frontiers in Conservation Science

POLICY AND PRACTICE REVIEWS
published: 10 May 2021
doi: 10.3389/fcosc.2021.631998

Transparency About Values and Assertions of Fact in Natural Resource Management

Adrian Treves[1]*, *Paul C. Paquet*[2,3], *Kyle A. Artelle*[2,3], *Ari M. Cornman*[4], *Miha Krofel*[5] and *Chris T. Darimont*[2,3]

[1] Carnivore Coexistence Lab, Nelson Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI, United States, [2] Department of Geography, University of Victoria, Victoria, BC, Canada, [3] Raincoast Conservation Foundation, Sidney, BC, Canada, [4] Little River Band of Ottawa Indians, Manistee, MI, United States, [5] Department of Forestry, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

OPEN ACCESS

Edited by:
Silvio Marchini,
University of São Paulo, Brazil

Reviewed by:
Yash Veer Bhatnagar,
Nature Conservation Foundation, India
Edson Gandiwa,
Chinhoyi University of Technology, Zimbabwe

***Correspondence:**
Adrian Treves
atreves@wisc.edu

Specialty section:
This article was submitted to Human-Wildlife Dynamics, a section of the journal Frontiers in Conservation Science

Received: 21 November 2020
Accepted: 25 February 2021
Published: 10 May 2021

Citation:
Treves A, Paquet PC, Artelle KA, Cornman AM, Krofel M and Darimont CT (2021) Transparency About Values and Assertions of Fact in Natural Resource Management. Front. Conserv. Sci. 2:631998. doi: 10.3389/fcosc.2021.631998

Worldwide, unsustainable use of nature threatens many ecosystems and the services they provide for a broad diversity of life, including humans. Yet, governments commonly claim that the best available science supports their policies governing extraction of natural resources. We confront this apparent paradox by assessing the complexity of the intersections among value judgments, fact claims, and scientifically verified facts. Science can only describe how nature works and predict the likely outcomes of our actions, whereas values influence which actions or objectives society ought to pursue. In the context of natural resource management, particularly of fisheries and wildlife, governments typically set population targets or use quotas. Although these are fundamentally value judgments about how much of a resource a group of people can extract, quotas are often justified as numerical guidance derived from abstracted, mathematical, or theoretical models of extraction. We confront such justifications by examining failures in transparency about value judgments, which may accompany unsupported assertions articulated as factual claims. We illustrate this with two examples. Our first case concerns protection and human use of habitats harboring the northern spotted owl (*Strix occidentalis caurina*), revealing how biologists and policy scholars have argued for divergent roles of scientists within policy debates, and how debates between scientists engaged in policy-relevant research reveal undisclosed value judgments about communication of science beyond its role as a source of description (observation, measurement, analysis, and inference). Our second case concerns protection and use of endangered gray wolves (*Canis lupus*) and shows how undisclosed value judgments distorted the science behind a government policy. Finally, we draw from the literature of multiple disciplines and wildlife systems to recommend several improvements to the standards of transparency in applied research in natural resource management. These recommendations will help to prevent value-based distortions of science that can result in unsustainable uses and eventual extinctions of populations. We describe methods for communicating about values that avoid commingling factual claims and discuss approaches to communicating science that do not perpetuate the misconception that science alone can dictate policy without consideration of values. Our remedies can improve transparency in both expert and public debate about preserving and using natural resources, and thereby help prevent non-human population declines worldwide.

Keywords: policy, preservation, owl, sustainable use, wolf, model, research conduct, scientific integrity wolf

INTRODUCTION

Worldwide, unsustainable use of nature threatens the collapse of ecosystems and the benefits they provide to non-humans and humans alike (Ceballos et al., 2015, 2020; Darimont et al., 2015; Ripple et al., 2017; Ceballos and Ehrlich, 2018; FAO, 2020). Yet, for at least a century, governments and researchers have invoked a long-standing set of scientific models as a basis for the claim that natural resource extraction (particularly of wild animals) is sustainable (Larkin, 1977; Oro, 2013). How can a well-understood and established science of "sustainability" commonly result in unsustainable extraction? We attempt to resolve the seeming paradox by describing the need to disentangle where the science begins and ends in natural resource management (NRM), and how uncertainty in science and mistrust of scientists are both exacerbated by a lack of transparency about value judgments (judgments about what one considers desirable or undesirable for goals and modes of conduct; Manfredo and Dayer, 2004). We acknowledge that all of us struggle to demarcate our observations and inferences about the world from what we desire to be true about the world. Yet, scientists, in particular, should strive for such clarity and openness because the ideal of objectivity in science means that our desires should be regarded as a poor guide to our approximations of reality.

We begin with disentangling where the science begins and ends in NRM use and policy. Governments often set targets (e.g., population goals or use quotas) for the abundance of nature's components that people want to use. Decisions on targets, goals, or quotas (i.e., annual use of populations) necessarily involve value judgments external to the science for answering how much to use or preserve: Should we extract a given component of nature? How? Where? And—importantly—how much should we use now or preserve for others and the future? Population goals and extraction quotas set by governments represent choices of certain quantitative amounts among many possible amounts. That choice is based in part on judgment and preference about how much humans ought to need or ought to take, not on mathematical models. We define science as observation, measurement, analysis, and inference following long-accepted principles of transparency, reproducibility, and impartiality. Science can only tell us how much to use or preserve to achieve a predetermined goal as guided by values.

Entanglements of science and values arise when people improperly conflate personal or community preferences with evidence at hand when justifying their decisions (Schrader-Frechette and McCoy, 1994; Menon and Lavigne, 2006; Artelle et al., 2014; Darimont et al., 2017, 2018; Artelle K. A. et al., 2018; Artelle K. et al., 2018; Jacquet and Delon, 2018). Science can only describe how nature works and predict the likely outcomes of our actions, or sometimes reveal the possible range of actions, as discussed for biodiversity and natural resources (Lynn, 2006, 2010; Nelson and Vucetich, 2009; Treves et al., 2009b; Vucetich and Nelson, 2014; Artelle K. et al., 2018; Jacquet and Delon, 2018). Value judgments can be concealed by suggestions that scientific theories or mathematical models command a limited range or single choice, such as setting a goal or quota.

Environmental sciences underlying policy and management of fisheries, wildlife, biodiversity, climate, etc., risk tangling personal, institutional, or societal preferences or value judgments with quantitative values derived from extraction models. For example, deciding how many fish to extract is informed by, but not the same as, inferring how non-human consumers might respond to the resulting population of fish, as the former inevitably involves considerations of the relative value of fish and other wildlife, along with other costs and benefits (Levi et al., 2012). Likewise, the amount of CO_2 emissions represents a measurement of a quantity, but setting the allowable level is a value judgment that entails balancing benefits and costs for health, wellbeing, resources, equity, diversity, ecosystem function, and any other criteria the decision makers choose to integrate.

What role do facts—and assertions of fact (hereafter fact claims)—play in justifying NRM goals? When public policy is being made, interest groups commonly call upon certain facts (or claims thereof) to justify their preferred policy outcomes. Science is valuable to assess the accuracy, precision, and reliability of such putative evidence before we can label it as fact or unverified assertion. Given competing values—and the inherent uncertainty that pervades scientific understanding, scientific processes should therefore keep evidence (and the processes generating it) transparent and accountable for the public, decision makers, and regulators. Transparency should also include a clear acknowledgment about the value judgments before asking scientific questions, such as "how much is out there to use; how much can we use without harming competing claims that we or others also value; and how much are we leaving for other users of the present and future?" Clearly, there is an interplay among values, fact claims, and the evidence (scientific inference about the uncertainty of the fact claims).

Scientists seem to need ways to keep claims about both facts and values in public affairs transparent and accountable. Values often play a dominant role in policy setting (Schrader-Frechette and McCoy, 1994; Lynn, 2006; Nelson et al., 2011; Darimont et al., 2017; Artelle K. et al., 2018). Scientifically inclined societies have developed robust (if fallible) systems for vetting fact claims through many processes and agents, such as scientific peer review, replication of research, inspector generals, and third-party watchdogs.

Our concern here lies at the intersection of science and values; how scientists and policy-makers make transparent their value judgments, separate these from fact-claims, and evaluate their own claims and those of others transparently. Our goal builds on a call by the National Academies of Science, Engineering and Medicine (2017) in which they clearly articulated the nature of our concern, offering, "Openness is fundamental to the success of the entire chain of processes and relationships involved in scholarly communication. Most centrally, those assessing the quality of science must be honest in their assessments and aware of and honest in reporting their own conflicts of interest or any cognitive biases that may skew their judgment in self-serving ways…" p. 33 (National Academies of Science, Engineering and Medicine, 2017). The arena in which such biases require addressing is in communications, where the tangles of values, facts, and fact claims are written or spoken to justify action or inaction. Often scientists are required to extrapolate beyond the science into more speculative ground. It is precisely in communications of scientific observations, measurements, and inferences that one finds extrapolation and uncertainty raise the risk of false fact claims, and transparency may be low. Therefore, our first case study examines the debate among scientists and between policy scholars and scientists regarding how verified, scientific evidence ("facts" hereafter) should be communicated in a policy debate founded on value judgments, in which the science will lead directly to action or inaction toward owls or their habitats (**Box 1**).

In the spotted owl case study, we reason that transparency on the parts of all scientists commenting on public policy would go a long way to revealing in the broad public when a value judgment has been made about a policy goal, when a fact claim has been made to justify action toward that goal, and when a fact claim is being evaluated scientifically. Training for such transparency has been taken up under the rubric of research integrity or scientific ethics, and we welcome the recent spread of such efforts (Mejlgaard et al., 2020). Our next case study raises questions about the internal domain of the conduct of science (observation, measurement, and inference) and specifically how sustainable use models and outputs might conceal value judgments. Before exploring the next case, we summarize the science of sustainable use models widespread in NRM.

TRANSPARENCY IN SUSTAINABLE USE SCIENCE

We focus on transparency because its pursuit and its breach illustrate how value judgments from the external domain can infiltrate and distort the conduct of science (its internal domain). Transparency can help an agency avoid overwhelming bias or help watchdogs check such biases before they do harm. Our concern with transparency begins with the wording used in our topic: sustainable use of natural resources. The phrase "natural resource" itself presupposes a value judgment about human claims to nature. Indeed, the field is littered with open or buried value judgments and euphemisms (Houck, 2001; Mark, 2014; Johns and DellaSala, 2017). For example, the word "exploitation" often surfaces in NRM. The OED (2020) defines "exploit" first as, "To harvest or extract (a natural resource); to extract resources from (a place)," but its second definition is, "To take advantage of in an unfair or unethical manner; to utilize for one's own ends." Given that exploit potentially enfolds a value judgment as in the latter definition, we encourage replacement with the simpler terms "use" and "extract," as in the former definition because "extract" does not enfold a value judgment: "Taken out, obtained out of something… Derived (from a source)" (OED, 2021). Many other euphemisms surface in NRM, e.g., "take," "harvest." Euphemisms and jargon pose many problems (Johns and DellaSala, 2017), but even those who use neutral terminology may overlook value judgments within mathematical models for the use of nature, as we examine next.

Estimations of the point of maximum sustainable yield (MSY) and forecasts of population change after extraction have dominated the science of NRM for decades (Larkin, 1977; Nelson et al., 2011; Levi et al., 2012; Patrick and Cope, 2014). Predictions of sustainability for points on a hypothetical curve (the science) can be confused with a value judgment.

