

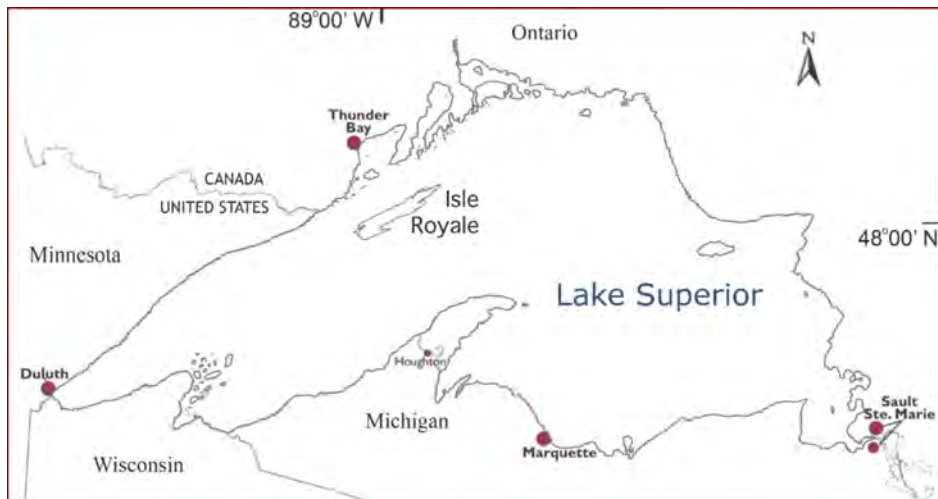
Should Isle Royale Wolves be Reintroduced? A Case Study on Wilderness Management in a Changing World

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Introduction

ISLE ROYALE NATIONAL PARK (IRNP) IS A US NATIONAL PARK and federally designated wilderness in Lake Superior, Michigan (Figure 1). The park is also inhabited by gray wolves and moose that have been the subject of a long-term research project that celebrated its fiftieth anniversary in 2008 (Nelson et al. 2008; Nelson et al. 2011). In January 2011 it became apparent that the wolves of Isle Royale, with a total population size of 16, were facing a substantial and elevated risk of extinction in the near future.¹ Specifically, the population was reduced to a single breeding pack, and contained no more than two adult females (Vucetich and Peterson 2011). The population is typically composed of three packs, and it has been four decades since the population was reduced to just a single pack. Should the two females die before giving birth to more females, imminent extinction would be almost certain. Even the most optimistic scenarios include an elevated risk of extinction for at least the next several years.

Figure 1. Location of Isle Royale National Park in Lake Superior, North America.



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With these circumstances the question arises: Is it appropriate to intervene on Isle Royale in an effort to prevent wolf extinction? The question is complicated because Isle Royale is a federally designated wilderness and a key point of US wilderness policy is assumed to be the principle of non-intervention. However, wilderness policy is not a simple, unquestioning, and inflexible dictate for non-intervention. A large body of wilderness policy treats the conflict between non-intervention and other wilderness values (Dawson and Hendee 2008; Cole and Yung 2010).

This Isle Royale case as an important example of an increasingly common type of challenge for environmental ethics, the academic field of inquiry aimed at understanding how we should and should not relate to nature and the environment around us. Ethical challenges, including the present Isle Royale case, typically involve conflicting values. Common mistakes in dealing with values include ignoring some, having a dismissive attitude about others, or insisting that only one value matters. The appropriate approach is to acknowledge and understand all of the values at stake, and then develop a perspective or position that would least infringe upon that set of values. We adopt this approach here.

The Isle Royale case also requires understanding the nature of wilderness, which is important because it says much about our relationship with nature in general (Callicott and Nelson 1998; Nelson and Callicott 2008). Our understanding of wilderness has evolved over the past 150 years (Turner 2002), and the Isle Royale case likely represents a new, emerging development in that evolution.

The history of wolves and moose on Isle Royale

Moose arrived on Isle Royale, apparently for the first time, early in the 20th century (Clark 1995). Moose most likely swam to Isle Royale (Mech 1966). However, some staff members of IRNP and long-time residents of Isle Royale believe moose were brought to Isle Royale by humans (see also Scarpino 2011). There is no direct evidence to indicate how moose arrived.

Moose lived on Isle Royale for about five decades in the absence of wolves. Without predation, moose increased to a very high level, perhaps 3,000 or more (>6 moose/km²) by the late 1920s (Murie 1934). During this population increase, moose browsing dramatically impacted Isle Royale's forest vegetation (Murie 1934). The moose population crashed in 1934 due to an acute lack of food, increased again, and then died back once more in the 1940s (Krefting 1974). Signs of overbrowsing were still apparent in the early 1960s (Mech 1996).

Isle Royale moose were seen as overabundant during the 1920s and 1940s, and that concern was a primary wildlife management issue for the National Park Service in the late 1940s (Allen 1979). The impact of moose browsing during the first half of the 20th century was dramatic enough to motivate Adolph Murie (1934) to urge that moose be culled or removed, or that large carnivores be introduced. A second important argument for introducing wolves to Isle Royale was to provide the only sanctuary from human exploitation for wolves in the central part of North America (unpublished correspondence, Michigan Technological University archives). Aldo Leopold and Sigurd Olson also supported introducing wolves to Isle Royale in the 1940s (unpublished correspondence, University of Wisconsin archives). Durward Allen (US Fish and Wildlife Service) and Victor Cahalane (National Park

