National Park Service
U.S. Department of the Interior




Isle Royale National Park
Draft Environmental Impact Statement to Address the Presence of Wolves

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
ENVIRONMENTAL IMPACT STATEMENT TO ADDRESS THE PRESENCE OF WOLVES

Lead Agency: National Park Service

This draft *Environmental Impact Statement to Address the Presence of Wolves* (draft plan/EIS) was prepared for the National Park Service to determine how to best manage the population of gray wolves on Isle Royale National Park. The purpose of this draft plan/EIS is to determine whether and how to bring wolves to Isle Royale to function as the apex predator in the near term within a changing and dynamic island ecosystem.

This draft plan/EIS describes how park resources would be affected by the alternatives and evaluates the impacts of each alternative, including the continuation of the current management practice (the no-action alternative), and three action alternatives that would involve the introduction of wolves to the island. The draft plan/EIS analyzes the impacts of each alternative on the island ecosystem, wilderness character, moose, and wolves of Isle Royale. The impacts are categorized as direct, indirect, beneficial, and adverse. Cumulative impacts are assessed by combining the impacts of each alternative with other past, present, and reasonably foreseeable future actions. Upon conclusion of the draft plan/EIS and decision-making process, one of the alternatives would present the management plan for the island.

The review period for this document will end 90 days after publication of the US Environmental Protection Agency Notice of Availability in the Federal Register. Comments will be accepted during the 90-day period through the National Park Service Planning, Environment, and Public Comment (PEPC) website at http://parkplanning.nps.gov/isrowolves or in hard copy delivered by the US Postal Service or other mail delivery service or hand-delivered to the address below. Comments will not be accepted by fax, email, or in any other way than those specified above. Bulk comments in any format (hard copy or electronic) submitted on behalf of others will not be accepted. Before including your address, telephone number, electronic mail address, or other personal identifying information in your comments, you should be aware that your entire comment (including your personal identifying information) may be made publically available at any time. While you can ask us in your comments to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

For more information, visit http://parkplanning.nps.gov/isrowolves.

Superintendent Phyllis Green
Isle Royale National Park
ISRO Wolves
800 East Lakeshore Drive
Houghton, Michigan 49931-1896

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Isle Royale National Park

ISLE ROYALE NATIONAL PARK

DRAFT ENVIRONMENTAL IMPACT STATEMENT TO ADDRESS THE PRESENCE OF WOLVES

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EXECUTIVE SUMMARY

This draft *Environmental Impact Statement to Address the Presence of Wolves* (draft plan/EIS) presents four alternatives for managing the presence of wolves on Isle Royale National Park: the no-action alternative, and three action alternatives involving various methods of the introduction of wolves to Isle Royale. This draft plan/EIS assesses the impacts to the island ecosystem, wilderness character, moose, and wolf populations that could result from the implementation of each alternative.

At the conclusion of this decision-making process, the alternative selected for implementation will guide the National Park Service in the management of the wolf population at Isle Royale over the next 20 years.

BACKGROUND

Isle Royale National Park (park) is an island archipelago located in the northwestern portion of Lake Superior. The Park was established in 1940. Isle Royale National Park consists of Isle Royale (hereafter referred to as the main island or Isle Royale) and roughly 450 smaller islands. By 1983, 99% of Isle Royale (132,018 acres) was designated as wilderness under the Wilderness Act of 1964. Public access to the park is limited by seasonal closures.

While the park, including Isle Royale, represents a unique dynamic ecosystem with limited human influences, certain species are more tolerant of island conditions than others. The population sizes of island-dwelling species that are specialists (rather than generalists) are typically less stable than mainland species. This instability is due to limited immigration opportunities (no new members of the species coming in, which restricts gene flow), and a higher risk of population reduction or extirpation. The isolation of Isle Royale has been seasonally minimized by the formation of ice bridges in winter between the island and the mainland. However, in recent years there has been a sharp decline in the number of years when these ice bridges have formed. As a result, Isle Royale is now more isolated from the mainland than at any other time in the last several decades. As isolation increases, impacts on the long-term population dynamics and survival of large species such as wolves will occur. Wolves play a critical role as apex predators on the main island in managing the abundance and spatial distribution of moose and, by extension, the distribution, type, and abundance of island vegetation.

The National Park Service is tasked with preserving and protecting the natural and ecological processes of all park units and looking broadly at ecosystem conservation. The National Park Service must determine how to fulfill the mandate of the park in the context of rapid and continuous climate change that will likely result in different environmental conditions than have existed in the past.

PURPOSE AND NEED FOR ACTION

Determining how to best manage wolves on Isle Royale, given the park service mandate, past human influence, and the uncertainty of climate change impacts on park resources, provides both a challenge and opportunity. The purpose of this draft plan/EIS is to determine whether and how to bring wolves to Isle Royale to function as the apex predator in the near term within a changing and dynamic island ecosystem.

A decision is needed because the potential absence of wolves raises concerns about possible effects to the current Isle Royale ecosystem, including effects to both the moose population and forest/vegetation communities. Over the past 5 years the wolf population has declined steeply and at this time, natural recovery of the population is unlikely. Although wolves have not always been part of the Isle Royale ecosystem, they have been present for more than 65 years, and have played a key role in the ecosystem, affecting the moose population and other species during that time.

This draft plan/EIS presents and analyzes the potential impacts of four alternatives: current management (the no-action alternative) and three action alternatives that evaluate various methods of wolf introduction to Isle Royale. Upon conclusion of the draft plan/EIS and decision-making process, one of the alternatives could be adopted and would guide future wolf management practices at the park for the next 20 years.

This draft plan/EIS has been prepared with guidance provided through the park's establishing legislation, park planning documents, park annual reports, and a variety of Isle Royale moose-wolf interaction studies.

ALTERNATIVES

The Council on Environmental Quality requires federal agencies to explore a range of reasonable alternatives that address the purpose of and need for taking action. The alternatives under consideration must include the "no-action" alternative as prescribed by 40 CFR 1502.14. Action alternatives may originate from the proponent agency, local government officials, or members of the public at public meetings or during the early stages of project development. Alternatives may also be developed in response to comments from coordinating or cooperating agencies.

The alternatives analyzed in this document, in accordance with the National Environmental Policy Act, are the result of internal and public scoping. These alternatives meet the overall purpose of and need for taking action. Alternative elements that were considered but were not technically or economically feasible did not meet the purpose of and need for the project, or created unnecessary or excessive adverse impacts on resources were dismissed from further analysis.

Four alternatives were developed which meet the stated objectives of this draft plan/EIS to a large degree and provide a reasonable range of options in addressing wolves on Isle Royale National Park. These alternatives are described briefly below and presented in greater detail in chapter 2.

Alternative A: No Action

The "no-action alternative" describes the continuation of existing management practices and assumes no new management actions would be implemented. Under the no-action alternative, wolves would not be introduced to the park.

Alternative B: Immediate Limited Introduction (Preferred Alternative)

Alternative B includes a limited introduction of wolves to the park over a three-year time period. The goal of this alternative is to provide an immediate introduction of wolves that has the potential to be self-sustaining.

Alternative C: Immediate Introduction with Potential Supplemental Introductions

Under alternative C, the National Park Service would immediately introduce wolves with the potential for subsequent introductions over a 20-year period. This alternative would allow the National Park Service to consider a variety of metrics before making supplemental introductions, including climate change impacts on the island, moose population trends on and off island, wolf genetics, and other metrics.

Alternative D: No Immediate Action, with Allowance for Future Action

Under alternative D, the National Park Service would continue to monitor conditions and take no immediate action but allow for future introductions of wolves to Isle Royale. The decision to introduce in the future would be based on moose population metrics and other observed changes in the ecosystem. Should introductions be warranted, they would follow alternative C procedures.

TABLE ES1. SUMMARY OF ALTERNATIVE ELEMENTS

	Alternative A: No Action	Alternative B: Immediate Limited Introduction (Preferred Alternative)	Alternative C: Immediate Introduction with Potential Supplementation Introductions	Alternative D: No Immediate Action, with Allowance for Future Action
NPS Wolf Introduction Could Occur	No	Yes	Yes	Yes
Timing of Release	Not applicable.	Starting immediately, completed within five years.	Starting immediately, supplemented as needed.	Introduction would not begin immediately, but may take place based on moose population metrics and other ecological factors.
Number/Duration of Releases	Not applicable.	One release event, lasting up to three to five years.	Multiple release events could take place over the 20-year life of the plan.	Once metrics for introduction are met, same as alternative C.
Number of Founding Wolves	Not applicable.	20-30 wolves selected to maximize genetic diversity and initial predation rates.	6-15 wolves including pairs or packs.	Once metrics for introduction are met, same as alternative C.

	Alternative A: No Action	Alternative B: Immediate Limited Introduction (Preferred Alternative)	Alternative C: Immediate Introduction with Potential Supplementation Introductions	Alternative D: No Immediate Action, with Allowance for Future Action
Supplementation of Wolf Population	The existing population would not be supplemented.	After the third year, should an unforeseen event impact the wolf population and the goals of the alternative are not met, wolves may be supplemented for an additional two years. After the fifth year, no additional supplementation would occur.	Supplemental introduction would occur as needed over the 20-year life of the plan.	Once metrics for introduction are met, same as alternative C.
Location of Release on the Island	Not applicable.	Complete groups would be released at one end of the island; individual wolves would be released at the opposite end of the island.	Same as alternative B, plus additional wolves would be released at locations away from established packs.	Once metrics for introduction are met, same as alternative C.
Radio Collaring	Wolves that immigrate to the island would be radio collared on a case-by-case basis to assess population dynamics.	Same as alternative A plus up to all wolves introduced to the island would be monitored via radio collar.	Same as A plus the minimum number of wolves necessary to meet monitoring goals would be monitored via radio collar.	Same as alternative C.

ENVIRONMENTAL CONSEQUENCES

Impacts of the alternatives were assessed using the Council on Environmental Quality definition of “significantly,” which required consideration of both context and intensity. Impacts were assessed as pertaining to four impact areas: island ecosystem, wilderness character, moose, and wolf population dynamics. Impacts were categorized as direct, indirect, adverse and beneficial. All alternatives were evaluated for each impact area. Cumulative impacts were assessed by combining the impacts of each alternative with other past, present, and reasonably foreseeable future actions.

A summary of the impacts are included below and a full impact analysis is in “Chapter 4: Environmental Consequences.”

Island Ecosystem – Comparative Conclusion of Alternatives

Under alternative A, the island ecosystem functions would continue to change from the past predator influenced ecosystem, to an ecosystem primarily influenced by bottom-up forces such as herbivores, bio-physical conditions and forest/vegetation community structure and composition. It is expected that with the continuation of a lack of predation and subsequent increase in herbivory, there would be broad ecosystem changes related to forest composition and structure. In comparison, alternative B and alternative C would restore predation by the addition of an apex predator to the island. This would be a significant change from current condition by restoring the ecological process of predation which currently does not exist. This alternative would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for forest succession to return to a historical trajectory last seen when predation was more of an influencing factor in community dynamics.

Under alternative A, increased herbivory is probable and combined with climate change effects, it is likely that the rate of vegetation changes would be exacerbated and potentially accelerated. Additionally, given the island's geographic isolation and the inherent dynamics of island ecosystems, it is expected that the resiliency of current wildlife populations to change would be reduced and contribute to more rapid population swings. Under alternative B and C, it is expected that climate change influences on the island would be less likely to be compounded by herbivory and its associated impacts. Alternative D encompasses the full spectrum of impacts described under the plan from alternative A to C, depending on whether and when NPS introduces wolves. However, the response to actions would vary because it is uncertain when action would occur.

Wilderness – Comparative Conclusion of Alternatives

Alternative A is likely to result in the least impacts to wilderness character. Alternative A primarily impacts the natural quality, although those impacts would likely not result in a significant change from the current condition. Current conditions reflect ecological processes typical in an island ecosystem. Alternative A is the only alternative that does not include human manipulation of the biophysical environment, with the exception of the potential use of radio collars if wolves naturally migrate to the island.

Alternatives B and C would likely result in the most impacts to wilderness character. Both include substantial impacts to wilderness character overall because of the intentional manipulation of the biophysical environment and the subsequent changes from current condition. However, both alternatives would likely restore an ecological function previously present on the island. Both alternatives include the use of radio collars and mechanized transport that impact the untrammeled and undeveloped qualities of wilderness. Alternative C may result in additional impacts to the untrammeled and undeveloped qualities depending on the number of introduction events. Alternative D encompasses the full spectrum of impacts described under the plan from alternative A to C, depending on whether and when NPS introduces wolves.

Moose – Comparative Conclusion of Alternatives

Alternative A would not pose immediate benefits to the moose population or ecosystem. Potential long-term benefits under alternative A would be low. The primary difference among the three action alternatives would be the timing of the release of additional wolves to the island and the potential timeframe for predation pressure to influence moose population numbers and positively affect the native plant communities on the island.

All action alternatives would have a beneficial impact to the moose population by providing a means for wolf numbers to control the resident moose population. In general, alternative B would attempt to re-establish the wolf-moose at near equilibrium in the shortest amount of time. Alternative C would provide the most options for a long-term planning. Alternative D would be similar to alternative A initially, potentially resulting in a population crash of moose on the island, and similar to alternative C should metrics be met and wolves introduced.

All action alternatives would have beneficial impacts in the form of increased moose predation by wolves. The moose population is increasing at a high rate, which will likely result in a population crash. Predation, as a result of wolf introduction, would potentially reduce the likelihood or minimize the magnitude of the moose population decline. Alternative B would most likely mitigate the magnitude of a population crash because of the larger number of wolves introduced at one time. However, alternatives C and D would most likely minimize the magnitude of a crash in the moose population more in the long term because these alternatives allow for wolves to be subsequently introduced, if necessary.

Wolves – Comparative Conclusion of Alternatives

Alternative A would not pose immediate benefits to the wolf population or ecosystem; but would still allow a potential, albeit low, for wolf restoration through natural processes. The primary difference among the three action alternatives would be the timing of the release and number of introduced wolves to the island and the potential timeframe for predation pressure to influence moose population numbers.

All action alternatives would have a beneficial impact to the wolf population by providing a means to increase wolf abundance and distribution of wolves on Isle Royale. In general, alternative B would attempt to re-establish the wolf population in the shortest amount of time. Alternative D is similar to alternative A in the short term initially, potentially resulting in a population crash of moose on the island, but in the long-term would result in future wolf introduction similar to alternative C. Thus, alternatives C and D would have a higher likelihood to sustain a beneficial wolf abundance and distribution on the island.

Under all action alternatives, breeding would likely be delayed for one year following translocation. All action alternatives are likely to result in successful reproduction after the first breeding season following initial introduction or any additional supplementation. Alternatively, under alternative A there would be little potential of reproduction, given the level of inbreeding among the existing two wolves and limited immigration from the mainland to Isle Royale. Natural immigration would benefit all alternatives by allowing for gene flow with mainland populations to minimize inbreeding effects.

On Isle Royale, the small population size of the original founding event, coupled with low immigration rates, and decline of the population from ecological events (including canine parvovirus) have all combined to reduce effective population size. While opinions differ as to whether the wolf population would persist over the long term, absent recent population declines due to viral infections and interspecific conflict, the observed survival of the population from initial founding until recently suggests that genetic issues would not drive population dynamics of the wolf population at Isle Royale National Park, as long as there was sufficient gene flow. However, the current population is highly inbred, and its survival is questionable. Some experts share the opinion that a long-term viable population of wolves on Isle Royale may always require human intervention because of inbreeding (appendix A). The genetic diversity of the founding population is an important criterion for population viability. All action alternatives pose a beneficial impact to genetics. For all action alternatives it is unknown whether the two remaining wolves on Isle Royale would contribute further to the gene pool or survive an introduction of unrelated, introduced individuals.

THE NEXT STEP

The public review and comment period for this draft plan/EIS will be for 90 days. Written comments on the draft plan/EIS will by fully considered and evaluated in preparing the final plan/EIS. A final plan/EIS will then be issued, which will be approved by the National Park Service after a minimum 30-day no-action period. The final plan/EIS will include agency and organization letters and responses to all substantive comments.

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Acronyms and Abbreviations

draft plan/EIS	Draft Environmental Impact Statement to Address the Presence of Wolves
Isle Royale or park	Isle Royale National Park
km	kilometer(s)
km^2	square kilometers
mi	mile
mi^2	square miles
NEPA	National Environmental Policy Act
NPS	National Park Service
PEPC	Planning, Environment, and Public Comment
USFWS	US Fish and Wildlife Service

CHAPTER 1:
Purpose of and Need for Action

CHAPTER 1: PURPOSE OF AND NEED FOR ACTION

INTRODUCTION

This “Purpose of and Need for Action” chapter explains what this plan intends to accomplish and why the National Park Service is evaluating a range of alternatives and management actions to address the presence of wolves at Isle Royale National Park (the park). This draft *Environmental Impact Statement to Address the Presence of Wolves* (draft plan/EIS) presents four alternatives. It assesses the impacts that could result from continuing current management (the no-action alternative) or implementation of any of the action alternatives. This chapter provides background on the park including the history of wolves on Isle Royale and the role they play in the island’s ecosystem, as well as presents the purpose and need for action.

BACKGROUND OF ISLE ROYALE NATIONAL PARK

Isle Royale National Park is an island archipelago located in the northwestern portion of Lake Superior (figure 1). It is located in an ecological transition zone between the boreal forests and the more southern temperate deciduous-hardwood forests. The purpose of the park as stated in the Foundation Document is to “set apart a remote island archipelago and surrounding waters in Lake Superior as a national park for the benefit and enjoyment of the public and to preserve and protect its wilderness character, cultural and natural resources, and ecological processes. Additionally, as a unit of the national park system, Isle Royale National Park provides opportunities for recreation, education and interpretation, and scientific study” (NPS 2014 a).

Isle Royale National Park consists of one large island, Isle Royale, and roughly 450 smaller islands. The park boundary extends 4.5 miles into Lake Superior from the outermost land areas. The southeastern shore is 45 miles northwest of the Upper Peninsula of Michigan and 12 miles southeast of Thomson Island in Ontario, Canada. The park encompasses 571,796 acres of land and water, of which land comprises only 133,788 acres (NPS 2016a). Isle Royale (the island) extends approximately 45 miles from southwest to northeast, and is approximately 9 miles across at its widest point. By 1983, 99% of Isle Royale (132,018 acres) was designated as wilderness under the Wilderness Act of 1964 (NPS 2016a).

At various times prior to European settlement, the islands were used by Native Americans for mining copper, fishing, hunting, and other purposes. The first immigrants of European descent arrived on the islands around the 1830s. Copper mining and logging operations to support mining activities were active from the 1840s through the 1890s. Almost the entire island and many of the smaller islands were disturbed by logging and mining operations prior to park establishment in 1940 (McLaren and Peterson 1994; Cole et al. 1997; The Nature Conservancy 1999). Trapping and hunting also had a significant impact on park fauna and likely extirpated some species, such as the Canada lynx (*Lynx canadensis*) that occupied the island until the 1930s (Licht et al. 2015). Despite these influences, the island maintained much of its wilderness character.

FIGURE 1. ISLE ROYALE NATIONAL PARK AND SURROUNDING REGION

Public access to the park is limited by seasonal closures. The park is open to visitation from May through October and access to the park is by boat or plane only. Hiking, canoeing, kayaking, and powerboating (restricted to Lake Superior) are the only forms of transportation allowed within the park. Further restrictions throughout the park that help protect the wilderness character and affect species management include prohibition of hunting; a park closure from November through April; only half of the park is open to overnight camping during the visitor season; and a prohibition on dogs (NPS 2015a). As a result of the limited public access and management restrictions, Isle Royale also represents a unique dynamic ecosystem with limited human influences.

In 1981, the United Nations designated the park as an International Biosphere Preserve giving it global scientific and educational significance. The United Nations Educational, Scientific, and Cultural Organization describes the park as offering “outstanding possibilities for research in a remote ecosystem where human influences are limited” (UNESCO 2016).

Certain species are more tolerant of island conditions than others. The population sizes of island-dwelling species that are specialists (rather than generalists) are typically less stable than mainland species. This instability is due to limited immigration opportunities (no new members of the species coming in, which restricts gene flow), and a higher risk of population reduction or extinction. This higher risk may result from chance events, limited resource availability, and/or human activity to name a few factors. Species composition and richness on the island, generally referred to as island biogeography, is well documented at Isle Royale, and studies on the island and its inhabitants have been conducted for more than seven decades. Studies of climate, forest dynamics, and the wolf-moose-vegetation system on Isle Royale provide a broader understanding of ecosystem change, trophic interactions, and how the importance of drivers can vary over time (Kraft et al. 2010). These studies and how climate change has shaped the current environment at Isle Royale are discussed further in “Chapter 3: Affected Environment.”

NATURAL RESOURCES AND ECOLOGICAL PROCESSES

The National Park Service is tasked with preserving and protecting the natural and ecological processes of all park units and looking broadly at ecosystem conservation. NPS *Management Policies* (NPS 2006) and guidance recognize the role of change in park ecosystems and encourages the stewardship of National Park Service (NPS) resources for environmental changes that increasingly exceed historical experiences (National Park System Advisory Board 2012). The National Park Service is actively developing climate change adaptation decision-support options. Scenario planning is an important tool in the NPS strategy for managing parks into a future of climate uncertainty (NPS 2010). Where and when to implement adaptation strategies will be critical and general guidelines for development are documented in both national and NPS policy (CEQ 2010*)*.

The composition and richness of species on the island over the past seven decades are generally well documented, although species thought to be extirpated persist (e.g., American marten) and genetic variants (e.g., garter snakes) are still being discovered. Organisms that live on islands tend to have more dynamic population swings (higher highs and lower lows) and are more often subjected to extinction events, with colonization and immigration dependent on island size, distance to the mainland, length of isolation (time), chance events, habitat suitability and human activity, to name a few influencing factors (MacArthur and Wilson 1967; Rosenzweig 1995). As a result, species change over time and local extirpation is natural, as is establishment and re-establishment of new populations. This theory is termed island biogeography.

The isolation of Isle Royale has been seasonally minimized by the formation of ice bridges in winter between the island and the mainland. However, in recent years there has been a dramatic decline in number of years when these ice bridges have formed (Licht et al. 2015), thus prohibiting species from migrating on or off the island and decreasing the genetic diversity and numbers of species. As a result, Isle Royale is now more isolated from the mainland than at any other time in the last several decades.

The Midwest is predicted to warm due to climate change (Christensen et al. 2007). If this trend continues over many years, the increase in isolation will likely result in species extinctions and modification of the ecological roles and functions fulfilled by surviving species. As isolation increases, the relatively small size of the island will have a greater impact on the long-term population dynamics and survival of large species, such as wolves and moose, compared to smaller species (Millien and Gonzalaez 2011).

Future combinations of temperature and precipitation in many areas may have no current analogues on the planet (Williams, Jackson, and Kutzbach 2007). Climate change also includes changes in climate variability and extreme events, such as potential increases in the frequency, duration, and intensity of droughts, heat waves, and storms (Melillo, Richmond, and Yohe 2014). Such changes will directly and indirectly impact the natural resources and ecological processes on the island including possible changes in the distribution and abundance of plant and animal life and the occurrence and prevalence of disease. Comprehensive, long-term studies of climate, forest dynamics, and the wolf-moose-vegetation system on Isle Royale provide a broader understanding of ecosystem change, trophic interactions, and how the importance of drivers can vary over time (Kraft et al. 2010). These studies and how climate change has shaped the current environment at Isle Royale are discussed further in “Chapter 3: Affected Environment.”

Island biogeography*—The study of species composition and richness on an island or another isolated area. Island size, isolation and other characteristics affect species diversity and population dynamics in comparison with similar, non-island ecosystems.*

Climate change presents unprecedented conservation challenges for the National Park Service (National Park System Advisory Board 2012). In an era of rapid and directional climate change, the location of climatically suitable habitat for many species will be altered on the landscape. To survive, species will respond either by adapting to their new environment or by shifting their range and distribution to meet their habitat needs. As a result, the range and distributions of many species of fish, birds, insects, plants, and other organisms will shift either by abandoning some areas of current or historical use or moving to areas where they have never been observed (Settele et al. 2014). Although climate change can make management of individual species more difficult than it has been in the past, the National Park Service can still find novel approaches to soften the impacts, slow down change so that species and populations can adapt, and assist species movements where it is deemed appropriate. Development of appropriate climate change adaptation strategies can assist in the development of such approaches. The potential impacts from climate change and other effects are somewhat unknown and the 20-year timeframe of the plan leaves the National Park Service the discretion to take different action in the future if conditions warrant.

WOLVES AT ISLE ROYALE NATIONAL PARK

History

The origin of the gray wolf (*Canis lupis*) on Isle Royale is not completely understood, nor is it known how many individual founding wolves contributed to the genetic makeup of the current Isle Royale wolf population (Mech 1966; Brown 2013). It is commonly thought that wolf immigration initially occurred between 1948 and 1950, with individuals crossing an ice bridge approximately 24 kilometers (15 miles) long from the United States or Canadian mainland to Isle Royale (Vucetich, Nelson, and Peterson 2012). However, early reports from residents in the 1930s and 1940s state that they observed wolf movement between the mainland and the island and saw possible signs of newly arrived individual wolves (Mech 1966). Other than these anecdotes, there is no documentation that wolves occurred on Isle Royale before the late 1940s (Martin 1995). Interest in introducing (or augmenting) the wolf population on Isle Royale in the 1940s and early 1950s resulted in the introduction of four wolves from the Detroit Zoo in 1952. The experiment was not successful, primarily due to human habituation by the wolves (Mech 1966). Accounts vary as to their outcome, but after an initial attempt at relocating the animals (Mech 1966), two or three were subsequently removed, and one or two remained in the wild (Mech 1966; Wockner 1997; Brown 2013). Differing scientific opinions on the genetic history of wolf lineage on Isle Royale make the origin of wolves inconclusive, but genetic research suggests a limited number of founding breeders.

Wolf numbers on Isle Royale have fluctuated since the animals first became established (Martin 1995; Wilmers et al. 2006), with the long-term average reported to be 22 animals (Vucetich and Peterson 2016). The wolf population reached its peak on the island in 1980, when 50 animals[1] were present (Peterson and Page 1988). However, a significant population crash between 1980 and 1981 reduced the number of Isle Royale wolves to 14 individuals (Peterson and Page 1988; Wilmers et al. 2006). The main cause of the population crash was associated with outbreak of canine parvovirus (Peterson et al. 1998; Wilmers et al. 2006). Wolf populations never recovered to pre-canine parvovirus population levels (Wilmers et al. 2006). Between January 2014 and January 2015, the wolf population decreased from nine to three, with only three wolves remaining on Isle Royale by April 2015 (Vucetich and Peterson 2015). During that winter of 2015, an ice bridge had formed and a pair of wolves crossed the ice bridge from the Grand Portage Indian Reservation to the island. The pair returned to the mainland five days later. The six wolves that are unaccounted for may have perished, or left the island during the 2015 ice bridge event. By 2016, observations suggest there are only two wolves remaining (Peterson and Vucetich 2016).

The legal status of the gray wolf in the United States has changed many times during the last decade, both on a federal and state basis, particularly for the Western Great Lakes Distinct Population Segment (USFWS 2015a; Michigan DNR 2015). The Western Great Lakes Distinct Population Segment includes the wolves located in all of Minnesota, Wisconsin, and Michigan, the eastern half of North Dakota and South Dakota, the northern half of Iowa, the northern portions of Illinois and Indiana, and the extreme northwestern portion of Ohio. The US Fish and Wildlife Service has proposed to completely remove the Western Great Lakes Distinct Population Segment of the gray wolf from protections under the Endangered Species Act.

At the time of this draft, the gray wolf continues to be protected under the Endangered Species Act (USFWS 2015a). Specifically, the gray wolf is listed as federally threatened in Minnesota, and federally endangered in the remaining Great Lakes area states (all of Wisconsin and Michigan, the eastern half of North Dakota and South Dakota, the northern half of Iowa, the northern portions of Illinois and Indiana, and the northwestern portion of Ohio) (USFWS 2015g). The park is designated as critical habitat for the gray wolf, as are parts of Minnesota and Michigan (USFWS 2015d). Isle Royale wolves have been identified as not contributing to the recovery of the species because of the isolation of this population on the island (Michigan DNR 1997).

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[1] The density of wolves recorded on Isle Royale in 1980 is equivalent to 9.23 wolves/100 square kilometers (km^2). Typical densities recorded in Michigan and northeastern Minnesota range from 0.63 wolves/100 km^2 to 3.8 wolves/100 km^2, with the highest record reaching 30.8 wolves/100 km^2 (Michigan DNR 1997; Mech and Tracy 2004). Therefore the Isle Royale wolf density is high in comparison.

Functional Role

> ***apex predator****—An apex predator, also known as an alpha predator or apical predator, is a predator residing at the top of a food chain upon which no other creatures prey.*

Wolves play a critical role as apex predators on the island in managing the abundance and spatial distribution of moose (*Alces alces*) and, by extension, the distribution, type and abundance of island vegetation. Since the initial wolf immigration in the late 1940s, the relationships among wolf, moose, and vegetation trophic levels have been well studied. This has included fluctuating population numbers, moose browse effects, wolf inbreeding depression, disease, vegetation dynamics, and ongoing climate change trends. Absent other large predators, such as bear, coyote, and mountain lion—and without human influences such as hunting, roads, and large-scale human habitation—wolves represent the only predators of moose on Isle Royale. Moose are the primary prey species for wolves on the island, and each species affects the distribution and abundance of the other species on the island (NPS 2015b). However, wolves will prey on beaver (*Castor canadensis*) and other small mammals when they are available on the island. The wolf-moose predator-prey relationship that is mostly isolated from adjacent populations has provided researchers with a rare opportunity to conduct extensive long-term (more than 40 years) two-level (wolf-moose) and three-level (wolf-moose-vegetation) scientific studies (UNESCO 2016; Wilmers et al. 2006).

Moose arrived on the island in the 1900s and lived on the island prior to the presence of wolves. The moose population has fluctuated dramatically over the past century due to disease, parasites, food availability and weather. The moose boom and bust population cycle has occurred in both the presence and absence of wolves.

Factors influencing the moose population have changed overtime. Currently, the moose population is influenced more heavily by vegetation, climatic conditions, disease and parasites, than by wolves. The combined effects of climate, balsam fir growth, and moose abundance have led to a shift from top-down driven ecosystem, where wolves had a greater influence, to bottom-up driven ecosystem, where climate and vegetation are the primary factors regulating moose population growth rate (Vucetich and Peterson 2004; Wilmers et al. 2006). It is likely that the moose population on the island will continue to increase until a lack of available forage, disease, weather, or other population control measures cause a decline. The growth rate of moose on Isle Royale does not mimic the patterns that are seen on the mainland in both Minnesota and Michigan where moose populations are either static or decreasing due to a variety of factors.

PURPOSE OF AND NEED FOR ACTION

Purpose

The purpose of this draft plan/EIS is to determine whether and how to bring wolves to Isle Royale to function as the apex predator in the near term within a changing and dynamic island ecosystem.

Need

A decision is needed because the expected extirpation of wolves and the decreasing potential for immigration raises concerns about possible effects to the current Isle Royale ecosystem, including effects to both the moose population and forest/vegetation communities. Over the past five years the wolf population has declined steeply, intensifying the need to determine these effects. Although wolves have not always been part of the Isle Royale ecosystem, they have been present for more than 65 years, and have played a key role in the ecosystem, affecting the moose population and other species during that time. At this time, due to the low number remaining, genetic inbreeding, and the remoteness of Isle Royale, natural recovery of the population is unlikely due to tenuous nature of ice bridge formation. Determining whether and how to best manage wolves on Isle Royale, given the uncertainty of climate change impacts on park resources, provides both a challenge and opportunity.

ISSUES AND IMPACT TOPICS CARRIED FORWARD

The National Park Service identifies issues in the context of National Environmental Policy Act (NEPA) as, "problems, concerns, conflicts, obstacles, or benefits that would result if the proposed action or alternatives, including the no-action alternative, are implemented" (NPS 2015a). The identification of such issues helps to focus the impact analysis by emphasizing the important environmental consequences related to a proposal. Issues are listed within the impact topics below.

Island Ecosystem

A central issue to the decision of whether to bring wolves to the island is how the presence or absence of an apex predator could affect the larger island ecosystem. The presence or absence of wolves could directly and indirectly affect a number of ecological processes on the island and contribute to effects to other resources. These processes include predation, competition, disturbance, and succession. A number of individual resources could be indirectly affected by NPS actions that are not discernible on their own; these resources are captured within the Island Ecosystem topic.

Wilderness Character Qualities - Untrammeled, Natural, Undeveloped

The vast majority (99% of the land mass or 132,018 acres) of Isle Royale is designated wilderness. The primary issues associated with wilderness are considerations about the natural quality, untrammeled quality, and undeveloped quality.

- **Natural Quality.** Bringing additional wolves to Isle Royale would be a major management action which could potentially affect ecological processes and functions related to wolves, moose, and other species. Such actions represent the effects of modern civilization and human influence with the potential to result in impacts to this quality of wilderness character.
- **Untrammeled Quality.** Bringing wolves to the island would represent a deliberate human manipulation of the biophysical environment and community of life that would impact the untrammeled quality of wilderness character. Other activities associated with wolf introduction

may also detract from the untrammeled quality of wilderness, including the use of radio collars and potential use of helicopters in wilderness.

- **Undeveloped Quality.** Radio collars that are placed on wolves are considered an installation that may impact the undeveloped quality of wilderness character. The landing of aircraft for wolf introduction, monitoring, and research represents the use of motorized equipment and mechanical transport that may also impact the undeveloped quality of wilderness character.

Moose

Currently, vegetation, parasites, and weather are the primary agents of moose population changes. Bringing wolves to Isle Royale could reduce the moose population directly through predation and may affect plant species' composition, distribution and abundance. Conversely, in the absence of predation, an overabundance of moose could result in more dramatic swings in the moose population and change moose population demographics, and alter forest/vegetation community successional trajectories.

Wolves

Wolves are the only apex predator on Isle Royale. The loss of wolves may impact the predator-prey relationship and other components of the ecosystem. Without intervention, wolves could be extirpated from the island.

The isolated nature of the island and the rising temperatures predicted with climate change could decrease the probability of ice bridge formation and raises concern for future genetic decay. The issue of genetic augmentation is also being considered because without occasional new wolf arrivals (e.g., immigration or managed relocation), an introduced wolf population could again experience a 13% loss of genetic diversity with each generation (on average every 4.2 years) (Peterson et al. 1998).

Wolves brought to the island would have limited means to disperse off the island due to a decrease in ice bridges thus increasing the potential for intraspecific competition when pack densities and population numbers are high.

ISSUES AND IMPACT TOPICS NOT CARRIED FORWARD FOR DETAILED ANALYSIS

Treaties, Tribal Rights, and Sacred Sites

Secretarial Order 3175, "Identification, Conservation and Protection of Indian Trust Assets" requires any anticipated impacts on Indian trust resources from a proposed project or action by Department of the Interior agencies to be explicitly addressed in environmental documents. The land of the park is not held in trust by the Secretary of the Interior for the benefit of Indians or because of their status as Indians. Moreover, none of the actions under consideration in this draft plan/EIS would in any way alter the government-to-government relations between tribal nations in the region and the National Park Service. Treaty rights are beyond the scope of this draft plan/EIS. Additionally, any actions taken to implement this plan would conform to existing laws pertaining to treaty rights. The National Park Service routinely consults with tribes that have treaty rights and their representatives on a government-to-government basis. Existing treaty rights or agreements between the National Park Service and tribes would not be altered if any of the alternatives under consideration were implemented. Therefore, this topic is not carried forward for detailed analysis.

Aquatic Vegetation and Wetlands

Although this issue is not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic as it relates to overall processes on the island. Changes in the level of wolf predation affect moose population abundance and distribution, with indirect effects on vegetation abundance and distribution from changes in the rate and intensity of moose herbivory. Since aquatic plants can range from 14% to 37% of a moose's summer diet (Bump et al. 2004), the abundance and distribution of aquatic plants could change as the moose population increases in the absence of wolves. Furthermore, high moose populations could result in trampling of vegetation near water bodies, such as sedge mats around the edges of lakes.

Isle Royale contains numerous wetlands (including marshes, bogs, and vegetated lake and pond shores) which support considerable biodiversity. Wetlands can be impacted either directly through effects such as trampling, or indirectly from erosion. Should the wolf population remain low, moose populations could eventually increase, which would increase herbivory on riparian and wetland vegetation. Conversely, if wolf population numbers become high, the resultant moose population numbers could drop because of increased predation. A smaller moose population could allow riparian and wetland vegetation (particularly shrubs, herbs, and grasses) to become dense, and could benefit those avian species dependent on densely vegetated habitats. Impacts associated with aquatic vegetation and wetlands would not result in measurable changes to existing conditions but may contribute to changes to the overall island ecosystem. Changes in vegetation may not be discernible in the 20-year plan horizon.

Terrestrial Vegetation

Although this issue is not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic as it relates to overall processes on the island. Moose prefer to browse saplings of the following common island species: white birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) (year-round, highly preferred); yellow birch (*Betula alleghaniensis*) and sugar maple (*Acer saccharum*) (year-round, moderately preferred); balsam fir (*Abies balsamea*) (winter only, moderately to highly preferred); and northern white-cedar (*Thuja occidentalis*) (winter only, low preference). Moose highly prefer American mountain-ash (*Sorbus americana*), but this species is much less abundant. Moose have also shown preference for uncommon species including red oak, red maple, and white pine (Jordan, McLaren, Sell 2000). Persistence on the island of big-tooth aspen (*Populus grandidentata*) and balsam poplar may also be threatened by moose browsing (Jordan, McLaren, Sell 2000). Although the tree species moose prefer can grow beyond moose browsing height, moose browse the young growth and deplete these species, which can result in changes to forest structure and composition over time. Absent wolves, possible changes associated with the current levels of moose herbivory include the decline of balsam firs on the west end of Isle Royale, and the potential for more savannah-like spruce-dominated forests (appendix A). Spruce in savanna-like settings with an exotic bluegrass understory (Cotter and Robertus 2015) would likely expand over the 20-year window (although a warming climate also may result in reductions in spruce). NPS action could indirectly affect moose herbivory; however, other factors such as climate change and succession may impact terrestrial vegetation regardless of the presence or absence of wolves on the island. Changes in vegetation may not be discernible in the 20-year plan horizon. Therefore, although this issue is not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic, specifically in the section “Disturbance and Succession,” as it relates to overall processes on the island.

Soil Processes

Moose herbivory can impact primary productivity in boreal forests on Isle Royale by changing plant communities and litter dynamics. The change in productivity from browse can influence soil processes (Pastor et al. 1993). Over-browsing would reduce the quantity of tree and shrub litter produced, and increase the proportion of herbaceous species present in litter (McInnes et al. 1992). Where browsing is intense, soil chemistry is affected through these browsing-induced changes to litter composition and reduced litter quantity. Soil carbon, nitrogen, cation exchange capacity, field nitrogen availability, potentially mineralizable nitrogen, and respiration rates are reduced compared to areas where there is little to no browsing. These soil microbial processes determine the amount of nitrogen available to plants (Pastor et al. 1988). If moose populations continue to grow unchecked by an apex predator, the available nitrogen for plants on the island could be impacted through reduction. Changes in the availability of nitrogen for plants and subsequent changes to the ecosystem from this change may not be discernible in the 20-year plan horizon. Therefore, this issue is not carried forward for detailed analysis as a stand-alone topic but is discussed broadly under the Island Ecosystem issue/impact topic as it relates to overall processes on the island.

Other Wildlife – Notable Scavenger, Avian, and Prey Species

Scavenger Species. The common raven (*Corvus corvax*) (Egan, Gostomski, and Ferrington 2015) and red fox (*Vulpes vulpes*) (Peterson and Vucetich 2016) are two important scavenger species documented at Isle Royale. Wolf predation of moose and beavers can provide increased foraging opportunities for these species (Mech 1970, as cited in Beyer et al. 2006; Krefting 1974). While this issue is not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic as it relates to overall processes on the island.

Avian Species. Representative bird species encompass a wide diversity of passerines and waterbirds, including a number of warblers, waterfowl, shorebirds, corvids, flycatchers, woodpeckers, sparrows, and other birds common to the northern forests (NPS 2008a). If wolf population numbers rise, the resultant moose population numbers could drop because of increased predation, which could allow riparian and wetland vegetation (particularly shrubs, herbs, and grasses) to become dense, which could benefit those avian species dependent on densely vegetated habitats. As noted under “Aquatic Vegetation and Wetlands,” should the wolf population remain low, moose populations could eventually increase, which would increase herbivory on riparian and wetland vegetation, and would benefit those avian species that prefer open habitats. While this issue was not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic as it relates to overall processes on the island.

Prey Species. The dynamic relationship between moose and wolves on Isle Royale has impacts on other wildlife species and to some degree most species on Isle Royale. Most notably are impacts to beavers from both wolves and moose. Although wolves feed primarily on moose at Isle Royale (Peterson 1977;

Peterson and Page 1988; Jordan, McLaren, Sell 2000), beaver are secondarily taken by wolves during the summer season and their population dynamics have been documented during studies of wolf ecology and prey relations at Isle Royale (Peterson 1977). The main impact of beavers on vegetation is from tree-cutting and dam-building activities (Krefting 1963). Although this issue is not carried forward for detailed analysis as a stand-alone topic, it is discussed under the Island Ecosystem issue/impact topic as it relates to overall processes on the island.

Water Quality

Isle Royale contains various water resources, including inland lakes, streams, and inlets from the surrounding Lake Superior waters. Changes in nutrient cycling could occur with increased moose foraging in aquatic environments in the absence of wolves. Large herbivores have a significant influence on internal phosphorus cycling (Bump et al. 2009). Nearly 50 years of data has shown that moose transfer significant amounts of aquatic-derived nitrogen to terrestrial systems from clustered foraging patterns such as feeding on aquatic plants and excreting in terrestrial habitats (Bump et al. 2009). The continuation of a low wolf population and associated low level of predation on moose would potentially cause an increase in nitrogen and other nutrients transferred from the aquatic environment to the terrestrial. Because water quality is also impacted by increased turbidity caused by foraging moose, a larger moose population would potentially cause a greater degree of turbidity with effects on water quality. Direct contributions to water quality impacts from actions considered in this draft plan/EIS, such as the transportation of wolves to the island and on-going monitoring activities to support the introduction of a viable population of wolves at Isle Royale, would be at levels similar to current park management activities and scientific studies on the island. Such impacts would not result in measurable changes to existing conditions. This issue is not carried forward for detailed analysis as a stand-alone topic, but it is discussed under the Island Ecosystem issue/imact topic as it relates to overall processes on the island.

Environmental Justice

Presidential Executive Order 12898 requires federal agencies to identify and address disproportionate impacts of their programs, policies, and activities on minority and low-income populations. Executive Order 13045 requires federal actions and policies to identify and address disproportionately adverse risks to the health and safety of children. Currently, there are no permanent human settlements at Isle Royale. Although life lessees do maintain valid existing rights to the use of property on the island, Isle Royale is not otherwise publicly inhabited on a permanent basis. No actions under consideration would affect valid existing rights, nor would wildlife management at the park have a disproportionate effect on minorities, children, or those living at or below the poverty level in areas outside the park. There would be no disproportionate impact to communities with potential environmental justice status. Therefore, this topic is not carried forward for detailed analysis.