The value judgment often used is that extractors should aim for that rate of extraction for current human consumers, and the extraction should be repeated to achieve sustainable preservation of the resource for future humans. Conflating these different components of decisions about use can mislead anyone into missing the associated personal or organizational value judgments (How much should we use and how much should we preserve for others? Who are the others, and what do we owe them?). We expose these issues to a clearer light for NRM by juxtaposing the mathematics against the value judgments that often follow such modeling.

Prevalent models of the sustainable use of natural resources often apply a theory of population dynamics called density dependence. Density-dependent dynamics arise when reproduction changes non-linearly with population density, or when mortality changes non-linearly with population density. A member of the family of logistic growth curves can describe such population dynamics. This family of curves has a convenient mathematical form that includes an inflection point between asymptotes at zero (local extinction) and carrying capacity (K) for a hypothetical closed ecosystem (**Figure 1**). The theory suggests that the use of natural resources at many points along the curve would be sustainable because new births could replace deaths caused by users. The point of maximum sustainable yield (MSY) is predicted to occur at the inflection point of the logistic growth curve in its simplest form, usually assumed to fall at half of K (**Figure 1**). The many uncertainties about the theory are well known (**Figure 1** caption). Even today, when MSY usually is not chosen as an explicit goal, modelers and managers often select a "safer" extraction point higher up the curve of presumed population growth (Kirkwood, 1981), still with implied reference to MSY. Even though some modelers have long recognized the risks of setting population goals, targets, or quotas, they have often only recognized the uncertainties about MSY but not the problem of buried value judgments about who benefits and who loses from such extraction. All the

BOX 1 | Debates over spotted owls reveal how scientists grapple with transparent value judgments in scientific communications.

Northern spotted owl (*Strix occidentalis caurina*) policy in the USA has been subject to repeated debate about biased scientific communications and embedded value judgments influenced by laws (Carroll et al., 2012; Wilhere, 2012; Wilhere et al., 2012; Peery et al., 2019; Rohlf, 2019). Simplifying the 2012 debate somewhat, Wilhere et al. (2012) criticized the scientific peer reviewers contracted by the US government under the Endangered Species Act (ESA) for not transparently explaining where the science began and ended. Wilhere et al. suggested that the scientists did not separate facts, whether measurements of the current status or inferences about future conditions of the owls under hypothetical policy scenarios, from the value judgments that must underlie recommendations to the US government. Again simplifying, Carroll et al. (2012) countered that an ESA peer review is embedded in a set of statutory value judgments about listing and delisting owls. The debate might have been just another example of one team of scholars citing another for bias and being rebutted, if not for the following elements of their debate that hold broad general interest.

Wilhere (2012) suggested that the scientists in the peer review panel had prioritized protection of the owls rather than treating the two policy options (protect or not) impartially. He went on to recommend that the government "…separate discussions of policy from discussions of science. In fact, consider submitting separate policy and science reviews authored by different groups and published as separate reports" p. 747 (Wilhere, 2012). Later, the US government tried something similar with a separate ethics review (Lynn, 2018; Andrews et al., 2019), but, to our knowledge, did not publish the recommendations. We are not aware if anyone followed another recommendation by Wilhere (2012) that policy-makers purge policy advocacy from scientific reviews (see a deep look at this issue in Doremus, 2004), though he neither recommended the converse nor examined the possible shortcomings of such a process.

We surmise it is no easier for scientists to articulate all their value judgments than for policy-makers to resist making unverified fact claims to support their value judgments that underlie policy proposals. Are we left with no resolution to this confounding interplay of facts and values? The next half of our case study of spotted owl science communication reveals an important dividing line between values about how science is conducted (the internal domain of research integrity) and values about how science is communicated to outside audiences (the external domain).

Peery et al. (2019) denounced another owl research team's verbal and legal actions against unnamed junior scientists. We echo their call for civil debate and for presenting facts in peer-reviewed journals that follow ethical guidelines. However, they also demarcated acceptable and unacceptable modes of communication and styles of verbal expression by scientists communicating science. Their **Supplementary Table 1** (Peery et al., 2019) shows the "symptoms" of agenda-driven science that intermingled personal value judgments about style, tone, and modality of communication with concerns about bias, with concerns how science should be conducted. We acknowledge that a tabular format may force authors into shorthand. Examples of this intermingling include, when labeling "Activities symptomatic of agenda-driven science," they included "Failure to disclose involvement in litigation related to a study." They probably intended something akin to competing interests in litigation over a study, but the recommendations will be quoted by others, so we address them as written in **Supplementary Table 1** (Peery et al., 2019). Our aim is to make clear that value judgments and debate about scientific communications should distinguish the internal domain (how the science was conducted) from the external domain of science communication (how the science was disseminated) because transparency about those two domains will help demarcate where value judgments concern personal or organizational differences of opinion and where judgments concern the validity of facts and fact claims.

We begin with the series of "Activities symptomatic of agenda-driven science" that Peery et al. use to address their concerns over how spotted owl science was conducted (the internal domain). For example, they cited: "Selective use of data…," "Selectively referencing…," "Emphasizing certainty and simplicity," and "Conducting biased review…" (**Supplementary Table 1**; Peery et al., 2019). These are poor practices in the conduct of science (National Academies of Science, Engineering and Medicine, 2017) but are also practices that might be construed as sloppy if unintentional. Although Peery et al. (2019) extensively documented their evidence for intention by one team of owl researchers, it is less clear if these practices identified in **Supplementary Table 1** are truly "agenda driven" in all cases.

Indeed, if the scientific community were held to some of the standards in **Supplementary Table 1** of Peery et al. (2019), almost everyone would be judged as "agenda driven." Poor practices lie alongside practices that might actually be good practices in their **Supplementary Table 1**. For example, depending on how one defines pressure, "Pressuring other scientists to retract…" might be good for research integrity, given that the Committee on Publication Ethics (COPE, 2019) recommends how retraction should proceed when third parties ask editors or publishers to investigate cases of possible research misconduct. Likewise, one of the proscriptions of Peery et al. (2019) seems to suggest that once a paper passes peer review, it is immune to criticism thereafter, in the phrase "…outside of the peer review process" **Supplementary Table 1** (Peery et al., 2019). Given that post-publication review is now being recommended by prominent journals and ethicists for improving reproducibility of science (Allison et al., 2016; Stern and O'Shea, 2019), the proscription on timing of criticism is yet another value judgment by Peery et al. (2019).

Although the last two value judgments might be excused as traditional facets of scientific integrity giving way to new norms, other value judgments in **Supplementary Table 1** of Peery et al. favor some actors over others within scientific debates rather than favoring some methods or evidence over other methods or evidence. If agendas should not drive science, then personal, organizational, or governmental preferences should not either. We have considerable concern for science driven by preference. Basing scientific inference or evaluation of the quality of science on the identities of the authors, their funders, or their access to data seems bad for efforts to observe and infer reality, which should be judged on their merits alone (National Academies of Science, Engineering and Medicine, 2017). Two of the recommendations in **Supplementary Table 1** (Peery et al., 2019) strike us as containing hidden value judgments about the establishment or status quo being good and others as bad. For example, the phrases "…unvetted data" and "…through [Freedom of Information Act requests (FOIA)]" treat established, traditional, government-funded or government-run research as good. Yet, litigation or FOIA requests can be an effective recourse to obtain information from secretive agencies, programs, or individuals (see Rohlf, 2019 for advocacy of scientific engagement in litigation and Doremus, 2004 for a history of non-transparency by agencies implementing the ESA). Similarly, litigation, social media, and critique of scientific papers in public media, comprise legitimate means of communication in a free, democratic society. None of these actions in the external domain of science (how it is communicated) are intrinsically bad for the internal domain of research integrity (Lackey, 2007; Garrard et al., 2016; National Academies of Science, Engineering and Medicine, 2017). By asserting norms of scientific communication, Peery et al. (2019) appear to have advocated for their values related to decorum, style, or modality. We doubt that public confidence in science will be increased by censorship of scientists. We fear a scientific culture that sanctions legitimate science communication is the next step if the "symptoms" in **Supplementary Table 1** (Peery et al., 2019) were widely sanctioned in norms of scientific communication.

mathematical and probabilistic reasoning about uncertainty is additive to the point about the external domain of science—choosing specific population targets or quotas involve value judgments independent of uncertainty in the model outputs.

MSY is just one point among an infinite number of points on an uncertain curve. The decision to set a population goal at MSY or any other point is just one alternative judgment about many possible values. Those are decisions that usually prioritize

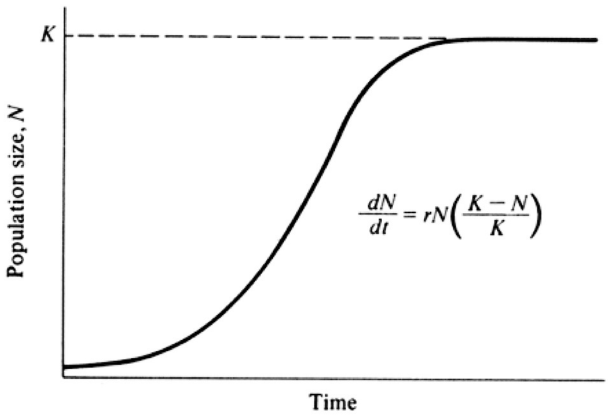

FIGURE 1 | The logistic growth curve resulting from density-dependent population dynamics. *K* is the asymptote or predicted carrying capacity of an idealized population and *r* is the intrinsic rate of increase. The equation is positioned at approximately the same height as the inflection point K/2, which is predicted to be the point of maximum sustainable yield, MSY (Pianka, 2000). Defined simply, the carrying capacity (K) is the maximum number of individuals that can be supported in each area at a given time. In populations following density-dependent population dynamics, the upper asymptote of the logistic growth curve is assumed to approach K because the average death rate and rate of recruitment of juveniles to adulthood equilibrate, and growth stops. The presence of carrying capacity, the prediction of logistic growth, and the point of MSY are all testable predictions of a general theory that may not be accurate *or even exist* in specific cases. Indeed, real populations vary in the shape of their growth curves, and these characteristics can change over time (Brook and Bradshaw, 2006; Ratikainen et al., 2008). Birth and death cannot be assumed to change symmetrically or non-linearly with density or population size. For example, with strictly territorial species, local density may not even increase much within a local subpopulation (see **Box 2** for an example). Even if the other conditions are met, the inflection point can lie higher or lower than K/2, depending on the symmetry of the birth and death curves in relation to density. Caution is warranted because of the vicissitudes of wild ecosystems, environmental stochasticity, and the uncertainty of any predictions about the future that are based on past patterns (Brook and Bradshaw, 2006; Ratikainen et al., 2008; Oro, 2013; Williams, 2013). Data limitations especially relating to migration into and out of the open ecosystems also commonly restrict our knowledge of growth rates of natural populations. Also, the predictions of sustainable use models become increasingly uncertain when mortality and natality are affected by unregulated factors, untested policies, or human errors (Fryxell et al., 2010). This is not to say that MSY is a fallacy, but rather that it is a prediction that needs frequent updating, continual review, and testing, rather than an *a priori* static point.

certain human users (i.e., current and often influential interest groups). Indeed, a rigid application of MSY benefits current human extractive users at the expense of all other users, often including non-consumptive users or non-human consumers who also use prey populations. That contrasts with other definitions of sustainability, in which, for example, unused individuals are not viewed as "wasted," but instead as feeding other life, preserved for the future, or serving other ecosystem functions, e.g., salmon *Oncorhynchus* spp. fisheries (Levi et al., 2012). Also, the interests of future generations are often presumed (rather than consulted explicitly or preserved for all possible uses) when current decision makers allocate to current human users (Treves et al., 2017b, 2018a). Finally, the very conception of nature as a resource that is claimed property privileges an anthropocentric, western worldview to the detriment of other lifeways, especially and commonly those of indigenous peoples and non-humans (Lynn, 2006; David, 2009; Levi et al., 2012; Artelle K. et al., 2018; Eichler and Baumeister, 2018; Treves, 2019a). Decisions to allocate natural resources often blur the line between real need for subsistence or survival and mere profit seeking, recreation, or luxury (Santiago-Avila et al., 2018b; Santiago-Ávila et al., 2020; Treves et al., 2018b; Treves, 2020). MSY thinking and density-dependent models of population dynamics applied to NRM illustrate the internal and external domains of science and their relationship to values well.