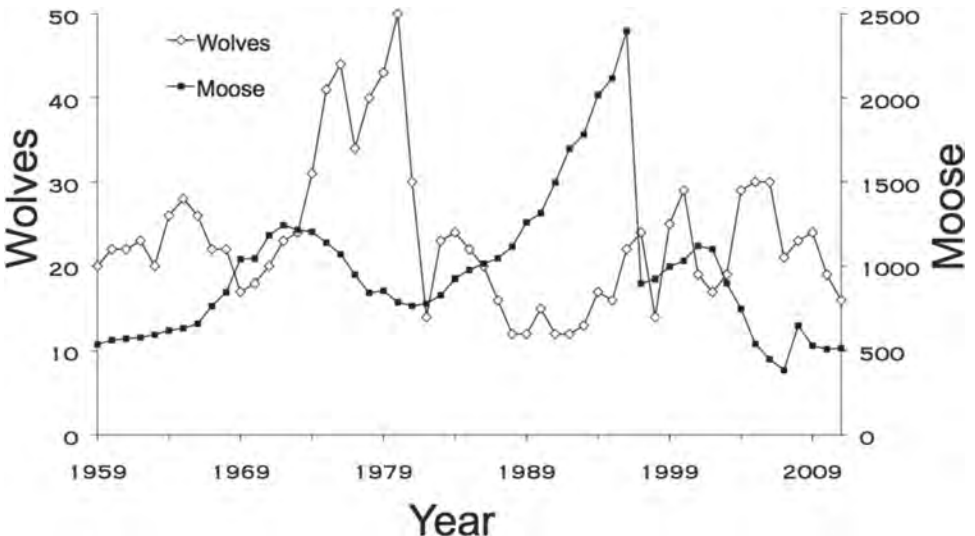
Service) discussed how wolves might be introduced (Allen 1979). These leaders were not only advocating on behalf of Isle Royale's wilderness character, they were also among the intellectual forefathers of our modern concept of wilderness, including the Wilderness Act of 1964.

Lee Smits, a Detroit newspaper editor, strongly advocated wolf reintroduction and led a private effort that in 1952 resulted in the release of four captive-raised wolves on Isle Royale. These plans were carried out even though it was known that wolves had already colonized Isle Royale on their own, most likely by crossing an ice bridge sometime between 1948 and 1950 (unpublished correspondence, Michigan Technological University archives). Three of the wolves that had been introduced by humans were killed or removed after they became a public nuisance and the other disappeared (Mech 1966). Ultimately, wild wolves flourished, and controversy over moose overabundance on Isle Royale largely ceased when wolves colonized the island (Peterson 1995).

Since their establishment on Isle Royale, wolves have been the primary source of moose mortality, and moose have comprised more than 90% of wolves' diet. In 1958, researchers began studying the population dynamics of wolves and moose on Isle Royale. Between 1958 and 1980, wolf predation had a substantial impact on moose abundance and rates of browsing (McLaren and Peterson 1994; Wilmers et al. 2006). Then in the early 1980s, the wolf population crashed after humans inadvertently introduced canine parvovirus (CPV) to the Isle Royale wolf population (Peterson et al. 1998; Figure 2).²

By the mid-1980s the wolf population seemed to begin making a quick recovery, but then declined again and remained in the low teens for the better part of a decade. With wolf predation dramatically reduced, moose abundance increased to approximately 5 moose/km², a remarkably (perhaps unprecedented) high density for a naturally regulated moose population (Karns 1998). With this high density, the impact of moose on the forest also rose to levels never previously measured.

Figure 2. Wolf and moose fluctuations, Isle Royale National Park, 1959–2011.



The human-introduced disease, CPV, has been the single most significant event in the chronology of wolf–moose dynamics on Isle Royale. Although researchers were unable to detect the presence of CPV after 1990 (Peterson et al. 1998), the disease fundamentally altered wolf population dynamics at least up to the year 1998 (Wilmers et al. 2006). Specifically, the period after the wolf crash was characterized by (1) fewer wolves per moose than the two decades prior to the advent of human-introduced disease, and (2) climatic variation replacing wolves as the dominant influence on moose dynamics (Wilmers et al. 2006). One plausible mechanism for these long-lasting effects is the general tendency for some ecosystems to remain altered for long periods following a major perturbation (Wu and Loucks 1995; Beisner et al. 2003). Another plausible mechanism is that the population bottleneck caused by the disease led to elevated levels of inbreeding, which reduced the wolf population's ability to control the moose population (Räikkönen et al. 2009). One long-lasting effect of the disease-induced wolf reduction during the 1980s was a fivefold increase in moose abundance that ended when the population crashed in 1996 (Figure 2). Approximately 2,000 moose (~75% of the population) starved to death in a four-month period.

The dramatic rise of moose abundance that CPV triggered, and its subsequent collapse in 1996, led to an altered age structure in the moose population that lasted for another 15 years. The altered age structure began with the substantial decline in birth rates for several years following the crash. Those years of low birth rate led to a shortage of old moose by 2009. Because wolves cannot easily kill middle-aged moose, a shortage of old moose is associated with declines in wolf abundance (Vucetich and Peterson 2004). The salient point is that the recent decline in wolf abundance is associated with a chain of events that began with the introduction of CPV by humans in the early 1980s.

In addition to an altered age structure, total moose abundance declined by more than 50% between 2001 and 2011 (from ~1100 to ~500). These are the lowest estimates of moose abundance ever documented on Isle Royale, and they play an important role in the elevated extinction risk now facing wolves. The moose decline was caused largely by a set of three interrelated factors: wolf predation, anthropogenic climate warming, and winter ticks (*Dermacentor albipictus*).