Archaeological Resources, Cultural Landscapes, and Ethnographic Resources

Potential management actions under this draft plan/EIS related to the introduction of wolves would not result in ground disturbing activities. Since archeological resources would not be impacted, this topic is not carried forward for detailed analysis.

Cultural landscapes at Isle Royale are those landscapes related to maritime, mining, commercial fishing, and resort-era stories that are important to understanding and interpreting island history (NPS 1998). Specific vegetation that contributes to these cultural landscapes would not be affected by a decision to bring wolves to Isle Royale. However, potential increases or decreases in moose herbivory could result from changes in the wolf population, and such changes would not translate directly to measureable impacts to cultural landscapes. Since there would be no potential for impacts to cultural landscapes from the actions, this topic is not carried forward for detailed analysis.

At Isle Royale, there is considerable evidence of both pre-historic and historic human occupation and use dating back more than 4,500 years. Collections of plants and animals on the island are important ethnographic resources. However, bringing wolves to Isle Royale under this plan would not impact these resources because there would be no resulting physical changes to the landscape where these resources occur or any potential for redesignation of the resources themselves.

Visitor Use and Experience

Visitor use and experience can be adversely impacted by actions that would reduce opportunities for visitor enjoyment. Although the presence of wolves contributes to a long-established predator–prey relationship on the island that is an important aspect of visitor experience, it constitutes just one of the ways in which visitors interpret and experience the park itself. Isle Royale offers opportunities for day hiking, backpacking and camping, cultural and historic resources interpretation, canoeing and kayaking, scuba diving, fishing, and various ranger-led programs (NPS 2016a). Visitor experience at the park is derived from this wide array of available activities, with wildlife viewing of moose and wolves in particular representing only a portion of the overall visitor experience. It can be presumed that particular visitors' anticipation of seeing or hearing wolves, moose and other species, and the opportunity to experience an ecosystem with a dynamic predator-prey system in place and abundant flora and fauna, are important aspects of visitor experience within the existing landscape aesthetic. If no action is taken, future visitors to the island could have different experiences, both positive and negative, in the presence of high moose population levels and amid increased evidence of balsam fir denudation by moose in the absence of wolves. However, such experiences would not considerably detract from the wider array of possible visitor experiences at Isle Royale.

Potential closures, when the island is open to visitation, related to wolf management may temporarily detract from visitor experience by eliminating opportunities for visitors to access certain portions of the island. The magnitude of potential impacts would be similar to those associated with normal maintenance and operations-related closures. Such impacts to visitor experience would be temporary and localized, and would therefore not result in measurable changes to the quality or quantity of available opportunities for visitors to experience the park. Therefore, this topic is not carried forward for detailed analysis.

Threatened and Endangered Species

The gray wolf is federally endangered, although the population on Isle Royale does not contribute to the federal recovery goals. The US Fish and Wildlife Service (USFWS 2015d) Final Rules for the Gray Wolf in the Western Great Lakes states that the park is designated critical habitat for the gray wolf. However, none of the actions being considered in this draft plan/EIS would jeopardize the continued existence of the gray wolf in the Western Great Lakes region because of the relatively small number of wolves even at the highest density. Natural wolf population recovery on the island without human intervention is unlikely at this time, and all of the action alternatives would increase the probability of wolves being present on the island during the life of the plan. The National Park Service continues to consult with the US Fish and Wildlife Service on the appropriate permitting path forward depending on the selected alternative.

In addition to the gray wolf, Isle Royale contains one federally threatened species, the northern long-eared bat (*Myotis septentrionalis*). The northern long-eared bat roosts in trees and forests; occasionally inhabits houses and other human structures; hibernates in rock crevices, caves, and mines; and can be found swarming in wooded areas in autumn (USFWS 2015c). Mine shafts at the park are not of the type and nature to support bat hibernacula; therefore bat populations are believed to migrate off the island in winter. Structures and trees that currently provide summer roosting habitat for these bats would not be affected by bringing wolves to Isle Royale. Moreover, actions under consideration would not involve potentially habitat-disturbing activities such as tree or structure removal or relocation. Therefore, this topic is not carried forward for detailed analysis.

The National Park Service will consult with the US Fish and Wildlife Service under the Endangered Species Act, as appropriate, throughout this planning process.

Wilderness: Opportunities for Solitude and Primitive/Unconfined Recreation and Other Features of Value

Opportunities for Solitude and Primitive/Unconfined Recreation. Bringing wolves to Isle Royale could affect opportunities for solitude and primitive/unconfined recreation to the extent that additional wolves on the island could lead to additional temporary area closures to protect wolf den sites. There could be changes in the number, frequency, and location of temporary closures of certain areas to protect wolf habitat. Bringing wolves to Isle Royale could enhance opportunities for visitors to experience wolves howling, thereby enhancing their sense of solitude. Noise disturbances generated from mechanized equipment to bring wolves to the island, possibly by boat, helicopter, or fixed wing aircraft, would likely not affect solitude because management actions would occur when the island is closed to public access (currently November 1 – April 15). Overall, the presence or absence of wolves could result in temporary and localized changes in the ability of visitors to enjoy the solitude and opportunities for primitive/unconfined recreation. However, analyzing the environmental impacts related to this quality of wilderness character is not necessary to make a reasoned choice between alternatives, and the environmental impacts associated with this issue would not be potentially significant; therefore, this topic is not carried forward for detailed analysis.

Other Features of Value: Scientific and educational purposes. Isle Royale is widely known as the focal point of the longest-running study of a predator-prey system in the wild (NPS 2006). The action of bringing wolves to Isle Royale could ensure the continuance of this study, albeit through human intervention. Resulting contributions to the ongoing study could lead to a more informed understanding of the natural quality of wilderness and its biological components. Conversely, if no action is taken, contributions to scientific and educational purposes of wilderness could occur as a result of new opportunities being created for research on an island system without an apex predator. Therefore, the presence or absence of wolves and wolf predation would alter this quality; however, it is not central to the proposal or of critical importance to this decision, and discussing this quality in detail is not necessary to make a reasoned choice between alternatives. The opportunity for scientific study would continue on the island regardless of which alternative is implemented. Therefore, this topic is not carried forward for detailed analysis.

Acoustic Environment

The noise associated with the action of bringing wolves to the island by plane, boat, or helicopter, particularly in or near designated wilderness areas, could result in infrequent noise impacts to the acoustic environment and could extend into wilderness. Impacts associated with management actions that require the use of boat, plane, or helicopter to bring wolves to the island are expected to be infrequent and short in duration and would not result in any significant impact to the acoustic environment or to wilderness character. Overall, the noise associated with management actions from bringing wolves to the island could result in temporary and localized changes in soundscape, but would not affect recreational experiences and solitude because management actions would occur when the island is closed to visitation or away from areas with visitation when the island is open to visitation. Therefore, this topic is not carried forward for detailed analysis.

CHAPTER 2:
Alternatives

CHAPTER 2: ALTERNATIVES

INTRODUCTION

The National Environmental Policy Act (NEPA) requires federal agencies to explore a range of alternatives and analyze impacts that any reasonable alternatives could have on the human environment. "Chapter 4: Environmental Consequences" of this draft plan/EIS presents the results of the analysis of alternatives.

This chapter describes the various short-term and long-term actions that could be implemented to address the presence of wolves on Isle Royale. The alternatives under consideration must include a "no-action" alternative as prescribed by 40 CFR 1502.14. Alternative A in this draft plan/EIS is considered to be the "no-action" alternative because it is the continuation of current management. The three action alternatives presented in this chapter were developed by a National Park Service (NPS) planning team and included feedback received during the public scoping process (see "Chapter 5: Consultation and Coordination"), as well as feedback from a questionnaire provided to various subject matter experts in the area of wolf biology.

Action alternatives carried forward for detailed analysis must meet the management objectives of Isle Royale National Park (the park) and the purpose of and need for taking action described in "Chapter 1: Purpose of and Need for Action." Action alternatives considered to be reasonable (CEQ 1981) would be technically and economically feasible, and show evidence of common sense. Alternatives or alternative elements that were considered but are not technically or economically feasible, do not meet the purpose of and need for the project, create unnecessary or excessive adverse impacts on resources, or conflict with the overall management of Isle Royale National Park or its resources were dismissed from detailed analysis. These alternatives or alternative elements and their reasons for dismissal are discussed at the end of this chapter.

ALTERNATIVE A: NO ACTION

The Council on Environmental Quality requires that the alternatives analysis in an EIS "include the alternative of no action" [40 CFR 1502.14(d)]. The no-action alternative (alternative A) would be a continuation of existing management practices and assumes no new management actions would be implemented beyond those currently available. Under the no-action alternative, wolves would not be introduced to the park.

NPS current management of wolves at Isle Royale does not include supplementation of the existing wolf population or introduction of new wolves to the island. Therefore, under the no-action alternative, wolves would not be released onto Isle Royale; however, wolves would not be prevented from immigrating to or emigrating from the island on their own. As long as wolves exist on Isle Royale, monitoring activities such as aerial survey and evaluation of genetics and food habits from wolf scat would continue as funds allow. Researchers may continue to conduct permitted studies on the island. Periodic, temporary closures to visitors in some areas of the park would continue to avoid wolf-human interactions, if necessary. The park would continue to intervene in human-to-wolf interactions to ensure visitor safety and resource protection. On a case-by-case basis, the park may radio collar wolves that immigrate to the island naturally to assess population health and demographics.

The park would continue monitoring efforts, regardless of the presence of wolves, as funds allow. The park would continue to research and monitor a wide variety of natural resources including the effects of climate change on the island. The park would continue to study moose impacts on vegetation, abundance of moose, and study the health of the Isle Royale ecosystem as detailed in table 1. Other species research, including beaver and snowshoe hare demographics, could continue.

TABLE 1. CURRENT INDICATORS AND METHODS OF MONITORING ECOSYSTEM CHANGE AT ISLE ROYALE

<table>
<tr><th>Resource</th><th>Current Monitoring</th></tr>
<tr><td>Vegetation</td><td>Exclosures to assess moose and snowshoe hare browse effects. Long-term monitoring of the composition and characteristics of terrestrial forest flora on permanently established plots. Approximately decadal assessments of changes in forest cover and human land use patterns through satellite imagery. Monitoring also includes periodic assessments of forest structure and composition, and treatment of invasive species.</td></tr>
<tr><td>Wolves</td><td>Current wolf monitoring includes the use of telemetry, non-invasive fecal DNA-based approaches, and direct monitoring via photo documentation and/or observation. Telemetry is used to monitor movements, pack formation, reproduction, and survival. DNA-based approaches are used to accurately assess pedigrees and understand population-scale genetic variability, and reproductive contributions of individuals. Data collected on wolves to inform wolf management include:
• Number of wolves inhabiting Isle Royale:
• Number and size of packs
• Wolf demographic and population trends
• Seasonal measures of reproduction and survival
• Genetic pedigree of all island wolves
• Levels of genetic variability and inbreeding depression
• Levels of phenotypic abnormalities
• Levels of natural immigration from the mainland
• Prey population density
• Prey use and kill rates by packs and individuals
• Indirect impacts of wolves on key plant taxa and communities
In general, due to its wilderness designation, Isle Royale would employ the least intrusive methods that provide the needed data or remote sensing, like dens.</td></tr>
<tr><td>Moose</td><td>There is ongoing winter aerial survey or remote sensing monitoring for the following:
• Population estimate (including using a sightability correction factor as appropriate)
• Moose population density
• Moose population growth rate
• Recruitment Rate
• Number of twins in the population
• Spatial distribution
• Predation rate
Systematic searches to evaluate remains (bone collections from kill sites) provide data for population reconstruction and body condition from analysis of bone marrow (fresh kill sites only).
The degree to which moose are impacted by winter ticks is also evaluated.</td></tr>
</table>

ACTIONS COMMON TO ALL ACTION ALTERNATIVES

Under each of the action alternatives, various management strategies, tools, and techniques would be employed for the purpose of addressing the presence of wolves at Isle Royale. These elements, common to all action alternatives, are described below.

Capture Tools

In compliance with state and federal requirements, wolves selected for introduction would be captured using available tools ranging from helicopter net-gunning, modified padded foot-traps, darting from a helicopter or modified snares with appropriate stops. Human and wolf interactions would be minimized.

Capture Location and Logistics

Wolves would be captured primarily from the Great Lakes Region, from areas with a similar vegetative make-up to Isle Royale and where wolves display behavioral traits representative of those needed to survive on Isle Royale (e.g., hunting large prey such as moose). Research suggests that introduced wolves would do best if from an area with similar prey base and habitat; therefore, selecting wolves from an area with moose that is not too geographically distant would be beneficial to population survival and growth. Areas of the Great Lakes Region where wolves would be captured could include, but are not limited to Minnesota, Wisconsin, Michigan, or Ontario, Canada. The National Park Service would seek wolves, that possess one or more of the following desirable traits: (1) are known to feed on moose as one of their prey sources; (2) exhibit good health with no apparent injuries based on examination by a qualified wildlife veterinarian; (3) are not habituated to humans or their food and are not nuisance animals; and (4) possess appropriate genetic diversity and mixture of age and sex. The National Park Service would aim to capture family groups that are separated by at least 40 miles to maximize genetic variation. Capture would include the use of chemical immobilization during capture and relocation efforts. Animals would be held for the minimum time necessary prior to introduction to Isle Royale.

Time of Capture and Relocation

For all action alternatives under consideration, the capture and release periods to bring wolves to Isle Royale would occur primarily between late fall and late winter.

Vaccinations/ Health Evaluations

For all action alternatives under consideration, captured wolves would be evaluated by a certified wildlife veterinarian, which could include collection of samples for health and genetic testing. Any injuries sustained during capture would be addressed prior to introduction and individual animals may be vaccinated, as deemed appropriate. Wolves would be sedated during examination.

Transportation

Once captured, wolves would be transported via boat, plane, or helicopter to the island. For example, wolves could be net-gun captured with a helicopter and flown to a site for evaluation by a certified wildlife veterinarian using a fixed-wing aircraft. Once fully evaluated, wolves could then be transported to Isle Royale with fixed-wing aircraft, helicopter, or the park's landing craft vessel. The National Park Service would remain as flexible as necessary to achieve transportation logistics safely and efficiently as determined by the management alternative employed. In order to avoid undue stress and the risk of habituation to humans, wolves would be held for the minimum amount of time necessary for examination and transport to Isle Royale. The wolves would remain sedated during transportation to a site for evaluation and subsequently during transport to the island.

Release

Wolf introduction would occur by hard release. This entails release of individuals or groups of wolves onto the island with no time to acclimate in holding pens prior to release and without intensive support provided following release. An example of hard release would include dropping wolves off on a suitable land area (e.g., beach, dock, or frozen lake) and allowing them to disperse freely. This type of release has been shown to work effectively and reduces the risk of wolf injury or habituation in holding pens. The location of the release may occur anywhere on the island and could involve multiple locations of simultaneous release.

Carcass Provisioning

During initial release, carcass provisioning of natural prey may be implemented to ensure the success of initial establishment. Moose carcasses would be harvested on Isle Royale and not from off island to prevent the exchange of disease, parasites, or other foreign materials from the mainland to the island. The provision of carcasses may serve as a means of encouraging recently introduced wolves to stay in certain areas of the island. Additionally, carcass provisioning may be used as a strategy to contain pair-bonded individuals to one area of the island while the release of another animal or group of wolves occurs elsewhere.

Monitoring of Released Wolves

Monitoring techniques may include telemetry (GPS or radio) collar tracking from ground and air, scat sample collection, visual observations, and other methodology as funding is available. Introduced wolves may be telemetered along with a subset of wild born Isle Royale wolves. The use of telemetry collars may be employed as a monitoring tool for population dynamics and to allow for the National Park Service to monitor for mortality and to aid in the location of den sites, where less invasive monitoring techniques, such as scat sampling could be conducted.

In general, monitoring of introduced wolves would serve two purposes. First it would allow program success to be assessed using metrics of relevance to wolf population restoration goals, including the demographic characteristics and genetic health of the population. Second, it would allow enhanced understanding of the role of the introduced wolves in restoring Isle Royale ecosystem function. Historically the monitoring approaches used have reflected the need to understand wolf movements, demography, social dynamics, and predator-prey dynamics.

ALTERNATIVE B: IMMEDIATE LIMITED INTRODUCTION (PREFERRED ALTERNATIVE)

Under alternative B, the National Park Service would implement a time-limited wolf introduction at Isle Royale. The goal of this alternative is to provide an immediate introduction of a large enough number of wolves to be self-sustaining throughout the 20-year planning period. The goal of this alternative is to allow the wolves to hunt, establish pair bonds, and ultimately establish packs. This alternative would introduce the historical average number of wolves on Isle Royale in an effort to have immediate effects on the island moose population, while minimizing impacts to the untrammeled quality over the course of the planning period.

After the third year, should an unforeseen event occur, such as disease or mass mortality, that impacts the wolf population and the goals of the alternative are not being met due to this event, wolves may be supplemented for an additional two years.

Number of Founding Wolves

Under alternative B, the National Park Service would introduce 20–30 wolves to the island within the first three years. During the three-year introduction process, multiple, separate, introductions would take place. Wolves would be selected to maximize genetic, age, and sex diversity. Because this alternative would elicit a greater need to ensure adequate genetic diversity in the initial wolf population, the exact number of individuals would be selected based upon available genetic data in order to maximize success based on subject matter expert recommendations (appendix A).

Supplementation of the Wolf Population

Under alternative B, the National Park Service would supplement additional wolves as needed until the third year as part of the initial introduction. After the third year, should an unforeseen event occur, such as disease or mass mortality, that decreases the wolf population to fewer than 12 individuals and less than 3 breeding age females and the goals of the alternative are not met, wolves may be supplemented for an additional two years. However, no additional wolves would be brought to the island after five years from date of initial introduction.

Location of Release on the Island

Under alternative B, complete groups of wolves, such as packs or pairs with pups, may be released simultaneously and distributed across the island, and individual wolves could be released in spatially disparate areas of to minimize conflict.

Monitoring via Radio Collar

Introduced wolves may be telemetered via radio collar, along with a subset of wild born Isle Royale wolves to assess population dynamics over time. Under this alternative, up to all wolves introduced to the island would be radio collared for monitoring purposes. Wolves that immigrate to the island would be radio collared on a case-by-case basis to assess population dynamics.

All other monitoring of introduced wolves under alternative B would be the same as that described under the no-action alternative and table 1.

ALTERNATIVE C: IMMEDIATE INTRODUCTION WITH POTENTIAL SUPPLEMENTAL INTRODUCTIONS

Under alternative C, the National Park Service would initially introduce a smaller number of wolves and supplement as needed.

The objective of this alternative is to provide an initial introduction of wolves into the Isle Royale ecosystem and then allow the wolves to hunt, establish pair bonds, and ultimately establish packs. The goal would be a self-sustaining population. This alternative would allow the National Park Service to use multiple subsequent introductions as necessary to supplement the population based on a variety of metrics described below. This alternative would allow the National Park Service to consider a variety of factors before additional supplementation including climate change impacts on the island, moose population trends, wolf genetics, and other factors.

Number of Founding Wolves

The numbers of wolves to be introduced initially under alternative C would likely be between six and 15 and could include one or more established pairs or packs, and an additional four to six unrelated individuals.

Supplementation of the Wolf Population

Under alternative C, additional wolves may be brought to the island after the initial introduction during a 20-year period. No single metric would trigger an action to bring additional wolves to the island; rather, the National Park Service would monitor and review multiple metrics using a weight-of-evidence approach before taking action. Supplemental introduction may occur if:

- Predation rates of moose by wolves are less than 5% over a three-year moving average.
- The overall ratio of moose to wolves is greater than 75 to 1.
- There is a lack of documented wolf reproduction for three consecutive years.
- Wolf emigration off the island is greater than 33% of the total population or if more than 33% of the existing breeding females leave the island.
- If the number of packs with at least one breeding female and four individual wolves having an equal sex ratio falls below two.
- If the genetic coefficient of inbreeding measures greater than 0.1 and measures of heterozygosity are below 0.6.
- If there are multiyear (e.g., greater than five years) negative trends in wolf population growth rates.

Location of Release on the Island

Under alternative C, the location for release of wolves on the island would be the same as that described for alternative B. Additionally, new wolves would be released at locations away from any existing wolf packs that have been established as a result of previous introductions.

Monitoring via Radio Collar

The minimum number of wolves necessary to meet monitoring goals may be telemetered via radio collar, along with a subset of wild born Isle Royale wolves to assess population dynamics over time. Wolves that immigrate to the island would be radio collared on a case-by-case basis to assess population dynamics.

All other monitoring of introduced wolves under alternative C would be the same as that described under the no-action alternative and table 1.

ALTERNATIVE D: NO IMMEDIATE ACTION, WITH ALLOWANCE FOR FUTURE ACTION

Under alternative D, the National Park Service would continue to monitor conditions and take no immediate action but would allow for future introductions of wolves to Isle Royale. The decision to introduce in the future would be based on moose population metrics and other observed changes in the ecosystem. Should introductions be warranted, they would follow alternative C procedures.

This alternative allows for the potential of wolves to naturally immigrate to the island, for moose populations to be influenced by natural forces as is now occurring, and defers potential impacts on the untrammeled quality of Isle Royale wilderness.

Metrics for Taking Action for Initial Release

Under alternative D, the decision to introduce wolves would be based on ecosystem changes with specific focus on moose population metrics to assess these changes. Subject matter experts and park management would meet to evaluate monitoring results, assess status of moose and wolves, and vegetation assemblages. No single metric would trigger an action to initially bring wolves to the island; rather, the National Park Service would monitor and review multiple metrics using a weight-of-evidence approach before taking action. One or more of the following would have to be met before the National Park Service would take initial action to bring wolves to the island:

- The moose population exceeds 1,500–1,800 animals.
- The three-year moving average moose population has a growth rate of greater than 15%.
- A moose calf recruitment rate over a three-year moving average is greater than 15%.
- The number of calf twins observed exceeds five total counted pairs.
- No natural emigration of wolves via ice bridges has been documented.

While these metrics trigger the need to review information and the decision point, current information on wolf demography and vegetation monitoring would also weigh into the decision. The park would consider if changes are associated with the lack of wolves in the ecosystem or associated with other potential stressors including climate change, disease, or other natural successional changes. At the conclusion of this annual assessment, a summary report consisting of a recommended course of action along with supporting data and interpretation would be submitted to the Superintendent.

Number of Founding Wolves

Under alternative D, should metrics show the need for action, the number of founding wolves would be the same as under alternative C.

Supplementation of the Wolf Population

Supplemental introductions could occur after initial introduction, following the criteria outlined under alternative C.

Location of Release on the Island

Under alternative D, the National Park Service would determine an appropriate location to release wolves at Isle Royale based on the strategy described under alternative C.

Monitoring via Radio Collar

Monitoring of introduced wolves under alternative D would be the same as alternative C.

SUMMARY OF ALTERNATIVE ELEMENTS

TABLE 2. SUMMARY OF ALTERNATIVE ELEMENTS

	Alternative A: No Action	Alternative B: Immediate Limited Introduction (Preferred Alternative)	Alternative C: Immediate Introduction with Potential Supplementation Introductions	Alternative D: No Immediate Action, with Allowance for Future Action
NPS Wolf Introduction Could Occur	No	Yes	Yes	Yes
Timing of Release	Not applicable.	Starting immediately, completed within five years.	Starting immediately, supplemented as needed.	Introduction would not begin immediately, but may take place based on moose population metrics and other ecological factors.
Number/Duration of Releases	Not applicable.	One release event, lasting up to three to five years.	Multiple release events could take place over the 20-year life of the plan.	Once metrics for introduction are met, same as alternative C.
Number of Founding Wolves	Not applicable.	20 - 30 wolves selected to maximize genetic diversity and initial predation rates.	6 -15 wolves including pairs or packs.	Once metrics for introduction are met, same as alternative C.
Supplementation of Wolf Population	The existing population would not be supplemented.	After the third year, should an unforeseen event impact the wolf population and the goals of the alternative are not met, wolves may be supplemented for an additional two years. After the fifth year, no additional supplementation would occur.	Supplemental introduction would occur as needed over the 20-year life of the plan.	Once metrics for introduction are met, same as alternative C.
Location of Release on the Island	Not applicable.	Complete groups would be released at one end of the island; individual wolves would be released at the opposite end of the island.	Same as alternative B, plus additional wolves would be released at locations away from established packs.	Once metrics for introduction are met, same as alternative C.

	Alternative A: No Action	Alternative B: Immediate Limited Introduction (Preferred Alternative)	Alternative C: Immediate Introduction with Potential Supplementation Introductions	Alternative D: No Immediate Action, with Allowance for Future Action
Radio Collaring	Wolves that immigrate to the island would be radio collared on a case-by-case basis to assess population dynamics.	Same as alternative A plus up to all wolves introduced to the island would be monitored via radio collar.	Same as A plus the minimum number of wolves necessary to meet monitoring goals would be monitored via radio collar.	Same as alternative C.

ALTERNATIVES CONSIDERED BUT DISMISSED FROM FURTHER DETAILED ANALYSIS

Introduction of Lynx and Caribou

During public scoping, some commenters advocated the introduction of lynx and caribou, including the attempted coexistence of moose and caribou and the replacement of moose with woodland caribou, as a means of restoring equilibrium to the ecosystem at Isle Royale. Both caribou and lynx have inhabited Isle Royale during the island's history. Commenters stated that an introduction of lynx would supplement current levels of moose predation by wolves, thereby serving to effectively decrease moose population and indirectly reduce herbivory on island vegetation. There is no documentation suggesting that lynx would affect the moose population or help address impacts from moose herbivory. Lynx are not known to prey on adult moose. In addition, the future forest ecosystem may not be supportive of caribou as a result of climate change.

This alternative was dismissed because the current plan is focused on management actions pertaining to wolf populations on the island. Because wolves are the key species considered for management under this draft plan/EIS, lynx and caribou populations are therefore outside the scope of the plan.

Managed Culling / Public Hunting

During public scoping, some commenters advocated the use of hunting in the park to reduce the moose population and reduce herbivory on island vegetation. Public hunting would be inconsistent with existing laws, policies, and regulations for the park because public hunting is not allowed by federal statutory law at the park. The NPS is not considering a managed harvest because of the difficulty related to logistics, increased staffing requirements, removal of carcasses from the landscape, and the impacts to wilderness character. In addition, a public comment was submitted suggesting NPS conduct non-lethal wolf hunts off-island using tranquilizer darts to provide wolves for introduction. Due to logistical constraints and animal welfare, this was element was not carried forward for detailed analysis. As a result, hunting and managed culling is dismissed from further consideration.

Alternative Vegetation Management Strategies

Some commenters suggested alternative elements related to vegetation management, such as rotating where moose are able to browse and restoring vegetation, erecting protective fencing, thinning trees to be more conducive to the movement of moose and wolves, planting specific species for vegetation restoration, restoring vegetation on surrounding islands, creating seed banks, managing non-native and invasive species, and conducting controlled burns.

Moose and wolf movement on the island is relatively unrestricted and is not impeded by vegetation. Both species use the 165 miles of trails. The feasibility of fencing off substantial areas of the island’s vegetation is limited due to the size of the protected areas that would be required and the costs associated with installation and maintenance of fencing. Such an undertaking would be technically and financially infeasible at this time.

Due to the isolation of Isle Royale, planting trees and vegetation either on Isle Royale or surrounding islands would require creating a seed bank and a nursery on the island in order to avoid introduction of diseases or foreign genetic sources. This proposal is outside the scope if this plan.

The park currently conducts invasive species management and will continue to do so. Such management includes the use of mechanical and chemical treatments. The use of prescribed fire as a method of managing moose populations was suggested. In the presence of a regulated moose population subjected to predation, prescribed fire would benefit moose and could cause populations to increase, which would not meet the purpose or need of the plan. Overall, vegetation management is outside the scope of the plan, although impacts to vegetation are evaluated in “Chapter 4: Environmental Consequences” in the section “Island Ecosystem.”

Captive Wolf Breeding Program

A captive wolf breeding and rehabilitation program at Isle Royale was discussed, which would use artificial insemination to increase the population of existing wolves on the island. However, the preliminary alternative was dismissed on the basis that such a plan would not meet the purpose and need for taking action. The current population is inbred and contains genetic abnormalities that may prevent successful pregnancies from occurring. Therefore, using the current population in a captive wolf breeding program would not be advisable. A captive program would be prohibitively expensive as it requires the construction of a facility at Isle Royale for the purpose of holding wolves in pens and feeding them on a regular basis, which would require additional funding for program maintenance. Captive wolves are also more likely to habituate to humans. Overall, the implementation of such a program at Isle Royale would be technically and financially infeasible and is unlikely to remain viable. Therefore, this alternative was dismissed from consideration.

Move Problem Wolves from the Mainland

Consideration was given to the option of moving wolves that have depredated livestock or domestic pets (referred to by commenters as “problem wolves”) and wolves that have become habituated to humans from the mainland to Isle Royale. Although it is technically feasible to import wolves from the mainland, wolves that have become habituated to humans could represent a potential danger to visitors to the park and bringing in non-habituated wolves as proposed in the alternatives minimizes these risks. As a result, this alternative was dismissed from consideration. However, the National Park Service would not preclude, and the action alternatives do not preclude, the option of relocating an individual animal from the mainland to Isle Royale that has preyed on livestock. NPS will not accept wolves that display human habituation or other problem behaviors that would have any potential for conflict with visitors or park operations (NPS 2006, section 4.4.2.2).

Translocate Wolves from the Island

During public comment it was suggested that wolves that may be introduced to the island under this plan be translocated from the island at a later date, if necessary in order to minimize the potential for inbreeding. However, this management action was dismissed because all of the wolves potentially introduced to the island would contribute to the genetic diversity of island packs and thus sustain a population that would continue to function as an apex predator. Therefore, this action would not resolve the purpose and need for taking action.

Natural Recovery / Non-Intervention

Comments received during public scoping requested that the National Park Service allow for wolves to immigrate to the island naturally and to not intervene in natural island processes. This approach is characterized by the no-action alternative and a consideration in alternative D.

Management of Moose through Translocation, Culling, Fertility Control, Biological Controls such as Use of Parasites or Bacteria.

The suggestions from public comment to manage the moose population on Isle Royale through translocation, culling, fertility control, biological controls, such as use of parasites or bacteria were also considered. However, these elements were dismissed on the basis that such management would not meet the purpose and need for taking action because it would not address the population of wolves at Isle Royale and the direct management of moose is outside the scope of this plan. If direct management of moose became necessary at a future date, it may require a separate planning effort. Currently, there is no approved agent for fertility control in moose. The introduction of a parasite or bacteria (non-native agent), in an effort to control the moose population is against NPS management policy. Therefore, the direct management of moose was dismissed from further consideration.

Establishing a Climate Refuge

The establishment of a climate refuge, where moose are removed from the landscape was discussed during the planning process. A refuge is an area in which biodiversity can retreat to, persist in, and can potentially expand from a changing climate (Conservation Biology Institute 2016). A refuge would allow for climate-driven successional vegetation to occur on the island, resulting in an understanding of how vegetation would change in the absence of moose. The removal of all moose would be a central component to the designation of Isle Royale as a climate refuge for vegetation.

Passage Island, located within the Isle Royale National Park archipelago of islands, has never supported a moose population, nor does it appear to have had hares and small rodents. As such, Passage Island could offer an opportunity to study vegetative response to climate change in the future without the impacts of moose, or other herbivores. While nothing in this plan precludes the National Park Service from managing moose by other means if needed in the future or studying climate change impacts, complete removal of moose from the island to support a climate refuge would not be consistent with NPS policy and would likely be technically and financially infeasible. This alternative was dismissed from further consideration because direct management of the moose population and the establishment of a climate refuge are outside the scope of the plan.

Extending the Life of the Plan beyond 20 Years

This plan, and most planning efforts conducted by the National Park Service, are intended to cover a 20-year period. After such a period, plans should be revisited to determine if the needs or conditions have changed. At that time this plan could be amended or supplemented to address new information as it arises. Additionally, the lifespan of the plan allows the National Park Service to evaluate the data collected during the plan and adjust as necessary. Some potential impacts, such as those from climate change, are somewhat unknown and the 20-year timeframe of the plan leaves the National Park Service the discretion to take different action in the future if conditions warrant. Therefore, expanding the lifespan of the plan beyond 20 years was not carried forward for further analysis.

Limit Human Visitation to the Island

During public scoping it was suggested that human visitation to the island be limited in order to limit impacts to the wolf population. The purpose of the plan is to determine whether and how to bring wolves to Isle Royale, and this would occur in the context of the park's mandate, which allows for public visitation of the island. Therefore, limiting human visitation would not resolve the purpose and need for action to a large degree. Further, since this is a wolf management plan, management of public visitation is outside the scope of this plan. As stated in the park general management plan, purposes of the park include providing opportunities for recreational uses and experiences that are compatible with the preservation of the park's wilderness character and park resources and providing park-related educational and interpretive opportunities for the public. Limiting public access to the park would be contrary to these purposes and, depending on the nature of the limits, could require a major change to a law, regulation, or policy.

Soft Release Techniques

The National Park Service discussed the use of soft release techniques during proposed capture and relocation of wolves. The National Park Service engaged subject matter experts in determining what technique would be most appropriate for Isle Royale. Soft release techniques increase the opportunity for animals to acclimate to a locale and, thus, increase the likelihood of animals remaining in a particular locale. Although the subject matter experts suggested that in the past, there has been a higher risk that hard release animals do not settle in a desired area, it was noted that the wolves would be released on an island with limited ability to leave. Some subject matter experts suggested a soft release where wolves captured on the mainland could be transferred to holding pens either on the mainland or at Isle Royale while health and genetic testing could be done might be beneficial. Other subject matter experts thought this soft release technique could increase stress and potential injury for the animal. Soft release techniques require infrastructure and habitat modification, as well as periodic visits by humans with an associated risk of habituation. During the winter, the subject matter experts suggested that soft release may be logistically difficult because of limited site accessibility (appendix A). While the National Park Service discussed at length the subject matter experts input, the National Park Service found that the logistics and expenses of a soft release including establishing a holding facility either on the mainland or on the island were not technically or economically feasible. In addition, impacts to wolf and human safety would be increased under a soft release technique versus a hard release technique.

CHAPTER 3:
Affected Environment

CHAPTER 3: AFFECTED ENVIRONMENT

This chapter describes the current condition of the island ecosystem, wilderness character, moose, and wolves that would be affected by the implementation of the proposed management alternatives. The resource topics presented in this chapter correspond to the resource impact discussion in "Chapter 4: Environmental Consequences."

ISLAND ECOSYSTEM

A central issue to the decision of whether to bring wolves to the island is how the presence or absence of an apex predator could affect the larger island ecosystem. Ecosystem processes are sequences of events or states, one following from and dependent on another, which lead to some outcome. The main fundamental ecological process discussed in detail as it relates to proposed National Park Service (NPS) action is vegetation and animal community dynamics. The presence or absence of wolves could directly and indirectly affect the community dynamics of the island and contribute to effects to other resources. Processes associated with community dynamics include predation, competition, disturbance and succession and were determined to be the primary determinants for this evaluation**.** Water, nutrient, and energy cycling are also important ecological processes present on the island and although these processes are impacted by predator-prey relationships, they are not carried forward for detailed analysis.

There are a number of individual resources (e.g., aquatic vegetation and wetlands; terrestrial vegetation; and other wildlife – notable scavenger, prey, and avian species) that could be indirectly affected by NPS actions that are not discernible on their own but will be captured within this issue/impact topic.

Community Dynamics

Community dynamics, including distribution, abundance, demography, structure, and function, are part of a complex array of interactions, directly or indirectly tying all members of an ecological community together in an intricate web. The ecological and evolutionary impact of a population extends in all directions throughout the trophic structure of the community by way of its influence on predators, competition, and prey, but this influence dissipates as it passes through each successive link in the chain of interactions. The impact spreads through space and forward through time by way of the movements of individuals and the inertia of population characteristics (e.g., birth rates, mortality rates, and recruitment). Community dynamics on Isle Royale central to this plan include predation, competition, disturbance, and succession**.**

trophic dynamics*—Trophic dynamics are the system of trophic levels describing the position that an organism occupies, as well as the sequence of consumption and energy flow in an ecosystem.*

mesopredator*—A mesopredator is a medium-sized, middle trophic level predator, which both predates and is predated upon. Examples are raccoons, skunks and snakes.*

mesopredator release*—The term "mesopredator release" describes a process whereby mid-sized carnivorous mammals became far more abundant after being "released" from the control of a larger carnivore.*

trophic downgrading*—Trophic downgrading is the process of removing large apex predators from nature and the consequences on ecosystems.*

Predation

Predation is a key ecological and evolutionary process (Estes et al. 2011), including the presence of apex predators. Apex predators are species that occupy the top trophic level in a community and (1) often have strong effects on trophic dynamics and diversity of systems, (2) effect mesopredators (mid-ranking) through lethal encounters, and (3) influence mesopredator behavior (Ritchie and Johnson 2009). Top-down control by apex predators can alter community structure of prey species (Pinnegar et al. 2000; Laliberte and Ripple 2004) and the loss of predation by apex predators in systems has resulted in indirect effects of mesopredator release and trophic cascades, resulting in widespread trophic downgrading of ecosystems (Crooks and Soulé 1999; Baum and Worm 2009; Estes et al. 2011). Mesopredator release may cause an increase in these predators; therefore, having a negative effect on the underlying prey community. For example, the loss of wolves from Yellowstone National Park resulted in mesopredator release and tropic cascades (Berger and Conner 2008; Baum and Worm 2009; Ferretti et al. 2010). As the only predator on Isle Royale, the gray wolf fills the apex predator role and asserts some control over the abundance and spatial distribution of prey species, primarily moose, typically preying on old, young, and sick individuals.

In contrast to apex predators, mesopredators comprise any mid-ranking predator in a food web regardless of size or taxonomy (Prugh et al. 2009; Ritchie and Johnson 2009). Mesopredators are more likely to provide diffuse predation within a community based on their relative position in the trophic pyramid. Due to greater energy availability and species richness at lower trophic levels (Lindeman 1942; May 1988), mesopredators should exploit a wider assemblage of shared food resources, and as such would be less specialized, with less influence on the behavior of other species (Prugh et al. 2009). Foxes and several mustelid species (e.g., American marten), comprise the island's mesopredators. Foxes are killed by wolves whenever they can kill them, primarily to reduce their use of moose carcasses. There is little data to suggest wolves kill mustelids in any meaningful way at Isle Royale; however, two American marten carcasses were recovered on the trail network within the past 10 years (Romanski pers. comm. 2016) and wolves have been known to kill river otter (Route and Peterson 1991).This illustrates the complex relationship between apex predators and mesopredators on Isle Royale.

diffuse predation*—Diffuse predation involves a suite of species all preying upon prey populations but with high redundancy, such that individual predator species have little measurable effect.*

Moose are the primary prey of wolves on Isle Royale. Prey populations, such as moose, largely determine the growth rate of predators, as they provide the food necessary for growth and reproduction. Wolves are long lived and must remain in prime condition to hunt frequently; as such, they avoid moose that are in prime condition to minimize harm to themselves.

Wolf-Moose Relationship. The wolf-moose relationship on Isle Royale is one of the most studied and well-documented predator-prey studies in the field of wildlife biology (Peterson 1977; Vucetich and Peterson 2004). Wolves and moose both have been subjected to various, and often confounding ecological principles such as vegetative response to herbivory, fire (or lack thereof), emigration and immigration of wolves (or lack thereof), changes in climate, the impacts of island biogeography, introduction of disease, and genetic inbreeding depression. All of these impacts have acted in concert and individually to impact the wolf and moose populations on the island. What have not impacted these populations, however, are direct, human-controlled actions such as hunting, vehicle accidents, and reduction via control efforts.

Data concerning the wolf-moose predator-prey relationship have generated a range of conclusions, some of which are contradictory. During the 1960s and 1970s, both wolf and moose increased in density. Wolf numbers then declined from 1980 to 1996, due in part to an introduced disease. The moose population began to increase in 1984–1985 and continued to climb until 1996 and then crashed, with 80% mortality (Peterson 1999). This suggests limited density-dependent regulation within the moose population and a rather loose coupling of the two species. Post (2002) reported a non-linear time series analysis of densities from 1958 to 1999. A concurrent analysis of the same data, but focused on kill-rate, found that (a) predator density outperformed prey density as a predictor, (b) a ratio of predator to prey model outperformed a prey-based model, and (c) the maximum explanatory power of any model was 36% suggesting that a large part of the system remains unexplained (Vucetich, Peterson, and Schaefer 2002). This means that roughly two-thirds of the interactions cannot be explained by the relationship between moose and wolves. These results support the characterization of a "loose" connection between species. Following the introduction of canine parvovirus, wolf numbers plummeted, precipitating a switch from top-down to bottom-up regulation of the moose population. Hereafter, the influence of climate on moose population growth rate doubled (described below); demonstrating the interactions between pathogens and climate can lead to shifts in trophic control (Wilmers et al. 2006). Furthermore, Peckarsky et al. (2008) explained this important weather signal in the relationship of the two species. In particular, the North American oscillation, which exerts a large influence on snowfall totals, impacts wolf predation rates due to the concentration of its prey during high snowfall years or its dispersion during low snow years. Thus, this more-or-less cyclic weather pattern is an important driver of predation rates (kill rates), and thus has some influence on the densities of both species.

With the arrival of wolves in the middle of the 20th century, moose population levels continued to fluctuate but now under the influence of predation. This was most evident when wolves were at higher levels and was extremely limited when they occurred at low levels, like they are currently. The existing two wolves have little or no impact on moose numbers. Predation rate is the proportion of the moose population killed by wolves each year. That statistic is calculated from estimates of kill rate and the ratio of wolves to moose. On the basis of those observations, the estimated predation rate for 2015 was 0.8%. The four lowest recorded predation rates occurred between 2012 and 2015 and the average for that four-year period was 2.2%. Previously, the average predation rate was 9.9% (Vucetich and Peterson 2015).

The presence of wolves has had a variety of impacts on moose including direct predation and more subtle impacts such as changing the way moose use the island spatially. It is theorized that over time moose have learned to use habitat on Isle Royale in order to avoid wolf predation. This is illustrated by frequent observations of cow moose choosing to calve on small islets offshore of the main island as a strategy to escape wolf predation on calves (Stephens and Peterson 1984). These spatial patterns appear currently to be intact in spite of an extremely limited risk due to the small numbers of wolves left. In the absence of wolves, the relationship of moose to their habitat and impacts on both the vegetation and other species will change dramatically, and likely reflect conditions seen prior to wolf arrival.

Wolf-Beaver Relationship. The dynamic relationship between moose and wolves on Isle Royale has impacts on other wildlife species and to some degree most species on Isle Royale. Most notably are impacts to beavers from both wolves and moose. Second only to moose, beavers are an important prey species for wolves. Beavers were first observed by John Tanner around 1790 (James 1830) and were notably absent with the exception of a few old lodges mentioned during a land survey in 1847 (Ives 1848). This absence continued through the 19th century (Adams 1909) as beavers were likely extirpated (Shelton 1966), or were purposefully not mentioned because their pelts were valuable, equivalent to $875 in the 2008 value of US currency (Romanski and Belant 2008).