The judgment whether one should or should not extract a given quota stems from values, which may be followed by a judgment whether to apply a density-dependent model, itself stems from scientific reasoning. Later, the judgment whether to act on the model predictions again stems from values informed by the consequences that science estimates with uncertainty. That three-step process involves interaction between values and science. Therefore, transparency about how much will be extracted, how and where to limit non-human populations, and which actors are expected to benefit or suffer, would expose the value judgments and outcomes in a policy decision or management action associated with a population target or extraction quota. We illustrate the consequences of non-transparent value judgments further complicated by non-transparent conduct of science with a case of gray wolves (*Canis lupus*) (**Box 2**).

GENERAL CONCLUSIONS FROM THE CASE STUDIES

Our cases reveal two features of transparency in science and public policy. The first case about northern spotted owls explained how scientists and scholars in policy-relevant research debated the thoroughness of transparency about value judgments and whether scientific debate could be purged of personal value judgments and how that might occur. We use the spotted owl case to argue for clearer thinking about—and behavior toward—the difference between the internal domain of science (how it is conducted) and its external domain facing the public and policy-makers (how it is communicated). In our second case, a government policy on population targets, quota levels, and wolf hunting was promoted by science that lacked transparency and from which—we infer—the value judgments of a handful of scientists and perhaps their institutions remained undisclosed but might have played a disproportionate role in guiding management for 21 years. The wolf case study began somewhat transparently with explicit statements, such as "The management goal represented the minimum level at which a full array of population control activities could occur including pro-active depredation control and the possibility of public harvest" p. 16 (WDNR, 1999). However, more fundamental questions were never addressed, such as "Should we kill wolves? And if so, why, what are the desired outcomes, under what conditions is it right and effective to pursue those outcomes, and how many wolves is it right to kill to attain the goals?" (Treves, 2009). This

BOX 2 | Science used to justify a gray wolf population goal and kill quota, 1999–2021 now.

Here we explain how a population model used to plan the regulated killing of wolves in Wisconsin, USA, was not transparent about value judgments in conducting or communicating the science marshaled in support of a use policy. The senior author here observed public policy and re-analyzed data from published reports in recent years (Treves, 2019a; Treves et al., 2014, 2017a,b,c) after collaborating with the state wildlife agency (WDNR) previously (Treves et al., 2002, 2004, 2009a, 2011; Wydeven et al., 2004; Olson et al., 2014); see the lead author's full declarations of potentially competing interests here (http://faculty.nelson.wisc.edu/treves/Vision.php accessed 29 October 2020).

The state of Wisconsin published its first wolf management plan in 1999 (WDNR, 1999), which included a projection of wolf population growth to 2020 (**Figure 2**) from the estimated minimum of 205 adult and yearling gray wolves in winter 1998–1999. The 1999 Plan codified two numerical value judgments that shape policy to this day. The first, the Delisting Level of 250, was set higher than the federal ESA delisting level of 100 (USFWS, 2020). The Delisting Level was set at the midpoint of the range of outputs of a population viability analysis (PVA), which the authors argued "needs to be cautiously interpreted and should not be used by itself to set management goals. Based on [the PVA], a population between 200 and 300 seemed appropriate for delisting wolves in Wisconsin" p. 16 (WDNR, 1999). We note the questionable idea that a model output could set management goals without policy-makers stating a goal based on value judgments. The second value chosen by the authors of the 1999 Plan was the Management Goal $N_{goal} = 350$ (**Figure 2**), also referred to as the "population goal" in WDNR, 1999 or "population objective" as of this writing (https://dnr.wisconsin.gov/topic/WildlifeHabitat/wolf/index.html accessed 28 October 2020).

By definition, $N_{goal} = 350$ is a value judgment, but this choice was couched in models and several fact claims as follows: Ostensibly, N_{goal} was a number of wolves supportable by suitable habitat, compatible with the PVA, and was also "socially tolerated" p. 15 (WDNR, 1999), i.e., "… a reasonable compromise between population capacity, minimum level of viability, and public acceptance." p. 16 (WDNR, 1999). As quoted above, the PVA seemed to be regarded ambiguously by the authors and appeared to have little or no influence in policy setting. Regarding "social tolerance" and "public acceptance," the 1999 Plan reported an informal survey about N_{goal} after it had already been selected, with the following statement of methods: "During the review of the second draft of the [1999 Plan], of persons commenting on the population goal, 38% supported the goal, 38% felt it was too low, and 24% felt it was too high…" p. 16 (WDNR, 1999). From the wording, we infer that N_{goal} was presented to the assembled individuals (of which a sample size and selection procedure were not stated). Methods were not disclosed, and independent review was apparently not conducted, as with most agency management plans in North America (Artelle K. A. et al., 2018). Therefore, the assertions about public opinion or social tolerance seems an untested fact claim. The third fact claim about N_{goal} was about "population capacity" or "suitable habitat" p. 15–16 (WDNR, 1999). Two estimates existed for carrying capacity, K, in 1999. One was based on habitat at K = 300–500 wolves (or possibly up to 800 if marginal habitat was to be occupied) and one based on prey at K = 262–662 (Mladenoff et al., 1995, 1997). The Delisting Level was half of the habitat-based maximum (K = 500), and the Management Goal was a round number set at 53% of the prey-based maximum (K = 662); note in 2012 the wolf population was estimated above 815. That N_{goal} was set at or near K/2 suggests scientific reasoning linked to MSY approaches. The similarity of these bracketing values to MSY thinking is suggestive, although this was not stated explicitly until 2009 (see next section). Even if there is another explanation (besides MSY) behind the choice of N_{goal} and the Delisting Goal, such reasoning was not provided, implying that these parameters were deterministically generated by the model in **Figure 2**, rather than the product of value judgments.

Turning to how the science was conducted in the 1999 Plan and particularly in **Figure 2**, an unstated assumption and two assertions of fact were made by fitting the logistic growth curve to the annual wolf population estimates. The unstated assumption was that the changes in census methods in the winter of 1994–1995 and in the early 2000s (detailed in the **Supplementary Material**) were inconsequential, such that a single curve could be fit to the point estimates of population size in **Figure 2**. Those changes in census methods were designed and implemented by some of the authors of the 1999 Plan and 2007 Addendum to the Plan (**Supplementary Material**). Also, the curve represents a fact claim and a prediction, both of which required explanation that was not provided in the 1999 Plan. Specifically, the assertion was that density-dependent growth dynamics were occurring. The assumption of density-dependent population growth was not contrasted with alternative forms of growth nor tested explicitly.

Density-dependent dynamics were known to be common at the time, but far from universal in that a substantial proportion of wild animal populations did not show such dynamics (Fowler, 1987). The next publication did not clarify. A 2007 addendum to the 1999 Plan by the same authors stated "Van Deelen (unpublished) fit simple growth models to a XX [sic] year time series of wolf population estimates. Models fit were the discrete logistic model (CITATION) [sic]…" p. 7 (WDNR, 2007). The omissions indicated by [sic] in the quotation further clouded the issue.

Before the publication of the addendum (WDNR, 2007) to the 1999 Plan, Brook and Bradshaw (2006) explained why populations might not show density dependence, including: (a) substantial errors or changes in sampling or measurement can mimic or obscure density-dependent dynamics; (b) populations growing without spatial bounds and limited mainly by exogenous factors are not expected to show density-dependent dynamics; and (c) minimal changes in density over the sampling period might not produce such dynamics. All three scenarios might apply to Wisconsin's wolf population history, given that (a) census methods had changed twice and showed substantial variance among years, (b) the leading cause of death were by vehicles and poaching that were correlated to geographic spread and policies, respectively, not to density; moreover, density only increased over time slightly relative to measurement precision (Wydeven et al., 2001, 2004, 2009; Chapron and Treves, 2017; Treves et al., 2017c; Treves, 2019a; Santiago-Ávila et al., 2020). Therefore, the authors of the 1999 Plan had 8 years to make the foundation of **Figure 2** transparent and test its fact claims with mortality or reproductive data and sensitivity analyses. The prediction of future growth in **Figure 2** could have benefited from a scientific statement or estimate of uncertainty against the alternative of exponential growth, especially given that the two policy values discussed above lay in the prediction interval. Additional information came out in 2009, but the apparent value judgments underlying the wolf population model and the science used to buttress the state approach to target setting remained non-transparent, and still do today.

Transparency and Tests of Fact Claims From 2009 to 2020

In 2009, the authors of the state wolf population model published a book in which the authors clarified the fitting procedure for the logistic growth curve and the role of K in modeling. Furthermore, the model was used to explore a single scenario involving "maximum *sustained* yield" p. 150 (Van Deelen, 2009), emphasis added because no legal killing had yet taken place. This scenario was instead a prediction about future sustainability if regulated use was implemented. That 2009 chapter did not mention the changes in census methods.

The issue of change in census methods was obscured by errors in relating the history of Wisconsin wolf policy and monitoring in the first peer-reviewed article in 2015 (**Supplementary Materia**l). Finally, the 2009 book did not quantitatively evaluate the 1999 assumption of negative density dependence on birth or mortality, although some trends in density were presented (Wydeven et al., 2009). Other authors agreed that negative density dependence on wolf mortality was not apparent in the period 1995–2012 (Stenglein et al., 2015; Chapron and Treves, 2016, 2017). There was less agreement on other issues central to the state wolf population model and its assumptions.

(continued)

BOX 2 | (continued)

From 2016 to 2020, several teams of independent scientists began to raise questions about population dynamics and wolf mortality patterns. They found that evidence for negative density dependence in reproduction (Stenglein et al., 2015) was not transparently presented in quantitative format but instead depended on a crude line drawing (Chapron and Treves, 2017). Independent scientists reported that the census method was associated with the mortality hazard among radio-collared wolves, and the legal killing policies from 2003 to 2012 were associated with hazard and incidence of mortality among radio-collared wolves (Santiago-Ávila, 2019; Santiago-Ávila et al., 2020), both of which are exogenous factors that could reduce the influence of any density dependence. Furthermore, state reporting had appeared non-transparent about mortality patterns, the effect of census method on the means and variances of wolf population estimates, and the effects of actual wolf-hunting (2012–2014) on model predictions (Treves et al., 2014, 2017a,b,c; Treves, 2019a).

While the public policy process in our case study in 1999–2020 began transparently (i.e., the state announced it will hunt wolves), the conduct of the science was not fully transparent beginning with the 1999 Plan. Whether the authors of the 1999 Plan, its 2007 addendum, and 2009 book chapter began with MSY thinking or began instead with the assumption of density-dependent growth is unclear, but either way, the problem of using models as justification for policies that are likely derived from value judgments (in this case, valuing maximal yield) is illustrated.

