Conservation Science and Practice
Open Access
A journal of the Society for Conservation Biology

Evaluating fact claims accompanying policies to liberalize the killing of wolves

Journal:	*Conservation Science and Practice*
Manuscript ID	CSP2-22-0319
Wiley - Manuscript type:	Review
Search Terms:	predator control, policy, lethal methods, non-lethal methods
Abstract:	Predators can support ecosystem health. And diversity disproportionate to their numbers. Nevertheless, several U.S. state governments recently initiated killing wolves non-selectively and in large numbers. Among the justifications, governments sometimes make four fact claims for policies that promote widespread wolf-killing. Wolf-killing would (1) increase human safety, (2) raise human tolerance for surviving wolves, (3) prevent livestock loss, and (4) increase wild ungulate populations. We reviewed the research into these claims and found scant evidence to support or refute claim (1). We found evidence against (2) from a dozen regions of the world and weak support from only three regions. We find evidence to suggest equivocal or no effects of wolf-killing on claims (3) and (4). Several studies that present the best evidence in their subfields find killing wolves likely led to counter-productive outcomes of intolerance, higher livestock losses, or reduced abundance of wild, adult ungulates. We also summarized reported benefits associated with wolves which might be lost if policies for widespread wolf-killing continue or spread. We proposed several hypotheses to explain the use of unsupported claims and to explain expansion of wolf-killing recently. The three, non-mutually exclusive hypotheses for unsupported fact claims refer to the reliability of trusted messengers, misinterpreting scientific uncertainty, and interest group politics. Finally, we summarize explanations for the politics behind wolf-killing and the potential harms of unsupported fact claims on democratic policy processes.

Evaluating fact claims accompanying policies to liberalize the killing of wolves

Abstract

Predators can support ecosystem health. And diversity disproportionate to their numbers. Nevertheless, several U.S. state governments recently initiated killing wolves non-selectively and in large numbers. Among the justifications, governments sometimes make four fact claims for policies that promote widespread wolf-killing. Wolf-killing would (1) increase human safety, (2) raise human tolerance for surviving wolves, (3) prevent livestock loss, and (4) increase wild ungulate populations. We reviewed the research into these claims and found scant evidence to support or refute claim (1). We found evidence against (2) from a dozen regions of the world and weak support from only three regions. We find evidence to suggest equivocal or no effects of wolf-killing on claims (3) and (4). Several studies that present the best evidence in their subfields find killing wolves likely led to counter-productive outcomes of intolerance, higher livestock losses, or reduced abundance of wild, adult ungulates. We also summarized reported benefits associated with wolves which might be lost if policies for widespread wolf-killing continue or spread. We proposed several hypotheses to explain the use of unsupported claims and to explain expansion of wolf-killing recently. The three, non-mutually exclusive hypotheses for unsupported fact claims refer to the reliability of trusted messengers, misinterpreting scientific uncertainty, and interest group politics. Finally, we summarize explanations for the politics behind wolf-killing and the potential harms of unsupported fact claims on democratic policy processes.

Introduction

Worldwide consensus among ecologists provides strong evidence that predators can support ecosystem health and diversity out of proportion to their numerical abundances (Estes et al. 2011; Peterson et al. 2014b; Ripple et al. 2014). For example, increasing evidence suggests that wolves (*Canis lupus*) play disproportionate roles in influencing deer behavioral ecology, forest diversity and ecology, and perhaps even disease ecology and deer-vehicle collisions (Hebblewhite et al. 2005; Wild et al. 2011; Callan et al. 2013; Waller & Reo 2018; Tanner et al. 2019; Raynor et al. 2021), withstanding an ongoing debate over the strength of wolves' effects in Yellowstone National Park. Perhaps related, the U.S. public has become more positive about wolves over the past half century (George et al. 2016; Slagle et al. 2017). Nevertheless, in 2021 some state governments began pursuing rapid efforts to reduce wolf populations through programs that included incentivized hunting (e.g., bounties) and liberalized (even unlimited) hunting, trapping, and hounding seasons. These policies differ from policies of the recent past permitting sustainable, recreational hunting and adaptive management that allowed carnivores to maintain and sometimes increase their populations (Brown 2008; Bruskotter et al. 2010; Bruskotter et al. 2011). For example, Wisconsin reduced its wolf population by >27% in <1 year and then proposed a second wolf-hunt in the same year (Treves et al. 2021b; Treves & Louchouarn 2022); Idaho, Montana, and Wyoming politicians articulated a goal to reduce their wolf populations even more; for Idaho by 90% https://www.npr.org/2021/05/21/999084965/new-idaho-law-calls-for-killing-90-of-states-wolves#:~:text=New%20Idaho%20Law%20Calls%20For,Of%20The%20State's%20Wolve

s%20%3A%20NPR&text=Press-
,New%20Idaho%20Law%20Calls%20For%20Killing%2090%25%20Of%20The%20State's,
different%20advice%20from%20wildlife%20 and enacted policies to help to reach that goal in 2021 and 2022 (Brown & Samuels 2021).

Here we address four fact claims commonly provided in policies for permitting or encouraging an increase in the legal killing of wolves and other large carnivores: (1) increasing human safety, (2) raising human tolerance for surviving wolves, (3) preventing livestock loss, and (4) increasing wild ungulate populations. We evaluate the fact claims (hereafter 'claims') by summarizing published scientific meta-analyses and systematic reviews in addition to reviewing a three dozen newer scientific studies on the social and ecological effects of these policies.

Increasing human safety

Wolves can, and in rare circumstances do, attack people (Linnell & Bjerke 2002; McNay 2002; Linnell et al. 2021). Thus, one justification governments provide for killing wolves has been to increase human safety. In Supplementary Materials 1, we present reports and statements by officials from the States of Michigan, Idaho, and Montana that show how claims about human safety have been used to raise fears or justify wolf-killing programs. Despite such warnings, zero humans have been killed by wolves in the Northern Rockies since their reintroduction and zero humans have been killed in the western Great Lakes region since written records have been kept. Wolves pose so little risk to people that aggressive killing programs proposed by U.S. states are almost certainly unable to reduce risk further as the following reviews showed.

Linnell and colleagues (2002, 2021) compiled documented reports of wolf attack on humans. The more recent study found evidence of 489 human victims of wolf attacks spanning 2002 to 2020 across the world, 26 of which were fatal, plus an equal number that were either too poorly documented to verify or “clearly” not caused by wolves, e.g., by dogs. Rabies explained 77% of the above attacks and 59% of fatalities, and the geographic distribution of attacks correlated with rabies incidence across Eurasia. These researchers classified 14% of attacks as “predatory,” which accounted for 36% of the fatalities. The remaining attacks were classified as “provoked/defensive”. In Europe and North America, they “found evidence for 12 attacks (with 14 victims), of which 2 (both in North America) were fatal across a period of 18 years” (Linnell et al. 2021, p.3). They conclude "Considering that there are close to 60.000 wolves in North America and 15.000 in Europe, all sharing space with hundreds of millions of people it is apparent that the risks associated with a wolf attack are above zero, but far too low to calculate.” p.3, (Linnell et al. 2021). 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. Indeed, Linnell and Alleau (2016, p.364), wrote that recent and historical predatory attacks on people in Europe “…are all associated with a very specific set of circumstances… [including]… landscapes with very fragmented habitat, low densities of wild prey, wolf dependence on livestock and anthropogenic foods and high human densities living poor rural lifestyles.” They conclude:

> “Despite the need to recognize that the potential for wolf attacks on people is greater than zero and management plans and procedures should take these into

account, it is still so small that it is impossible to calculate in a meaningful manner" (Linnell & Alleau 2016, p.365).

Occasionally, wolf attacks may be precipitated by incidents of accidental or purposeful conditioning of wild wolves, whereby wolves learn to associate humans with food or lose fear of people via habituation (McNay 2002). However, there is simply no evidence that such behavior is as widespread as it may have been before the 20th century (Linnell & Bjerke 2002). Finally, a rabid or threatening individual wolf might be seen as a hazard for human or domestic animals necessitating a law enforcement response. However, that situation bears no logical relationship to a policy that implements widespread wolf-killing to address human or domestic animal safety. The two North American fatalities were from Alaska, USA and Saskatchewan, Canada, rather than the jurisdictions whose governments we referenced above that have recently enacted policies of widespread wolf-killing. Even if one adds human injury cases to the tally, the odds that non-selective, public hunting, trapping, or hounding methods to kill wolves over wide areas will remove the rare wolf that attacks a human seem too low to calculate. Because our purpose is to evaluate the governmental fact claims (e.g., Supplementary Material 1) -- rather than the reality of fear of wolves or the possible rhetorical gains a politician might perceive from claiming to protect human safety -- we have to conclude that this fact claim is unsupported by evidence.

Increasing human tolerance for wolves

Governments often claim that killing wolves increases public tolerance (or decreases intolerance) for wolves and their conservation (Refsnider 2009; Bruskotter et al. 2013; Treves & Bruskotter 2014; Chapron & Treves 2017b; Epstein et al. 2019). Yet, reviews

of existing scientific evidence indicate that policies that liberalize the killing of wolves generally have not improved public tolerance for wolves (Treves & Bruskotter 2014). At most, some scientists claim a small demographic subpopulation reports they will tolerate wolves better if they can kill them (e.g., male residents of wolf range in Wisconsin with familiarity with hunting and Western livestock owners, respectively (Hogberg et al. 2015; Richardson 2022). That claim has rarely been tested objectively. The best evidence comes from the state of Wisconsin, where researchers assessed human attitudes using long-term, repeated measures (same individuals) before and after policy changes that liberalized wolf-killing or conversely, tightened protections for wolves. In total, three independent studies come from Wisconsin and Montana, (Supplementary Material 2). In the Wisconsin cases, tolerance for wolves declined after policies for killing wolves were liberalized (Naughton-Treves et al. 2003; Treves et al. 2013; Browne-Nuñez et al. ; Hogberg et al. 2015). In Montana, tolerance did not change pre/post the implementation of a hunt, but increased slightly (from baseline) several years later (see Supplementary Material 2).

