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Predators and the public trust

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ABSTRACT

Many democratic governments recognize a duty to conserve environmental resources, including wild animals, as a public trust for current and future citizens. These public trust principles have informed two centuries of U.S.A. Supreme Court decisions and environmental laws worldwide. Nevertheless numerous populations of large-bodied, mammalian carnivores (predators) were eradicated in the 20th century. Environmental movements and strict legal protections have fostered predator recoveries across the U.S.A. and Europe since the 1970s. Now subnational jurisdictions are regaining management authority from central governments for their predator subpopulations. Will the history of local eradication repeat or will these jurisdictions adopt public trust thinking and their obligation to broad public interests over narrower ones? We review the role of public trust principles in the restoration and preservation of controversial species. In so doing we argue for the essential roles of scientists from many disciplines concerned with biological diversity and its conservation. We look beyond species endangerment to future generations' interests in sustainability, particularly non-consumptive uses. Although our conclusions apply to all wild organisms, we focus on predators because of the particular challenges they pose for government trustees, trust managers, and society. Gray wolves *Canis lupus* L. deserve particular attention, because detailed information and abundant policy debates across regions have exposed four important challenges for preserving predators in the face of interest group hostility. One challenge is uncertainty and varied interpretations about public trustees' responsibilities for wildlife, which have created a mosaic of policies across jurisdictions. We explore how such mosaics have merits and drawbacks for biodiversity. The other three challenges to conserving wildlife as public trust assets are illuminated by the biology of predators and the interacting behavioural ecologies of humans and predators. The scientific community has not reached consensus on sustainable levels of human-caused mortality for many predator populations. This challenge includes both genuine conceptual uncertainty and exploitation of scientific debate for political gain. Second, human intolerance for predators exposes value conflicts about preferences for some wildlife over others and balancing majority rule with the protection of minorities in a democracy. We examine how differences between traditional assumptions and scientific studies of interactions between people and predators impede evidence-based policy. Even if the prior challenges can be overcome, well-reasoned policy on wild animals faces a greater challenge than other environmental assets because animals and humans change behaviour in response to each other in the short term. These coupled, dynamic responses exacerbate clashes between uses that deplete wildlife and uses that enhance or preserve wildlife. Viewed in this way, environmental assets demand sophisticated, careful accounting by disinterested trustees who can both understand the multidisciplinary scientific measurements of relative costs and benefits among competing uses, and justly balance the needs of all beneficiaries including future generations. Without public trust principles, future trustees will seldom prevail against narrow, powerful, and undemocratic interests. Without conservation informed by public trust thinking predator populations will face repeated cycles of eradication and recovery. Our conclusions have implications for the many subfields of the biological sciences that address environmental trust assets from the atmosphere to aquifers.

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Key words: *Canis lupus*, carnivore, ecosystem services, endangered species, environmental law, lethal management, policy, sustainability, wolf.

CONTENTS

I. INTRODUCTION

The fundamental principle of the public trust and our starting premise is that just, democratic governments must preserve environmental components as assets held in trust for current and future generations. The governments of at least 22 countries accept some legal responsibilities for environmental conservation as some form of trust to benefit their citizens, although the contours and details vary markedly across jurisdictions (see Fig. 1; Sand, 2004; Blumm & Guthrie, 2012; Sagarin & Turnipseed, 2012). Public trust principles have ancient roots in many cultures, although 19th century courts and 20th century legal scholarship in the U.S.A. played a seminal role in their modern expressions (Sand, 2004; Blumm & Guthrie, 2012; Hare & Blossey, 2014). Despite a long history of recognizing a public trust doctrine (PTD) that includes wildlife as assets (see online Appendix S1 for glossary of terms and case law history), U.S.A. federal and state governments allowed, or actively pursued, the eradication of terrestrial, mammalian, large-bodied, carnivores (predators hereafter) including grizzly bears *Ursus arctos* L., mountain lions *Puma concolor* L. and gray and red wolves *C. rufus* Audubon & Bachman, 1851. Since the 1970s, several large carnivore species have recolonized portions of North America and Europe (Mech, 1995; Eberhardt & Breiwick, 2010; LaRue *et al.*, 2012; Chapron *et al.*, 2014). The future of predator recoveries depends on whether governments embrace and fulfil their trust responsibilities (Bruskotter, Enzler & Treves, 2011, 2012). Even today, the fates of numerous predator species worldwide depend on a complex mix of laws and social norms superimposed on the behavioural ecology of sympatric predators and people (see Sections IV–VI). Here we examine the persistent challenges humanity faces in conserving predators. In parallel, we explore the many obstacles to upholding a public trust. The one illuminates the other. Thus we translate legal instruments and multidisciplinary science to connect biological scientists to policy-makers and legal scholars concerned with environmental conservation. In Section II, we interweave varied perspectives on the U.S.A. PTD with federal and state duties recognized for wildlife conservation, to illustrate the challenges of centralized and decentralized authority for environmental trust assets such as predators. In Section III, we recount the volatile history of U.S.A. policy on predators with a focus on gray wolves, to place current predator conservation in historical context and illuminate a neglected public trust. In Section IV, we examine the lack of scientific consensus on sustainable mortality within predator populations and its consequences for efforts to preserve predators as trust assets. In Section V, we review evidence about human tolerance and intolerance for predators to illustrate two competing hypotheses for predator extirpation and the attendant interventions needed to avoid future extirpation. In Section VI, we review predator behavioural biology and the challenges it poses in attempting to balance consumptive and non-consumptive uses. Finally, in Section VII we recommend steps to implement public trust principles for predator conservation by any government. Throughout, we follow Hare & Blossey (2014) when referring to public trust thinking or principles generally, and we follow Blumm

& Guthrie (2012) when we refer specifically to a PTD in a particular jurisdiction. Appendix S1 presents a glossary of PTD and legal terms.

II. VISIONS OF THE PUBLIC TRUST MEET MOSAICS OF GOVERNMENTAL RESPONSIBILITIES

Although public trust thinking has roots dating back millennia (Sand, 2004), our modern recognition of the PTD began with a few U.S.A. court cases in the early 19th Century. U.S.A. and state Supreme Courts ruled that the 1776 American Revolution made the people sovereign and held the union of states responsible for many, if not all, environmental assets. These include wildlife. One landmark U.S.A. Supreme Court case in particular (Illinois Central Railroad Company, 1892, hereafter Illinois Central) clearly articulated how the public interest in waters and lands represented a permanent trust encompassing diverse environmental resources, which obligated the government to limit private property rights, commercial uses, and grants of environmental assets (see online Appendix S1). The PTD articulated by Illinois Central (1892) is still cited today and featured prominently in the U.S.A. revival of public trust thinking in the 1970s. Some claim that other countries have recently surpassed the U.S.A. in extending and enforcing public trust principles (Blumm & Guthrie, 2012). Certainly E.U. case law positions governments as trustees of the public interest in the environment including wildlife (see online Appendix S1). The international revival is widely credited by recent authors (Hare & Blossey, 2014; Wood, 2014*a*) to the writings and teachings of Judge Joseph Sax (Sax, 1970, 1971, 1980–1981).

(1) A historical, democratic vision of the public trust doctrine (PTD)

Reviewing U.S.A. federal and state case law, Sax articulated a coherent vision of the environmental public trust as an evolving doctrine that was responsive to changing societal needs and whose paramount role was to preserve public, environmental assets for future generations and defend society from undemocratic allocations of environmental assets. We define undemocratic allocations as those that reflect tyranny of minority or majority, or are otherwise illegal or unjust. Sax (1970) urged courts to protect and prioritize the broadest public interest in environmental resources, even if diffuse and difficult to measure,

> '. . . when [ignorance] is joined with the courts' strong feeling that *diffuse public uses are both poorly represented and, by their nature, difficult to measure*, judicial wariness is inevitably enhanced . . . And if the relevant facts are unknown and yet legislatures and administrative agencies show eagerness to go forward, the courts are only reinforced in their overall suspicion that they are dealing with governmental responsiveness to pressures imposed by *powerful but excessively narrow interests*.' (emphasis added, Sax, 1970, pp. 564–565)

For our purposes, 'diffuse' uses of wildlife would be inconspicuous, dispersed in space or time, or affecting individual wild animals subtly (e.g. wildlife watching, aesthetics and reverence). Sax's (1970) formulation and those of recent writers in his tradition (Horner, 2000; Sand, 2004; Hare & Blossey, 2014) differ from narrower views of the PTD that prioritize consumptive uses – especially hunting (NAM Technical Review, 2010). We detail similarities and contrasts between the two perspectives in Section III. Several U.S.A. state and local governments recognize and protect diffuse uses for wildlife in their constitutions, statutes, and mission statements (e.g. Michigan Constitution Article IV Section 52, 1963; Wisconsin Statutes & Annotations § 29.011-1; Alaskan Constitution, Article VIII Section 3). Several countries have recognized a fundamental, diffuse use as the right to a healthy environment (Blumm & Guthrie, 2012), e.g. Norway's 2014 Constitution states, 'Every person has a right to an environment that is conducive to health and to a natural environment whose productivity and diversity are maintained' (Norway 2014 Constitution, Article 112).

In the U.S.A., despite widespread recognition of the legitimacy of diffuse uses, many observers have noted that U.S.A. citizens' diffuse uses of wildlife tend to be under-represented by environmental resource agencies and often under-studied by wildlife researchers (Gill, 1996; Rutberg, 2001; Dunkley & Cattet, 2003; Way & Bruskotter, 2011). The pro-hunting values in U.S.A. society associated with the widespread neglect of diffuse uses are generating a lively debate today (Clark & Milloy, 2014).

Sax's (1970, 1980–1981) revival of the call to defend the broadest public interest and diffuse uses was not simply aspirational. It had a U.S.A. Supreme Court basis and it had practical consequences manifested in state courts since 1972. State courts paved the way for an expansive PTD addressing a broad array of environmental assets (see online Appendix S1). New Jersey case law led the way since Arnold (1821) and Martin (1842). One hundred and fifty years later, the New Jersey Supreme Court held, 'The public trust doctrine, like all common law principles, should not be considered fixed or static, but should be molded and extended to meet changing conditions and needs of the public it was created to benefit.' (Borough of Neptune City, 1972, p. 54). Sax (1980–1981) framed the PTD explicitly as evolutionary not revolutionary, protecting customary uses but allowing for change in societal priorities and cultural uses. The California Supreme Court decision on Mono Lake (National Audubon Society, 1983) followed that lead but set precedents that simultaneously clarified, extended, and constrained the PTD (Blumm & Guthrie, 2012). Probably the most significant extension was not the geographic one that extended the water trust beyond navigable waters, but that which extended the PTD to protect newer, non-traditional uses of the waters. The limits placed on the PTD by the Mono Lake decision are equally notable. In addition to U.S.A. Constitutional limits (see online Appendix S1), the California Supreme Court

set a precedent that allocation of the water in Mono Lake should reflect customary and newer uses of those waters, but limited by the paramount public interest in that water. In ruling, 'The state has an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible' (National Audubon Society, 1983, note 14), the California Supreme Court obligated the state to protect water if feasible. Because the definition of feasible, 'Capable of being done, accomplished or carried out; possible, practicable' (Oxford English Dictionary, 2013), does not consider cost except at a hypothetical extreme that exceeds that possible for a State, the feasibility of protecting water presumably is limited mainly by the technologies, skills, and knowledge of the times. That put the public interest in water above any economic concerns (Sax, 1980–1981; Blumm & Guthrie, 2012). It also seemed to place technical and scientific assessments of feasibility in a central role for determining the scope of preservation of waters. The preceding two court cases on the PTD protected society's self-determination about acceptable uses rather than enshrining any particular uses.