The issue is broader than a scientific or political debate because US federal legal issues (and perhaps constitutional issues) are at play. Legitimate, competing value claims were not explicitly acknowledged, e.g., of Ojibwe sovereign tribes who view wolves as companions and equal to humans and federal treaty rights governing wolf hunting (David, 2009; Fergus and Hill, 2019), nor of diverse opponents of wolf hunting. We did not examine in detail those competing value claims here, but end by pointing out that that State of Wisconsin statutes proclaim that "legal title to, and the custody and protection of, all wild animals within this state is vested in the state for the purposes of regulating the enjoyment, use, disposition, and conservation of these wild animals." (WI STAT. ANN. §29.011).

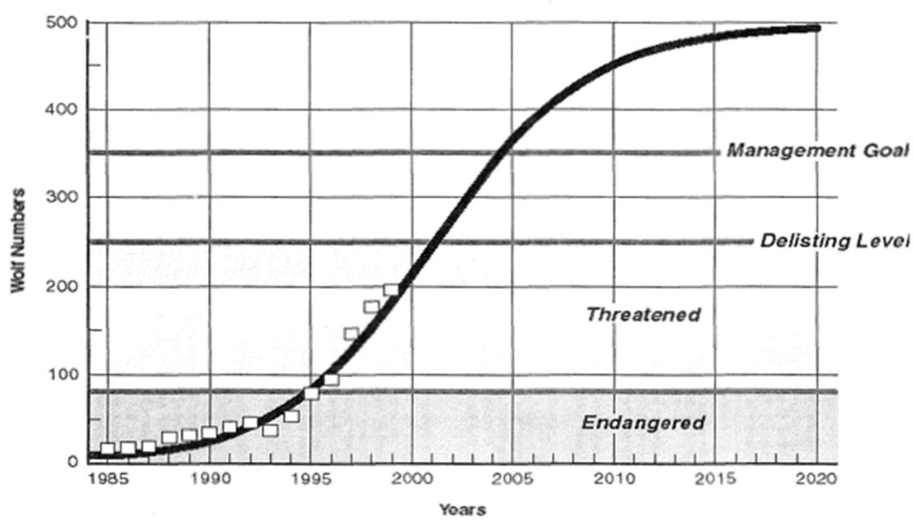

FIGURE 2 | The 1999 Plan Figure 7 "Wisconsin Wolf Population Growth If Carrying Capacity Is 500 Wolves." The 1999 Plan forecast wolf population growth to 2020 from a superimposed, generic logistic growth curve (WDNR, 1999). The model treated the population estimates as a single time series, although according to Treves (2019a) this should have been presented as two time series because of a change in wolf census methods in the winter of 1994–1995. The "Delisting Level" was set at 250, when the legal removal of wolves from the state's list of threatened and endangered species would begin. The "Management Goal" codified a population target (N_{goal} = 350), which is still the state population target today (USFWS, 2020). Vertical lines represented 5-year intervals and horizontal lines represented hundreds of wolves. Arguably, the explicit value judgments (Delisting Level and Management Goal) appear as outputs of the model, though their origin was not explained in WDNR (1999).

omission left a gap in understanding how a broader value-based approach could have occurred. The available evidence suggests that the gap was apparently filled implicitly (i.e., apparently through use of MSY reasoning) and introduced assumptions and untested fact claims about wolf census and density-dependent population dynamics) without fair scrutiny of alternatives, such as the population dynamic not being density dependent, or the carrying capacity not having been estimated accurately. A more reasoned approach would have been for the natural scientists to acknowledge the considerable uncertainty about the science and return to policy-makers (and ideally, social scientists and legal experts) for clarity on the value judgments being made.

NRM can attract controversy, often related to clashing values because in practice, NRM reflects long established belief systems, with varying scientific groundings and unknown or undisclosed risks. Wolves or perhaps endangered species, in general, may be particularly susceptible to implicit value judgments and contested science (Nie, 2001) but prior work has summarized how hundreds of management plans in which a claim was made of science-based harvest yet the basis in science was invisible to the public and to peer scientists seeking information from managers (Artelle K. A. et al., 2018). Some of these cases might fit the descriptions of "political populations" (Darimont et al., 2018), i.e., characterized by unrealistic parameters to promote a particular policy. Scientists working outside of government agencies are also implicated in non-transparency about so-called sustainable-use models. Scott et al. (2007) found policy advocacy throughout most of a random selection of wildlife papers from noted scientific journals, to varied extents, and with different degrees of disclosure. A recent analysis of publications regarding trophy hunting revealed non-governmental researchers evincing breaches of transparency (Koot et al., 2020), including omission of methods, failure to disclose competing interests, reinforcing weak evidence by publishing it repeatedly, and ignoring contradictory evidence but citing allied authors despite the weakness of their evidence (see also Santiago-Avila et al., 2018a; Treves et al., 2019). Therefore, we hypothesize that wildlife science is experiencing its own reproducibility crisis like that of many other scientific disciplines (Open Science Collaboration, 2015; Allison et al., 2016; Baker and Brandon, 2016; Goodman et al., 2016; Munafò et al., 2017; Clark and Alvino, 2018), but with potential consequences for the persistence of wild populations.

Scientists allied to agencies might face a competing interest to conceal potential problems with sustainability from public view and the scrutiny of independent scientists. The competing interest might be if agencies allocating natural resources to current users are under political pressure to allocate more than is safe. The wolf case study is one example where the 1999 estimate of carrying capacity of wolves was likely 25–50% lower than current estimates, the inference being that the MSY-associated population goal was set too low for the safety of the wolf population from unsustainable use. Non-transparent science, fact claims that are never tested, and unwarranted assumptions all characterized that case. Should these processes be widespread, we see a possible explanation for why natural resource management has a record of poor performance globally.

RECOMMENDATIONS FOR NATURAL RESOURCE MANAGEMENT MODELS AND SUSTAINABLE USE POLICIES

To guard against the misappropriation of scientific methods and inferences, and to promote a clearer understanding of the rationale for the management decisions made by public officials, we argue for enhancing the level and scope of scientific integrity practiced in NRM science and fortifying it with rigorous independent review of extraction policies (**Figure 3**).

Recommendation 1 is aimed at the dialogue between science and policy. We encourage a clear demarcation between scientists' value judgments and scientific observations or inferences when providing scientific communications. For example, one might state "We ought to do x or y because we believe those actions are right..." (values) and separately, "we predict the outcomes will benefit actor a and harm actor b" (fact-claims). Those two paired statements make obvious the need for science in service to public policy without cloaking value judgments in fact claims. In turn, the scientists serving the public should state assertions along the lines of, "The net costs and benefits of x and y to actors a and b are..., and the side-effects, long-term consequences, and unnamed actions and actors might be...." The latter statement does not conceal the value judgments themselves, which science cannot evaluate with observations or inferences about how the system works, nor does it ignore unspecified actions, actors, or effects. If those were ignored, the scientists would have unjustly limited their inquiry because science can and should make the public more aware of unanticipated effects and "winners and losers" without interposing the scientists' preferences unduly. Thus, science can inform values and lead to management shifts if the previously unappreciated actors, effects, or actions are perceived as better or worse than the preconceived ones in policy statements.

Recommendation 2 is also aimed at the dialogue between scientists and NRM decision makers. Scientists should be alert to hidden value judgments at each step (Doremus, 2004). For one, we advise scientists not to begin with "maximum sustainable yield" as their own *de facto* starting point or end goal because it camouflages a value judgment within scientific estimates and predictions yet to be validated. A corollary is to present transparently more than one scenario to the public and to policy-makers. The additional scenarios should reflect sensitivity analyses (What if K is much higher or lower? What if natality or mortality are linearly related to density or unrelated?) and risk assessments (How certain are we about our pronouncements? What if conditions change?). Indeed, we recommend higher standards of evidence in modeling sustainability before authorizing extraction. However, we suspect the politics behind the use of wild populations will not abide such delays. Instead, we advise that extraction models be adapted rapidly when changes to allowable uses are proposed. We acknowledge that agreement might be needed from the scientific community on standards of evidence for natural resource extraction under various circumstances (Oro, 2013), as in other fields (van Eeden et al., 2018; Treves et al., 2019). That agreement should address how scientists should respond with precaution when risk or uncertainty is too great to recommend even moderate extraction (Doremus, 2004). Likewise, we suggest that the dependence of MSY on biological estimates (e.g., of carrying capacity, growth rates, and density dependence) be made explicit in scientific communications, so that changes in biological parameters or parameters of human use result in changes in MSY estimates, rather than fixing population goals and quotas for longer periods. Finally, we encourage policy makers to engage with social scientists and legal scholars, who can appropriately characterize the diversity of values among the public and policy makers (Manfredo et al., 2019; Darimont et al., 2021), so that influence of values can be explicitly acknowledged (Doremus, 2004).

This recommendation may require retooling of governmental procedures to support its strictures. Many regulatory processes, under which decisions regarding natural resource extractions are made, are not well suited to the analysis of mutually exclusive goals or alternative scenarios. We point to laws, such as the US National Environmental Policy Act (which entails analyses regarding alternative actions, including a "no action" option) as potential models. While a preferred alternative may still be advanced, analysis of a range of options more transparently reveals the consequences of our choices on both the natural

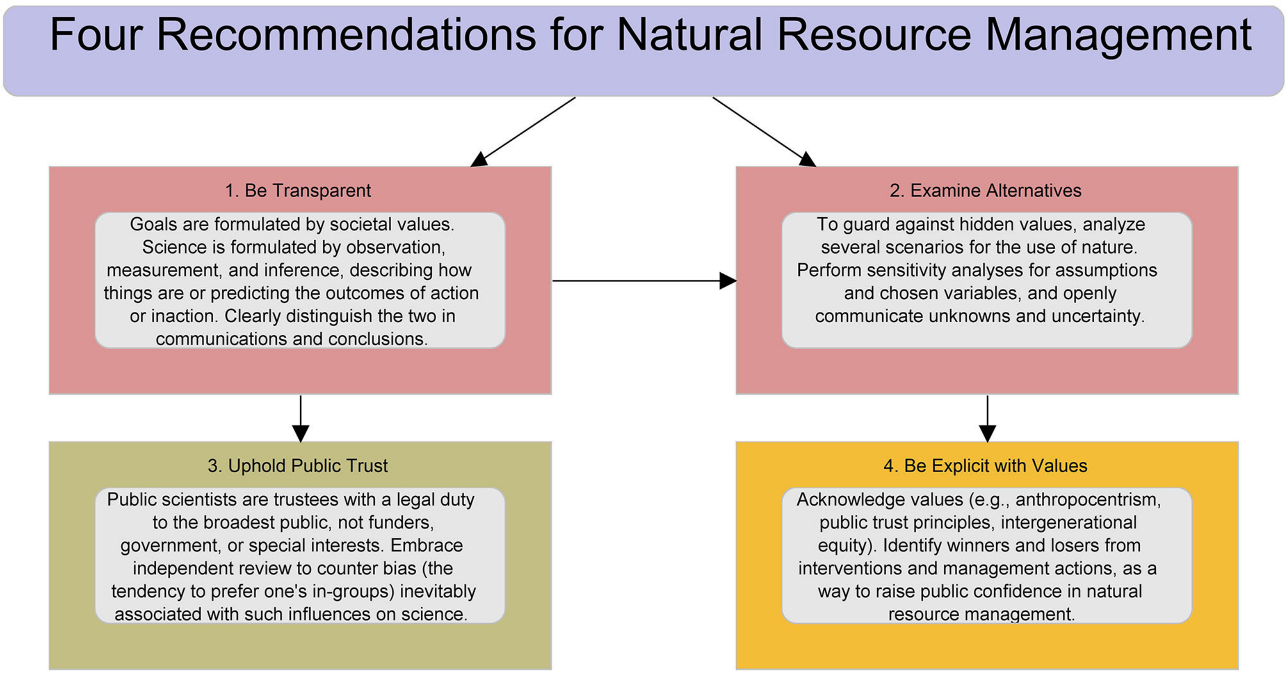

FIGURE 3 | Recommendations for where the science begins and ends in NRM. Pink boxes are aimed at the dialogue between science and public policy, the orange box is aimed at policy-makers, and the green box is aimed at scientists. Arrows indicate cause and effect relationships, e.g., being transparent and examining alternatives will help scientists to uphold the public trust although not sufficient by themselves.

resources themselves and the involved interests (both human and non-human). Alternatives can be better framed in terms of the value judgments that underlie them, and thereby help the public and decision makers to discern among competing policy goals.

