BEFORE THE SECRETARY OF THE INTERIOR

PETITION TO LIST THE U.S. POPULATION OF NORTHWESTERN MOOSE (*ALCES ALCES ANDERSONI*) UNDER THE ENDANGERED SPECIES ACT

JULY 9, 2015
CENTER FOR BIOLOGICAL DIVERSITY
HONOR THE EARTH

NOTICE OF PETITION

Sally Jewell, Secretary
U.S. Department of the Interior
1849 C Street NW
Washington, D.C. 20240
exsec@ios.doi.gov

Dan Ashe, Director
U.S. Fish and Wildlife Service
1849 C Street NW
Washington, D.C. 20240
Dan_Ashe@fws.gov

Douglas Krofta, Chief
Branch of Listing, Endangered Species Program
U.S. Fish and Wildlife Service
4401 North Fairfax Drive, Room 420
Arlington, VA 22203
Douglas_Krofta@fws.gov

PETITIONERS

The Center for Biological Diversity (Center) is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center is supported by more than 900,000 members and activists throughout the United States. The Center and its members are concerned with the conservation of endangered species and the effective implementation of the Endangered Species Act.

Honor the Earth is a Native-led organization, established by Winona LaDuke and Indigo Girls Amy Ray and Emily Saliers. Our mission is to create awareness and support for Native environmental issues and to develop needed financial and political resources for the survival of sustainable Native communities. Honor the Earth develops these resources by using music, the arts, the media, and Indigenous wisdom to ask people to recognize our joint dependency on the Earth and be a voice for those not heard.

CENTER *for* BIOLOGICAL DIVERSITY   *Because life is good.*

<u>Submitted this 9th day of July, 2015</u>

Pursuant to Section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. § 1533(b); section 553(e) of the Administrative Procedure Act (APA), 5 U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), the Center for Biological Diversity, Honor the Earth, Tara Easter, and Jane Reyer hereby petition the Secretary of the Interior, through the U.S. Fish and Wildlife Service (FWS or Service), to list the U.S. population of *andersoni* moose (*Alces alces andersoni*) as a threatened or endangered Distinct Population Segment.

FWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on FWS. Specifically, the Service must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). FWS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id.*

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EXECUTIVE SUMMARY

The moose (*Alces alces*) is a circumpolar species that migrated to North America during the Pleistocene era some 14,000 years ago. Standing six feet tall, it has evolved into the largest member of the deer family, but unlike deer, it is specifically adapted to cold environments, with thick insulating fur to survive freezing temperatures, and long legs and wide feet to move easily through deep snow and avoid predation. The moose also has become an emblematic animal that represents the places in which it lives, and it is deeply woven into the social, economic, and cultural fabric of the people who share this habitat.

But this iconic creature is at imminent risk of disappearing from a large portion of its natural range, with populations plummeting in recent years and trends showing further dramatic reductions to come. Declines have been most severe in Minnesota, where populations have dropped by 58 percent in just ten years – with just 3,450 moose surviving there today (DelGiudice 2015, p. 3). The Moose Advisory Committee warned that moose will be virtually extirpated from Minnesota by 2020 if trends are not reversed, signaling an urgent need for action (Moen *et al.* 2011, p. 2).

Scientists generally recognize three subspecies of moose in the lower 48 states: *Alces alces andersoni* in the Midwest and northern Great Lakes; *Alces alces americanus* in the northeastern United States; and *Alces alces shirasi* from the northern Rockies to the Pacific Northwest. This petition concerns only the first of these, *A. andersoni,* which is likely to become in danger of extinction in the foreseeable future in a significant portion of its range.

A. andersoni is threatened by a myriad of factors, including habitat loss and disease, but the greatest threat confronting the species is climate change, which is exacerbating existing problems and creating new adverse effects. The Endangered Species Act (ESA) states that a species shall be protected as endangered or threatened based on any one of five factors. 16 U.S.C. § 1533 (a)(1). The best available science shows that *Alces alces andersoni* is threatened by four of these factors, and thus its protection as a threatened or endangered species is warranted:

Modification or Curtailment of Habitat or Range

Moose have a multitude of habitat requirements needed for survival. Forest disturbance needed to regenerate high quality forage has been altered through human development, and it is rapidly changing in the face of climate change. Tree communities in boreal and hardwood forests that moose call home are shifting northward, being replaced by oak forests that are less suitable for moose. Rising temperatures and decreasing snowfall are putting moose at increased risk of overheating, which causes malnutrition and lowers their immune systems, and pathogens are also becoming more prevalent in a warming climate. Much of the moose's range in Minnesota, Michigan, and North Dakota is also threatened by oil and gas drilling and mining for precious metals.

Overutilization

Hunting was not a significant factor in the decline of Midwest moose populations, and subsistence hunting is not a current threat. Minnesota cancelled its moose hunt, and Michigan and Wisconsin have never allowed it.

North Dakota does have a hunt, but the impact on populations in the state are poorly known because the state uses hunting statistics as a primary means of monitoring populations without considering additive habitat threats to moose. Nevertheless, the number of tags has been reduced in response to apparent declines.

Disease and Predation

The U.S. population of *andersoni* moose is threatened by a number of parasites and diseases. The meningeal worm (*Parelaphostrongylus tenuis*) is believed to be a significant factor in the decline of moose in the Great Lakes region. The liver fluke (*Fascioloides magna*) is affecting moose populations across the United States, and Elaeophorosis (*Elaeophora schneideri*) is a concern for moose in the west that could potentially affect Midwest moose as well. The winter tick (*Dermacentor albipictus*) is causing high mortality rates in the Northeast and Midwest due to its higher than average survival in milder winters. Chronic wasting disease (CWD) is a new discovery in moose in the United States. This disease has not spread yet, but the potential for it to do so is alarming. Finally, malnutrition, whether brought on by another disease or by element deficiencies in a moose's diet, also threatens moose populations. A warming climate is exacerbating the prevalence of all of these diseases. As deer and other hosts for these parasites shift farther north into moose habitat in response to less snow and warmer winters, transmission of these diseases also expand and increase.

Inadequacy of Existing Regulatory Mechanisms

There are no existing regulatory mechanisms at the federal level to adequately protect moose from the threats they face from climate change, habitat loss, and disease. State protections are minimal and do not provide protection for moose from development and other harm. The United States has inadequately addressed climate change and needs to steeply curb greenhouse gas emissions from fossil fuels to save species threatened by climate change.

Other Factors

Moose are threatened by vehicular collisions, noise, and small population size. As populations contract and expand in response to climate change, small, unviable groups of moose will likely be lost.

As such, the best available science demonstrates that the U.S. population of *andersoni* moose warrants protection under the Endangered Species Act as a Distinct Population Segment. A prompt decision on this petition is required to ensure that *andersoni* do not decline to a point beyond recovery before listing occurs.

I.   Introduction

Moose are among the most charismatic species in North America. With their massive antlers and powerful bodies, moose are synonymous with the cold regions they inhabit – standing as an iconic animal for such places. Moose migrated to North America some 14,000 years ago and became vital to the sustenance and culture of Native Americans, and they continue to be an integral part of the economies and cultures of the people who share their habitat today. But climate change and other impacts are now having severe impacts on moose, with impacts most profound in the range of the *Alces alces andersoni*. This subspecies is at imminent risk of being extirpated from a significant portion of its range in the Midwest and Great Lakes regions, and protection under the ESA is not only warranted, it is also urgently necessary to prevent its demise.

Moose provide significant revenue to state wildlife departments through tourism and hunting (*see, e.g.*, MNDNR 2011, p. 44). Thousands of hunters enter state-held lotteries for their chance at a moose hunt, and one moose can provide hundreds of pounds of meat. Local tribes hunt moose for subsistence as well and have witnessed their decline in the northern woods, lending a hand to state agencies and researchers to help understand why moose are vanishing (Foster, Access Minnesota 7/9/2014).

Moose are scientifically valued as well. As a model herbivore, their dietary habits can change or maintain a forest, and their unique behavior has provided 50 years of research into answering questions such as: 1) how do we define niche breadth relative to specialist and generalist herbivores, 2) how do herbivores trade off food quality and quantity when selecting diets, and 3) what are the roles of top-down and bottom-up processes in regulating populations (Shipley 2010, p. 2). Moreover, moose-wolf interactions in recent years in closed systems such as Isle Royale National Park have given scientists a look at predator ecology in mammalian systems to confirm what was only previously understood in fish and insects (Montgomery *et al.* 2014). By studying moose-wolf dynamics on Isle Royale, Vucetich and Peterson (2004) were able to provide evidence that in some terrestrial systems, bottom-up processes may be more important in influencing interannual variation in herbivores/prey, contrary to popular beliefs that top-down is more or equally as important (p. 188). Their study on Isle Royale is in its 56th year – the longest continuous study of any predator-prey system in the world.