Pondering the role of the government trustee led Sax to consider the sometimes-conflicting, relative roles of the three branches of U.S.A. government (executive, legislative, and judicial). Sax (1970) admonished the courts to balance the legislative and executive branches of U.S.A. government, which most often allocate benefits,

> 'When a claim is made on behalf of diffuse public uses, courts take the first step in the process by *withdrawing the usual presumption that all relevant issues have been adequately considered and resolved* by routine statutory and administrative processes. That first step is tantamount to a court's acceptance of jurisdiction.' (emphasis added, Sax, 1970, p. 561)

In his vision, the judiciary checks executive or legislative allocations of trust assets, such as permitting and privatizing, by using democratic doctrines and constitutional provisions that protect minorities and diffuse uses (Sax, 1970, 1980–1981). Later observers noted that the judiciary faces dynamic tensions with regard to interpreting or rewriting law (Wood, 2014*a*). On the one hand, courts may counter tyranny of the majority to protect minority interests (e.g. protecting the rights of trappers to pursue their customary uses of wildlife) no matter how unpopular they may be (Reiter, Brunson & Schmidt, 1999). On the other hand, the U.S.A. judiciary should counter the majority only by interpreting the law, constitution, and regulation, not by rewriting these expressions of majority rule. An opponent of judicial activism has characterized court efforts to rewrite law as fuelling a

> 'developing clash in liberal ideology between furthering individual rights of security and dignity, bound up in notions of private property protection, and supporting environmental protection and resource preservation goals, inevitably dependent on intrusive governmental programs designed to longer-term collectivist goals' (Lazarus, 1986, p. 633).

The tension between judicial activism and passivism plays out differently under PTD than under more common administrative law. Under more common administrative law, courts defer to administrative agencies whereas courts that are asked to consider PTD may be more liable to scrutinize agency decisions without deference. Hence some assert that the U.S.A. PTD relied unduly 'on a proenvironmental judicial bias' (Lazarus, 1986, p. 692). On the other hand, Sax (1980–1981) argued the PTD imposed a pro-democratic bias and he expressed strong views on undemocratic decisions by administrative agencies,

> '. . . many – if not most — of the depredations of public resources are brought about by public authorities who have received the permission of the state to proceed with their schemes . . . [courts] can assure that decisions made by mere administrative bodies are not allowed to impair trust interests in the absence of explicit, fully considered legislative judgments.' (Sax, 1980–1981, pp. 186, 194)

Sax was highly alert to undemocratic allocation and excessive use by current interest groups, but he did not write extensively about intergenerational equity, which we view as fundamental to public trust principles. President Theodore Roosevelt (1858–1919), was particularly eloquent on this theme,

> 'Defenders of the short-sighted men who in their greed and selfishness will, if permitted, rob our country of half its charm by their reckless extermination of all useful and beautiful wild things sometimes seek to champion them by saying that "the game belongs to the people." So it does; and not merely to the people now alive, but to the unborn people. The "greatest good for the greatest number" applies to the number within the womb of time, compared to which those now alive form but an insignificant fraction. Our duty to the whole, including the unborn generations, bids us to restrain an unprincipled present-day minority from wasting the heritage of these unborn generations. The movement for the conservation of wildlife and the larger movement for the conservation of all our natural resources are essentially democratic in spirit, purpose, and method.' (Roosevelt, 1916, Chapter 10, passage 25)

Few advocates for children have pursued legal claims for intergenerational equity and the few cases brought to U.S.A. courts have not succeeded so far (e.g. atmospheric trust litigation in Wood, 2014*a*). Nevertheless, many legal scholars in Sax's tradition view intergenerational equity as fundamental to PTD (Sagarin & Turnipseed, 2012; Hare & Blossey, 2014). The rise of conservation sciences and sustainability sciences have made it practical to quantify the 'insignificant fraction' of users and in some cases predict the extermination, referenced by Roosevelt (1916) above. The need to account completely, transparently and scientifically for environmental asset preservation and use leads us to turn back to Sax's vision because he envisioned accountability to the broad public interest as a critical prerequisite for just allocation of environmental assets,

> 'The courts properly evince reluctance to approve decisions based upon ignorance... One product of such judicial reluctance is an incentive for decision-making agencies to begin seeking *careful and sophisticated measurements of the benefits and costs involved in resource allocations*. To the extent that judicial hesitancy cautions the agencies against making such allocations without better information on the public record, the courts are deterring ventures into the unknown.' (emphasis added, Sax, 1970, p. 564–565)

Sax's warning about 'ventures into the unknown' lives on in mandates to use the 'best scientific data available' [Endangered Species Act of 1973, 16 U.S.A. Congress (hereafter USC) § 1531] and E.U. laws requiring 'relevant and reliable scientific information' and 'necessary research and scientific work' (Habitats Directive, 1992). Norway's 2014 amended Constitution Article 112 grants. '... citizens are entitled to information on the state of the natural environment and on the effects of any encroachment on nature that is planned or carried out.' Hawaii's Court of Appeals went further and authorized the use of the precautionary principle to protect trust assets when conclusive scientific proof of harmful use was absent (Water Use Permit Applications, 2000; see online Appendix S1). A 2011 U.S.A. presidential order warned against ventures into the unknown, requiring regulation to be transparent, accountable, and based on the best available science (see online Appendix S1; Obama, 2011).

Thus far we have described four fundamental principles of any PTD. The first pair of principles is that PTDs must evolve with changing societal uses of assets while preserving the principal of the asset for future generations (Illinois Central, 1892; Borough of Neptune City, 1972; National Audubon Society, 1983). Also, the allocation of public trust assets to current users should be accounted transparently and completely, while also being subject to judicial review or challenges by beneficiaries to ward against undemocratic allocations (see online Appendix S1). These powerful principles appear simple but they set a high standard for trustees (Sax, 1980–1981; Sand, 2004; Klass, 2006; Blumm & Guthrie, 2012; Hare & Blossey, 2014).

Later legal scholars have proposed an even higher standard. Some see public trust principles including a fiduciary obligation similar to that of a financial or charitable trust (Scott, 1999; Horner, 2000; Wood, 2014*a*). Trusts require prudent management to preserve the principal, favouring asset growth over expenditure, to allow future generations to choose their own uses as well as continuous, scientific, and transparent accounting before allocating assets to current beneficiaries (Horner, 2000; Hare & Blossey, 2014; Wood, 2014*a*). Several U.S.A. state courts have taken steps in this direction (see online Appendix S1). The role of scientific evidence in accounting for the trust assets becomes clearer when one considers a fiduciary obligation. Therefore much of our review addresses how biological scientists and conservation scientists from many disciplines might support fiduciary accounting for wildlife trusts.

Neither Sax (1970) nor we are making the positivist claim that scientific evidence will settle debates that are fundamentally about values (Clark & Milloy, 2014). Rather Sax (1970) implicitly acknowledged that all the governments that recognize a PTD have already decided to measure environmental assets so they can be shared, preserved, and monitored. Whether measuring, preserving, or allocating assets is right or wrong is beyond our scope, so we direct the reader to treatments of balancing private and public interests (Lazarus, 1986; Lasswell & McDougal, 1992; Wood, 2014*a*). In practice, predators and other wildlife have been and will continue to be allocated for preservation or use, so we are concerned with scientific evidence about the effectiveness of trustees and the balance of interventions they select. Using reason to find balance between competing claims for our common interests can be assisted greatly by sciences and allied disciplines such as bioethics and political ecology.

(2) A confusing mosaic of U.S.A. PTDs

Even if visions of the public trust were clear, in practice, many U.S.A. governmental responsibilities for wildlife are a confusing mosaic (Fig. 1A). Although many states followed National Audubon Society (1983) in adjudicating water trust issues (Scanlan, 2000; Blumm *et al.*, 2014), precedents for wildlife trusts, especially for terrestrial species, have not been articulated so clearly (Blumm & Paulsen, 2013; Blumm *et al.*, 2014). A minimum standard for wildlife conservation was set by U.S.A. federal court rulings that confirmed the authority and responsibility of states to 'preserve', 'protect', 'manage', 'conserve', and 'regulate the exploitation' of wild animals to avoid impairment of the public interest (see online Appendix S1). We encompass all these state duties generally with the term 'preserve', to capture the principle of leaving intact the principal of the trust for the next generation and avoiding impairment of the trust. Although the U.S.A. federal wildlife PTD (wildlife trust hereafter) is ambiguous or absent and only a matter of U.S.A. state law (see online Appendix S1), the federal Endangered Species Act of 1973 (ESA) is widely recognized as a powerful instrument to prevent extinction (Norris, 2004). Recent judicial interpretations have strengthened the linkages between the PTD and ESA, as we make explicit in Section III. To begin, the U.S.A. Congress enacting the ESA found diverse customary uses and benefits of wildlife for all citizens,

> '... fish, wildlife, and plants are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people... for the benefit of all citizens... The Secretary shall ... give priority to ... particularly those species that are, or may be, in conflict with construction or other development projects or other forms of economic activity;' (16 USC § 1531, Sec. 2(3)(5) and 4(f)(1)(A)).

The ESA thereby prioritized preservation over any development or economic activity, generating political vitriol as no other environmental act in U.S.A. history (Plater, 2004; The New York Times Editorial Board, 2015). Prioritizing