Avoiding risk, especially for vulnerable parties, is often an ethical standard for well-reasoned action, regardless of the uncertainty or magnitude of the risk measured by scientists. Risk and uncertainty can be characterized or quantified and should be disclosed, which can be the foundation of a more informed decision and can help efforts to be adaptive in the future (Doremus, 2004; Regan et al., 2005; Artelle et al., 2013; Chapron and Treves, 2016; Milner-Gulland and Shea, 2017). Such clarity might also motivate efforts to increase the quality of ecosystems so that carrying capacity would be increased for populations facing human use, which might favor preservation for the future. The latter is a value judgment consistent with public trust thinking described below and also consistent with some indigenous systems of values and associated management practice.

Our third recommendation is that the vital role of independent review deserves amplification (Allison et al., 2016). Independent reviewers can help scientists see the alternatives and make them more than straw-person hypotheses. Also, diversity within the groups of scientists working on a problem may enhance the transparency of assumptions held by a smaller number of scientists who have been trained similarly, influenced each other over long periods, or face similar incentives for particular methods or ways of interpreting observations. Indeed, the values held by scientists within US wildlife management agencies often do not reflect that of the broader public (Manfredo et al., 2019). The legal doctrine of the public trust could provide an important guide to NRM policy-makers and managers when their personal values do not match the majority of the broad public (Treves et al., 2017b). It forms the basis for guidance to the judicial, legislative, and executive branches of democratic governments that declares that components of the environment are held in trust for the broadest public, including current and future generations. That legal doctrine has been interpreted by many to imply a thorough and stringent transparency by the trustees (e.g., agencies and individual staff) as a legal duty to account explicitly and in a sophisticated manner for uses and preservation of the trust components, particularly when allocating public assets to private users, as is usually the case with NRM (Sax, 1970, 1971, 1980–1981; Wood, 2009, 2013; Blumm and Wood, 2017; Treves et al., 2017b, 2018a). This legal tradition stands in stark contrast to interpretations that professional societies and agencies should take sides with extractive user groups, often in opposition to private property and animal rights interests, e.g., synopsis in Batcheller et al. (2010). Trustees are called to avoid practices that promote picking their preferred scientists to cite or cherry picking their preferred scientific findings and to reject the notion that governments can vaguely aspire to natural resource sustainability without enforcing measurable goals or enforcing against illegal uses (Nie et al., 2020). Precautionary decision making, intergenerational equity, and public trust thinking of the sort we recommend above are not new. Sharing a concern for future generations' needs and non-anthropocentric concerns for other beings, contemporary indigenous governance systems are notable in our context of transparently disclosing the role of values in their governance (Artelle K. et al., 2018). For example, many such NRM governance documents begin by stating underlying and guiding principles (e.g., Te Runanga o Kaikoura, 2007; Marine Planning Partnership Initiative, 2015; Fergus and Hill, 2019), often with a cultural context that brings meaning to the analysis as a whole.

Interest group relationships to scientists can potentially lead to corruption if interest groups can capture agencies, and agencies, in turn, control funding that can capture scientists. Alliances or rivalries between agencies and scientists are, by definition, competing interests that commonly bias science and often lead to irreproducible results (Munafò et al., 2017). NRM is not revenue-neutral so the policy neutrality of scientists who may stand to benefit from extraction is paramount—particularly regarding the analysis of winners and losers. In North America, wildlife agencies are commonly and unduly responsive to a minority of extractive interest groups (Gill, 1996; Batcheller et al., 2010; Clark and Milloy, 2014; Treves et al., 2017b; Serfass et al., 2018), so the scientists who support agency plans frequently encounter competing interests and become suspect by the public and peers of biased results (Doremus, 2004, Rohlf, 2019). Stringent attention to principles of scientific integrity (National Academies of Science, Engineering and Medicine, 2017) and following long-standing and novel safeguards for reproducibility (Allison et al., 2016; Munafò et al., 2017) would go a long way to avoiding a full-blown reproducibility crisis and losing public confidence in the field of sustainable use altogether. Accordingly, we recommend that natural resource managers seek authentic independence in their reviewers, which implies data sharing, replication of findings, tests of cherished assumptions, and avoiding affiliative or antagonistic relationships with any scientists. Separating funding for science from the policy-making arms of the government would also help if independence between the two arms were enforced.

The above relates to unstated and broader value judgments about human claims to nature. Therefore, our final recommendation relates to transparent claims and assessments of winners and losers. The terms and techniques of sustainable use and MSY expose an underlying anthropocentric paradigm. Treating living organisms as objects that can be "owned," subject to "harvest," or the amount such extraction "yields" enfolds value judgments about the priority of humans over non-humans. These terms are not scientific terms but rather euphemisms (Johns and DellaSala, 2017) and privilege the worldviews of some people over those of others, e.g., settler societies over Indigenous peoples (Eichler and Baumeister, 2018). Indeed, much of sustainable wildlife management is simply wildlife demography and ecology, but in the service of anthropocentric interests. We are not asking that management documents expound detailed philosophical discourses on values. Rather, they should simply and coherently state their basic assumptions and the views on which their decisions are based. For example, "we hold non-anthropocentric worldviews that all of nature is held in trust for the futurity of all life on Earth" (an approximation of many of the present authors' worldviews). If the value judgments are stated clearly and allow the general, non-scientific public to discern what is evidence and what is value based, the discussion has improved in our view and that of others who have taken deep looks at NRM and endangered species policy (Doremus, 2004; Carroll et al., 2017; Nie et al., 2020).

In conclusion, we believe that scientific integrity is a fundamental professional ethic and, in many cases, a legal obligation of scientists. Public scientists or government trustees who compromise scientific integrity open themselves to capture by narrow interest groups vying over permit fees or private uses of nature (Finley, 2011; Kolowich, 2016; Treves et al., 2017b). Our cautions are particularly focused on public scientists—individual scientists supported by public monies, whether by past training, salaries, or current project grants. We encourage strict adherence to transparency which demands introspection by scientists first and then clear, honest communication to all others.

AUTHOR CONTRIBUTIONS

AT wrote the first draft. All authors contributed equally to the conception of the study and contributed revisions.

FUNDING

AT and MK received support from the Brooks Institute for Animal Rights Law & Policy. CD, KA, and PP were generally supported in part by the Raincoast Conservation Foundation, with KA primarily supported by the Vanier and Mitacs Fellowships.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2021.631998/full#supplementary-material

REFERENCES

Allison, D. B., Brown, A. W., George, B. J., and Kaiser, K. A. (2016). Reproducibility: a tragedy of errors. *Nature* 530, 27–29. doi: 10.1038/530027a

Andrews, K., Comstock, G. L., Donaldson, S., Fenton, A., John, T. M., Johnson, L. S. M., et al. (2019). *Chimpanzee Rights: The Philosopher's Brief*. New York, NY: Routledge.

Artelle, K., Stephenson, J., Bragg, C., Housty, J., Housty, W., Kawharu, M., et al. (2018). Values-led management: the guidance of place-based values in environmental relationships of the past, present, and future. *Ecol. Soc.* 23:35. doi: 10.5751/ES-10357-230335

Artelle, K. A., Anderson, S. C., Cooper, A. B., Paquet, P. C., Reynolds, J. D., and Darimont, C. T. (2013). Confronting uncertainty in wildlife management: performance of grizzly bear management. *PLos ONE* 8:e78041. doi: 10.1371/journal.pone.0078041

Artelle, K. A., Reynolds, J. C., Paquet, P. C., and Darimont, C. T. (2014). When science-based management isn't. *Science* 343:1311. doi: 10.1126/science.343.6177.1311-a

Artelle, K. A., Reynolds, J. D., Treves, A., Walsh, J. C., Paquet, P. C., and Darimont, C. T. (2018). Hallmarks of science missing from North American wildlife management. *Sci. Adv.* 4:eaao0167. doi: 10.1126/sciadv.aao0167

Baker, M., and Brandon, K. (2016). 1,500 scientists lift the lid on reproducibility. *Nature* 533, 452–454. doi: 10.1038/533452a

Batcheller, G. R., Bambery, M. C., Bies, L., Decker, T., Dyke, S., Guynn, D., et al. (2010). *The Public Trust Doctrine: Implications for Wildlife Management and Conservation in the United States and Canada*. Bethesda, MD: The Wildlife Society, the Association of Fish and Wildlife Agencies (AFWA), the Western Association of Fish and Wildlife Agencies (WAFWA), and the Wildlife Management Institute (WMI).