Policies may fail to affect tolerance if they are perceived by those who are intolerant as insufficient for reducing the risks they associate with wolves, or there may be a lag between the time the policy is enacted and subsequent changes in tolerance. The Wisconsin study shows a 12-year lag during which time tolerance declined among Euroamericans in the face of such policies. These factors could explain both the growing intolerance witnessed in Wisconsin and the lack of change witnessed in the 2012 and 2018 studies in Montana.

A second way to examine the effect of policy on tolerance is to examine tolerance within a society across regions with different policies. To that end, Kaczensky and colleagues (Kaczensky et al. 2004) compared attitudes toward brown bears in a region of Slovenia where bears are protected and exhibit high conflicts with livestock to a region where bears are harvested as a game species and exhibit minimal conflict with livestock. They found no difference in attitudes toward bears across regions. Similarly, Bruskotter et al. (2018) found no differences in attitudes towards wolves across three regions of the U.S. with different wolf management policies and histories (Bruskotter et al. 2018). However, a follow-up study found lower levels of tolerance in areas with wolves among certain sub-groups (i.e., hunters, ranchers; Carlson et al. 2020).

Research suggests that tolerance for wolves is strongly affected by social group and cultural group identity (Naughton-Treves et al. 2003; Shelley et al. 2011; Lute & Gore 2014), both of which are influenced by powerful social norms that change more slowly than policies (Kinzig et al. 2013). Researchers have proposed a variety of mechanisms that may cause attitudes to change both at the individual and societal level. e.g., (Ericsson et al. 2007; Karlsson & Sjöström 2007; Heberlein & Ericsson 2008; Bruskotter et al. 2017). A full review of these mechanisms is beyond the scope if this essay. However, a few findings are worth summarizing: (i) At the societal level, the U.S. public at large has become substantially more positive towards wolves over the past half-century (George et al. 2016; Slagle et al. 2017); (ii) improving tolerance is strongly associated with changing social conditions (e.g., increased urbanization, education, income) (Bruskotter et al. 2017; Manfredo et al. 2019; Manfredo et al. 2020; Manfredo et al. 2021). While these findings raise intriguing hypotheses,

153 experimental studies would be useful to better understand causal mechanisms (Slagle et al.
154 2013). Collectively, however, existing evidence indicates that tolerance for wolves across
155 society in general is largey unaffected by management policies.

156 Other studies have assessed the effects of liberalized killing policies on tolerance
157 more directly by examining hazard and incidence rates of poaching (illegal killing of wolves).
158 In three populations of wolves, growth rates decreased, independent of the number of
159 wolves killed legally, following liberalized wolf-killing (Chapron & Treves 2016a, b, 2017a, b;
160 Louchouarn et al. 2021). Slower population growth was inferred to reflect a hidden cause of
161 mortality, called "cryptic poaching" (Liberg et al. 2012). Failure to account for cryptic
162 poaching – for example, discarding information on missing radio-collared wolves – can
163 obscure the dynamics of poaching and bias population models (Treves et al. 2017; Santiago-
164 Ávila et al. 2020b; Agan et al. 2021; Santiago-Ávila & Treves 2022); contra (Hill et al. 2022).
165 For example, research on radio-collared, gray wolves in Wisconsin, Mexican gray wolves in
166 Arizona and New Mexico, and red wolves (C. rufus) in North Carolina, all revealed patterns of
167 human poaching behavior in relation to policy (Santiago-Ávila et al. 2020a; Louchouarn et al.
168 2021; Santiago-Ávila et al. 2022; Santiago-Ávila & Treves 2022). In summary, research to
169 date has found that the ratio of reported poaching to cryptic poaching, and the sum of all
170 poaching, varies with 1) policy on hunting bears, deer, and coyotes; 2) federal policy on wolf
171 protection; and 3) the methods used to census wolves. In short, liberalizing wolf-killing did
172 not raise tolerance when tolerance was measured in terms of poaching rates. Therefore,
173 intention to poach is a behavioral measure of tolerance corroborating the attitudinal
174 measures of tolerance in the previous paragraphs. Moreover, the latest studies follow new

Open Science rules for registered reports that reduce publication biases (Sanders et al. 2017), following current standards of evidence accepted by the global scientific community.

The only credible peer-reviewed research that suggests that wolf policy can reduce poaching comes from two studies of gray wolves in Nordic countries (Suutarinen & Kojola 2017; Suutarinen & Kojola 2018; Liberg et al. 2020). However, the Scandinavian study has been questioned on statistical grounds for inappropriate survival analyses, and an unusual and possibly incorrect population-level models (Treves et al. 2020). The models ignored an apparent positive correlation between liberalizing killing and rising rates of illegal killing and disappearance, in favor of a claim about a negative correlation that did not seem to account for collinearity or autocorrelation (Treves et al. 2020). It also did not account for deaths of non-breeding wolves. Nor did it address findings 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 (Suutarinen & Kojola 2017; Suutarinen & Kojola 2018). Moreover, as Santiago-Ávila and Louchouarn pointed out, when the government preemptively removes wolves suspected of problems before they can be killed illegally, it's difficult to claim humans are exhibiting greater tolerance (Santiago-Ávila et al. 2020a; Louchouarn et al. 2021).

Collectively, virtually all studies of wolf-poaching support the hypothesis that governments send a signal to would-be poachers that wolves are low in value, or that the government needs the support of poachers to control wolf populations (Chapron & Treves 2016a). Most such policy signals seem to be unintentional but of late state governments have sent explicit signals to would-be poachers. For example, Idaho recently contributed

funds to pay bounties for dead wolves (https://www.kmvt.com/2021/10/14/idaho-fish-game-reimburse-hunters-wolf-kills/), which could inspire poachers in other states to draw on Idaho bounties. Also, in years past, the same agency defied federal regulations protecting wolves by announcing that they would no longer allow their own personnel to investigate reports of wolf poaching https://www.spokesman.com/stories/2010/oct/19/idaho-pulling-back-on-wolves/. Thus, we predict the recent state wolf policies have led and will continue to lower tolerance for wolves and increase wolf killing. We find no support for claim 2.

3. Killing wolves to prevent domestic animal losses

One of the long-standing reasons for humans to kill wolves and other threatening animals is to protect domestic animals, especially historically, before secure fencing or structures separated livestock from wild animals (Treves & Bonacic 2016). For example, the U.S. Department of Agriculture's Wildlife Services division was created largely to kill offending animals (Robinson 2005; USDA APHIS 2015), and local jurisdictions also do this in many countries (Bjorge & Gunson 1983; Fritts et al. 1992; Musiani et al. 2005; Epstein & Chapron 2018; Darpö 2020).

In the case of determining whether the lethal removal of wolves increases livestock protection, the best available evidence would come from before-and-after comparisons of interventions with random sampling (Khorozyan 2021) and other safeguards against research bias (Treves et al. 2016; Treves et al. 2019). No such studies exist for wolf-killing. To date, research on protecting livestock from wolves' ranges from before-and-after comparisons without randomization to lower standard, correlational

219 analyses that leave numerous potentially confounding variables uncontrolled (Treves et al.
220 2016; Eklund et al. 2017; van Eeden et al. 2018b; Treves et al. 2019). The four studies with
221 the highest (silver) standard for before-and-after comparisons of wolf-killing without
222 randomization drew somewhat variable conclusions. From Slovenia, (Krofel et al. 2011)
223 reanalyzed in (Treves et al. 2016) found no annual reduction in livestock losses after years
224 with high wolf-killing. Studying nine French sites with wolves, Grente (Grente 2021)
225 reported the majority showed no effect of killing hundreds of wolves, a minority showed
226 the desired decline in livestock losses and a smaller minority showed counter-productive
227 increases in livestock losseses. The two U.S. studies disagree on the effects of wolf-killing
228 on future livestock losses (Bradley et al. 2015; Santiago-Avila et al. 2018). Although many
229 Northern Rockies wildlife agencies rely on (Bradley et al. 2015), the study remains
230 irreproducible and methodologically biased towards finding an effect of wolf-killing, as
231 explained by (Santiago-Avila et al. 2018). Even after (Santiago-Avila et al. 2018)
232 corresponded repeatedly with the two lead authors to understand their methods, (Bradley
233 et al. 2015) could not explain how they conducted their analyses. By contrast, when making
234 those methods reproducible and adapting the methods to the data for Michigan's wolf
235 control program, Santiago-Avila (Santiago-Avila et al. 2018) found no significant benefit of
236 wolf-killing for Michigan livestock/ They also reported a non-significant tripling of risk for
237 cattle in neighboring townships after one or more wolves were killed at farms within
238 approximately 18 km. Therefore, the majority of studies suggest wolf-killing as practiced in
239 the USA, France, and Slovenia does not prevent future livestock losses reliably and can, in
240 fact, sometimes raise such losses. Therefore, the most rigorous and replicable research to

241 date found that targeted wolf-killing appeared effective for preventing recurrent livestock
242 killing in only a minority of cases. Furthermore, the risk of raising livestock losses appears in
243 numerous studies cited in those summarized above.