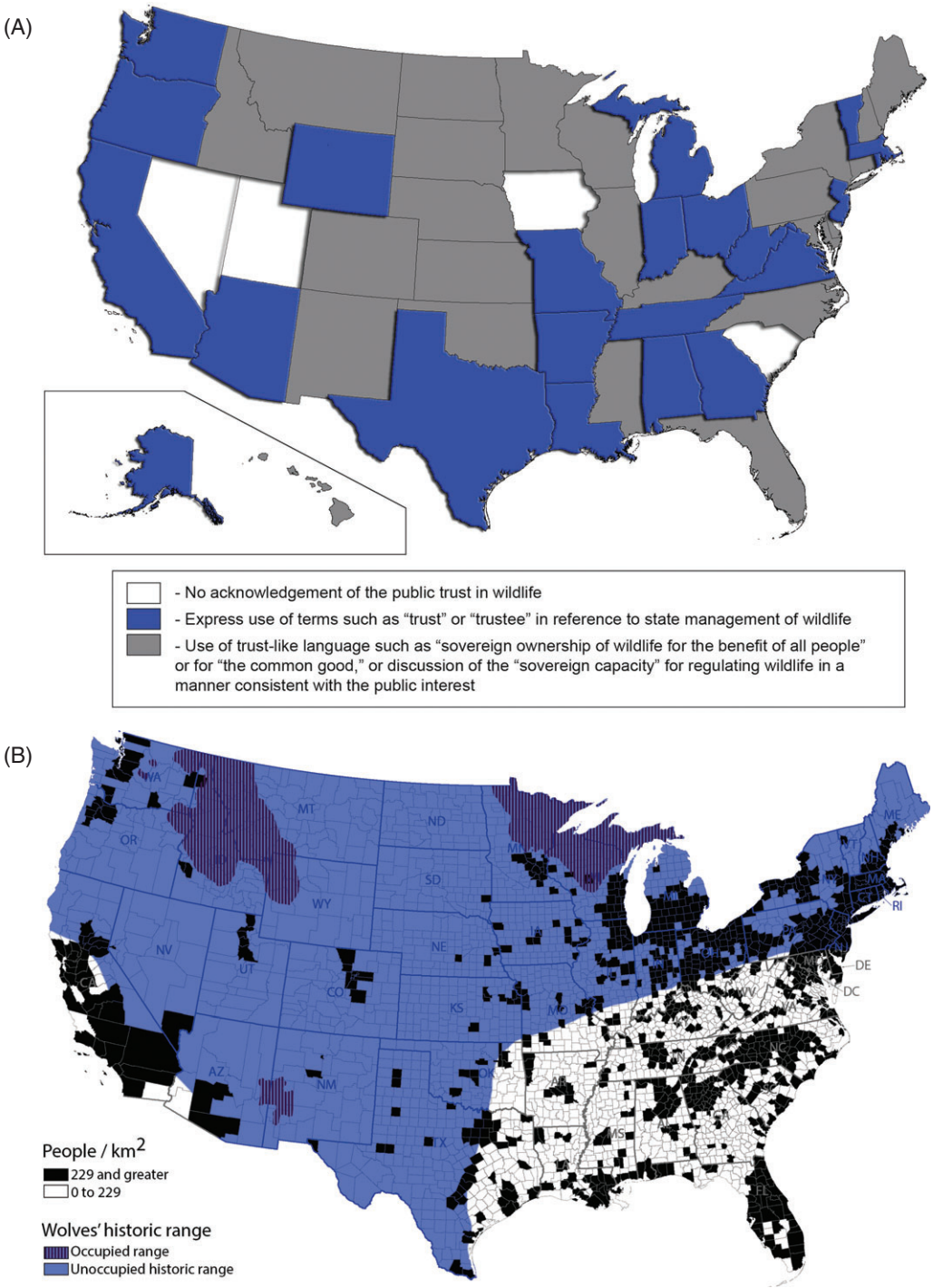

Fig. 1. (A) Three categories of state public trust doctrine (PTD) in the U.S.A. following Blumm & Paulsen (2013). (B) Historic range of the gray wolf reproduced from Bruskotter *et al.* (2013).

preservation above allocations of assets is central to public trust thinking because of intergenerational equity.

Beyond the ESA, the U.S.A. federal government played a national, coordinating role in environmental protection starting in the 1960s when several Congressional Acts established cooperative federalism, within which the federal government set the standards and states responded (Plater, 2004; Klass, 2006). The U.S.A. Supreme Court recently opined that setting state trustees' responsibilities is a matter of state law for all three branches (PPL Montana, 2012). This does not exclude a possible challenge that a state does not meet some minimum, federal standard of wildlife trusteeship, but the legal test for terrestrial wildlife has yet to be made to our knowledge. U.S.A. federal regulation such as the

ESA led states to enact their own regulatory statutes and build their own wildlife agencies to meet or exceed federal standards for wildlife regulation. The results were wildlife trusts that vary from state to state (Fig. 1A) including states with none (Blumm *et al.*, 2014). Further complicating the interstate mosaic are federal and tribal jurisdictions within states, which may have their own trust obligations and serve as co-trustees (e.g. Sanders, 2013; Wood, 2014*b*).

Blumm & Paulsen (2013) reviewed state constitutions, laws, and regulations for assertions that wildlife is a public trust asset or state assertions using 'public trust-like language to describe management of wild animals' (Blumm & Paulsen, 2013, Section IV.B). Twenty-two U.S.A. states used the words 'trust' or 'trustee', to describe management of wildlife (Fig. 1A). Another 22 states used other PTD language 'such as sovereign ownership of wildlife for ''the benefit of all people'' or for ''the common good'', or discussion of the ''sovereign capacity'' for regulating wildlife in a manner consistent with the public interest' (Fig. 1A). The remaining states either had less articulated versions of the public trust in wildlife (Iowa, Delaware, and Nebraska), or did not acknowledge it at all (Nevada, South Carolina, and Utah) (Blumm & Paulsen, 2013, Section IV.B). Interpretations of the PTD also vary within states over time (Horner, 2000; Klass, 2006; Redmond, 2009; Blumm *et al.*, 2014). Although one can visualize the mosaic based on legal language (Fig. 1A), in practice, some states may not uphold those duties recognized in legal language.

One measure of the strength of a state PTD is whether citizens can challenge the government's allocations. As of 2006, only 2 states had the strongest form of PTD in which constitutional rights to trust assets were established, and 15 others mentioned such rights in statutes but limited accountability of the trustee (Klass, 2006).

In sum, governmental responsibilities to conserve wildlife have been subject to variable, state-level, democratic processes producing a mosaic of wildlife conservation responsibilities. The U.S.A. wildlife trust is also murky because of narrow influences on administrative agencies.

(3) Agency capture and public trustees

Asset allocation readily becomes undemocratic when special interests capture the administrative agencies, or capture the constitutive process, defined as the rules governing wildlife agency decision-making (Lasswell & McDougal, 1992; Clark & Milloy, 2014). Prukop & Regan (2005, p. 375–376, cited on p. 20 in Chapter 9 of Clark & Milloy, 2014), writing for the U.S. Association of Fish and Wildlife Agencies noted many problems with the constitutive process in current U.S.A. wildlife management. Clark & Milloy (2014) comprehensively examined the constitutive process in predator policy and science in the western U.S.A., and concluded, '… the decision process needs to be made more open to everyone, more factual about the entire context, … more focused on achieving common interests … Recurring weaknesses [include] expert biases, … ''benefit leakage'', intelligence failures and delays, … inappropriate organizational arrangements, insensitivity of decision makers to valid and appropriate criticism … ' (Clark & Milloy, 2014, p. 21 in Chapter 9). Indeed, the majority of U.S.A. states assigned trust responsibilities to individuals selected for experience working within an interest group or affinity with consumptive users of wildlife (Gill, 1996; Horner, 2000; Clark & Milloy, 2014; Hare & Blossey, 2014). Agency capture will be facilitated if trustees are selected for their affinity to narrow interests. The government trustees responsible for allocation of benefits from wildlife are vulnerable to individual corruption or agency capture by financial inducement or political patronage. Scanlan (2000) described the many forms of trustee abdication associated with agency capture that led to degradation of trust assets,

> '… the regulators entrusted with the duty to implement the [water trust] are restricted from acting to the full extent allowed by the court … [by] inability to deny permits, a perceived dependence on local district attorneys to prosecute violations, understaffing, and pressure from supervisors and politicians to … degrade trust resources' (Scanlan, 2000, p. 139).

Appointing trust managers or trustee agencies with affinity to special interests clashes with recommendations for selecting fiduciary or charitable trustees based on independence, integrity, expertise with trusts or beneficiaries, comprehensive knowledge of uses, and accountability to challenges by beneficiaries (e.g. U.S. Uniform Code of Trusts http://uniformlaws.org/ActSummary.aspx?title=Trust%20Code, accessed September 2014). The general standard of care holds trustees to 'manifest the care, skill, prudence and diligence of an ordinary prudent man engaged in similar business affairs' (Bogert & Bogert, 1993, p. 167). An ordinary and prudent man is determined by an objective standard (Scott, 1999, p. 143), which favours preservation of the trust principal over expenditures, so must refrain from maximizing disbursements of benefits in favour of optimizing preservation of future benefits (Scott, 1999; Sagarin & Turnipseed, 2012, p. 145). Besides a duty prudently to apply that expertise, a trustee also has a duty to solicit sound advice, and keep good records of the assets (Scott, 1999, p. 144).

As a result of the disparity between recommendations about public trustees and current practices in hiring and appointing wildlife trustees, North American wildlife agencies are facing criticism from those that do not align with hunting, trapping, and angling interests (Clark & Milloy, 2014). The same may hold for the E.U., whose Commission recently endorsed management guidelines from the Large Carnivore Initiative for Europe (Linnell, Salvatori & Boitani, 2008) as best-management practices despite the guidelines including an unsubstantiated claim that hunting is permitted for species listed under Annex IV of the Habitats Directive (1992) see also Michanek (2012). In the U.S.A., accusations of agency capture have focused on the North American Model (NAM) which arose in the 1990s (Geist, Mahoney & Organ, 2001) as promoting hunting, trapping, and angling as the purpose of wildlife management. In 2010, a document

on the NAM, published by four professional societies allied to governmental fish and wildlife agencies, identified the 'Democracy of hunting' as one of seven principles of the NAM and commensurate with the PTD (NAM Technical Review, 2010). The principle of Democracy of hunting has been thoroughly examined by Clark & Milloy (2014) who concluded, 'The [principle] that we recommend be changed is the idea of the "democracy of hunting." ... these are special interests.' (p. 366–367). Problems of agency capture are particularly important for predator conservation under the NAM, because '... at various times and places, the [NAM] has been used to justify extermination of large carnivores for purposes such as increasing populations of ungulate game species' (Clark & Milloy, 2014, p. 294–295, citing Robinson, 2005; see also Bruskotter *et al.*, 2013). Raising a special interest credo of 'Democracy of Hunting' to a level commensurate with the PTD (NAM Technical Review, 2010, p. 10 Synopsis) has perpetuated and reinforced an illegitimate view of the U.S.A. and Canadian wildlife trusts.

(4) An illegitimate view of wildlife trusts

The writings of Sax (1970) and successive generations, many of whom were practicing lawyers or law professors (Horner, 2000; Wood, 2009, 2014*a*; Blumm & Guthrie, 2012; Hare & Blossey, 2014) have elaborated a legitimate 'broad public interest view' of the PTD supported by case law and other legal instruments. By contrast, the NAM has been advocated by professionals in fish and wildlife management (NAM Technical Review, 2010) and espouses seven principles including the 'Democracy of hunting' or 'Hunting opportunity for all', depending upon the specific articulation (NAM Technical Review, 2010). This 'pro-hunting view' canonizes regulated public hunting of wildlife as *the* purpose of wildlife management, and hunters as privileged beneficiaries of the trust in wildlife (Geist *et al.*, 2001; Clark & Milloy, 2014, pp. 366–367). The broad public interest view and this more recent pro-hunting view differ on the following three points that bear on our topic: (*i*) changes in societal values are comfortably accommodated in the PTD (broad public interest view) rather than threatening it (pro-hunting view); (*ii*) the benefits of wildlife are shared equitably by all members of current and future generations regardless of their awareness, uses, value systems, or fees they have paid (broad public interest view) *versus* an asymmetrical share with priority given to hunting, trapping, and angling (pro-hunting view); and (*iii*) wildlife differs from other environmental assets because some interest groups seek eradication, it responds to people's actions and policy interventions and *vice versa* (this review) *versus* wildlife differ because they pose liabilities (pro-hunting view).

The first point of difference (changing societal values) is illustrated well by the following,

> 'The underpinnings of the PTD and the future relevance and successful application of the [NAM] may be *at risk due to recent changes in society, government policies, and case law ... Several significant threats have been identified that directly or indirectly erode or challenge the PTD* in North America ... These threats undermine existing state, provincial, and federal laws, as well as governmental policies and programs. Moreover, they inhibit sound conservation practices for fish and wildlife resources ...' (emphasis added, NAM Technical Review, 2010, p. 10).