Blumm, M. C., and Wood, M. C. (2017). "No Ordinary Lawsuit": climate change, due process, and the public trust doctrine. *Am. Univ. Law Rev.* 67, 1–83. Available online at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2954661

Brook, B., and Bradshaw, C. (2006). Strength of evidence for density dependence in abundance time series of 1198 species. *Ecology* 87, 1445–1451. doi: 10.1890/0012-9658(2006)87[1445:SOEFDD]2.0.CO;2

Carroll, C., Hartl, B., Goldman, G. T., Rohlf, D. J., Treves, A., Kerr, J. T., et al. (2017). Defending scientific integrity in conservation policy processes: lessons from Canada, Australia, and the United States. *Conserv. Biol.* 31, 967–975. doi: 10.1111/cobi.12958

Carroll, C., Rohlf, D. J., Noon, B. R., and Reed, J. M. (2012). Scientific integrity in recovery planning and risk assessment: comment on Wilhere. *Conserv. Biol.* 26, 743–745. doi: 10.1111/j.1523-1739.2012.01875.x

Ceballos, G., and Ehrlich, P. R. (2018). The misunderstood sixth mass extinction. *Science* 60, 1080–1081. doi: 10.1126/science.aau0191

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., and Palmer, T. M. (2015). Accelerated modern human–induced species losses: entering the sixth mass extinction. *Sci. Adv.* 1:e1400253. doi: 10.1126/sciadv.1400253

Ceballos, G., Ehrlich, P. R., and Raven, P. H. (2020). Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. *Proc. Natl. Acad. Sci. U.S.A.* 117, 13596–13602. doi: 10.1073/pnas.1922686117

Chapron, G., and Treves, A. (2016). Blood does not buy goodwill: allowing culling increases poaching of a large carnivore. *Proc. R. Soc. B* 283:20152939. doi: 10.1098/rspb.2015.2939

Chapron, G., and Treves, A. (2017). Reply to comments by Olson et al. 2017 and Stien 2017. *Proc. R. Soc. B* 284:20171743. doi: 10.1098/rspb.2017.1743

Clark, A., and Alvino, G. (2018). "Building research evidence towards reproducibility of animal research," in *PLoS ONE blog*. Available online at: https://everyone.plos.org/2018/08/06/arrive-rct/

Clark, S. G., and Milloy, C. (2014). "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*, eds S. G. Clark and M. B. Rutherford (Chicago, IL: The University of Chicago Press), 289–324. doi: 10.7208/chicago/9780226107547.003.0009

COPE, C.o.P.E. (2019). "COPE guidelines: retraction guidelines," in *Promoting Integrity in Scholarly Research and its Publication*. Available online at: https://publicationethics.org/retraction-guidelines. doi: 10.24318/cope.2019.1.4

Darimont, C. T., Artelle, K. A., Moola, F., and Paquet, P. (2017). Trophy hunting: science on its own can't dictate policy. *Nature* 551:565. doi: 10.1038/d41586-017-07553-6

Darimont, C. T., Fox, C. H., Bryan, H. M., and Reimchen, T. E. (2015). The unique ecology of human predators. *Science* 349, 858–860. doi: 10.1126/science.aac4249

Darimont, C. T., Hall, H., Mihalik, I., Artelle, K. A., Eckert, L., and Paquet, P. (2021). Large carnivore hunting and the social license to hunt. *Conserv. Biol.* (in press). doi: 10.1111/cobi.13657

Darimont, C. T., Paquet, P. C., Treves, A., Artelle, K. A., and Chapron, G. (2018). Political populations of large carnivores. *Conserv. Biol.* 32, 747–749. doi: 10.1111/cobi.13065

David, P. (2009). "Ma'iingan and the Ojibwe," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: An Endangered Species Success Story*, eds A. P. Wydeven, T. R. Van Deelen, and E. J. Heske (New York, NY: Springer), 267–278.

Doremus, H. (2004). The purposes, effects & future of the ESA's BAS mandate. *Environ. Law* 34, 397–450. Available online at: https://escholarship.org/uc/item/3md016kg

Eichler, L., and Baumeister, D. (2018). Hunting for justice: an indigenous critique of the North American model of wildlife conservation. *Environ. Soc.* 9, 75–90. doi: 10.3167/ares.2018.090106

FAO (2020). *State of World Fisheries and Aquaculture*. Rome: Food and Agricultural Organization of the United Nations. Available online at: http://www.fao.org/publications/sofia/2020/en/ (accessed Decemebr 28, 2020).

Fergus, A., and Hill, L. (2019). *Mashkiiziibii Wildlife Program. Mashkiiziibii Ma'iingan (Gray Wolf) Relationship Plan (Edition 2).*, Odanah, WI: Bad River Band of Lake Superior Tribe of Chippewa Indians, Mashkiiziibii Natural Resources Department. Available online at: http://www.badriver-nsn.gov/wp-content/uploads/2020/01/NRD_MaiinganPlan_2019.pdf (accessed December 28, 2020).

Finley, C. (2011). *All the Fish in the Sea: Maximum Sustainable Yield and the Failure of Fisheries Management*. Chicago, IL: University of Chicago Press.

Fowler, C. W. (1987). "A review of density dependence in populations of large mammals," in *Current Mammalogy*, ed H. H. Genoways (Boston, MA: Springer), 401–441. doi: 10.1007/978-1-4757-9909-5_10

Fryxell, J. M., Packer, C., McCann, K., Solberg, E. J., and Saether, B.-E. (2010). Resource management cycles and the sustainability of harvested wildlife populations. *Science* 329, 903–906. doi: 10.1126/science.1185802

Garrard, G., Fidler, F., Wintle, B., Chee, Y., and Bekessy, S. (2016). Beyond advocacy: making space for conservation scientists in public debate. *Conserv. Lett.* 9, 208–212. doi: 10.1111/conl.12193

Gill, R. B. (1996). The wildlife professional subculture: the case of the crazy aunt. *Hum. Dimens. Wildl.* 1, 60–69. doi: 10.1080/10871209609359052

Goodman, S., Fanelli, D., and Ioannidis, J. (2016). What does research reproducibility mean? *Sci. Transl. Med.* 8:341ps312. doi: 10.1126/scitranslmed.aaf5027

Houck, O. A. (2001). Damage control: a field guide to important euphemisms in environmental law. *Tulane Environ. Law J.* 15, 129–132. Available online at: https://journals.tulane.edu/elj/arWcle/view/2064

Jacquet, J., and Delon, N. (2018). The values behind calculating the value of trophy hunting. *Conserv. Biol.* 30, 910–911. doi: 10.1111/cobi.12749

Johns, D., and DellaSala, D. A. (2017). Caring, killing, euphemism and George Orwell: how language choice undercuts our mission. *Biol. Conserv.* 211, 174–176. doi: 10.1016/j.biocon.2017.03.030

Kirkwood, G. (1981). Allowing for risks in setting catch limits based on MSY. *Math. Biosci.* 53, 19–129. doi: 10.1016/0025-5564(81)90042-0

Kolowich, S. (2016). *The Water Next Time: Professor Who Helped Expose Crisis in Flint Says Public Science Is Broken*. Chronicle of Higher Education. Available online at: http://chronicle.com/article/The-Water-Next-Time-Professor/235136

Koot, S., Hebinck, P., and Sullivan, S. (2020). Science for success—a conflict of interest? Researcher position and reflexivity in socio-ecological research for CBNRM in Namibia. *Soc. Nat. Resour.* 1–18. doi: 10.1080/08941920.2020.1762953

Lackey, R. (2007). Science, scientists, and policy advocacy. *Conserv. Biol.* 21, 12–17. doi: 10.1111/j.1523-1739.2006.00639.x

Larkin, P. A. (1977). An epitaph for the concept of maximum sustained yield. *Trans. Am. Fish. Soc.* 106, 1–11. doi: 10.1577/1548-8659(1977)106<1:AEFTCO>2.0.CO;2

Levi, T., Darimont, C. T., MacDuffee, M., Mangel, M., Paquet, P. C., and Wilmers, C. C. (2012). Using grizzly bears to assess harvest-ecosystem tradeoffs in Salmon fisheries. *PLoS Biol.* 10:e1001303. doi: 10.1371/journal.pbio.1001303

Lynn, W. S. (2006). "Between science and ethics: what science and the scientific method can and cannot contribute to conservation and sustainability," in *Gaining Ground: In Pursuit of Ecological Sustainability*, ed D. Lavigne (Limerick: University of Limerick), 191–205.

Lynn, W. S. (2010). Discourse and wolves: science, society and ethics. *Soc. Anim.* 18, 75–92. doi: 10.1163/106311110X12586086158529

Lynn, W. S. (2018). Bringing ethics to wild lives: shaping public policy for barred and northern spotted owls. *Soc. Anim.* 26, 217–238. doi: 10.1163/15685306-12341505

Manfredo, M. J., and Dayer, A. A. (2004). Concepts for exploring the social aspects of human–wildlife conflict in a global context. *Hum. Dimens. Wildl.* 9, 317–328. doi: 10.1080/10871200490505765

Manfredo, M. J., Salerno, J., Sullivan, L., and Berger, J. (2019). For US wildlife management, social science needed now more than ever. *BioScience* 69, 960–961. doi: 10.1093/biosci/biz122

Marine Planning Partnership Initiative (2015). *Haida Gwaii Marine Plan*. Available online at: https://mappocean.org/haida-gwaii/haida-gwaii-marine-plan/ (accessed December 28, 2020).

Mark, J. (2014). Eco euphemisms confuse our understanding of environmental destruction. *Earth Island J*. Available online at: https://www.earthisland.org/journal/index.php/articles/entry/eco_euphemisms_confuse_our_understanding_of_environmental_destruction/

Mejlgaard, N., Bouter, L. M., Gaskell, G., Kavouras, P., Allum, N., Bendtsen, A., et al. (2020). Research integrity: nine ways to move from talk to walk. *Nature* 586, 358–360. doi: 10.1038/d41586-020-02847-8

Menon, V., and Lavigne, D. M. (2006). "Attitudes, values and objectives: the real basis of wildlife conservation," in *Gaining Ground, In Pursuit of Ecological Sustainability* ed D. M. Lavigne (Limerick: University of Limerick), 173–190.

Milner-Gulland, E. J., and Shea, K. (2017). Embracing uncertainty in applied ecology. *J. Appl. Ecol.* 54, 2063–2068. doi: 10.1111/1365-2664.12887

Mladenoff, D. J., Haight, R. G., Sickley, T. A., and Wydeven, A. P. (1997). Causes and implications of species restoration in altered ecosystems. *Bioscience* 47, 21–31. doi: 10.2307/1313003

Mladenoff, D. J., Sickley, T. A., Haight, R. G., and Wydeven, A. P. (1995). A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. *Conserv. Biol.* 9, 279–294. doi: 10.1046/j.1523-1739.1995.9020279.x

Munafò, M. R., Nosek, B. A., Bishop, D. V. M., Button, K. S., Chambers, C. D., Percie du Sert, N., et al. (2017). A manifesto for reproducible science. *Nat. Hum. Behav.* 1:21. doi: 10.1038/s41562-016-0021

National Academies of Science, Engineering and Medicine (2017). *Fostering Integrity in Research*. Washington, DC: The National Academies Press.

Nelson, M. P., and Vucetich, J. A. (2009). On advocacy by environmental scientists: what, whether, why, and how. *Conserv. Biol.* 23, 1090–1101. doi: 10.1111/j.1523-1739.2009.01250.x

Nelson, M. P., Vucetich, J. A., Paquet, P. C., and Bump, J. K. (2011). An inadequate construct? *Wildl. Profess.* 5, 58–60. Available online at: https://isleroyalewolf.org/sites/default/files/Nelson%20et%20al%202011-An%20Inadequate%20Construct.pdf

Nie, M. (2001). The sociopolitical dimensions of wolf management and restoration in the United States. *Hum. Ecol. Rev*. 8, 1–11.

Nie, M., Landers, N., and Bryan, M. (2020). The public trust in wildlife: closing the implementation gap in 13 western states. *Environ. Law Rep.* 50, 10909–10919. doi: 10.2139/ssrn.3679325

OED (2020). *Oxford English Dictionary*. Available online at: http://www.oed.com.ezproxy.library.wisc.edu/ (accessed May 30, 2020).

OED (2021). *Oxford English Dic1onary*. Available online at: https://www.oed.com/

Olson, E. R., Treves, A., Wydeven, A. P., and Ventura, S. (2014). Landscape predictors of wolf attacks on bear-hunting dogs in Wisconsin, USA. *Wildl. Res.* 41, 584–597. doi: 10.1071/WR14043

Open Science Collaboration (2015). *Reproducibility Project: Psychology*. OSF. Available online at: https://osf.io/ezcuj/. doi: 10.17605/OSF.IO/EZCUJ

Oro, D. (2013). Grand challenges in population dynamics. *Front. Ecol. Evol.* 1: 2. doi: 10.3389/fevo.2013.00002

Patrick, W., and Cope, J. (2014). Examining the 10-year rebuilding dilemma for U. S. fish stocks. *PLoS ONE* 9:e112232. doi: 10.1371/journal.pone.0112232

Peery, M. Z., Jones, G. M., Gutiérrez, R. J., Redpath, S. M., Franklin, A. B., Simberloff, D., et al. (2019). The conundrum of agenda-driven science in conservation. *Front. Ecol. Environ.* 17, 80–82. doi: 10.1002/fee.2006

Pianka, E. R. (2000). *Evolutionary Ecology, 6th Edn.* San Francisco, CA: Benjamin-Cummings, Addison-Wesley-Longman.