Moose have been impacted by habitat loss, hunting, and other anthropogenic impacts for more than a century, but populations are now confronting a host of additional threats with the onset of climate change. Related impacts are reducing available habitat, causing physical stress, and increasing the rate of disease. The resulting effects are most pronounced in Minnesota, where the population of *andersoni* moose dropped 58 percent in the last ten years. While scientists race to understand the cause for this unprecedented decline, policy makers cannot wait and watch *andersoni* vanish. Immediate action must be taken to protect this iconic animal before it is too late.

II.   Natural History and Ecology

A. Taxonomy

The moose is the only animal of the *Alces* genus (order *Cetartiodactyla*, family *Cervidae*). The world moose population is circumpolar, with a divergence of opinion among biologists regarding the species and subspecies status of various regional populations. Thus, if the European and western Asian ("Eurasian elk") populations are considered a separate species from the North American and east Asian ("North American moose") populations, the North American moose is designated as *Alces americanus* (Wilson and Reeder 2005; Boeskorov 1997). If all of the various populations are treated as one species, the species is designated as *Alces alces*. This petition follows the latter nomenclature, which is currently the most widely used.

Four subspecies of *Alces alces* in North America have been recognized: *Alces alces americanus* (eastern moose), *Alces alces andersoni* (northwestern moose), *Alces alces gigas* (Alaska moose), and *Alces alces shirasi* (Shiras moose).

Morphological differences support the distinction of the four recognized subspecies. The gigas moose in Alaska are the largest and lightest in color, followed by andersoni, while shirasi and americana moose are the smallest and darkest (Geist 1999, pp. 16-18). Similarly, Alaskan moose typically have the largest and most palmated antlers, followed by the andersoni moose, with Americana and shirasi subspecies having the smallest, most finger-like antlers. Peterson (1952) also recorded a number of skeletal morphological differences between the four North American groups. The cranial details of andersoni moose were found to be significantly different from the other groups, especially with respect to the shape of the palate. Andersoni moose's palate was wider than the americana moose and narrower than shirasi and gigas moose (Peterson 1955, p. 10). Other differences related to the height and width of the occiput in relation to the mastoid width, and the width and flare of the nasal aperture.
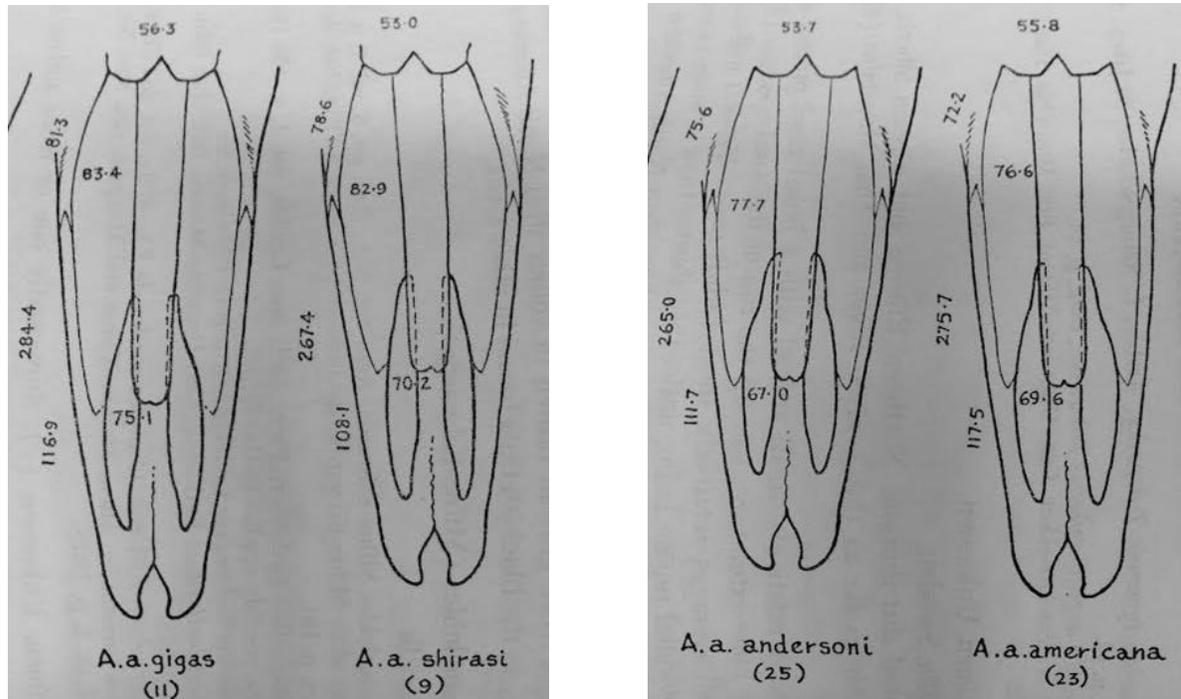
Figure 1: (Peterson 1955, Fig. 2): The average size and shape of the nasal apertures of the races of Alces alces (adult bulls). Figures in parenthesis refer to the number of specimens averaged.

Cronin (1992) examined mitochondrial DNA of the North American cervids and found no variation between the moose subspecies, but he did note that the lack of variation may stem from an overall low level of genetic variation of the species (p. 78). This could be supported by the findings of Mikko and Anderson (1995), who found there is very little genetic variation of Swedish and Canadian moose populations (p. 4261). However, more recent genetic studies support the subspecies designation.

Bowyer (2002) found support for the genetic distinction between moose populations in Alaska, Saskatchewan, and Minnesotan moose by comparing their antler sizes. As predicted, he found that Alaskan moose had significantly larger antlers than the other two populations, which he determined was due to genetic factors, and he rejected the hypothesis that the difference in size is a result of a variation in nutrition (p. 161).

Hundertmark *et al.* (2003) found further support for the subspecies designation by analyzing the variation in mitochondrial DNA nucleotide sequences to examine population structure in moose across North America. They found evidence showing that gene flow was restricted among regional populations of moose in the past. Their data indicate a pattern of genetic structure among regional moose populations that is consistent with the distribution of the four subspecies of moose in North America based on the morphological characteristics used by Peterson (1955, p. 726).

The mtDNA haplotypes of North American moose did not exhibit reciprocal monophyly with respect to currently recognized subspecies (Hundertmark *et al.* 2003, p. 726) However, it is possible that the differentiation necessary for subspecies designation may occur before a genetic

marker is present because monophyly is only an indicator of a long-term separation of populations and a function of effective population size, failing to account for rapid evolutionary change from dispersal and colonization of a new range (Neigel and Avise 1986; Geist 1987b; Hewitt 1996; cited in Hundertmark *et al.* 2003 p. 726),. Hundertmark *et al.* concluded that,

> Although further investigations incorporating nuclear loci, particularly in contact zones, may be necessary to achieve a final conclusion, there is evidence of restriction in gene flow among regional populations of moose in the past, which is consistent with the distribution of 4 subspecies of moose in North America (2003, p. 726).

Wildlife managers generally follow this traditional subspecies taxonomy. Thus, wildlife managers in the Midwest refer to the local moose as *Alces alces andersoni* (MNDNR 2011, p. 13; Murray *et al.* 2006, p. 1; DeCesare *et al.* 2014, p. 37); managers in the Northeast refer to local moose as *Alces alces americana* (Frank *et al.* 2004, p. 89; Timmerman 2003, p. 131). Managers in the Rocky Mountains refer to local moose as *Alces alces shirasi* (WGFD 2010, p. 2; DeCesare *et al.* 2014, p. 37; Toweill and Vecellio2004, p. 33; UDWR 2012, p. 1; Colorado Parks and Wildlife 2013), and managers in Alaska *Alces alces gigas* (West 2009, p. 59). This petition refers only to the first – *Alces alces andersoni*.

B. Physical Description

Moose are the largest members of the deer family, characterized by massive heads; long noses; short tails; a hump on the shoulders; and large, rotating ears. They have brown summer and winter coats of fur that shed in the spring and fall (Franzmann 1981, cited in Innes 2010, unpaginated), and their long legs and wide feet allow them to move easily through deep snow and avoid predation (Geist 1998, cited in Innes 2010). They exhibit sexual dimorphism, with males being greater than 40 percent larger than females (Feldhamer *et al.* 2003, cited in Innes 2010) and possessing large sets of antlers and a long, floppy "dewlap" or "bell" that hangs below their throat.

Male moose have the largest set of antlers of any living cervid, which can weigh more than 35 kg. The antlers begin to grow and mineralize in mid-March under the velvet and go through rapid growth in June and July. Full development is typically reached in August, and the velvet is shed until mid-September. The antlers begin to drop after the mating season ends. This process is usually complete by January, though younger bulls can retain their antlers as late as March (Bubenik 2007; Bishop 1988, cited in Innes 2010).

North American moose size varies greatly according to their range, with the smallest individuals occurring in the southern portion of their range and the largest being in Alaska and Yukon (Geist 1998; Feldhamer *et al.* 2003, cited in Innes 2010). In the southern portion of their range, males are typically 2.5 to 3.2 m long and weigh 360 to 600 kg, and females range from 2.4 to 3.1 m long and weigh 270 to 400 kg (Innes 2010). In Alaska, males and females can reach 680 kg and 590 kg, respectively (Bishop 1988, cited in Innes 2010). Adult moose can weigh as much as four or five times the amount of a full grown white-tailed deer (MNDNR, Mammals: Moose).