Murie described 27 locations in which he observed signs of beavers in 1929 and 1930. Murie felt that beavers would have been abundant were it not for the activities of poachers. By the mid-1940s beavers became quite abundant. Beavers declined in the mid-20th century likely due to tularemia, a disease that was widespread in the Great Lakes region at this time (Shelton 1966). Analysis of 1930 aerial photography identified a portion of those locations identified by Murie and an additional 27 sites with observed sign of beavers (Shelton 1966). Using results from his study, area and proportion of active versus non-active sites, Shelton (1966) estimated that approximately 146 sites with observed sign of beavers were on Isle Royale and 103 were active. Live trapping at 31 sites provided an average of 6.4 beavers per colony. When combined with 140 active colonies determined by aerial survey and ground reconnaissance, Shelton (1966) estimated a total population of 900 animals. Growth rates and weights were comparable to other populations. Kits comprised 40% of the summer population and juvenile mortality was low until the third year, when dispersal increased vulnerability to gray wolf (*Canis lupus*) predation. Beavers began to deplete their favored food, quaking aspen (*Populus tremuloides*), and as available aspen decreased, beavers ate more paper birch (*Betula papyriferya*), shrubs, and aquatic plants. Around 15% of wolf scats collected contained beaver remains; however, this mortality did not overcome beaver productivity. Shelton continued aerial survey for active sign of beavers; partial counts were conducted in 1969 and 1973, and a full survey completed in 1974. Thereafter, a complete survey was conducted biennially starting in 1978. Through 2004, Smith and Shelton (2002) documented two population cycles beginning with 125 active sites in 1962, increasing to 286 in 1974, then decreasing to 83 in 1980, followed by an increase to 204 in 1986 and a gradual decline to about 50 sites in 2004. Despite documenting more sites, Peterson and Romanski (2012) inferred a continuing decline through 2009; thereafter the population increased as wolf numbers decreased and predation was lacking. The most recent estimate from October 2016 was over 300 colonies, which is a 64% increase from 189 colonies documented by Romanski in 2014 (NPS unpublished data 2016b).

Shelton and Peterson (1983) contemplated the wolf crash of 50 to 12 and its relationship to the population dynamics of moose and beavers suggesting moose vulnerability and high beaver numbers led to increased number of wolves and ultimately the increased use of beavers between 1974 and 1980. Romanski (2010) demonstrated that beaver colony abundance could predict predation rate, suggesting prey density drives predation in the Isle Royale system concerning beavers and wolves. Shelton and Peterson (1983) suggest the lack of available forage for beavers, the potential for increased predation risk, and foraging and resource competition with moose could prevent the beaver population from reaching high numbers previously observed.

Wolf-Moose-Avian Relationship. The impacts of wolves on the avian community of Isle Royale are related primarily to how they impact moose herbivory. Wolves rarely hunt or eat birds and there is no documentation that wolves on the island use any bird species as a prey resource. Wolves do impact some scavenger species such as ravens by killing moose and leaving carcasses that can be scavenged. Raven numbers are declining on Isle Royale (Egan and Gostomski 2012) and while it is surmised that this is due to lack of predation and the resultant scarcity of carcasses on the landscape, this relationship has not been explicitly demonstrated.

Competition

Competition is a central force in structuring ecological communities. The presence of other organisms may limit the distribution of some species. Such competition can occur between any two species (interspecific) or individuals of the same species (intraspecific), which use the same type of resources and habitat. As population densities within a species increases, intraspecific competition for resources increases and evolutionary pressure on individuals occurs, altering genetic and phenotypic composition so that those best suited to current conditions have higher survival rates.

phenotype—*Observable physical or biochemical characteristics of an organism, as determined by both genetic makeup and environmental influences.*

Competition among animals is often over food and mates but can be over water, territory, or other limiting resources. For example, plants can compete for light, water, nutrients, or pollinators. When two species compete for resources, one species will often be better suited than the other in gathering or using the scarce resource. Two general strategies for the weaker competitor include avoiding the superior competitor by changing their habitat preference and thus their distribution on the landscape, or changing diet. These strategies demonstrate how competition influences natural selection.

Competition for resources on islands is further complicated. Island species often compete poorly with introduced animals from the mainland that have undergone extensive selection over relatively long evolutionary periods (Cox and Elmqvist 2000). This may facilitate further introductions (Simberloff and von Holle 1999) and extirpations, thus continuing, and in some cases amplifying, the dynamic nature of an island ecosystem. The most explicit example of interspecific competition on Isle Royale was the arrival of a male wolf in 1997 whose phenotypic traits and associated genotype soon became the dominant pedigree of the population displacing the previous population's genetic make-up almost entirely (Adams et al. 2011).

Holt and Lawton (1994) use the terms focal (moose) and alternate (beavers) in a review of apparent competition and suggest complicated relationships between one predator, and a focal prey and an alternate prey, vary on short and multi-generational time scales and often manifest quite differently at each scale. On Isle Royale there is evidence beaver population dynamics influence (bottom-up) on long-term time scales and are influenced themselves (top-down) on a short-term time scales in its interactions with the wolf population. Theory predicts that when predators are limited by prey availability, alternate prey experience long-term negative interactions via shared predation leading to species exclusion (Holt and Lawton 1994). The long-term decline in overall abundance and mean annual growth rate of beaver colonies may provide evidence for apparent competition (Romanski 2010).

Red foxes and snowshoe hares are also linked to some degree to the wolf-moose system on the island. Red foxes use wolf kills as a supplemental food resource and carcasses may be a particularly important source of winter food. An index of fox abundance, the number of foxes seen per 100 hours of flight time has declined over the past decade and may suggest that the lack of wolf killed moose carcasses could be influencing this population. Snowshoe hare populations are not systematically surveyed on the island but indices are available based on hares seen in summer over specific distances walked (Peterson and Vucetich 2016). Hares are highly cyclical in nature and appear to be so on Isle Royale. Hares are not particularly important as prey source for wolves but are one of the principal prey for red foxes on the island.

Disturbance and Succession

Disturbances to the system (such as fire, herbivory, and extreme weather events), however, can cause shifts to earlier stages of ecological succession that do not necessarily reset the developmental trajectory. Succession is a directional, cumulative change in the species that occupy a given area through time.

A disturbance may change a vegetation community significantly. Afterwards, the ground is often littered with dead material and has greater exposure to sunlight. This decaying matter and abundant sunlight can promote an abundance of new vegetative growth. Many plants and animals benefit from disturbance conditions and some species are particularly suited for exploiting changed conditions at recently disturbed sites. For example, vegetation species with rapid growth traits can quickly take advantage of a lack of competition. Species that are well adapted for exploiting disturbance sites are referred to as pioneers or early successional species. On Isle Royale, examples of these include: paper birch, quaking aspen, dogwood, and others. These shade-intolerant species are able to photosynthesize at high rates and as a result grow quickly. Their fast growth is usually balanced by short life spans. These species often dominate immediately following a disturbance that causes open conditions, but they are unable to compete with shade-tolerant species, and are eventually replaced through succession. However, non-native and invasive species can establish themselves after a disturbance event and often times change community dynamics by permanently displacing native species.

The process of succession is likely to change the biodiversity of an ecosystem and subsequently the relative abundance and distribution of species. In general, biodiversity improves ecosystem productivity and contributes to natural sustainability. Biodiversity also contributes to resiliency that will allow for greater recovery from unpredictable events, including providing population reservoirs for rare or unique species and a larger gene pool that contributes to the long-term survival of species. Disturbances on Isle Royale include herbivory (and beaver activities), fire, and weather events. The influence of these disturbances and successional patterns at Isle Royale are discussed further below.

Herbivory. Large ungulate herbivores (e.g., moose) are functionally important components of many ecosystems, including the island ecosystem of Isle Royale. Herbivory is largely characterized through direct interactions; as consumers of plants and as food for predators (Pringle et al. 2010). Studies indicate that standing biomass is increased in the absence of herbivory, dependent on physical parameters, such as climate and soil conditions which can moderate these changes (Pringle et al. 2010). Some woody species, like balsam fir, produce chemical compounds that may provide a defense to herbivory (Koricheva et al. 1998). Herbivory has also been shown to induce morphological changes in woody species that might alter the availability to future consumption (as referenced in Crête, Ouellet, and Lesage 2001: Krefting, Stenhund, and Seemel 1966; Willard and McKell 1978; Danell and Bergström, 1989; Edenius 1993; Danell et al. 1994; McLaren 1996).

On Isle Royale, herbivory and its effects have played a large role in shaping the island ecosystem. Moose are dependent on vegetation for food and cover, and can influence the characteristics of vegetation (e.g., species composition, spatial heterogeneity) as much as they are influenced by it (Pastor et al. 1988). Estimates of biomass removal by moose on Isle Royale range from 0.1 to 25 kilograms per hectare per year (McInnes et al. 1992) and represents less than 3% of annual shrub and sapling production. An important factor in determining effects of moose herbivory is the rate at which plants recover from herbivore-inflicted damage. Herbaceous and aquatic vegetation may recover from herbivory relatively quickly; however, shrubs and saplings grow more slowly, and growing shoots are preferentially removed; thus, the functional groups typical of forests may be disproportionately affected by moose herbivory (McInnes et al. 1992).

DeJager et al. (2016) developed a browsing extension for the LANDIS-II forest landscape simulation model to simulate long-term and large-scale reciprocal interactions between the moose population and forest landscape of Isle Royale in the context of different predation rates. Increasing the predation rate in the model simulations led to progressively weaker impacts of the moose population on total aboveground live biomass and biomass within the height reach of moose (available forage biomass). In the absence of wolf predation, simulations yielded an upward trend in the moose population that closely matches the recent population trends at Isle Royale. This upward trend in the modeled population continued until a peak of approximately four moose km^{-2} in 2028, at which time the population reached the island carrying capacity. Thereafter, both the population and the carrying capacity of the island declined in lock-step with each other for the next couple of decades. These dynamics differed from those in either of the predation scenarios and resulted in strong effects on forage production.

Differences in aboveground biomass occurred quickly, within the first two decades, while changes in forest composition occurred later in the simulations, following senescence of the existing mature forest stands at Isle Royale. Compositional changes that were attributable to heavy moose browsing (no predation) included strong declines in the abundance of highly preferred species such and balsam fir, paper birch (*B. papyrifera*), and trembling aspen (*P. tremuloides*). Unbrowsed species, such as white spruce (*P. glauca*) benefited from heavy moose browsing on the other more preferred species.

When assessing potential impacts of climate change to Isle Royale's forests, Sanders and Grochowski (2013) identified five forest types where three of these (sugar maple/birch, eastern white cedar (*Thuja occidentalis*), and balsam fir were already climax types with little likelihood of succeeding into another type over the next two to three decades. Two forest types (white spruce (*Picea glauca*) / trembling aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) were in a state of transition. The long-term (> 50 year) successional pathways of all five forest types will be influenced by climate change, species' migration abilities, and disease. Many dominant species currently on the island, including balsam fir, black spruce (*Picea mariana*), and white spruce, are expected to become extirpated, while the abundance of other common species, including paper birch and trembling aspen, is expected to decline.

The above studies conclude that change is not tied to moose alone as it relates to island vegetation. Natural successional changes, without climate change influences, lead to a reduction in balsam fir. Climate change influences in the future appear to also lend to a reduction in the primary species for forage for moose. See the "Weather Events" section for further information on climate changes on the island.

Forage Availability and Preferences—Moose on Isle Royale show variable preferences for different plant species depending on season. An important factor influencing moose population trends is the abundance of highly preferred browse species available in winter, which can fluctuate from year to year. Factors responsible for these differences include growing conditions, mortality, plant succession, and severity of browsing in previous years. Browse availability is reduced when trees grow out of a moose's reach, increasing canopy cover and suppressing understory shrubs (Krefting 1974).

Observations in the 1930s indicated balsam fir was the most important winter food (Murie 1934); it was not only abundant, but palatable. Several authors subsequently reported the importance of balsam fir in the moose's winter diet (Aldous and Krefting 1946; McLaren and Peterson 1994 Pimlott 1953; Jordan 2000). Fecal pellet group counts in 1961, 1965, and 1970 suggested heaviest winter habitat use was in the paper birch-balsam fir-white spruce climax boreal forest type. During 1948 and 1950, when regeneration from the 1936 burn (described further below) was available to moose, use of other forest types exceeded use of the boreal forest type (Hansen, Krefting, and Kurmis 1973).

Murie (1934) observed that ground-hemlock, a preferred food of moose in both winter and summer, was quickly disappearing, and attributed it to browsing pressure by moose. Other favored species noted by Murie (1934) were trembling aspen, paper birch, willow, beaked hazelnut, American mountain-ash, juneberry (*Amelanchier arborea*), fire cherry (*Prunus pensylvanica*), red-osier (*Cornus stolonifera*), staghorn sumac (*Rhus typhina*), sugar maple, wild rose (*Rosa acicularis*), Canadian honeysuckle (*Lonicera canadensis),* and red oak. Species less frequently browsed were white pine, mountain alder, mountain maple, red-berried elder (*Sambucus racemosa*), and huckleberry (*Gaylussacia baccata*). Rarely browsed plants included juniper (*Juniperus communis*), white-cedar, black spruce, white spruce, speckled alder (*Alnus incana*), and bush honeysuckle (*Diervilla lonicera*).

Preference by moose for browse is generally shown for saplings of common species including white birch and quaking aspen (year-round, highly preferred); yellow birch and sugar maple (year-round, moderately preferred); balsam fir (winter only, moderately to highly preferred); northern white-cedar (winter only, low preference); white spruce and black spruce (not used at all). Other species moose prefer are less abundant than those previously listed including American mountain-ash, red oak, red maple, and white pine (Jordan, McLaren, Sell 2000). Persistence on the island of big-tooth aspen, red oak, and balsam poplar is thought to be threatened by moose browsing (Jordan, McLaren, Sell 2000).

Moose also show preference for some common shrubs, including beaked hazel, mountain maple, bush honeysuckle, and mountain alder. One of the most common species of shrub is thimbleberry (*Rubus parviflorus*), which moose do not commonly browse elsewhere or on the mainland. Thimbleberry increased in abundance in response to moose browsing of the formerly dominant American yew to a mostly ground-level, nonreproductive state. Other less common species that moose browse include *Prunus* spp., juneberries (*Amelanchier* spp.), willow (*Salix* spp.), and red-osier (Jordan, McLaren, Sell 2000).

Herbaceous species important as moose forage in summer include large-leaved aster (*Aster macrophyllus*), sarsaparilla (*Aralia nudicaulis*), and lady fern (*Athyrium felix-femina*) (Edwards 1985; Jordan, McLaren, Sell 2000). Aquatic macrophytes are also consumed by moose and aquatic vegetation is estimated to comprise 14–37% of the summer diet, and is considered a high-quality food source that may ultimately help sustain individuals during winter (Bump et al. 2004). Contemporary moose diets include various species of *Potamogeton* (Murie 1934; Faaborg 1981; Jordan, McLaren, Sell 2000).

Moose Population and Changes to Vegetation Structure and Composition—Moose browsing has resulted in a reduction in biomass of balsam fir and an increase of white spruce through competitive release. These changes in species composition may have important consequences for moose and the availability of their preferred forage species (McInnes et al. 1992).

Moose are affected by vegetation structure and composition not only through the influence on the distribution of their forage species, but also through the distribution of particular cover characteristics. The distribution and depth of snow is influenced by landforms and the characteristics of vegetation (Pastor et al. 1988). Moose are affected by the distribution and depth of snow that buries and reduces access to forage (Pastor et al. 1988). Moose require wet conifer forests for cooling in summer, and conifer forests are important for thermal cover during winter (Pastor et al. 1988). Moose may benefit from transient habitats (e.g., temporary habitat characteristics produced by fire or timber harvest) because of increased food abundance (Pastor et al. 1988).

Forest Complexity—Browsing by moose can influence plant species composition, primary productivity, soil processes, nutrient availability, and vegetation structure in boreal forests on Isle Royale (Pastor et al. 1988; Pastor et al. 1993). McLaren and Peterson (1994) examined growth rings in balsam fir, important for moose winter forage. They reported a decline in balsam fir abundance since the arrival of moose to the island from 46% cover in 1848, to 13% in 1978, to approximately 5% in 1994.

basal area*—The common term used to describe the average amount of an area (usually an acre) occupied by tree stems.*

Preferences for particular forage species influence the abundance of tree species, and in some parts of Isle Royale have resulted in "spruce-moose" savannas in which white spruce is the only species that grows above the browse line (Pastor et al. 1988; McInnes et al. 1992; Cotter and Robertus 2015). Cotter and Robertus (2015) demonstrated that by 1996, 16% of the forest at the southwest end of Isle Royale had been converted to "moose-spruce savanna," while another 20% were starting to have canopy break-up. One of the clearest effects of moose browsing is opening of the tree canopy (Snyder and Janke 1976; McInnes et al. 1992). When compared to offshore islets that have few or no moose, overall tree density is lower and mean basal area per tree is higher on the main island (Snyder and Janke 1976). Height of aspen, birch, American mountain-ash, and mountain maple trees is greater in areas where moose browsing is less intense or nonexistent than in areas where there is intense moose browsing. At even moderate browsing levels, American mountain-ash is nearly nonexistent in the tree layer and American yew is eliminated from the understory (Snyder and Janke 1976). Shrub biomass becomes more variable, but tends to be higher in areas with more intense moose browsing, suggesting that browsing may decrease recruitment rates of saplings of preferred species into the canopy, thus maintaining them in the shrub layer (Pastor et al. 1988; McInnes et al. 1992; Sell and Jordan 2007). Biomass of the herbaceous layer is benefitted by moose browsing, likely because of reduced shading from the tree canopy (McInnes et al. 1992), although biomass alone is not necessarily the best metric to forest health. For example, moose may feed heavily on favorite herbaceous plants, thus removing them from the islands flora.

Soil properties are affected by moose in multiple ways. The influence on soil processes through browse-induced change to plant communities and associated litter dynamics is one way moose can have an important effect on primary productivity in boreal forests on Isle Royale (Pastor et al. 1993). Browsing alters the composition of the litter layer and results in reduced thickness of the forest floor (Pastor et al. 1988). Specifically, browsing reduces the quantity of tree and shrub litter produced, and increases the proportion of herbaceous species present in litter (McInnes et al. 1992). Where browsing is intense, soil chemistry is affected through these browsing-induced changes to litter composition and reduced litter quantity. Soil carbon, nitrogen, cation exchange capacity, field nitrogen availability, potentially mineralizable nitrogen, and respiration rates are reduced compared to areas where there is little to no browsing. These soil microbial processes determine the amount of nitrogen available to plants (Pastor et al. 1988).

In addition to browsing-induced alterations to soil properties, moose mediate the flow of resources (specifically, nitrogen) from aquatic to terrestrial habitats through excretion and carcass decomposition upon their death. Variation in moose density is an important predictor of total nitrogen flux between aquatic and terrestrial systems on Isle Royale, and moose confer a net nitrogen influx to terrestrial habitats. The spatial and temporal distribution of moose carcasses influence spatial and temporal variation in aquatic subsidies, and represent an important link affecting ecosystem heterogeneity (Bump et al. 2009). Although moose excretion has local and stimulatory effects of soil nitrogen mineralization, it does not compensate for the broader and longer-lasting suppressive effects of changes in litter quality and quantity facilitated by selective browsing (Pastor et al. 1993).

Moose impact birds on Isle Royale in a variety of ways but mainly by habitat change from herbivory. Moose herbivory can change both the ground cover density and composition and the overstory and these changes can have impacts on avian species. These can range from ground nesting species such as the ovenbird to neotropical migrants that nest on Isle Royale.

Aquatic Communities—In summer, moose use aquatic habitats for foraging, and feed on a variety of aquatic plants. On Isle Royale, foraging on aquatic vegetation generally begins in June, reaching a peak in late July, and tapering off in August (Krefting 1974). The plant communities associated with ponds have been identified as an important source of sodium for moose, a nutrient in short supply in terrestrial forage (Jordan, McLaren, Sell 2000). Moose remove 60–95% of annual production of aquatic plants at heavily used ponds through foraging and may further reduce aquatic plant biomass by trampling (Aho and Jordan 1979), as moose destroy sedge mats around the edges of lakes (Krefting 1974). Cooper (1928) noted in studies performed on Isle Royale from 1909 through 1910 and in 1926 that moose had converted the sedge mats to mud wallows. Additionally, moose may reduce biomass of aquatic vegetation by increasing suspension of particles as they move through the water, thus reducing photosynthetic rates (Aho and Jordan 1979). At population densities similar to current estimates (approximately 1,200), Jordan (1973) reported that ponds were virtually denuded of aquatic plants by the month of September.

Selective foraging by moose further alters aquatic plant communities by influencing species composition. Adam’s 1909 photographs of aquatic vegetation showed water lilies abundant on the surface of the water, particularly on Moose and Sumner Lakes. However by the 1930s, Murie (1934) reported yellow pond-lily (*Nymphae advena*) and white pond-lily (*Castalia odorata*), formerly abundant, were rare because of moose feeding, and Brown (1935) reported pond lilies were absent. Although water lilies (*Nymphae odorata, N. tetragona*, and *Nuphar variegata*) currently occur on Isle Royale, they are not abundant

(Meeker et al. 2007). *Nuphar variegata* is reported as having less than 1% cover out of 47 inland lakes surveyed, and most lakes from which *Nymphae* spp. were reported only have trace numbers (Meeker et al. 2007). Murie (1934) observed moose feeding extensively on pondweeds (*Potamogeton sp*.), sedges (*Carex sp*.) and rushes (*Juncus sp.)* in several lakes. Other plants that moose browsed included cow parsnip (*Heracleum lanatum*), *Nymphaea americana*, slender naiad (*Najas flexilis*), Canadian waterweed (*Elodea canadensis*), royal fern (*Osmunda regalis*), and interrupted fern (*O. claytonia*) (Krefting 1974). When compared to areas grazed by moose, aquatic plant communities in exclosures have higher species richness and diversity (Qvarnemark and Sheldon 2004).

Moose herbivory also interacts with beaver herbivory in and around lakes and ponds. In years of low or average population density, herbivores appear to cause a short-term reduction in plant biomass in dammed ponds, and dammed lakes; resulting in greater light availability, without depleting biomass over a number of years (Bergman and Bump 2015).

The increasing number of beavers likely impacts various other species that use the habitat created by their dams (e.g., waterfowl, water birds and various passerines that nest in riparian habitat, brook trout). The beaver has been characterized as an ecosystem engineer and keystone species (Naiman, Melillo, and Hobbie 1986) due to its impacts on key processes such as hydrology and, in some cases, channel geomorphology. At Isle Royale, more than 80% of the active colonies are on streams (Shelton 2004), primarily 3rd and 4th order streams (Naiman, Melillo, and Hobbie 1986). The dams erected by a colony, which typically include primary and secondary dams, have a multitude of influences. They temporarily create new shallow, flooded wetland habitat in and adjacent to the stream channel. The dam(s) catch sediment (up to 6,500 square meters per dam), moderate some floods, alter hydrology, change channel morphology, and alter biogeochemical pathways such as denitrification (Naiman, Melillo, and Hobbie 1986). Due to their ability to fell relatively large, sometimes mature trees, beavers have profound effects on riparian community structure and composition (Johnston and Naiman 1990). These effects fall into two distinct classes when viewed from the standpoint of temporal persistence. All effects directly or indirectly associated with dams are typically short-lived (less than 10 years) because most colony sites are not used consistently for extended periods of time (Fryxell 2001; Peterson and Romanski 2008). In contrast, effects related to the utilization of trees can last for many decades and even exceed 100 years.

Use of woody plants by beavers is concentrated in a small area; for streams, beavers do not commonly forage more than 50–70 m from the water's edge. Within this zone, tree basal area can be reduced up to 43% over a six-year period. Beavers show strong preference for deciduous species, especially aspen, willow, and birch, and avoid conifers and alder (Johnston and Naiman 1990). In one study, about two-thirds of all stems cut were shorter than 5 cm, but the average size of aspen used was 12 cm, and the largest was 43.5 cm (Johnston and Naiman 1990). This selective foraging shifts the woody plant composition toward conifers, non-palatable hardwoods, and shrubs. Thus, over decades, the long-term effect of beaver activity is to make the habitat sub-optimal for the species. Moen, Pastor, and Cohen (1990) studied the cumulative effects of moose and beaver herbivory in a selected portion of northeastern Isle Royale. Using the analysis of aerial photography, their results showed that beavers significantly reduced aspen overstory from 140 stems per hectare to 27 between 1957 and 1978. Balsam fir was more prevalent in beaver cut areas as opposed to non-cut areas. Moose herbivory combined with the changes by beavers were suspected to alter succession and change soil fertility.

Weather Events. Disturbances that lead to changes to succession of vegetation communities due to weather events at Isle Royale include climate change and wind.

The climate of the region surrounding Isle Royale is changing, bringing warmer overall temperatures, extended summer seasons, changes to the precipitation regime, warmer water and reduced ice cover of

Lake Superior (Kunkel et al. 2013). Temperate tree species on Isle Royale are at or near their northern range limits and conversely, boreal trees are near their southern range margins, suggesting that even small changes in climate may cause major shifts in vegetation (Parmesan et al. 2005). Recent changes including lack of beaver habitat (Shelton 1966; Jenkins 1980; and Fryxell and Doucet 1993) and expanding old-growth stands of sugar maple and yellow birch (Janke 1978; Sell and Jordon 2007) are likely the beginning of an increased dynamic change for the island ecosystem driven by climate change. In addition to vegetation shifts, a shift in species range could also result from climate change. A climate change workshop conducted at Isle Royale in 2013 resulted in four plausible scenarios for the moose population. In three out of four scenarios they do not survive the influences of climate change over 50 years, and in the remaining scenario they do not survive at levels to sustain a wolf population (NPS 2013c).

The climate, both air and water temperatures, of the Great Lakes region and Isle Royale has exhibited detectable changes over the past century and particularly over recent decades. The upper mid-west region showed some of the most rapid warming trends within the United States in recent years, +0.5 °F (+0.26 °C) per decade between 1979 and 2010. Lake Superior summer water temperatures increased 4.5 °F (2.5 °C) from 1979 to 2006. Ice cover on the Great Lakes decreased 71% between 1973 and 2010 due to warmer winters and windier conditions. The frequency of an ice bridge forming between the mainland and Isle Royale declined over the past 50 years, from occurring two out of every three years in the 1960s to only once during the first decade of the 21st century. Climate projections for the 21st century indicate a continuation of recent trends, including projected temperature increases of 5.0–8.8 °F (2.8–4.9 °C) by the end of the century (Fisichelli et al. 2013).

The frequency, intensity, extent, and duration of extreme weather events are increasing under climate change. Notably, in the winter of 1995 and 1996 heavy snowfall in the region and a late spring exacerbated a shortage of browse and a winter tick infestation from the previous summer, all contributing to a moose population crash (Peterson 1997).

Wind can also play a role in shaping successional patterns but historical data for Isle Royale is lacking. Regionally, the Boundary Waters Wilderness Canoe Area experienced a significant blowdown event in 1999 that flattened 477,000 acres of forest. Kirschbaum and Gafvert (2012) quantified disturbance agents using satellite imagery for the period 2003–2008 on Isle Royale to include blowdown. They documented one event in 2007 near the Washington Harbor area. Anecdotally, another wind event in the fall of 2010 blew down pockets of forest around the island.

WILDERNESS

Isle Royale National Park comprises 132,018 acres of designated wilderness (NPS 2014b). The National Park Service manages all designated and potential wilderness areas of the park to protect physical resources, as well as wilderness character, consistent with the direction of NPS *Management Policies* and the Wilderness Act. Figure 1 in chapter 1 provides an illustration of park lands and water and figure 2 illustrates the park's wilderness areas.

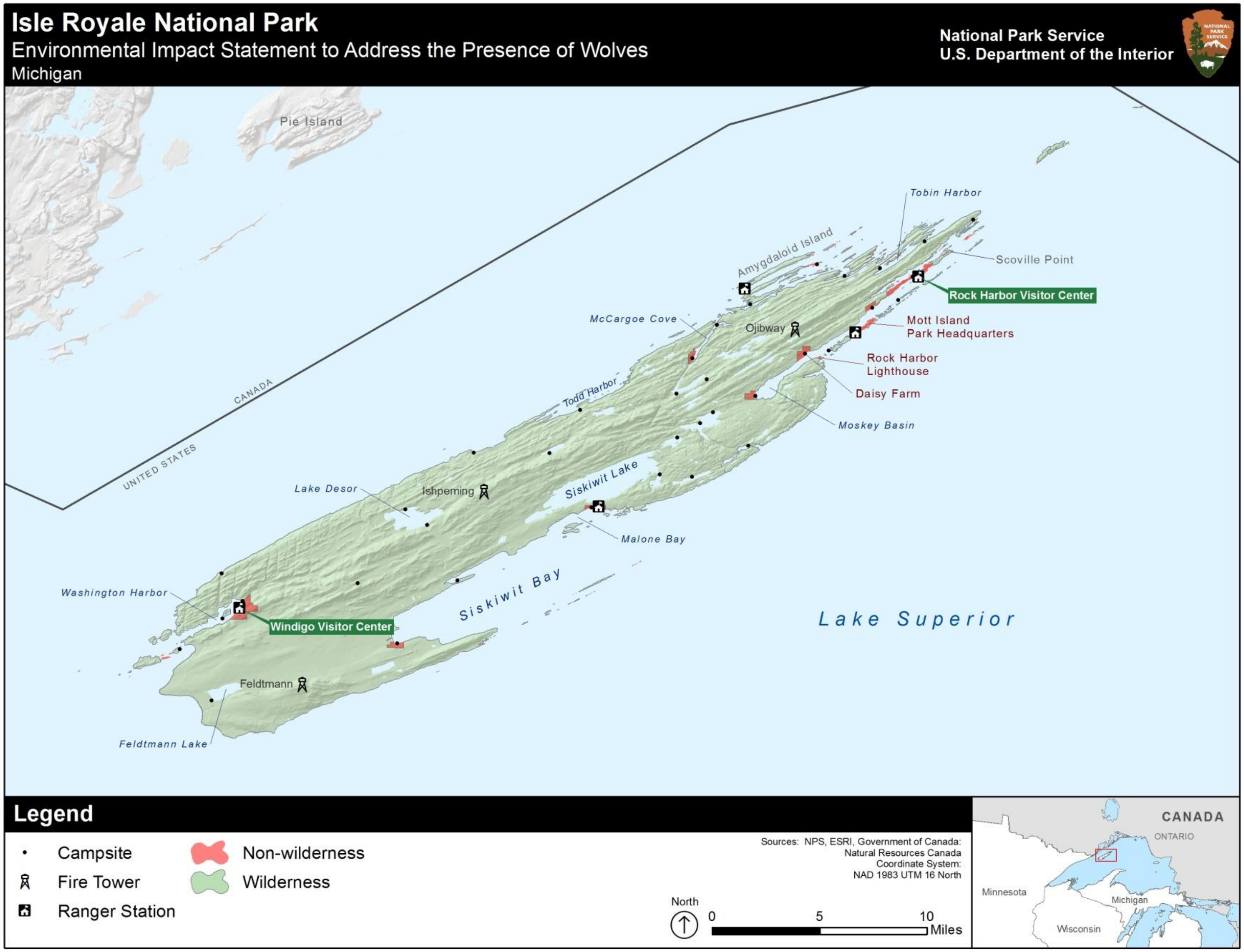

FIGURE 2. WILDERNESS AREAS AT ISLE ROYALE NATIONAL PARK

There are five tangible and measurable qualities of wilderness character: (1) untrammeled, (2) natural, (3) undeveloped, (4) opportunities for solitude or primitive and unconfined recreation, and (5) other features of historical, scientific, educational and scenic value, that collectively compose the Isle Royale Wilderness (NPS 2014d). Opportunities for solitude and primitive/unconfined recreation and Other Features of Value have been dismissed from further analysis but are discussed in chapter 1. The following provides a description of the wilderness character qualities that may be affected by the management actions of this plan.

Wilderness Character Qualities

Natural Quality. The Wilderness Act states that wilderness is “protected and managed to preserve its natural conditions.” Under the natural quality of wilderness, ecological systems are substantially free from the effects of modern civilization. This quality is preserved or improved, for example, by controlling or removing nonindigenous species or restoring ecological processes. This quality is degraded by the loss of indigenous species, occurrence of nonindigenous species, alteration of ecological processes such as water flow or fire regimes, and effects of climate change (NPS 2014c).

The overall climate of Isle Royale is insulated from seasonal extremes by the surrounding immensity of Lake Superior. The lake chills the island in the summer and warms it in the winter, such that environmental conditions on Isle Royale are noticeably different than conditions on the adjacent mainland. The island embodies a transitional assortment of climatic regimes and environmental variations both east to west, upslope and down, and along the interface of land and water, creating rich and diverse microclimates and habitat types (NPS 2014b). The northeast end of the main island is characterized by boreal forest of balsam fir, quaking aspen, white spruce, and white birch, while the more temperate southwest end, with deeper soils, is characterized by old growth maple and yellow birch forests (NPS 2014b).

The island biogeography and the immigrating and emigrating of animals to an island is a natural occurrence influenced by many factors, including: degree of isolation, size of the island, climate, serendipity, and human activity. Some species have been extirpated from Isle Royale, like the lynx, caribou, and coyote; while others may have come and gone over time.

Historic human activity has influenced the species composition of Isle Royale. Trapping and hunting led to the extirpation of lynx and caribou, respectively, and it appears that climate change may lead to the loss of the cisco, a cold-water adapted fish, in a few inland lakes. The wolves and moose on Isle Royale have an uncertain origin. Wolves have migrated to the island and have been introduced by humans to the island at different times; moose may have made the swim to the island, or have been stocked (along with white-tailed deer) (Peterson 1998). Some current human activities have caused some minor alterations to the natural qualities such as the introduction of exotic plants or disease to the environment. The island flora and fauna remains relatively free from the overt effects of modern civilization, with the exception of climate change, atmospheric pollution, and invasive species (NPS 2014b). Climate change is affecting a multitude of natural processes on the island and is discussed under the *Island Ecosystem* affected environment section.

Overall, Isle Royale wilderness is largely free from direct human influence and natural processes are largely intact because of the isolated nature of the island and park management practices.

Untrammeled Quality. The Wilderness Act states that wilderness is "an area where the earth and its community of life are untrammeled by man" and that "generally appears to have been affected primarily by the forces of nature." The word "untrammeled" describes something that is unconstrained, not limited or restricted. An untrammeled wilderness is essentially unhindered and free from intentional actions of human control and manipulation of the biophysical environment and community of life.

In the wilderness at Isle Royale, natural processes are generally allowed to occur without overt manipulation. Wildlife is unrestricted to wander about the island, and is free to cross back to the mainland during episodic ice bridge formation. Vegetation prospers in the summer and dies back in the winter. The untrammeled quality of wilderness at Isle Royale is preserved in several ways. Overall, preferred research methods in the wilderness involve nondestructive, noninvasive sampling. An example of a management action that may affect the untrammeled quality of wilderness are control activities for invasive species as well as aquatic invasive species prevention programs with visitors and NPS vectors. This detracts from the untrammeled quality of wilderness.

Deliberate actions to manipulate the biophysical environment degrade this quality. While most of the physical features, flora, and fauna within wilderness are unimpeded by human intervention, the National Park Service does authorize manipulation of some natural processes. In general, management intervention in park wilderness is undertaken to restore or preserve ecosystems in a natural, resilient, or sustainable state to support native biodiversity (NPS 2014b). These include management of trails, invasive species prevention and control, monitoring human impacts on the island, prescribed fire, and some research activities.

Undeveloped. The Wilderness Act states that wilderness is "an area of undeveloped federal land retaining its primeval character and influence, without permanent improvements or human habitation," with "the imprint of man's work substantially unnoticeable." Many of the historic remnants of human occupation and activities have been diminished due to the effects of time, natural weathering, and unhindered forest growth (NPS 2014a).

Administrative developments in Isle Royale designated wilderness include one remote ranger station and two research stations with residences and associated utilities support; communications structures; and three fire towers. The Bangsund Research Station is a former fish camp in designated wilderness that now hosts wolf and moose researchers during the summer months. The station includes numerous wooden cabins and storage sheds, weather and communication equipment, wind turbines, wooden benches to hold moose skulls and antlers in a circular arrangement, formalized garden beds, picnic tables, outhouses, a yurt, and a tree swing.

Administrative developments in wilderness at Isle Royale include Davidson Island Boreal Research Station, Amygdaloid Ranger Station (which also includes communications installations), and more than 60 recreational cabins and associated outbuildings at Tobin Harbor, Crystal Cove, Edwards Island, Johns Island, and Captain Kidd Island. About 20 standing structures in historic fish camps at Wright Island, Fisherman's Home, Johnson Island, and Tobin Harbor are located in potential wilderness. Many of these structures are historic.

Administrative installations in wilderness include concentrations of scientific instrumentations at Wallace Lake environmental monitoring site and scattered research plot markers and instrumentation (including wildlife collaring) and two herbivory exclosure fences used by external researchers and NPS resource managers to gain knowledge of the impacts of moose herbivory on park resources.

The use of motorized equipment and mechanical transport is also considered under the undeveloped quality of wilderness. Such uses (contingent on a Minimum Requirement Analysis) include the authorized use of chainsaws until June 15 each year for preseason trail clearing and the use of power tools to repair and maintain campground facilities in wilderness. Rarely, emergency landing of aircraft or wheeled litters are employed during search and rescue operations. Helicopters are infrequently (roughly three times in 30 years) used to move critical supplies and material for trail maintenance and other administrative processes. Fixed wing aircraft in the summer is used for monitoring of specific species such as bald eagles and moose and land outside of wilderness. Fixed wing aircraft in the winter is used extensively over a 10-week period for wolf and moose monitoring and research with multiple landings in interior lakes in wilderness. Chainsaws and water pumps may be used during fire suppression if such action is deemed necessary in wilderness.

MOOSE

Four subspecies of moose (*Alces alces*) are recognized in North America. Morphological and genetic differences result in distinction among the subspecies (Bowyer et al. 2002; Hundertmark et al. 2003; Peterson 1955). The northwestern moose (*Alces alces andersoni*) is the subspecies occurring on Isle Royale, characterized as the second largest (both in body and antler size) and lightest in color after the *A. a. gigas* subspecies in Alaska (Peterson 1955).

Status

Currently, the US Fish and Wildlife Service initiated a 12-month status review, requesting applicable scientific and commercial information, under section 4(b)(3)(B) of the Endangered Species Act, in order to determine whether the distinct population segment of this subspecies of moose in the Great Lakes region warrants federal listing as a threatened or endangered species. In Michigan, moose are presently considered a species of special concern. Declines in the state moose population have been attributed to habitat loss, predation and climate change. Increasing temperatures put moose at risk of overheating, which can result in malnutrition and effects to their immune system (Michigan DNR 2016a). Similarly, moose populations in Minnesota have been declining since 2006 (Lenarz et al. 2010; DelGiudice 2016). Parallel to the federal listing petition (Center for Biological Diversity 2015), the 2016 population estimate for Minnesota is 55% less than the 2006 estimate, and the declining population trend over the last 10 years is considered to be a significant decline. Between 2012 and 2016, the numbers have stabilized somewhat, although this short-term trend may not translate to a long-term trajectory (DelGiudice 2016).

Origin

Moose arrived on Isle Royale between 1905 and 1914 (Snyder and Janke 1976), although the origin of how moose arrived on Isle Royale is inconclusive. No moose were reported on the island in 1905, but the moose population on the mainland had been increasing from the late 1890s into the early 1900s after a period of low numbers from hunting pressure (Cochrane 2013). In 1915, the estimated number of moose on Isle Royale was 200 animals (Hickie 1936). Given the individual nature (i.e., nonherding) and breeding phenology of moose, Mech (1966) concluded the animals would have had to colonize Isle Royale in the early 1900s.

Moose, as a species, have relatively low genetic variation (Wilson et al. 2003). A genetic study of multiple populations of moose, including those on Isle Royale, suggested the Isle Royale population has relatively low genetic variability, compared to other moose populations. The same study confirmed Isle Royale moose are genetically isolated from the similar mainland population in northwestern Ontario, which suggests Lake Superior provides a significant barrier to immigration of new individuals into the Isle Royale population (Wilson et al. 2003).

Abundance and Distribution

Moose have been protected in Michigan since 1889, and state management has not used hunting as a management tool for either the statewide moose population (Beyer et al. 2011) or the more localized Isle Royale population (Murie 1934; Krefting 1974; Peterson et al. 2014). Translocation efforts in the 1930s and 1980s targeted reintroducing moose to the Upper Peninsula of Michigan. The early attempt translocated moose from Isle Royale (where the population was at a historical high), and the later effort translocated moose from Ontario (Murie 1934; Beyer et al. 2011). The early effort failed, but the more recent translocations have resulted in an established moose population in the Upper Peninsula.

Moose existed on Isle Royale for almost 50 years without wolves. In the late 1920s, Murie (1934) estimated a minimum of 1,000 moose on Isle Royale, stating this may be a low estimate. By 1930, the population may have increased to upwards of 2,000 to 3,000 moose on the island (Murie 1934), which would have equated to more than six moose per km^2 (15–16 per square mile (mi^2)) for the higher estimate (Vucetich, Nelson, and Peterson 2012). Murie (1934) recommended active management of the Isle Royale moose population, including proactive culling and introduction of large carnivores.

The Isle Royale moose population numbers have fluctuated over the last century. The percent of yearlings in the total population from 1930 through 1970 ranged between a low of 9% to a high of 23% (Murie 1934; Hakala 1953; Cole 1957; Mech 1966; Krefting 1974). The 50-year average percentage of 8-month-old calves is estimated as 13.4% of the total moose population (Peterson and Vucetich 2016). Between the early 1900s and 1934, the moose population increased significantly by several thousand animals. Subsequent to a large die-off in 1934, the population increased in response to increased browse following a wildfire in 1936, allowing the herd to increase again to approximately 800 individuals before another die-off in 1948 (Peterson 1999). These patterns suggest that productivity of the moose herd on Isle Royale has historically been good (Krefting 1974). Table 3 summarizes the estimated moose population numbers from 1936 to 2015. The moose population fluctuations between 1959 and 2015, as compared to the wolf population on Isle Royale, also are shown graphically in figure 3 and discussed in more detail in the "Mortality" and "Predation" sections.

The estimated 50% reduction in moose abundance between 2001 and 2011 was attributed to wolf predation, increased temperatures, and winter ticks (Vucetich, Nelson, and Peterson 2012).

TABLE 3. ESTIMATED MOOSE POPULATION NUMBERS ON ISLE ROYALE FROM 1915 TO 2016

Years	Estimated Population Numbers	Source	Comments
1915	200	Hickie 1936	
1928	1,000-5,000	Hickie 1936	
1930	1,000-3,000	Murie 1934; Michigan DNR 2016b	
1936	400-500	Hickie 1936	
1936-1948	800	Peterson 1999	Die-off in 1948
1950	500	Peterson 1999	
1970	1,000	Peterson 1999	
1974	1,500	Peterson 1999	
1974-1981	Overall decline	Peterson 1999	
1981-1995	Steady increase	Peterson 1999	
1995	2,400	Peterson 1999	
1997	500	Peterson 1999	Die-off in 1996 attributed to starvation
1995-1997	800-1,200	Vucetich and Peterson 2015	
1997-1998	700	Vucetich and Peterson 2015	
2001	1,500	Vucetich and Peterson 2015	
2001-2011	1,100 (high) to 500 (low)	Vucetich, Nelson, and Peterson 2012	50% population reduction
2014	1,050	Vucetich and Peterson 2014	
2015	1,250	Vucetich and Peterson 2015	
2016	1,300	Peterson and Vucetich 2016	Possibly underestimated, based on reduced survey coverage (75% of survey plots examined)

The 2015 aerial moose survey on Isle Royale reported an estimated abundance of 1,250 moose (with a 90% confidence interval of 950 and 1,580 animals) across the island, with moose density estimated at 2.3 moose/km^2 (0.4 mi^2) (Vucetich and Peterson 2015). The 2016 aerial moose survey reported an estimated abundance of 1,300 moose (with a 90% confidence interval of 960 and 1,690 animals), with moose density estimated at 2.4 moose/km^2 (0.4 mi^2). However, in 2016, only 75% of the survey plots were examined; therefore, the 1,300 estimated abundance may be an underestimate of the winter moose population on the island (Peterson and Vucetich 2016). Of the 139 moose observed during the 2016 winter surveys, 22% were calves. This total is the second-highest recorded number of calves and higher than the long-term average of 13.4% (Vucetich and Peterson 2015; Peterson and Vucetich 2016). These numbers are anticipated to increase in the near term in response to the low number of wolves currently on the island (NPS 2015b).