Ratikainen, I., Gill, J., Gunnarsson, T., Sutherland, W., and Kokko, H. (2008). When density dependence is not instantaneous: theoretical developments and management implications. *Ecol. Lett.* 11, 184–198. doi: 10.1111/j.1461-0248.2007.01122.x

Regan, H. M., Ben-Haim, Y., Langford, B., Wilson, W. G., Lundberg, P., Andelman, S. J., et al. (2005). Robust decision-making under severe uncertainty for conservation management. *Ecol. Appl.* 15, 1471–1477. doi: 10.1890/03-5419

Ripple, W. J., Wolf, C., Newsome, T. M., Galetti, M., Alamgir, M., Crist, E., et al. (2017). World scientists' warning to humanity: a second notice. *Bioscience* 67, 1026–1028. doi: 10.1093/biosci/bix125

Rohlf, D. J. (2019). Scientists, agendas, and litigation: a response to Peery et al. *Front. Ecol. Environ.* 17, 555–556. doi: 10.1002/fee.2130

Santiago-Ávila, F. J. (2019). *Survival rates and disappearances of radio-collared wolves in Wisconsin* (Ph.D. dissertation), Nelson Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI, United States.

Santiago-Ávila, F. J., Chappell, R. J., and Treves, A. (2020). Liberalizing the killing of endangered wolves was associated with more disappearances of collared individuals in Wisconsin, USA. *Sci. Rep*. 10:13881 doi: 10.1038/s41598-020-70837-x

Santiago-Avila, F. J., Cornman, A. M., and Treves, A. (2018a). Killing wolves to prevent predation on livestock may protect one farm but harm neighbors. *PLoS ONE* 13:e0189729. doi: 10.1371/journal.pone.0189729

Santiago-Avila, F. J., Lynn, W. S., and Treves, A. (2018b). "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, NY: Taylor & Francis), 227–251. doi: 10.4324/9781315175454-12

Sax, J. L. (1980–1981). Liberating the public trust doctrine from its historical shackles. *UC Davis Law Rev.* 14, 185–194.

Sax, J. L. (1970). The public trust doctrine in natural resource law: effective judicial intervention. *Michigan Law Rev.* 68, 471–566. doi: 10.2307/1287556

Sax, J. L. (1971). *Defending the Environment: A Strategy for Citizen Action*. New York, NY: Knopf.

Schrader-Frechette, K. S., and McCoy, E. D. (1994). How the tail wags the dog: how value judgments determine ecological science. *Environ. Values* 3, 107–120. doi: 10.3197/096327194776679764

Scott, J., Rachlow, J., Lackey, R., Pidgorna, A., Aycrigg, J., Feldman, G., et al. (2007). Policy advocacy in science: prevalence, perspectives, and implications for conservation biologists. *Conserv. Biol.* 21, 29–35. doi: 10.1111/j.1523-1739.2006.00641.x

Serfass, T. L., Brooks, R. P., and Bruskotter, J. T. (2018). North American model of wildlife conservation: empowerment and exclusivity hinder advances in wildlife conservation. *Can. Wildl. Biol. Manage.* 7, 101–118.

Stenglein, J. L., Zhu, J., Clayton, M. K., and Van Deelen, T. R. (2015). Are the numbers adding up? Exploiting discrepancies among complementary population models. *Ecol. Evol.* 5, 368–376. doi: 10.1002/ece3.1365

Stern, B., and O'Shea, E. (2019). A proposal for the future of scientific publishing in the life sciences. *PLoS Biol.* 17:e3000116. doi: 10.1371/journal.pbio.3000116

Te Runanga o Kaikoura. (2007). *Te Poha o Tohu Raumati Te Runanga o Kaikoura Environmental Management Plan*. Takahanga Marae Kaikoura. Available online at: https://ngaitahu.iwi.nz/te-runanga-o-ngai-tahu/papatipu-runanga/kaikoura/environmental-management-plan/ (accessed December 28, 2020).

Treves, A. (2009). Hunting to conserve large carnivores. *J. Appl. Ecol.* 46, 1350–1356. doi: 10.1111/j.1365-2664.2009.01729.x

Treves, A. (2019a). *Peer Review of the Proposed Rule and Draft Biological Report for Nationwide Wolf Delisting*. Washington, DC: Department of Interior. Department of Interior, U. S. Fish & Wildlife Service. Available online at: https://www.fws.gov/endangered/esa-library/pdf/Final%20Gray%20Wolf%20Peer%20Review%20Summary%20Report_053119.pdf(accessed December 28, 2020).

Treves, A. (2019b). Scientific ethics and the illusion of naïve objectivity. *Front. Ecol. Environ.* 7:361. doi: 10.1002/fee.2091

Treves, A. (2020). Elephants and pandemics. *Anim. Sent.* 28, 330–335. Available online at: https://animalstudiesrepository.org/animsent/vol5/iss28/20/. doi: 10.51291/2377-7478.1582

Treves, A., Artelle, K. A., Darimont, C. T., Lynn, W. S., Paquet, P. C., Santiago-Avila, F. J., et al. (2018a). Intergenerational equity can help to prevent climate change and extinction. *Nat. Ecol. Evol.* 2, 204–207. doi: 10.1038/s41559-018-0465-y

Treves, A., Artelle, K. A., Darimont, C. T., and Parsons, D. R. (2017a). Mismeasured mortality: correcting estimates of wolf poaching in the United States. *J. Mammal.* 98, 1256–1264. doi: 10.1093/jmammal/gyx052

Treves, A., Bergstrom, B. J., Parsons, D., Paquet, P. C., and Thiel, R. P. (2014). *Letter to the USFWS Describing Concerns About Use of the Best Available Science in the State of Wisconsin's Post-delisting Monitoring Report on Gray Wolves*. Available online at: http://faculty.nelson.wisc.edu/treves/ (accessed December 28, 2020).

Treves, A., Chapron, G., López-Bao, J. V., Shoemaker, C., Goeckner, A., and Bruskotter, J. T. (2017b). Predators and the public trust. *Biol. Rev.* 92, 248–270. doi: 10.1111/brv.12227

Treves, A., Jurewicz, R. L., Naughton-Treves, L., Rose, R. A., Willging, R. C., and Wydeven, A. P. (2002). Wolf depredation on domestic animals: control and compensation in Wisconsin, 1976–2000. *Wildl. Soc. Bull.* 30, 231–241. Available online at: https://www.jstor.org/stable/3784658

Treves, A., Langenberg, J. A., López-Bao, J. V., and Rabenhorst, M. F. (2017c). Gray wolf mortality patterns in Wisconsin from 1979 to 2012. *J. Mammal.* 98, 17–32. doi: 10.1093/jmammal/gyw145

Treves, A., Martin, K. A., Wiedenhoeft, J. E., and Wydeven, A. P. (2009a). "Dispersal of gray wolves in the Great Lakes region," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: An Endangered Species Success Story*, eds A. P. Wydeven, T. R. Van Deelen, and E. J. Heske (New York, NY: Springer), 191–204. doi: 10.1007/978-0-387-85952-1_12

Treves, A., Martin, K. A., Wydeven, A. P., and Wiedenhoeft, J. E. (2011). Forecasting environmental hazards and the application of risk maps to predator attacks on livestock. *Bioscience* 61, 451–458. doi: 10.1525/bio.2011.61.6.7

Treves, A., Naughton-Treves, L., Harper, E. L., Mladenoff, D. J., Rose, R. A., Sickley, T. A., et al. (2004). Predicting human-carnivore conflict: a spatial model based on 25 years of wolf predation on livestock. *Conserv. Biol.* 18, 114–125. doi: 10.1111/j.1523-1739.2004.00189.x

Treves, A., Santiago-Ávila, F., and Lynn, W. S. (2018b). Just preservation. *Biol. Conserv.* 229, 134–141. doi: 10.1016/j.biocon.2018.11.018

Treves, A., Santiago-Ávila, F. J., Popescu, V. D., Paquet, P. C., Lynn, W. S., Darimont, C. T., et al. (2019). Trophy hunting: insufficient evidence. *Science* 366:435. doi: 10.1126/science.aaz4389

Treves, A., Wallace, R. B., and White, S. (2009b). Participatory planning of interventions to mitigate human-wildlife conflicts. *Conserv. Biol.* 23, 1577–1587. doi: 10.1111/j.1523-1739.2009.01242.x

USFWS (2020). Endangered and threatened wildlife and plants; removing the gray wolf (*Canis lupus*) from the list of endangered and threatened wildlife (final rule). *Federal Register* 85, 69778–69895. Available online at: https://www.govinfo.gov/content/pkg/FR-2020-11-03/pdf/2020-24171.pdf?utm_campaign=subscripWon+mailing+list&utm_source=federalregister.gov&utm_medium=email

Van Deelen, T. R. (2009). "Growth rate and equilibrium size of a recolonizing wolf population in the southern Lake Superior region," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: an Endangered Species Success Story*, eds A. P. Wydeven, T. R. Van Deelen, and E. J. Heske (New York, NY: Springer), 139–154. doi: 10.1007/978-0-387-85952-1_9

van Eeden, L. M., Eklund, A., Miller, J. R. B., López-Bao, J. V., Cejtin, M. R., Chapron, G., et al. (2018). Carnivore conservation needs evidence-based livestock protection. *PLoS Biol.* 16:e2005577. doi: 10.1371/journal.pbio.2005577

Vucetich, J. A., and Nelson, M. P. (2014). *Wolf Hunting and the Ethics of Predator Control, In Political Science, Comparative Politics, Political Theory*. Oxford: Oxford Handbooks Online.

WDNR (1999). *Wisconsin Wolf Management Plan*. Madison, WI: Wisconsin Department of Natural Resources.

WDNR (2007). *Wisconsin Wolf Management Plan Addendum 2006 and 2007*. Madison, WI: Wisconsin Department of Natural Resources. Available online at: https://dnr.wi.gov/files/PDF/pubs/ER/ER0099.pdf (accessed May 19, 2018).

Wilhere, G. F. (2012). Inadvertent policy advocacy in peer review of recovery plans: reply to Carroll et al. *Conserv. Biol.* 26, 746–748. doi: 10.1111/j.1523-1739.2012.01874.x

Wilhere, G. F., Maguire, L. A., Michael Scott, J., Rachlow, J. L., Goble, D. D., and Svancara, L. K. (2012). Conflation of values and science: response to Noss et al. *Conserv. Biol.* 26, 943–944. doi: 10.1111/j.1523-1739.2012.01900.x

Williams, C. (2013). Accounting for wildlife life-history strategies when modeling stochastic density-dependent populations: a review. *J. Wildl. Manage.* 77, 4–11. doi: 10.1002/jwmg.429

Wood, M. C. (2009). Advancing the sovereign trust of government to safeguard the environment for present and future generations (part I): ecological realism and the need for a paradigm shift. *Environ. Law* 43, 44–88. doi: 10.2139/ssrn.1946078

Wood, M. C. (2013). *Nature's Trust*. New York, NY: Cambridge University Press.