C. Behavior

Moose are mostly solitary, coming together in aggregations only during rut and before migrating. When aggregations do occur, they are loose-knit, transitory, and mostly made up of cow-calf pairs. However, the largest groups recorded (up to 60 individuals) consisted of cows without calves and young bulls. They are the least gregarious of all North American cervids (Peek *et al.* 1974, Van Ballenberghe 1992, cited in Innes 2010).

Moose are active throughout the day and night, but they can change their activity levels depending on the weather or length of daylight (Feldhamer *et al.* 2003, Franzman 1981, cited in Innes 2010). Cows with calves remain concealed, only coming in the open to feed, whereas cows without calves and bulls appear in the open much more often (Franzman 1981, Hauge and Keith 1981, Hundertmark 2007, cited in Innes 2010).

Moose are non-territorial, and their home ranges often overlap and are unclearly defined (Feldhamer *et al.* 2003, Franzman 1981, Hundertmark 2007, cited in Innes 2010). Moose may occupy the same range throughout the year or migrate between summer and winter habitats depending on where they live and the weather. If they migrate, they use the same route every time unless they are exploring new habitat (Franzman 1981, Hundertmark 2007, LeResche 1974, Garner and Porter 1990, cited in Innes 2010). Timing of migration can vary depending in part on the weather (snow depth, spring green-up, etc.) (reviewed in Innes 2010). Moose may migrate alone or in groups, and migration and movement patterns are a learned behavior (Feldhamer *et al.* 2003, Hundertmark 2007, cited in Innes 2010). Migration distances vary from one to 58 miles between population regions (Hundertmark 2007, cited in Innes 2010). Populations living in mountainous regions tend to move farther than those living in flat terrain (Innes 2010).

Both young and adult moose disperse, but males are more likely to disperse than females (Hundertmark 2007, cited in Innes 2010), which typically establish ranges overlapping with their mothers (Feldhamer *et al.* 2003, cited in Innes 2010). Dispersal usually happens in a moose's second year, and movements are usually short (Feldhamer *et al.* 2003, cited in Innes 2010). Moose are more likely to inhabit new areas that overlap with an existing home range due to their the tendency to use traditional ranges and travel routes (Gasaway *et al.* 1989, Labonte *et al.* 1998, LeResche 1974, cited in Innes 2010).

D. Mating and Reproduction

Moose are polygamous and seasonally polyestrous (Innes 2010). Peak breeding season is called the "rut," and it typically occurs from September to October with a three to four week peak of mating. A study in British Columbia showed that 89 percent of cow moose conceived within ten days of the rut (Edwards and Ritcey 1958, cited in Innes 2010), but estrous periods occur every 22 to 28 days if the cow is not bred (Feldhamer *et al.* 2003, Schwartz 2007, cited in Innes 2010). She is receptive for seven to 12 days even though true estrous only lasts for less than 24 hours (Franzmann 1981, cited in Innes 2010). Females will only mate once during estrous, while males will move around and mate multiple times (Feldhamer *et al.* 2003, cited in Innes 2010).

Moose in tundra ecosystems (Alaska and Yukon populations) tend to maintain harem mating strategies, but there are too few females in a given area to do this in the taiga (continental U.S. populations). Taiga-dwelling moose operate under tending-bond systems, where one male stays with one female until they mate, and he then moves on to find another female with which to mate (Feldhamer *et al.* 2003, cited in Innes 2010). Bulls will travel long distances in search of females in estrous. Typically, the largest bulls with the largest antlers outcompete smaller males and have the highest reproductive success (Feldhamer *et al.* 2003, cited in Innes 2010).

Gestation is about eight months long, and calving occurs from mid-May to mid-June (Schwartz 2007, cited in Innes 2010). Moose may have single or twin calves, and triplets are rare (Franzmann 1981, Schwartz 2007, cited in Innes 2010). A cow's physical condition before breeding may determine pregnancy and twinning rates, weight of neonates, and date of birth – ultimately influencing calf and population survival rates (Bishop 1988, Feldhamer *et al.* 2003, Franzmann 1981, cited in Innes 2010). Timing of parturition is highly synchronous within a population and is likely determined by how long the calves need to acquire fat reserves necessary to survive winter, making it necessary to give birth early (Feldhamer *et al.* 2003, cited in Innes 2010).

Females give birth in different calving sites year to year, selecting sites based on the availability of high nutritional forage and cover, and low predation risks (reviewed in Innes 2010). Females stay at their calving sites until the calf is able to move around safely. Calves are weaned in the fall when the mother breeds again, and she drives them away in the spring just before giving birth to her next calf or calves (Bishop 1988, Feldhamer *et al.* 2003, Franzmann 1981, cited in Innes 2010).

E. Diet

Moose are generalist browsers, but their main diets vary according to their habitat. They are known to eat leaves, stems, buds, grasses, forbs, lichens, mosses, mushrooms, and even the bark on trees, though this is usually a sign of malnutrition (Renecker and Schwartz 2007, cited in Innes 2010). Although the overall moose diet is composed of a wide variety of vegetation and other matter, selected foods are usually shade-intolerant, early-successional, woody plants. Most individuals consume a high quantity of only a few species that grow in the region in which they live.

In North America, moose principally consume: willow (28 species), birch (paper birch, water birch, dwarf birch, bog birch, Kenai birch, and yellow birch), and *Populus* spp. (quaking aspen, balsam poplar, black cottonwood, and bigtooth aspen) (Feldhamer *et al.* 2003, Geist 1998, Peek 1974, Renecker and Schwartz 2007, cited in Innes 2010). They may also consume hardwoods such as: maple (*Acer* spp.), dogwood (*Cornus* spp.), serviceberry (*Amelanchier* spp.), mountain ash (*Sorbus* spp.), cherry (*Prunus* spp.), hazelnut (*Corylus* spp.), viburnum (*Viburnum* spp.), and alder (*Alnus* spp.). Winter diets of moose in North America commonly include conifers such as: balsam fir, subalpine fir, Canada yew (*Taxus canadensis*), and Pacific yew (Geist 1998, Peek 1974, Renecker and Schwartz 2007, cited in Innes 2010).

In the summer and fall, moose load up on easily digestible plants with high nutritional value. Their resting/feeding cycles are short with a high intake of food to build up fat reserves, and an individual moose can store more than 100 pounds of food in its stomach at once (Minnesota DNR, Mammals: Moose). This usually includes herbaceous grasses, sedges, and aquatic plants. They prefer young plants and green deciduous leaves when available because they are more nutritious (Franzmann 1981, Renecker and Schwartz 2007, cited in Innes 2010). To get sodium, moose rely on aquatic species such as pondweed, horsetail, pond-lily, water-lily, bur-reed, and cattail species (Peek 1974, Renecker and Schwartz 2007, cited in Innes 2010). In areas without the availability of aquatic plants, moose must get these nutrients from woody vegetation that is high in sodium, such as willows.

The resting/feeding cycles of moose are much longer in winter months when vegetation is less nutritious, and they consume less food while their fat reserves slowly decrease. Their diets are made up of hardwoods and browse from fallen branches. Where there are few hardwoods available, particularly during harsh winters, moose replace them with balsam firs and conifers (Peek 1974, Jankins and Wright 1988, cited in Innes 2010).Moose lose a large amount of fat and energy during this time, reducing their intake even in winters that have a high abundance of quality foods (Schwartz 1992, Renecker and Schwartz 2007, cited in Innes 2010).

F. Habitat Selection and Requirements

Habitat selection for moose generally revolves around forage availability, nutritional quality, and canopy cover (Innes 2010). Robin (2010) provides a comprehensive description of the plant communities moose tend to prefer by region. In the Midwest/Great Lakes Region, moose have the following habitat associations:

> On the Superior National Forest, Minnesota, moose occurred in early-successional clearcuts dominated by shrubs and interspersed with balsam fir, black spruce, red pine, and jack pine stands (Peek *et al.* 1976). On Isle Royale, a 210-mile² (544 km²) island in Lake Superior, Michigan, moose occurred in young postfire paper birch-quaking aspen-white spruce; "climax" sugar maple-yellow birch (*Acer saccharum-Betula alleghaniensis*); mature (80-100 years old) paper birch-aspen-balsam fir-white spruce; "climax" paper birch-balsam fir-white spruce; and lowland northern whitecedar (*Thuja occidentalis*) and black spruce forests (Hansen *et al.* 1973, Jordan *et al.* 2000).

Significant differences exist in the diets of andersoni moose versus those in eastern North America and the Rocky Mountains which affects their habitat selection (Peterson 1955, p. 1, Bishop 1988, cited in Innes 2010). Outside of ubiquitous quaking aspen and paper birch, little overlap exists between the preferred vegetation of andersoni moose and moose in the eastern and western United States (Renecker 1998, p. 414-419). Andersoni moose rely most heavily on hardwoods during the dormant season, while the eastern and Shiras moose mostly eat conifers, especially balsam fir (Feldhamer *et al.* 2003, cited in Innes 2010). Moose are generalists, consuming a wide range of food if necessary, but they prefer hardwoods in areas where they are available, such as the north-central United States.