Forage and Cover

Moose depend on vegetation for food and cover and show variable preferences for different plant species, depending on the season. An important factor influencing moose population trends is the abundance of highly preferred browse species available in winter. On Isle Royale, browse availability during the winter season generally fluctuates from year to year. Determining factors for these changes include growing conditions, plant succession, weather, mortality rates, and severity of browsing in previous years (Krefting 1974).

On Isle Royale balsam fir has been reported as the most important winter food for moose (Murie 1934; Aldous and Krefting 1946; Pimlott 1953; Jordan 2000). However, other studies conducted in 1961, 1965, and 1970 suggested the heaviest winter use was of the paper birch-balsam fir-white spruce climax type (Hansen, Krefting, and Kurmis 1973).

Murie (1934) observed that Canada yew was a preferred food both winter and summer and that it was quickly disappearing, due to browsing pressure by moose. Other favored browse species including woody, herbaceous, and aquatic species are described above under "Island Ecosystem."

Browsing by moose can influence plant species composition, primary productivity, soil properties, nutrient availability, and vegetation structure in both boreal forests and aquatic communities on Isle Royale (Pastor et al. 1988; Pastor et al. 1993). Moose can strongly influence vegetation characteristics (e.g., species composition and diversity in certain areas) (Pastor et al. 1988). The effects of moose herbivory on forest composition and aquatic vegetation on Isle Royale are described in detail under "Island Ecosystem." As further described under *Herbivory*, changes in vegetation structure and composition can have important consequences for moose through the availability of their preferred forage species the distribution of particular cover characteristics (McInnes et al. 1992).

Mortality Factors

Disease. Moose on Isle Royale are subject to several diseases, ranging from relatively benign afflictions to those that result in either direct mortality or weakened individuals, increasing the predation risk. Diseases and conditions have included benign papillomas (epithelial tumors) and hydatid cysts (parasitic infestation by tapeworm larva [*Echinococcus granulosus, Taenia hydatidgena*]) (Murie 1934; Mech 1966); actinomycosis (lumpy jaw) (Mech 1966); lungworm (*Dictyocaulus*) documented in one moose (Mech 1966; Krefting 1974); and the meningeal worm (or brainworm) (*Parelaphostrongylus tenuis*), which was documented as early as 1965 (Karns and Jordan 1969). Although brainworm has been recorded at low incidence on Isle Royale (0.8%), the infection is often fatal in moose (Karns and Jordan 1969).

Disease may contribute to the susceptibility of moose to wolf predation. Conditions that may increase predation vulnerability would include high parasite loads, osteoarthritis, and advanced periodontal disease (Murie 1934; Peterson 1977; Jordan, McLaren, and Sell 2000). The winter tick (*Dermacentor albipictus*) is commonly found on Isle Royale moose (Hickie 1936; Krefting 1974) and may be an especially important parasite. Although ticks may not often cause direct mortality, heavy tick loads can result in hair loss, nutritional deficiencies, and behavioral changes, combining with other factors to contribute to moose mortality. DelGiudice, Peterson, and Samuel (1997) reported nutritional restrictions in moose coincided with a moose population decline observed over a seven-year period (winters of 1987 to 1994) and involved an epizootic of winter tick. During this period, tick loads were estimated as high as 28,000 on one individual moose, and tick infestation among moose was as high as 34%, concluding that severe nutritional deficiency was exacerbated by high tick loads and likely contributed to population declines during a period of very high moose density (2.2 to 3.5 moose/km^2 [0.4 mi^2]).

Malnutrition. Malnutrition and predation are the leading causes of death for moose on Isle Royale (Krefting 1974; Peterson 1977). Long-term moose population fluctuations, along with patterns of habitat use and browse availability, suggest moose die-offs on Isle Royale have been frequently related to starvation (Krefting 1974; Vucetich and Peterson 2004; Peterson et al. 2014). Nutritional condition of moose can be predicted by winter severity and is positively correlated to the proportion of balsam fir in the diet (Parikh 2015). However, with projected climate change fundamentally altering ecosystems across the boreal forests (IPCC 2007; Gonzalez 2012), anticipated short- and long-term effects to moose, vegetation, and how these interact on Isle Royale are currently unknown.

Predation. Wolves and moose form a complex and dynamic predator-prey relationship on Isle Royale, each affecting the other's distribution and abundance on the island (NPS 2015b). Peterson et al. (2014) concluded wolves on Isle Royale have strongly influenced the moose population with interspersed multi-year periods of weak influence, although effects can be indirect, complicated, and driven by "multicausality" (i.e., the interaction of multiple factors). The wolf-moose, predator-prey relationship has provided an opportunity to conduct comparative scientific studies on landmark predator-prey dynamics on the island, supporting some commensurate comparisons between Isle Royale and other small or isolated moose and wolf populations.

Figure 3 compares wolf and moose population numbers on Isle Royale between 1959 and 2016 (Peterson and Vucetich 2016). Population estimates from 1959 to 2001 were based on population reconstruction from recorded moose mortalities. Moose population estimates from 2002 to 2016 reflected data collected during aerial surveys. The 2016 estimate of moose abundance shown in red in figure 3 reflects a modified aerial coverage of approximately 75% of the typical survey plots on the island, and, therefore, the 2016 population estimate may be underestimated (Peterson and Vucetich 2016).

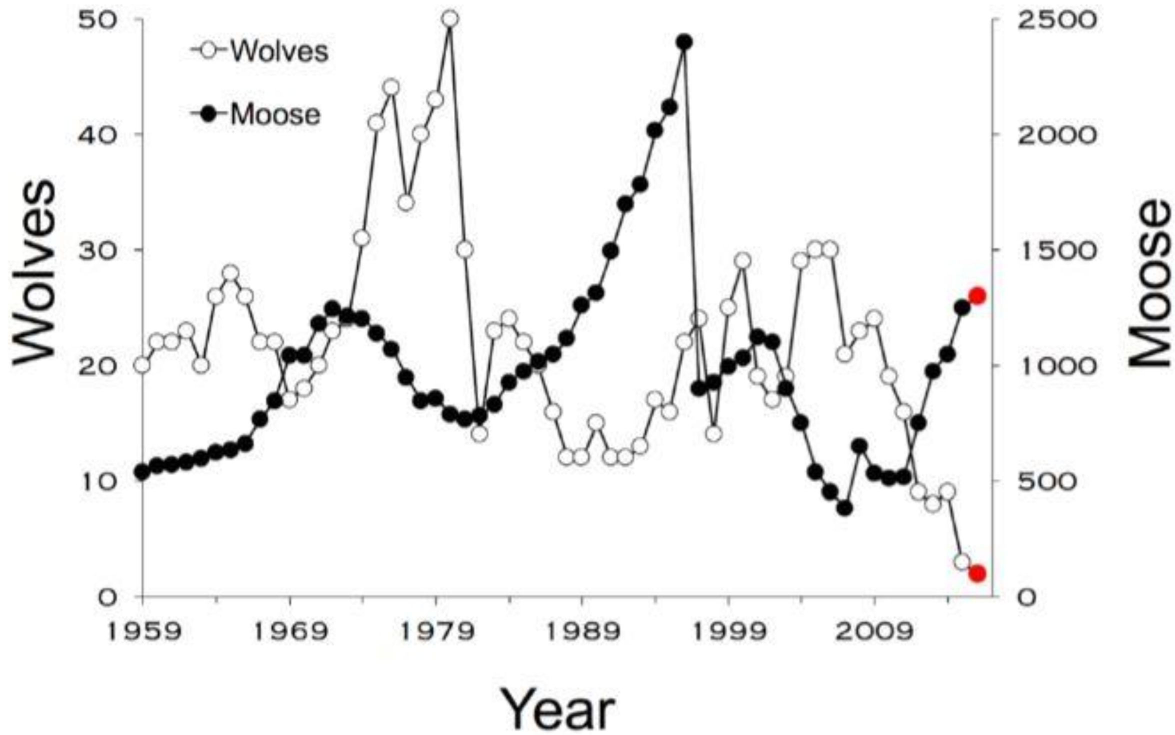

FIGURE 3. COMPARISON OF WOLF AND MOOSE POPULATIONS ON ISLE ROYALE 1959 TO 2016

Predation of moose by wolves on Isle Royale follows fundamental predator-prey dynamics, where moose taken are typically in the younger or older age classes or are individuals that have been compromised by disease or injury. During a three-year period, Mech (1966) examined 51 moose killed by wolves. Of these 51 moose, 18 were calves and the majority of other age classes were 8 to 15 years. None of the carcasses examined were in the age class of one to six years, or of prime age. Of the adult moose examined, 39% showed some level of debilitating condition or disease, including two intact individuals exhibiting a high level of hydatid cysts in the lungs.

Peterson (1977) initially found similar patterns, where winter wolf predation on moose for moose age class of one to seven years was low, with the average annual mortality rate estimated to be 13%. The oldest male and female moose recorded was 15.5 and 19.5 years, respectively. As the population dynamics changed in the early 1970s, the rate of wolf predation on adult moose age class one to six years increased from 13% to 53%, indicating a significant increase in young adult moose vulnerability to wolf predation. Peterson (1977) determined the majority of the young adult moose reflected in this increase were calves born following winters of nutritional stress, inferring increased malnutrition early in life may increase the susceptibility to predation. The trend observed in the early 1970s likely resulted from reduced browse availability for moose, increased snow depths, and an increase in the moose population in the late 1960s and early 1970s.

Wolfe (1977) also reported comparable results. Of the 439 Isle Royale moose examined, at least 45% had been killed by wolves and calves and yearlings made up approximately 30% of moose killed by wolves. Another 30% of moose killed by wolves included older (12 to 17 years) individuals, showing preference for this group, along with females. Moose dying of unknown causes (35% of the total sample) consisted of a different age distribution. Most (38%) were 7 to 11 years old, and were more commonly male.

Of the wolf-moose interactions observed, the large wolf pack of 15 to 16 individuals tested an average of 13 moose for each successful moose kill (Mech 1966). Peterson (1977) found moose that typically stand their ground to wolves generally are not killed. Based on his observations of wolf responses to moose behavior, Peterson theorized that moose that run from wolves exhibit cues to the level of their vulnerability (Peterson 1977).

Anti-predator behavior exhibited by moose on Isle Royale is diverse. Based on annual winter studies on moose and wolves over a 14-year period, snow depth and snow condition were found to influence wolf-moose predation rates. Deep snow (>76 centimeters or 30 inches) with a low snow density hindered wolf predation of moose; whereas, increased snow density and surface crusting benefitted wolf mobility when hunting (Peterson 1977). Wolves commonly use shoreline ice for winter movements, if conditions permit, avoiding the deep inland snows. Increased snow depths also reduced moose forage availability, resulting in increased calf malnutrition and associated wolf predation. Therefore, moose were found to concentrate in areas with increased conifer canopy and reduced snow depth and density along the shorelines (Peterson 1977). Montgomery et al. (2014) discovered landscape patterns related to wolf predation on moose on Isle Royale, determined by moose condition and life stage. Aging moose chose higher and denser forest structure to decrease the probability of detection by wolves and increase defensibility. Younger moose in their prime were more likely to choose lower, shoreline habitats with higher quality forage, but frequented more by wolves.

Similarly, Stephens and Peterson (1984) described subtle anti-predator strategies, based on moose habitat selection on small islets (<1.5 km^2 or 0.6 mi^2) surrounding Isle Royale, where the average moose density was 415% greater than moose density recorded on the main island. Stephens and Peterson (1984) documented the increased incidence of cow and calf moose in and near camps occupied by humans on the island. Wolves rarely occur within 1 km (0.6 mi) of human-use areas during the summer season. The incidence of cow moose in the camp areas was 87% higher than cows located farther than 1 km (0.6 mi) from the camp areas, with a higher percentage of cow/calf pairs (34% versus 23%, respectively). These results inferred female moose recognized the lower frequency of wolves within 1 km (0.6 mi) of these camp areas, suggesting these human-use areas provided a refuge for moose in this population lacking moose hunting pressure (Stephens and Peterson 1984).

Messier (1994) examined wolf-moose interactions across a variety of geographic areas with varying moose and wolf densities, reporting that wolf density is a function of moose density, and to reach an equilibrium requires an interaction between habitat quality and predation pressure. In Alaska, Gasaway et al. (1992) found that predation was the primary limiting factor for moose already at low densities. Moose populations increased in response to predator control, and a low-density equilibrium was achieved when wolves and bears in Alaska were near carrying capacity and moose was their primary prey. Related studies on trends in moose health and natality rates compared to dynamics of wolf kills and moose carcass condition point to wolf predation as a means to regulate the moose population on Isle Royale (Mech 1966; Peterson 1977).

WOLVES

Status

Taxonomic debates regarding the species or subspecies of wolves occupying the western Great Lakes Region are divided between the gray wolf and the timber or eastern wolf (*C. lycaon*) (Mech 1966;

Michigan DNR 2015). Current classification recognizes the species on Isle Royale to be the gray wolf (Michigan DNR 2015).

The legal status of the gray wolf in the United States has changed many times during the last decade, both on a federal and state basis, particularly for the Western Great Lakes Distinct Population Segment (USFWS 2015a; Michigan DNR 2015). The Western Great Lakes Distinct Population Segment includes the wolves located in all of Minnesota, Wisconsin, and Michigan, the eastern half of North Dakota and South Dakota, the northern half of Iowa, the northern portions of Illinois and Indiana, and the extreme northwestern portion of Ohio. The US Fish and Wildlife Service proposed to remove the Western Great Lakes Distinct Population Segment of the gray wolf from protections under the Endangered Species Act. These proposals were not finalized.

The gray wolf continues to be protected under the Endangered Species Act (USFWS 2015a). Specifically, the gray wolf is listed as federally threatened in Minnesota, and federally endangered in the remaining Great Lakes area states (all of Wisconsin and Michigan, the eastern half of North Dakota and South Dakota, the northern half of Iowa, the northern portions of Illinois and Indiana, and the northwestern portion of Ohio) (USFWS 2015g). The park is designated as critical habitat for the gray wolf, as are parts of Minnesota and Michigan (USFWS 2015z, 2016). Isle Royale wolves have been identified as not contributing to the recovery of the species because of the isolation of this population on the island (Licht et al. 2010).

In Michigan, the gray wolf was previously state-listed as threatened. However, currently, it is considered a species of special concern (Michigan DNR 2016a).

Origin

There are conflicting theories on origin of wolves on Isle Royale. Mech (1966) enumerates anecdotal reports from island residents and early park personnel that signs of individual wolves were observed on Isle Royale during the 1930s and early 1940s. However, common narrative reflects wolf immigration likely occurred between 1948 and 1950 from individuals crossing an ice bridge approximately 24 km (15 mi) from the United States or Canadian mainland to Isle Royale (Vucetich, Nelson, and Peterson 2012).

Mech (1966) described the initial interest in introducing (or augmenting) the wolf population on Isle Royale, indicating dialog for possible wolf introductions originated in the 1940s and early 1950s. Failure in a wild wolf trapping and relocation effort from the mainland to the island in the early 1950s resulted in a change in approach, introducing four wolves from the Detroit Zoo in 1952. The experiment was not successful, primarily due to habituation of the four wolves to humans (Mech 1966). Accounts vary as to their outcome, but after an initial attempt at relocating the animals (Mech 1966), two or three were subsequently removed, and one or two remained in the wild (Mech 1966; Wockner 1997; Brown 2013). It is unknown whether one or more of these wolves contributed to the genetic makeup of the Isle Royale wolf population (Mech 1966; Brown 2013).

Genetic uncertainty on wolf lineage on Isle Royale makes the origin of wolves inconclusive, but genetic research suggests a limited number of founding breeders. Analysis of mitochondrial DNA and the Y chromosome suggests the Isle Royale wolf population was founded by one female and two males, with new and significant genetic contributions to the population occurring via a lone male wolf that immigrated to Isle Royale in 1997 (Adams et al. 2011). The importance of wolf genetics to the Isle Royale population is discussed further in the “Genetics” section.

Abundance and Distribution

Wolf numbers on Isle Royale have fluctuated since the animals became established in the late 1940s. The long-term average number of wolves on Isle Royale is reported to be 22 animals (41/1,000 square kilometers (km^2)) (NPS 2015b).

In 1964, the estimated number of wolves on Isle Royale was 22 (Mech 1966). Numbers dropped to 17 animals in 1968, followed by a gradual increase to 31 wolves in 1974 (Peterson 1977). Availability of vulnerable moose as prey began to decline between 1976 and 1981, increasing food stress on wolves in the late 1970s, and the wolf population stabilized at a comparatively low level in the early 1980s (Peterson and Page 1988). The wolf population reached its peak in 1980 with 50 animals and the calculated density of 92 wolves/1,000 km^2 (386 mi^2), which became the highest recorded density for wild wolves on Isle Royale (Peterson and Page 1988; Cochrane 1996). However, a significant population crash occurred in 1982, reducing the number of Isle Royale wolves to 14 individuals (Peterson and Page 1988). Between 1985 and 1992, wolf numbers continually declined, dropping to 12 animals (Peterson and Page 1992). A slow population increase followed over the next decade, achieving 30 individuals by 2005 (Peterson and Vucetich 2006). Subsequent population declines showed wolf numbers decreasing from 30 to 21 individuals in 2006–2007, down to 16 wolves in 2011, 8 wolves in 2013, and 9 wolves in 2014 (Vucetich, Nelson, and Peterson 2012; Michigan DNR 2015). In April 2015, only 3 wolves remained on Isle Royale (NPS 2015b, Vucetich and Peterson 2015). In February 2016, only 2 wolves were documented (Vucetich and Peterson 2016). The wolf population fluctuations between 1959 and 2016, as compared to the moose population on Isle Royale, are shown graphically in figure 3 and discussed in more detail in the “Moose” section under the “Mortality” and “Predation” sections. The precise causal factors of the declining wolf population on Isle Royale over the last three decades are not proven, but a number of issues have been identified that may have contributed to this decline.

Population Dynamics

Breeding and Pack Dynamics. Wolves typically reach sexual maturity at 22 months of age (Peterson 1977) and have been documented to live 10 to 14 years in the wild (Mech 1966). Mating occurs in February, dens are excavated in March, and pups are born in mid- to late April (Peterson 1977; Michigan DNR 2015). Dens are typically excavated in sandy soil, but they also can be established in rock cavities, hollow logs, other species dens, and beaver lodges. Dens are often located near water (Peterson 1977).

The number of wolf pups per litter will vary, but litter size typically numbers four to five pups (Michigan DNR 2015). Pups emerge from the den site at approximately 3 weeks, are weaned at about 9 weeks, and are moved to aboveground at a series of “rendezvous sites” until they can travel with the pack. On Isle Royale, wolf pups used rendezvous sites from 11 to 48 days and have been documented using these areas as late as October (Peterson 1977).

The pack is the functional unit, typically consisting of the two dominant breeders (i.e., alpha pair), their offspring, and other individuals that may or may not be related to the alpha pair (Mech 1966). The social structure and framework of a wolf pack maintains pack integrity and delineates pack hierarchy based on relationships and food allocation (Peterson 1977).

Pack territories range in size, primarily dependent on regional wolf density and prey density and distribution (Fuller 1989; Gogan et al. 2004; Michigan DNR 2015). The number of wolf packs and the number of individuals in each pack on Isle Royale have fluctuated. From 1959 through 1966, the winter wolf population was a single pack (Mech 1966; Peterson 1977), initially hunting the full length of Isle Royale, although in 1963, the pack restricted its hunting territory to the western half to two-thirds of the island. From 1959 through 1980, reproducing packs increased from one to five with distinct but shifting boundaries, based on pack dynamics across Isle Royale (Peterson and Page 1988). By 1970, increasing moose malnutrition and an increased susceptibility to predation in addition to the rising numbers of beavers, resulted in expanding food resources for wolves and a reduced pack territory size. This trend allowed a second prominent pack to become established on the island in 1971 and the wolf population increased from 20 to 31, with each of the two packs occupying approximately half of the island (Peterson 1977).

From 1980 through 1986, pack territories changed to reflect the new population demographics following the 1980–1982 population crash. During this period, the reduction of the wolf population from 50 to 14 individuals resulted in substantially reduced pack size, with one pack disappearing. Four breeding females remained in the population in 1982; three of those females formed the foundation of the three remaining wolf packs that divided the island between 1982 and 1986. Intraspecific competition and conflict began to affect pack boundaries and pack composition (Peterson and Page 1988).

The changing pack dynamics and wolf demographics, in turn, affected both interpack and intrapack behavior, particularly related to food availability (Peterson and Page 1988). The increased food supply for island wolves in the early 1970s resulted in an increased number of smaller wolf-pack territories and a low dispersal rate from the packs. Immediately prior to the 1980–1982 population crash, wolf numbers had continued to increase, but shrinking food supply caused a higher dispersal of individual wolves, interpack conflicts, and ultimately a fewer number of smaller packs. With declining food availability and increasing food stress in the late 1970s, 30% of the population was not associated with “core” packs, and by 1981, all packs on the island contained fewer than 10 individuals (Peterson and Page 1988).

At the population peak in 1980, the average number of wolves per pack was 9.5, with an annual survival rate of 84–87%. During the crash, average pack size dropped to 4.7 and the annual survival rate dropped to 49%. The population subsequently stabilized between 1983 and 1986, with an average pack size of 6.5 animals, an annual survival rate of 66–67%, and an annual recruitment of two pups per pack. Total wolf numbers for the island at equilibrium was 20–24 animals; the same number of wolves estimated in the 1960s, exhibiting a similar distribution pattern (Peterson and Page 1988).

Immigration and Emigration. Wolf dispersal rates from a pack vary based on pack size, dynamics, and demographics. Wolves have great stamina and can travel long distances. In 1960, Mech (1966) recorded a pack of 15–16 individuals on Isle Royale that traveled an average of 50 km (31 mi) per day over 9 days. Between 1959 and 1961, the longest distance traveled in 24 hours Mech observed was approximately 72 km (45 mi). Between 1970 and 1974, Peterson (1977) reported the average distance traveled by packs was 11 km (7 mi) per day.

Although some wolf immigration and emigration to and from Isle Royale has been reported, exchange of wolf genetics between the mainland and the island has been long debated. Early reports from residents in the 1930s and 1940s relate observed wolf movement between the mainland and the island when lake ice formed and possible signs of individual wolves (Mech 1966).

In the winter of 1967, four black wolves were observed on the island (NPS 1967); the origin of these wolves was unknown. Theories ranged from all four being melanistic young of the year to possible pack immigration across the ice in February 1967 (NPS 1967). Subsequent observations concluded the four black wolves likely emigrated from Canada and assimilated into the Isle Royale population (NPS 1968; Peterson 1977). In 1997, one male wolf immigrated to Isle Royale, contributing significantly to the genetic base (Adams et al. 2011). More recently, during the winter of 2015, an ice bridge formed and a pair of wolves crossed the ice bridge from the Grand Portage Indian Reservation, traveling approximately 23 km (14 mi) to the island. The pair explored the island and returned to the mainland 5 days later (Moore et al. 2015; Vucetich and Peterson 2015). Furthermore, five of nine wolves in a pack counted in 2014 were not subsequently observed. The fate of these five animals is unknown, but could include persistence on the island, mortality of a portion or all five, or emigration from the island during the 2015 ice bridge (NPS 2015b, Vucetich and Peterson 2015). As of 2016, there are only two known animals on the island that are related and inbred.

Mortality Factors

Annual wolf mortality rates fluctuate, but estimates range from 60% mortality during the first 6 months of life from disease and malnutrition, 45% from 6 months to 1 year, and 20% between years 1 and 2 (Michigan DNR 2015). There are no other predators on Isle Royale (e.g., grizzly bears) that could prey on wolves or wolf pups; however, wolves have been injured or killed by moose during encounters (Mech and Nelson 1989). Other wolf mortality factors include malnutrition, starvation, parasites, diseases, intraspecific conflict with other packs, and accidents (Mech 1966; Peterson 1977; Vucetich and Peterson 2014; Michigan DNR 2015; NPS 2015b).

Peterson and Page (1988) determined causal mortality for nine wolf fatalities recorded between 1975 and 1986. Seven of those nine were attributed to intraspecific strife, with five of these wolves discovered during the population crash of 1980–1982. The remaining two wolves succumbed to malnutrition and showed infections from recent rib fractures (likely from moose encounters). Human-induced mortality common to main wolf populations, such as intentional killing or vehicle collisions, does not apply to Isle Royale, given its location and wilderness status. However, human influences have affected wolves on the island. In 2011, three wolves on Isle Royale drowned in an open, flooded mine shaft, a feature from the historic 19th century copper mining on the island (Vucetich and Peterson 2014).

After initiating radio telemetry tracking in 1988 via collar, wolf mortality could be more readily determined. Of 30 wolves documented alive between 1988 and 1995, 15 died by March 1995. Fatalities for 5 of 10 radio-collared wolves were verified, including two intraspecific conflicts (killing by other wolves), two from malnutrition at advanced ages, and one from an accident (i.e., falling through Lake Superior ice). Mortality factors associated with the remaining five radio-collared wolves could not be determined due to radio failure (Peterson et al. 1998).

Although the issues associated with physical deformities common to many of the Isle Royale wolves are debated (Mech 2013; Vucetich, Peterson, and Nelson 2013), it is believed that inbreeding depression from the isolated population may have contributed to these skeletal deformities and is likely to lower productivity and survival rates (Vucetich, Peterson, and Nelson 2013; NPS 2015b), as discussed further in the “Genetics” section.

Intraspecific Conflicts

Peterson and Page (1988) concluded the majority of wolf intraspecific aggression observed on Isle Royale encompassed purposeful attacks by an established wolf pack for either territorial defense or rarely to expand territorial boundaries. Peterson (1977) summarizes the declining food supply between 1970 and

1974 for wolves, resulting in a spatial overlap between two packs and one wolf fatality in 1974 from interpack conflict.

Marucco et al. (2012) suggest the moose kill rates by wolves and the wolf to moose ratio positively correlate with adult wolf survival, but not necessarily with juvenile wolf survival. Their findings infer at the highest moose kill rates and highest wolf to moose ratio, adult wolf survival may increase, resulting in higher intrapack competition for food resources. Therefore, the increased number of wolves may result in increased intraspecific conflict and higher starvation and mortality rates for juvenile wolves.

Mech (2013) attributes the population crash of Isle Royale wolves from 1980 to 1982, where numbers declined from a high of 50 animals in 1980 to 14 wolves in 1982, more to intraspecific conflict and malnutrition. During the territorial reorganization in the early 1980s, following the population crash, interpack aggression was frequent. However, other theories on this rapid population decline are discussed in the “Disease and Parasites” section.

Disease and Parasites

Historically, diseases and parasites affecting wolves have included canine distemper, canine parvovirus, rabies, Lyme disease, leptospirosis, tularemia, blastomycosis, canine heartworm, intestinal worms, echinococcosis, sarcoptic mange, lice, and ticks (Gogan et al. 2004; Michigan DNR 2015). Specific to Isle Royale, canine parvovirus and a number of endoparasites have been documented (Peterson et al. 1998; Vucetich, Nelson, and Peterson 2012).

In the early 1980s, canine parvovirus introduced to the island was thought to have caused wolf numbers to drop precipitously (Vucetich, Nelson, and Peterson 2012). However, the significance of canine parvovirus to Isle Royale wolves is unconfirmed (Mech 2013). Many North American wolf populations have been exposed to and recovered from parvovirus events (Zarnke and Ballard 1987; Gogan et al. 2004). However, Vucetich, Peterson, and Nelson (2013) state, causal factors may be multidimensional and it should be noted the two most substantive wolf population declines on Isle Royale (i.e., 1980–1982 and 2009–2013) coincided with the two periods when canine parvovirus was detected on the island.

An alternating theory is whether a sudden epizootic event of parvovirus, with subsequent lack of pup survival, could have triggered inter-pack aggression that resulted in adult mortalities. For example, in nearby Voyageurs National Park, researchers hypothesized the accidental death of a lactating alpha female of one pack may have resulted in the remaining pack members roaming widely into a nearby pack territory, which then resulted in a battle where two wolves were found dead from wolf-inflicted wounds (Gogan et al. 2004). Further analyses by disease experts may be warranted, if future management of wolves hinges on the potential long-term effects from the disease (Vucetich, Peterson, and Nelson 2013).

Genetics

There is extensive literature on the genetics and taxonomy of wolves, throughout the Holarctic (Wayne et al. 1992; Vila et al. 1999, 2003; Lucchini, Galov, and Randi 2004; Musiani et al. 2007; Kolbmuller et al. 2009; Chambers et al. 2012; Leonard 2014; Cronin et al. 2015; Frederickson et al. 2015). The widespread availability of molecular techniques and the ease of sampling (either directly from captured or sampled animals or from fecal material) ensure that there is a strong basis for understanding the structure and genetic relationships of wolf populations.

In the past, the immigration of wolves from the mainland of either Canada or the United States (across ice bridges) was sufficiently frequent that there was a "genetic rescue" effect, with the new genes of the immigrants rapidly incorporated into the population, increasing diversity (and presumably viability) (Adams et al. 2011). In 1997, a lone male wolf crossed to Isle Royale from the mainland, resulting in a significant increase in genetic diversity among the island wolves (Adams et al. 2011). Such genetic rescue effects have been noted for other conservation priority species: panthers (Johnson et al. 2010), sheep (Hogg et al. 2006), birds (Westermeier et al. 1998), and snakes (Madsen, Ujvari, and Olsson 2004), as well as in other populations of wolves (Vila et al. 2003; Frederickson et al. 2007).

However, the Isle Royale population has declined to extremely low levels where inbreeding has affected viability of the animals. Of the 94 progeny in the pedigrees described by Hedrick et al. (2014), 42 (45%) were the result of father-daughter, mother-son, or brother-sister matings. Hedrick and Lacy (2015) report additional supporting information. By 2005, the ancestry of the Isle Royale wolves was believed to have ultimately descended from the 1997 lone immigrant male and two resident females (Hedrick et al. 2014).

Although the issues associated with physical deformities common to many of the Isle Royale wolves are debated (Mech 2013; Vucetich, Peterson, and Nelson 2013), it is believed that inbreeding depression from the isolated population may have contributed to skeletal deformities and likely to lower productivity and survival rates (Vucetich, Peterson, and Nelson 2013). One of the remaining survivors in 2013 had very unusual coloration and was very small. Such depression of individual viability due to inbreeding also has been found in other isolated populations of wolves (Liberg et al. 2005; Asa et al. 2007; Frederickson et al. 2007). Similar skeletal deformities and dental anomalies also have been recorded in a small Scandinavian wolf population with low genetic variability, which also exhibited a lower juvenile survival rate, as compared to non-inbred wolves from Finland and Russia (Räikkönen et al. 2009).

Predation

Wolves generally prey on a diversity of wildlife species geographically and seasonally, with prey abundance, distribution, vulnerability, and behavior affecting wolf prey preferences (Michigan DNR 2015). On Isle Royale, wolves feed primarily on moose and beavers (Peterson 1977; Peterson and Page 1988; Jordan, McLaren, Sell 2000). Moose comprise more than 90% of a wolf's diet (Vucetich, Nelson, and Peterson 2012), forming virtually 100% of the wolf prey base from December to April and more than 80% prey biomass during the summer (Peterson and Page 1988). Beavers are taken during the summer season (Peterson 1977). Mech (1966) recorded the moose predation rate of a large wolf pack (15–16 individuals) on Isle Royale, where the pack killed an average of one moose per 3 days during the winter survey periods.

Based on the estimated carcass weight of moose kills by wolves, Mech (1966) calculated the average daily meat consumption per wolf ranged from 4.4 to 6.3 kilograms (kg) (9.7–13.9 pounds [lb]) between 1960 and 1961. Individual wolves could consume up to 9 kg (20 lb) of meat at one time, but animals may go 5 days between feeding (Mech 1966). Between 1971 and 1974, during mid-winter tracking by plane of two wolf packs on Isle Royale for a total of 234 pack-days (a pack-day in this context is a day when a pack was observed), Peterson (1977) reported daily consumption rates of 4.4–10 kg (9.7–22 lb) per wolf. On Isle Royale, as in other regions, wolves disproportionately predate young and old moose (Mech 1966; Peterson 1977; NPS 2015b).

From effects reported by Peterson (1977) between 1970 and 1974, the moose population began to experience nutritional stress and became more susceptible to wolf predation, particularly for moose in the age class of one to six years, typically an age class with low predation pressure. Because of the increase in moose vulnerability, initial food availability simultaneously increased for wolves in the early 1970s.

Palm (2001) reported parallel findings in central Sweden for radio-collared wolves tracked in three packs of different sizes during the winter. In all three packs, wolves consistently selected moose calves at comparable rates. Calves comprised 87% of all moose taken by wolves, as compared to the proportion of calves in the population equaling 27%. Comparatively, prey selection by wolves in Denali National Park, Alaska, from 1986 through 1992 showed a disproportionate take of calves and older, deteriorating adults of wolves, caribou (*Rangifer tarandus*), and Dall sheep (*Ovis dalli*). Seasonal prey selection by species, age, and sex was exhibited, improving hunting success rates with increasing snow depth (Mech et al. 1995). Detailed predation rates and age classes on moose by wolves are discussed in the section that describes moose mortality by predation.

Distances of wolf movement between moose kills varies. Based on 25 observations, Mech (1966) reported the maximum distance traveled between kills was 108 km (67 mi), the minimum was 0, and the average was 43 km (27 mi). Between 1970 and 1974, Peterson (1977) recorded an average of 33 km (21 mi) per day between kills.

Messier (1994) examined wolf-moose interactions across a variety of geographic areas with varying moose and wolf densities to assess whether wolf predation directly regulates moose numbers within a population. Determining that wolf density is a function of moose density, Messier's empirical model suggests moose would stabilize at 2.0 moose/km^2 in the absence of predators and at approximately 1.3 moose/km^2 with wolves as the lone predator, these high-density equilibriums resulting from density-dependent food competition. If moose productivity is reduced, from either deteriorating habitat quality or early calf mortality, a lower equilibrium at 0.2–0.4 moose/km^2 was predicted (Messier 1994).

Wolves may influence population-level characteristics such as age structure or sex ratio because they exhibit selective predation of moose. Mech (1966) reported the majority of moose taken by wolves in winter on Isle Royale was composed of calves, or weak or old individuals. Between 1950 and 1969, from a sample of 439 moose carcasses, approximately 45% of the moose had been predated by wolves, with calves and yearlings totaling 29.3% and 3.5%, respectively, of the moose killed by wolves. Older moose (age class 12–17 years) comprised 29.3% of the wolf-kills. Wolves also demonstrated a preference for predation on female moose, whereas moose mortality from unknown causes (i.e., no wolf-kill) showed a significant trend toward males (Wolfe 1977).

CHAPTER 4:
Environmental Consequences

CHAPTER 4: ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This "Environmental Consequences" chapter analyzes the beneficial and adverse impacts that would result from implementation of any of the alternatives considered in this draft plan/EIS. The resource topics presented in this chapter correspond to the descriptions of existing conditions in "Chapter 3: Affected Environment."

GENERAL ANALYSIS METHODOLOGY AND ASSUMPTIONS

The interdisciplinary planning team reviewed a substantial body of scientific literature and studies applicable to wolves on Isle Royale and other areas, as well as associated resources. This information augmented observations and documentation gathered by the National Park Service (NPS) personnel to support the analysis presented for each issue/impact topic. When available, these studies are cited, and other resource-specific data, observations, or personal communications, are noted. This analysis focuses on expected environmental impacts related to the presence or absence of wolves on Isle Royale, and associated management actions.

The following guiding assumptions were used for this analysis:

Analysis Period. The plan considers actions over the anticipated 20-year life of this draft plan/EIS.

Analysis Area. The analysis focuses on impacts to wolves and other resources on the island of Isle Royale. The analysis considers the welfare of the source wolves, where appropriate, but because of the relatively small number of animals and their wide distribution, it assumes no potential for demographic impacts to source populations.

Type of Impacts. The following types of impacts are assessed:

- **Direct and Indirect.** Direct impacts would occur as a result of the proposed action at the same time and place of implementation (40 CFR 1508.8). Indirect impacts would occur as a result of the proposed action but later in time or farther in distance from the action (40 CFR 1508.8).
- **Cumulative**. The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions (40 CFR 1508.7).

ASSESSING IMPACTS USING COUNCIL ON ENVIRONMENTAL QUALITY CRITERIA

The impacts of the alternatives are assessed using the Council on Environmental Quality definition of “significantly” (1508.27), which requires consideration of both context and intensity:

> (a) **Context.** This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.
>
> (b) **Intensity.** This refers to the severity of impact.

For each impact topic analyzed, an assessment of the potential significance of the impacts according to context and intensity is provided in the “Conclusion” section that follows the discussion of the impacts under each issue/impact topic.

CUMULATIVE IMPACTS

Cumulative impacts were determined by combining the impacts of each alternative with the impacts of other past, present, and reasonably foreseeable future actions. Therefore, it was necessary to identify other past, ongoing, or reasonably foreseeable future projects and plans that are impacting or will impact the same resources that will be affected by actions taken under any of the alternatives under consideration. Following Council on Environmental Quality guidance, past actions were included, “to the extent that they are relevant and useful in analyzing whether the reasonably foreseeable effects of the agency proposal for the actions and its alternatives may have a continuing, additive, and significant relationship to those effects” (CEQ 2005).

Cumulative Impact Scenario

Past projects or plans with ongoing effects and reasonably foreseeable future projects and plans were identified by an interdisciplinary team and through the public scoping process to provide the cumulative impact scenario. Similar to the analysis of impacts of the alternatives, the cumulative impacts analysis focuses on cumulative actions within the analysis area, but also includes actions within the surrounding region as they apply to specific impact topics.

US Fish and Wildlife Service Moose Listing. The US Fish and Wildlife Service initiated a status review for the United States population of northwestern moose, specifically moose in the upper Midwest, as a result of a 90-day finding on a petition submitted on July 9, 2015, by the Center for Biological Diversity and Honor the Earth. The distinct population segment in the Upper Peninsula of Michigan, westward across the northern counties of Wisconsin and Minnesota, and into northeastern North Dakota is being included in the status review by the US Fish and Wildlife Service. The final determination of whether the petitioned action is warranted will be made after the US Fish and Wildlife Service has completed a thorough status review of the species, which is now being conducted as a result of the positive 90-day finding (USFWS 2016). This review is currently scheduled for completion in 2023.

Isle Royale National Park Fire Management Plan (2004). The purpose of the Fire Management Plan is to outline a detailed program of actions to be taken by the park to meet its fire management goals, which include improving prevention and suppression, reducing hazardous fuels, restoring fire-adapted communities, and promoting community assistance. Fire can be used to provide a natural vegetative setting for the park. Fuel management, using both mechanical means and prescribed fire, can reduce the risk to cultural and historic resources and NPS infrastructure on the park. The Fire Management Plan is an addendum to the Isle Royale National Park Resource Management Plan (NPS 1999).

Under the Fire Management Plan, all wildland fires and prescribed fires will be monitored. Information gathered during fire monitoring is needed to keep fires within predetermined criteria, to help identify trigger points for initiating holding and suppression actions, and to protect human life and property. While there is a possibility of a large wildland fire affecting thousands of acres on the island, most fires for which there is information have been relatively small. Large fires would be more apt to occur under dry conditions, but most large mammals would have little trouble avoiding a fire of any size.

Wildland fires are managed with the appropriate management response as outlined in the Fire Management Plan. Lightning-caused fires in the park are allowed to burn under prescribed conditions unless they threaten human life, private property, or other critical park resources and objectives; prevent escape from the management unit; or violate air pollution control laws and regulations. Prescribed fires may be used to accomplish vegetation management objectives, such as encouraging pine regeneration or creating wildlife habitat and fuel hazard reduction objectives, such as removing fuel ladders and downed woody debris from the sub-canopy of pine stands (NPS 2004).

Invasive Species Management. Annually, the natural resources management staff at the park target specific invasive species for both chemical and mechanical treatment. These species include wild parsnip (*Pastinaca sativa*), spotted knapweed (*Centaurea sp.*), mountain bluet (*Centaurea montana*), common burdock (*Arctium minus*), thistles (*Cirsium sp.*), creeping bellflower (*Campanula rapunculoides*), curly dock (*Rumex crispu*s), goatsbeard (*Tragopogon spp.*), butter and eggs (*Linaria vulgaris*), tansy (*Tanacetum vulgare*), and common mullein (*Verbascum thapsus*). Herbicides employed for these species may change annually depending on inventory, effectiveness, development of new products and consumer availability (Henquinet and Romanski pers. comm. 2016). Additionally, the discharge of untreated ballast water from boats is prohibited within the boundaries of park waters to help prevent the spread of invasive species such as zebra mussels and the Viral Hemorrhagic Septicemia pathogen (NPS 2008b).

Service Animals on the Island and in the Wilderness. Dogs, cats, and other mammals are not permitted on Isle Royale or on boats within the park boundaries due to the potential spread of disease and disturbance to wildlife. Service animals are granted permission onto the island in compliance with the Americans with Disabilities Act.

Service animals are only allowed in the park with an approved service dog permit. Application for such permits are mailed or emailed to applicants. Permits require a veterinarian's certification that the dog has had all the required shots and is free of communicable diseases. Upon arrival to the island, visitors with service animals are met by a member of the park staff to ensure compliance. Permitted service animals must be leashed and under control at all times. Fecal matter must be picked up and properly disposed of. Approved service animals are permitted to travel anywhere on the island that allows for park visitors; however, due to potential risks to animals, it is recommended that service animals remain in developed areas.

ISLAND ECOSYSTEM

Methodology and Assumptions

Like most protected areas, Isle Royale is the setting for complex physical and biotic resources and the related interactions among them. Nature is extremely complex, and it is not always possible to apply generalized rules, especially in the island ecosystem of Isle Royale. That is, no set of scientific concepts completely explain all island-specific processes, such as the influence of soil on plant communities, the full effects of moose browse on vegetation, or the role each organism plays across multiple ecosystem types on the island.

Further contributing to the dynamic nature of island systems, island habitats undergoing rapid environmental change may contain fewer species in the short term with shorter food chains and fewer trophic interactions than more complex, diverse ecosystems that would develop in a period of more stability (Post 2002). Colonists during such a dynamic period may often experience changes in diet and trophic position due to fewer predators and competing species (Post 2002), and successful colonists may experience ecological (Crowell 1962) or competitive (Persson and Hansson 1999) release. They may have a more important ecological function than they did in their ancestral habitat because they consume a greater variety of available prey across different trophic levels (Case, Gilpin, and Diamond 1979). Additionally, differences in resource availability (Grant and Grant 1989) and the trophic level of prey species could lead to changes in diet and trophic position (Matthews et al. 2010) of species.