Wydeven, A. P., Mladenoff, D. J., Sickley, T. A., Kohn, B. E., Thiel, R. P., and Hansen, J. L. (2001). Road density as a factor in habitat selection by wolves and other carnivores in the Great Lakes Region. *Endang. Species Update* 18, 110–114. Available online at: https://go.gale.com/ps/anonymous?id=GALE%7CA79902391&sid=googleScholar&v=2.1&it=r&linkaccess=fulltext&issn=10813705&p=AONE&sw=w

Wydeven, A. P., Treves, A., Brost, B., and Wiedenhoeft, J. E. (2004). "Characteristics of wolf packs in Wisconsin: identification of traits influencing depredation," in *People and Predators: From Conflict to Coexistence*, eds N. Fascione, A. Delach, and M. E. Smith (Washington, DC: Island Press), 28–50.

Wydeven, A. P., Wiedenhoeft, J., Schultz, R. N., Thiel, R. P., Jurewicz, R. R., Kohn, B., et al. (2009). "History, population growth and management of wolves in Wisconsin," in *Recovery of Gray Wolves in the Great Lakes Region of the United States: an Endangered Species Success Story*, eds A. P. Wydeven, T. R. Van Deelen, and E. J. Heske (New York, NY: Springer), 87–106. doi: 10.1007/978-0-387-85952-1_6

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supporting Material

The first change in census methods involved tripling the number of wolf census-takers by recruiting citizen volunteers to count wolves independently with variable, undocumented verification by the WDNR biologists who had conducted censuses alone previously (WDNR 1999; Wiedenhoeft et al. 2003; Wydeven 1994, 1996; Wydeven and Megown 1995); for further details see the official USFWS peer review (Treves 2019). The second change was actually three changes in methods involving screening and verifying more of the volunteers' data, setting minimum requirements for training and census efforts, and preliminary statistical analyses of differences between volunteers, WDNR biologists, and standardized tests of accuracy for both parties (Wiedenhoeft et al. 2003; Wydeven et al. 2006; Wydeven et al. 2004). Finally, in 2004, the author who designed the wolf census introduced the public to the author who designed the population model. "Between October 2003 and March 2004,… agency personnel were asked to report wolf observations to Tim Van Deelen with DNR Science Bureau." p.8, (Wydeven et al. 2004). Therefore, the authors seemed to have been intimately familiar with the changes in methods and the resulting changes in mean annual growths and variances that resulted from those changes (Treves 2019).

The changes in census methods seem particularly relevant to efforts to understand individual survival and predict the growth of the Wisconsin wolf population (Chapron and Treves 2017; Santiago-Ávila et al. 2020). The census period or method was shown to correlate with hazards for radio-collared wolves (Santiago-Ávila et al. 2020). The above changes in census methods seemed unaccounted for in the three presentations of the state wolf population models (Van Deelen 2009; WDNR 1999, 2007) and subsequent peer-reviewed scientific articles (Olson et al. 2017; Olson et al. 2015; Stenglein et al. 2015a; Stenglein and Van Deelen 2016; Stenglein et al. 2018; Stenglein et al. 2015b). The first peer-reviewed article confused the issue of change in census methods by conflating them with undocumented policy changes, when it stated,

> "The population grew slowly from 1980 to 1995 at which point the winter count surpassed **the endangered status of 80 wolves [sic, a]** (Wydeven et al. 2009). Since 1995, the wolf population increased dramatically, and management policy **changed with respect to the degree to which managers may kill wolves to address depredation problems [sic, b]**. Hence, policy changes and population growth interacted to define three recovery periods… **During 1996–2002, wolves were listed as endangered under the US Endangered Species Act [sic, c]** and protected from all hunting and trapping. In 2003, wolves were downgraded to threatened status and lethal control actions [followed]…. The period 2003–2012 was dominated by this on-again and off-again lethal control management..." internal citations relating to lethal control omitted, emphasis added, p. 371, (Stenglein et al. 2015b).

The paper does not mention the changes in census methods described above and the boldface passages contain errors **[sic a–c]** below.

(sic a) Reclassification is a legal designation, not a biological one, and no change in federal policy was implemented before 2003, as described fully in (Refsnider 2009). Moreover, the architect of the census change and a co-author on the above passage had written, "The 1994-1995 wolf population was 66% above the wolf population present in 1993-1994 (50-57 wolves). This increase probably represents more than just natural reproduction. Some wolves were probably missed in 1993-1994 surveys." p. 10, (Wydeven and Megown 1995). That spike in the population estimate was detected in the winter of 1994-1995 before the observation that wolves had exceeded 80 individuals in April 1995. Therefore, any ostensible change in state or federal management policies (for which there is no record) follows the change in methods, not the other way around.

(sic b) Authority for killing wolves was not granted to the state of Wisconsin until 1 April 2003 (Refsnider 2009). Moreover, lethal methods were only permitted on 1 April 2003, which means 95.9% of that wolf-year (15 April 2002–14 April 2003) should be assigned to the prior policy period without lethal management (Chapron and Treves 2016).

(sic c) Similarly, wolves were federally listed as endangered since the late 1970s, so identifying a break in policy relating to lethal control in 1995 or 1996 is inaccurate.

The errors or inaccuracies noted above were not insignificant given the population modeling used the three recovery periods as parameters, "…we fit a model with three correction factors that were constant within each recovery period (1980–1995, 1996–2002, and 2003–2011)." p.372, (Stenglein et al. 2015b). The first period should have ended in April 1994, before volunteers' data suggested an impossibly large one-year spike in the wolf population and not actual growth. The second period should have ended sometime between summer 2000 and winter 2003–2004 (Wiedenhoeft et al. 2003; Wydeven et al. 2006; Wydeven et al. 2004). Furthermore, the latter authors showed that lethal management changed 5 more times in the period under question, so we cannot understand why Stenglein et al. (2015b) did not define more policy periods by their own stated rationale for defining periods.

Subsequent work by the architects continued to omit serial changes in wolf census methods described above (Stenglein and Van Deelen 2016; Stenglein et al. 2018).

References cited

Chapron, G., Treves, A., 2016. Blood does not buy goodwill: allowing culling increases poaching of a large carnivore. Proceedings of the Royal Society B 283, 20152939.

Chapron, G., Treves, A., 2017. Reply to comments by Olson et al. 2017 and Stien 2017. Proceedings of the Royal Society B 284, 20171743.

Olson, E.R., Crimmins, S., Beyer, D.E., MacNulty, D., Patterson, B., Rudolph, B., Wydeven, A., Van Deelen, T.R., 2017. Flawed analysis and unconvincing interpretation: a comment on Chapron and Treves 2016. Proceedings of the Royal Society of London B 284, 20170273.

Olson, E.R., Stenglein, J.L., Victoria Shelley, Adena R. Rissman, Christine Browne-Nuñez, Zachary Voyles, Wydeven, A.P., Deelen, T.V., 2015. Pendulum swings in wolf management led to conflict, illegal kills, and a legislated wolf hunt. Conservation Letters 8, 351-360.

Refsnider, R., 2009. 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. eds A.P. Wydeven, T.R. Van Deelen, E.J. Heske, pp. 311-330. Springer, New York.

Santiago-Ávila, F.J., Chappell, R.J., Treves, A., 2020. Liberalizing the killing of endangered wolves was associated with more disappearances of collared individuals in Wisconsin, USA. Scientific Reports 10, 13881.

Stenglein, J.L., Gilbert, J.H., Wydeven, A.P., Van Deelen, T.R., 2015a. An individual-based model for southern Lake Superior wolves: A tool to explore the effect of human-caused mortality on a landscape of risk. Ecological Modelling 302, 13-24.

Stenglein, J.L., Van Deelen, T.R., 2016. Demographic and Component Allee Effects in Southern Lake Superior Gray Wolves. PLos ONE 11, 10.1371/journal.pone.0150535

Stenglein, J.L., Wydeven, A.P., Van Deelen, T.R., 2018. Compensatory mortality in a recovering top carnivore: wolves in Wisconsin, USA (1979–2013). Oecologia 187, 99–111.

Stenglein, J.L., Zhu, J., Clayton, M.K., Van Deelen, T.R., 2015b. Are the numbers adding up? Exploiting discrepancies among complementary population models. Ecology and Evolution 5, 368-376.

Treves, A., 2019. Peer review of the proposed rule and draft biological report for nationwide wolf delisting, ed. U.S.F.W.S. Department of Interior. Department of Interior, U.S. Fish & Wildlife Service, Washington, D.C. https://www.fws.gov/endangered/esa-library/pdf/Final%20Gray%20Wolf%20Peer%20Review%20Summary%20Report_053119.pdf,

Van Deelen, T.R., 2009. Growth Rate and Equilibrium Size of a Recolonizing Wolf Population in the Southern Lake Superior Region, In Recovery of Gray Wolves in the Great Lakes Region of the United States: an Endangered Species Success Story. eds A.P. Wydeven, T.R. Van Deelen, E.J. Heske, pp. 139-154. Springer, New York.

WDNR, 1999. Wisconsin Wolf Management Plan. Wisconsin Department of Natural Resources, Madison, WI.

WDNR, 2007. Wisconsin Wolf Management Plan Addendum 2006 and 2007, p. 57. Wisconsin Department of Natural Resources, Madison. https://dnr.wi.gov/files/PDF/pubs/ER/ER0099.pdf, accessed 19 May 2018.

Wiedenhoeft, J.E., Boles, S.R., Wydeven, A.P., 2003. A Volunteer Carnivore Tracking Program and its Potential Use in Monitoring the Timber Wolf (Canis lupus) Population in Northern and Central Wisconsin, In World Wolf Congress 2003: Bridging Science and Community. p. abstract only, Banff, Alberta, Canada..

Wydeven, A.P., 1994. Wisconsin Endangered Resources Report #102: Status of the timber wolf in Wisconsin, performance report 1 July 1993 through 30 June 1994, ed. B.o.E. Resources. Wisconisin Department of Natural Resources, Madison, WI.

Wydeven, A.P., 1996. Wisconsin Timber Wolf Population Monitoring #113: March 31, 1995 - June 31(sic), 1996 report for U.S. Fish & Wildlife Service Region 3, Endangered Species Grant Program Section 6, p. 11 pp. Wisocnisin Department of Natural Resources.

Wydeven, A.P., Megown, R.A., 1995. Wisconsin Endangered Resources Report #104: Status of the timer wolf in Wisconsin, performance report 1 July 1994 through 30 June 1995, ed. B.o.E. Resources. Wisconsin Department of Natural Resources, Madison, WI.

Wydeven, A.P., Wiedenhoeft, J.E., Schultz, R.L., Thiel, R.P., Boles, S.H., Heilhecker, E., 2006. Progress Report of Wolf Population Monitoring in Wisconsin for the Period October 2005 - March 2006, ed. W.D.o.N. Resources. Wisconsin Department of Natural Resources, Park Falls, Wisconsin PUB-ER- 2006.

Wydeven, A.P., Wiedenhoeft, J.E., Schultz, R.L., Thiel, R.P., Boles, S.H., Heilhecker, E., Hall, W.H.J., 2004. Progress Report of Wolf Population Monitoring in Wisconsin for the Period October - March 2004, ed. W.D.o.N. Resources. Wisconsin Department of Natural Resources, Park Falls, Wisconsin PUB-ER- 2004.