Climate warming is widely regarded as a serious future risk to the survival of moose at the southern edge of its range in North America, that is, at the latitude of Isle Royale (Lenarz et al. 2009, 2010). The reality of this risk became clear to moose managers in the first decade of the 21st century as moose populations in Wyoming, Ontario, and Minnesota showed signs of reduced demographic vigor and even local population collapse (Murray et al. 2006). One impact of climate warming is to reduce time spent foraging in summer, which is critical for moose survival in winter and probably determines female ovulation rates during the autumn breeding season (Frisch 2002). Climate warming also likely favors populations of winter ticks (Wilton and Garner 1993; DelGiudice et al. 1997; Samuels 2004), which can cause a moose to die by reducing its nutritional well-being (Garner and Wilton 1993; Addison et al. 1994; DelGiudice et al. 1997; Lankester and Samuel 1997; Samuel 2004). Tick infestations on Isle Royale had risen to very high levels by 2007, when at winter's end most moose had lost more than 75% of their hair to ticks (Vucetich and Peterson 2011). The summers asso-

ciated with the moose decline in the early 2000s were warm, beginning with an El Niño event of unprecedented strength in 1998 (Vucetich and Peterson 2008).

In 2007, CPV was again detected in the wolf population (along with adenovirus, which causes respiratory infections in human and wildlife, and *Anaplasma phagocytophilum*, a bacterium implicated in human and wildlife tickborne disease). Human introduction is the most likely source of these diseases. Although it is difficult to know the impact of these diseases, we do know the population experienced a substantial decline in abundance, from 30 to 21 wolves, between 2006 and 2007, and declined further to 16 by 2011.

Chances for natural recolonization. Wolves colonized Isle Royale on their own by crossing an ice bridge sometime between 1948 and 1950. Genetic analyses also indicate that lone male wolves immigrated to Isle Royale on one to three occasions between 1950 and 1997 (Adams et al. 2011). However, a single wolf is unable to found a population. Only once in recorded history has a breeding pair of wolves capable of founding a population immigrated to Isle Royale (i.e., when the current population was first established in the late 1940s).

Immigration is, in principle, limited by wolves' access to Lake Superior shoreline on the mainland and the presence of an ice bridge stable enough to allow wolves to walk the 24 kilometers that separate Isle Royale from the mainland (Figure 1). Since wolves first colonized Isle Royale, human activities have limited wolves' access to Lake Superior shoreline because of the development of the Trans-Canada Highway and the expansion of Thunder Bay, Ontario. Climate warming has also greatly reduced the frequency and duration of stable ice bridges. During the 1960s, stable bridges formed in most years and lasted for several weeks to well over a month. Between 1998 and 2011, a suitably stable ice bridge formed only once, in 2008. So far this century, ice bridges have typically lasted just a few days. Natural recolonization would not be impossible, but human action, as manifested in land-use change on the north shore of Lake Superior and global climate change, has significantly reduced the likelihood of what was already an extremely rare event.

It seems that humans have now impacted nearly every landscape on the planet and often in ways that are as significant as they are subtle. The history of human influence on the wolves and moose of Isle Royale is an important example.

Analysis: Wolf reintroduction

In principle there are three cases of intervention that could be considered. The first case, hereafter referred to as "wolf reintroduction," would involve reintroducing wolves if the wolf population were to go extinct. A second case, "genetic rescue," is motivated by concern that some conservation scientists have for the high rate of inbreeding that Isle Royale wolves exhibit (unpublished correspondence with the editor of the journal *Biological Conservation*). A third case, which we term "female reintroduction," would involve reintroducing female wolves if all the females were to go extinct.

Here we provide a detailed analysis for the ethics of wolf reintroduction. Afterward we present a briefer description of how the cases for genetic rescue and female reintroduction compare and contrast with the wolf reintroduction case. Next, we identify and describe the values involved in deciding whether to reintroduce wolves. Afterward we evaluate whether these values are more likely overridden by reintroducing or by not reintroducing wolves.

The value of non-intervention. A central management principle of wilderness policy is the principle of non-intervention, which is sometimes casually characterized as “not intervening, so that nature can take its course.” As a central principle of wilderness, non-intervention is not valuable for its own sake; instead it is valuable as a means toward two critical ends. First, it can prompt an attitude of humility that mitigates pathological obsessions to control nature (Meffe and Holling 1996; Landres 2010). Second, using language of the US Wilderness Act 1964, non-intervention can help maintain natural conditions and the primeval character of landscapes that have not already been influenced by human activities.³ According to well-established wilderness policy, non-intervention is not, in general, a preferred management option when “nature’s course” has been altered by humans. In such cases, intervention is commonly adopted in an effort to mitigate human influence (Dawson and Hendee 2008; Cole and Yung 2010).

During the past three decades the wolf population has been affected by disease and moose population decline, which was influenced by predation, ticks, and climate warming. Humans had a hand in all of these influences. If wolves were to go extinct, it would be plausible to conclude that humans had exacerbated the extinction risk of wolves during the past three decades and that humans have significantly reduced the chances of natural recolonization. As such, non-intervention would override the wilderness values of Isle Royale while intervention would enhance and honor wilderness values of Isle Royale.

One might object and suggest, hypothetically, that Isle Royale wolves would go extinct due to inbreeding and chance demographic events (e.g., skewed sex ratio) that are likely to occur naturally and inevitably on a small island. However, a fundamental principle of extinction is that it is not in general the result of a single cause. Extinction is almost always the result of an interrelated web of both proximate and ultimate causes. Even if inbreeding or natural random chance occurrences were part of the extinction process, the salient conclusion remains: Human actions importantly increased extinction risk and decreased the chance of re-colonization.