Moose often face trade-offs between the use of food-rich habitats in the open and the use of habitats that provide cover from predators, snow accumulation, and thermal stress (Dussault *et al.* 2005, Herfindal *et al.* 2009, cited in Mabille and Ouellet 2012, p. 966). In early spring and late fall, moose tend to occupy more open areas in search of high quality forage that will help them last through the colder months (Innes 2010). Although habitat selection is largely governed by forage availability, severe weather or human disturbance can shift selection for the use of more closed-canopy forests (Innes 2010; Mabille and Ouellet 2012, p. 975). Moose often reside in habitats with more cover to avoid late summer heat and deep snow in harsh winters (Innes 2010; Mabille and Ouellet 2012, p. 975), and they select the best combination of cover and food quality to use as calving sites (Innes 2010).

In general, moose that occupy flat terrain move from aquatic, open habitats with aspen or willow stands in the summer to dense conifer forest in the winter (Telfer 1984, cited in Innes 2010). The spatial and temporal structure of moose populations can easily be altered by the presence or absence of mineral licks and other sources of sodium, including willows (Panichev *et al.* 2002, cited in Rea *et al.* 2004, p. 162). Overall, willow habitats are considered the most important ecosystem based on year round use throughout the moose's range (Peek 1974, Telfer 1984, cited in Innes 2010). And while moose need young plants for their nutritional quality, research shows that a mix of old and new forests is important for moose health and productivity (Thomas 1990, cited in Innes 2010).

III. The U.S. Population of "*Andersoni*" Moose Qualifies as a Distinct Population Segment

The ESA broadly defines "species" as "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature" (16 U.S.C. § 1532(16)). The FWS and National Marine Fisheries Service (NMFS) published a policy to define a "distinct population segment" (DPS), specifying three elements they consider in determining the status of a possible DPS as endangered or threatened. These are: (1) The discreteness of the population segment in relation to the remainder of the species to which it belongs; (2) The significance of the population segment to the species to which it belongs; and (3) The population segment's conservation status in relation to the Act's standards for listing (61 Fed. Reg. 4722, 4725 (Feb. 7, 1996)) (hereafter, DPS Policy). As discussed below, the U.S. population of *andersoni* moose (*Alces alces andersoni*) meets all of these criteria and thus qualifies as a DPS under the ESA.

A. Discreteness

Under the DPS Policy, a population segment is discrete if it satisfies either of the following criteria:

> i. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation. The

policy further clarifies that a population need not have "absolute reproductive isolation" to be recognized as discrete.

ii. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act (61 FR 4725).

1. The U.S. population of *andersoni* moose is discrete because it is markedly separate from other populations of the same taxon due to genetic, physical, ecological, and behavioral factors.

The U.S. population of *andersoni* moose is markedly separated from its counterparts farther north. Bowyer (2002) found a genetic distinction between moose populations in Alaska (*A. a. gigas*) vs. Saskatchewan and Minnesotan moose (*A. a. andersoni*) by comparing their antler sizes, but he also discovered that Saskatchewan *andersoni* moose had consistently smaller antlers than *andersoni* moose in Minnesota.
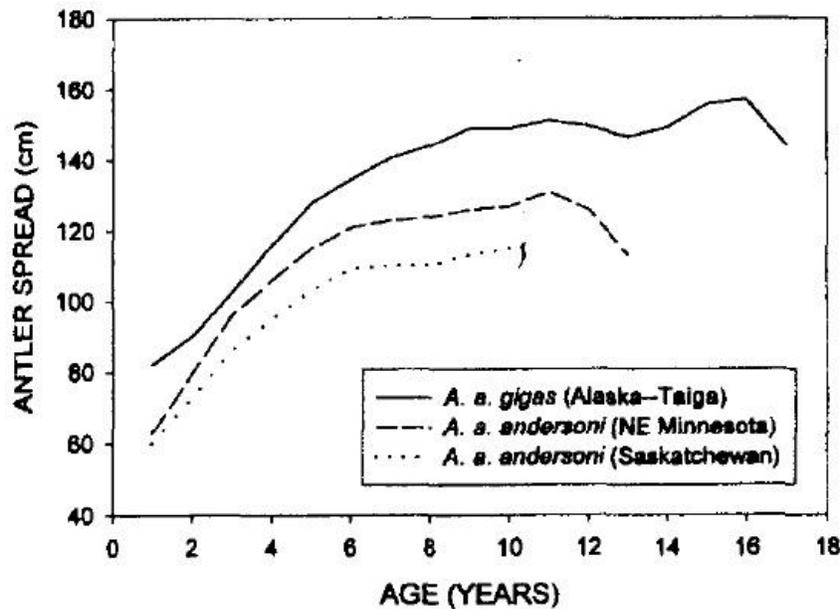

Figure 2: (Bowyer *et al.* 2002, p. 159, Fig. 3): Antler size (spread) in relation to age for *Alces alces gigas* from taiga habitat in Alaska, USA, compared with *A. a. andersoni* from forested habitats in northeastern Minnesota, USA, and Saskatchewan, Canada. Lines are 3-year running means (adapted from Gasaway *et al.* 1987).

This finding supports the hypothesis that the difference in antler sizes between Canadian *A. a. andersoni* and Minnesotan *A. a. andersoni* likely results from variable nutrition availability. The Minnesota population experiences more intense predation and has not yet met its carrying capacity; therefore, it has more available browse than its counterparts farther north (2002, p. 161).

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Andersoni differ from moose in Canada in terms of their reproductive behavior, and lower population densities of moose inhabiting the forested regions of the continental United States result in a different breeding strategy as well. In the tundra ecosystems of Yukon Territory, moose demonstrate polygamy and form assemblages during the rut. In contrast, taiga moose that inhabit the boreal and mixed-transitional forests of southern Canada and the United States generally form pairs for breeding (Schwartz, 1998, p. 162) because their habitat does not allow for a high density of females in one given area (Feldhamer *et al.* 2003, cited in Innes 2010).

2. The U.S. population of *andersoni* moose is delimited by international government boundaries.

Moose habitat in Minnesota is contiguous with habitat in Ontario, and Ontario may act as a source of moose migration into the state. However, the U.S. population of *andersoni* moose is discrete from the Ontario population due to vast differences between the two in terms of exploitation, habitat management, conservation status, and regulatory mechanisms. For example, the moose hunt has been called off completely in Minnesota, but moose are still hunted throughout their range in Ontario, with every Ontario resident entitled to harvest a moose calf each year (Rodgers, Centre for Northern Forest Ecosystem Research, slide 22). This includes areas just north of the northeastern Minnesota population that is on the verge of collapse, and this remains true despite a precipitous drop in the ratio of cows to calves in recent years – declining from 90 percent in 1980 to about 25 percent in 2007 (Rodgers, Centre for Northern Forest Ecosystem Research, slide 10).

Other regulatory mechanisms for wildlife conservation in Canada differ dramatically from those in the United States. In its decision to list the Canada lynx, FWS (65 Fed. Reg. 16,052, 16,060 (Mar. 24, 2000)) stated:

> In Canada, management of forest lands and conservation of wildlife habitat varies depending on Provincial regulations. Canada has no overarching forest practices legislation, such as the United States National Forest Management Act, governing management of national lands and/or providing for consideration of wildlife habitat requirements. Additionally, in Canada, lynx harvest regulations, such as length of season and quotas, vary, being regulated by individual Provinces or, in some cases, individual trapping districts. Therefore, we conclude that the contiguous United States population of the lynx is discrete based on the international boundary between Canada and the contiguous United States due to differences in management of lynx and lynx habitat.

Similar determinations were made for the Pacific fisher (69 Fed. Reg. 18,770, 18,769 (Apr. 8, 2004)), and the same situation exists in regard to the moose.

The conservation status also differs between U.S. *andersoni* moose and Canadian moose. Managers in both countries have noted a decline in their populations, but the United States has experienced a far more severe crash while Canada still bolsters a relatively sizeable population of moose. In the past, FWS has considered substantial differences in the number of animals across international borders to be sufficient cause for considering a DPS discrete, including its findings

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for Steller's eider, peninsular bighorn sheep, and cactus ferruginous pygmy owl. For example, the FWS's finding for the Steller's eider states:

> [T]he Alaska breeding population of Steller's eiders is delimited by international boundaries. Within these international boundaries differences in conservation status exist. While available information suggests that the species in Russia also may have declined, population numbers are estimated to range well over 100,000 birds. However, the status of the breeding population in the U.S., as inferred by the contraction of nesting range, is reduced considerably from historic times, despite the existence of regulatory protections and an abundance of seemingly suitable habitat. (62 Fed. Reg. 31,748, 31,752 (June 11, 1997)).

Similar factors exist for *andersoni* moose today, and relevant findings should also apply.

