Enzler, and R. H. Schmidt. "Are Gray Wolves Endangered in the Northern Rocky Mountains? A Role for Social Science in Endangered Species Listing Determinations." *Bioscience* 60, no. 11 (2010): 941-48.

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