Proponents of the pro-hunting view perceive threats to the entire institutional and legal framework of fish and wildlife management in North America. The authors name the perceived threats, '... inappropriately claiming ownership of wildlife as private property; unregulated commercial sale of live wildlife; *prohibitions on access to and use of wildlife; personal liability issues; and a value system oriented toward animal rights*' (emphasis added, NAM Technical Review, 2010, p. 10).

The synopsis of the pro-hunting view of the PTD quoted above identifies a value system (the animal rights movement) and a legally recognized concern (personal liability), and therefore the organizations espousing both, as existential threats to democratic institutions and the PTD itself. That identification is illegitimate. It not only demonizes legally recognized interests but pits government agencies against citizens who advocate for such interests and concerns. In this way, the pro-hunting view of the PTD attempts to turn government trustees and trust managers against a subset of legally recognized interests. By contrast, the broad public interest view of the PTD recognizes all legal interests and provides a guide to how to balance their claims on public trust assets (Hare & Blossey, 2014). The changes in society, policy, and law that the authors mistrust are not a concern for the legitimate broad public interest view of the PTD because its underpinnings (state and federal constitutions, laws, and common law) need no protection from democratic expressions of social change. If the pro-hunting view were simply an articulation of a special interest agenda, we would not devote text to this critique. But it is the statement of appointed trust managers who should even-handedly consider all legally recognized interests in wildlife (Scott 1999). If adopted legally, the pro-hunting view of the PTD and the NAM would prevent future citizens from recognizing animal rights or personal liability concerns. Although the NAM Technical Review (2010) reprinted Roosevelt's (1916) quotation as we did in Section II, the authors missed the significance of his eloquent articulation of intergenerational equity.

Furthermore, the NAM Technical Review (2010) warns about 'prohibitions on access to and use of wildlife' above, which at face value are required elements of the PTD (Illinois Central, 1892; see online Appendix S1). Prohibitions on access and take are encoded in federal and state laws and rules (e.g. restrictions on the timing, location, and method for hunting). The authors specify more clearly what they mean later, '... the public is having an increasingly difficult time gaining entry to hunt or trap on private property or reach tracts of public land' (p. 17, NAM Technical Review, 2010). Vucetich, Bruskotter & Nelson (2015) point out that

support for wildlife conservation does not depend on hunting and trapping access. Therefore the NAM Technical Review (2010) epitomizes agency capture by narrow special interests.

Although some of the pro-hunting authors of the NAM Technical Review (2010) recently struck a more inclusive note (Decker *et al.*, 2013; Organ *et al.*, 2014), the later authors also exposed a further difference relating to the public interest in preserving wildlife in the face of private interests. The broad public interest view sees wildlife damages, whether to private property or public interests, as inevitable consequences of the public interest in preserving wildlife assets (Bruskotter *et al.*, 2011, 2012). Damage by wildlife is therefore similar to preserving rivers as assets that occasionally flood private property and restoring natural fire regimes that occasionally burn private property. Nevertheless all native wildlife, as with all rivers, provides benefits to some citizens and unpredictable benefits to future generations. The pro-hunting view sees some wildlife as liabilities,

> '. . . some species have rebounded from scarcity to become *socially overabundant* in particular contexts. While it may not be possible to have a financial trust with 'too much money,' it is possible to have too many individuals of a wildlife trust species within certain contexts, such as those wherein the wildlife have extensive negative impacts on ecosystems and humans. This can result in their status *becoming a liability rather than an asset*. *Controlling the negative impacts* of overabundant populations . . . ' (emphasis added, Organ *et al.*, 2014, p. 412).

A liability is a debt, pecuniary obligation, responsibility, answerable by law or equity (Oxford English Dictionary, 2013). Reframing a public trust asset as a liability is neither useful nor consistent with the broad public interest view of the PTD that environmental assets are benefits. Although democratic societies can self-determine the optimal level of an environmental asset, the mandate for intergenerational equity sets priority on preservation over any private interest that currently holds a wildlife population as 'socially overabundant'. The challenge as the above authors correctly note arises when a democratic society determines that an environmental asset is harming the public interest because of its over-abundance. The State of Louisiana struck a balanced note in American Waste and Pollution Control (1993) (see online Appendix S1) when the Appeals Court held that trustees might diminish the principal of a public trust asset after diligent, fair, careful, transparent measurement of all costs and benefits to the public interest. We are not aware of any trust managers that have undertaken such diligent accounting before reducing predator populations and some state trustees have clearly not respected such principles (e.g. see online Appendix S2).

The terms liability and socially overabundant may foster intolerance, particularly for predators. If left unchecked, intolerance can lead to impairment of the asset by poaching and also lethal management (Sections IV and V). The broad public interest view acknowledges that the public interest in environmental assets can infringe on other public interests and on private interests (see Section VI and online Appendix S1). That is not new to wildlife. Water trust assets frequently impose costs on riparian landowners (Scanlan, 2000). The costs are imposed by the public interest in preserving the asset (navigable waterways) not imposed by the asset itself (water). Riparian owners are not entitled to block waterways (i.e. impair the public interest) because they perceive waterways in a negative light, e.g. as over-abundant. Likewise a private interest should not destroy wildlife because it perceives a cost. Sometimes private interests may merit compensation for wildlife 'takings' (Doremus, 1999); wildlife damage has been adjudicated using takings law (Thompson, 1997). Nevertheless, the public interests are inalienable so private rights do not include destruction of the asset, as established in Illinois Central (1892) (see online Appendix S1). Therefore liability is not a concept in the PTD, and it has limited application in wildlife takings case law (Thompson, 1997). The differences between wildlife and other environmental assets do not lie in their threats to private interests. Instead the difference lies in how wild animals and people respond to each other and how some narrow interests promote eradication of controversial wildlife.

Wild animals and people typically respond with aversion (if harmed) and attraction (if helped). Few, if any, other environmental assets respond to policy or human behaviour, which changes the compatibility of various uses (Section VI). The problem with framing wildlife as liabilities is illustrated by the authors' leap of logic to advocating 'controlling negative impacts of overabundant populations' (Organ *et al.*, 2014, p. 412). In traditional wildlife contexts in English-speaking countries, control means killing (Boumez, 1989; Allen & Sparkes, 2001; Berger, 2006), especially when joined to the phrase 'overabundant populations'. Even if that phrase was meant to include non-lethal methods, a mindset of controlling wildlife skips the rational chain of cause and effect that would lead a trustee to ask if complaints relate to real or perceived costs, and if real, whether the property was adequately protected from a public asset, the wildlife. A mindset that all wildlife are assets held in trust for current or future generations leads one down a more prudent route of examining alternatives to depleting the asset. In sum, the pro-hunting view in 2014 still prioritized lethal uses of wildlife and remains out of line with public trust thinking until it disavows its narrow preference for lethal management and consumptive uses. We conclude the pro-hunting view of the PTD and its over-arching NAM has failed to guide trust managers (e.g. wildlife agencies; Smith, 2011) in adopting a broad public interest view of the PTD.

The vagaries of majority values in particular jurisdictions, legislative processes, case laws, and administrative agency rules create legitimate mosaics of wildlife trusts. Murkiness arises from narrow interests capturing governmental allocations and even the trust managers. These mosaics and murkiness are not unique to the U.S.A. (see fig. 1 in Sagarin & Turnipseed, 2012). E.U. Member States are trustees of European environmental protections and their interpretations of that trust responsibility may vary (López-Bao *et al.*, 2015; see online Appendix S1). Member States' interpretations of their own trustee responsibilities

toward predators protected by E.U. law are being adjudicated as we write (Epstein, 2013; Epstein & Darpö, 2013; Chapron, 2014). The full contours of wildlife trusts are rarely clear within a country and neighbouring countries often have very different obligations for wildlife (Blumm & Guthrie, 2012). Geographically variable interpretations and enforcements of the PTD may have advantages and disadvantages for wildlife populations. Mosaics varying in environmental protection can potentially provide refuges for imperilled species, or act as sinks, if one jurisdiction's policies are more or less protective than those of its neighbours. Thus trustee failure may not be irrevocable for a subpopulation of wildlife. A drawback may be that a mosaic of interpretations can hamper collective action if different jurisdictions cannot align policies or transboundary activities Historically many predator subpopulations were driven extinct in many regions but persisted in a few. They have only recently begun to recolonize. That volatile history of predator conservation and the legal and policy instruments that now exist are well illuminated by the case of the gray wolf.

III. THE VOLATILE HISTORY OF U.S.A. PREDATOR POLICY WITH A FOCUS ON GRAY WOLVES

Despite explicit trust obligations for wildlife articulated by the U.S.A. Supreme Court in Geer (1896) and other cases (see online Appendix S1), both state governments and the federal government continued to enact policies that jeopardized entire populations of various species during the past century (Wilcove *et al.*, 1998; Estes *et al.*, 2011). Globally, extirpations of predators resulted from the destruction and modification of habitat, direct competition with people over space and resources, commercial extraction, culturally perpetuated antagonisms, or political scape-goating, all of which might have been abetted by governmental neglect (Knight, 2000; Pereira, Navarro & Martins, 2012; Chapron & Lopez-Bao, 2014; Ripple *et al.*, 2014; Treves & Bruskotter, 2014). Numerous populations of predators including felids, ursids, and canids were extirpated across the U.S.A. and Europe in the mid-20th century (Woodroffe, 2000; Chapron *et al.*, 2014). For example, two U.S.A. federal agencies eradicated gray wolves in National Parks and National Forests (Bangs & Fritts, 1996; Smith, Peterson & Houston, 2003), and many states used bounties to eradicate cougars or wolves (Thiel, 1993; Riley, Nesslage & Maurer, 2004). Indeed, bounties on coyotes are still in use (Bartel & Brunson, 2003).

Nevertheless, predator recoveries began in the 1970s in the U.S.A. and the 1980s in Europe. Two legal instruments are largely credited with these recoveries; the U.S.A. ESA of 1973 (Plater, 2004) and the international Bern Convention of 1979 followed by the Habitats Directive of the European Union (Epstein, 2013), which protect most large carnivore populations (Habitats Directive, 1992, Annexes II, IV, and V). The Habitats Directive (1992) requires that Member States contribute to reach and maintain a favourable conservation status for all listed species, and in particular constrains governments from permitting local disturbance or disappearance of species listed in Annexes II and IV (European Commission, 2006; Michanek, 2012; Epstein & Darpö, 2013). Similarly, the ESA prohibits the 'take' (e.g. killing, harm, capture, pursuit) of listed species, which includes transforming habitat determined to be 'critical', thus providing at least temporary federal authority over state wildlife species listed under the law (Freyfogle & Goble, 2009). Many populations of predators (e.g. gray wolves, grizzlies in the conterminous U.S.A. states) were listed shortly after the ESA's passage, and 40 years later, several U.S.A. states and local jurisdictions are preparing for, or have recently regained, management authority (delisting) for their predator subpopulations. The process of listing and delisting has not been smooth.