Typically, analysis of effects on ecosystem level resources includes analysis of energy flow through food webs, and hydrology and biogeochemistry cycles. Because this plan has an anticipated 20-year life, and because of the expected delay in response on forest and physical condition, the focus of the analysis is on first order, or direct and short-term (still within the 20-year life but considered short-term in ecosystem scale periods) effects of ecological interactions and the responses of these to proposed management actions. These interactions or community dynamics occurring on Isle Royale include:

- Predation (wolves acting as apex predators on moose and beavers);
- Competition for resources; and
- Disturbance and succession (herbivory and weather).

Predation of wolves on moose and beavers was considered as top-down regulation of those herbivore populations; however, disturbance also affects these community characteristics. Through top-down regulation of herbivores, herbivory pressures are tempered by predator effects on (1) total number of herbivores; and (2) spatial use patterns of moose including time spent browsing in specific locations.

Alternative A: No Action

Predation. It is likely that during the life of this plan the wolf population on the island would become extirpated unless there was natural immigration to the island via ice bridge. Trends discussed in “Chapter 3: Affected Environment” would continue on the island. With no wolves on the island, predation would no longer influence moose and beaver populations.

As discussed in “Chapter 3: Affected Environment,” trends have indicated that as the wolf numbers decreased and predation was lacking, both the moose and beaver population gradually increased. If the current wolf population is extirpated and no wolves are introduced, it is likely the moose and beaver populations would continue expanding until other regulatory forces (e.g., food resources, disease, extreme weather events) limit their populations.

Under alternative A, scavenger species like ravens and red foxes could decline because of fewer moose carcasses on the landscape to scavenge from. Carrion makes up a large portion of these two species winter diet. Carrion from wolf kills, however, make up a small portion of the overall diet of these species in the summer and therefore there would only be a negligible incremental loss of the total food available for scavengers on the island.

Competition. Trends described in chapter 3 would continue related to competition under the no action. Without an apex predator, moose and beaver populations are expected to increase, thereby further increasing pressure on plant species and precipitating changes in the interspecific interactions of mesopredators on the island. In the absence of predation, there is increased competition for food resources among moose and beavers because they consume similar species. This could lead to a depletion of available resources for both species. Lack of predatory pressures for both species could lead to preferred plant species being consumed first, followed by consumption of less desirable species and ultimately a long-term decline in beaver abundance due to apparent competition.

Snowshoe hare browse similar plant species as moose and could contribute to the depletion of shared food resources. Without an apex predator such as wolves in the island system, there could be an increase of mesopredators such as foxes, which prey on snowshoe hares (Crooks and Soulé 1999; Baum and Worm 2009; Estes et al. 2011). Currently fox populations on the island are trending downward, however, there are currently adequate snowshoe hare populations on the island as a food source for foxes. In the absence of wolves, fox populations may trend upward in the future. Snowshoe hares are cyclical in nature and would not show population levels impacts from the presence or absence of wolves on the island.

Disturbance and Succession. Trends discussed in “Chapter 3: Affected Environment” would continue on the island. Increasing moose and beaver populations would increase browse pressure, impacting tree species ability to regenerate and grow. This could affect the vegetative community composition, forest structure, and browse availability for moose and beavers.

More specifically, balsam fir is likely to decline drastically with little reproduction occurring and the near disappearance of seedlings and saplings from over browse. Other tree species such as aspen, birch, mountain ash, and various deciduous shrubs also could likely have reduced regeneration and some could continue to decline. Non-browsed species such as spruce could expand. Absent wolves, increasing levels of moose herbivory would exacerbate the decline of balsam firs on the west end of Isle Royale, increasing the potential for more savannah-like spruce-dominated forests (appendix A). Spruce in savanna-like settings with non-native plant species understory would likely expand over the 20-year life of the plan, making the island less favorable for moose due to shifts in community structure and composition (although a warming climate also may result in reductions of spruce).

Food resources, primarily aspen, in and around beaver ponds could be depleted from over browse by both moose and beavers. Because of this depletion, beavers may expand their distance of browse, further depleting resources in the area thus changing forest community structure and composition.

An increase in abundance of moose and beavers may impact the shrub layer of the forest through increased herbivory which could lead to impacts on species such as small mammals and ground nesting birds from habitat removal.

Impacts from alternative A to aquatic plants and wetlands due to browse and trampling would follow trends discussed in chapter 3 and would likely increase leading to possible denuded plant communities and reduced biomass of aquatic vegetation by increasing suspension of particles as moose move through the water, thus reducing photosynthetic rates.

Climate change is expected to alter ecosystems across the boreal forests on the island (IPCC 2007; Gonzalez 2012) leading to a decline of balsam firs on the west end of Isle Royale and the potential for more savannah-like spruce-dominated forests on the island. Without the presence of an apex predator on the island, this shift to the savannah-like spruce-dominated forests may be accelerated due to an increase in herbivory of the already stressed balsam fir species. The shift to a more savannah-like environment would also increase the predominance of non-native plant species which would be more susceptible to fire in severe drought periods.

In addition to the impacts described above, other indirect effects to the ecosystem could result from increased herbivory related to soil composition, nutrient cycling, water quality, and plant growth that would not be impacted from NPS actions to a large enough degree for detailed analysis. Where browsing is intense, soil chemistry is affected through these browsing-induced changes to litter composition and reduced litter quantity. Soil carbon, nitrogen, cation exchange capacity, field nitrogen availability, potentially mineralizable nitrogen, and respiration rates are reduced compared to areas where there is little to no browsing. These soil microbial processes determine the amount of nitrogen available to plants (Pastor et al. 1988). If moose populations continue to grow unchecked by an apex predator, the available nitrogen for plants on the island could be impacted through reduction.

Cumulative Impacts

Past, present, and reasonably foreseeable future actions with the potential to have cumulative impacts with alternative A include the ongoing implementation of the current fire management plan and ongoing management of invasive species at the park.

The boreal forest on Isle Royale historically experienced frequent natural disturbance, including fire, which makes it a dynamic community. Under the current fire management plan (NPS 2004), most naturally ignited fires would continue to be allowed to burn and most human-caused fires are suppressed. Prescribed burns would continue to be used to accomplish specific vegetation management objectives such as restoring or maintaining jack pine stands or increasing red pine and white pine abundance. Prescribed fire that reduces fuel hazards can reduce the period of active burning during wildland fires and monitoring will track regrowth of fuels in the treated areas and the need for followup treatment. Fire also plays a role in nutrient cycling that supports the island ecosystem. While natural fires occur, fire-adapted vegetation on the island would likely be rejuvenated to pre-fire levels over the short term providing habitat for animal species.

Treatment of invasive plant species would have a long-term beneficial effect to the island ecosystem through control of invasive plant species that impact the growth and distribution of native vegetation species as well as threaten the integrity of terrestrial and aquatic ecosystems on Isle Royale.

Overall, past, present, and reasonably foreseeable future actions would continue to have short-term adverse and long-term beneficial impacts on the island ecosystem. Actions such as prescribed fire and invasive species management are carried out to maintain natural ecological processes on the island and can be considered beneficial. The likely extirpation of wolves under alternative A would result in widespread changes to the island ecosystem, as described above, due to the absence of an apex predator on the island. This would continue to alter predator-prey dynamics, competition, disturbance. When the incremental impacts of alternative A are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the island ecosystem would cause broad ecosystem changes to the island ecosystem, with the incremental impacts of alternative A being responsible for the majority of these changes.

Conclusion

> ***bottom-up control****—ecosystems primarily influenced by physical conditions and vegetation community structure*

Under this alternative, the island ecosystem functions would continue to change, from the past predator influenced ecosystem, to an ecosystem primarily influenced by physical conditions and vegetation community structure (lower trophic levels influences (“bottom-up control”)). There is a debate among scientists as to which is most viable or preferable. Whether this is beneficial or adverse for the system depends on whether there is a preference for an ecosystem more influenced by predation or an ecosystem more influenced by bottom-up controls. Most ecosystems function with varying influences on population control from both the top-down and bottom-up. Under the no-action alternative, the change from the current condition would be small since the current wolf population is already so low and not functioning as an apex predator and this would continue to alter predator-prey dynamics, competition, disturbance, and succession.

It is expected that with the continuation of a lack of predation and an increase in herbivory, there would be broad ecosystem changes related to forest composition and structure. These changes would result in less favorable environments for moose and beavers, a shift in plant community composition from native to non-native, and influence wildlife habitat and interactions. While it is uncertain exactly how climate change may impact the island, the rate of vegetation change could depend on the magnitude of climate warming, which would exacerbate and potentially accelerate vegetation changes, and the occurrence of disturbance events likely to form novel communities. The response of wildlife populations to these vegetation shifts is difficult to predict because trophic interactions are dynamic. Additionally, given the island’s geographic isolation and the inherent dynamics of island ecosystems, it is expected that the resiliency of current wildlife populations to change would be reduced and contribute to more rapid population swings (Fisichelli et al. 2013).

Alternative B: Immediate Limited Introduction (Preferred Alternative)

Impacts associated with island ecosystem under alternative B are based on the assumption that wolf introduction would be successful throughout the 20-year life of the plan.

Predation. Under alternative B, the predator-prey dynamic on the island would be restored and the predation of wolf on moose and beavers would increase compared to the current condition. It is anticipated that wolf predation would return to levels seen on the island in the last 50 years when there was a strong influence by an apex predator. The introduction of wolves would increase the likelihood of a top-down, predator-influenced system. The presence of wolves may increase the health of prey species over time as wolves cull older, weaker, and diseased individuals. Most ecosystems function with varying influences on population control from both the top-down and bottom-up. For detailed information on anticipated predation impacts to moose, see the “Moose” section of this chapter.

Predation of wolves on beavers would increase compared to current conditions but is not expected to dramatically influence population dynamics as moose are the primary prey species of wolves.

Under alternative B, scavenger species like ravens and red foxes may benefit from more moose carcasses on the landscape to scavenge from. Carrion from wolf kills would provide a small beneficial impact to these species in the summer and would largely benefit these species in the winter when food sources are more limited.

Competition. In the short term, beaver populations may decrease due to predation. In the long term it is expected that predation of moose would benefit beavers because there would be a reduction in the competition for shared resources. As opposed to impacts discussed under the no-action alternative, with an introduction of an apex predator under this alternative, it would be expected that the rate of the long-term decline in beaver populations would be diminished because more moose would be consumed by the introduced wolf population. Competition between these herbivores for key resources such as aquatic vegetation and aspen would be reduced.

Through the introduction of an apex predator, there could be a decrease of mesopredators such as foxes from interspecific conflict leading to fox mortality. With the introduction of an apex predator, the current downward trend of fox populations is expected to continue.

Disturbance and Succession. With the introduction of an apex predator, the rate of herbivory would decrease, thus slowing the rate of change in forest structure and composition. Some species, such as balsam fir, yew, and mountain ash would benefit from the introduction of an apex predator by reducing herbivory of these key browse species and could promote regeneration as new shoots would be less heavily browsed. Depending on the ratio of moose to wolves, there would be a varying effect on the moose population and therefore a varying effect on how browsed species respond to herbivory. With the introduction of wolves, top-down influences would be restored and that would lessen the effects on these key browse species and enhance ecosystem resiliency to climate change. However, it is expected that savannafication, as described in the no-action alternative, would continue but the rate of change would slow from NPS actions.

Impacts from alternative B to aquatic plants and wetlands would likely include reduced browse and trampling impacts resulting in increased aquatic plant abundance and distribution.

While boom and bust cycles may occur for both beavers and moose, it is anticipated that with the introduction of an apex predator there would be reductions in abundance. This may impact the shrub layer of the forest through a reduction in browse. The shrub component of the forest would be retained, thus benefiting small mammals and ground nesting birds through habitat protection.

As discussed under alternative A, a shift is currently occurring on the island to a savannah-like spruce-dominated forest. Under alternative B, the presence of wolves on the island would likely slow this shift by decreasing the moose populations browse impacts on the boreal forest community type.

While it is uncertain exactly how climate change would influence rates of vegetation change on the island as discussed above, these rates of change would likely depend on the magnitude of climate warming and the occurrence of disturbance events. It is expected that climate change influences would be retarded with an increase in predation and a decrease in herbivory. This alternative would result in more favorable long-term environmental conditions for both moose and beavers by retaining plant communities that provide forage. Consequently, given the island's geographic isolation and the inherent dynamics of island ecosystems, it is likely that the resiliency of current wildlife populations to change would be enhanced by the restoration of predation.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative B, the introduction of wolves would restore predation on the island and would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. When the incremental impacts of alternative B are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the island ecosystem would restore a beneficial ecosystem function, with the incremental impacts of alternative B being responsible for the majority of these changes.

Conclusion

Under alternative B, the introduction of wolves would restore predation on the island. This would be a significant change from the current condition by restoring the ecological process of predation that currently does not exist. This alternative would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for forest succession to return to a historical trajectory last seen when predation was more of an influencing factor in community dynamics. It is expected that with an increase in predation and a decrease in herbivory, the rate of ecosystem shifts (e.g., boreal to northern hardwood forest or savannification) would be slowed.

While it is uncertain exactly how climate change would influence rates of vegetation change on the island as discussed above, these rates of change would likely depend on the magnitude of climate warming and the occurrence of disturbance events. It is expected that in the presence of wolves, herbivory and its associated impacts would be less likely to exacerbate or compound climate change influences over the long term.

Alternative C: Immediate Introduction with Potential Supplemental Introductions

Predation. Impacts to predation and the predator-prey dynamic on the island would be similar to those under alternative B except the annual number of moose and beavers killed under this alternative would be less than alternative B initially. Because a smaller number of wolves would be introduced under this alternative, it is likely that the direct and indirect effects of predation of wolf on moose and beavers would be not be as large as described under alternative B initially. Over time, the effects of predation on the island ecosystem would be the same as those described under alternative B.

Competition. Impacts to competition would the same as those under alternative B.

Disturbance and Succession. Impacts to disturbance and succession would the same as those under alternative B.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative C, the introduction of wolves would restore predation on the island and would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. When the incremental impacts of alternative C are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the island ecosystem would restore a beneficial ecosystem function, with the incremental impacts of alternative C being responsible for the majority of the changes.

Conclusion

As described under alternative B, the introduction of wolves would restore predation on the island. Under this alternative, a smaller number of wolves would be introduced initially and therefore would not have as great an impact on prey species as alternative B initially. The long-term impacts would be the same as those described under alternative B. This would be a significant change from current condition by restoring the ecological process of predation which currently does not exist. This alternative would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for forest succession to return to a historical trajectory last seen when predation was more of an influencing factor in community dynamics. It is expected that with an increase in predation and a decrease in herbivory, the rate of ecosystem shifts (e.g., boreal to northern hardwood forest or savannification) would be slowed. It is expected that in the presence of wolves, herbivory and its associated impacts would be less likely to exacerbate or compound climate change influences over the long term.

Alternative D: No Immediate Action, with Allowance for Future Action

Predation. With no immediate wolf introduction, impacts to predation would be similar to those described under alternative A. However, should the NPS take action, the impacts would be the same as those described for alternative C.

It is possible that the trends under alternative A may have already occurred or may be occurring at a greater rate, and when action is taken, the impacts from taking action may be less visible in the ecosystem initially. Additionally, the response of the island ecosystem to wolf introduction may not occur as quickly as under alternative C. It is unclear what these conditions would be because it is uncertain when action would occur.

Competition. With no immediate wolf introduction, impacts to competition would be similar to those described under alternative A. However, should the NPS take action, the impacts would be the same as those described for alternative C.

Disturbance and Succession. With no immediate wolf introduction, impacts to disturbance and succession would be similar to those described under alternative A. However, should the NPS take action, the impacts would be slightly different than those described under alternative C, because the condition of the island ecosystem would likely change in the time period before introduction due to the ongoing trends described in the affected environment and no-action alternative.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative D, if metrics are met and wolves are introduced, it would restore predation on the island. This would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. Prior to this introduction, the likely extirpation of wolves would result in widespread changes to the island ecosystem, as described under alternative A, due to the absence of an apex predator on the island. This would continue to alter predator-prey dynamics, competition, disturbance, and succession on the island until introduction occurs. When the incremental impacts of alternative D are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the island ecosystem would cause broad ecosystem changes, with the incremental impacts of alternative D being responsible. Once introduction occurs, the overall cumulative impacts would restore a beneficial ecosystem function, with the incremental impacts of alternative D being responsible for the majority of the changes.

Conclusion

Impacts under alternative D would vary depending on the timing of wolf introduction. With no immediate wolf introduction, impacts to island ecosystem would be similar to those described under alternative A. However, should the NPS take action, the impacts would be similar to but may be different than alternative C.

It is expected that with the continuation of a lack of predation and an increase in herbivory, there would be broad ecosystem changes related to forest composition and structure. These changes would result in less favorable environments for moose and beavers, a continued shift in plant community composition from native to non-native, and influence wildlife habitat and interactions. These impacts would continue until wolves were introduced.

Once an introduction occurs, an apex predator influenced ecosystem would be restored. However, it is possible that the trends that would continue from taking no action (as described under alternative A) may have already occurred or may be occurring at a greater rate, and when action is taken, the impacts from taking action may be less visible in the ecosystem initially. Additionally, the response of the island ecosystem to wolf introduction under alternative D may not occur as quickly as under alternative C.

Once a response to wolf introduction occurs, this would be a significant change from the current condition on the island. Alternative D would restore forest components that would have been reduced in the presence of increased herbivory, allowing for forest succession to return to a historical trajectory last seen when predation was more of an influencing factor in community dynamics. It is expected that with an increase in predation and a decrease in herbivory, the rate of ecosystem shift from boreal to northern hardwood forest would be slowed. While it is uncertain exactly how climate change would influence rates of vegetation change on the island as discussed under the other alternatives, these rates of change would likely depend on the magnitude of climate warming and the occurrence of disturbance events. In the absence of wolves, climate change would exacerbate and potentially accelerate vegetation changes, and the occurrence of disturbance events would likely be to form novel communities. Once wolves were introduced, herbivory and its associated impacts would be less likely to exacerbate or compound climate change influences in the long term.

Comparative Conclusion of Alternatives

Under alternative A, the island ecosystem functions would continue to change from the past predator influenced ecosystem, to an ecosystem primarily influenced by bottom-up forces such as herbivores, bio-physical conditions and forest/vegetation community structure and composition. It is expected that with the continuation of a lack of predation and subsequent increase in herbivory, there would be broad ecosystem changes related to forest composition and structure. In comparison, alternative B and alternative C would restore predation by the addition of an apex predator to the island. This would be a significant change from current condition by restoring the ecological process of predation which currently does not exist. This alternative would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for forest succession to return to a historical trajectory last seen when predation was more of an influencing factor in community dynamics.

Under alternative A, increased herbivory is probable and combined with climate change effects, it is likely that the rate of vegetation changes would be exacerbated and potentially accelerated. Additionally, given the island’s geographic isolation and the inherent dynamics of island ecosystems, it is expected that the resiliency of current wildlife populations to change would be reduced and contribute to more rapid population swings. Under alternative B and C, it is expected that climate change influences on the island would be less likely to be compounded by herbivory and its associated impacts. Alternative D encompasses the full spectrum of impacts described under the plan from alternative A to C, depending on whether and when NPS introduces wolves. However, the response to actions would vary because it is uncertain when action would occur.

WILDERNESS

NPS wilderness management policies are based on provisions of the 1916 NPS Organic Act, the 1964 Wilderness Act, NPS policies and Director’s Orders, and legislation establishing individual units of the national park system. Adherence to the Wilderness Act, including prohibitions on certain activities, and NPS wilderness management policies inform this analysis. NPS policy requires that all management decisions affecting wilderness must be consistent with the minimum requirement concept, which is a documented process to determine if administrative actions, projects, or programs undertaken by the park and affecting wilderness character, resources, or the visitor experience are necessary, and if so, how to minimize impacts (NPS 2008).

Methods and Assumptions

The focus of the wilderness impact analysis is on changes to wilderness character, specifically to the natural, untrammeled, and undeveloped qualities that would result from the alternatives (Landers et al. 2015). Potential impacts on wilderness were evaluated qualitatively, based on best professional judgement of park, region, and Washington Office staff. The baseline conditions of wilderness character for Isle Royale National Park potentially affected by the alternatives are described in chapter 3. Alternatives are evaluated against these baseline conditions to determine the changes to each wilderness quality expected under each alternative. The area of analysis for impacts of alternatives on wilderness character is the main island of Isle Royale.

There are five qualities of wilderness character: natural, untrammeled, undeveloped, solitude or unconfined recreation, and other features of value. As described in chapter 1, solitude and primitive and unconfined recreation and other features of value are not analyzed in further detail. The other three qualities are described below.

Natural. The Wilderness Act states that wilderness is "protected and managed so as to preserve its natural conditions." This means that wilderness ecological systems are substantially free from the effects of modern civilization. Within a wilderness, for example, indigenous plant and animal species predominate, or the fire regime is within what is considered its natural return interval, distribution over the landscape, and patterns of burn severity. This quality directly relates to "biophysical environments primarily free from modern human manipulation and impact." The natural quality is preserved when there are only indigenous species and natural ecological conditions and processes, and may be improved by controlling or removing non-indigenous species or by restoring ecological conditions.

Untrammeled. The Wilderness Act states that wilderness is "an area where the earth and its community of life are untrammeled by man," that "generally appears to have been affected primarily by the forces of nature" and "retain[s] its primeval character and influence." This means that wilderness is essentially unhindered and free from the intentional actions of modern human control or manipulation. This quality directly relates to "biophysical environments primarily free from modern human manipulation and impact" and "symbolic meanings of humility, restraint, and interdependence that inspire human connection with nature" described in the above definition of wilderness character. The untrammeled quality is preserved or sustained when actions to intentionally control or manipulate the components or processes of ecological systems inside wilderness (for example, suppressing fire, stocking lakes with fish, installing water catchments, or removing predators) are not taken. This quality is improved when suppression of wildfire or manipulation of habitat is stopped or significantly reduced.

Undeveloped. The Wilderness Act states that wilderness is "an area of undeveloped Federal land … without permanent improvements or human habitation," "where man himself is a visitor who does not remain" and "with the imprint of man's work substantially unnoticeable." This means that wilderness is essentially without permanent improvements or the sights and sounds of modern human occupation. This quality is affected by "prohibited" or "nonconforming" uses (section 4(c) of the Wilderness Act), which include the presence of modern structures, installations, and habitations, and the administrative and emergency use of motor vehicles, motorized equipment, or mechanical transport. Some of these uses are allowed by special provisions required by legislation. This quality directly relates to "personal experiences in natural environments relatively free from the encumbrances and signs of modern society" and "symbolic meanings of humility, restraint, and interdependence that inspire human connection with nature" described in the above definition of wilderness character. The undeveloped quality is preserved or sustained when these nonconforming uses are not used by the agency for administrative purposes or by others authorized or not authorized by the agency. It is improved when the prohibited use is removed or reduced.

Alternative A: No Action

Natural. The natural quality of wilderness directly relates to the degree to which the biophysical environment is free from human manipulation and natural ecological processes are allowed to occur. Under alternative A, NPS would not introduce wolves. Therefore, the ecological functions under this alternative would remain free from human manipulation. Extirpations, such as the extirpation of wolves likely to result under this alternative, are typical in island ecosystems. Predation, succession, competition, and disturbance functions on the island are likely to change in the absence of wolves. The direct and indirect impacts of the potential extirpation of wolves to the ecological functions of Isle Royale are described in greater detail under the “Island Ecosystem” section of this chapter.

Under this alternative, the island ecosystem functions would change from the past predator-prey ecosystem to an ecosystem primarily influenced by physical conditions and vegetation community structure (lower trophic levels influences (“bottom-up control”)). There is a debate among scientists as to which is most viable or preferable. Whether this is beneficial or adverse for the system depends on whether there is a preference for an ecosystem more influenced by predation or whether the ecosystem is more influenced by bottom-up controls. Most systems function with varying influences on population control from both the top-down and bottom-up. Since this alternative does not involve the introduction of wolves, it would potentially remove the predator dominated ecosystem.

Under alternative A, the continued existence of moose in the absence of wolves would likely lead to repeated boom and bust cycles over evolutionary time scales and a reduction in the size of large animals (insular dwarfism) over a number of generations when their populations range is limited to a small environment like islands. This is a natural process and can lead to evolution within a species over time. The timeline for changes in island biogeography far exceeds the planning horizon of 20 years and changes are difficult to predict.

Currently, the National Park Service conducts moose counts and some wolf monitoring by aircraft during the winter season. Noise from aircraft would continue to result in short term, sporadic impacts to the acoustic environment as well as to wildlife, degrading the natural quality of this wilderness as described in chapter 3.

Untrammeled. Under alternative A, there would be no changes to the untrammeled quality of wilderness. The National Park Service would not take any actions that would detract from this quality.

Undeveloped. Under alternative A, radio collaring of wolves would continue to have the potential to impact the undeveloped quality. The National Park Service would continue to collar wolves that immigrate to the island naturally on a case-by-case basis; however, because the existing population is likely to be extirpated without additional natural immigration, this would be infrequent. Accordingly, as the formation of ice bridges for wolves to immigrate is less likely, the presence of collars on Isle Royale is not likely under this alternative. As wolves with collars die off, absent some large natural migration of wolves to the island, the undeveloped quality would be slightly improved as the collars would be removed from wilderness. However, overall, the undeveloped quality as described in chapter 3 would not change in a meaningful way.

Cumulative Impacts

Past, present, and reasonably foreseeable future actions with the potential to have cumulative impacts with alternative A include the ongoing implementation of the current fire management plan and ongoing management of invasive species at the park.

Under the current fire management plan (NPS 2004), most naturally ignited fires are allowed to burn as a natural part of this dynamic system. Prescribed burns are sometimes used to accomplish vegetation management objectives and most human-caused fires are suppressed. The suppression of man-made fires and the use of prescribed fires would continue to have a long-term beneficial effect on the natural quality of the Isle Royale wilderness but would continue to degrade the untrammeled quality. The use of mechanized equipment in the suppression of fires would continue to result in the short-term adverse impact on the undeveloped quality of Isle Royale wilderness.

Actions to address invasive plants are typically concentrated in disturbed areas such as trails and campgrounds. Actions include physical removal and chemical applications. In addition, vegetation is managed and monitored through the installation of exclosures to keep browsing animals away from vegetation. These actions would continue to have a long-term beneficial effect to the natural quality but would continue to contribute to the degradation of the untrammeled and undeveloped qualities of Isle Royale wilderness.

Overall, past, present, and reasonably foreseeable future actions would continue to have short-term adverse and long-term beneficial impacts on wilderness. Actions such as prescribed fire and invasive species management are carried out to maintain natural ecological processes on the island and can be considered beneficial to the natural quality. While fire management or invasive species management actions are being carried out, impacts could be adverse to the untrammeled and undeveloped qualities. The likely extirpation of wolves under alternative A would result in widespread changes to the island ecosystem, as described above, due to the absence of an apex predator on the island. This would result in continued noticeable changes to the ecological functions and impacts to the natural quality. However, those changes may be described as either adverse or beneficial depending on the preference for an ecosystem more influenced by predator dynamics or an ecosystem largely driven by changes from the bottom-up. When the incremental impacts of alternative A are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to wilderness would vary depending on preference for ecosystem influences, with the incremental impacts of alternative A being responsible for impacts to the natural quality, and unnoticeable for the untrammeled and undeveloped qualities.

Conclusion

Alternative A would result in little change to wilderness character as described in the affected environment. The changes and trends described in the affected environment would continue. Under this alternative, there would be no additional human manipulation or intervention to detract from the natural and untrammeled qualities. Ecological functions on the island would continue to evolve and change in the absence of wolves. Additionally, it is unlikely that new radio collars would be placed on wolves in wilderness, therefore enhancing the undeveloped quality compared to current conditions.

Alternative B: Immediate Limited Introduction (Preferred Alternative)

Natural. Under alternative B, the introduction of wolves to Isle Royale would result in impacts to the natural quality of wilderness. As described under alternative A, the natural quality is directly characterized by the absence of human manipulation to the biophysical environment and whether the ecological functions are free from human interference. Under alternative B, NPS would bring wolves to Isle Royale, thereby manipulating the biophysical environment.

The introduction of wolves would alter ecological functions currently occurring on the island. Those impacts or changes are described in detail under the “Island Ecosystem” section of this chapter. However, the introduction of wolves would be beneficial if an ecosystem that is more influenced by predator dynamics is desirable. Once the introductions are complete, the wolves should be able to function without human intervention. Keeping it Wild 2 indicates that the natural quality may be preserved by restoring ecological conditions (Landers et al. 2015). Under alternative B, wolf introduction would restore the predator dynamic on the island and support the natural quality of wilderness.

Alternative B includes the potential for moose and wolf monitoring by aircraft during the winter season. Noise from aircraft would result in short-term, isolated, sporadic impacts to the acoustic environment detracting from the natural quality of wilderness. The National Park Service would continue to evaluate alternative options for conducting these monitoring efforts, which may result in fewer impacts to the natural quality of wilderness.

The capture of wolves outside of Isle Royale would have no impact on Isle Royale wilderness. However, the specific location of where wolves may be captured is not known at this time. If wolves are captured in an existing wilderness area, the action of capturing and removing those animals would detract from the natural quality of that wilderness. The number of wolves removed would not disrupt the ecological function of that wilderness. Under alternative B and all action alternatives, the capture of wolves for introduction to Isle Royale would be done in support of the purpose of conservation, which is a purpose of wilderness.

Under alternative B and all action alternatives, during initial release of wolves, the National Park Service may use carcass provisioning to ensure success of wolf establishment. This deviation in the natural processes of the wolves hunting and feeding would result in short-term, adverse impacts to the natural quality of wilderness. The impacts would cease when the activities are discontinued and would not interfere with any ecological functions in any significant way.

Untrammeled Quality. To preserve the untrammeled quality of wilderness, managers should exercise restraint when taking actions that manipulate any aspect of the wilderness. Under alternative B, NPS would manipulate the island ecosystem by intentionally introducing wolves. This introduction would detract from the untrammeled quality.

The capture of wolves outside of Isle Royale would have no impact on Isle Royale wilderness. However, the specific location of where wolves may be captured is not known at this time. If wolves are captured in an existing wilderness area, the action of capturing and removing those animals would detract from the untrammeled quality of that wilderness. Under alternative B and all action alternatives, the capture of wolves for introduction to Isle Royale would be done in support of the purpose of conservation, which is a purpose of wilderness.

Under alternative B and all action alternatives, the National Park Service would radio collar wolves to allow for monitoring of the species and ensure the success of the introduction. The introduction of collared wolves to Isle Royale wilderness would detract from the untrammeled quality as long as the collars remain in the wilderness. Should NPS decide to collar a subset of wild born wolves on Isle Royale under any of the action alternatives, the act of capturing a wolf and placing a collar on the wolf is an intentional manipulation of the biophysical environment. The impact from the act of collaring would be sporadic, and would only last for only a few hours at most, but other impacts of collaring could last longer. The collaring may result in stress or mortality to the wolf, which is discussed in detail in the "Wolves" section of this chapter.

During the initial release efforts, carcass provisioning may be used to support introduced wolves and assist the recolonization efforts. Carcasses for provisioning would be moose from Isle Royale. Found carcasses may be used; however, this action would most likely require a certain level of harvesting of moose from the island. The number of carcasses needed would be no more than 24 moose during the first five years of the release. The intentional placement of supplement food sources in wilderness would be intended to support wolf establishment and would be an intentional manipulation. Therefore, this would have an adverse impact on the untrammeled quality of the wilderness. These impacts would continue until the action is stopped and therefore would be short term.

Undeveloped Quality. Under alternative B, radio collars may be placed on all wolves introduced to the island. A radio collar is generally considered an installation that affects the undeveloped quality of wilderness. Under Keeping it Wild 2, scientific installations detract from the undeveloped quality (Landers et al. 2015). Installations in wilderness are a prohibited use, a Wilderness Act 4c violation. Prohibited uses may occur in wilderness if the action is necessary to meet minimum requirements for the administration of the area for the purpose of the Wilderness Act. This purpose includes recreational, scenic, scientific, educational, conservation, and historical use (Wilderness Act of 1964 (Pub.L. 88–577)). There is general agreement among wolf experts that collaring is necessary to evaluate and monitor the success of a wolf introduction effort (appendix A). Radio collaring wolves would support both the wilderness purposes of conservation and scientific study.

Under alternative B, the impact to the undeveloped quality would result from both the presence of the collars in wilderness and from the potential for visitors to see this installation in wilderness. The latter is highly unlikely because wolves generally avoid humans. With rare exception, most visitors would never see collared wolves. Therefore, the presence of collars would not significantly alter the visual experience associated with the undeveloped quality of wilderness. The collar itself is small and mobile, limiting its intrusion on the undeveloped quality of wilderness. Under all alternatives, the collars would most likely remain on the animal for the duration of their lives, resulting in long-term impacts to the undeveloped quality. Under all action alternatives, impacts to the undeveloped quality of wilderness would be long-term adverse and minor because collars would most likely remain on the animals for the duration of their lives but would not significantly alter the visual experience associated with the undeveloped quality of wilderness. The National Park Service continues to explore whether there are new ways to effectively monitor wolves without collaring. However, it is likely that during the life of this plan, collaring is the minimum requirement necessary to accomplish the goal of the plan.

Under alternative B and all action alternatives, the National Park Service would transport wolves to the island via boat, fixed-winged aircraft, or helicopter. These transportation mechanisms all detract from the undeveloped quality of wilderness since they are all forms of mechanized transport. Impacts to the undeveloped quality from these uses would be short-term and adverse as they would detract from the undeveloped quality at the time of wolf introduction, but would not result in long-term impacts. Regardless of type of transportation used, the National Park Service would attempt to land in non-wilderness areas only. However, due to the need to release wolves in a certain area of the park in order to increase the success of the introduction, or because of unsafe landing conditions in non-wilderness areas, the National Park Service may land in wilderness. A helicopter, aircraft, or boat landing in wilderness would constitute a prohibited use, a Wilderness Act 4c violation, and would be subject to the minimum requirements analysis process. Prohibited uses may take place in wilderness if the action is taken for the purpose of wilderness and is the minimum tool necessary to accomplish that purpose. Motorized access for introduction efforts in wilderness would temporarily degrade the undeveloped quality of wilderness at the time and location of the landing, and only for the duration of the activity.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative B, the introduction of wolves would restore predation on the island and would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. The introduction of wolves would have an adverse impact to the untrammeled quality. When the incremental impacts of alternative B are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the natural quality would vary depending of preference for ecosystem influences and the impacts to untrammeled and undeveloped qualities would be adverse, with the incremental impacts of alternative B being responsible.

Conclusion

Alternative B would result in substantial impacts to wilderness character compared to the current condition. Under this alternative, there would be human manipulation and intervention that would detract from the natural and untrammeled qualities. Ecological functions on the island would be restored to a set of natural conditions more heavily influence by an apex predator. The influence associated with bottom-up control of the ecosystem would be diminished by the inclusion of an apex predator. This alternative would result in insignificant impacts to the undeveloped qualities through the use of radio collars and potentially helicopters, fixed winged aircraft, or boats.

Alternative C: Immediate Introduction with Potential Supplemental Introductions

Natural. Impacts to the natural quality would be the same as alternative B except under this alternative there would likely be additional introductions. There could be up to four additional introductions over a 20-year period. This alternative could result, depending on how many introductions ultimately occur, in additional noise from the use of helicopters and other mechanized transportation in wilderness.

Untrammeled. Impacts under this alternative are the same as alternative B, except the potential for subsequent introductions would result in additional adverse impacts to the untrammeled quality, if the NPS chose to introduce additional animals.

Undeveloped. Under alternative C, wolves would be collared, but fewer wolves may be collared than alternative B, which would result in fewer installations as well as the frequency by which visitors might observe these installations than under alternative B.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative C, the introduction of wolves would restore predation on the island and would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. The introduction of wolves would have an adverse impact to the untrammeled quality. When the incremental impacts of alternative C are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to the natural quality would vary depending of preference for ecosystem influences and the untrammeled and undeveloped qualities being adverse, with the incremental impacts of alternative C being responsible.

Conclusion

Alternative C would result in substantial impacts to wilderness character compared to the current condition. Under this alternative, human manipulation and intervention would detract from the natural and untrammeled qualities. Ecological functions on the island would be restored to more closely represent a set of natural conditions, that of an apex predator-based ecosystem. The influence associated with bottom-up control of the ecosystem would be diminished by the inclusion of an apex predator. This alternative would result in insignificant impacts to the undeveloped qualities through the use of radio collars and potentially helicopters, fixed winged aircraft, or boats.

Alternative D: No Immediate Action, with Allowance for Future Action

Natural. With no immediate wolf introduction, impacts to the natural quality would be similar to those described under alternative A. However, should the NPS take action, the impacts would be the same as those described for alternative C.

Untrammeled. Impacts to the untrammeled quality of wilderness would be the same as alternative A while NPS takes no action to introduce wolves. If NPS decides to introduce wolves, impacts to the untrammeled quality would be the same as those described under alternative C.

Undeveloped. Impacts to the undeveloped quality of wilderness would be the same as alternative A while NPS takes no action to introduce wolves. If NPS decides to introduce wolves, impacts to the untrammeled quality would be the same as those described under alternative C.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative D, once metrics are met the introduction of wolves would restore predation on the island and would retain forest components that would otherwise be reduced in the presence of increased herbivory, allowing for succession to return to a historical trajectory. Prior to introduction the likely extirpation of wolves under alternative A would result in widespread changes to the island ecosystem, as described above, due to the absence of an apex predator on the island. This would continue to alter predator-prey dynamics, competition, disturbance, and succession on the island and impact the natural quality of wilderness. If metrics are met, the introduction of wolves would cause adverse impacts to the untrammeled quality. When the incremental impacts of alternative D are added to the past, present, and reasonably foreseeable future impacts, the overall cumulative impacts prior to introduction would cause broad ecosystem changes, with the incremental impacts of alternative A being responsible for impacts to the natural quality, and unnoticeable for the untrammeled and undeveloped qualities. Once introduction occurs, the overall cumulative impacts to the natural quality would vary depending of preference for ecosystem influences, and the untrammeled and undeveloped qualities being adverse, with the incremental impacts of alternative D being responsible.

Conclusion

The impacts of alternative D would be similar to alternative A until introduction would occur. This would result in beneficial impacts to the untrammeled quality of wilderness. However, if the wolves are introduced, the impacts would be similar to alternative C.

Comparative Conclusion of Alternatives

Alternative A is likely to result in the least impacts to wilderness character. Alternative A primarily impacts the natural quality, although those impacts would likely not result in a significant change from the current condition. Current conditions reflect ecological processes typical in an island ecosystem. Alternative A is the only alternative that does not include human manipulation of the biophysical environment, with the exception of the potential use of radio collars if wolves naturally migrate to the island.

Alternatives B and C would likely result in the most impacts to wilderness character. Both include substantial impacts to wilderness character overall because of the intentional manipulation of the biophysical environment and the subsequent changes from current condition. However, both alternatives would likely restore an ecological function previously present on the island. Both alternatives include the use of radio collars and mechanized transport that impact the untrammeled and undeveloped qualities of wilderness. Alternative C may result in additional impacts to the untrammeled and undeveloped qualities depending on the number of introduction events. Alternative D encompasses the full spectrum of impacts described under the plan from alternative A to C, depending on whether and when NPS introduces wolves.

MOOSE

Methodology and Assumptions

The interdisciplinary planning team reviewed both historic and contemporary scientific studies specific to the moose population on Isle Royale. In addition, the subject matter experts established to compare and share knowledge on wolves and moose and their habitats on Isle Royale, provided recommendations and input specific to each of the impact topics discussed (appendix A). The following analysis focus on potential environmental impacts for each alternative.

Alternative A: No Action

The wolf population on Isle Royale would likely continue to decline under alternative A and become extirpated. The declining frequency of ice bridge formation between the mainland and Isle Royale would further reduce the potential for wolf immigration to the island and potential genetic rescue, with the probability of an ice bridge forming between the mainland and Isle Royale declining from 0.8 in 1959 to 0.1 in 2013 (Licht et al. 2015).

Moose population trends noted in the 2014–2015 annual report (Vucetich and Peterson 2015) indicate the moose population has been growing at a mean rate of 22% per year for four consecutive years and is estimated to double in size by 2018 (Vucetich and Peterson 2015). With no future wolf augmentation or introduction to the island, the moose population would likely fluctuate from bottom-up control, a function of moose browse reduction and recovery, plant dynamics, and climate change (Peterson et al. 2004; Wilmers et al. 2006). Additional increases in the moose population would likely be followed by a decreased nutrition for individuals and a decrease in overall in population health with the potential for large-scale starvation events from insufficient browse, low winter, and increased susceptibility to disease, likely resulting in moose population crashes from malnutrition and starvation and indirect effects to the island ecosystem.

Historically, wolf predation (or lack thereof) of moose on the Isle Royale has resulted in indirect effects to the plant communities (Peterson 1999; Peterson et al. 2014). With a reduction in wolf predation on moose, the moose population could increase, and a commensurate increase in the rate and intensity of moose herbivory would occur on the island. Under alternative A, the ecosystem would be more influenced by bottom-up controls.

With increased browse pressure and insufficient time for these tree species to regenerate and grow, sapling diversity and density would decline, affecting the long-term vegetative community composition, forest structure, and both the short- and long-term browse availability for moose. More generally across the island, balsam fir is likely to significantly decline with little reproduction occurring and the near disappearance of seedlings and saplings. Other tree species such as aspen, birch, mountain ash, and various deciduous shrubs also would likely have reduced regeneration and low vigor and would enter a phase of gradual decline. Non-browsed species such as spruce would expand. Absent wolves, possible changes associated with the current levels of moose herbivory include the decline of balsam firs on the west end of Isle Royale, the potential for more savannah-like spruce-dominated forests, and changes in moose populations (population crash associated with over-browsing, followed by recovery) (appendix A). Spruce in savanna-like settings with an exotic bluegrass understory would likely expand over the 20-year window (although a warming climate also may result in reductions in spruce). If fires occur on Isle Royale during the 20-year plan, high moose herbivory would likely eliminate regeneration of deciduous shrub and tree species that are important for foraging moose, thus accelerating the conversion of the forest community to a simplified ecosystem (appendix A). In addition to impacting upland plant communities, anticipated impacts from alternative A to aquatic plants and wetlands would likely include increased direct impacts to browse and trampling, as well as indirect impacts from erosion. Habitat effects would indirectly affect other species dependent on these communities (e.g., songbirds, beavers) on the island. Impacts of moose on vegetation have been observed at moose densities of $2/km^2$ and substantively increased as density approached $5/km^2$ (Jordan, McLaren, Sell 2000). With this population increase, reduced body size and vigor were recorded in Isle Royale moose before the population crashed from starvation (appendix A).

Cumulative Impacts

Past, present and reasonably foreseeable future actions with the potential to have cumulative impacts with alternative A include the ongoing implementation of the current fire management plan and ongoing management of invasive species at the park. The listing of the moose by the US Fish and Wildlife Service under the Endangered Species Act would not be expected to adversely impact moose on Isle Royale. Preserving the species habitat and further protecting the species and the role they play in the island ecosystem would not effect, and could benefit moose.