The value of wilderness character. Preserving the “wilderness character” of a landscape is another fundamental value of wilderness management, particularly for Isle Royale National Park (USNPS 1999). Wilderness character arises from the properties of a landscape that evoke a feeling or emotion that the landscape is wild and primeval. Wilderness character is also a special kind of “sense of place,” which is formed when the natural history, culture, and geography of a place commingle in our minds and form the stories—lyrical stories and scientific stories—that define a place. Sense of place and wilderness character are critical because they provide the points of connection between a place and a person’s knowledge, emotions, and values.

Wolves are a critical component of Isle Royale’s wilderness character—not merely the presence of wolves, but the interactions among wolves, moose, and the forest, all in the absence of any hunting or logging by humans (Appendix 1; see below, p. 144). This condition is, on our planet today, rare, special, and critical for evoking a feeling that Isle Royale’s landscape is wild and primeval.⁴ Wolves and their connections provide the most important and widely appreciated narratives that create a wilderness sense of place for this island. This importance is reflected in NPS policy, interpretive activities, and widespread interest among

park visitors, scientists, and supporters of wild places (see Appendix 2, pp. 145–147, for details).

For Isle Royale, wolves are the icons of wilderness culture. Therefore, allowing wolves to remain extinct on Isle Royale would significantly wound Isle Royale's wilderness character and important points of connection between people and Isle Royale. It may seem odd that non-intervention would conflict with the preservation of a land's wilderness character. However, this ironic juxtaposition is not odd, so much as it is the result of a tragedy: humans have reduced the planet's unexploited landscapes to small remnants in remote places.

The value of ecosystem health. In the United States, the preservation of ecosystem health is also broadly appreciated as a central value of wilderness (Nelson 2009a, 2009b). Ecosystem health has been defined, roughly, as the structure, function, composition, and resilience of an ecosystem that was native prior to the modern era (Rappport et al. 2002). Ecosystem health is a coherent blend of normative and objective concepts (Nelson 2009a). That is, society, led by the voices of conservation leaders, has indicated that structure, function, composition, and resilience are the ecosystem properties that have moral value; and, science is able to objectively measure and evaluate these properties. The meaning of ecosystem health is both flexible enough to be applied to any particular place or time and concrete enough to make it a useful platform for management.

A great deal of conservation science affirms that ungulate overabundance is a widespread and severe threat to ecosystem health, and that top predators, like wolves, are vital components of ecosystem health for limiting ungulate abundance (Miller et al. 2001; Beschta and Ripple 2009; Estes et al. 2011). North American national parks, in particular, have been challenged by this fact (e.g., Rocky Mountain, Great Smoky Mountains, and Yellowstone national parks). In Canada's Gros Morne National Park, the loss of wolves resulted in moose overabundance that degraded 44% of that park's forests (Woodley 2010). The health of island ecosystems seems particularly vulnerable to ungulate overabundance in the absence of predators, for example at Anticosti Island, Quebec (Potvin et al. 2003) and North Manitou Island of Sleeping Bear Dunes National Lakeshore (Case and McCullough 1987). In several parks where wolves have (or had) been excluded, hunting or culling of ungulates has been, with great controversy, considered or mandated (e.g., Rocky Mountain and Yellowstone national parks). Unless possibly very high rates of moose harvest were mandated,⁵ allowing wolves to be lost from Isle Royale would significantly diminish its ecosystem health.

A detractor of this perspective might suggest that using "ecosystem health" in this way to justify wolf reintroduction disguises a romantic and outdated desire to preserve "vignettes of primitive America," and that wolves were a critical part of IRNP's ecosystem health from ca. 1950 until the time of their extinction, but not afterward. Certainly, top carnivores were an important aspect of historic conditions. This does not mean, however, that maintaining and restoring top carnivores to places where large herbivores live represents maintaining "vignettes of primitive America." Instead, top predators are a basic principle of ecosystem health (Estes et al. 2011).

A detractor might also object by first citing NPS management policies (2006) which mandates "maintain[ing] all the components and processes of *naturally* evolving park ecosystems, including the *natural* abundance, diversity, and genetic and ecological integrity

of the plant and animal species native to those ecosystems [and recognize] *natural* change ... as an integral part of the functioning of *natural* systems” [italics added]. With this policy in mind, a detractor might assert that the defining characteristic of Isle Royale’s ecosystem health is its small, isolated nature, where colonization by wolves and moose are rare “accidents” and extinction is a *natural* process. Isle Royale is a dynamic place, and wolves and moose have been a part of Isle Royale’s history for only a short time. For these reasons, the argument would go, losing wolves from Isle Royale leaves the place no less healthy than it had been before their arrival.

The weakness of this argument may be first recognized by noting that wolf–ungulate–vegetation interactions used to be a dominant set of ecological relationships throughout much of North America. By the 21st century, however, humans have restricted such relationships, operating in the absence of human exploitation, to very rare and small remnants. The detractor’s perspective pits the value of one natural process—extinction on small islands—against another—predation (Peterson and Krumenaker 1989; Peterson 1995). The detractor’s position overlooks the process of wolf predation, which is essential to the health of Isle Royale’s ecosystem.

The weakness of the detractor’s position arises from the concept of *natural* being fraught with debilitating dilemmas that have remained intractable despite being considered for more than two millennia (Desjardins 2000; Cole and Yung 2010). The concept of “natural” is increasingly difficult to make sense of because of human impact on the planet.