When determining the listing status of a species, the U.S.A. Fish and Wildlife Service (USFWS) must examine five 'threat factors' defined by the ESA (16 USC § 1533(a)(1)). A species can be removed from ESA protection (or 'delisted') when the threats that led a species to be listed are sufficiently mitigated that the species no longer meets the definition of either a 'threatened' or 'endangered' species (Vucetich, Nelson & Phillips, 2006). Yet delisting is not the end of USFWS authority under the ESA. The ESA requires the USFWS to monitor a delisted species for a minimum of 5 years (16 USC § 1531 Sec. 4(g); USFWS, 2006). Among U.S.A. predators listed under the ESA, only subpopulations of the gray wolf have been delisted due to recovery, although these actions have been controversial and federal courts recently reversed two such determinations. At least seven federal court cases involved wolves in the last 12 years (http://ecos.fws.gov/tess_public/pub/delistingReport.jsp). To understand the implications for predator conservation under the U.S.A. PTD, we examine the history of wolf policy in greater detail.

Wolves in the conterminous 48 states declined to a few hundred animals in a small portion of northeastern Minnesota and on tiny Isle Royale, Michigan by the 1960s (Mech, 1995). Non-conterminous Alaska retained a population estimated in the thousands across a wide area, but controversies over wolf policy surfaced there as well (Fitzgerald, 2009). The USFWS took authority for all non-Alaskan gray wolves in 1978 and soon after for the Mexican subspecies *C. l. baileyi* and the red wolf *C. rufus*, and began work on plans to recover all three predators. Recovery efforts took different approaches in different regions of the U.S.A. Gray wolves were reintroduced to Yellowstone National Park and parts of central Idaho during the mid-1990s, and considered for reintroduction elsewhere (Bangs & Fritts, 1996). In the western Great Lakes states, wolf recovery efforts involved protecting naturally recolonizing wolf populations from excessive mortality (Wydeven, Van Deelen & Heske, 2009*a*). Efforts to recover the Mexican gray wolf and the red wolf also involved reintroductions; however, in both of these cases, the source animals for reintroductions were captive-bred for release (Bangs & Fritts, 1996; Parsons, 1998). Those efforts testify to the desperate straits of some predators and to the force of the enabling statute.

By 2009, gray wolf subpopulations totalled several thousand animals in five states with tendrils beginning to extend and establish into states adjacent to recovery areas (Fig. 1B). Between 2005 and 2013, the USFWS proposed delisting two noncontiguous, regional populations of gray wolves and then the whole species (http://www.fws.gov/midwest/wolf/). Several commentators voiced the opinion that recovery was complete, based primarily on wolf population size (Wydeven, Van Deelen & Heske, 2009*b*; Mech, 2013), whereas other scientists disagreed in part or entirely; citing, for example, lack of geographic representation across the species' historic range and assertions that USFWS failed to use the best available science (Carroll *et al.*, 2010; Bruskotter *et al.*, 2013; Bergstrom, 2014; NCEAS, 2014). Citing these and other issues, federal courts have consistently ruled that alleged recovery of wolves was insufficient to satisfy the ESA requirements. A series of federal court decisions between 2005 and 2014 restored federal protections for wolves (http://www.fws.gov/home/wolfrecovery/). Federal courts did not agree with USFWS determinations that gray wolves had recovered sufficiently to delist; or in narrower challenges, did not agree that the USFWS could issue permits for states to kill wolves in hopes of preventing livestock attacks (Refsnider, 2009). In 2011, a Congressional budget rider side-stepped ESA protections and an ongoing federal lawsuit about gray wolves in the Northern Rocky Mountains (Treves & Bruskotter, 2011). A Congressional budget rider had previously been used to side-step ESA protections and permit timber sales in the habitat of the spotted owl (*Strix occidentalis* De Vesey 1860) (Plater, 2004). Because of years of political conflict over wolves and USFWS' inability to win in federal court, Treves & Bruskotter (2011) proposed three compromise scenarios that reduced legal take of wolves for at least 5 years, while balancing competing public interests and the resulting power struggle between states and federal governments. One scenario proposed down-listing wolves to 'threatened' status under the ESA, which allows more flexibility in state-initiated removal of wolves (16 USC § 1531 Sec. 4d permits) while preventing controversial public hunting seasons. Two years later, the USFWS proposed removing federal protections nationwide (USFWS, 2013) and then lost two more lawsuits addressing regional subpopulations (Defenders of Wildlife, 2014; Humane Society of the U.S. (HSUS), 2014).

(1) The courts' perspectives

The two most recent U.S.A. federal court decisions comprehensively analysed the USFWS' delisting determinations for gray wolves in Wyoming and for the Western Great Lakes (WGL) region, respectively (Defenders of Wildlife, 2014; HSUS, 2014). In so doing, federal judges clarified important passages in the ESA and instructed the USFWS on future determinations. Their clarifications and instructions echoed principles of the public trust albeit implicitly. The echoes will reverberate for many other predators, if not other wildlife.

In the Wyoming case, the court held that, 'Wyoming's statutory and regulatory regime is legally inadequate under the ESA . . . ' (Defenders of Wildlife, 2014, p. 206) because Wyoming's plan lacked protections for wolves throughout the vast majority of the state. Throughout state lands, wolves could be killed for any purpose. The plan also classified wolves as a game animal in areas adjacent to Yellowstone and Grand Teton National Parks. In the court's view, this policy threatened the capacity of Wyoming to meet minimum federal recovery goals (100 wolves in 10 packs). From the standpoint of public trust thinking, the Wyoming plan allowed the state to deplete the trust asset on state lands, impede recolonization from the federal source lands, and potentially diminish the sources by attracting wolves into hunting zones (*sensu* Loveridge *et al.*, 2007). It also contained an unenforceable promise to stop depleting. The judge spent 10 pages clarifying the significance of the ESA mandate that delisting proceed only if the USFWS finds, 'adequacy of existing regulatory mechanisms' (16 USC. § 1533(a)(1)(D)). The court held that '[USFWS] cannot rely solely on an unenforceable promise as a basis to delist a species . . . ' (Defenders of Wildlife, 2014, p. 208), and agreed with a prior federal court that,

> 'Absent some method of enforcing compliance, protection of a species can never be assured. Voluntary actions, like those planned in the future, are necessarily speculative . . . Therefore, voluntary or future conservation efforts by a state should be given no weight in the listing decision.' (Oregon Natural Resources Council, 1998, p. 1155)

The court's decision evoked three elements of Sax's (1970) vision. He called for judicial scrutiny of decisions to allocate trust assets. The first element was the federal one restoring authority for wolves to a government that had helped to extirpate them. The second was Wyoming's allocation to any person wishing to kill a wolf on State lands. The third element was the lack of sophisticated and transparent accounting within Wyoming's' proposed regulatory mechanisms accepted by USFWS. A few months later, another federal court ruling evoked public trust principles for wolves.

On 19 December 2014, a federal court overturned the USFWS' decision to delist wolves in the WGL (HSUS, 2014). The judge issued a detailed, 111-page decision that examined the Congressional record and the language of the ESA, prior USFWS policy, and prior court precedents. The court reminded the USFWS that delisting determinations must consider all of the range of the listed species and could not delist a species that remained threatened or endangered throughout 'all or a significant portion of its range' (HSUS, 2014, p. 78). The court required – as had a prior federal court – the USFWS to explain why territory that was part of a species' historical range but no longer occupied by that species, fell outside a significant portion of the species' range (Fig. 1B). The USFWS instead focused on the species' conservation status within its current range (HSUS, 2014). That court also criticized the USFWS for approving inadequate regulatory protections for wolves, singling out Minnesota. Nor had Wisconsin and Michigan escaped scientific criticisms of their regulatory mechanisms

(Vucetich *et al.*, 2013; Treves *et al.*, 2014; see online Appendix S2). The judge ruled that the USFWS failed to explain why mortality factors did not combine or interact to create a clear threat to the species (HSUS, 2014). These concerns echo Sax's (1970) admonition to agencies on clear and sophisticated measurements of costs and benefits as well as the public trust principle that citizens of all states are trust beneficiaries. Clearly federal judges did not agree with the federal administrative agency making determinations about endangered species but were larger issues at stake?

The debate over wolves has raised serious questions about U.S.A. federal wildlife trust obligations. For one, the court rulings suggest state management of wildlife is subject to federal court review, despite wildlife trusts lodging initially in the states (see online Appendix S1). Furthermore, the historic range of wildlife was scrutinized by the court in HSUS (2014), which evokes the trust duties of governments far beyond current range. In 2015, 8 states contained wolves, leaving approximately 29 that once hosted wolves (Fig. 1B). U.S.A. citizens living outside the wolf range in 2015 had little or no opportunity to benefit from the asset not only because of the need to travel to a range state but also because lethal management appears to make wolves shy of people (Section VI). The number of states in which wolves might recolonize is partly a value judgment for society, and partly depends on the uncontrollable movements of wild wolves. But the ESA phrase 'a significant portion of range' would seem to be more than the current range of ∼22% of all states in the historic range (Fig. 1B). Moreover citizens of historic range now depleted of wolves might ask whether their state abrogated its duty under the wildlife trust. Given the U.S.A. wildlife trust is a benefit for current and future citizens can citizens of one state challenge another state's wildlife management? Can citizens challenge their own state's failure to promote recovery of native wildlife? Tests of these and other unanswered questions may be forthcoming if wolves continue to be managed without public trust thinking.

(2) Predator litigation will recur

The U.S.A. court rulings affirmed the importance of sophisticated, careful measurements of costs and benefits (e.g. mortality, range expansion, regulatory mechanisms) before allocating a public trust asset. Scientists and their advocates have been scrutinizing agency decisions, particularly for the ESA with its mandate for use of the best available science. Both courts emphasized the affirmative duty of enforceable protection measures and adequate regulations for delisted species. The decisions also confirmed the rights of citizens to challenge the trustees. Each effort by USFWS to relax wolf protections met legal resistance under the civil suit provision (16 USC § 1531 Sec. 11(g)), which allows any citizen to challenge the federal government's actions or inactions under the ESA. By 19 December 2014, the USFWS had won none of the civil suits on wolves. Federal court setbacks to the USFWS do not mean ESA protections will persist forever. The U.S.A. Congress in 2015 has again drafted bills to delist wolves by decree including immunity from judicial review as in 2011 (Treves & Bruskotter, 2011; The New York Times Editorial Board, 2015). More court challenges relating to predators should be expected.

We expect more legal challenges for several reasons. The first reason is that lethal management interests have captured many agencies and otherwise dominate the process for decision-making about wildlife in the U.S.A. (Section II; Clark & Milloy, 2014). Lacking a strong voice in the policy-making process 'pro-predator' interests turn to the courts. Also, the 'pro-wolf' plaintiffs' successes described above may inspire further efforts because numerous national interest groups have expressed concern over the sustainability of state policies on wolves and other predators (Grandy, 2008; Male & Li, 2010). State courts will also probably see wolf litigation. Minnesota and Wisconsin courts already ruled against plaintiffs in two pro-wolf lawsuits pertaining to public wolf-hunting seasons (Center for Biological Diversity, 2013; Wisconsin Federated Humane Societies, 2013). Both of these lawsuits addressed wolf hunting regulations. Neither invoked the PTD forcefully. That omission may reflect the uncertain contours of state trust responsibilities for wildlife (Section II).