Under the current fire management plan (NPS 2004), most naturally ignited fires would continue to be allowed to burn and most human-caused fires are suppressed. The boreal forest on Isle Royale historically experienced frequent natural disturbance, including fire, which makes it a dynamic community. Most of the large mammals on Isle Royale are likely to avoid fire of any size. Rejuvenation of fire-adapted vegetation on the island would likely occur in the short-term to pre-fire levels providing habitat for moose. Moose primarily use young forests that are periodically disturbed. If fire does occur during the 20-year life of the plan, high moose herbivory would likely eliminate regeneration of deciduous trees and shrubs that are important foraging for moose. Prescribed fire that reduces fuel hazards can reduce the period of active burning during wildland fires and monitoring will track regrowth of fuels in the treated areas and the need for follow-up treatment. Monitoring of vegetation that measures the influence of moose on the structure and species composition of the forest types on Isle Royale provides information to managers that is beneficial in decision making for future management actions. Fire suppression or fire monitoring activities could temporarily disturb moose in the area where activities would occur, particularly near calving and rutting sites (NPS 2004).

Treatment of invasive plant species could have localized temporary impacts on moose that are in the area during treatment from displacement from work crews. Displacement of moose could temporarily disrupt travel patterns, feeding, and breeding. Displaced moose would likely use adjacent habitats temporarily and return once work crews leave the area. Indirect adverse impacts could occur to moose if non-target vegetation that are browse species for moose are adversely impacted. Overall, control of invasive plant species would have a long-term beneficial effect to the island vegetation through control of invasive plant species that impact the growth and distribution of native vegetation species.

Under alternative A, lack of wolf predation would likely cause the moose population to fluctuate, with an initial increase in the population size. An increase in the moose population size would allow moose herbivory to increase and could ultimately change plant diversity and productivity by not providing regulation of the key herbivore species. Growing moose populations would also result in an increase in herbivory on key forage plants like balsam fir and aquatic plants that could lead to reduced abundance or disappearance of these species. The increase in the moose population would likely be followed by a decrease in the population health and the potential for large-scale starvation likely resulting in moose population crashes that would have indirect impacts to the native vegetation communities on the island. The presence of moose on the island has affected the amount of fuels and Cole (1996) indicates that the large-scale vegetation change due to moose browsing may affect the natural frequency of fire occurrence, although the one study that examined this relationship did not support this claim (Peterson et al 2003). Although there is potential of a large wildlife fire on Isle Royale, most fires are relatively small and the effect of moose browsing may actually reduce the potential for large fire unless extremely dry conditions are present (NPS 2004).

Overall, past, present, and reasonably foreseeable future actions would continue to have potential temporary adverse impacts and long-term beneficial impacts to moose. Actions such as listing of the moose and preservation of their habitat and cumulative actions that enhance habitat for moose would be considered beneficial. The continuation of current management under alternative A would likely result in extirpation of wolves given the current population size, and inbreeding and reproductive issues. With no future wolf introduction the moose population would likely fluctuate from bottom-up control, a function of moose browse and recovery, plant dynamics, and climate change leading to a decrease in population health with the potential for large-scale starvation resulting in moose population crashes. When the incremental impacts of alternative A are added to the impacts of past, present, and reasonably foreseeable future actions, the overall cumulative impacts to moose would be adverse a potential population crash, with the incremental impacts of alternative A being responsible.

Conclusion

Under alternative A, the moose population is forecasted to increase upwards of 20% per year and estimated to double in size by 2018, likely resulting in a population crash from a decrease in population health. The wolf population would continue to decline and potentially disappear from the island. With no future wolf augmentation or introduction to the island, the moose population would likely continue to fluctuate, as a function of moose browse reduction and recovery, with a decrease in overall population health and vigor, an increased potential for large-scale starvation events and density-dependent disease. Thus, alternative A would likely result in significant and long-term adverse effects to the moose population on Isle Royale and associated plant communities.

Impacts Common to All Action Alternatives

The Isle Royale wolf population depends primarily on moose for prey, with moose comprising more than 90% of wolf diets (Vucetich, Nelson, and Peterson 2012), forming virtually 100% of the wolf prey base from December to April and more than 80% prey biomass during the summer (Peterson and Page 1988). The introduction of wolves to Isle Royale, regardless of the action alternative, would directly impact individual moose and the overall moose population and indirectly impact the vegetation communities and overall island ecology.

No impacts to Isle Royale moose would occur from the various wolf capture tools, vaccinations and health evaluations, transportation, or monitoring of released wolves. The following topics specific to wolf introduction could affect Isle Royale moose under all three action alternatives.

Capture Location and Logistics. Wolf groups (e.g., pack, pairs with pups) would be released at designated island locations, separating established pairs or packs from single individuals, which would be released at spatially disparate areas. Potential impacts to moose from this approach would include an increase predation pressure on moose in the vicinity of the release sites.

Time of Capture and Relocation. The timing of capture on the mainland would not impact moose on Isle Royale. However, the timing of relocation (i.e., release) of wolves on Isle Royale from the late fall to the late winter would directly impact individual moose on the island. Next to calving season, winter is when moose are most vulnerable to wolf predation. A winter release would likely result in more successful hunts by wolves, typically focusing on older or infirm moose, which would directly benefit the overall moose population health. Additionally this would provide time for wolves to establish social relationships and territories before the spring calving season. The newly introduced wolves would increase the mortality rates in spring of moose calves and decrease calf survival.

Wolf Release. Because the formation of wolf social bonds may be delayed in the short term during wolf release, the moose predation rate the first year would be lower than that anticipated in subsequent years, as wolves form packs and hunt more efficiently. This delay in pack predation pressure may result in a lag in beneficial effects to the Isle Royale moose population; however, it is assumed this lag would be short term. Since the release strategies differ under each action alternative, the variation in anticipated effects is discussed under each alternative.

Carcass Provisioning. Carcass provisioning would be expected to require no more than 24 moose during the first five years of the release. If all 24 moose were harvested from the island, impacts would be limited to the individual animals, and no population effects would occur. This assessment is based on the current moose population of an estimated 1,300 animals, with 24 animals representing 2% of the total population (Peterson and Vucetich 2016).

Alternative B: Immediate Limited Introduction (Preferred Alternative)

Under alternative B, the number of introduced wolves would be 20–30 individuals over a three-year period and direct impacts to moose through increased predation pressure from these founders may be low initially, as social relationships and packs are formed, although this is an unknown. As detailed in chapter 3, the last 65 years of research on Isle Royale have shown that the presence of wolves may reduce herbivory and facilitate natural rates of forest regeneration by reducing the number of moose and beavers and altering their behavior. Historically, moose on Isle Royale have fluctuated greatly but the presence of wolves may have moderated the amplitude of these fluctuations.

In order to better understand the predation pressure on moose from wolf introduction on the island, the average number of moose kills per wolf was estimated annually. Mech (1966) recorded a moose predation rate of a large wolf pack (15–16 individuals) on Isle Royale that averaged one moose per three days during the winter survey periods. Since moose comprise virtually 100% of the wolf prey base from December to April (Peterson and Page 1988), an estimated 50 moose kills by a large pack may occur during a five-month period in the winter. Assuming moose comprise 80% prey biomass for wolves on Isle Royale during the summer (three months) (Peterson and Page 1988) and 90% the remainder of the year (four months) (Vucetich, Nelson, and Peterson 2012), an additional 24 and 36 moose would be taken (60 total for a seven-month period), totaling 110 moose kills per pack of 15–16 individuals annually. These estimates would equate to a kill rate of approximately seven moose per wolf per year.

Consequently, under alternative B, the founding number of wolves introduced to the island over a three-year period could approach 30 wolves. Once established, a population of 30 wolves could result in a predation of approximately 210 moose per year, affecting a range of age classes. At the current population estimate of 1,300 moose on Isle Royale for 2016, (likely underestimated per Vucetich and Peterson 2016), 210 moose kills per year would approach approximately 16% of the estimated current population. This estimated predation level would be below the moose population mean growth rate of 22% between 2012 and 2015 (Vucetich and Peterson 2015). If the current moose population on the island is greater than the estimated 1,300 animals recorded in 2016 (90% confidence interval ranging upwards to 1,690), the percentage kill rate would be even lower at approximately 12%. The current moose population is potentially within three years of reaching the population levels exhibited in the mid-1990s (appendix A; Peterson and Vucetich 2016). This was immediately prior to the moose population crash in 1996, when moose numbers declined approximately 80%, from 2,400 animals estimated in 1995 to approximately 500 individuals in 1997 after an extreme winter (Peterson 1999). The wolf introduction level under alternative B may result in a kill rate lower than the current moose growth rate, resulting in an increasing moose population on Isle Royale and a possible population crash from loss of browse and other moose forage.

The reduction of moose from increased wolf predation would have a beneficial indirect impact on moose habitat. Mech (1966) calculated approximately 5,823,300 pounds of browse are required annually to support approximately 89,425 pounds of moose or approximately 99 moose, assuming an average moose weight of 900 pounds. Further estimates calculate a single moose could consume on average 58,912 pounds of browse annually. Therefore, a release of 20–30 wolves and a reduction of 210 moose per year would result in approximately 12,371,545 pounds of browse not removed by moose annually. The reduction in this browsing pressure would reduce pressure on plant communities, assuming favorable climatic conditions. Alternative B would introduce 20–30 wolves through the three- to five-year introduction period, equaling upwards of 61,857,600 pounds of browse not consumed.

If winter tick parasitism of moose is density-dependent or associated with predation pressures (appendix A), the increased predation pressure from wolves also may reduce the severity or incidence of tick infestation. Thus, the introduction of a larger population of wolves under alternative B may potentially provide a benefit to the moose population through reduction of winter tick infestations, as population numbers began to decline. However, this benefit would not be immediate, and a lag period would be present between the time of wolf introduction and effects to moose numbers.

Under alternative B, introducing 20–30 wolves over a three to five year period should reduce the rate at which moose utilize vegetation, but would not initially produce a predation rate more than the moose population growth rate. Assuming the wolf population would grow in response to the abundance of food, it is possible that after five years of increased wolf predation moose numbers might begin to decline resulting in reduced herbivory that would allow plant communities a greater potential to recover. After five years, assuming no unforeseen events occur resulting in a wolf population crash and the wolf and moose populations can reach equilibrium at moose numbers below the current level, the plant communities should provide adequate browse and thermal protection for moose on the island. Ultimately the recovery of the plant communities would have a beneficial indirect impact on moose.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. However, the introduction of wolves to Isle Royale could support federal listing of the northwestern moose, depending on the final Recovery Plan and both the USFWS and NPS goals to support a healthy moose population on the island. The introduction of wolves under alternative B could support the goals of a northwestern moose Recovery Plan. Under alternative B the presence of wolves would aid in structuring food webs and maintaining ecological processes for the benefit of biodiversity at lower trophic levels. The introduction of wolves could bring the moose population to equilibrium, reduce herbivory, and facilitate natural rates of forest regeneration in time to avoid an extreme population crash. When the incremental impacts of alternative B are combined with the impacts of other past, present, and reasonably foreseeable future actions, the overall cumulative impacts to moose would be both beneficial and adverse. The incremental impacts of alternative B would provide a noticeable contribution to these cumulative impacts to moose by adding to the beneficial impacts to the moose population and indirect changes in island vegetation.

Conclusion

Under alternative B, the one-time introduction effort of 20–30 wolves to the island would attempt to bring the moose population under varying control of wolf predation, reduce herbivory, and facilitate natural rates of forest regeneration in the shortest amount of time to avoid a significant population crash. Overall, restoring predator-prey interactions could result in long term beneficial impacts to the moose population. This would be a significant change from current conditions which consists of a likely population crash from a decrease in population health in the near future.

Alternative C: Immediate Introduction with Potential Supplemental Introductions

Under alternative C, the initial direct impacts to the moose population would be similar to those described for alternative B, but less extensive, because a smaller number of wolves would be released (6–15 wolves). The lag period between the initial wolf introduction and the ability of the newly formed packs to achieve the similar predation pressure discussed under alternative B would be longer under alternative C, although this period is unknown for all action alternatives.

As discussed in chapter 3, the current growth rate in the moose population is quickly approaching levels that have historically resulted in a moose population crash given accompanying abiotic drivers (e.g., extreme weather events). Although the lower number of wolves introduced under alternative C may result in a smaller number of moose killed in the short term, the lower number of wolves and packs on the island would be better suited to withstand a rapid reduction in moose numbers and prey availability, moving toward historically observed interactions between moose and wolves.

Using the same average predation rates historically recorded on Isle Royale (Mech 1966; Peterson and Page 1988), under alternative C, a population of 6–15 wolves and a kill rate of 7 moose per wolf per year could result in a reduction of approximately 42–105 moose per year. Assuming a mean of 74 moose are removed during the first year and an average of 58,912 pounds of browse annually consumed by one moose (Mech 1966), predation of 74 moose could result in approximately 4,359,488 pounds of browse not removed by moose in the first year of release. However, this calculation likely underestimates the potential in browse retention from reduction in moose numbers, since a moose population crash could occur and the wolf population would be growing at a positive rate, which could be high. Recolonization of wolves in northern Wisconsin grew from an estimated 34 wolves in 1990 to 248 wolves in 2000, an average annual growth rate of 22% (USFWS 2000). It should be noted, however, the wolf population growth rate on Isle Royale would have different control parameters than those on the mainland.

The potential for beneficial reductions in winter tick parasitism on moose would be associated with a reduction in moose numbers and density. However, this potential effect would be more of a long-term beneficial impact with a lag period between the wolf introduction and effects to moose density. This lag period would be longer than that anticipated under alternative B, unless the moose population experienced a dramatic decline.

Alternative C would allow the National Park Service to tailor the release program to the moose population responses to both increased wolf predation pressure and the trend in browse and thermal cover availability. The ability to supplement over the 20-year life of the plan to optimize the top-down influences would improve the native plant communities and habitat conditions. Reduced herbivory would reduce pressure on plant communities, reduce the effects to browse species from variable weather patterns, result in a long-term beneficial impact to moose.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative C the presence of wolves would aid in structuring food webs and maintaining ecological processes for the benefit of biodiversity at lower trophic levels. The introduction of wolves could reduce the moose population numbers, reduce herbivory, and facilitate natural rates of forest regeneration in time to avoid an extreme population crash. Under this alternative, the island ecosystem functions would retain previously observed predator-prey characteristics and result in an ecosystem influenced by both predation (“top-down”) and physical conditions and vegetation community structure (lower trophic levels influences (“bottom-up control”)).

When the incremental impacts of alternative C are combined with other past, present, and reasonably foreseeable future actions, the overall cumulative impacts would be both beneficial and adverse. The incremental impacts of alternative C would provide a noticeable contribution to these cumulative impacts to moose by adding to the beneficial impacts to the moose population and indirect changes in island vegetation.

Conclusion

Overall, under alternative C, the NPS would have the ability to supplement wolves to maximize population viability and genetic health and manage the increasing moose population. This would be a significant change from current conditions which consists of a likely population crash from a decrease in population health in the near future. However, meeting established triggers may result in a delay in wolf introduction and some level of a population crash may be inevitable. The National Park Service would be able to subsequently release wolves based on the moose population responses to both increased wolf predation pressure and the trend in browse and thermal cover availability. Overall, beneficial impacts to the moose population would result in the long term, aiding to restore the balance between the predator-prey relationship of wolves and moose.

Alternative D: No Immediate Action, with Allowance for Future Action

Wolves would be introduced into the system when primarily moose population based metrics are met. However, waiting for established metrics may result in a delay in wolf introduction and some level of population crash may be inevitable. Under this scenario, potential wolf introductions and population supplementation also may be delayed after a moose population crash and until the population had recovered sufficiently to again meet the NPS metrics described in chapter 2.

If future conditions warranted wolf introduction, the number of wolves would be the same as under alternative C. Potential short-term effects to moose would be similar to those described for alternative A. The potential long-term effects to moose would be the same as alternative C.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A and the other action alternatives. Under alternative D the presence of wolves would have an indispensable role in structuring food webs and maintaining ecological processes for the benefit of biodiversity at lower trophic levels. The introduction of wolves could bring the moose population to equilibrium and reduce herbivory.

However, alternative D could delay these effects likely resulting in a crash in the moose population. When the incremental impacts of alternative D are combined with other past, present, and reasonably foreseeable future actions, the overall cumulative impacts would be both beneficial and adverse. The incremental impacts of alternative D would provide a noticeable contribution to these cumulative impacts to moose both before and after action is taken by NPS.

Conclusion

Alternative D would delay wolf introduction until moose metrics and other contributing factors occur, which could be a minimum of three to four years. As a result, some level of population crash may be inevitable and associated adverse effects to native plant communities on the island could occur. If this occurred, potential wolf introductions would likely be delayed until the moose population had recovered sufficiently to meet the alternative's metrics. Once metrics are met, wolves may be introduced allowing for the predator-prey relationship on the island to exert top-down influences.

Comparative Conclusion of Alternatives

Alternative A would not pose immediate benefits to the moose population or ecosystem. Potential long-term benefits under alternative A would be low. The primary difference among the three action alternatives would be the timing of the release of additional wolves to the island and the potential timeframe for predation pressure to influence moose population numbers and positively affect the native plant communities on the island.

All action alternatives would have a beneficial impact to the moose population by providing a means for wolf numbers to control the resident moose population. In general, alternative B would attempt to re-establish the wolf-moose at near equilibrium in the shortest amount of time. Alternative C would provide the most options for a long-term planning. Alternative D would be similar to alternative A initially, potentially resulting in a population crash of moose on the island, and similar to alternative C should metrics be met and wolves introduced.

All action alternatives would have beneficial impacts in the form of increased moose predation by wolves. The moose population is increasing at a high rate, which will likely result in a population crash. Predation, as a result of wolf introduction, would potentially reduce the likelihood or minimize the magnitude of the moose population decline. Alternative B would most likely mitigate the magnitude of a population crash because of the larger number of wolves introduced at one time. However, alternatives C and D would most likely minimize the magnitude of a crash in the moose population more in the long term because these alternatives allow for wolves to be subsequently introduced, if necessary.

WOLVES

Methodology and Assumptions

The interdisciplinary planning team reviewed a substantial body of scientific literature on the wolf population on Isle Royale, wolf packs located on the mainland United States and Canada, and other smaller, isolated wolf populations. In addition, the planning team formed a panel of subject matter experts knowledgeable about wolves and moose and their habitats on Isle Royale (appendix A). This information augmented historical observations and documentation gathered by the National Park Service and other researchers, and was used to support each of the impact topic discussions. The following analyses focus on potential environmental impacts for each alternative.

Alternative A: No Action

> ***genetic rescue****—The recovery of the average fitness of individuals through increased gene flow into small populations, typically following a fitness reduction due to inbreeding depression.*

Under alternative A, the wolf population on Isle Royale would likely be extirpated, given the current population size (two wolves), and inbreeding and reproductive issues. However, natural immigration to the island and subsequent potential genetic rescue is still possible and would depend on the frequency of ice bridges forming between the mainland and the island, which has become more sporadic in recent decades. The effects of climate change on the frequency of ice bridge formation is a fundamental reason that natural wolf immigration is now less likely than in the past (appendix A). As detailed in the affected environment, Hedrick and others (2014) calculated the probability of ice-bridge formation in the near and middle term, concluding the percentage of days with ice formation is now dropping so swiftly that Lake Superior may be largely ice-free within 30 years. If this trend continues it would further limit and potentially prevent natural immigration of wolves. This increasing island isolation offers little opportunity for outside genetic contribution or genetic rescue, which would directly and indirectly affect not only wolves but associated plant and animal communities on the island (MacArthur and Wilson 1967; Rozenzweig 1995; Hedrick et al. 2014).

Hedrick et al. (2014) and Adams et al. (2011) were able to demonstrate that even a limited immigration of wolves to the island has strongly positively influenced the genetic diversity of wolves on Isle Royale. The most recent representative example of this dynamic was the immigration of a lone male wolf to Isle Royale in 1997 via an ice bridge, resulting in an increase in genetic diversity of the resident wolf pack (Adams et al. 2011). However, recent wolf mortality appears to be correlated with the decreased viability of highly inbred individuals (Hedrick et al. 2014). The current population of two animals appears to be inbred, and their survival is questionable due to a combination of ecological and genetic problems and a synergy between the two. A growing consensus is that, while the animals themselves may persist for several years, under alternative A, the population (absent intervention) would likely be extirpated, and associated efforts to manage the moose population would not occur (Hedrick et al. 2014; Mlot 2015; Rahn 2015). Because of the low number of resident wolves, immigration of mainland wolves arriving naturally on the island may not be sufficient without intervention.

Therefore, the likelihood of the remaining two resident wolves surviving and contributing to future population would be very low under alternative A. Immigration may occur in the future, but it is unlikely to occur within a sufficient timeframe or on a sufficient scale (sufficient number of animals) to rescue the current population. Given the geographic isolation of Isle Royale, a rapid loss of genetic variability is likely inevitable (appendix A), even if the historical rate of immigration persists. Under alternative A, the ecosystem would be more influenced by bottom-up controls.

Cumulative Impacts

Past, present, and reasonably foreseeable future actions with the potential to have cumulative impacts with alternative A include the ongoing implementation of the current fire management plan, ongoing management of invasive species at the park, and the management of service animals. The listing of the moose by the US Fish and Wildlife Service under the Endangered Species Act would not be expected to adversely impact wolves on Isle Royale. Preserving habitat and further protecting the species and the role it plays in the island ecosystem would not adversely effect, and could benefit wolves.

Under the current fire management plan (NPS 2004), most naturally ignited fires would continue to be allowed to burn and most human-caused fires are suppressed. Wolves are not directly dependent on, or adversely affected by, fire. Most of the large mammals on Isle Royale are likely to avoid fire of any size. If a fire occurs in the spring when wolves are denning, wolf pups could suffer adverse effects from fire because they are not very mobile. Fires that occur after the end of June generally will not impact wolf pups because they are likely to be mobile enough to move away from the denning site and avoid a fire (NPS 2004). Fire occurrence and size in the spring, when wolves are denning, are generally low because of cooler wet spring weather and less human caused fires typically occur due to lower park visitation during this period. Although the probability of a fire affecting denning wolves is low, there is still a possibility that it could occur. Mitigation measures are taken to reduce impacts on any known wolf den sites (NPS 2004).

Treatment of invasive plant species could have localized temporary adverse impacts on wolves or their prey species that are in the area during treatment from displacement from work crews. Displacement of wolves or their prey species could temporarily disrupt travel patterns, feeding, and breeding. Wolves and their prey species would likely use adjacent habitats temporarily and return once work crews leave the area. Control of invasive species that is beneficial to the growth and distribution of browse species for moose would indirectly benefit wolves by sustaining their primary prey species.

The current management directives for only allowing service animals on the island and in the wilderness would be expected to have a beneficial impact to remaining wolves or immigrant wolves in the future from less risk of interaction between wolves or their prey with pets.

Overall, past, present, and reasonably foreseeable future actions would continue to have potential temporary adverse impacts and long-term beneficial impacts to wolves. Actions such as listing of the moose and preservation of their habitat and actions that enhance habitat for prey species would be considered beneficial. The continuation of current management under alternative A would likely result in extirpation of wolves given the current population size (two wolves), and inbreeding and reproductive issues. When the incremental impacts of alternative A are added to the impacts of past, present, and reasonably foreseeable future actions, the overall cumulative impacts to wolves would be adverse due to the assumption that they would be extirpated, with the incremental impacts of alternative A being responsible.

Conclusion

Under alternative A, the existing wolf population on the island would be impacted because all wolves would likely be extirpated from the island. The change from the current condition would be small since the current wolf population is already so low and not functioning as an apex predator. Future wolves on Isle Royale would depend on immigration from the mainland and genetic diversity and inbreeding would continue to be a problem and it is unknown whether or not it would prevent successful reproduction. Wolf immigration would become more infrequent as climate changes continue to reduce the formation of ice bridges to the island. The absence of wolves would lead to continued change to island ecosystem from the past predator influenced ecosystem to an ecosystem primarily influenced by physical conditions and vegetation community structure (lower trophic levels influences (“bottom-up control”)).

Impacts Common to All Action Alternatives

Under each of the three action alternatives, select management strategies, tools, and techniques would be used for introducing wolves to Isle Royale, under varying management scenarios. Annual wolf mortality has ranged from 0% in 1990 to 70% in 2014 (Vucetich and Peterson 2015). The goals and objectives of each of these action alternatives are to restore the predator-prey dynamics, and ensure the wolf continues to function as the apex predator within the Isle Royale island ecosystem.

For all action alternatives it is unknown whether the two remaining wolves on Isle Royale would contribute further to the gene pool or survive an introduction of unrelated, introduced individuals from the mainland. The two remaining wolves are a single male-female pair that is also father-daughter and half siblings; therefore, the genetic diversity of this remaining pair is low. The resident pair may breed together or breed with introduced individuals, although the reduced viability of the inbred animals would not be expected to contribute significantly to the genetic diversity going forward.

Impacts from intraspecific conflict (e.g., territory defense, prey) are likely under all action alternatives, potentially resulting in mortality of resident and introduced wolves. However, the anticipated level of intraspecific or interpack conflict is likely to vary among the three action alternatives. Overall, it is assumed that up to 10% of introduced wolves may not contribute to population goals due to mortality (e.g., natural death, intraspecific conflict) and; emigration from the island.

Capture Tools. Potential impacts to individual wolves from capture and chemical immobilization may include individual wolf injury or fatality. Wolf experts agree the capture process typically is the most stressful component of wolf introduction (appendix A). Potential effects could include broken bones, localized trauma, drug overdose, hypothermia, hyperthermia, respiratory depression, asphyxia, capture myopathy, pneumothorax (i.e., from tranquilizer darts), trauma, spinal injuries, and drowning (Arnemo et al. 2006; Van Ballenberghe 1984; Sikes et al. 2011).

Capture risk would vary by method used and season implemented. The Northern Rocky Mountain Wolf Recovery Program found that wolves captured using aerial techniques took longer to calm after capture, as compared to wolves caught with modified snares, suggesting the aerial method increased trauma (Fritts et al. 1997). Winter capture using footholds may pose an increase in the risk of temperature-related injuries, such as frostbite and hypothermia (appendix A). Wolf mortality from delivering tranquilizers through darting has been shown to be low (Bangs and Fritts 1996; Fritts et al. 1997). In 1995, 34 individual wolves were captured for the Northern Rocky Mountain Wolf Recovery Program using various methods and only one individual died from a capture-related injury (i.e., dart wound). Other studies have reported capture-related mortality for wolves for all methods ranging from 0.7% (captured (n)=711; Smith et al. 2010) to less than 2% (n=126; Van Ballenberghe 1984) to 3.0% (n=87; Peterson et al. 1984) to 3.4% (n=89; Arnemo et al. 2006).

Capture Location and Logistics. The source populations of wolves would undergo direct social impacts in the form of pack disruption, depending on the number and status of animals removed. Removal of breeders (i.e., breeding pair) in a pack would have a larger impact on the pack from which they are taken than removing lower status individuals, such as non-breeding adults. However, selecting existing breeding pairs may facilitate introduction success (appendix A). Existing pairs would potentially expedite the settling process because a pair bond has already formed. Since wolves are generally thought to avoid incestuous matings (Smith et al. 1997), selecting pairs also would decrease concern of kinship among the founders and reduce potential inbreeding.

Due to the geographic isolation of Isle Royale, a rapid loss in genetic variability is inevitable (NPS 20016b). Therefore, if pups are introduced along with a breeding pair there is concern that impacts from inbreeding could occur sooner than if all founders were unrelated. Brainerd et al. (2008) suggest if a pack has six or more additional non-breeding adults, pup survival is reduced. Additionally, pups are less resilient than adults and adverse impacts from the introduction pose a greater risk to pups than adults.

Time of Capture and Relocation. Potential impacts to introduced wolves could include potential mortality of introduced individuals attempting to return to the mainland via ice bridges from the island, if the season is not cold enough to ensure solid bridge formation. Disruption of the breeding season around mid-February could result in a limited period to form pair bonds, thereby affecting annual reproduction for that year. If pack establishment is delayed, the initial growth rate for the introduced population could be reduced in the short term. Survival rates reported for colonizing wolves following the Northern Rocky Mountain Wolf Recovery Program averaged 0.75 (Smith et al. 2010).

Vaccinations and Health Evaluations. The effect of these health inspections on captured wolves would be beneficial in the short and long term, ultimately better protecting the health of the introduced wolves and minimizing specific diseases (e.g., canine parvovirus). This process would provide baseline samples needed to track the genetic health of the population into the long term.

Transportation. In general, the shorter the time and distance involved for transportation, the less stress on the animals and the greater the chances for a successful introduction. Once captured on the mainland, wolves would be transported to the island via boat, plane, or helicopter. Potential impacts to individual wolves during transportation include increased stress, injury, and habituation to humans. In addition, potential impacts associated with sedation may apply, as discussed for capture methods. Holding facilities in locations near Grand Portage or on the North Shore of Ontario would facilitate shorter transport times. The National Park Service would be able to introduce wolves safely and efficiently, and transportation time would be reduced to the extent possible to avoid adverse impacts to introduced wolves (see chapter 2).

Release. Since releases would occur in the late fall to late winter, the National Park Service would choose release locations to facilitate dispersal, prey location, and carcass provisioning in the short term. The release would minimize the time animals spend in captivity (Fritts et al. 1997; appendix A). The timing of releases would be staggered and dependent on source wolves, and later releases would occur in localities where pack territories adjoin or where packs are presumed not to occur (appendix A).

A concern with other wolf efforts was that individual wolves may attempt to return to their previous territories, as opposed to settling into a new territory. Wolves released into central Idaho traveled almost four times as far as wolves in Yellowstone (82 and 22 kilometers, respectively), and the majority of telemetry locations (77%) from 14 wolves were northward of their release site, toward their area of origin (Fritts et al. 1997). As an island, Isle Royale would limit the ability of released wolves to reach their previous territories on the mainland, unless an ice bridge is present. Given that on average ice bridge formation occurs in one out of 10 years and when formed, typically is short lived (approximately 10 days) (Licht et al. 2015), the potential emigration of introduced wolves back to the mainland would be low. As discussed in the section “Time of Capture and Relocation,” there would be a low-level increase in potential individual wolf mortality under this scenario, if individuals attempted to cross an ice bridge not solidly formed.

Wolves are generalists and highly adaptable, allowing them to occupy a variety of ecosystems; however, they are less flexible socially. The release methods would allow individuals to create a new social hierarchy because they are removed from their previous social construct. However, individuals would need time to discover one another, build social relationships, and establish territories. After release it could take longer to establish pair bonds, delaying successful breeding for up to one year. In the release effort completed in central Idaho in January of 1995 from the Northern Rocky Mountain Wolf Recovery Program, 15 wolves were released, and of these 15 individuals, three pairs had formed within a few months and the first pups were produced in the following spring of 1996 (Fritts et al. 1997). In summary, potential adverse impacts associated with a release would be short term; no long-term impacts would be anticipated.

Carcass Provisioning. Carcass provisioning in the short term would be beneficial to introduced wolves, improving the potential for introduced wolves to remain on the island, separating groups to reduce intraspecific conflict, and ensuring sufficient food availability until the wolves form social bonds and begin hunting as packs. Conversely, providing carcasses also could delay predation and increase intraspecific conflict by concentrating wolves in an area and increase the potential for wolves to associate humans with food. However, the NPS release protocol would limit this latter effect of associating humans with food, thereby, minimizing the potential for future human-wolf conflicts.

Monitoring of Released Wolves. Radio collaring would be expected under all action alternatives, but the number of animals radio collared would vary. The addition of radio telemetry collars to introduced wolves would have a potentially low increase in risk, since the National Park Service would carefully fit the radio collars to the animal to minimize the potential for external injuries (e.g., chafing). The subset of wild-born Isle Royale wolves subsequently collared could experience the same potential adverse effects as described in the “Capture Tools” discussion. Potential effects from aerial telemetry surveys as part of the monitoring program could adversely affect individuals or packs, if monitoring were to occur during deep snow and energy expenditures and stress levels were to increase, accordingly. However, the NPS biologists and research biologists have been conducting aerial monitoring of the Isle Royale wolves for decades. These teams have developed specific winter survey protocols to minimize adverse effects to wolves if environmental conditions warrant, as described in chapter 2.

Alternative B: Immediate Limited Introduction (Preferred Alternative)

Alternative B would have a noticeable initial impact to the mainland wolf population, because of the number of founding wolves (20–30 wolves) taken over a relatively short time period (approximately three years) for initial introduction to Isle Royale. This one-time introduction would require identifying a sufficient number of source wolves on the mainland with adequate geographic spacing and a mix of related individuals (pairs with pups) and non-related individuals to maximize the genetic diversity in the introduced wolves. Although the experts agree the number of founding wolves would likely be more critical to program success than identifying specific source populations, a founding population near carrying capacity of Isle Royale and with an age structure demographically similar to non-harvested populations would likely maximize genetic variation and delay any potential future inbreeding problems (appendix A).

Assuming similar mortality rates from the various capture approaches discussed in the section “Impacts Common to All Action Alternatives,” an estimated 0.5 to 1 wolf fatality could result from capture-related injuries under alternative B over the three- to five-year introduction period for 30 wolves captured (Bangs and Fritts 1996; Fritts et al. 1997; Arnemo et al. 2006; Smith et al. 2010). Potential wolf mortality from capture techniques would be minimized by the capture protocol developed by NPS biologists and capture specialists designed to minimize stress, reduce injuries, and prevent mortalities, as outlined in chapter 2.

The protocol would minimize contact between wolves and humans to reduce potential habituation to human presence or association of food with humans.

Adverse effects under alternative B would include the potential for social competition and increased intraspecific conflict, because a greater number of individuals would be establishing territories, pair bonds, and packs on the island. Peterson and Page (1988) documented wolf mortality from interspecific conflicts on Isle Royale, and the potential for interspecific or interpack conflicts could result in mortality to either the current resident wolves or introduced individuals. However, if food is abundant and some relatedness exists, even in a growing population, intraspecific competition generally is reduced (Mech and Boitani 2003). Since competition and social interactions are natural among wolves and wolf packs, a potential increase in wolf mortality from interpack or interspecific competition and aggression would be expected to be relatively short term as wolves are introduced over a three-year period with the possibility of additional introductions up to five years, with pack stabilization forming once packs and territorial boundaries have been re-established.

Another potential adverse effect from alternative B would be the limitations the National Park Service would have to manage the Isle Royale wolf and moose populations, in the event the wolf population crashed during or after the five-year introduction period. Historically (see chapter 3), a rapid reduction in wolves on Isle Royale have been attributed to disease, malnutrition, starving, parasites, inbreeding, interpack aggression, and accidents (Mech 1966; Peterson 1977; Vucetich and Peterson 2014; Michigan DNR 2015; NPS 2015b). Many of these factors are density dependent and if the goal is to restore wolves on the island to allow maximum likelihood of persistence, the ideal minimum number of wolves derives from the prey biomass (appendix A). Wolf survival on Isle Royale is best explained by the wolf to moose ratio and kill rate, and adult survival is an important predictor of population growth rate (Marucco et al. 2012).

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative B, introducing wolves to Isle Royale could minimize extreme population fluctuations for both wolves and moose, balance the predator-prey dynamics, and reestablish the wolf population to function as the apex predator. Potential adverse impacts could occur to individual wolves during capture, transport, and release and from competition and social interactions once introduced on the island. When the incremental impacts of alternative B are combined with the impacts of other past, present, and reasonably foreseeable future impacts, the overall cumulative impacts to wolves would be both beneficial and adverse. The incremental impacts of alternative B would provide a large contribution to these cumulative impacts to wolves.

Conclusion

Overall, under alternative B, the introduction of wolves would be beneficial. A founding population near carrying capacity of Isle Royale and with an age structure demographically similar to non-harvested populations would likely maximize genetic variation and delay any potential future inbreeding problems (appendix A). This would be a significant change from current conditions which consists of one pair of wolves that appear to be inbred. Some short-term adverse impacts could occur during capture and release and from increased competition and intraspecific competition.

Alternative C: Immediate Introduction with Potential Supplemental Introductions

Under alternative C, capturing and reintroducing a lower number of wolves initially would be more logistically feasible than alternative B, and potential impacts to the source population of wolves on the mainland would be lower initially and more dispersed over the life of the plan, if supplemental captures were implemented. Under alternative C, the potential mortality of wolves during the capture process on the mainland would be expected initially to be less than one individual, given the lower number of wolves to be captured (Bangs and Fritts 1996; Fritts et al. 1997; Arnemo et al. 2006; Smith et al. 2010). However, if supplemental relocations were deemed warranted over the 20-year period, the number of wolves released and wolf fatalities could be similar to those estimated for alternative B (0.2 to 1 wolf fatality for 30 wolves captured; Bangs and Fritts 1996; Fritts et al. 1997; Arnemo et al. 2006; Smith et al. 2010). The National Park Service and capture biologists would implement the same capture protocol, as described in chapter 2, to minimize stress, reduce injuries, prevent wolf mortalities, and minimize contact between wolves and humans.

Under alternative C, the mode of transporting wolves and the location of wolf release sites on the island would be the same as described under alternative B, with one modification. If supplemental releases of wolves were warranted through the 20-year period, the additional wolves would be released at locations separate from established packs and pack activity on the island to minimize potential intraspecific conflict (see chapter 2). This protection measure would aid in minimizing conflicts; however, interpack competition or intraspecific aggression could still occur, but would likely be less than under alternative B. The competition and intraspecific aggression would likely be similar to that typical of wolf social hierarchy, in that some mortality may occur from new wolves moving into established pack territories. If supplemental wolves include breeding pairs or packs, intraspecifc conflict could be higher, since established packs would have high territorial defense against a new pack and established packs are more likely to adopt single individuals.

The lower number of introduced wolves to Isle Royale under alternative C initially would result in a low genetic diversity in the short term. However, the ability of the National Park Service to monitor metrics for both wolves and moose and implement supplemental wolf introductions based on these metrics would enable the National Park Service to achieve population viability and genetic health. As shown in the most recent immigration to Isle Royale in 1997 by a lone male wolf, genetic contribution from mainland wolves can be significant to wolf diversity on the island (Adams et al. 2011).

Given the mean moose population growth rate was 22% between 2012 and 2015 (Vucetich and Peterson 2015) and the population may potentially reach a critical threshold within the next three years, releasing a smaller number of wolves in the short term would be beneficial in the event the island experienced a moose population crash. Introducing a smaller number of wolves during a period of low moose density also might increase the chances of the two populations reaching a historical balance during the 20-year life of the plan.

Cumulative Impacts

Overall, past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative C, introducing wolves to Isle Royale could minimize extreme population fluctuations for both wolves and moose, balance the predator-prey dynamics, and reestablish the wolf population to function as the apex predator. Potential adverse impacts could occur to individual wolves during capture, transport, and release and from competition and social interactions once introduced on the island. When the incremental impacts of alternative C are combined with other past, present, and reasonably foreseeable future impacts, the overall cumulative impacts would be both beneficial and adverse. The incremental impacts of alternative C would provide a large contribution to these cumulative impacts to wolves.

Conclusion

Overall, under alternative C, the ability of the National Park Service to monitor population metrics for both wolves and moose and implement supplemental wolf introductions based on these metrics would enable the National Park Service greater ability to achieve the goal of population viability and genetic health. This would be a significant change from current conditions which consists of two wolves that appear to be inbred. This alternative may increase the chances of the two populations, wolf and moose, reaching a relatively stable level during the 20-year life of the plan. As stated for alternative B, long-term beneficial impacts to wolves would result under alternative C, supporting the wolf as the apex predator on Isle Royale and working to restore the predator-prey relationship of wolves and moose. Some short-term adverse impacts could occur during capture and release and from increased competition and intraspecific competition.

Alternative D: No Immediate Action, with Allowance for Future Action

Under alternative D, when no intervention is convened the current population of wolves is likely to be extirpated. With extremely low or no wolf predation on moose, a crash in the moose population may occur in the near term, with associated adverse and long-term impacts to their associated plant communities.

Moose and ecosystem metrics would be monitored under alternative D and action taken if metrics are met, but given this delay and a likely crash in the moose population, the population size metric would not be met for some time, although the moose population growth rate, calf recruitment, and number of twins could increase after the effect of a crash on animal health subsides. Under this scenario, potential wolf introductions and population supplementation also may be delayed after a moose population crash and until the population had recovered sufficiently to again meet the NPS metrics described in chapter 2.

If future conditions warranted wolf introduction, the number of wolves would be the same as under alternative C (6–15 individuals) with similar relatedness and unrelatedness among the wolves captured. At that point, alternative D would have the same potential beneficial and adverse impacts to wolves as alternative C.

Cumulative Impacts

Overall, impacts from other past, present, and reasonably foreseeable future actions would be the same as described for alternative A. Under alternative D, introducing wolves to Isle Royale could minimize extreme population fluctuations for both wolves and moose, balance the predator-prey dynamics, and reestablish the wolf population to function as the apex predator. However, these beneficial impacts would be delayed under alternative D. Potential adverse impacts could occur to individual wolves during capture, transport, and release and from competition and social interactions once introduced on the island. When the incremental impacts of alternative D are combined with other past, present, and reasonably foreseeable future impacts, the overall cumulative impacts would be both beneficial and adverse. The incremental impacts of alternative D would provide a large contribution to wolves once action is taken to introduce wolves.

Conclusion

Overall, the impacts of alternative D would be similar to alternative A until introduction occurs. Introduction would be taken once the moose and ecosystem metrics are met. The moose and ecosystem metrics may not be met for some time and introduction of wolves would likely be delayed. Once conditions warranted wolf introduction, alternative D would have the same beneficial and adverse impacts to wolves as alternative C and would be a significant change from current conditions.

Comparative Conclusion of Alternatives

Alternative A would not pose immediate benefits to the wolf population or ecosystem; but would still allow a potential, albeit low, for wolf restoration through natural processes. The primary difference among the three action alternatives would be the timing of the release and number of introduced wolves to the island and the potential timeframe for predation pressure to influence moose population numbers.

All action alternatives would have a beneficial impact to the wolf population by providing a means to increase wolf abundance and distribution of wolves on Isle Royale. In general, alternative B would attempt to re-establish the wolf population in the shortest amount of time. Alternative D is similar to alternative A in the short term initially, potentially resulting in a population crash of moose on the island, but in the long-term would result in future wolf introduction similar to alternative C. Thus, alternatives C and D would have a higher likelihood to sustain a beneficial wolf abundance and distribution on the island.

Under all action alternatives, breeding would likely be delayed for one year following translocation. All action alternatives are likely to result in successful reproduction after the first breeding season following initial introduction or any additional supplementation. Alternatively, under alternative A there would be little potential of reproduction, given the level of inbreeding among the existing two wolves and limited immigration from the mainland to Isle Royale. Natural immigration would benefit all alternatives by allowing for gene flow with mainland populations to minimize inbreeding effects.

On Isle Royale, the small population size of the original founding event, coupled with low immigration rates, and decline of the population from ecological events (including canine parvovirus) have all combined to reduce effective population size. While opinions differ as to whether the wolf population would persist over the long term, absent recent population declines due to viral infections and interspecific conflict, the observed survival of the population from initial founding until recently suggests that genetic issues would not drive population dynamics of the wolf population at Isle Royale National Park, as long as there was sufficient gene flow. However, the current population is highly inbred, and its survival is questionable. Some experts share the opinion that a long-term viable population of wolves on Isle Royale may always require human intervention because of inbreeding (appendix A). The genetic diversity of the founding population is an important criterion for population viability. All action alternatives pose a beneficial impact to genetics. For all action alternatives it is unknown whether the two remaining wolves on Isle Royale would contribute further to the gene pool or survive an introduction of unrelated, introduced individuals.