Additionally, U.S. populations of moose face greater threats due to the impacts of climate change. Higher temperatures are changing precipitation, altering the composition of forests, and creating conditions more favorable to parasite transmission – forcing moose at the southern edge of their range to move northward out of the United States and into Canada to seek suitable habitat (Lawler *et al.* 2009, p. 594).

B. Significance

Under the DPS policy, a population is considered significant based on, but not limited to, the following factors:

    i.   Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,

    ii.   Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,

    iii.   Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or

    iv.   Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

1. Andersoni moose in the United States differ from other moose in Canada in its genetic characteristics.

Andersoni moose in the United States are at the edge of the subspecies' range. As such, they likely have unique genetic characteristics important to the viability, adaptability and evolutionary potential of the species (Lesica and Allendorf 1994). Many studies aimed at predicting the impacts of climate change on intraspecific variation suggest that populations that occur at the

margins of ranges often harbor unique genotypic and phenotypic characteristics that play an important role in the species' response to changing environmental conditions and future persistence (Hampe and Petit 2005; Provan and Maggs 2011; Provan 2013; Assis *et al.* 2013; Beatty and Provan 2011; Diekmann and Serrao 2012).

> **2. Loss of *A. a. andersoni* in the United States would result in a significant gap of range.**

Losing the U.S. population of *andersoni* moose would result in a significant gap in the range of the species. Indeed, it inhabits a narrow band of mixed coniferous-deciduous forest that represents the southern extent of its range. Moose populations decline as that ecosystem changes, thus they are significant as an indicator species for the forests and other species that inhabit them.

For all these reasons, the U.S population of *andersoni* moose is significant and discrete. This population has experienced notable decline, and threats remain imminent and of high severity. Therefore, this population of moose qualifies for listing as a DPS.
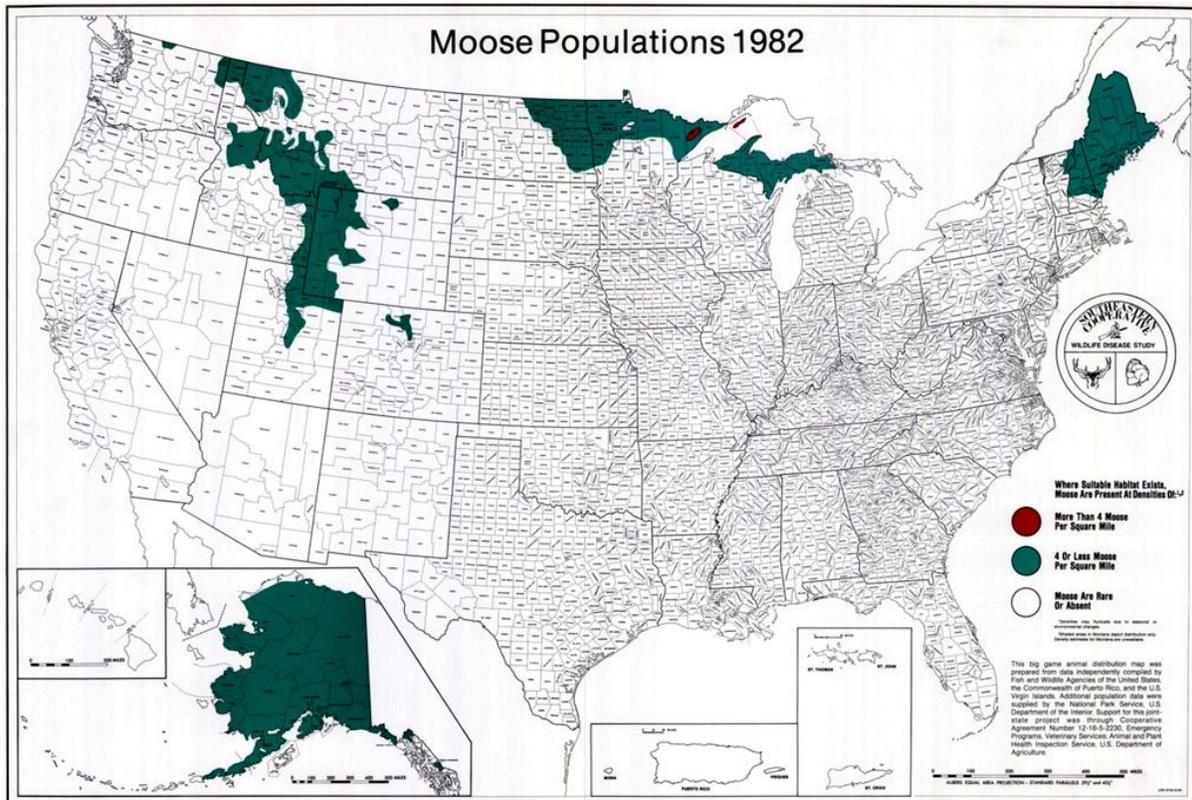
IV. Population Distribution, Status and Trends

Figure 3: Moose range in the United States, with *A. a andersoni* occurring in the Midwest states of North Dakota, Minnesota, and Michigan's Upper Peninsula. Red indicates moose occurring at densities of four or more per square mile, and blue indicates four or fewer moose per square mile (courtesy of UGA College of Veterinary Medicine, available at http://vet.uga.edu/scwds/range-maps).

Moose are among the most difficult ungulates to count due to their solitary behavior and preference for cover (Tyers 2008, p. 3; Toweill and Vecelllio 2004, p. 40). Many states with moose are lacking comprehensive surveys, but most biologists agree their moose populations are declining and are concerned about their future. *A. a. andersoni* moose, in particular, has dramatically declined in number.

Five main populations and one recently established, small population of the northwestern (*A. a. andersoni*) moose exist in the Midwest: the northeastern and northwestern populations of Minnesota, the northeastern North Dakota population, the Upper Peninsula of Michigan population, and the Isle Royale population (Lankester 2010; Franzmann 1981, p. 2). All of these populations have or are expected to experience significant decline, though a small population in Wisconsin has been increasing (Wiedenhoeft et al. 2010, p. 4).

Table 1: Most recent *A. andersoni* moose population estimates by location.

Location	Year	# Moose	Trend	Reference
NE Minnesota	2015	3,450	Declining	DelGiudice 2015
NW Minnesota	2007	<100	Declining, practically extirpated	MN Moose Advisory Committee 2009
North Dakota	2012	1300	Steady overall, some populations declining	Smith 2014, pers. comm.
Michigan's UP	2015	323	Down from 2013, but trend uncertain	Stewart 2015, Upper Michigans Source
Isle Royale	2014	>1000	Increasing due to rapid wolf die-off	Vucetich and Peterson 2014
Wisconsin	2003	20-40	Increasing but variable	WDNR 2004

1. Minnesota

Moose were found throughout the northern forested portion of Minnesota prior to European settlement (Idstrom 1965, cited in Lenarz *et al.* 2009, p. 503). However, moose were pushed into two disjunct populations in the corners of the state by habitat loss from mining, logging, and residential development, as well as hunting and potentially disease (Lenarz *et al.* 2009, p. 503). Both populations have experienced severe declines, and only the northeastern group remains viable today.
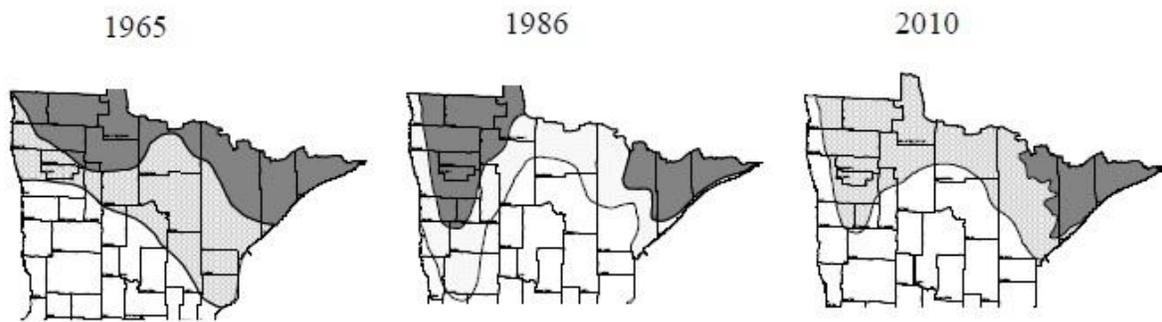

Figure 4: (Minnesota Dept. of Natural Resources 2011, p. 14, Fig. 1): Changes in estimated moose distribution in Minnesota between 1965 and 2010. Dark grey represents the primary moose range and lighter grey represents the secondary range where moose occur at very low density and their distribution is patchy.