244 In every review thus far published on the effectiveness of lethal methods as a way
245 to protect livestock from predators in general, authors from nearly 30 countries report
246 occasional counter-productive effects resulting in higher livestock losses after predator-
247 killing (Miller et al. 2016; Eklund et al. 2017; Lennox et al. 2018; Moreira-Arce et al. 2018;
248 van Eeden et al. 2018a; van Eeden et al. 2018b; Khorozyan & Waltert 2019; Treves et al.
249 2019; Khorozyan & Waltert 2020). In contrast, the effectiveness of non-lethal methods and
250 the standards of evidence used for their study have been higher than for lethal methods
251 (Supplementary Material 3).

252 Although eradication of all predators would, of course, protect livestock from
253 predation (Breitenmoser 1998; Riley et al. 2004; Nilsen et al. 2007), less drastic killing can
254 produce variable and unpredictable results. Killing one carnivore may leave survivors more
255 prone to kill livestock thereafter. Survivors may be younger, less experienced or find
256 themselves competing for food with immigrants for long periods—any of these situations
257 may lead a hungry wolf to find the most predictable and vulnerable prey, often livestock,
258 e.g., reviewed in (Treves & Elbroch 2022). Removing apex carnivores may also result in
259 higher abundances of subordinate carnivores (Newby & Brown 1958; Crooks & Soulé 1999).
260 Those and other mesopredator interactions suggest that eradications of large predators like
261 the wolves may have varied effects on other animals including domestic ones (Krofel et al.
262 2007; Prugh et al. 2009; Allen et al. 2016; Minnie et al. 2016; Newsome et al. 2017; Nattrass

et al. 2019; Elbroch et al. 2020). For example, the eradication of the Tasmanian thylacine *Thylacinus cynocephalus*) seems to have left niche vacancies for the smaller dingoes (*Canis familiars dingo*) and red foxes (*Vulpes vulpes*) to become the dominant livestock predators of Australia and Tasmania (Greentree et al. 2000; Allen & Sparkes 2001; Sillero-Zubiri et al. 2007; Newsome et al. 2017). Or consider the expansion of range by coyotes (*C. latrans*) in the wake of extermination of red and gray wolves across many U.S. States and Canadian provinces (Gompper 2002; Hinton et al. 2016), and an associated increase in complaints of losses from sheep owners (Murray Berger 2006).

4. Killing wolves to improve wild ungulate abundances

Relatedly, governments have for a century or more justified killing wolves as a means to increase hunting opportunity for ungulates, such as elk and deer (Leopold 1933 reprinted 1986, 1949; Harbo & Dean 1983; Theberge & Gauthier 1985). Wolves are capable of reducing wild ungulate populations (Ripple & Beschta 2012); however the effect of wolves on ungulates depends on other factors, such as ungulate vulnerability driven by winter severity (Vucetich & Peterson 2009; Peterson et al. 2014a), local primary productivity (Melis et al. 2009), the abundance of ungulates relative to their carrying capacity (Ballard et al. 2001) , the diversity of the local carnivore guild and potential for multiple ungulate predators (Griffin et al. 2011) and the abundance of alternative prey (i.e. apparent competition; (Wittmer et al. 2005). A rigorous, recent meta-analysis of the outcomes of carnivore removal on ungulate populations estimated that predator removals resulted in increased juvenile survival and recruitment, but equivocal effects on ungulate abundance, which should be the

metric that determines success if in fact management objectives are to increase herd size or hunting opportunity (Clark & Hebblewhite 2021). Also, it was not uncommon for counter-productive effects lowering ungulate abundance after predator-killing (Clark & Hebblewhite 2021). In a meta-analysis of female elk survival from western North America, (Brodie et al. 2013) concluded that the best way to increase ungulate abundance was instead to decrease human harvest rather than predators.

The exceptions to these general patterns are predator effects on small ungulate populations. Wolf predation can impact rare ungulates via apparent competition. However, the underlying circumstances that lead to apparent competition are generally created by anthropogenic influences on ecosystems (Wittmer et al. 2005). Even in cases of rare ungulates, however, intensive wolf killing must be maintained to increase ungulate population growth rates. For example, (Hervieux et al. 2014) reported that killing 841 wolves over 7 years, which equated to a 45% reduction in mid-winter wolf abundance, was sufficient to increase population growth rates of endangered woodland caribou in their study area, but insufficient to increase caribou abundance.

Reports from all U.S. states with wolf populations indicate that opportunities to hunt wild ungulates have not been diminished statewide by increased wolf populations. 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. Data from Idaho, Montana and Wyoming were summarized here: https://extension.colostate.edu/topic-areas/people-

predators/wolves-big-game-and-hunting-8-001/. In Wisconsin, the forty-five-year period from 1975-2020 saw the state deer population grow from 600,000 to 1.61 million (https://www.researchgate.net/figure/Wisconsin-Prehunt-and-Posthunt-Deer-Population-Estimates-and-Goal-1960-2010-Source_fig5_324135601), while the wolf population grew from zero to 1034 in late winter counts (Wiedenhoeft et al. 2020). Also, hunters took 200,000 deer in the 1980s as compared to 500-600,000 in the 2000s (https://www.researchgate.net/figure/Wisconsin-Prehunt-and-Posthunt-Deer-Population-Estimates-and-Goal-1960-2010-Source_fig5_324135601). Collectively, these data and the scientific studies suggest that the positive effects of killing wolves on wild ungulate abundance are negligible.

A mismatch between goals of wolf-killing and approaches taken

Three of the four fact claims we have reviewed seem most commonly to be motivated by negative interactions with individual wolves or wolf packs, rather than populations of wolves. The exception may be the fourth relating to wild ungulates. Therefore, one should address policy interventions for three of the four claims in the most efficient and effective way to mitigate the costs and risks posed by individual wolves. This logic suggests that policies for targeted removal should be improved and tailored to specific situations, rather than liberalized killing aimed at reducing the entire wolf population across wide areas. A return to policies and studies of targeted removal of confirmed culprits with a record of posing threats to humans and domestic animals seems reasonable. This strategy has long been understood as the most effective strategy for coyotes (Knowlton et al. 1999),

329 and there is no scientific reason not to expect the same for wolves. Our inference is
330 especially important in instances when killing succeeds in reducing the wolf population, but
331 misses the individual wolves responsible for livestock loss or human safety concerns; in such
332 situations, the conflicts driving claims 1-3 are likely to continue unabated and calls for more
333 killing may persist or escalate.

334 Liberalized killing to reduce the wolf population is, at first glance, possibly a better
335 match for increasing ungulate populations at large scales. Nevertheless, reducing wolves to
336 increase ungulate abundance rarely works for any but the smallest ungulate populations for
337 the reasons we describe in the previous section, and because ungulate abundance is
338 primarily explained by weather and primary productivity (White 2008), rather than apex
339 carnivore abundances. Furthermore, any benefit of wolf-killing (to ungulate hunters) should
340 be weighed against the benefits of maintaining or increasing wolf abundance.

341

342 The benefits and costs of coexistence between humans and wolves

343 Ideal public policy maximizes the benefits (minus associated costs of) management
344 interventions. Thus, having considered the various risks (i.e., to human safety, livestock, and
345 wild ungulates), we find it appropriate to detail potential benefits to humans associated with
346 wolves. In general, research shows that majorities of people appreciate wolves and other
347 carnivores, e.g., cougars, coyotes (Bruskotter et al. 2018; Manfredo et al. 2020), and that
348 people report both financial and non-financial benefits of wildlife (Kellert 1985; Williams et
349 al. 2002; Naughton-Treves et al. 2003). One subpopulation of wolves in Yellowstone
350 National Park, for example, has produced net financial benefits beyond the boundaries of

the park and revenues that far exceeded the costs of reintroduction (Duffield & Neher 1996; Duffield et al. 2008). Findings from Wisconsin suggest that counties hosting one or more packs of wolves report fewer deer-vehicle collisions and reduced human injuries and fatalities, saving millions of dollars (Raynor et al. 2021). That result grew out of an awareness that wolves were changing the behavior of deer and elk and some evidence of broader ecosystem effects of wolves.

Many studies suggest wolves can also benefit ecosystems through their effects on their prey and associated ecological communities. For example, wolves may reduce the incidence or transmission of zoonotic and wildlife diseases (Wild et al. 2011; Tanner et al. 2019), increase scavenger diversity (Smith et al. 2003), and reduce deer damage to vegetation (Martin et al. 2020). Regarding the latter, rare understory plants fared better near the center of wolf pack territories in Wisconsin (Callan et al. 2013), and forests were more biodiverse, more mature, had higher tree volumes and regeneration rates, and resisted non-native plant invasions in the presence of wolves (Waller & Reo 2018). Though such effects may vary with conditions, research suggests wolves enhance biodiversity via direct and indirect pathways that begin with limiting ungulate herbivory, or by altering the competition between prey species. A persistent debate about Yellowstone's wolves notwithstanding, scientific consensus holds that top predators generally play such roles (Estes et al. 2011; LaBarge et al. 2022).