UNAVOIDABLE ADVERSE IMPACTS

The agencies are required to consider if the alternative actions would result in impacts that could not be fully mitigated or avoided (NEPA section 101(c)(ii)).The following discussion describes the potential unavoidable adverse impacts by alternative.

Alternative A: No Action

Under alternative A there would be long-term, unavoidable adverse impacts to wolves on Isle Royale, because without introducing new wolves, wolves would become extirpated from the island, which would continue to change the island to a bottom-up influenced ecosystem. These impacts include a rise in moose populations and corresponding increase in herbivory. Unavoidable adverse impacts to the natural quality of wilderness would also result due to the eventual extirpation of wolves from a natural system. Loss of the wolf population would also result in the loss of some research possibilities.

Alternatives B, C, and D

Under alternatives B, C, and D, there would be unavoidable adverse impacts to wilderness. The introduction of wolves at Isle Royale would have unavoidable adverse impacts on the untrammeled quality as the introduction of wolves would be a direct manipulation of the species and the predator-prey dynamic. This would result in a direct, short-term adverse impact to the untrammeled quality of the wilderness. Unavoidable impacts to wilderness would also occur from the transportation of animals to the island by aircraft if needed, which would impact the undeveloped quality of the island. Long-term impacts to the untrammeled quality of wilderness would result from monitoring activities from activities associated with wolf management and undeveloped qualities from the use of radio collars to various degrees for monitoring purposes.

SUSTAINABILITY AND LONG-TERM MANAGEMENT

In accordance with NEPA, consideration of long-term impacts and the effects of foreclosing future options should be included throughout any NEPA document. According to the World Commission on Environment and Development, "sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their needs." For each alternative considered in a NEPA document, considerations of sustainability must demonstrate the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity. This is described below for each alternative. The agencies must consider if the effects of the alternatives involve tradeoffs of the long-term productivity and sustainability of resources for the immediate short-term use of those resources. It must also consider if the effects of the alternatives over the long term without causing adverse environmental effects for future generations (NEPA section 102(c)(iv)).

Alternative A: No Action

Alternative A would trade long-term productivity for short-term use of resources. The wolf population at Isle Royale would likely be extirpated during the life of the plan, at the expense of the long-term productivity and sustainability of the current overall island ecosystem including the moose population, herbivory and other impacted resources as described in the section "Island Ecosystems" in chapter 3.

Alternatives B, C, and D

Under all action alternatives, there would be a short-term commitment of human resources and short-term impacts to the wilderness on Isle Royale, during wolf introduction activities. The introduction of wolves to Isle Royale would potentially result in protection of the long-term productivity of the current overall island ecosystem. Climate change will affect the long-term sustainability of the current system and these alternatives delay those projected changes.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The agencies must consider if the effects of the alternatives cannot be changed or are permanent (that is, the impacts are irreversible). The National Park Service must also consider if the impacts on park resources would mean that once gone, the resource could not be replaced; in other words, the resource could not be restored, replaced, or otherwise retrieved (NEPA section 102(c)(V)).

Alternative A: No Action

Under alternative A, the absence of any active efforts to introduce wolves to Isle Royale could result in irreversible impacts to wolves because it is expected that without introduction, the small number of wolves currently present on Isle Royale would continue to diminish until the species is extirpated from the island. The island will also continue to change to a bottom-up influenced system.

Alternatives B, C, and D

Alternatives B, C, and D each have the potential to result in irreversible and irretrievable commitment of resources related wolf introduction activities. Capture, transportation, and release of wolves would require the use of non-renewable fossil fuels for the operation of vehicles and equipment.

CHAPTER 5:
Consultation and Coordination

CHAPTER 5: CONSULTATION AND COORDINATION

The National Environmental Policy Act (NEPA) regulations require an "early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action" (40 CFR 1501.7). This section describes the consultation that occurred during development of this draft plan/EIS, including consultation with scientific experts and other agencies. This chapter also includes a description of the public involvement process and a list of the recipients of the draft plan/EIS.

HISTORY OF PUBLIC INVOLVEMENT

The draft plan/EIS was formerly referred to as the Isle Royale Moose-Wolf-Vegetation Management Draft plan/EIS. Based on public comments received and additional internal deliberations, the National Park Service revised and narrowed the scope of the draft plan/EIS to solely focus on the question of whether or not to bring wolves to Isle Royale in the near term.

The Scoping Process

The National Park Service divides scoping process into two parts: internal scoping and external/public scoping. Internal scoping involved discussions among National Park Service (NPS) personnel regarding the purpose of and need for management actions, issues, literature reviews, management alternatives, mitigation measures, how analysis will be completed, available references and guidance, and other related topics.

Public scoping is the early involvement of the interested and affected public in the environmental analysis process. The public scoping process helps ensure that people have been given an opportunity to comment and contribute early in the decision-making process. For this draft plan/EIS, project information was distributed to individuals, agencies, and organizations early in the scoping process, and people were given opportunities to express concerns or views and identify important issues or even other alternatives or alternative elements.

Taken together, internal and public scoping are essential elements of the NEPA planning process. The following sections describe the various ways scoping was conducted for this project.

Internal Scoping

Internal scoping for this project began on May 11, 2015, with a three-day meeting between NPS staff from the Isle Royale National Park, Environmental Quality Division, Midwest Region, Great Lakes Network Inventory and Monitoring Network, and contractor personnel. During the meetings, the National Park Service identified the purpose of and need for action, management objectives, issues, and impact topics. The planning team discussed possible alternative elements, cumulative impacts, and strategies for public involvement throughout the process. The team also clarified various roles and responsibilities for developing the draft plan/EIS. The results of the meeting were captured in a report that is part of the decision file.

The National Park Service coordinated with technical experts during the planning process and solicited input from a team of subject matter experts. The subject matter expert team was chartered to provide technical recommendations to the National Park Service on matters regarding scientific data and analysis through responses to a questionnaire developed by the National Park Service. The subject matter expert team provided technical background information and research references for this draft plan/EIS and input on the range of information and science available on wolf introduction techniques and methodology. The subject matter expert team included individuals with scientific background in the fields of wildlife biology including genetics, wolf biology, and moose biology as well as social scientists. The subject matter expert team lead developed a report that summarized responses to the questionnaire. This summary report provided information on the range of available scientific information related to wolf introduction methodologies and wolf and moose biology. The subject matter expert team also noted future research and monitoring that could be conducted. This report, the Summary of Subject Matter Experts Technical Input Regarding Options for Bringing Wolves to Isle Royale National Park (appendix A) is noted throughout this document and can be found in appendix A.

Public Scoping

Early in the planning process, the park held public meetings in November 2013 to discuss the status of wolf management on the island. The public was provided with background about wolves on the island and was provided the opportunity to ask questions regarding the current status and future of wolf management (NPS 2013b). The public scoping process began on July 10, 2015, with the publication of a Notice of Intent for the Isle Royale Moose-Wolf-Vegetation Management Draft plan/EIS in the *Federal Register* (FR, Volume 80, Number 132) and closed on August 29, 2015, 30 days after the last public meeting. In addition to the Notice of Intent, the National Park Service issued a press release and published a public scoping newsletter on the NPS Planning, Environment, and Public Comment (PEPC) website at http://parkplanning.nps.gov/ISROwolves. The newsletter was also sent to individuals, businesses, agencies, and organizations via email.

The National Park Service held four public scoping meetings:

- On July 27, 2015, in Houghton, Michigan, at the Magnuson Hotel Franklin Square Inn; 47 people attended.
- On July 28, 2015, at Isle Royale National Park, Michigan, at the Rock Harbor Auditorium; 46 people attended.
- On July 29, 2015, in Grand Portage, Minnesota, at the Grand Portage National Monument Visitor Center; 11 people attended.
- On July 30, 2015, at Isle Royale National Park, Michigan, at the Windigo Visitor Center; 24 people attended.

At each meeting, the National Park Service provided attendees with a public comment form and a hard copy of the public scoping newsletter. The newsletter included the proposed purpose and need for the plan, the range of preliminary draft alternative concepts and issues being considered, information on how to comment, and the schedule. Key information was also displayed on banners at each meeting.

During the public scoping comment period from July 10, 2015, to August 29, 2015, 3,583 pieces of correspondence (including letters, emails, and signatures) were received. Of those, approximately 1,822 were not form letters and were considered unique. All public comments were considered to be important and useful guidance in the draft plan/EIS process and were posted on the PEPC website on February 2, 2016.

After review of public comments and internal deliberations, the National Park Service revised and narrowed the scope of the draft plan/EIS to address the presence of wolves on Isle Royale. On March 16, 2016, a second public scoping comment period was announced through a news release and an updated newsletter was published on the NPS PEPC website at http://parkplanning.nps.gov/ISROwolves. The newsletter was also sent to individuals, businesses, agencies, and organizations via email. An amended Notice of Intent was published in the *Federal Register* (FR, Volume 81, Number 108) on June 6, 2016. The second public scoping comment period was open from March 16, 2016, to July 6, 2016.

During this time, 6,517 pieces of correspondence (including letters, emails, and form letters) were received. Of those, approximately 4,637 were not form letters and were considered unique correspondence. All public comments were considered to be important and useful guidance in the draft plan/EIS process and were posted on the PEPC website on October 4, 2016.

Agency Consultation

Agency consultation is an ongoing process, and agencies will receive updated information and newsletters as they become available.

Tribal Consultation. On January 11, 2016, the park held a meeting in Grand Portage, Minnesota, at the Reservation Tribal Council Headquarters, with the Grand Portage Band of the Minnesota Chippewa Tribe. The group discussed the draft plan/EIS, focusing specifically on the potential introduction of wolves. The Tribe had concerns about bringing wolves to the park and questioned the benefits of re-introduction. They also expressed interest in the management of moose through culling.

On July 28, 2016, the park met with the Voight Intertribal Taskforce of the Great Lakes Indian Fish and Wildlife Commission in Carlton, Minnesota. This meeting was not an official tribal consultation, but instead provided an update on park planning efforts, after which individual member tribes could request tribal consultation. The taskforce represented the following member tribes:

- Misi-zaaga'iganiing (Mille Lacs)
- Nagaajiwanaang (Fond du Lac)
- Bikoganoogan St. Croix (Danbury)
- Gaa-miskwaabikaang (Red Cliff)
- Mashkiigong-ziibiing (Bad River)
- Ginoozhekaaning (Bay Mills)
- Waaswaaganing (Lac du Flambeaau)
- Gete-gitigaaning (Lac Vieux Desert)
- Zaka'aaganing (Mole Lake/Sokaogon)

- Gakiiwe 'onaning (Keweenaw Bay)
- Odaawaa-zaaga'iganiing (Lac Courte Oreilles)

During the meeting, various commission members asked questions about the wolf introduction planning efforts at the park. The Ojibwe expressed interest in assisting the park in wildlife management through harvesting. Meeting attendees also noted climate change and questioned how it would be incorporated in the planning process. The Great Lakes Indian Fish and Wildlife Commission members stated they would like to be more involved in research and planning processes at the park since common research projects are currently ongoing.

State Consultation. On September 18, 2015, the Michigan Department of Natural Resources was contacted regarding the process and plan. The Michigan Department of Natural Resources indicated that they did not want to serve as a cooperating agency during the planning process, but will review and provide input into the draft plan/EIS.

As part of the distribution of the draft plan/EIS, the National Park Service will send a copy of this document to the Michigan State Historic Preservation Officer, along with correspondence requesting concurrence with the determination under section 106 that the plan would have no adverse effects on listed cultural resources.

US Fish and Wildlife Service Consultation. On September 21, 2015, the US Fish and Wildlife Service was contacted regarding the process and plan. The US Fish and Wildlife Service indicated that they did not want to serve as a cooperating agency during the planning process. During this communication, the park discussed the current position of the US Fish and Wildlife Service on NPS actions related to this planning process. The US Fish and Wildlife Service indicated that Isle Royale qualifies as critical habitat for the gray wolf but the population of wolves is not counted toward a recovery population goal under the Endangered Species Act.

The National Park Service sent a technical assistance request letter to the US Fish and Wildlife Service on November 9, 2016, for input on determination of affects to listed species and seeking US Fish and Wildlife Service (USFWS) input and technical assistance on the potential consultation and permit process needed for the translocation of wolves should the National Park Service ultimately select a translocation alternative.

RECIPIENTS OF THE DRAFT PLAN / ENVIRONMENTAL IMPACT STATEMENT

Upon publication of the Notice of Availability of the draft plan/EIS in the *Federal Register*, a press release will be issued announcing the availability of the document for public review. Notice will be provided to interested individuals and organizations via the park website, email, Facebook, or postcard. Copies of the document will be available at local libraries and the document will also be provided to the following:

Congressional Delegates

Honorable Gary Peters, Senator

Honorable Debbie Stabenow, Senator

Office of the Michigan 1st District Representative

Federal Agencies

Environmental Protection Agency, Region 5

U.S. Fish and Wildlife, Ecological Services, East Lansing Field Office

State and Local Governments

Michigan Office of the Governor

Michigan Department of Natural Resources

Michigan State Historic Preservation Officer

Village of Michiana

Affiliated Tribes

Tribes listed in the “Tribal Consultation” section above will receive a copy of the document.

Organizations

Center for Biological Diversity

DeGraaf Nature Center

Defenders of Wildlife

Humane Society of the United States

Isle Royale and Keweeaw Parks Association

Michigan Technological University

Michigan United Conservation Club

National Parks Conservation Association

National Wildlife Federation

Sierra Club

The Wildlife Society

Upper Peninsula Environmental Coalition

Wilderness Watch

LIST OF PREPARERS AND CONSULTANTS

Name	Title	Education/Experience	Role
National Park Service			
Kelly Daigle	Team Lead, Environmental Protection Specialist, Environmental Quality Division, Washington Support Office	3 years with National Park Service; B.S. Journalism and International Studies, University of Kansas; M.A.S. Environmental Policy and Natural Resource Management, University of Denver	Project Management; Document Review
Lindsay Gillham	Project Manager/ Environmental Protection Specialist, Environmental Quality Division, Washington Support Office	10 years with National Park Service; 15 years of NEPA experience; B.S. Natural Resources Recreation, Colorado State University; J.D. (Juris Doctorate) University of Oregon School of Law	Project Management; Document Review
Phyllis Green	Superintendent, Isle Royale National Park	20 years of experience with the USDA Forest Service and 15 years of experience with the National Park Service evaluating and implementing projects under NEPA and project planning needs for resource enhancement or protection B.S. Forestry, Michigan Technological University; B.A. Liberal Arts, Technical Writing/Communication, M.S. Natural Resource Management minor in Business	Document Review; Recommending Officer
Jeff Henquinet	Environmental Protection Specialist, Isle Royale National Park	6 years with National Park Service; Ph.D. Fisheries and Wildlife, Michigan State University; J.D. (Juris Doctorate), Lewis & Clark Law School; B.S. Biology, University of Wisconsin – La Crosse	Document Review
Rick Kahn	Wildlife Biologist, Biological Resources Division, Washington Office	6 years with National Park Service; 40 years of professional wildlife experience	Technical Review; Document Review
Mark Romanski	Chief of Natural Resources, Isle Royale National Park	20 years with the National Park Service to include wildlife and natural resources management; M.S. Applied Ecology, Michigan Technological University; B.S. Biology, University of Wisconsin-Stevens Point	Document Preparation; Technical Review
Bill Route	Ecologist and Program Manager, Great Lakes Inventory and Monitoring Network	28 years with National Park Service; B.S. Wildlife Resources, University of Idaho; M.S. Vertebrate Ecology, Michigan Technological University; Certified Wildlife Biologist	Document Review: Ecology, Monitoring, and Policy

Name	Title	Education/Experience	Role
Tanya Shenk	Ecologist and NPS Research Coordinator, Great Plains Cooperative Ecosystem Studies Unit	6 years with the National Park Service: M.S. and Ph.D. in Wildlife Biology from the Department of Fish, Wildlife and Conservation Biology at Colorado State University; B.S. in Zoology from Ohio State University	Document Development: Ecology
Elizabeth Valencia	Chief of Interpretation and Cultural Resources	26 years National Park Service; M.A. History, Purdue University; B.A. History, University of Wisconsin-Platteville	Document Review, primarily Cultural Resources and Interpretation; Public Information Officer
Louis Berger, Inc.			
Lori Fox	Planner, Project Manager	M.C.P. University of Maryland; B.S. Natural Resources and Environmental Science, University of Michigan	Project Management; Document Compilation and Review
Joshua Schnabel	Environmental Planner, Deputy Project Manager	M.A. Geography/Natural Resource Management, San Francisco State University; B.A. Sociology, University of Northern Colorado	Project Management; Document Compilation and Review
Jeffrey Gutierrez	Environmental Planner	M.U.R.P. Environmental Land Use Planning, University of Colorado-Denver; B.A. Environmental Studies, University of Vermont	Document Compilation and Review
Katie Prince	Planner	B.S. Political Science, United States Military Academy	Document Compilation
Rudi Byron, AICP	Senior Environmental Planner	M.U.R.P. Urban and Regional Planning, Virginia Tech; B.S. Environmental Science and Policy, University of Maryland, College Park	Document QA/QC
Laura Totten	Senior Environmental Scientist	M.S. Biology, Fort Hays State University; B.S. Biology, Fort Hays State University	Document QA/QC
Megan Blue-Sky	Environmental Scientist / GIS Specialist	B.A. Geography, University of Colorado Denver	Map Production
Kara Grosse	Environmental Planner	Master of Environmental Management, Water Resource Management, Duke University; B.A. Environmental Studies and Natural Resource Management, University of Colorado at Boulder	Document Compilation
West, Inc.			
Bret Callaway	Biologist 3	M.S. University of California, Environmental Science and Management; B.S., University of California, Environmental Science	Vegetation and Climate Change Literature Review
Steven Courtney	Principal Ecologist	Ph.D. University of Durham, Biology; B.S. University of Durham, Botany and Zoology	Wolf Literature Review; Wolf Analysis

Name	Title	Education/Experience	Role
Tracey Johnson	Research Biologist 2	Ph.D., Oregon State University, Wildlife Science; M.S., Kansas State University, Biology; B.S. Texas A&M University, Psychology, Minor: Wildlife and Fisheries Sciences	Moose Literature Review; Moose Analysis
Lori Nielson	Research Biologist 5	B.S. Oklahoma State University, Wildlife Ecology and Management	Literature Review Manager and Wolf Compilation; Wolf and Moose EIS Analyses
Gretchen Norman	NEPA Project Manager	B.A. Colorado College, Biology; M.S. New Mexico State University, Range Science	EIS Analyses and Data Compilation
Carisa Stansbury	Biologist 3	M.S. University of Idaho, Environmental Science; B.S. University of Wyoming, Zoology and Physiology	Wolf Analysis; EIS Data Compilation
Dale Strickland	Principal Ecologist 3	Ph.D., University of Wyoming, Ecology; M.S., University of Tennessee, Wildlife Biology; B.S. University of Tennessee, Zoology	Wolf and Moose EIS Analyses
EA Engineering Science and Technology			
Jayne Aaron, LEED AP, Envision SP	Wilderness Planner, NEPA Specialist	M.A. Environmental Policy and Management, University of Denver; Bachelors of Environmental Design, University of Colorado, Boulder	Wilderness Character Assessment
The Final Word			
Juanita Barboa	Technical Editor	B.S. Technical Communication, New Mexico Institute of Mining and Technology	Technical Editing
Sherrie Bell	Technical Editor	Business Management Coursework, New Mexico State University	Technical Editing; Document Design

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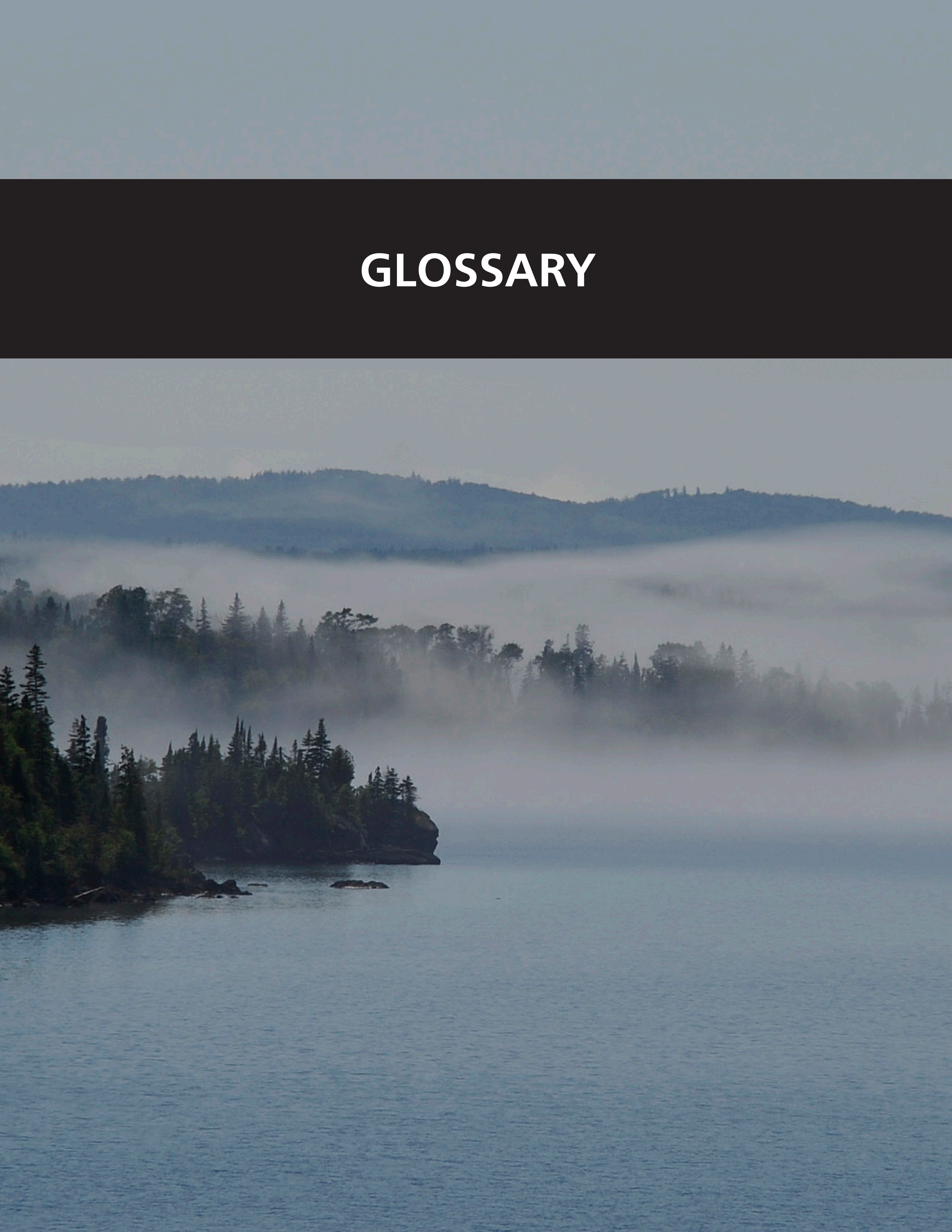
GLOSSARY



GLOSSARY

action alternative—An alternative that would involve a change from existing conditions, including changes to established trends or management direction.

adverse impacts—A change that declines, degrades, and/or moves the resource away from a desired condition or detracts from its appearance or condition.

affected environment—Term used in the *National Environmental Policy Act* to denote surface or subsurface resources (including social and economic elements) within or adjacent to a geographic area that could potentially be affected by a proposed action; the environment of the area to be affected or created by the alternatives under consideration. (40 CFR 1502.15).

alternative—Combination of management prescriptions applied in specific amounts and locations to achieve desired management goals and objectives.

apex predator— An apex predator, also known as an alpha predator or apical predator, is a predator residing at the top of a food chain upon which no other creatures prey.

ballast water—Water carried in a ship's ballast tank to improve stability. The release of ballast water can result in the unwanted introduction of invasive species to new environments.

beneficial impacts—A positive change in the condition or appearance of the resource or a change that moves the resource toward a desired condition.

biodiversity—The degree of variation of life forms within a given ecosystem, biome, or on an entire planet.

bottom-up control-when the nutrient supply and productivity and type of primary producers (plants and phytoplankton) control the ecosystem structure.

carcass provisioning — The intentional placement of supplement food sources on the island, resulting in an intentional manipulation of the wolves' hunting and feeding.

climate change (global warming)—The effects of rising global atmospheric greenhouse gas emission concentrations on global temperature and weather patterns over an extended period of time.

collaring—The act of capturing a wolf and placing a radio collar on the wolf.

Council on Environmental Quality—A division of the Executive Office of the President that acts as a coordinator for federal environmental efforts. The Council on Environmental Quality works closely with federal agencies and White House offices to develop environmental policies and initiatives.

cultural landscape—A geographic area, including both cultural and natural resources and the wildlife or domestic animals, associated with a historic event, activity, or person exhibiting other cultural or aesthetic values.

cumulative impacts—The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions.

demographics—Statistical data relating to the population and particular groups within it.

denitrification—The biological reduction of nitrate to nitrogen gas by denitrifying bacteria in the soil.

diffuse predation—A suite of species all preying upon populations but with high redundancy, such that individual predator species have little measurable effect.

direct impacts—Impacts that would occur as a result of the proposed action at the same time and place of implementation.

disturbance—A temporary change in environmental conditions that can cause a distinct change in an ecosystem.

Ecological Integrity Framework—Methodology to guide planning for the conservation of biological and ecological resources in U.S. National Parks. It combines aspects of the planning processes for conservation that were developed between NatureServe and The Nature Conservancy.

effects—See “impacts.”

enabling legislation— A national park's enabling legislation is the Act of the United States Congress that provides authority to legally establish the park as a unit of the NPS system.

endangered species— The classification provided by the US Fish and Wildlife Service to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range.

Endangered Species Act—Provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. The *Endangered Species Act* was passed by Congress on December 28, 1973.

environmental assessment—A concise public document prepared to provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement or a finding of no significant impact. An environmental assessment includes a brief discussion of the need for a proposal, the alternatives considered, the environmental impacts of the proposed action and alternatives, and a list of agencies and individuals consulted.

environmental impact statement (EIS)—A document prepared to analyze the impacts on the environment of a proposed project or action and released to the public for comment and review. EISs are prepared when there is the potential for major impacts on natural, cultural or socioeconomic resources. An EIS must meet the requirements of *National Environmental Policy Act*, Council on Environmental Quality, and the directives of the agency responsible for the proposed project or action.

epizootic—Of or relating to a disease that is temporarily prevalent in an animal population.

extirpate—To remove completely.

fauna- all the animal life in a particular region or period

fecundity—The ability to produce offspring.

Federal Register—Daily publication of the National Archives and Records Administration that updates the Code of Federal Regulations, in which the public may review the regulations and legal notices issued by federal agencies.

floodplain—The lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands, and including at a minimum, that area subject to temporary inundation by a regulatory flood.

flora-all the plant life in a particular region or period

genetics—Unique genes pertaining to a specific population (population genetics).

genetic rescue—The process where inbred populations receive genes from another population to increase their genetic diversity and overall survival success.

hard release—A release tactic where the animal is allowed to exit a transport container into the wilderness. This method does not require the construction of a containment system or additional care while in captivity.

herbivory—The eating of plants, specifically plants that are still living.

impacts—The likely effects of an action upon specific natural, cultural, or socioeconomic resources. Impacts may be beneficial, or adverse and direct, indirect, and / or cumulative.

impairment (NPS policy)—As used in NPS Management Policies, “impairment” means an adverse impact on one or more park resources or values that interferes with the integrity of the park's resources or values, or the opportunities that otherwise would exist for the enjoyment of them, by the present or a future generation. Impairment may occur from visitor activities, NPS activities in managing a park, or activities undertaken by concessioners, contractors, and others operating in a park. As used here, the impairment of park resources and values has the same meaning as the phrase “derogation of the values and purposes for which these various areas have been established,” as used in the *General Authorities Act*.

indirect impacts—Impacts that would occur as a result of the proposed action but later in time or farther in distance from the action.

interpack—Among different packs.

interspecific—Occurring between two species.

Intrapack—Within one pack.

Intraspecific—Occurring between individuals of the same species

invasive species—Species that are non-native to the ecosystem being considered.

island biogeography—The study of species composition and richness on an island or another isolated area.

key ecological attributes—Resources that result in less confusion as to how goal are interpreted, and greater clarity for management to develop detailed plans.

litter dynamics—The interplay of leaf fall, deposition, and decomposition.

management policies—The NPS *Management Policies* set the basic servicewide policy of the National Park Service. They provide the overall foundation, set the framework, and provide direction for management decisions within the National Park Service. The management of the National Park System and National Park Service programs is guided by the US Constitution, public laws, proclamations, executive orders, rules and regulations, and directives of the Secretary of the Interior and the Assistant Secretary for Fish and Wildlife and Parks. Other laws, regulations, and policies related to the administration of federal programs, although not cited, may also apply.

melanistic—All black, specifically relating to animals.

mesocarnivore—Animals whose diet consists of 50-70% meat balanced with fungi, fruits, and other plan material (e.g., coyotes, foxes, martens).

mesopredator—A medium-sized, middle trophic level predator, which both predates and is predated upon. Examples are raccoons, skunks and snakes.

mesopredator release—A process whereby mid-sized carnivorous mammals became far more abundant after being "released" from the control of a larger carnivore.

mitigation—"Mitigation" as defined in the *National Environmental Policy Act* (40 CFR 1508.20), includes: avoiding the impact altogether by not taking a certain action or parts of an action; minimizing impacts by limiting the degree or magnitude of the action and its Implementation; rectifying the impact of repairing, rehabilitating, or restoring the affected environment; reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; compensating for the impact by replacing or providing substitute resources or environments.

mitochondrial DNA—DNA located in the mitochondria, which are structures within cells that convert chemical energy into adenosine triphosphate.

mustelidae—A family of carnivorous mammals, including the otter, badger, weasel, marten, ferret, stoat, mink and wolverine.

national park system—The total sum of the land and water now and hereafter administered by the Secretary of the Interior through the National Park Service for park, monument, historic, parkway, recreational, or other purposes.

natural floodplain values—Attributes of floodplains which contribute to ecosystem quality, including soils, vegetation, wildlife habitat, dissipation of flood energy, sedimentation processes, ground water (including riparian ground water) recharge, etc.

natural quality—The natural quality of wilderness ecological systems are substantially free from the effects of modern civilization. This quality is preserved or improved, for example, by controlling or removing nonindigenous species or restoring ecological processes. This quality is degraded by the loss of indigenous species, occurrence of nonindigenous species, alteration of ecological processes such as water flow or fire regimes, and effects of climate change.

no-action alternative—An alternative that maintains established trends or management direction. For an oil and gas operation, it typically means that the action as proposed would not occur or current management would continue.

Organic Act—The law that established the National Park Service in 1916.

parasitism—A non-mutual symbiotic relationship between species, where one species, the parasite, benefits at the expense of the other, the host.

pathogen—A specific impetus of disease.

phenotype—Observable physical or biochemical characteristics of an organism, as determined by both genetic makeup and environmental influences.

population dynamics—The changeability of a population, specifically relating to birth and death rates.

predation—The act of killing and eating prey.

preferred alternative—The alternative that "would best accomplish the purpose and need of the proposed action while fulfilling the NPS statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors.

prey species—Species that are subject to hunting by predators.

refuge—A place that provides shelter or protection.

resiliency—The ability of an ecosystem to recover quickly from a disruption.

riparian-of or relating to wetlands adjacent to rivers and streams

scavenger species—Species that feed on dead animals and plants.

scoping—Scoping is done during the initial phase of project planning to seek input from a variety of sources. This input is used to identify issues, areas requiring additional study, alternative methods and locations, and topics to be analyzed in the *National Environmental Policy Act* document. Scoping is done internally with National Park Service staff and externally with the interested public, other agencies, and stakeholders.

seral—Relating to an ecological sere, which is an intermediate stage in ecological succession in a community that is advancing towards a climax community.

soft release—A release tactic that gradually introduces an animal into an environment.

spatial heterogeneity—Refers to the uneven distributions of various concentrations of each species within an area.

succession—The sum of the changes in the composition of a community that occur during its development towards a stable climax community.

supplementation—Something added to complete, make up for a deficiency, or strengthen something.

temporary closures—Temporary area closures to avoid human-wolf interactions and ensure resource protection and visitor safety.

threatened species—Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

top-down driven ecosystem—When a top predator controls the structure or population dynamics of the ecosystem.

translocation—The capture, transport and release or introduction of a species.

trophic cascade—When a change in the abundance of predators at higher trophic levels alter the behavior of their prey.

trophic downgrading—The process of removing large apex predators from nature and the consequences on ecosystems.

trophic dynamics—The system of trophic levels describing the position that an organism occupies, as well as the sequence of consumption and energy flow in an ecosystem.

trophic level—The trophic level of an organism is the position it occupies in the food chain.

undeveloped quality—An area of undeveloped federal land retaining its primeval character and influence, without permanent improvements or human habitation.

untrammeled quality—The word "untrammeled" describes something that is unconstrained, not limited or restricted. The untrammeled wilderness is one in which ecological systems and their biological and physical components are autonomous and free from human intervention.

vegetation (aquatic)—Plants that are adapted to living in fresh or saltwater environments.

vegetation (terrestrial)—Plants that occur on land.

visitor experience—The experience incurred by people to an area.

water quality—The biological, chemical, and physical characteristics of water compared against the needs of biotic species.

wetlands—land or areas that are covered, often intermittently, with shallow water or have soil that is consistently saturated with moisture.

wilderness—An area that is uncultivated and uninhabited by humans.

Wilderness Act—A law which formally recognized wilderness as "an area where the earth and its community of life are untrammeled by man." It created the National Wilderness Preservation System which dedicated acres of federal lands as wilderness. The law was passed by Congress into law in 1964.

wolves—Large predatory canids (genus *Canis*) that live and hunt in packs and resemble the related dogs. Native to North America.

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APPENDIX A

APPENDIX A: SUMMARY OF SUBJECT MATTER EXPERTS

Summary of Subject Matter Experts Technical Input Regarding Options for Bringing Wolves to Isle Royale National Park

Matthew Gompper, Lead Coordinating Subject Matter Expert, School of Natural Resources, University of Missouri, Columbia, MO 65211

Overview

As part of the National Park Service (NPS) evaluative process for alternatives and approaches for determining whether and how to bring wolves to Isle Royale National Park (IRNP), a team of eight Subject Matter Experts (SMEs; Appendix 1a) were tasked with completing a NPS-approved questionnaire (dated May 16 2016, version 4). The questionnaires were developed and distributed by a Lead Coordinating SME with significant input and approval from the NPS. The Lead Coordinating SME was tasked by the NPS with compiling the resulting completed questionnaires, and with summarizing the technical input with regards to the various options for bringing wolves to Isle Royale, as well as any considerations regarding a no-action alternative. This document is the summary product.

The questionnaire addressed issues associated with four potential management options (Appendix 2) delineated by the NPS. These options, are respectively deemed Alternative A (A non-intervention, no action alternative), Alternative B (Immediate Limited Introduction), Alternative C (Immediate introduction with potential supplemental introductions), and Alternative D (No immediate action with allowance for future actions). Some portions of the questionnaire addressed issues common to all or multiple alternatives.

On the Value, Need, and Time-frame Associated with Scientific Research and Monitoring on IRNP

1.1. *Scientific Research and Monitoring: Regardless of actions taken as a result of the NPS's current planning process regarding wolf reintroduction, research and monitoring of Isle Royale's ecosystem will be necessary to inform park managers on ecosystem health. Answer the following questions to exclude research and monitoring activities associated with wolf reintroduction alternatives as these will be addressed later in this document.*

1.1.1. *What research and monitoring activities should be conducted, excluding wolf introduction, with what goals, and how should these research and monitoring protocols be undertaken? Discuss the pros and cons of the suggestions you provide. Topics or subject matter under this question could include: moose population demography, distribution and abundance; herbivory and associated ecosystem impacts; climate change; or any salient research and monitoring activities that, in your opinion, is critical to understanding the island's ecosystem.*

1.1.2. *Other Suggestions or recommendations?*

1.1.3. *The life of this EIS is intended to cover about a 20 year operational period, what is the range of changes to habitat and the ecosystem that might occur.*

The first set of questions addressed scientific research and monitoring (excluding wolf research) activities and goals on IRNP, as well as the ecological change in IRNP habitat and the IRNP ecosystem that might occur during the 20 year operational time-frame of the Environmental Impact Statement. In general there was consensus among the SMEs that research and monitoring on IRNP should "strive to determine and monitor ecosystem function", would aid in identifying and quantifying deviations from expected patterns of ecosystem function and structure, and should include monitoring of representative species from all trophic levels, and the interactions of those trophic levels.

More specifically, the SME noted the need for continued research on, and monitoring of:

- Moose, beaver and snowshoe hare demographics, including population size and age structure, pregnancy and reproductive rates, cause specific mortality rates, and related measures such as those providing measures of health such as marrow fat levels and body size measures. For beavers, additional parameters include counts of the numbers of colonies and the size of colonies.
- Moose genetic homozygosity and moose genetic 'connectedness' to the mainland populations.
- Moose and beaver feeding rates and foraging paths, and their impacts on plant (fir, aspen, spruce, maple birch, yew, ash and aspen) recruitment so as to address whether sustained recruitment gaps are occurring. Further, continued research should focus on understanding the intensity of moose and beaver herbivory in aquatic systems, with a goal of understanding herbivore impacts on native fish taxa.
- The influence of abiotic factors such as weather patterns (e.g. the North Atlantic Oscillation) and climate warming, snow depth, drought and fire on the plant community.
- Connectedness and the possibility for natural migration between island and mainland populations of plants and animals. This research focus, by incorporating climate predictions and ice connections might allow models that predict the likelihood of natural migration, which in turn might inform management decisions for IRNP.
- The dynamics of invasive as well as native rare species on the island, with a particular emphasis on how vulnerability or establishment is influenced by climate change and changes in large mammal populations (or indeed, how invasive species might influence large mammal populations on IRNP).
- The dynamics of scavenger species such as red fox and raven. On IRNP, these species are key scavengers of dead moose.
- Visitor expectations, the impact of herbivory on these expectations, and the "essential character" of the park.

These various foci are non-exclusive and are linked by a need extend the existing body to data to understand the linked issues of how herbivory and climate influence the IRNP ecosystem. The SMEs also indicated the need to consider the approaches that would best provide this data, including non-invasive camera, genetic and dietary sampling, new moose and beaver exclosures, enhanced GIS capacity and weather and water quality monitoring for IRNP.

Several of the SMEs noted that a past panel comprised of a well-recognized group of ecologists was previously brought together to address a similar topic (ongoing research and recommendations for science in IRNP). The panel produced a *Strategic Plan for Scientific Research in Isle Royale National Park* (Schlesinger et al. 2009) whose time frame was relatively long-term. The advice and foci noted in that document remain appropriate and pertinent.

Research and monitoring programs are potentially expensive and laborious. This derives from the sample sizes necessary to overcome drawbacks associated with expected losses of known individual plants or animals, and from the technologic or logistic difficulties of data collection. Research and monitoring also has the potential to negatively influence visitor experiences or perceived wilderness values. Further, research outcomes can sometimes be inconclusive. However, such programs would provide the necessary information to assess and understand the abundance and dynamics of IRNP's major herbivore species and the trophic levels above and below these. The programs would also provide the necessary information for understanding the likelihood of successfully meeting specific management goals and would "increase the value of this NPS unit."

With regard to the 20 year operational period, the primary influences on the community are likely to be herbivory and fire, with other key factors being variance in snow depth and the North Atlantic Oscillation. Assuming no increase in wolves, possible changes associated with high levels of moose herbivory include the decline of balsam firs on the west end of IRNP, the potential for more savannah-like spruce-dominated forests, and changes in moose populations (population crash associated with over-browsing, followed by recovery). Beaver populations will possibly reduce abundance of aspen and willows and promote more coniferous forest or wetland meadows. Fire levels are likely to stay the same or increase (but not decrease). New invasive species are likely to colonize the island.

Obtaining, Releasing and Monitoring Wolves on IRNP

Management alternatives B and C involve translocating wolves from the mainland to IRNP. The second component of the questionnaire focused on how this might occur, should one of these options be chosen. Questions addressed obtaining wolves, the number of wolves, the logistics of release, and the monitoring of released wolves.

2.1.1. Where (geographic location) should the source wolves be obtained? If wolves are added over time, should NPS use multiple source populations?

2.1.2. What pre-release care or treatment should wolves receive?

2.1.3. Genetics

- *a) What are the pros and cons of various genetic mixes of reintroduced wolves?*
- *b) Provide an assessment of genome variation and deleterious variants and our awareness and ability to track them.*
- *c) What level of genetic dissimilarity between prospective mates should be considered and used to select among founders?*
- *d) If the current population of wolves on Isle Royale persists to the time of reintroducing new wolves, are there concerns with these wolves passing on deleterious traits (e.g., spinal malformations) to the introduced population? Should members of the current resident population of wolves be removed from the island before the introduction of new wolves due to their poor genetic health? What are the pros and cons of retaining these wolves or removing these wolves?*

Should translocations occur, source wolves should ideally derive from populations geographically near the park, such as north-central Ontario, Minnesota, and Michigan or Wisconsin. Selecting wolves from widely separated regions (e.g. western North America and Michigan) might increase the risk of outbreeding depression. Selecting wolves from near the park where ice bridges have historically occurred would increase the chance of the wolves having locally adapted genotypes that would enhance survival and population growth, and would have experience with the prey species occurring on Isle Royale. Ideally wolves would have experience with moose, but given recent declines in mainland moose, these animals may be more difficult to obtain in the future. Previous research has suggested wolves sort according to similarity in prey base and habitat, and thus selecting wolves from a habitat that is similar to that observed on Isle Royale and is not too geographically distant should be considered. Selecting existing wolf mating pairs from the mainland might facilitate translocation success as these individuals are likely not closely related and have already pair-bonded. Wolves associated with pet or livestock depredation may be less desirable for translocation.

Given the geographic isolation of Isle Royale, a rapid loss of genetic variability is likely inevitable. Therefore concerns regarding inbreeding depression in a reestablished IRNP wolf population are paramount. One approach to minimizing this concern in the short term is to obtain wolves from several source populations so as to maximize genetic variability and reduce the rate of loss of heterozygosity. However, more critical than the specific source population(s) is the number of founding wolves. A founding population of nearly that expected of an Isle Royale population near carrying capacity and with an age structure demographically similar to that of non-harvested mainland populations would maximize genetic variation and importantly, "*…would delay inbreeding problems beyond the EIS period."*

Independent of the geographic source, time in captivity should be minimized so as to avoid exposure to humans. Wildlife veterinarians should be involved in any release effort to as to ensure that injuries sustained during capture are addressed prior to release and to vaccinate wolves against pathogens of concern (e.g. canine parvovirus, canine distemper virus, rabies virus). Consideration should also be given to macroparasites so as to avoid introduction of parasites such as the tapeworm, *Taennia krabbei*, and the causative agent of sarcoptic mange, *Sarcoptes scabiei*, which are currently absent from the island.