The moose population in northwestern Minnesota has experienced a significant decline in the past half century. Following a decline in the 1940s, it began to rebound from 1300 individuals to 4000 by 1985 (Murray *et al.* 2006 cited in Lankester 2010, p. 56). In 1971, regulated hunting of moose was allowed for the first time in 49 years (Karns 1972, cited in Lankester 2010, p. 56), but it was called off again in 1996 when the population began declining again. By the late 1990s, cow to calf ratios were down to 1:2, and reproductive degradation was observed in moose as young as eight years (Lankester 2010, p. 57). This population has sharply declined since 2000, and by 2007 there were less than 100 individuals (Lenarz 2007, cited in Lankester 2010, p. 57). Murray *et al.* (2006, p. 1) predicted that the northwestern Minnesota population would not persist over the next 50 years, and the Moose Advisory Committee reported that "essentially, Minnesota has lost one of two relatively disjunct populations of moose in the state" (2009, p.1).
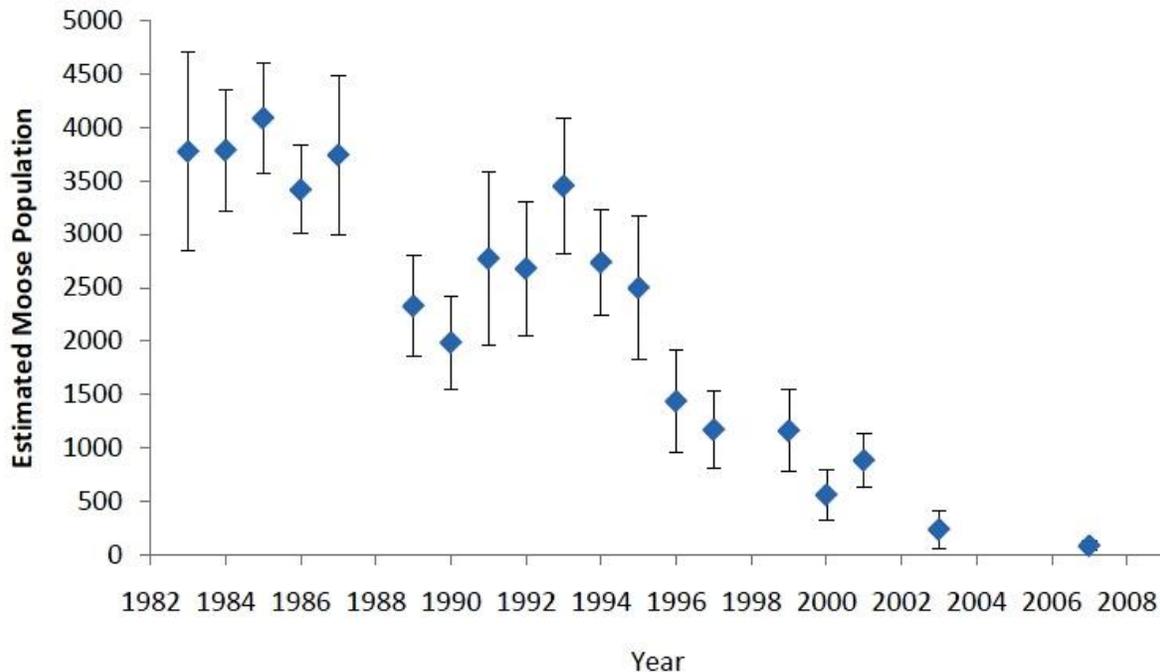

Figure 5: (Minnesota Dept. of Natural Resources 2011, p. 15, Fig. 2): Estimated moose population in northwest Minnesota, 1983-2007. Error bars reflect 90% confidence intervals.

The moose population in northeastern Minnesota appeared stable from 1983 to 2008, but the methodology produced high uncertainty rates in early years, and long term trends could not be identified (Moose Advisory Committee 2009, p. 13; Lankester 2010, p. 58, Lenarz 2010, p. 1020). Lankester (2010) determined there was no evidence of decline at that point, but Lenarz *et al.* (2009) and Peterson and Moen (2009) correctly predicted a precipitous drop in its population.

Warning signs also came between 1998 and 2010 when both calf-to-cow ratios and hunters' success rates were markedly reduced (Lankester 2010, p. 58). The estimated adult annual mortality rate from 2002 to 2007 was 21 percent – twice that expected – and mortality mostly occurred within the southern portion of the moose's range (Lenarz *et al.* 2009, cited in Lankester 2010, p. 58). Lenarz *et al.* (2009) noted the mortality rate likely indicated a decline in the moose population that aerial surveys could not detect (cited in Lankester 2010, p. 58). He recommended a 20 percent difference in estimates to detect a significant change in population size with future aerial survey methods (Lenarz *et al.* 2010, p. 1020).

Scientists improved population estimation methods in 2005 and have documented a dramatic decline in *andersoni* moose since, revealing there are just 3,450 individuals surviving in northeastern Minnesota today – a decline of 58 percent in the last ten years (DelGiudice 2015, p. 3). The most recent population surveys show a 21 percent reduction from 2014 to 2015 alone – dropping from 4,350 individuals to 3,450. The 2015 surveys also indicate that additional dramatic declines are ahead: calf to cow ratios are markedly down compared to 2014, and state wildlife officials believe calf recruitment this year may be the lowest in several years *(id)*. The Moose Advisory Committee warned there will be very few moose remaining in Minnesota in only five years from now if current trends continue, signaling an urgent need for action (Moen *et al.* 2011, p. 2).

Table 2: Estimated moose numbers, 90 percent confidence intervals, calf:cow ratios, percent calves, percent cows with twins, and bull:cow ratios estimated from aerial surveys in northeastern Minnesota, 2005-2014 (Adapted from DelGiudice 2014, p. 3, Table 1).

| Survey	Estimate	90 % CI	Calf:Cow	% Calves	% Cows w/ Twins	Bull:Cow
2005	8,160	5,960 – 11,170	0.52	19	9	1.04
2006	8,840	6,670 – 11,710	0.34	13	5	1.09
2007	6,860	5,230 – 9,000	0.29	13	3	0.89
2008	7,890	5,970 – 10,420	0.36	17	2	0.77
2009	7,840	6,190 – 9,910	0.32	14	2	0.94
2010	5,700	4,480 – 7,250	0.28	13	3	0.83
2011	4,900	3,810 – 6,290	0.24	13	1	0.64
2012	4,230	3,190 – 5,600	0.36	15	6	1.08
2013	2,760	2,120 – 3,580	0.33	13	3	1.23
2014	4,350	3,220 – 6,210	0.44	15	3	1.24
2015	3,450	2,610 – 4,770	0.29	13	3	0.99
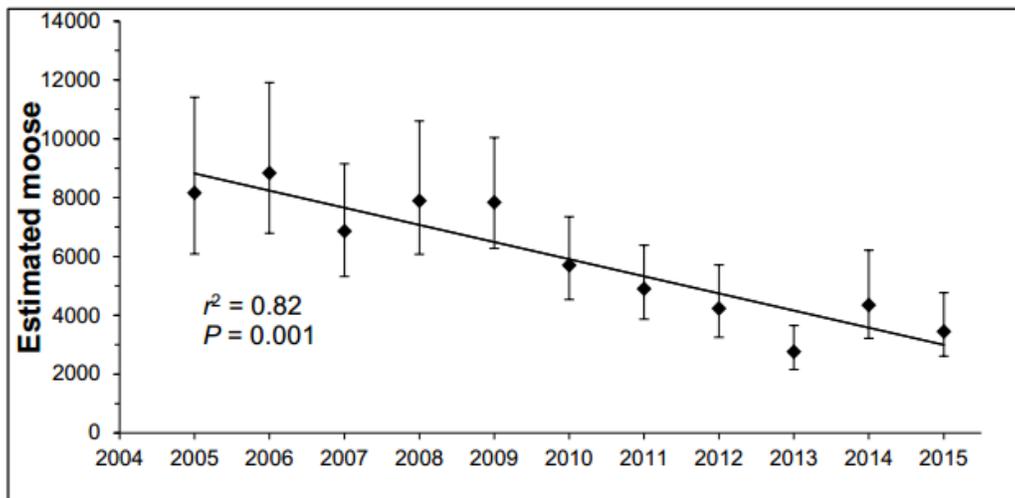
Figure 6: (DelGiudice 2015, p. 4, Fig. 2): Point estimates, 90 percent confidence intervals, and trend line of estimated moose numbers in northeastern Minnesota, 2005-2015. (Note: The 2005 survey was the first to be flown with helicopters and to include a sight-ability model and a uniform grid of east-west oriented rectangular 5 x 2.67 mi plots).

2. North Dakota

In the early 1900s, moose had disappeared from the state of North Dakota, but by 1960 they returned again to the Turtle Mountains, Pembina Hills, the Red River Valley, and, eventually, the Drift Prairie (Smith, Moose Management in ND, slides 5-7; Lankester 2010, p. 58-59). North Dakota generally has not attempted to estimate the size of its moose population, but instead uses a number of factors such as aerial counts and hunting success to track population trends (i.e., whether the population is increasing or decreasing) (Jason Smith 2014, pers. comm).

The Pembina Hills area in northeast North Dakota neighbors the northwest Minnesota population and, as expected, has seen the same decline in moose numbers. From 1974, when the first population survey for moose was conducted, to 1995, moose populations increased from 19 to 261 animals (Smith, Moose Management in ND, slide 6). But the population crashed after that, and only three moose were observed in 2013 (*id.*).