Killing wolves is not cost-free, and so we need to weigh the use of public funds for wolf killing against the benefits minus the costs of maintaining wolves, or expanding their ranges. It is not at all clear that aggressive killing of wolves will significantly reduce the real

or perceived risks associated with living with wolves. Conversely, it is likely that the large-scale killing of wolves as proposed by some governments will substantially diminish the benefits associated with their presence. We highlight the need for formal comparisons between the benefits associated with apex carnivores and the economic costs long attributed to wolves (Gilbert et al. 2021),to set policies that optimize wolves' beneficial contributions to ecosystems and human communities.

Why do governments cite weak or unsupported claims for aggressively killing wolves?

The scarcity of scientific evidence for the claims made to justify killing wolves leads to an obvious question: why are governments making such claims? To begin with, three non-exclusive explanations seem plausible.

1. Policy makers believe their wolf-killing claims are true because of the source of their information or their existing belief system. The trusted messenger theory of communication sciences predicts that messages are believed or embraced more quickly, and that they shape behavior more effectively when delivered by a trusted messenger (Dunwoody 2007; Kinzig et al. 2013). Further, people tend to filter information and retain what supports their existing belief and value systems (Kinzig et al. 2013; Bruskotter et al. 2016; Antonelli & Perrigo 2018; Byerly et al. 2018; Kinka & Young 2019). That propensity has led at times to predator management that conflates value-based decisions with evidence-informed decisions (Mitchell et al. 2018; Koot et al. 2020; Santiago-Ávila 2020; Treves et al. 2021a). If a trusted messenger delivers inaccurate information, policy-makers may find themselves weighing apparently contradictory science and then selecting that

395 which they trust more based on the identity of the messengers or their inherent biases
396 and beliefs on the subject.

397 2. Policy-makers advancing wolf-killing with unsupported claims may not know
398 the scientific evidence or may think the science is unclear enough to support their claims.
399 We view this as unlikely because peer-reviewed scientific evidence has been presented
400 repeatedly to debunk the claims via public comments, litigation, and official federal peer
401 reviews, since 2013 (Bruskotter et al. 2013; Treves et al. 2021a). For example, the litigation
402 and federal agency peer reviews have addressed some or all of the claims surrounding
403 wolf protection and wolf-killing in Wisconsin, the northern Rockies, and nationwide (Atkins
404 2019) and (Humane Society of the U.S. 2014. 2017, 1:13-cv-00186-BAH Doc 52, Western
405 Watersheds Project 2018, 1:17-cv-00206-BLW Doc 22-3). Furthermore, the suggestion that
406 scientific uncertainty about the four claims among scientists left policy with equivocal
407 recommendations, has a prerequisite of transparent debate between experts with diverse
408 views. We know of no such policy review or debate. In general, hunting plans in North
409 America lack the hallmarks of independent review and transparency, as revealed by a close
410 reading of 666 such plans and a survey of the agency staff responsible for writing and
411 carrying out such plans (Artelle et al. 2018a; Artelle et al. 2018b).

412 3. Policy-makers may know their claims are unlikely to be true, and these policies
413 instead reflect internal values or external pressures acting on policy decisions, e.g.,
414 (Chapron & Lopez-Bao 2014; Darimont et al. 2018). This possibility finds circumstantial
415 support in several other claims made by current governments to justify wolf-killing. One
416 such value-based claim is that hunters, trappers, and hound-hunters should be given

417 additional hunting opportunities, or that the reduction in the number of hunters requires
418 agencies to create unlimited harvest to meet objectives previously achievable with limited
419 take and more hunters. The claim is that governments are creating more opportunities for
420 these people via aggressive wolf policies. Although such justifications are not entirely in
421 the domain of facts that scientists can evaluate, they are dubious on their face because of
422 a logical flaw. Reducing carnivore abundance comes at the expense of carnivore hunters,
423 who lose hunting opportunities over the long term (Mitchell et al. 2018). A more plausible
424 political pressure for widespread wolf-killing comes from electoral politics. Recent
425 research documenting the relationship between voting for the reintroduction of wolves (a
426 Colorado ballot measure in the 2020 election) and presidential voting may provide insights
427 into the internal and external pressures that may be acting on policy makers and their
428 constituents. That study found the strongest predictor of voting for wolf restoration at the
429 precinct level was the proportion that voted for the Democratic candidate for president
430 (Ditmer et al. 2022). Specifically, as Democratic voting increased, support for wolf
431 restoration increased. Similarly, other research shows that political party affiliation and
432 socio-political identity were strong predictors of attitudes toward carnivore policies in
433 other jurisdictions (Hamilton et al. 2020; van Eeden et al. 2021), however, see (Carlson et
434 al. 2020).

435 Collectively, these data suggest that the general issue of how to manage wolves
436 has become politicized precisely at a time when the U.S. electorate is extremely polarized
437 as well (McCoy et al. 2018). In such environments, the wolf policies pursued by
438 governments may not serve any traditional wildlife management purpose. Wolf-killing

policies align with the positions of interest groups that are themselves aligned with a conservative agenda (e.g., agricultural groups, hunting groups (Clark & Milloy 2014)). Because these groups traditionally hold great sway with wildlife policy-making bodies, there is little risk for decision-makers in supporting such policies, e.g.,(Chapron & Lopez-Bao 2014). In contrast, pursuit of policies viewed as supportive of wolves may carry substantial risk for policy-makers, wildlife commissions and wildlife managers. Indeed, research in psychology has long shown how pressure to conform to group settings can powerfully influence decision-makers (Asch 1951; Asch 1952; Asch 1956). Moreover, the dynamics of multiple individual decision-makers acting in concert may complicate the policy analysis.

Regardless of the underlying causal explanation for why governments are using unsupported claims, the effect is corrosive on a constitutional democracy like that of the U.S., particularly one whose environmental assets are held in trust for current and future generations (Geer 1896, 161 U.S. 519, Hughes 1979, 441 U.S. 322, U.S. 1989, 710 F. Supp. 1286). Reliance on unlikely or false factual claims undermines both public policy and the authorities from which it emanates. As public trustees for wildlife under U.S. common law and sometimes statute, elected and appointed government officials have a professional, legal, and ethical duty to avoid unlikely or false claims about public interests. Such conduct misleads the sovereign public.

References

461 Agan SW, Treves A, Willey EL. 2021. Estimating poaching risk for the critically endangered
462 wild red wolf (Canis rufus). PLoS One **16**:e0244261.
463 Allen BL, Geoff Lundie-Jenkins, Neil D. Burrows, Richard M. Engeman, Peter J.S. Fleming,
464 Leung LK-P. 2016. Does lethal control of top-predators release mesopredators? A re-
465 evaluation of three Australian case studies. Ecological Management & Restoration
466 **15**:193-195.
467 Allen LR, Sparkes EC. 2001. The effect of dingo control on sheep and beef cattle in
468 Queensland. Journal of Applied Ecology **38**:76-87.
469 Antonelli A, Perrigo A. 2018. The pitfalls of taking science to the public. Science **359**:283.
470 Artelle KA, Reynolds JD, A. T, Walsh JC, C. PP, Darimont CT. 2018a. Distinguishing science
471 from “fact by assertion” in natural resource management. Science Advances (eLetter)
472 **4**:eaao0167.
473 Artelle KA, Reynolds JD, A. T, Walsh JC, Paquet PC, Darimont CT. 2018b. Hallmarks of science
474 missing from North American wildlife management. Science Advances **4**:eaao0167.
475 Asch SE. 1951. Effects of group pressure upon the modification and distortion of judgment in
476 Guetzkow H, editor. Groups, leadership and men. Carnegie Press., Pittsburgh, PA.
477 Asch SE. 1952. Group forces in the modification and distortion of judgments. Pages 450–501
478 in Asch SE, editor. Social psychology. Prentice-Hall, Inc., New York.
479 Asch SE. 1956. Studies of independence and conformity: I. A minority of one against a
480 unanimous majority. Psychological Monographs: General and Applied **70**:1–70.

Atkins. 2019. Summary Report of Independent Peer Reviews for the U.S. Fish & Wildlife Service Gray Wolf Delisting Review. Atkins, https://www.fws.gov/media/summary-report-independent-peer-reviews-gray-wolf-delisting-review.

Ballard WB, Lutz D, Keegan TW, Carpenter LH, deVos Jr. JC. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin **29**:99–115.

Bjorge RR, Gunson JR. 1983. Wolf predation of cattle on the Simonette River pastures in northwestern Alberta. Pages 106-111 in Carbyn LN, editor. Wolves in Canada and Alaska: their status, biology and management. Canadian Wildlife Service, Edmonton.

Bradley EH, Robinson HS, Bangs EE, Kunkel K, Jimenez MD, Gude JA, Grimm T. 2015. Effects of Wolf Removal on Livestock Depredation Recurrence and Wolf Recovery in Montana, Idaho, and Wyoming. Journal of Wildlife Management **79**:1337–1346.

Breitenmoser U. 1998. Large predators in the Alps: The fall and rise of man's competitors. Biological Conservation **83**:279-289.

Brodie J, et al. 2013. Relative influence of human harvest, carnivores, and weather on adult female elk survival across eastern North America. Journal of Applied Ecology **50**:295–305.

Brown M. 2008. Three states seek to retain control of wolves. Associated Press.

Brown M, Samuels I. 2021. 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.