Because of these problems with the concept of “natural,” Parks Canada recently replaced “naturalness” with “ecological integrity”⁶ as a general management objective for their natural areas (Woodley et al. 2010). A specific example of this attitude is likewise reflected in the general management plan for IRNP (1999), which indicates that “preserving and protecting the park’s wilderness character ... natural resources ... and ecological processes” is one of the park’s purposes and that to “preserve ecological integrity of Isle Royale” is one of the park’s priorities (USNPS 1999).

Again it seems ironic to pit the value of non-intervention and natural processes (like extinction on small islands) against the value of ecosystem health. However, the tragedy is having reduced the planet’s unexploited areas to small remnants, resulting in the need to actively maintain ecosystem health in these tiny remnants. This concern is aptly captured by the ecologist Daniel H. Janzen: “What escapes the eye ... is a much more insidious kind of extinction: the extinction of ecological interactions” (Janzen 1974).

The value of science. The primary scientific mission of the Isle Royale wolf–moose project is to document and understand predation and herbivory—two of the most important ecological relationships on the planet. Isle Royale’s biogeography is critically unique for this mission. The island’s isolation means that fluctuations of wolves and moose are caused almost entirely by births and deaths, not immigration and emigration. Isle Royale is also the only location on the planet where wolves and moose interact in the absence of other important predators and prey, such as coyotes, deer, and bears. Studying simplified food webs is critical to ecologists’ understanding of nature. Perhaps most importantly, the wolves and moose on Isle Royale are not hunted, nor is the vegetation logged or otherwise harvested. This circumstance is very rare on the planet today.

Wilderness areas are uniquely valuable to science as places for establishing baselines of ecosystem health that can be applied in areas far beyond wilderness. These baselines cannot be established overnight, as they require long-term research. Long-term research is not only rare, it is valuable for its distinctive ability to help us better understand how ecosystems are affected by unexpected events, rare events, and multicausal relationships (Turner et al. 2003).

The Isle Royale wolf–moose project is the longest study of any predator–prey system in the world. The project has made valuable scholarly contributions on a wide range of topics, including population biology of wolves (e.g., Vucetich and Peterson 2004), effect of wolf predation on moose (e.g., McLaren and Peterson 1994; Vucetich et al. 2011), effect of climate and disease on population dynamics (e.g., Post et al. 1999; Wilmers et al. 2006), the nature of extinction risk (e.g., Vucetich et al. 1997, 2009), the effect of genetic rescue on population dynamics (e.g., Adams et al. 2011), the nature of inbreeding depression (e.g., Rääkkönen et al. 2009), connections between individual life history and population dynamics (Peterson et al. 1984), social behavior of wolves (Vucetich et al. 2004), the effect of the US clean air and water legislation on mercury pollution (Vucetich et al. 2009), the role of predation in nutrient cycling (Bump et al. 2009), the ecology of arthritis in moose (Peterson et al. 2011), the relationship between ecological science and environmental ethics (Nelson et al. 2010; Vucetich et al. 2010), and the relationship between ecological science and sociology (Gore et al. 2011). Papers from the wolf–moose project have been cited more than 1,200 times during the past ten years. The scientific value of the wolf–moose project was recently affirmed by an independent panel of scientists commissioned by the National Park Service who reviewed the state of science in Isle Royale National Park (Schlesinger et al. 2009).⁷

Allowing wolves to be excluded from Isle Royale would cause the end of wolf–moose research and its extensive outreach program. Superficially, one might think the loss of wolves would simply cause the wolf–moose project to become a moose–vegetation study. While studies focusing on three trophic levels are rare, studies focusing on ungulate herbivory in the absence of top predators are extremely common. Moreover, the approach and methods used to conduct state-of-the-art herbivory research are very different from the methods appropriate for studying interactions across three trophic levels. As such, without wolves the Isle Royale wolf–moose project would be in no position to effectively compete for funding from the US National Science Foundation, the loss of which would be the death of the project. In 2009 and 2010, the wolf–moose project proposed research to NPS that would expand the moose–vegetation component of the research. NPS chose to not fund that research. There is little reason to think that the longest study of any predator–prey system in the world would survive the loss of wolves from Isle Royale.

Should science ever, in principle, trump wilderness values in a wilderness area? Well-established wilderness policy clearly indicates the answer to this question is, “yes.”⁸ The question at stake here is: Should one of the longest and most prominent research projects to ever take place in a federally designated wilderness be sacrificed for the far-from-solid claim that doing so might affirm the value of non-intervention?

The value of education. Wilderness policy also recognizes the vital role that education about “wilderness character, resources, and ethics” play in maintaining values that promote healthy relationships with nature (§6.4.2 in NPS 2006). The educational mission of the Isle

Royale wolf–moose project is to use scientific discoveries about the wolves and moose of Isle Royale as a basis for “generat[ing] a sense of wonder toward nature in as many people as possible,” a sense of wonder that would inspire a caring relationship with nature (Vucetich 2010). The mission is not only true to the project’s science, but it is informed by inclusion of an environmental philosopher (MPN) as part of the wolf–moose project.

To this end, associates of the wolf–moose project disseminate knowledge to the general public through a vigorous outreach program that includes books, DVDs, annual reports, a website, pieces of art, museum exhibit displays, and public presentations delivered to thousands annually by the project principal investigators and other associates, and opportunities for members of the general public to volunteer for the research project (see Appendix 3 for details). The extent of outreach associated with the wolf–moose project and sophistication of its purpose is rare among research projects of any kind.

Wilderness policy also recognizes that recreation is an important value that is sometimes associated with compromising the wilderness value of non-intervention (§6.4.3 in NPS 2006). Hiking trails, boat docks, and sleeping shelters (and the machinery and infrastructure necessary to maintain them) are examples of such concessions. The wolf–moose project also represents an important form of recreation. For many people, participating in the wolf–moose project’s outreach activities represent a particularly deep kind of recreation, an opportunity to re-evaluate and subsequently re-create their relationship with nature.