Moose populations further west in the state have remained steady overall, but they have moved out of what would be described as typical moose habitat into the prairies. Maskey (2008) found that moose were only able to exist in prairies by using tree rows and other landscape modifications. The population in the Turtle Mountains has declined from 112 moose in 1996 to eight in 2013. But while moose are no longer found in their usual, forested habitats, there seems to be an expanding population in the prairies. Although they are present in very low densities, their range currently covers about one-third of the state. This is a recent trend, and it is difficult to reach any conclusions about the status of this population. While the original prairie population may have already peaked and densities are declining, moose are still dispersing into new areas.

An aerial count in 2012 indicates that the total population in North Dakota may be around 1300 individuals (Smith 2014, pers. comm.).
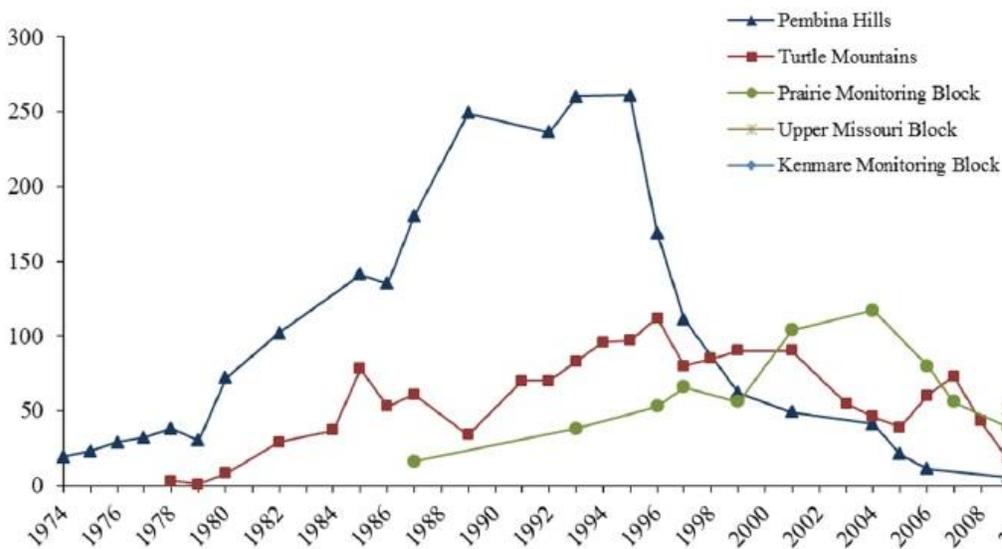

Figure 7: (Smith: Moose Management in North Dakota, slide 15): Trends from winter aerial surveys indicate declining population.

3. Michigan's Upper Peninsula

Moose originally occurred throughout the state of Michigan, but they were extirpated from lower Michigan by the late 1800s, and by 1900, they also disappeared from the Upper Peninsula (Lankester 2010, p. 59). The Michigan Department of Natural Resources attempted two reintroductions by transferring moose from Ontario. The second was marginally successful, but growth has been slow.
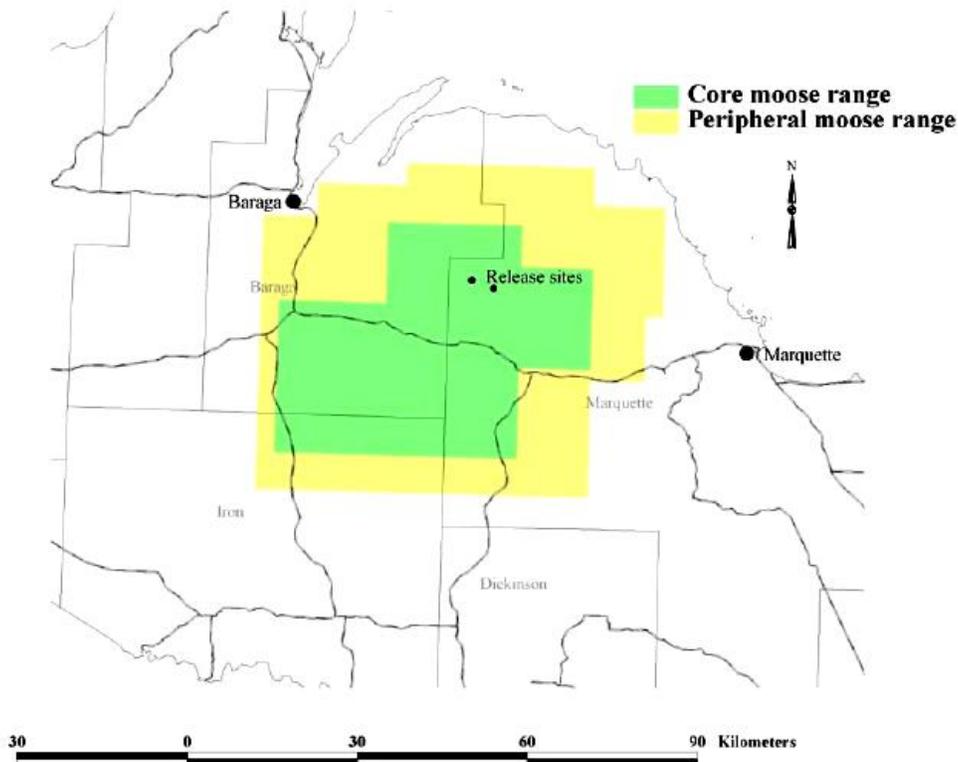

Figure 8: (Beyer *et al.* 2012, Fig. 1): Core and peripheral moose range in Western Upper Peninsula.

In 1996 the population was estimated to be less than 150 moose despite the expectation that it would reach 1000 individuals by the year 2000 (Lankester 2010, p. 59). It has steadily increased since then, but growth has slowed from ten percent a year up to 2007 to two percent from 2009 to 2013 (Zeigler, The Daily News 4/28/14). In 2013, there were an estimated 451 moose in the Upper Peninsula population (id.). In 2015, the number dropped to 323 (Barker, Upper Michigans Source 3/16/15); there may be less than 100 moose on the eastern side of the Peninsula (*id.*).
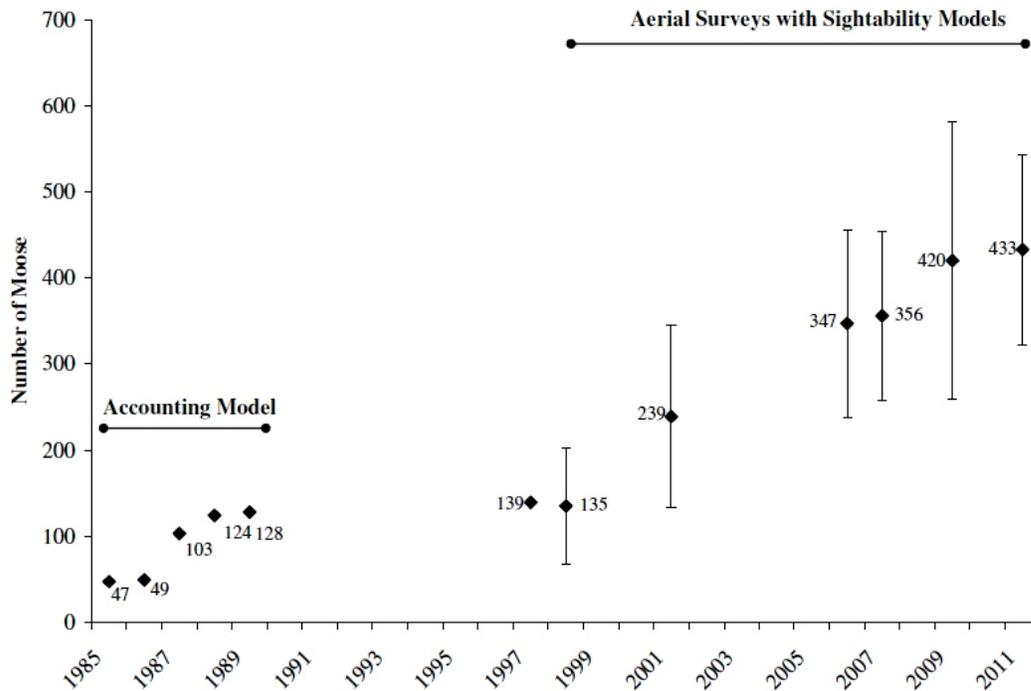
Figure 9: (Beyer *et al.* 2012, Fig. 2): Winter population estimates and 95% confidence intervals (for 1999-2011) of moose in the western Upper Peninsula, 1985-2011. Estimates from 1985-1989 were based on an accounting model and estimates from 1997-2011 were based on aerial surveys corrected with sightability models.