503 Browne-Nuñez C, Treves A, Macfarland D, Voyles Z, Turng C. 2015. Tolerance of wolves in
504 Wisconsin: A mixed-methods examination of policy effects on attitudes and
505 behavioral inclinations. Biological Conservation **189**:59–71.
506 Bruskotter JT, Enzler S, Treves A. 2011. Rescuing wolves from politics: wildlife as a public
507 trust resource. Science **333**:1828-1829.
508 Bruskotter JT, J, . A. Vucetich, M. J. Manfredo, G. R. Karns, C. Wolf K, N. H. Carter, J. V. López-
509 Bao, G. Chapron, Gehrt SD, Ripple WJ. 2017. Modernization, Risk, and Conservation
510 of the World's Largest Carnivores. BioScience **67**:646-655.
511 Bruskotter JT, Toman E, Enzler SA, Schmid RH. 2010. Gray wolves not out of the woods yet.
512 Science **327**:30.
513 Bruskotter JT, Vucetich JA, Enzler S, Treves A, Nelson MP. 2013. Removing protections for
514 wolves and the future of the U.S. Endangered Species Act (1973) Conservation
515 Letters **7**:401-407.
516 Bruskotter JT, Vucetich JA, Slagle KM, Berardo R, Singh AS, Wilson RS. 2018. Support for the
517 U.S. Endangered Species Act over time and space: Controversial species do not
518 weaken public support for protective legislation. Conservation Letters**;e12595**:1-7.
519 Bruskotter JT, Vucetich JA, Wilson RS. 2016. Of bears and biases: scientific judgment and the
520 fate of Yellowstone's grizzlies. The Conversation **June 21, 2016**.
521 Byerly H, Balmford A, Ferraro PJ, Wagner CH, Palchak E, Polasky S, Ricketts TH, Schwartz AJ,
522 Fisher B. 2018. Nudging pro-environmental behavior: evidence and opportunities.
523 Frontiers in Ecology and the Environment:doi:10.1002/fee.1777.

524 Callan R, Nibbelink NP, Rooney TP, Wiedenhoeft JE, Wydeven A. 2013. Recolonizing wolves
525 trigger a trophic cascade in Wisconsin (USA). Journal of Ecology **101**:837–845
526 Carlson SC, Dietsch AM, K.M. S, J.T. B. 2020. The VIPs of Wolf Conservation: How Values,
527 Identity, and Place Shape Attitudes Toward Wolves in the United States. Frontiers in
528 Ecology and Evolution **8**:6.
529 Chapron G, Lopez-Bao J. 2014. Conserving Carnivores: Politics in Play. Science **343**:1199-
530 1200.
531 Chapron G, Treves A. 2016a. Blood does not buy goodwill: allowing culling increases
532 poaching of a large carnivore. Proceedings of the Royal Society B **283**:20152939.
533 Chapron G, Treves A. 2016b. Correction to 'Blood does not buy goodwill: allowing culling
534 increases poaching of a large carnivore'. Proceedings of the Royal Society B **Volume**
535 **283**:20162577.
536 Chapron G, Treves A. 2017a. Reply to comment by Pepin et al. 2017. Proceedings of the
537 Royal Society B **2016257**:20162571.
538 Chapron G, Treves A. 2017b. Reply to comments by Olson et al. 2017 and Stien 2017.
539 Proceedings of the Royal Society B **284**:20171743.
540 Clark SG, Milloy C. 2014. The North American Model of Wildlife Conservation: An Analysis of
541 Challenges and Adaptive Options. Pages 289-324 in Clark SG, and Rutherford MB,
542 editors. Large Carnivore Conservation: Integrating Science and Policy in the North
543 American West. The University of Chicago Press, Chicago.
544 Clark TJ, Hebblewhite M. 2021. Predator control may not increase ungulate populations in
545 the future: A formal meta-analysis. Journal of Applied Ecology **58**:812-824.

546 Crooks KR, Soulé ME. 1999. Mesopredator release and avifaunal extinctions in a fragmented
547 system. Nature **400**:563-566.
548 Darimont CT, Paquet PC, Treves A, Artelle KA, Chapron G. 2018. Political populations of large
549 carnivores. Conservation Biology **32**:747–749.
550 Darpö J. 2020. The Last Say? Comment on cjeus Judgement in the Tapiola Case (C-674/17).
551 Journal for European Environmental & Planning Law **17**:117-130.
552 Ditmer MA, Niemiec RM, Wittemyer G, Crooks KR. 2022. ocio-ecological drivers of public
553 conservation voting: restoring gray wolves to Colorado, USA. Ecological Applications,
554 e2532. . ocio-ecological drivers of public conservation voting: restoring gray wolves
555 to Colorado, USA:e2532. .
556 Duffield JW, Neher CJ. 1996. Economics of wolf recovery in Yellowstone National Park.
557 Transactions of the North American Wildlife and Natural Resources Conference
558 **61**:285-292.
559 Duffield JW, Neher CJ, Patterson DA. 2008. Wolf recovery in Yellowstone: Park visitor
560 attitudes, expenditures, and economic impacts. George Wright Forum **25**:13-19.
561 Dunwoody S. 2007. The challenge of trying to make a difference using media messages
562 Pages 89-104 in Moser SC, and Dilling L, editors. Creating a climate for change.
563 Cambridge University Press, Cambridge.
564 Eklund A, López-Bao JV, Tourani M, Chapron G, Frank J. 2017. Limited evidence on the
565 effectiveness of interventions to reduce livestock predation by large carnivores.
566 Scientific Reports **7**:2097 | DOI:2010.1038/s41598-41017-02323-w.

567 Elbroch L, Ferguson J, Quigley H, Craighead D, Thompson D, Wittmer H. 2020. Reintroduced
568 wolves and hunting limit the abundance of a subordinate apex predator in a multi-
569 use landscape. Proceedings of the Royal Society B **287**:e20202202.
570 Epstein Y, Chapron G. 2018. The Hunting of Strictly Protected Species: The Tapiola Case and
571 the Limits of Derogation under Article 16 of the Habitats Directive. European Energy
572 and Environmental Law Review **June**:78-87.
573 Epstein Y, Lopez-Bao J, Trouwborst A, Chapron G. 2019. EU Court: Science must justify future
574 hunting. Science **366**:961.
575 Ericsson G, Bostedt G, Kindberg J. 2007. Wolves as a symbol of people's willingness to pay
576 for large carnivore conservation. Society and Natural Resources **21**:294-309.
577 Estes JA, et al. 2011. Trophic Downgrading of Planet Earth. Science **333**:301-306.
578 Fritts SH, Paul WJ, Mech LD, Scott DP 1992. Trends and management of wolf-livestock
579 conflicts in Minnesota. US Fish and Wildlife Service, Resource Publication 181,
580 Washington, DC.
581 George KA, Slagle KM, Wilson RS, Moeller SJ, Bruskotter JT. 2016. Changes in attitudes
582 toward animals in the United States from 1978 to 2014. Biological Conservation
583 **201**:237–242.
584 Gilbert S, Carter N, Naidoo R. 2021. Predation services: Quantifying societal effects of
585 predators and their prey Frontiers in Ecology and the Environment **19**:292– 299.
586 Gompper ME. 2002. Top carnivores in the suburbs? Ecological and conservation issues raised
587 by colonization of North-eastern North America by coyotes BioScience **52**:185-190.

588 Greentree C, Saunders G, McLeod L, Hone J. 2000. Lamb predation and fox control in south-
589 eastern Australia. Journal of Applied Ecology **37**:935-943.
590 Grente O. 2021. résentation des objectifs et de la méthodologie de la thèse sur l'efficacité
591 des tirs de loup et la gestion adaptative du loup, menée conjointement par l'ONCFS
592 et le CEFE. OFB, Direction de la recherche et de l'appui scientifique, Unité Prédateurs,
593 animaux déprédateurs et exotiques, Équipe Loup et Lynx, Gières, France.
594 Griffin KA, et al. 2011. Neonatal mortality of elk driven by climate, predator phenology and
595 predator community composition. Journal of Animal Ecology **80**:1246–1257.
596 Hamilton LC, J. E. Lambert, L. A. Lawhon, J. Salerno, Hartter J. 2020. Wolves are back:
597 Sociopolitical identity and opinions on management of Canis lupus. Conservation
598 Scienceand Practice **2**:e213.
599 Harbo SJ, jr., Dean FC. 1983. Historical and current perspectives on wolf management in
600 Alaska. Pages 51-64 in Carbyn LN, editor. Wolves in Canada and Alaska: Their Status,
601 Biology and Management. Canadian Wildlife Service, Edmonton.
602 Hebblewhite M, White CA, Nietvelt CG, McKenzie JA, Hurd TE, Fryxell JM, Bayley SE, Paquet
603 PC. 2005. Human activity mediates a trophic cascade caused by wolves. Ecology
604 **86**:2135-2144.
605 Heberlein TA, Ericsson G. 2008. Public attitudes and the future of wolves Canis lupus in
606 Sweden. Wildlife Biology **14**:391-394.
607 Hervieux D, Hebblewhite M, Stepnisky D, Bacon M, Boutin S. 2014. Managing wolves (Canis
608 lupus) to recover threatened woodland caribou (Rangifer tarandus caribou) in
609 Alberta. Canadian Journal of Zoology **93**:245–247.