Synthesis. Should the wolves of Isle Royale go extinct, human response involves five principal values: non-intervention, wilderness character, ecosystem health, science, and education. Failing to reintroduce wolves would:

- Dismiss the value of *science* and *education* by resulting in the end of a long-term research project that is globally significant, unique, and irreplaceable.
- More likely denigrate the value of *non-intervention* because this value is contingent on humans not having impaired the wolf population’s viability or the chances for subsequent recolonization; human activities have impaired these processes.
- Diminish the island’s *wilderness character* and *ecosystem health*.

For these reasons, failing to reintroduce wolves would degrade the wilderness value of Isle Royale, and wolf reintroduction is an appropriate way to honor that value. Lingering concerns about the inappropriateness of intervening in a wilderness are further mollified by the evolution of our understanding of wilderness. That is, ecosystem health may well be superseding non-intervention as the central value of wilderness (Cole and Yung 2010).

These perspectives are complemented by sociological research indicating that an “overwhelming majority” of Michigan residents do not believe that allowing “nature to take its course” is an adequate reason to allow the extinction of Isle Royale wolves and support the belief that Isle Royale wolves should be maintained should they begin to disappear from the park.⁹

Would reintroducing Isle Royale wolves because of their contributions to ecosystem health in boreal forests open a kind of Pandora’s box requiring one to consider introducing black bears, which also prey upon moose in many boreal forest ecosystems, and consider

reintroducing lynx and caribou to IRNP for their contributions to ecosystem health? Perhaps. There would be nothing wrong with conducting an analysis like that presented here to consider the appropriateness of introducing or reintroducing these species to Isle Royale. The development of such arguments is beyond the scope of this essay, except to mention a few considerations. First, the ecology of black bear predation on moose differs substantially from the ecology of wolf predation. If wolf predation is essential for ecosystem health where moose live, then bear predation is unlikely a substitute for wolf predation. Consequently, if a robust argument could be developed for black bear introduction,¹⁰ it is difficult to imagine how that would end up being an argument against wolf reintroduction. Similarly, if a robust argument could be developed for establishing a lynx population, such an argument is unlikely to be an argument against wolf reintroduction.

Caribou persistence on Isle Royale is unlikely in the presence of wolves (Cochrane 1996). As such, an argument for caribou reintroduction may well be an argument against wolf reintroduction. If so, one would have to assess whether the value of caribou on Isle Royale would outweigh the value of wolves. Both species probably have similar value in terms of wilderness character. However, the scientific and educational value of caribou on Isle Royale is likely less than the scientific value of wolves on Isle Royale (because the wolves have been studied for half a century). Introducing caribou, rather than wolves, would add a second large ungulate to an ecosystem lacking a top predator. While these considerations do not represent a complete argument, they do suggest, at least *prima facie*, that a complete argument would support wolf reintroduction.

Genetic rescue

The appropriateness of genetic rescue (i.e., introducing wolves to Isle Royale while male and female wolves are still present) would also be judged by evaluating the same values described above. However, assessing the appropriateness of rescue might also require three additional considerations.

First, a case can be made that population health ought to be promoted in wilderness populations, and that a population is not healthy if it suffers from inbreeding depression.

Second, the inbreeding depression observed on Isle Royale involves malformations in the spinal column that are known to cause pain and suffering in some domestic dogs that suffer from the same condition (Räikkönen et al. 2009). Genetic rescue might alleviate that suffering. The unresolved relationship between conservation ethics and animal welfare ethics, in general, is evidence that this value should not be dismissed without consideration (Vucitch and Nelson 2007).

The third concern is represented by asking, how would genetic rescue affect scientific values? Many population geneticists would likely make the case that more would be learned from monitoring genetic rescue than from monitoring the continued effect of inbreeding; because there exist several hundred very well documented cases of monitoring the effects of inbreeding (Hedrick and Kalinowski 2000). However, genetic rescue has been monitored carefully in fewer than about seven instances (Adams et al. 2011). One would also have to consider how the importance of this value compared with other competing (non-scientific) values.

These additional considerations make the development of judgments about whether genetic rescue is or is not appropriate a substantially more difficult task.

Female reintroduction

Understanding the appropriateness of taking management action to reintroduce females in the event that all existing females go extinct would also require similar considerations. From a genetic perspective, reintroducing females would represent genetic rescue. This circumstance would also be characterized by brief period of time. That is, if females went extinct, the period of time during which the population would exist without females would be brief (no more than approximately seven years before the males would also go extinct).

General lessons

We hope this analysis represents a useful and general framework for approaching any decision that involves values that compete in complex ways. The wolves of Isle Royale also represent an important case study of a more general policy concern. Our ideas about what wilderness is, and why wilderness is valuable, change over time. During the first half of the 20th century, wilderness philosophy focused on woodcraft, a principle of self-sufficient living in the wilderness characterized by experiences like utilizing trees for temporary structures and fires. By the mid-20th century, wilderness leaders grew to realize that the growing number of people wishing to have this kind of wilderness experience in a diminishing number of wilderness areas would result in a devastating loss of wilderness. From this concern grew a new philosophy of wilderness, a philosophy associated with the principles of “leave no trace,” and along with it the principle of non-intervention (Turner 2002).