A further consideration is the extent of admixture of the founding translocated wolves. There is conflicting research on the genetic history of wolves from the Great Lakes region with some research suggesting past admixture between grey wolves and coyotes, and other research indicating admixture of grey wolves and eastern wolves (*Canis lycaon*) with relatively little introgression from coyote. Some recent work has also suggested that the eastern wolf is not a valid taxon. While the recent IRNP wolf population showed genotypic evidence of past admixture with coyotes, the uncertain status of hybrids under the US Endangered Species Act, and the potential for pure grey wolves to be somewhat larger in body size and therefore potentially more efficient predators of moose are deserving of consideration. On the one hand, selecting wolves from a source region that is pure grey wolf or that has relatively lower levels of eastern wolf or coyote ancestry should be encouraged. On the other hand, larger pure grey wolves may require larger territories than the smaller Great Lakes wolves, which might alter the carrying capacity and the predator-prey dynamics on Isle Royale.

Nonetheless, levels of heterozygosity and inbreeding coefficients of the Isle Royale wolf population have fluctuated greatly over time, and have changed rapidly when short-term genetic rescue has occurred. In general, variability is lower than observed on the mainland. The fixation of deleterious alleles has been inferred based on observations of putatively maladaptive phenotypes. While a full genome analysis of wolves to identify deleterious variation is underway, insights from these analyses are not yet available. Thus if translocations occur, the issue of selecting top candidates should be revisited with researchers knowledgeable in canid genetics.

Concerns as to whether the existing wolves on Isle Royale, which may possess deleterious traits, might pass the alleles underpinning these traits to translocated wolves elicited a diversity of responses from the SMEs. There was general support for not removing the remaining wolves, as this would be a further deviation from a natural processes paradigm for park management, would potentially raise significant public-relations concerns, would result in the loss of opportunity to gain insights on genetic rescue, and would be logistically difficult. Furthermore, the passing on of the deleterious alleles might not be a concern because the alleles would be masked by those of the new founders (although the characteristic may arise again as inbreeding levels for the rescued wolf population increase). On the other hand, the existing wolves would provide additional genetic variability to the restored population and might enhance rates of knowledge transfer to the translocated wolves. Given the low number of wolves remaining on the island, if concerns remain, a strategy to avoid the maintenance of deleterious alleles in the population might be to wait until the last wolves have died before commencing translocations, or sterilize the existing wolves to remove the risk. However, a risk associated with such an approach is that the continued delay in the onset of translocations would also allow the ecological processes (e.g. herbivore increases and potentially deleterious herbivory pressures on IRNP's plant community) acting on the island to continue or even increase with minimal top-down predation pressure.

2.1.4. Do the source wolves need to have experience killing the moose, found on Isle Royale? Explain.

A primary prey species on Isle Royale is moose, and so ideally the translocated wolves would have experience in killing moose. However, wolves are capable of learning to kill novel prey, although this learning may take years and is potentially risky to individual animals. If some of the wolves have experience with moose, social collaboration may increase the rates of learning.

2.1.5. Suggest a strategy for handling the animals during capture and holding prior to release.

Animals should be captured using either helicopter net-gunning or modified foothold traps. It is important to minimize opportunities for humans and wolves to interact or for wolves to associate people with food. However, the SMEs were divided in opinion on whether animals should be immediately transferred to IRNP or instead first transferred to mainland holding pens while health and genetic protocols are conducted. On the one hand, transfer to a holding pen would increase stress for the animal and enhance the potential for injury. It would also necessitate the logistics and expenses of having a holding facility on the mainland. On the other hand, holding pens allow time for genetic and health screenings. If capture and translocation of mainland wolves moves forward, consultation with personnel experienced with wolf reintroductions and translocations (e.g. Yellowstone, Mexican and red wolves) should occur.

2.1.6. If the source wolves are pairs should they show evidence of having bred and raised pups successfully?

2.1.7. Based on current knowledge, is there an approximate demographic profile (age and sex) that should be developed as the source wolves are assembled into a population?

The issue of which individuals to target should translocation efforts move forward is complex. If wolves are translocated as pairs, breeding experience would be desirable but not absolutely necessary. Further, targeting only wolves demonstrating evidence of breeding will result in release of older wolves with reduced life expectancy and reduced reproductive output on IRNP relative to younger wolf pairs.

An alternative approach is starting with single animals and allowing pair-bonding on the island, as a pair taken from the mainland may attempt to return to their source territory, especially if they had pups. Or, translocation could focus on a mix of single (unrelated) individuals and one or more pack(s). Sex ratio should be balanced (1:1), and there should be a focus on younger adults (or even subadults), as older adults may be more likely to attempt a return to the mainland. Targeting individuals in the 1-3 yr age range would focus on dispersal-age wolves who are experienced hunters and are attempting to establish territories.

2.1.8. Comment on the pros and cons of the best time of year to obtain source wolves.

There are trade-offs in designating potential capture (and associated release) periods. During open water season (May-October) moose calves and beaver are available and the likelihood of leaving the island is reduced by the lack of an ice bridge. During the late summer and early fall wolves are using rendezvous sites, which might improve trapping success, and if trapping involves foot-hold traps, there is decreased chance of freezing digits or of hypothermia. However, the cons for a late summer/early fall focus include greater opportunity for capturing non-target individuals (both wolf pups and domestic hunting dogs), and an increase in nomadic activity in late fall. A winter focus would increase the chances of capturing packs, as pups are travelling with packs and pack are more cohesive and wolves tend to be in good condition. However, a winter release date would leave less time for pair-bonding and increase the potential for attempted escape. Winter release on IRNP would also be logistically problematic.

2.2. What is minimum number of wolves and of wolf packs desired for IRNP? Why?

2.2.1. What number of source wolves would facilitate reaching the minimum threshold of wolves and wolf packs?

Answers to questions about target population size are tied to the goals of reintroduction. A small number of wolves or a single wolf pack could provide the ecological and human social goals that the park has for wolf restoration. If, however, the goal is to restore wolves on the island to allow maximum likelihood of persistence, the ideal minimum number wolves derive from the prey biomass. The long-term average ratio of moose to wolves is 30:1 at Isle Royale, so there is probably sufficient food for >30 wolves distributed among 2-6 packs (historically 3 wolf packs on IRNP has been most common).

The number of wolves to translocate is tied to the need to maintain genetic variability, and also to decisions regarding translocation of packs versus single individuals. Minimum numbers might be 4-6 unrelated adults (3 males and 3 females) to facilitate formation of 2-3 packs. But the addition of a greater number of animals might increase success rates. Translocation of 1-2 packs, or 1-2 packs plus an additional approximately 10 wolves might be a reasonable target. Thus, a relocation might be attempted with as few as 4 individuals and with as many as 18-20 or more animals, with greater numbers of translocated wolves having a higher likelihood of restoration success and of maintaining the success over a longer period. Ultimately however, the wolves (and prey) will determine the longer-term population size.

2.2.2. If multiple source individuals or breeding pairs are desired, how should genetic relatedness/inbreeding concerns be minimized?

Ideally, genetic testing should be conducted to assess kinship, and if a subset of individuals is found to be closely related one or more of these wolves should be excluded from the putative translocation effort. Aside from direct genetic assessment, focusing on wolves that are geographically separated should minimize relatedness. Given that wolves can disperse long distances, selecting target individuals for translocation who are separated by >50 km should increase the likelihood that the animals are unrelated, as median dispersal distance in the upper Midwest is <50 km.

2.3. Logistics and timing of release on IRNP

2.3.1. What level of health-related concerns during translocation and holding should be addressed?

2.3.2. Discuss how distance and timing of transporting animals to IRNP may or may not affect viability of the translocation?

Wildlife veterinarians should be consulted regarding appropriate vaccination strategies and animal health checks. It is likely that the most stressful period for the wolves will be times of restraint and captivity. Minimizing this time is desirable. During times of transport and anesthesia, hypothermia and hyperthermia risks should be considered.

Regarding transport, the shorter the time and distance involved, the less stress on the animal(s) and the greater the chances for a successful translocation. Decreased distances also decrease the costs of transport. Transport by airplane or helicopter may be feasible; transport by boat might increase logistic considerations depending on the deemed need to maintain wolves in holding pens on the mainland prior to release on the island, and on the location of the holding pens. Holding facilities in locations near Grand Portage or on Ontario's North Shore would facilitate short transport times.

2.3.3. Discuss the pros and cons of a soft release versus a hard release approach, and should timing of either approach depend on whether winter or summer season releases are conducted?

Both hard and soft release approaches have been successfully used for wolves. Soft releases increase the opportunity for animals to habituate to a locale and thus increase the likelihood of animals remaining in a particular locale. As such, soft release strategies increase the opportunity for managers to mediate the likely short-term locations of animals once released. On the other hand, soft release requires infrastructure and habitat modification, as well as periodic visits by humans with an associated risk of habituation. During some seasons on Isle Royale (winter) soft release may be logistically difficult because of limited site accessibility. There is also the need to minimize park visitor contact with soft release sites.

In contrast, hard release logistics are less complicated and the associated costs are lower. However there is a higher risk that hard release animals don't settle in the desired area, and during winter there may be a greater risk of the animals leaving the island. If hard releases occur in non-winter periods, the likelihood of the animal attempting to leave the island are likely lower and so a hard release might be more appropriate.

2.3.4. Discuss the role of location of the release site in terms of individual animals or mated pairs. The island is 45 miles long and 9 miles wide and contains 132,000 acres.

Release locations are partly influence by a hard versus soft release strategy, as the later requires pen infrastructure, and by the need to reduce exposure to park visitors and occur near areas with higher moose densities. Wolves captured together should be released together, while individual wolves could be released at one or more locations. For pair or pack release using a soft release strategy, a pen in the southwest and one towards the northeast, with animals released at similar times might reduce the likelihood of near-term inter-pack agonism. Alternatively, releases might target three regions: the western, eastern and middle portion of the island where packs have historically and most commonly occurred

If the timing of releases is more staggered, later releases should be hard releases in localities where pack territories adjoin or where packs are presumed to not occur. If hard releases are used across the board, and boats were used to transport wolves to Isle Royale, places with remote docks might be appropriate. If wolves arrived by plane, Windigo and Tobin Harbor might be feasible if human traffic could be temporarily reduced.

2.3.5 Discuss the pros and cons of providing dead prey during the initial release phase.

A soft release approach requires the use of dead prey to provision the translocated animals. A benefit of supplying dead prey near release sites is that it might reduce initial ranging patterns and reduce the likelihood of wolves attempting homing movements. It might also increase survival. The con of providing prey is that it is costly, logistically difficult (especially if the prey are moose), and there is a risk of wolves associating humans with food. Provisioning with prey may also be unnecessary when moose calves are available or during the winter when older and vulnerable moose are available prey.

2.3.6 What measures are there available to decrease the probability that wolves become habituated to humans?

On IRNP, hard release without provisioning of dead prey or supplemental food, in combination with a winter release would aid in minimizing exposure and habituation to humans, including human scent. If wolves are maintained in captivity prior to release, efforts should be made to minimize contact with humans. USFWS personnel working with Mexican wolves have experience with this topic and should be consulted.

2.4. Monitoring of released wolves

2.4.1. If released wolves are to be monitored, what is the purpose of this monitoring and how might this purpose influence monitoring approaches?

In general, monitoring of translocated wolves would serve two purposes: (1) allowing program success to be assessed using metrics of relevance to wolf population restoration goals, including the demographic and genetic health of the population, and (2) allowing enhanced understanding of the role of the translocated wolves in restoring IRNP ecosystem function. Meeting both goals would also contribute to building on a nearly 60 year research program for understanding wolf and predator-prey biology.

Historically the monitoring approaches used have reflected the need to understand wolf movements, demography, social dynamics and predator-prey dynamics. This includes the use of telemetry, non-invasive fecal DNA-based approaches, and direct monitoring/aerial photography. Telemetry is necessary to monitor movements, pack formation, reproduction, survival, and the need for additional releases to address demographic concerns. DNA-based approaches are necessary to accurately assess pedigrees and understand population-scale genetic variability, reproductive contributions of founders, and the need for additional releases to address genetic concerns.

2.4.2 Define critical data for long term wolf population management and how it should be collected. Explain the various options you considered and why you defined critical data the way you did.

Wolf population management on IRNP is principally focused on monitoring, and if necessary, addressing wolf population persistence. Such goals require the collection of demographic data, genetic data, and prey population data. Each requires different data collection methodologies.

The SMEs suggested a variety of data that needs to be collected to meet the goals. These include periodic and long-term information on:

- The number of wolves inhabiting IRNP
- The number and size of packs
- Wolf demographic and population trends
- Seasonal measures of reproduction and survival
- The genetic pedigree of all island wolves
- Levels of genetic variability and inbreeding depression
- Levels of phenotypic abnormalities
- Levels of natural immigration from the mainland
- Prey population density
- Prey use and kill rates by packs and individuals
- Indirect impacts of wolves on key plant taxa and communities

In general, the least intrusive methods that will provide the needed data are preferred. These data can be gained from:

- GPS telemetry collars to monitor individual movements, pack formation, denning activity, rendezvous and kill sites
- Winter aerial flights to gain counts of wolves and moose, determining kill rates
- Locating dead wolves (indicated by telemetry)
- Collecting fecal DNA, using visitations to heavily used sites after wolves have left to collect scats.
- Long-term monitoring of plant taxa and communities that might be indirectly influenced by wolf-herbivore dynamics

Given the importance of non-invasive genetic approaches, collections should be made of scats during specific surveys and opportunistically. Intensive collections of scats should be done around rendezvous sites and winter kill sites to identify new wolves produced in the population. Exact birth rates are difficult to obtain even with genetic and observational approaches as not all pups may survive to reach periods when surveys occur. Thus surveys focused on determining reproduction and pup survival need to take into account the desired timeframe. Death rates would probably need to be estimated, unless carcasses can be reliably located in the field. Ultimately this data would facilitate the building of population models that incorporate demographic and environmental stochasticity and that can be used to project demographic trajectories over the 20-year management horizon.

2.4.3 What are the least intrusive methods of monitoring the offspring of reintroduced wolves and what data can be provided by those methods? If telemetry or methods that involve handling animals is added, what are the additional information data sets and hypothesis that could be explored?

The least intrusive methods for monitoring the IRNP wolf population is fecal DNA collected from scats. The collection of scats does not require handling of wolves, and can be gained from den, rendezvous, and kill sites (when not used by wolves). Information gained from fecal DNA facilitates placement of the individual into a population-wide pedigree, which will provide insights on ancestry, total lifespan, reproductive success, year of birth and death, mate selection, and pack affiliation.

Additional non-invasive data collection approaches include camera trapping, snow-tracking and winter aerial surveys. These techniques provide data on site occupancy. The use of game cameras to monitor sites known to be heavily used can provide imagery to assess the survival of known individuals, assess phenotypic deformities, and in some cases monitor pack size. Snow-tracking can be used to assess population trends. Aerial surveys have been conducted in IRNP since 1958.

Adding telemetry-based monitoring will provide highly detailed information on behavior, movement, and demography, including cause-specific mortality and social relationships and will facilitate the finding of rendezvous, kill and dens sites. Given that founder wolves will be handled anyway, the collaring of these individuals is likely a minor additive stressor. As such, the advantage of not placing telemetry collars on individuals is unclear, and would seem like a lost opportunity for science and informed management.

2.4.4. How should reproductive success of released wolves be assessed?

2.4.5. How, and how often, should natural wolf immigration to IRNP be monitored?

A variety of approaches can be used to assess reproductive success of wolves at different times of the year, including GPS movements to reveal denning behavior, and non-invasive sampling of scats at dens, rendezvous sites, and winter kills to assess the numbers and parentage of pups, (and if combined, survival of pups). Scat collection allows for extractions of DNA which facilitates parentage analyses. Additional methods include direct counts gained from aerial flyovers, winter tracking, howling surveys in late summer, camera trapping near rendezvous sites and examination of female carcasses for placental scars.

Many of the approaches used to monitor reproductive success would also facilitate monitoring of natural wolf immigration. Non-invasive genetic monitoring focusing on scats collected from dens, rendezvous sites and winter snow-tracking would facilitate construction of a pedigree for all wolves inhabiting IRNP, and would facilitate the identification of novel genotypes (indicating the presence of an immigrant wolf, and potentially the presence of the individual's offspring if it successfully breeds). Exhaustive fecal sampling during the summer might best provide an annual record of the reproductive success of novel immigrants.

Alternative B: Immediate Limited Introduction

The third component of the questionnaire was specific to Alternative B. Alternative B calls for translocating wolves to IRNP as a one-time event over a defined period (i.e. over a 36 month period) to increase the longevity of the wolf population on the island. However, answers to these questions may also be potentially relevant to Alternative C.

3.1. During the re-introduction time period, can you identify any issues that should be monitored if it affects the characteristics of the startup population; i.e. wolf on wolf predation is high, affecting an age distribution?

Monitoring the survival of reintroduced wolves through telemetry would provide information on the near-term outcome of releases, including initial mortality whether due to intraspecific aggression or other causes, and the success and spatial dynamics of pack establishment. Such an approach would also provide insights on the need for translocation of additional individuals.

3.2. Discuss timing factors for the release of animals.

3.2.1. Should the release of wolves at different IRNP sites be simultaneous or staggered? When should animals be released?

The SMEs varied in their suggested periods for the release of wolves on IRNP. Winter might be an optimal period as food availability is high given an older vulnerable moose population, and aerial monitoring is easier during the winter. Furthermore, any possible 'orphan' wolves on the mainland should be relatively self-sufficient by this period. On the other hand, a fall release would allow the development of pair bonds well before the winter breeding season and would reduce the chance that wolves would leave the island if an ice bridge forms to the mainland. A summer release may be more problematic, as body condition and moose kill rates tend to be lower, so wolves released in summer into unfamiliar locales might have difficulty meeting nutritional needs.

A simultaneous release is preferred to a staggered release, although release(s) need not be completely simultaneous. If a soft release approach is chosen, than simultaneous release is preferred. If a hard release strategy is chosen, than this creates some staggering by default, as releases should occur as soon as possible after transport to IRNP. A simultaneous release approach will maximize the chance that individuals or packs are able to feed and establish territories before potentially engaging in antagonistic encounters with other released wolves. As one SME noted, the presence of a member of the opposite sex in an area of suitable habitat is generally the factor that causes a pair to localize activity and begin defending a territory. Without a potential mate present and no barrier of other pack territories to restrict movement, lone wolves would be encouraged to roam widely. If one pair established well ahead of one or two other pairs, the original pair may try to defend and hold larger portions of the island, making it more difficult for an additional pack to develop.

3.3. Define what should be the genetic and health characteristics of wolves chosen for reintroduction so that the packs that form have the best chance of long term viability without further addition via human intervention. Note additional natural immigration events are assumed to be limited.

As in previous answers to questions posed in section 2 of the questionnaire, the SMEs focused on the importance of selecting genetically unrelated individuals, selecting younger adults who will have longer reproductive lifespans on IRNP, selecting individuals who are pair bonded, selecting larger individuals with a history of hunting moose, and on the importance of health checks and immunizations so as to minimize translocating unhealthy or diseased individuals.

Note that one SME observed that given the size of IRNP, "I do not believe that any mix of wolf genetics introduced will result in long-term viability without human intervention given limited or no natural immigration events". A second SME mirrored this comment, although noting viability over the life of the recovery plan (20 yrs) may occur.

3.4. If wolves leave IRNP during the translocation period, what effort should be made to translocate additional wolves?

If animals die or leave IRNP during the translocation period and prior to the formation of multiple functional packs, additional wolves of the same gender should be released on the island. Caveats include that prey availability remains sufficient. However if ≥2 packs remain on the island when a single wolf disperses, translocation of an additional individual may not be necessary unless the goal is to provide the additional genetic variability that would enhance long-term persistence.

Alternative C: Immediate Introduction with Potential for Supplemental Introductions

Under Alternative C the NPS would translocate wolves to IRNP as often as necessary to maintain wolves on the island such that the wolf population is sufficient to function in an apex predator role with associated effects on prey (moose) populations and forest/vegetation communities. The fourth component of the questionnaire was specific to Alternative C, with a focus on informing the need to augment the initially translocated population over the 20 year operational period of the management plan.

4.1. What threshold(s) or ecological criteria should be considered for augmenting the IRNP wolf population and why are they important? Consider: wolf and prey density, wolf demographics, habitat, and/or social parameters, (growth rate, juvenile mortality, number of successful breeders, number of packs, etc.), on the ability to perform an expected ecological role as apex predators (predation rate), moose population growth rate, herbivory metrics, etc.

The SMEs had highly variable responses to this particular question, noting the potential for demographic and genetic thresholds, as well as broader questions related to how wolves might modulate prey populations and vegetation communities. Once wolves are reestablished on the island and are found across the entire IRNP landscape, it is unlikely that further wolf reintroductions will increase the population or result in higher predation rates because of likely intraspecific agonism. Thus, when wolf numbers are relatively high the opportunity to further supplement the population to influence prey or plant community dynamics is limited independent of how the wolves are influencing the broader IRNP ecosystem. Furthermore, it may take some time for herbivory to be reduced, so one indication of top-down impacts may simply be reduced herbivory levels rather than an absolute measures. An additional consideration is that population fluctuation is the norm for any populations (that is, populations are not necessarily in equilibrium), responses of ecosystem components to wolves are often not immediate, effect sizes may not be large, and effects of wolves can be increased or decreased by other environmental factors. Therefore absolute values might be less important than simply maintaining the ecological processes themselves, or indeed, the potential for the ecological processes to occur. As noted by one SME, these general observations regarding how apex predators interact with the broader ecosystem suggest that using some type of apex predator indicator or threshold might not be practical for management purposes as it lacks sensitivity.

However, from the perspective of maintaining a viable wolf population, a focus on genetics and on predator:prey ratios (or solely predator numbers) may provide insights and perhaps thresholds. Population viability could be assessed based on levels of inbreeding that may reduce reproductive success, which could be assessed from studies of other wolf populations or assessed from historic IRNP pedigree data. An inbreeding coefficient below a particular threshold (e.g. $F > 0.15$) could be used to trigger population augmentation.

From a demographic perspective, a ratio of moose to wolves could be used to trigger augmentation. Values of >75 moose per wolf could trigger immediate consideration of intervention, as over the past 58 years, ratios >100 only occurred when inbreeding was negatively influencing the wolf population. If focusing solely on wolves, should the population drop below 10 animals or two packs, augmentation might be considered. Augmentation might also be considered if there are multiyear (e.g. >5 yrs) negative trends in growth rates. In a more dynamic predator-prey framework that also incorporates inbreeding, augmentation could be triggered when a 3 year moving average of predation rate drops below 5% and the inbreeding coefficient F is >0.15. One of the SMEs provides a highly detailed assessment and discussion of this topic.

An alternative approach might be to set a process for putative immigration, based on augmentation, such that there is regularly the potential for gene flow, as might occur on mainland systems.

4.2. If using wolf demography and social structure alone to inform augmentation, what would be the pros and cons to this type of approach?

Focusing solely on wolves, provided monitoring is sufficient to have high confidence in the metrics of interest, benefits from simplicity and recognizes the vital importance of pack formation and wolf reproduction. On the other hand, focusing solely on wolf demography and pack numbers is problematic because of high variability associated with small population size. Such an approach also ignores the direct and indirect ecological roles of the species, in particular with regard to moose-wolf dynamics. It also lacks information on the genetics of the wolves.

4.3. If genetic factors are considered in determining the need to augment the population of wolves inhabiting IRNP, what are genetic factors or phenotypic characteristics that could be considered in determining whether additional wolf translocations to IRNP are necessary?

4.3.1. If inbreeding is to be accounted for, how should inbreeding be estimated and what threshold inbreeding coefficients, measures of heterogeneity, or levels of genetic diversity would be considered problematic and trigger translocation of additional wolves?

4.3.2. Should phenotypic signs of inbreeding depression be the primary trigger for augmentation? If the inbreeding coefficient is considered problematically high, but wolves continue to reproduce without clear phenotypic or functional role indications of inbreeding depression, should translocations nonetheless occur? Why or why not?

Genetic evidence of inbreeding as quantified from inbreeding coefficients and measures of variability, close observed kinship among breeders, congenital defects (e.g. lumbosacral transitional vertebrate or other skeletal malformations), observed decreases in reproduction or decreased survivorship among pups and juveniles, and even decreases in kill rates should all be considered if not attributed to disease, prey density or other non-genetic explanatory factors.

A primary metric for assessing levels of inbreeding is the inbreeding coefficient F. Data from IRNP indicates the values of $F > 0.15$ are associated with reproductive and population declines, and values from Scandinavian wolves indicate an approximate 15% decline in juvenile survivorship with an increase in the inbreeding coefficient of 0.1. Measures of heterozygosity might also contribute to decisions. The same Scandinavian wolf population showed levels of heterozygosity of 0.5 when in decline, but the decline was reversed when immigration raised heterozygosity to a value of 0.62. Thus, measures of $F > 0.1$ and measures of heterozygosity below 0.6 might be potential threshold values for consideration in triggering augmentation.

While phenotypic signs of inbreeding are important considerations, it is important not to wait until these signs occur. There is strong evidence that increased inbreeding will eventually influence fitness and that high inbreeding coefficients are signals of impending reproductive dysfunction. Augmentation to prevent critical increases in inbreeding is a better strategy than waiting until putatively deleterious phenotypic characteristics are observed. Even if the inbreeding coefficient is high without evidence of inbreeding depression, translocations should occur.

An alternative to setting criteria for augmentation is routinely releasing a new wolf or wolves onto IRNP on a regular basis (e.g. every generation if natural immigration is not occurring), thereby simulating natural immigration scenarios as might occur on the mainland or in the past. Previous research suggests that approximately two breeding immigrants every three generations may have entered the IRNP population for much of its history. Further release of additional wolves might be considered if inbreeding coefficients remain high or if phenotypic concerns arise. On the other hand, if the basis for the wolf restoration effort is to restore ecological function, remedial strategies to address inbreeding levels may not be warranted if the desired ecological functions remain within some normal expected ranges.

Alternative D: No Immediate Action with Allowance for Future Action

Section 5 of the questionnaire addresses non-wolf ecological thresholds that might act as the basis for wolf translocations. Under Alternative D, The NPS would not take immediate wolf restoration action, but rather would continue current management, allowing natural processes to continue. Resource indicators and ecological thresholds potentially directly or indirectly linked to wolves would be identified, and if a threshold were to be met, wolves would be translocated to IRNP either as a one-time event (per Alternative B) or through multiple introductions (per Alternative C).

5.1. Assessing wolf-mediated resource thresholds

5.1.1. What aspects of prey and habitat health are a concern, and why. How may they be mediated or affected by wolves through top-down control? (i.e. winter ticks)

Hyperabundance of moose can lead to forest degradation and greatly reduce balsam fir regeneration in parts of IRNP, resulting in pronounced forest structural changes (e.g. increases in species such as spruce). Other species and communities may be similarly negatively affected, such as aquatic habitats influenced by moose and beaver. Wolves may reduce herbivory and facilitate natural rates of forest regeneration by reducing the number of moose and beaver (lethal effects) and by affecting the behavior of moose and beaver. Historic data from IRNP supports these observations; moose on IRNP have historically fluctuated greatly but the peak extremes were moderated by the presence of wolves.

Fluctuations in moose numbers mediated by wolf predation may be a factor in winter tick abundance and ecology, although abiotic factors associated with climate change may at times be more important than top-down factors. If winter tick parasitism of moose is density-dependent or associated with predation pressures, then increases in wolves might reduce the incidence or severity of infestation. Therefore if wolves are restored in IRNP it will be important to evaluate impacts of winter ticks and other parasites in light of predation pressures.

5.1.2. What are historic baselines available for Isle Royale and the surrounding mainland ecosystem that would inform identifying thresholds?

There are a number of potential historic baselines for the island, the nearby mainland, as well as other more distant locales that may be relevant such as the Scandinavian peninsula and maritime Canadian provinces where management of moose at specific densities occurs to reduce the negative impacts of herbivory. In IRNP, impacts of moose on vegetation have been observed at moose densities of 2 per km^2, and strongly increased as density approached 5 per km^2. With this increase also came reduced body size and vigor in moose before the population crashed from starvation.

5.1.3. What prey and plant species should be monitored?

There is a need to monitor moose, beaver, and perhaps snowshoe hare and small mammal communities. Plants that should be monitored are those commonly browsed on by moose, including balsam fir, aspen, paper birch, mountain maple, yew, mountain ash, and wild sarsaparilla. In addition, species such as white spruce and alder that are generally poor moose browse may become more abundant and should be monitored. Changes in species such as aspen, willow and birch that may be influenced by beaver population dynamics should also be monitored. Finally, any plant taxa of conservation concern that have been identified as preferred foods of moose should be monitored.

5.1.4. What prey or vegetation demographic or community measures should be monitored?

For moose and beaver, monitoring should focus on general demographic measures, distribution, abundance (for beavers, counts of active lodges in the Fall) and the changing impacts they are having on vegetation (for moose, browse surveys). For vegetation, changes in abundance, distribution, growth forms, and reproduction in balsam fir and deciduous trees and shrubs should be monitored, as well as the plants and communities that replace them. Annual recruitment of tree seedlings, mainly balsam fir, white spruce, sugar maple, and trembling aspen into size classes (< 10 cm tall; 10-29 cm tall; 30-99 cm tall, and > 100 cm tall) would provide a measure of community dynamics appropriate for the time horizon of the plan. The frequency of flowering and average height of wild sarsaparilla might be used as an indicator of browsing intensity, as it would likely be correlated with recruitment of browse-sensitive woody species and negatively correlated with white spruce recruitment. Because of the potential importance of beavers, assessment of changes in the amount of beaver-created wetlands, successional patterns in beaver-created habitat, and alteration in plant growth caused by beaver feeding on aspen, willow and birch should be monitored.

5.1.5. What threshold(s) of prey population size or prey vital rates would result in the translocation of wolves to IRNP? What has been the range of variability for population sizes for species of concern?

Answers to these questions are potentially disparate. On the one extreme, absolute prey population sizes or vital rates in and of themselves are only relevant to the extent they influenced lower trophic levels. On the other hand, high moose populations (e.g. >1500-2500) may be indications of overabundance, or pending overabundance, and might be used as a threshold for translocation to avoid population collapse and damage to lower trophic levels. A typical mainland density is <1 moose per km^2, equating to approximately 544 in an area the size of IRNP. Assuming species of concern refers to moose, numbers in IRNP have varied from <500 to approximately 2500. A key parameter of interest might be predation rate rather than population size or vital rates per se. A predation rate of <5% (versus a long term rate of approximately 13% on IRNP) might act as a threshold for wolf translocation. By way of comparison, recent (2012-2015) predation rates have been <2%, with little moose mortality from other causes.

5.1.6. For plants, what thresholds of population size, vital rates, or aspects of vegetation structure or composition would result in wolves translocated to IRNP?

In general, the concern is whether sufficient forest succession is occurring to maintain the desired current and historical vegetation communities. Factors to consider for assessing balsam fir would include lack of reproduction, elimination of sapling tree stages, major reduction in balsam coverage, replacement of balsam by spruce, and the growth and expansion of white spruce savanna. For aspen and birch being influenced by both moose and beaver, factors to consider would include levels of regeneration, lack of sapling recruitment, and drastic decline including flooding of aspen stands caused by beaver modifications of local habitats. Thresholds can be based on recruitment of tree seedlings, focusing in particular on balsam fir, sugar maple, and aspen into size classes (<10 cm tall; 10-29 cm; 30-99 cm, and >100 cm). A reasonable threshold to trigger reintroduction might be mortality of >75% in the 10-29 cm size class and >75% in the 30-99 cm size class. However, a limitation of using measures of seedling recruitment for identifying thresholds is that it is a slow indicator relative to management needs. A faster but less precise way is to examine browsing rates on an indicator plant such as wild sarsaparilla in the spring. Browsing rates in excess of 70% on flowering plants would be above a historical norm observed when the IRNP wolf population was high in the 1970s.

5.1.7. If natural colonization of IRNP by wolves occurs, but prey or vegetation-based thresholds are nonetheless triggered, should translocations of additional wolves occur?

On the one hand, such natural colonization will likely involve a very small number of wolves, and any lag between colonization and altered prey or vegetation metrics is likely to be long. As such, one might argue that prey or vegetation triggers should not be used to reintroduce additional wolves until the effect of any natural colonization can be adequately evaluated. On the other hand, the lag itself may be decreased by introducing additional wolves. It should also be noted that the outcome of natural colonization or population augmentation depends on the island population size; if thresholds are met despite a high wolf density (independent of the addition of natural colonization), further augmentation is unlikely to increase the wolf population or predation rates, unless there is a genetic basis to the lack of top-down impacts, because of the expected intraspecific agonism that introduction of additional wolves would cause.

5.1.8. What are the pros and cons of basing the translocation of wolves on a primary indicator or multiple indicators?

Any indicator, whether used in isolation or as one of multiple metrics, is likely an imprecise tool. Therefore the resulting decision making is necessarily based on interpretations of the indicator(s). Basing translocation decisions on a relatively few primary indicators is simpler and less ambiguous, but the risk is that the few indicators of choice may not provide the necessary precision or sensitivity. Focusing on multiple indicators potentially provides a more comprehensive evaluation but may require a level of research and monitoring that is difficult to maintain and significant negative ecological effects may commence prior to translocations occurring. If thresholds are met based on multiple indicators, it may also be easier to gain the necessary stakeholder support to enact translocation protocols. Furthermore, if wolf translocations are based on ecological indicators, there is an assumption of top-down control that may not be entirely valid and alternative justifications for wolf translocations such as park visitor expectations may not be accounted for.

5.1.9. How does the potential for climate change influence the suggested thresholds?

Climate change can be viewed as a fundament cause of the decline of wolves in IRNP as well as a factor that is likely to perturb the IRNP (and surrounding mainland) ecosystem in ways that will influence the thresholds triggering further wolf management on the island. Yet given the relatively small size of IRNP, the relatively brief (20 year) window of analysis, and the fact that climate change will likely manifest its strongest effects through both changes in the occurrence of extreme events (e.g. fires, drought, derechos, heat waves, extreme precipitation events) as well as the general slow changes in trends, the influence of climate changes on possible thresholds for wolf translocations is difficult to foresee. The effects of climate change on the frequency of ice bridge formation is a fundamental reason that natural wolf immigration is now less likely to occur than in the past, but its influences on ecological thresholds derived from prey and vegetation metrics are uncertain.

Vegetation-based indicators should ideally account for projected changes in the growth rates of specific plant species, and well as forest succession rates, independent of the influence of wolves. Since climate change is likely to change the boreal forest character of the island to a more temperate deciduous one, decisions regarding the meeting of thresholds should be evaluated in light of climatic events underpinning any observed meeting of a suggested threshold rather than a lack of top-down control of the system. An increase in primary productivity and plant biomass in IRNP associated with climate change could alter how herbivores limit plant populations and communities. Further, warming conditions may stress plant species such as balsam fir, aspen and birch, in a way that is additive to the stress of browsing by moose or cutting by beaver. Spruce, and the potential replacement of fir by spruce would also likely change with a generally warmer climate in IRNP.

Regarding moose, Isle Royale is at the southern edge of the North American moose range. Climate warming may be contributing to the decline in mainland moose over the past decade. Yet while moose in the mainland upper Midwest have declined, this has not occurred in IRNP. Thus it is difficult to predict how climate change will influence IRNP moose population dynamics and vital rates, especially given the 20 year timeframe of the management plan. On the one hand, a warming climate may impair moose ability to cope with summer heat stress, make them more vulnerable to wolves, or even make IRNP less suitable for moose regardless of mitigation efforts. On the other hand, the loss of predation from this moose-dominated ecosystem is a *known* critical loss to the ecological integrity of IRNP health, while the possible impacts of climate change on IRNP's moose population should be viewed as *potential* drivers of ecosystem health over the next two decades. Therefore a management strategy that attempts to preserve predation until knowledge of how climate change is contributing to changes in IRNP's prey (and vegetation) communities might be appropriate.

A Non-intervention Strategy and the Loss of IRNP's Wolves

The final section of the questionnaire addressed outcomes associated with Alternative A, the no action alternative. Under Alternative A, the NPS would not intervene and would continue current non-interventionist management. The current population of wolves would likely die out, and the near-term future of wolves on the island would depend on rates of natural migration. Section 6 of the questionnaire addresses changes to the IRNP ecosystem that might occur as a result of the likely loss of wolves from IRNP without subsequent translocation events.

6.1. The life of this EIS is intended to cover about a 20 year period, what changes to habitat and the ecosystem might occur as a result of our decision under this alternative (IRNP without a top predator)?

The direct effect of wolf loss from the IRNP ecosystem is that the moose (and possibly beaver) population would likely greatly increase, and possibly crash, after which it would begin to increase again. Increasing moose numbers would likely increase impacts on preferred food plant species, with the most severe impacts on understory woody browse plants (balsam fir, Canada yew, eastern hemlock, and possibly northern white cedar) that grow slowly. Western IRNP's balsam fir will likely become functionally absent due to moose herbivory as that region of the island is already under considerable herbivore pressure and it is likely that the last cohort of regenerating balsam fir will be browsed sufficiently to reverse height growth that began when stems were released from moose herbivory in the 2000s when wolf predation pressure on moose was high.

More generally across the island, balsam fir is likely to decline drastically with little reproduction occurring, and the near disappearance of seedlings and saplings. Other tree species such as aspen, birch, mountain ash, and various deciduous shrubs will also likely have reduced regeneration, low vigor and will enter a phase of gradual decline. Non-browsed species such as spruce will expand. Spruce in savanna-like settings with an exotic bluegrass understory will likely expand over the 20 year window (although a warming climate may also result in reductions in spruce). Should fires occur in IRNP during the 20 year timeframe, high moose herbivory would likely eliminate regeneration of deciduous shrub and tree species that are important for foraging moose, thus accelerating the conversion of the forest community to a simplified ecosystem.

An expanding beaver population will result in a maximum extent of wetlands across the island. Such beaver wetland expansion may benefit some species, but would be detrimental to portions of the forest ecosystem. Tree species such as aspen and birch are likely to decline near beaver ponds, and with lack of wolf predation, beaver will likely travel further from ponds to cut trees. Aquatic systems, especially interior beaver impoundments, will be degraded by moose foraging and trampling of shoreline areas, a process that has already begun in ponds dominated by watershield, a native aquatic plant.

6.2. What other factors associated with climate change might alter the environment regardless of wolf being present?

Based on climate models, IRNP sits in a region of Lake Superior where precipitation might either increase or decrease over the next half century. As such, predicted responses of IRNPs climate to broader changes in the Great Lakes regional climate are unclear. Furthermore, possible changes in fire and drought frequency and severity are also unclear. Fire and drought could make vegetation more susceptible to insect and pathogen outbreaks. Climate warming, infectious disease and other stressors may affect tree growth, and most of the stressors are likely to negatively influence the more boreal taxa, with herbivory likely to enhance the effect of these stressors. Conifers such as fir and spruce would seem especially at risk. Deciduous taxa such as birch and aspen may also decline. From a prey perspective, warming weather may also result in greater levels of parasitism by winter ticks which could be detrimental to moose.

6.3. What monitoring should be conducted, with what goals, and how should these monitoring protocols for wolves and the broader animal and plant community be undertaken?

Monitoring should continue to focus on any remaining wolves with annual searches for natural immigrant wolves conducted during winter moose counts. Beaver counts should also be conducted regularly. For each of these species, it is important to continue to collect demographic data so as to understand and allow predictions regarding the impact these species have on one another and on the plant community. If a wolf population is observed to occur on the island, additional surveys should be conducted to obtain scats on all individuals for genotyping and associated assessments of the number of individuals and levels of relatedness.

Vegetation surveys should have a goal of determining abundance and condition of major browse species, such as balsam fir, yew, and eastern hemlock as outlined in discussions of plant recruitment above (see 5.1.4 and 5.1.6). In addition, monitoring should include study plots in which individual seedlings are followed through time to get estimates of growth rates and size class recruitment, and study plots to provide spot counts of seedlings in each size class and estimates of the extent of moose browsing on each of size classes, and how this is changing through time. Given that herbivory impacts are likely to be strong in the absence or rarity of wolves, consideration should also be given to focusing additional research on other plant and animal communities that might be influenced by changes in litter accumulation, shading, and soil chemistry brought on by altered browsing pressures. Monitoring should also account for the North Atlantic Oscillation and snow depth as well as fire risk and occurrence.

6.4. Describe ecological processes important to monitor to assess changes in the system.

In general, the important ecological processes are predation, competition, nutrient and energy flows, and other interspecific interactions. Given the evidence for both bottom up and top down regulatory processes in IRNP, the status and functioning of lower trophic levels and of nutrient cycling over the long term may be considered indicative of the robustness of ecological function at higher tropic levels. More specifically, monitoring changes in seedling recruitment as a function of changes in moose and beaver numbers, climate, pathogens, and disturbances such as fire should be prioritized. Such measures would provide insights into changes in forest structure, community shifts and succession.

6.5. Describe what components of the IRNP ecosystem are specifically important to preserve (we ask since there are other ways to protect and manage park resources other than using wolf).

A starting point for preserving the ecological integrity of IRNP is to target the maintenance of all ecological processes and to ensure that these processes are functioning with resilience within and among trophic levels in natural and expected ranges. This would facilitate maintaining healthy temperate-boreal forest dynamics that remain minimally altered by human activities such as hunting and resource extraction. It is also important to preserve the integrity of interior watersheds and ponds which may be dramatically influenced by an overabundance of moose and beaver in the absence of wolves.

An additional consideration is specifically focused on maintenance of IRNP's moose population. The species has been petitioned for listing under the U.S. Endangered Species Act, and although IRNP's moose population is currently large, the species has declined dramatically elsewhere in the region. Thus it is important that IRNP's moose population continue to receive attention so as to maintain this iconic herbivore at healthy population levels. Given the potential for ungulates to degrade the landscape in the absence of predation, management plans should identify maximal acceptable densities of moose and a desired condition for browse-sensitive plants, so as not to result in population crashes of moose or their food sources.

6.6. Are there aspects of the ecosystem that will be better served by allowing ecological processes to continue unimpeded by any intervention?

Protected areas are not static, and IRNP will change independent of intervention decisions on the restoration of wolves. Some species will increase, and others will decline as a function of the presence or absence of wolves. Irrespective, there is a body of evidence to indicate the loss of wolves from IRNP will contribute to dramatic ecosystem changes. Thus, a non-intervention approach should be based more on the philosophy of nonintervention than on the perception that some component of the ecosystem (e.g. specific species) might benefit from the absence of a primary ecological process such as predation. Given that human intervention in the form of climate change contributed to the decline of IRNP's wolves, it isn't clear that any broader aspects of the ecosystem are somehow better served by not applying science and existing knowledge to provide resilience to IRNP's ecological processes.

Appendix 1a. List of Subject Matter Experts who Provided Technical Input.

Matthew Gompper (Lead Coordinating Subject Matter Expert)
Professor, School of Natural Resources, University of Missouri

Brent Patterson
Research Scientist, Ontario Ministry of Natural Resources, Wildlife Research & Monitoring Section, Trent University

Rolf Peterson
Research Professor, School of Forestry and Wood Products, Michigan Technological University

Daniel Pletscher
Professor Emeritus, College of Forestry & Conservation, University of Montana

Thomas Rooney
Associate Professor, Department of Biological Sciences, Wright State University

Tim Van Deelen
Associate Professor, Department of Wildlife Ecology, University of Wisconsin

John Vucetich
Associate Professor, School of Forest Resources and Environmental Science, Michigan Technological University

Robert Wayne
Professor, Department of Ecology & Evolutionary Biology, University of California, Los Angeles

Adrian Wydeven
Timber Wolf Alliance Coordinator, Sigurd Olson Environmental Institute, Northland College

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historic places, and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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