If U.S.A. nationwide wolf delisting proceeds, at least 29 additional states would be affected because they contained the historic range of wolves (Fig. 1B). Of 22 states that use the words 'trust' or 'trustee' to describe management of wildlife (Blumm & Paulsen, 2013, Section IV.B), 5 host breeding wolves: Alaska, Michigan, Oregon, Washington, and Wyoming. Another 22 states use other PTD language (Blumm & Paulsen, 2013, Section IV.B) and 4 of those host breeding wolves: Idaho, Minnesota, Montana, and Wisconsin (Fig. 1A, B). If plaintiffs choose to file suits against states that eradicated their wolves to compel them to restore wolves, another 14 states might see lawsuits (Fig. 1A, B). Some states with few or no breeding wolves have already accepted responsibilities to preserve wolves. For example, the states of Illinois, Oregon, Washington, and California listed wolves recently. Predator litigation might echo Sax's (1970) concerns about 'ventures into the unknown' and challenge state plans for lethal management, because there is currently little scientific consensus about sustainable mortality of predators.

IV. HUMAN-CAUSED MORTALITY IN PREDATOR POPULATIONS

Effective trustees must impose regulatory authority to prevent over-use of wild animals. Identifying unsustainable use or threats to populations is a traditional area of interest in conservation and wildlife management. Lately attention has focused keenly on human-caused mortality in predator populations. That interest reflects appreciation that human-caused mortality provoked or significantly contributed to past predator extinctions or species extinctions including the Falklands wolf (*Dusicyon australis* Kerr, 1792), sea mink (*Neovison macrodon* Prentis, 1903), giant fossa (*Cryptoprocta spele*a Grandidier, 1902), and Tasmanian thylacine (*Thylacinus cynocephalu*s Harris, 1808)

among other national subpopulations eradicated (IUCN Red List http://www.iucnredlist.org accessed 31 August 2015). Determining sustainable levels of human-caused mortality demands that managers understand the effects of vehicle collisions, poaching, legal take (government culling or permitted hunting), etc., together with variability in birth and mortality factors that affect census and effective (breeding) population size.

Models of sustainable mortality for several predator populations suggest total mortality rates higher than 15–30% would be unsustainable (Adams *et al.*, 2008; Chapron *et al.*, 2008; Vucetich, 2012). The models seem supported by empirical estimates showing that various population recoveries have been slowed or reversed by mortality rates of 19–37% or human-caused mortality of 14–32% (Woodroffe & Frank, 2005; Goodrich *et al.*, 2008; Creel & Rotella, 2010; Smith *et al.*, 2010; Liberg *et al.*, 2012; Vucetich, 2012; Artelle *et al.*, 2013). Therefore the addition of a few percentage points of human-cause mortality can drive a predator population decline. Prudent governments following public trust principles should avoid additional uses that deplete the principal of the trust asset, as we noted in Section II.

(1) Lack of scientific consensus on sustainable, human-caused mortality

Setting sustainable quotas for hunting or fishing is fundamental to regulating exploitation. Yet a recent commentary on scientific understanding of population dynamics concluded that the field remains under-developed because non-linear dynamics, time-lags, and regime shifts are poorly understood (Oro, 2013). In part, typical management tactics, such as setting future quotas by past reported take (Logan & Sweanor, 2001) may augment the volatility of wildlife populations and lead to crashes (Fryxell *et al.*, 2010; Bischof *et al.*, 2012; Artelle *et al.*, 2013). Furthermore, predator populations are even less well understood than most hunted species (e.g. waterfowl or ungulates). Predators experience local mortality sinks and super-additive mortality due to breeding failure, infanticide, or social group dissolution (Swenson *et al.*, 1997; Loveridge *et al.*, 2007; Brainerd *et al.*, 2008; Andreasen *et al.*, 2012; Doak & Cutler, 2014). Sinks and super-additive mortality may deplete broader regions than the sites affected by predator-killing. As a result the science behind sustainable use of predators remains contentious and unsettled, even for gray wolves, one of the best-studied predators globally.

Recently concerns about jeopardizing two U.S.A. wolf populations arose because six states moved to reduce their wolf populations substantially by regulated hunting and other legal killing (Bergstrom *et al.*, 2009; Bruskotter *et al.*, 2013; Treves *et al.*, 2014). All but one of the states managed populations of <1000 animals and several states implemented relatively large quotas (20–34%) by global standards (Creel & Rotella, 2010). The latter authors triggered a scientific debate about sustainable mortality that remains unresolved. Examining the same population of wolves, three teams of scientists investigated the relationship between the observed rates of human-caused mortality and growth of wolf populations in the Northern Rocky Mountains (NRM) from 1999 to 2009 (Creel & Rotella, 2010; Gude *et al.*, 2012; Vucetich, 2012). In a federal review of one NRM state's wolf management plan, Vucetich (2012) evaluated and replicated the other two teams' analyses after correspondence with each. He found a 26% disparity in their estimates of sustainable levels of human-caused mortality and inconsistency of methods. Estimating human-caused mortality rates that a wolf population might sustain without declining, Creel & Rotella (2010) estimated <22%, whereas Gude *et al.* (2012) estimated <48%. The former was consistent with three prior reviews and estimates of 14–30% for a wider set of North American wolf populations (Fuller, Mech & Cochrane, 2003; Vucetich, 2012). Vucetich (2012) found that both teams' notations and calculations were different, non-standard, and did not account for error in the measurement of human-caused mortality. Vucetich (2012) predicted that isolated NRM wolves were more vulnerable than other populations surrounded by contiguous source populations, suggesting that prudent wolf-managers should aim for the lower values in the range of mortalities. He also found evidence to support a prior observation of accelerating declines in wolf populations (Adams *et al.*, 2008). For 37 North American wolf populations, declines were best described by a downward sloping curve (depensatory mortality); that implies accelerating declines for each increment in human-caused mortality, a pattern not well explained by current theory (Vucetich, 2012). The major component of human-caused mortality in many carnivore populations is poaching, which is also not well understood yet.

(2) The nascent science of poaching

Poaching (illegal killing or capture of wildlife) is a major source of human-caused mortality in predator populations. Estimates of poaching as a percentage of all mortalities (relative risk) ranged from 24–75% across regions and predator species (Fuller *et al.*, 2003; Andren *et al.*, 2006; Chapron *et al.*, 2008). As a percentage of predator populations (hazard), poaching accounted for 6% of NRM wolves in and around a vast protected area (Smith *et al.*, 2010); 15% in Scandinavia's mixed-use landscape (Liberg *et al.*, 2012); 34% of Amur tigers *Panthera tigris* L. in four high-poaching years across a mixed-use landscape (Goodrich *et al.*, 2008); and 11–30% of wolverines *Gulo gulo* L. in mixed-use northern Scandinavia (Persson, Ericsson & Segerstrom, 2009). Therefore, poaching represents a major mortality factor for predators, which is often underestimated (Gavin, Solomon & Blank, 2010; Liberg *et al.*, 2012) (see online Appendix S2). Poaching is difficult to quantify accurately because poachers have strong incentives to conceal evidence. In the best scientific study available, two thirds of poaching of Scandinavian wolves remained undetected by direct observation (Liberg *et al.*, 2012).

Counterintuitively, a commonly proposed remedy for poaching is to legalize killing *via* regulated hunting or government-regulated culling (Mincher, 2002; Refsnider, 2009), despite the scientific uncertainties described above. At

present, the only systematic study of the relationship between poaching rate and hunting rate showed no relationship among four subpopulations of European lynx (*Lynx lynx* L.; Andren *et al.*, 2006); the subpopulation with the highest hunting rate had the second highest poaching rate and the lowest hunting rate had the highest poaching rate. A meta-analysis of many more populations would be useful to help resolve this issue.

Under these conditions, prudent government trustees managing populations of predators that face high poaching should prioritize understanding and preventing poaching. Because illegal uses detract directly from all other legal uses, anti-poaching interventions seem high priority for every prudent predator trust manager. Public trust thinking suggests illegal uses should be counted directly against any other uses that deplete the resource. But the difficulty of accounting for illegal uses may lead trustees to turn a blind eye to illegal killing.

Hopeful fixes for poaching have been proposed, such as increasing government-sponsored culling or regulated harvest, Indeed, the USFWS asserted in federal court that permitting states to kill wolves perceived as problems would reduce poaching (Refsnider, 2009). That prediction was examined for wolf-culling in Wisconsin (Olson *et al.*, 2014). Although the authors concluded that more culling led to less poaching, their analysis did not account properly for within-year and between-year time series that affect observed poaching and culling patterns. Other scientists have proposed a more subtle benefit of legalizing predator-killing. Legalizing predator-killing might raise tolerance and inhibit poaching among those that benefit from predator-hunting (Ericsson & Heberlein, 2003; Heberlein, 2008; Refsnider, 2009). In 2007, when the USFWS proposed removing federal protections for grizzly bears, the agency claimed that hunting promoted '. . . tolerance for grizzly bear recovery' (USFWS, 2007, p. 14784), but acknowledged that, 'there is no scientific literature documenting that delisting would or could build . . . tolerance for grizzly bears' (USFWS, 2007, p. 14902). Some evidence suggests that approval for poaching or intentions to poach increase when other forms of predator-killing are legalized (Treves & Bruskotter, 2014). Therefore public trust thinking would demand a clear understanding of poaching, intolerance, and proposed interventions for either.

V. HUMAN ATTITUDES TO PREDATORS

A prudent trustee will want to understand how the beneficiaries perceive the asset lest they use it illegally or disdain the benefits. When the beneficiaries are legion, such understanding demands the most sophisticated and clear methods from social science. Decades of research since the 1970s show that majorities of residents within and without predator range care about predators and how they are managed (Kellert, 1985; Williams, Ericsson & Heberlein, 2002; Dressel, Sandström & Ericsson, 2014). The prevailing view of attitudes to predators is that society today accepts predators more than in most of the 20th century, and in part, changing attitudes allowed predator recolonization (e.g. Schanning, 2009). In this view, the environmental decades of the 1960s and 1970s in the U.S.A. and Europe reflected a sea change in individual attitudes to predators across broad regions and many sectors of society. The claim is reasonable and straightforward but discounts the pervasive, positive icons associated with predators in western and non-western cultures (Knight, 2000; David, 2009). The nearly complete lack of quantitative data on attitudes of the average citizen before 1970 has hampered scientific examination of the prevailing view (Kellert, 1985; Schanning, 2009). One alternative hypothesis is that powerful but narrow interest groups have long pushed for predator eradication, independent of individual attitudes in the broader public. Because legislation can both lead and follow public opinion, it seems plausible that the power elites that shaped predator policy in the past have changed recently and may do so again. To elucidate these competing hypotheses, we review research on attitudes to predators.