610 Hill, Jacob E., et al. 2022. Quantifying anthropogenic wolf mortality in relation to hunting
611 regulations and landscape attributes across North America.
612 Hinton JW, Brzeski KE, Rabon DR, Chamberlain MJ. 2016. Effects of anthropogenic mortality
613 on critically endangered red wolf Canis rufus breeding pairs: implications for red wolf
614 recovery. Oryx **doi:10.1017/S0030605315000770**.
615 Hogberg J, Treves A, Shaw B, Naughton-Treves L. 2015. Changes in attitudes toward wolves
616 before and after an inaugural public hunting and trapping season: early evidence
617 from Wisconsin's wolf range. Environmental Conservation **43**:45-55.
618 Kaczensky P, Blazic M, Gossow H. 2004. Public attitudes towards brown bears (Ursus arctos)
619 in Slovenia. Biological Conservation **118**:661–674.
620 Karlsson K, Sjöström M. 2007. Human attitudes towards wolves, a matter of distance.
621 Biological Conservation **137**:610-616.
622 Kellert SR. 1985. Public perceptions of predators, particularly the wolf and coyote. Biological
623 Conservation **31**:167-189.
624 Khorozyan I. 2021. Defining practical and robust study designs for interventions targeted at
625 terrestrial mammalian predators. Conservation Biology **in press**:1–11.
626 Khorozyan I, Waltert M. 2019. How long do anti-predator interventions remain effective?
627 Patterns, thresholds and uncertainty. Royal Society Open Science **6**.
628 Khorozyan I, Waltert M. 2020. Variation and conservation implications of the effectiveness
629 of anti-bear interventions. Scientific Reports **10,**:15341.

630 Kinka D, Young JK. 2019. The tail wagging the dog: positive attitude towards livestock
631 guarding dogs do not mitigate pastoralists' opinions of wolves or grizzly bears.
632 Palgrave Communications **5**.
633 Kinzig AP, et al. 2013. Social Norms and Global Environmental Challenges: The Complex
634 Interaction of Behaviors, Values, and Policy. Bioscience **63**:164–175.
635 Knowlton FF, Gese EM, Jaeger MM. 1999. Coyote depredation control: An interface between
636 biology and management. Journal of Range Management **52**:398-412.
637 Koot S, Hebinck P, Sullivan S. 2020. Science for Success—A Conflict of Interest? Researcher
638 Position and Reflexivity in Socio-Ecological Research for CBNRM in Namibia. Society &
639 Natural Resources:1-18.
640 Krofel M, Černe R, Jerina K. 2011. Effectiveness of wolf (Canis lupus) culling as a measure to
641 reduce livestock depredations. Acta Silvae et Ligni **95**:11-22.
642 Krofel M, Giannatos G, Ćirović D, Stoyanov S, Newsome TM. 2007. Golden jackal expansion
643 in Europe: a case of mesopredator release triggered by continent-wide wolf
644 persecution? . Hystrix **28**:9-15.
645 LaBarge L, Evans M, Miller J, Cannataro G, Hunt C, Flemming E, Elbroch L. 2022. Pumas as
646 ecological brokers: a review of their biotic relationships. Mammal Review. .
647 Lennox RJ, Gallagher AJ, Ritchie EG, Cooke SJ. 2018. Evaluating the efficacy of predator
648 removal in a conflict-prone world. Biological Conservation **224**:277-289.
649 Leopold A 1933 reprinted 1986. Game Management. Scribner 1933 , University of Wisconsin
650 Press 1986, New York and Madison, Wisconsin.

651 Leopold A 1949. A Sand County Almanac: And Sketches Here and There. Oxford University
652 Press.
653 Liberg O, Chapron G, Wabakken P, Pedersen HC, Hobbs NT, Sand H. 2012. Shoot, shovel and
654 shut up: cryptic poaching slows restoration of a large carnivore in Europe.
655 Proceedings of the Royal Society of London Series B **270**:91-98.
656 Liberg O, Suutarinen J, Åkesson M, Andrén H, Wabakken P, Wikenros C, Sand H. 2020.
657 Poaching-related disappearance rate of wolves in Sweden was positively related to
658 population size and negatively to legal culling. Biological Conservation **243**.
659 Linnell JD, Kovtun E, Rouart I. 2021. Wolf attacks on humans: an update for 2002–2020.
660 Norwegian Institute for Nature Research.
661 Linnell JDC, Bjerke T. 2002. Frykten for ulven. En tverrfaglig utredning. (Fear of wolves: an
662 interdisciplinary study.). NINA oppdragsmelding **722**:1-110.
663 Louchouarn NX, Santiago-Ávila FJ, Parsons DR, Treves A. 2021. Evaluating how lethal
664 management affects poaching of Mexican wolves Open Science **8 (registered**
665 **report)**:200330.
666 Lute ML, Gore ML. 2014. Stewardship as a path to cooperation? Exploring the role of identity
667 in intergroup conflict among Michigan wolf stakeholders. Human Dimensions of
668 Wildlife **19**:267-279.
669 Manfredo mJ, Salerno J, Sullivan L, Berger J. 2019. For US wildlife management, social
670 science needed now more than ever. BioScience **69**:960-961.
671 Manfredo MJ, Teel TL, Berl RE, Bruskotter JT, Kitayama S. 2021. Social value shift in favour of
672 biodiversity conservation in the United States. Nature Sustainability **4**:323–330.

673 Manfredo MJ, Teel TL, Don Carlos AW, Sullivan L, Bright AD, Dietsch AM, Bruskotter J, Fulton
674 D. 2020. The changing sociocultural context of wildlife conservation. Conservation
675 Biology.
676 Martin J-L, Chamaillé-Jammes S, Waller DM. 2020. Deer, wolves, and people: costs, benefits
677 and challenges of living together. Biological Reviews **95**:782-801.
678 McCoy J, Rahman T, Somer M. 2018. Polarization and the global crisis of democracy:
679 Common patterns, dynamics, and pernicious consequences for democratic polities.
680 American Behavioral Scientist **62**:16-42.
681 McNay ME. 2002. Wolf-Human Interactions in Alaska and Canada: A Review of the Case
682 History. Wildlife Society Bulletin **30**:831-843.
683 Melis C, et al. 2009. Predation has a greater impact in less productive environments:
684 Variation in
685 roe deer, Capreolus capreolus, population density across Europe. Global Ecology and
686 Biogeography **18**:724–734.
687 Miller J, Stoner K, Cejtin M, Meyer T, Middleton A, Schmitz O. 2016. Effectiveness of
688 Contemporary Techniques for Reducing Livestock Depredations by Large Carnivores.
689 Wildlife Society Bulletin **40**:806-815.
690 Minnie L, Gaylard A, Kerley G. 2016. Compensatory life-history responses of a mesopredator
691 may undermine carnivore management efforts Journal of Applied Ecology **53**:379-
692 387.

693 Mitchell MS, Cooley H, Gude JA, Kolbe J, Nowak JJ, Proffit KM, Sells SN, Thompson M. 2018.
694 Distinguishing values from science indecision making: setting harvest quotas for
695 mountain lions in Montana. Wildlife Society Bulletin **42**:13-21.
696 Moreira-Arce D, Ugarte CS, Zorondo-Rodríguez F, Simonetti JA. 2018. Management Tools to
697 Reduce Carnivore-Livestock Conflicts: Current Gap and Future Challenges. Rangeland
698 Ecology & Management.
699 Murray Berger K. 2006. Carnivore-livestock conflicts: Effects of subsidized predator control
700 and economic correlates on the sheep industry Conservation Biology **20**:751-761.
701 Musiani M, Muhly T, Cormack Gates C, Callaghan C, Smith ME, Tosoni E. 2005. Seasonality
702 and reoccurrence of depredation and wolf control in western North America. Wildlife
703 Society Bulletin **33**:876-887.
704 Nattrass N, Conradie B, Stephens J, Drouilly M. 2019. Culling recolonizing mesopredators
705 increases livestock losses: Evidence from the South African Karoo. Ambio.
706 Naughton-Treves L, Grossberg R, Treves A. 2003. Paying for tolerance: The impact of
707 livestock depredation and compensation payments on rural citizens' attitudes toward
708 wolves. Conservation Biology **17**:1500-1511.
709 Newby F, Brown R. 1958. A new approach to predator management in Montana. Montana
710 Wildlife **8**:22-27.
711 Newsome TM, et al. 2017. Top predators constrain mesopredator distributions. Nature
712 Communications **8**:15469.

713 Nilsen EB, Milner-Gulland EJ, Schofield L, Mysterud A, Stenseth NC, Coulson T. 2007. Wolf
714 reintroduction to Scotland: public attitudes and consequences for red deer
715 management Proceedings of the Royal Society B **274**:995-1002.
716 Peterson RO, Vucetich JA, Bump JK, Smith DW. 2014a. Trophic cascades in a multicausal
717 world: Isle Royale and Yellowstone. Annual Review of Ecology, Evolution, and
718 Systematics **45**:325-345.
719 Peterson RO, Vucetich JA, Bump JM, Smith DW. 2014b. Trophic cascades in a multicausal
720 world: Isle Royale and Yellowstone. Annual Review of Ecology, Evolution, and
721 Systematics **45**:325-345.
722 Prugh LR, Stoner CJ, Epps CW, Bean WT, Ripple WJ, Laliberte AS, Brashares JS. 2009. The Rise
723 of the Mesopredator. Bioscience **59**:779-791.
724 Raynor JL, Grainger CA, Parker DP. 2021. Wolves make roadways safer, generating large
725 economic returns to predator conservation. Proceedings of the National Academy of
726 Sciences **118**:e2023251118.
727 Refsnider R. 2009. The Role of the Endangered Species Act in Midwest Wolf Recovery. Pages
728 311-330 in Wydeven AP, Van Deelen TR, and Heske EJ, editors. Recovery of gray
729 wolves in the Great Lakes region of the United States: An endangered species success
730 story. Springer, New York.
731 Richardson JE. 2022. The Cows May Safely Graze: Placing Expert-Lay Relationships at the
732 Center of Overcoming the Expert-Lay Knowledge Divide. Rural Sociology **in press**.