Now, in the early 21st century, wilderness areas have been reduced even further and human impacts on those areas have become pervasive. Anthropogenic climate change and exotic species have altered the course of nature in nearly every protected area. Consequently, the principle of managing for naturalness is becoming less coherent, and the value of non-intervention as a means of preserving naturalness is becoming less useful. The transition from naturalness to ecosystem health as a basis for understanding the value of wilderness was reflected in the life-long development of Leopold’s thought on wilderness (Nelson 2009b). This transition was fully articulated by wilderness scholars from the 1980s to 2000s (Callicott and Nelson 1998; Nelson and Callicott 2008). By 2010, these ideas were being appreciated by land management agencies, including the US National Park Service (Cole and Yung 2010; Harmon 2010; Parsons 2011). The emerging challenge is to better understand the meaning of ecosystem health in a world that appears committed to anthropogenic climate change, species invasions and extinctions, and increasing resource extraction (Vucetich and Nelson, in press).

We hope this analysis motivates broader discussions that deepen understanding of the specifics on Isle Royale and the associated underlying principles. Broader discussion is well justified because the meanings of wilderness and ecosystem health are powerful reflections on our overall relationship with nature.¹¹

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Endnotes

1. As this article goes to press, the 2012 winter study has just been completed; with high mortality and low reproduction, the population has declined to nine wolves.
2. After CPV was suspected to be the cause of the crash, NPS staff decided not to vaccinate Isle Royale wolves because doing so would have made it impossible to know if the disease was still present (antibody levels would be similar in response to disease exposure or vaccination). The decision was based on the value of scientific knowledge, not the wilderness value of non-intervention.
3. The US Wilderness Act of 1964 says: “An area of wilderness is further defined to mean ... an area of undeveloped Federal land retaining its primeval character and influence ... which is protected and managed so as to preserve its natural conditions.”
4. This value is related to another traditional value of wilderness, i.e., wilderness as a sanctuary for nature (see Leopold 1949; Sanders 2008). Wolves on Isle Royale have been and continue to be the only wolves in North America who can live their lives without the risk of being legally hunted or poached. That Isle Royale might be a sanctuary for wolves had also been a motivation for those who had originally considered reintroducing wolves to Isle Royale in 1940s and 1950s (unpublished correspondence, Michigan Technological University archives).
5. Although non-extraction is an important principle of wilderness, hunting (and fishing) is permitted in many federally designated wilderness areas. While it may seem far-fetched to be concerned that the loss of wolves would lead to the hunting of Isle Royale moose, that prospect has been enacted or considered in cases where the absence of top predators led to ungulate overabundance in a national park (e.g., Theodore Roosevelt National Park, Rocky Mountain National Park).
6. “Ecosystem integrity” and “ecosystem health” are essentially synonymous.
7. The number two “Priority Recommendation” of this panel was “Maintain financial support for and expansion of ongoing studies of moose-wolf dynamics at Isle Royale.”
8. “Scientific activities are to be encouraged in wilderness. Even those scientific activities (including inventory, monitoring, and research) that involve a potential impact to wilderness resources or values (including access, ground disturbance, use of equipment, and animal welfare) should be allowed when the benefits of what can be learned outweigh the impacts on wilderness resources or values” (§6.3.6.1 of USNPS 2006). Additionally, Isle Royale’s general management plan (1999) states that two of the park’s five purposes are not only to “preserve and protect the park’s ... natural resources and ecological processes” but also to “provide opportunities for scientific study of ecosystem components and processes.”
9. Specifically, 62% of surveyed residents strongly or moderately disagreed with the state-

ment, “We should let nature take its course even if wolves start to disappear from Isle Royale National Park,” and 73% of respondents strongly or moderately agreed with the statement, “Wolf numbers should be maintained in Isle Royale National Park if they start to disappear from the park” (Kellert 1990: 57, 61).

10. Other considerations, beyond the scope of this essay, suggest it is doubtful that a robust argument could be developed.
11. Research on the wolves and moose of Isle Royale is supported in part by the US National Science Foundation and the National Park Service. The views expressed here do not necessarily reflect the views of these institutions.

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Appendix 1

Evidence that wolves are an important part of Isle Royale's wilderness character

The general management plan (GMP) for Isle Royale offers important evidence that NPS has a responsibility to preserve Isle Royale's wilderness character and ecological integrity, and that wolves are an important element of that wilderness character (USNPS 1999). Specifically, one of the park's five purposes is to "preserve and protect the park's wilderness character." Moreover, two of the three characteristics of Isle Royale that make it significant are (a) the wolves and moose of Isle Royale, and (b) Isle Royale's remote biogeography. (The third characteristic of significance refers to the fisheries of Isle Royale.) The GMP explains how the "purpose" and "significance" of the park are derived from the park's enabling legislation. Moreover, the GMP states that the "primary goal of natural resource management is to preserve the ecological integrity of Isle Royale" and the second-highest priority is to "convene a panel of NPS and other subject matter experts to identify and evaluate potential actions for managing the wolf population if viability becomes a concern."

Other evidence suggesting that wolves are an important component of Isle Royale's wilderness character include the following.

- Two of the most prominent artistic depictions of Isle Royale depict Isle Royale wolves. Specifically, wolves and moose are the central figures in a well-known poster by the artist Charlie Harper depicting the wildlife of Isle Royale, and in the cover image of the free map of Isle Royale made available to every park visitor.
- The public has demonstrated a continuing interest in learning more about the wolves and moose of Isle Royale, which is indicated by the success of the Isle Royale wolf-moose project's outreach program (see Appendix 2), and by the fact that the most prominent displays in the Isle Royale visitor center at Windigo feature wolves and moose.
- The NPS staffed the organization of a multi-day event to celebrate the 50th anniversary of the wolf-moose project. The celebration was repeated at three venues (Duluth, Minnesota; Houghton, Michigan; Isle Royale National Park). More than 3,000 people were present for some portion of these celebrations, including US Senator Carl Levin's senior aide, the NPS associate director for science and natural resource management, the Midwest regional director of the NPS, and the assistant secretary of the interior.