Most research on attitudes to predators has been conducted on gray wolves. An early meta-analysis of 37 data sets spanning 1972–2000 showed attitudes towards wolves correlated negatively with age, rural residence, and agricultural occupation; and positively with education, income, and living outside wolf range (Williams *et al.*, 2002; see for Europe more recently, Dressel *et al.*, 2014). People active near wolves expressed more negative attitudes than those more insulated by distance, livelihoods, or pro-wolf world-views (Naughton-Treves, Grossberg & Treves, 2003; Karlsson & Sjöström, 2007; Heberlein & Ericsson, 2008; Shelley, Treves & Naughton-Treves, 2011). Recent reviews confirmed that attitudes to wolves were more positive outside wolf range than inside it, both in the U.S.A. and in Europe (Bruskotter *et al.*, 2013; Dressel *et al.*, 2014). Furthermore, negative attitudes tended to increase with time within wolf range (Majic & Bath, 2010; Treves, Naughton-Treves & Shelley, 2013; Dressel *et al.*, 2014), although the causes of change are not clear because individual experience did not seem to predict longitudinal change in individual attitudes (Treves *et al.*, 2013). Negative messages – media emphasizing negative aspects of wolf recovery (Houston, Bruskotter & Fan, 2010) and political rhetoric (Bruskotter, 2013; Bruskotter *et al.*, 2013), largely unleavened by positive messaging – might have reduced tolerance for wolves among sympatric residents of wolf range (Treves & Bruskotter, 2014). Expansion of lethal management may also have diminished the perceived value of wolves (Treves *et al.*, 2013). Inaugural implementation of one season of permitted wolf-hunting in 2012 was associated with an average decrease in individual tolerance for wolves among male residents of Wisconsin's wolf range (Hogberg *et al.*, 2015). Likewise, an unpublished report on Montana residents' self-reported recollections of their own attitudes suggested a wolf-hunt did not change tolerance for wolves, although it did improve attitudes towards wolf managers (Lewis *et al.*, 2012). Yet attitudes are mainly relevant to

trustees to the extent that attitudes shape beneficiaries' expectations about the balance of use and preservation.

Attitudes may ultimately manifest in a variety of individual behaviours that can directly and indirectly influence predators and conservation outcomes. Direct behaviours may include poaching or protective stewardship among others. Indirect behaviours may include communications and contributions for or against policies for predator conservation. Therefore attitudes to poaching, preservation, and legal uses are of particular interest.

The mechanisms that facilitate predator-poaching and the motives behind such behaviour have only recently been studied. The traditional view that poaching is driven by retaliation for livelihood losses is inconsistent with evidence that wealthier individuals are more involved in and intent on jaguar poaching (Marchini & Macdonald, 2012; see also Browne-Nuñez *et al.*, 2015, for wolves). Therefore, the causes of poaching reflect complex social patterns beyond simple retaliation for economic losses caused by predators and other wildlife. Individual fear, direct financial incentives, pathological behaviour, beliefs that predator-killing is beneficial for game conservation or property protection, or identity group norms and values that attach status or rewards to illegal behaviour, all may lead an individual with opportunity to poach into that action (Marchini & Macdonald, 2012; Kahler, Roloff & Gore, 2013; Sharmaa *et al.*, 2014; Browne-Nuñez *et al.*, 2015). Poaching may be encouraged by scapegoating, downgrading the value of predators, or beliefs that poaching is a common or acceptable behaviour unlikely to be punished (St. John *et al.*, 2012; Chapron & Lopez-Bao, 2014; Treves & Bruskotter, 2014). Poachers also sometimes justify their crimes by citing deficient knowledge of the rules, or corruption and other unfairness in systems of wildlife allocation (Gore, Ratsimbazafy & Lute, 2013). Consistent with empirical findings in other social psychological studies of sensitive behaviours, St. John *et al.* (2012) documented that respondents inclined to poach predators believed their behaviour and intentions were in the majority. If would-be poachers who only have intentions to behave illegally are encouraged to act by other illegal actions, then the result could be propagation of predator poaching through a social network. Social norms are often resistant to policy interventions because members of identity groups gain status by defying outgroups, which often include law enforcement (Kinzig *et al.*, 2013; Lute & Gore, 2014). These findings suggest that policy interventions designed to increase acceptance of predators should be evaluated scientifically and informed by recent social science (Dickman, Marchini & Manfredo, 2013; Treves & Bruskotter, 2014). If poaching is caused by this complex interplay of psychological and social factors, policy interventions that hope to reduce poaching will need to integrate more sophisticated measurements using a mix of quantitative and qualitative social scientific methods (Browne-Nuñez *et al.*, 2015). Because illegal uses of predators are poorly understood, remedies for poaching are on uncertain ground.

Practitioners and scientists commonly assume that intolerance for predators leads to retaliation because people perceive threats to human safety and livelihoods. Therefore, it is reasoned, reductions in predator populations can reduce perceived threats associated with the species and thereby improve acceptance. But hazard-acceptance theory predicts acceptance of risks such as predators is influenced by the benefits as well as the costs of the hazard; both cross-sectional and experimental tests support the theory for predators (Slagle *et al.*, 2013; Bruskotter & Wilson, 2014). Furthermore, indirect anti-poaching interventions such as financial incentives may have to reach potential poachers not just the individuals who express intolerance for predators; indirect interventions may have to be paired with a direct anti-poaching interventions in any case (Persson, Rauset & Chapron, 2015). Yet, the path to better understanding of poaching will be uphill if the alternative hypothesis we proposed above finds support. If intolerant interest groups exert their power by capturing agencies, media, and constitutive processes, then measuring the attitudes of the more-readily accessed public may not shed much light on actions that oppose predator preservation. Successful and prudent trust asset preservation under these conditions may demand that trustees be separated from the asset managers who are exposed to many pressures from those they regulate and with whom they interact. Full treatment of the separation of powers between trustees and trust managers is beyond our scope but that deep reflection has begun (Scott, 1999; Horner, 2000; Smith, 2011; Hare & Blossey, 2014). Even if predator managers grapple successfully with the scientific uncertainties and the political obstacles to preserving predator populations, independent trustees may still face genuine conceptual challenges in balancing alternative uses of predators.

VI. BALANCING COMPETING USES OF PREDATORS WITH COMPLEX BEHAVIOURAL ECOLOGY

The public expresses a variety of legally recognized uses and interests in predators. People observe, feed, track, and discuss them, in addition to hunting, trapping, and retaliating for property losses. In principle, the PTD protects all legally recognized interests against infringement by any of the others. Therefore depletion of the asset requires scrutiny, following Illinois Central (1892) in the U.S.A. and other countries' constitutional provisions (Blumm & Guthrie, 2012; see online Appendix S1). The nature of any infringement between uses will necessarily be influenced by the behavioural ecology of predators and humans.

(1) Lethal and non-lethal customary uses

Because most people are urban residents and that trend is continuing worldwide, the majority will probably never use predators by killing them (Treves & Martin, 2011;

Bruskotter *et al.*, 2013). Even within an urbanizing world, diffuse uses of predators continue. For example, the Anishinaabe (Ojibwe) value the gray wolf above other animals http://www.ojibwe.org/home/about_anish.html (David, 2009; Shelley *et al.*, 2011). Diverse groups of people appreciate the wolf aesthetically in art or in wildlife-watching (Duffield, Neher & Patterson, 2008). For example, the Swedish Association of Ecotourism Industries complained in 2013 to the Swedish government that the decision to eliminate wolf packs in a licensed hunt would jeopardize the profitability of eco-tourism companies (see also Center for Biological Diversity, 2013; Collins, 2013). Organized non-consumptive users may perceive infringement by consumptive users such as predator-hunters although data on this infringement are sparse at present. Consumptive uses bear a special burden when one employs public trust thinking. Intergenerational equity demands that one prioritize preservation of the principal of the asset for future generations. Whether this goal is achieved by legally recognizing the intrinsic value of environmental assets (i.e. independent from current human uses) or by requiring trustees to advocate explicitly for future generations remains debated. Regardless, current generations should not decide how future citizens should preserve or use the assets. Setting aside this argument about intrinsic value and intergenerational equity, we turn to the adjudication of conflicts between current uses of predators.

Similar to how courts may play counter-majoritarian roles to protect minority interests, the government trustees that allocate wildlife resources should not be swayed unduly by the popularity of certain uses. The test for a trustee adjudicating between uses should rather be whether the trustee has recognized and successfully balanced the diverse public interests in predators, especially the diffuse uses (Sax, 1970).

Although hunters are a minority in the U.S., E.U., and likely most industrialized countries (Pergams & Zaradic, 2008; see also http://www.face.eu/about-us/members/across-europe/census-of-the-number-of-hunters-in-europe-september-2010 accessed April 2015), majorities in most regions support regulated hunting with variable bounds on its purposes, methods, locations, and sustainability (Reiter *et al.*, 1999; Treves & Martin, 2011). Nevertheless, neither the number participating, nor the popularity of a particular use, should dictate strongly how a trustee allocates wildlife to beneficiaries. Because future generations inherit the asset in perpetuity, without substantial impairment, the allocation to current users that deplete the asset is an incremental addition to 'impairment', which must always be less than 'substantial' (Illinois Central, 1892). In the following sections, we explain why diffuse uses would receive preferential treatment under the U.S.A. Supreme Court's interpretation of the PTD (see online Appendix S1).

Generally public trust thinking would view non-consumptive uses as more prudent uses of a trust asset because they rarely deplete the asset. Certainly some diffuse uses deplete the asset. For example, tourism can harm wildlife, although rarely to the point of mortality (e.g. Dunstone & O'Sullivan, 1996; Treves & Brandon, 2005). On the other hand, some diffuse uses of wildlife may enhance the asset by increasing others' access or enjoyment. For example, if feeding, creating refuges, restoring habitat, etc. were measurably enhancing the benefits for other users, the activity might be seen as highly preferred to taking wildlife or otherwise depleting the asset. Given the possibility of harming or depleting wildlife, trustees should look more cautiously at lethal uses than has been traditional under North American wildlife management (Section III). Trustees held to a fiduciary trust standard would likely suspend lethal uses until uncertainty and scientific controversy about sustainability are deemed minor (Section IV). However the PTD recognizes customary uses, which include hunting, so outright bans on predator-killing seem unlikely. Therefore balancing lethal and non-lethal uses of predators will remain important.

Balancing lethal and non-lethal uses is not straightforward. Advocates often claim a broad public interest in killing predators. Similar statutory claims exist. For example, the ESA allows proactive killing of wild animals before human injury occurs as an exception to prohibitions on take, when wild animals 'constitute a demonstrable but non-immediate threat to human safety' (http://www.fws.gov/policy/library/2002/02fr1494.html accessed 31 August 2015 citing 50 CFR1 § 17.31). The ESA also accommodates predator-killing as a conservation practice, '. . . predator control, protection of habitat and food supply, or other conservation practices . . . ' (16 USC § 1531 Sec. 4(b)). Indeed state and federal agencies have long cited the protection of listed species, as well as health and human safety reasons, to kill small numbers of listed predators, including entire wolf packs. However the most frequent and widespread reason governments give to kill predators is to protect wild game or domestic animals and other property (Doremus, 1999; Treves, 2009). There are three problems with this justification as a broad public interest.