733 Riley SJ, Nesslage GM, Maurer BA. 2004. Dynamics of early wolf and cougar eradication
734 efforts in Montana: implications for conservation. Biological Conservation **119**:575-
735 579.
736 Ripple WJ, Beschta RL. 2012. Large predators limit herbivore densities in northern forest
737 ecosystems. European Journal of Wildlife Research **58**:733-742.
738 Ripple WJ, et al. 2014. Status and ecological effects of the world's largest carnivores. Science
739 **343**:1241484.
740 Robinson M 2005. Predatory Bureaucracy. University of Colorado Press, Boulder, CO.
741 Sanders J, et al. 2017. Transparency and openness in science. Royal Society Open Science
742 **https://doi.org/10.1098/rsos.160979**.
743 Santiago-Ávila FJ. 2020. Muddled Facts and Values: Positivism, Egoism, and
744 Anthropocentrism in the Anthropocene. Animals and Society.
745 Santiago-Ávila FJ, Agan S, W.,, Hinton JW, Treves A. 2022. Evaluating how management
746 policies affect red wolf mortality and disappearance. Royal Society Open Science
747 **9**:210400. .
748 Santiago-Ávila FJ, Chappell RJ, Treves A. 2020a. Liberalizing the killing of endangered wolves
749 was associated with more disappearances of collared individuals in Wisconsin, USA.
750 Scientific Reports **10**:13881.
751 Santiago-Avila FJ, Cornman AM, Treves A. 2018. Killing wolves to prevent predation on
752 livestock may protect one farm but harm neighbors. PLoS ONE **13**:e0189729
753 Santiago-Ávila FJ, Treves A. 2022. Poaching of protected wolves fluctuated seasonally and
754 with non-wolf hunting. Scientific Reports **12**:e1738

755 Santiago-Ávila FJ, Treves A, Lynn WS, co-authors) e. 2020b. Just preservation, trusteeship
756 and multispecies justice. Animal Sentience: Response to Commentary on Treves et al.
757 on Just Preservation **27**:393-409.
758 Shelley VS, Treves A, Naughton-Treves L. 2011. Attitudes to wolves and wolf policy among
759 Ojibwe Tribal members and non-tribal residents of Wisconsin's wolf range. Human
760 Dimensions of Wildlife **16**:397–413.
761 Sillero-Zubiri C, Sukumar R, Treves A. 2007. Living with wildlife: the roots of conflict and the
762 solutions. Pages 266-272 in MacDonald D, and Service K, editors. Key Topics in
763 Conservation Biology. Oxford University Press, Oxford.
764 Slagle K, Zajac R, Bruskotter J, Wilson R, Prange S. 2013. Building tolerance for bears: A
765 communications experiment. Journal of Wildlife Management **77**:863-869.
766 Slagle KM, Bruskotter JT, Singh AS, Schmid RH. 2017. Attitudes toward predator control in
767 the United States: 1995 and 2014. Journal of Mammalogy **8**:7-16.
768 Smith DW, Peterson RO, Houston DB. 2003. Yellowstone after wolves. Bioscience **53**:330-
769 340.
770 Suutarinen J, Kojola I. 2017. Poaching regulates the legally hunted wolf population in
771 Finland. Biological Conservation **215**:11–18.
772 Suutarinen J, Kojola I. 2018. One way or another: predictors of wolf poaching in a legally
773 harvested wolf population. Animal Conservation **21**:–9.
774 Tanner E, A. White, P. Acevedo, A. Balseiro, Marcos J, Gortázar C. 2019. Wolves contribute to
775 disease control in a multi-host system. Scientific Reports **7940**.

776 Theberge JB, Gauthier DA. 1985. Models of wolf-ungulate relationships: When is wolf control
777 justified? Wildlife Society Bulletin **13**:449-458.
778 Treves A, Artelle KA, Darimont CT, Parsons DR. 2017. Mismeasured mortality: correcting
779 estimates of wolf poaching in the United States. Journal of Mammalogy **98**:1256–
780 1264.
781 Treves A, Bonacic C. 2016. Humanity's dual response to dogs and wolves. Trends in Ecology
782 and Evolution TREE **31**:489-491.
783 Treves A, Bruskotter JT. 2014. Tolerance for predatory wildlife. Science **344**:476-477.
784 Treves A, Elbroch L. 2022. Does killing wild carnivores raise risk for domestic animals? Wild
785 Felid Association Newsletter **in rpess**.
786 Treves A, Krofel M, McManus J. 2016. Predator control should not be a shot in the dark.
787 Frontiers in Ecology and the Environment **14**:380-388.
788 Treves A, Krofel M, Ohrens O, Van Eeden LM. 2019. Predator control needs a standard of
789 unbiased randomized experiments with cross-over design. Frontiers in Ecology and
790 Evolution **7** 402-413.
791 Treves A, Louchouarn NX. 2022. Uncertainty and precaution in hunting wolves twice in a
792 year. PLoS One **17**:e0259604.
793 Treves A, Louchouarn NX, Santiago-Ávila F. 2020. Modelling concerns confound evaluations
794 of legal wolf-killing. Biological Conservation **249**:108643.
795 Treves A, Naughton-Treves L, Shelley VS. 2013. Longitudinal analysis of attitudes toward
796 wolves. Conservation Biology **27**:315–323.

797 Treves A, Paquet PC, Artelle KA, Cornman AM, Krofel M, Darimont CT. 2021a. Transparency
798 about values and assertions of fact in natural resource management. Frontiers in
799 Conservation Science: Human-Wildlife Dynamics **2**:e631998.
800 Treves A, Santiago-Ávila FJ, Putrevu K. 2021b. Quantifying the effects of delisting wolves
801 after the first state began lethal management. PeerJ **9**: e11666.
802 USDA APHIS. 2015. Wildlife Services Enabling Legislation. U.S. Department of Agriculture
803 Animal and Plant Health Inspection Services.
804 van Eeden LM, Crowther MS, Dickman CR, Macdonald DW, Ripple WJ, Ritchie EG, Newsome
805 TM. 2018a. Managing conflict between large carnivores and livestock. Conservation
806 Biology: doi: 10.1111/cobi.12959.
807 van Eeden LM, et al. 2018b. Carnivore conservation needs evidence-based livestock
808 protection. PLOS Biology **l 16**.
809 van Eeden LM, S. Rabotyagov, M. Kather, C. Bogezi, A. J. Wirsing, Marzluff J. 2021. Political
810 affiliation predicts public attitudes toward gray wolf (Canis lupus) conservation and
811 management. Conservation Science and Practice **3**:e387.
812 Vucetich JA, Peterson RO. 2009. Wolf and moose dynamics on Isle Royale. Pages 35-48 in
813 Wydeven AP, Van Deelen TR, and Heske EJ, editors. Recovery of gray wolves in the
814 Great Lakes region of the United States: An endangered species success story.
815 Springer, New York.
816 Waller DM, Reo NJ. 2018. First Stewards: Ecological Outcomes of Forest and Wildlife
817 Stewardship by Indigenous peoples of Wisconsin, USA. Ecology and Society **23**:45-60.

White T. 2008. The role of food, weather and climate in limiting the abundance of animals. Biological Reviews **83**:227–248.

Wiedenhoeft JE, Walter S, Gross M, Kluge N, McNamara S, Stauffer G, Price-Tack J, Johnson R. 2020. Wisconsin gray wolf monitoring report 15 April 2019 through 14 April 2020 in MANAGEMENT BOW, editor. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Wild MA, Hobbs T, Graham MS, Miller MW. 2011. 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**:78-93.

Williams CK, Ericsson G, Heberlein TA. 2002. A quantitative summary of attitudes toward wolves and their reintroduction (1972-2000). Wildlife Society Bulletin **30**:575-584.

Wittmer HU, Sinclair ARE, Mclellan BN. 2005. The role of predation in the decline and extirpation of woodland caribou. Oecologia **144**:257-267.

Supplementary Material 1. Unsupported claims about threats to human safety.

Officials in three states alleged threats to human safety that did not materialize or proved inaccurate.

In 2016, Michigan state officials used stories about wolves alleged threats to human safety to justify wolf-hunting. A subsequent investigation uncovered that these stories were fabrications, leading one biologist to recant his story and a state Senator to apologize on the Capital floor for providing a misleading account (https://www.bridgemi.com/michigan-environment-watch/michigan-dnr-said-it-killed-wolves-protect-humans-then-we-got-its-emails, accessed 14 January, 2022). Similarly, arguing against a proposed reintroduction of wolves into Yellowstone National Park in the mid-1990s, U.S. Senator Conrad Burns (R-Montana) predicted "there'll be a dead child within a year [of reintroduction]" p.348, (Schullery 2003). And in 2011, Idaho's legislature declared, "The uncontrolled proliferation of imported wolves on private land has produced a clear and present danger to humans…dramatically inhibiting previously safe activities such as walking, picnicking, biking, berry picking, hunting and fishing."