Appendix 2

Summary of outreach activities associated with Isle Royale wolf–moose research

Below is an annotated list of recent outreach activities associated with the Isle Royale wolf–moose project:

Film

- *Fortunate Wilderness* (www.fortunatewilderness.com) is a feature-length film by George Desort that describes the Isle Royale wolf–moose project. It premiered in July 2008, has been shown at 20 venues throughout the Midwest and Canada (more than 2,500 in attendance) and broadcast on 30 different public TV stations, with an estimated total audience of 10,000. *Fortunate Wilderness* was released on DVD in June 2009, and has since sold more than 1,000 copies.
- *Alces alces: Uncut* is a short film that was shown at film festivals and art galleries in Houghton and Ann Arbor, Michigan, and Washburn, Wisconsin. Both films feature wolf–moose research.

Books and other print media for popular audiences

- *The Wolves of Isle Royale: A Broken Balance* (Peterson 1995) by R. Peterson is a popular account of the project's research findings.
- *A View from the Wolf's Eye* (Peterson 2008) by C. Peterson is a memoir that expresses reverence for Isle Royale and gratitude for opportunities to serve wolf–moose research and park visitors.
- *Winter Study* (Barr 2008) by N. Barr is a fictionalized, though informative, account of the annual winter study at Isle Royale. In April 2008, *Winter Study* made the *New York Times* bestseller list at no. 10 for hardcover fiction.
- *Notes from the Field*, presented in journal format, details the work and observations of each annual winter field season. *Notes from the Field* shares with the general public how observations are transformed into discoveries, and describes how at least one scientist relates research on nature with a broader relationship to nature. *Notes from the Field* are first presented as a daily blog (www.isleroyalewolf.org) and later in the year in hard-copy.
- *The Wolves of Isle Royale, Annual Report*. The annual reports, produced by J. Vucetich and R. Peterson, present each year's scientific findings for a general audience.

Web-based outreach

The wolves and moose of Isle Royale website (www.isleroyalewolf.org) is aimed at a general audience and continues to be visited by more than 10,000 people annually. More than 1,100 people have signed up to receive occasional research updates via email.

Public involvement in research

- Members of the public have an opportunity each year to work with the Isle Royale wolf–moose project during week-long research expeditions. Participants learn about the

project and help collect vital data. In the past five years, 170 people (many of them teachers) have participated in the expeditions.

- For more than three decades, two to four undergraduate students are selected as interns or field assistants from among dozens that apply from three continents. These undergraduates live in the field for one to three months with project leaders. Former assistants include Douglas Smith (director of wolf research in Yellowstone National Park) and Michael Phillips (director of the Turner Endangered Species Fund).

Science museum exhibits

- Since 2007, a 1,000-square-foot exhibit featuring the project's scientific discoveries has been viewed by over 5,000 people during 12 months of display at three different venues (Carnegie Museum, Houghton, Michigan; library of the University of Minnesota at Duluth; Hartley Nature Center, Duluth, Minnesota).
- Since 2000, the project's summer field station at the historic Bangsund cabin on Isle Royale has served as a field museum featuring the world's largest collection of antlered skulls of bull moose, other displays, and informal presentations by the principal investigators. During 2009–2011, this field site was visited by more than 3,200 visitors.

The arts

- The wolf-moose study has been a means to connect the arts and sciences.
- In October and November 2008, the Omphale Gallery (Calumet, Michigan) featured *Thinking Like an Island*, a collection of 38 still images depicting wolf-moose research from an artistic perspective. A portion of this exhibit was also shown at The Gallery Project (Ann Arbor, Michigan; October 2008) for an exhibit designed to connect science and art. More than 2,000 people visited one of these venues. The exhibit was also viewed by more than 30,000 visitors to the International Wolf Center (Ely, Minnesota) during 2010–2011.
- The moose bones collected during wolf-moose research have been featured in work by at least four professional artists and in a major art exhibition in Minneapolis. Two internationally recognized artists, R. Bateman and G. Jensen, have each associated one of their pieces with the wolf-moose research at Isle Royale.
- In fall 2007, there was a nationwide art contest for high school students. The contest theme was to depict, in art, some scientific lesson from wolf-moose research.

Public presentations

In the past five years (2007–2011), associates of the wolf-moose project have delivered more than 200 talks to more than 7,500 members of the general public, mostly national park visitors and K–12 students.

Journalism

In the past five years, wolf-moose research on Isle Royale was featured by national media on over 75 occasions (e.g., *Washington Post*, Associated Press, *Audubon* magazine), and by local or regional media on more than 25 occasions.

Conservation and management

To promote wolf conservation, the Isle Royale project was featured on the 2008 wolf awareness poster, of which 35,000 copies were distributed nationally.

US Congressional Record

On 21 July 2008, Senator Carl Levin entered into the *Congressional Record* a statement of gratitude for the Isle Royale wolf-moose project.

Other educational venues

Wolf-moose research findings are also featured in: (a) at least 12 books used as texts for university courses; (b) lecture material for graduate and undergraduate courses taught in at least 20 universities; (c) popular education software such as *Ecobeaker* (Symbiotic Software, Ithaca, New York) and *Wolf Adventures* (Bowling Green State University, Ohio); and (d) more than 12 books or book chapters published by scientific presses (e.g., Chicago, Princeton, Blackwell, Sinauer, etc.).