First, protection of property is a private interest in most cases. U.S.A. federal courts have repeatedly rejected the notion that the government is responsible for takings that result from the actions of wild animals (Thompson, 1997). Reintroduced wild animals are more often subject to lethal intervention though (Doremus, 1999). Second, justifying killing predators to prevent property damage erects a false dichotomy, '. . . "Environment or healthy human economics. You cannot have both." This classic false dichotomy of an inexorable tradeoff is a powerful and seductive mind-framing which serves to undercut environmental regulation generally' (Plater, 2004, p. 303). A recent review of that question concluded, 'an increase in stringency of environmental policies does not harm productivity growth' (The Economist, 2015). Treves, Wallace & White (2009*b*) provided evidence for why there is always more than one intervention to resolve human–wildlife conflicts, one that addresses the outcomes of encounters between people and wildlife, and another that addresses how people perceive such encounters. Thus lethal

management should be viewed as a candidate intervention, not the only option. Indeed, physical intervention directed at wildlife, should always be juxtaposed with other interventions that influence human perceptions or behaviour (Treves *et al.*, 2006). A prudent trustee should be aware of and weigh alternatives on their merits as well as their effect on preservation and other legal uses. Third, experts worldwide agree that non-selective killing of predators typically does not prevent property losses (Knowlton, Gese & Jaeger, 1999; Greentree *et al.*, 2000; Bartel & Brunson, 2003; Donnelly & Woodroffe, 2012; Vial & Donnelly, 2012; Krofel, Cerne & Jerina, 2011), except for the extreme of local eradication or extremely high mortality for long periods over large geographic areas, which is incompatible with public trust thinking. Even moderately selective killing has a poor record of preventing predator damages (Knowlton *et al.*, 1999; Greentree *et al.*, 2000; Peebles *et al.*, 2013; McManus *et al.*, 2015; Wielgus & Peebles, 2014; Krofel *et al.*, in press). The allegedly most effective techniques for eliminating confirmed culprit predators thus far documented include the following: shooting lions *Panthera leo* L. over a carcass within 24 h of a kill (Woodroffe & Frank, 2005) or acoustic mimicry of coyotes *Canis latrans* Say, 1823, followed by shooting those that arrive to investigate the caller (Sacks, Blejwas & Jaeger, 1999; Mitchell, Jaeger & Barrett, 2004). Neither has been subjected to experimental comparisons with non-lethal methods (reviewed in McManus *et al.*, 2015). The shortage of evidence for the effectiveness of killing predators to protect property or human safety should induce hesitancy among trustees to provide for this use. Under a fiduciary standard, trustees presented with evidence of inefficacy or counter-productive effects (Wielgus & Peebles, 2014) might prohibit the practice as a precaution. Finally, killing predators to protect private property is an unlikely public interest, but falls under the more general legal issue of 'takings' that often regulates conflicts between public interests and private title (Section II). If one cannot demonstrate a broad public interest in killing predators, then predator-killing becomes a competing, private use without priority.

Adopting public trust thinking sheds a different light on permit fees and payments for private uses of public assets. In the U.S.A., those seeking a pragmatic remedy to the status quo of preferential treatment of hunters in allocation of wildlife assets have argued that non-consumptive users should pay equivalent taxes and fees for bird feeders, binoculars, tripods, etc. as hunters pay for ammunition, permits, etc. Public trust thinking would suggest that taxes and fees are levied for uses that deplete the asset or infringe on other protected public interests. Uses that do not deplete or even enhance the asset should be encouraged not taxed, in this view. Legally recognized private uses must be balanced with other legal uses. However, predator behavioural ecology complicates the search for balance between depleting and non-depleting uses.

(2) Predators as atypical game species

First and foremost, predators occur at lower densities than virtually all other game species such as white-tailed deer *Odocoileus virginianus* Zimmerman 1780, elk *Cervus elaphus* L., and moose *Alces americanus* Clinton 1882 in North America. For example, estimates for Algonquin Park and North Central Minnesota spanned the range of wolf densities relative to ungulate prey at 97 and 617 ungulates per wolf, respectively (Fuller *et al.*, 2003). Sparseness by itself argues against widespread killing of many predators if one wishes to protect other uses.

Second, sparseness of predators is partly maintained by territoriality within and among species. Predators defend territories more aggressively than most animals (Palomares & Caro, 1989; Wrangham, Gittleman & Chapman, 1993). For example wolves kill interloping dogs (Olson *et al.*, 2015), coyotes (Arjo & Pletscher, 1999; Switalski, 2003), and conspecifics (Smith *et al.*, 2010). Many predators defend year-round territories to exclude competitors and neighbours from vast areas (Gittleman, 1989). When gregarious predators defend territories cooperatively, the size of the cooperating group influences success in territorial defence (Packer *et al.*, 1988; McComb, Packer & Pusey, 1994). Therefore human uses that deplete individuals essential to cooperative defence may lead to the collapse of territorial defences (Whitman *et al.*, 2004; Brainerd *et al.*, 2008; Borg *et al.*, 2014). If neighbouring territorial residents take over vacated territories without permitting new immigrants to do so, the local density may diminish for some time. For example, established packs of wolves occasionally took over neighbouring territories that were vacated after human-caused depletions (Bradley *et al.*, 2008; Brainerd *et al.*, 2008). Depleted territories near to protected source populations refill more quickly than isolated territories (Adams *et al.*, 2008). As a result of strict defence of territories and background sparseness, local predator densities may increase only slightly when populations grow (Fuller *et al.*, 2003; Cubaynes *et al.*, 2014; Kittle *et al.*, 2015). In sum, for many predator populations, depleting a group of predators may not result in rapid replenishment for other users (lethal or not).

Third, and unlike typical game species, deaths of essential members (e.g. breeders) in cooperative groups of predators can destabilize social structures for long periods. For example, many wolf packs that lost a breeding adult disbanded and others did not reproduce for one or more years afterwards; rates of disbanding and reproductive failure increased when both breeders died (Brainerd *et al.*, 2008; Borg *et al.*, 2014). Removal of resident African lions often resulted in infanticide, injuries to lionesses, and long-lasting instability of prides (Packer *et al.*, 1988; Whitman *et al.*, 2004). Infanticide has been detected in solitary predators as well. For solitary species, the effects of infanticide and other social instability on population dynamics of small or hunted populations remain uncertain and controversial (Swenson *et al.*, 1997; Logan & Sweanor, 2001; Packer *et al.*, 2010; Peebles *et al.*, 2013). Social disruptions and reproductive failure would presumably rise in frequency as lethal uses intensify.

Fourth, predator behaviour and spatial ecology may also challenge zoning schemes commonly used by managers to separate different uses. Long-range movements can make

hunting zones a drain on adjacent non-hunting zones for many predators (Woodroffe & Ginsberg, 1998; Loveridge *et al.*, 2007). Predators may make long-lasting, long-distance, extra-territorial forays, often followed by returns to their source ranges. For example, ~25% of radio-collared Wisconsin wolves made long-range, extra-territorial movements lasting 1 month or more (Treves *et al.*, 2009*a*) and 25% of such movements were detected at least once out-of-state. Also predator populations experiencing high levels of human-caused mortality travelled or bred further from settlements and roads (Mladenoff *et al.*, 2009; Theuerkauf, 2009; Ordiz, Bischof & Swenson, 2013). Researchers on foot using telemetry had difficulty seeing radio-collared wolves or brown bears in areas of human use or past persecution (Theuerkauf *et al.*, 2003; Karlsson, Eriksson & Liberg, 2007; Zedrosser *et al.*, 2011). Therefore, people may not be able to use predators for feeding, viewing, or stalking, if those predators are fearful of humans.

In sum, uses of predators that deplete the asset have the potential to reduce the success of later users over large areas for years. Although the quality and quantity of predator population depletion by human use is still genuinely debated, the conclusion that lethal use needs prudent and precautionary management has been made repeatedly for many predators (Whitman *et al.*, 2004; Balme *et al.*, 2010; Artelle *et al.*, 2013). Yet concerns have lately risen that government agencies are failing to apply the precautionary principle and prudent interventions (Bruskotter *et al.*, 2013; Chapron *et al.*, 2013; Vucetich *et al.*, 2013; Artelle *et al.*, 2014). We end this review with recommendations for prudent trustees to adopt precautionary management that prioritizes preservation of predators as trust assets.

VII. CONCLUSIONS

(1) Traditional wildlife conservation in the U.S.A. and western Europe, and particularly predator conservation, has been dominated by a constitutive process that favoured hunting and other forms of lethal management. Those traditions often led to abdication of governmental trust duties and eradication of predators over vast areas, contrary to public trust principles. However recolonization by several species of predators since the 1970s suggests that stronger public trust doctrines can prevent renewed cycles of eradication.

(2) In Section II and Appendix S1, we described the modern codification and vision of the environmental public trust. We distinguished and rejected a variant that expressed preference for narrow, lethal uses of wildlife. Public trust thinking demands disinterested trustees that take a broad public interest approach to allocating environmental assets to current and future generations, while keeping up to date with evolving legal and societal recognition of new and customary uses and accounting transparently and scientifically for the assets and their uses. A logical but idealized form of the public trust that holds governments to a fiduciary standard for environmental assets would demand stronger preservation by non-extractive use predominantly, 'prudent man' standards for allocations, and the strictest accounting standards involving the best available science. Improving trustee effectiveness will require equitable partnerships between trustees and scientists who are as insulated as possible from political and financial incentives for undemocratic allocations. Those partnerships must avoid the political misuse of scientific evidence and eliminate the current conflicts of interest inherent to agency capture by narrow interests. Governance reforms that address constitutive rules are needed in the U.S.A. and beyond to enforce the broad public interest in the environment.

(3) In Section III, we reviewed variable expressions of PTDs across jurisdictions and the abdication of trust duties for many predators in many U.S.A. states. We examined recent legal decisions that incorporated public trust principles for wolf preservation. In the U.S.A., we identified uncertain, legal application of the PTD and power struggles between the federal and state governments that together make a fiduciary trust for wildlife unlikely in the near future.

(4) In Sections IV–VI, we reviewed the essential role of scientific evidence from multiple disciplines in assisting a public trustee to account for predators transparently and quantitatively. We refined the oft-repeated call for interdisciplinarity in conservation sciences by explaining how scientific uncertainty often revolves around understanding and balancing legal and illegal uses by humans. That balance will require a sophisticated understanding of human cognition and action, wildlife behavioural ecology, and the sustainability of human uses that deplete the assets, as well as multiple criteria for evaluating the effectiveness of policy interventions.

(5) In Section IV, we reviewed genuine conceptual uncertainty about the sustainability of human-caused mortality. In Sections IV and V, we reviewed poaching research and the consequences of policy interventions for people's attitudes to predators and behaviour toward predators. In Section VI, we reviewed several aspects of behavioural ecology among sympatric humans and predators, which can complicate the trustees' tasks of balancing competing uses. To avoid tyrannies of the minorities or majorities who may demand depletion of unpopular, native wildlife, we recommend that trustees use the most prudent principles of scientific evaluation, precaution, and intergenerational equity to balance competing uses. We explain how lethal uses of predators need immediate scientific scrutiny to justify their proposed contribution to the public interest.

(6) We recommend public trust principles be applied to the appointment of trustees, separation of powers between trust managers (wildlife agencies) and trustee decision-makers, and judicial oversight and intervention when executive or legislative branches abdicate their trust obligations. Judges should not hesitate to review agency

decisions if given evidence of mismanagement, unscientific accounting, or undemocratic decisions. The judiciary should not hesitate to examine scientific facts, using independent scientists it selects itself rather than the litigants' experts. Deference to agencies risks capture of the judiciary by narrow interests. Delegates of the government should adhere to the same legal standards of trust duties as the government. Universities with enforceable academic freedom will be essential in the face of political pressures to submerge or distort scientific findings. Without such reforms, public trust in science may dwindle and the credibility of scientific evidence in policy debates and legal proceedings may erode further. Regardless we expect predator policy will remain controversial and continue to test public trust in government.

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X. SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.

Appendix S1. PTD case law, wildlife trusts and a glossary of PTD terms.

Appendix S2. Allocating predators without regard to the public trust.

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