In sum, concerns about human safety in wolf range have been tremendously exaggerated. Apparently for political gain (Chapron & Lopez-Bao 2014; Darimont et al. 2018).

References

Chapron G, Lopez-Bao J. 2014. Conserving Carnivores: Politics in Play. Science **343**:1199-1200.

Darimont CT, Paquet PC, Treves A, Artelle KA, Chapron G. 2018. Political populations of large carnivores. Conservation Biology **32**:747–749.

23 Schullery P 2003. The Yellowstone wolf: a guide and sourcebook. University of Oklahoma Press,
24 Oklahoma City, USA.
25

Supplementary Material 2. Wisconsin and Montana studies of change in attitudes before-and-after wolf killing was liberalized.

Three independent studies measured changes in human attitude before and after changes in wolf-killing policies. 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 for wolves among men who lived in wolf range who self-identified as hunters (i.e., they hunted regularly in the past, or had hunted in the last 2 years (Hogberg et al. 2015).

Browne-Nuñez et al. (2015) convened focus groups of deer hunters, hound hunters, and livestock owners and analyzed anonymous questionnaires filled out by the same participants in a mixed-methods approach to understand attitudes to wolf-killing before and after changes in wolf policy that liberalized wolf-killing (Browne-Nuñez et al. 2015). Focus groups conducted after the change in policy showed increased calls for more wolf-killing, little or no change in tolerance for wolves, and zero change in the inclination to kill wolves illegally.

Multiple surveys conducted by Montana Fish Wildlife & Parks (MFWP) provide mixed evidence for the idea that liberalized killing can create tolerance (though, to our knowledge, these studies have not been peer reviewed). A report from 2012 compared data from surveys conducted before and after a 2011 wolf-hunt. That study used a single item to identify tolerance for wolves: "…how tolerant are you with wolves being on the Montana landscape" p.2 (Lewis et al. 2012). Researchers found that pre- and post-hunt responses did not differ

across any of four sampled populations (i.e., Montana residents, private landowners, wolf license holders and deer/elk license holders) concluding, "…tolerance amongst survey respondents for each of the four survey [groups] was the same before and after the 2011 wolf hunt." p.2 (Lewis et al. 2012). This survey was replicated with the same four groups in 2017 using identical methods, but different respondents. That study found increases in tolerance from the 2012 survey across all four survey groups (Lewis et al. 2018). However, a key group representing those holding wolf-hunting permits, changed least and it is unclear if the change exceeded the margin of error. The survey group that changed most were general Montana residents. Independent research, however, estimated that the majority of Montana residents (65.9%) opposed the statement, "Wolves that kill livestock should be lethally removed" and 84.6% were not active hunters defined as having hunted in the past and in the last 12 months (Manfredo et al. 2020). Therefore, the subgroup in the Montana state survey that shifted most to become more tolerant of wolves was the subgroup least likely to kill wolves legally or illegally of the three subgroups. Regardless, the MFWP study did not address mechanisms of change, so it is unclear what role liberalized killing played or whether their responses reflected other widespread demographic changes in attitudes to wolves over time (George et al. 2016; Slagle et al. 2017). Moreover, the same study found that more than half of the MT residents sampled opposed wolf trapping (a primary means of reducing wolves), though a majority in all groups supported hunting generally (Lewis et al. 2018).

In summary, the longitudinal studies that resampled the same individuals before and after changes in policy or intensification of wolf-killing policies did not find the desired outcome and instead found the opposite pattern of attitudinal changes.

References

Browne-Nuñez C, Treves A, Macfarland D, Voyles Z, Turng C. 2015. Tolerance of wolves in Wisconsin: A mixed-methods examination of policy effects on attitudes and behavioral inclinations. Biological Conservation **189**:59–71.

George KA, Slagle KM, Wilson RS, Moeller SJ, Bruskotter JT. 2016. Changes in attitudes toward animals in the United States from 1978 to 2014. Biological Conservation **201**:237–242.

Hogberg J, Treves A, Shaw B, Naughton-Treves L. 2015. 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**:45-55.

Lewis MS, Metcalf AL, Metcalf EC, Phelan C, Gude JA, Kujala Q, Inman B. 2018. vSummary of Research: Better Understanding Montanans Thoughts Regarding Wolves and Wolf Management in Montana in 2018 HURSNJ, editor. Montana Fish Wildlife & Parks

Lewis MS, Pauley G, Kujala Q, Gude JA, King Z, Skogen K. 2012. Selected Results from Four Separate Surveys of Resident Montanans Regarding Montana's Wolf Hunt.

Manfredo MJ, Teel TL, Don Carlos AW, Sullivan L, Bright AD, Dietsch AM, Bruskotter J, Fulton D. 2020. The changing sociocultural context of wildlife conservation. Conservation Biology.

Slagle KM, Bruskotter JT, Singh AS, Schmid RH. 2017. Attitudes toward predator control in the United States: 1995 and 2014. Journal of Mammalogy **8**:7-16.

Supplementary Material 3. Non-lethal methods have aa stronger record of effectiveness and scientific standards of study than do lethal methods for protecting livestock

In contrast to lethal methods intended to control predators, research indicates at least three forms of non-lethal interventions are effective specifically against wolves. (i) fladry, a Polish word for a visual deterrent, consisting of flagging hung from fence-lines: (Davidson-Nelson & Gehring 2010) following captive trials, tests without livestock, and non-randomized before-and-after comparisons with and without electrification of the flagging (Musiani & Visalberghi 2000; Musiani et al. 2003; Shivik et al. 2003; Lance et al. 2010); (ii) Specialized dog breeds bonded to livestock not people, and often used in combination with fencing or night-time enclosures (Gehring et al. 2010) are also well supported by before-and-after comparisons and correlational studies (Espuno et al. 2004); (iii) low-stress livestock handling practiced by 'range riders' or specially trained herdsmen periodically visiting cattle on public, open-range pastures (Stone et al. 2017; Louchouarn & Treves in review Biorxiv pre-print). 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 (e.g., (Angst 2001). But these have not been tested on wolves using high enough standards of evidence (Treves et al. 2016; Eklund et al. 2017; van Eeden et al. 2018; Khorozyan & Waltert 2019; Treves et al. 2019; Khorozyan et al. 2020; Khorozyan & Waltert 2020).

References

Angst C. 2001. Electric fencing of fallow deer enclosures in Switzerland--a predator-proof method. Carnivore Damage Prevention News **3**:8-9.

Davidson-Nelson SJ, Gehring TM. 2010. Testing fladry as a nonlethal management tool for wolves and coyotes in Michigan. Human–Wildlife Interactions **4**:87-94.

Eklund A, López-Bao JV, Tourani M, Chapron G, Frank J. 2017. Limited evidence on the effectiveness of interventions to reduce livestock predation by large carnivores. Scientific Reports **7**:2097 | DOI:2010.1038/s41598-41017-02323-w.

Espuno N, Lequette B, Poulle ML, Migot P, Lebreton JD. 2004. Heterogeneous response to preventive sheep husbandry during wolf recolonization of the French Alps. Wildlife Society Bulletin **32**:1195-1208.

Gehring TM, Vercauteren KC, Provost ML, Cellar AC. 2010. Utility of livestock-protection dogs for deterring wildlife from cattle farms. Wildlife Research **37**:715–721.

Khorozyan I, Siavash G, Mobin S, Soofi M, Waltert M. 2020. Studded leather collars are very effective in protecting cattle from leopard (Panthera pardus) attacks.

Khorozyan I, Waltert M. 2019. How long do anti-predator interventions remain effective? Patterns, thresholds and uncertainty. Royal Society Open Science **6**.

Khorozyan I, Waltert M. 2020. Variation and conservation implications of the effectiveness of anti-bear interventions. Scientific Reports **10,**:15341.

Lance NJ, Breck S, Sime C, Callahan P, Shivik JA. 2010. Biological, technical, and social aspects of applying electrified fladry for livestock protection from wolves (Canis lupus). Wildlife Research **37**:708-714.

Louchouarn NX, Treves A. in review Biorxiv pre-print. Low-stress livestock handling protects cattle in a five-predator habitat. https://www.researchsquare.com/article/rs-1061804/v1.

Musiani M, Mamo C, Boitani L, Callaghan C, Gates CC, Mattei L, Visalberghi E, Breck S, Volpi G. 2003. Wolf Depredation Trends and the Use of Fladry Barriers to Protect Livestock in Western North America. Conservation Biology **17: 1538–1547**.

Musiani M, Visalberghi E. 2000. Effectiveness of fladry on wolves in captivity. Wildlife Society Bulletin **29**:91-98.

Shivik JA, Treves A, Callahan M. 2003. Non-lethal techniques: Primary and secondary repellents for managing predation. Conservation Biology. **17**:1531-1537.

Stone SA, Breck SW, Timberlake J, Haswell PM, Najera F, Bean BS, Thornhill DJ. 2017. Adaptive use of nonlethal strategies for minimizing wolf–sheep conflict in Idaho. Journal of Mammalogy **98**:33-44.

Treves A, Krofel M, McManus J. 2016. Predator control should not be a shot in the dark. Frontiers in Ecology and the Environment **14**:380-388.

Treves A, Krofel M, Ohrens O, Van Eeden LM. 2019. Predator control needs a standard of unbiased randomized experiments with cross-over design. Frontiers in Ecology and Evolution **7** 402-413.

van Eeden LM, et al. 2018. Carnivore conservation needs evidence-based livestock protection. PLOS Biology **l 16**.