Low pregnancy rates may be attributing to the slow growth rate. The Upper Peninsula population had an average pregnancy rate of 71 percent from 1999 to 2004 (Beyer *et al.* 2011, p. 11), while the average rate in North America is 84 percent (Boer 1992, cited in Beyer *et al.* 2011, p. 11). Biologists fear Michigan's moose will suffer the same fate as Minnesota's. Beyer noted there may be less than 100 moose on the eastern side of the Peninsula that appeared independent of the reintroduction (*id.*).
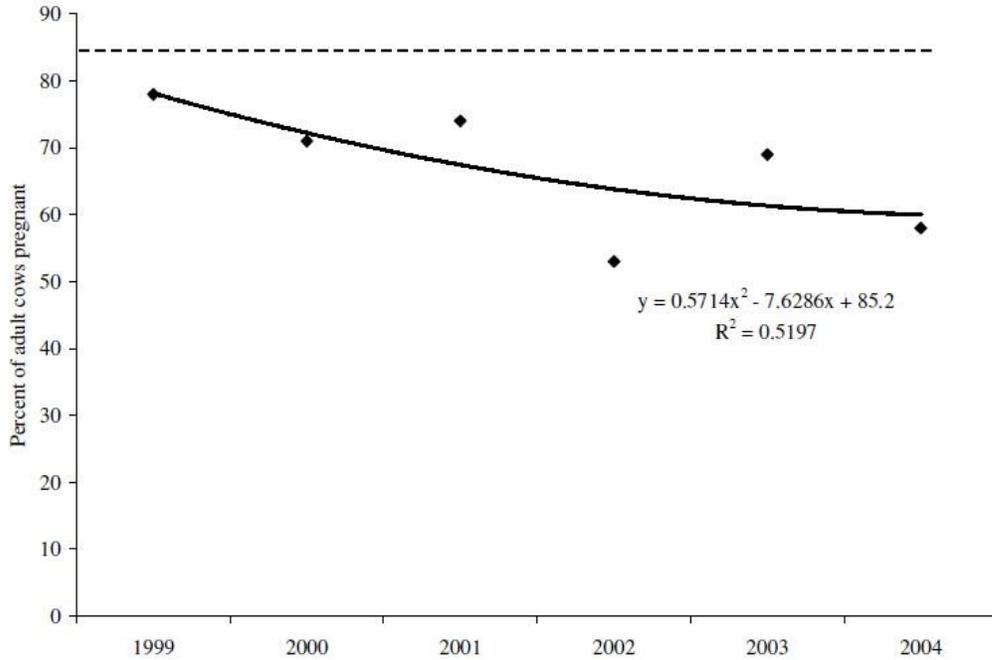
Figure 10: (Beyer *et al.* 2011, Fig. 4)**:** Percentage of pregnant adult cow moose in the western Upper Peninsula of Michigan, 1999-2004. The dashed line shows the North American average pregnancy rate of adult cows (84 percent). The solid line is a regression equation (2nd order polynomial) fit to the pregnancy data.

4. Isle Royale

Moose arrived on Isle Royale National Park in the early 1900s. In the absence of predators, the population rapidly expanded and then fluctuated dramatically based on availability of forage for the size of the population. When wolves arrived in the late 1940s, a more typical predator-prey population dynamic was observed. The moose population declined slightly from 2002 to 2010, but a steeper decline in the wolf population has brought moose numbers back up to over 1000 (Vucetich and Peterson 2014, p. 9).
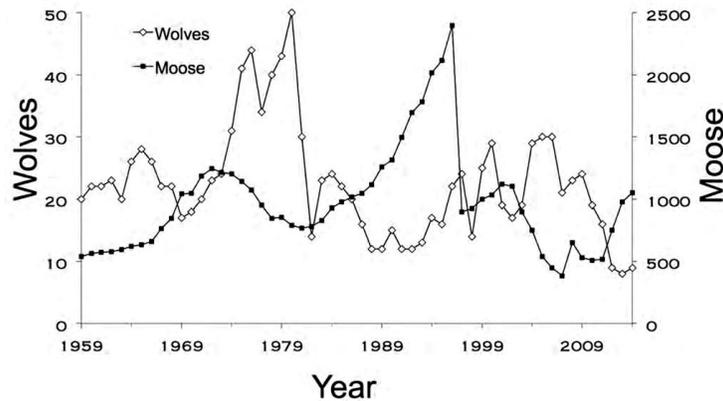

Figure 11: (Vucetich and Peterson 2014, Figure 1, p. 3): Wolf and moose fluctuations, Isle Royale National Park, 1959---2014. Moose population estimates during 1959–2001 were based on population reconstruction from recoveries of dead moose, whereas estimates from 2002–14 were based on aerial surveys.

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5. Wisconsin

Moose were once fairly common in the forests of northern Wisconsin, but were no longer found by the early 1900s (Government Product News 3/3/03). Beginning in the 1960s, moose began migrating from the native population in Minnesota, and later the introduced population in Michigan (Smith, Journal Sentinel 10/7/11; Government Product News 3/3/03). A moose birth in the state was documented in 2002 for the first time in a century (Smith, Journal Sentinel 10/7/11), and now Wisconsin maintains a small but apparently increasing population. Reported sightings of moose have increased considerably in recent years (Wiedenhoeft et al. 2010, p. 4), but they remain well under 100 yearly. Wisconsin has not done an official survey to estimate their moose population. Biologists note that moose do not occur at historical numbers due to a lack of habitat and a high deer population which transmit disease (See "Disease and Predation") (Smith, Journal Sentinel 10/7/11).

V. Threats

Moose warrant protection as endangered or threatened species under the Endangered Species Act (ESA), 16 U.S.C. § 1533(a)(1). Under the ESA, FWS is required to list a species for protection if it is in danger of extinction or threatened by possible extinction in all or a significant portion of its range.

In making such a determination, FWS must analyze the species' status in light of five statutory listing factors:

    (A) the present of threatened destruction, modification, or curtailment of its habitat or
         range
    (B) overutilization for commercial, recreational, scientific, or educational purposes;
    (C) disease or predation;
    (D) the inadequacy of existing regulatory mechanisms;
    (E) other natural or manmade factors affecting its continued existence.

16 U.S.C. § 1533(a)(1)(A)-(E); 50 C.F.R. § 424.11(c)(1)-(5).

A species is "endangered" if it is "in danger of extinction throughout all or a significant portion of its range" due to one or more of the five listing factors. 16 U.S.C. § 1531(6). A species is "threatened" if it is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." *Id.* § 1531(20).

While the ESA does not define the "foreseeable future," the FWS must use a definition that is reasonable, that ensures protection of the petitioned species, and that gives the benefit of the doubt regarding any scientific uncertainty to the species. Climate change is one of the main drivers in the decline of moose. A time period through 2100 is the minimum amount of time that addresses these climate change related threats to moose.

Because climate change is one of the foremost threats to the moose, the Service should use timeframes used in climate modeling to assess climate impacts to the moose. Predictions of

climate change impacts through 2100 are routine in scientific literature. As the International Panel on Climate Change (IPCC) stated in its Fourth Assessment:

> Advances in climate change modeling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios. Results for different emission scenarios are provided explicitly in this report to avoid loss of this policy-relevant information. Projected global average surface warnings for the end of the 21st century (2090–2099) relative to 1980–1999 are shown in Table SPM.3. These illustrate the differences between lower and higher SRES emission scenarios, and the projected warming uncertainty associated with these scenarios (IPCC 2007: 13).

Additionally, Representative Concentration Pathways (RCPs) were developed for the 2013 IPCC Fifth Assessment, which similarly provide updated, high-resolution datasets for emissions trajectories and impacts analysis through 2100, including estimates of uncertainty and extensions (Extended Concentrated Pathways) through the year 2300 (van Vuuren *et al.* 2011).

Recent listing decisions have also supported defining the "foreseeable future" through the year 2100 for climate-threatened species. In a final listing rule for the ringed seal and bearded seals, NMFS states:

> NMFS scientists have revised their analytical approach to the foreseeability of threats and responses to those threats, adopting a more threat-specific approach based on the best scientific and commercial data available for each respective threat. For example, because the climate projections in the Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (AR4; IPCC, 2007) extend through the end of the century (and we note the IPCC's *Fifth Assessment Report* (AR5), due in 2014, will extend even farther into the future), for our analysis for bearded seals we used the same models to assess impacts from climate change through 2100. We continue to recognize that the farther into the future the analysis extends, the greater the inherent uncertainty, and we incorporated that limitation into our assessment of the threats and the species' response (77 Fed. Reg. 76,706, 76,741(Dec. 28, 2012)).

Status reviews for these species also found that climate projections through the end of the twenty-first century "currently form the most widely accepted version of the best available data about future conditions" (Cameron *et al.* 2010; Kelly *et al.* 2010, p. 43). The same determination of foreseeable future was made for coral species (Bainard *et al.* 2012, p. 100), in which 66 of 82 species included in a petition were listed, with NMFS saying:

> We agree with the [Corral Biological Review Team's] judgment that the threats related to global climate change (e.g., bleaching from ocean warming, ocean acidification) pose the greatest potential extinction risk to corals and have been assessed with sufficient certainty out to the year 2100. Therefore, we have determined the foreseeable future for the 82 candidate species to be to the year 2100 (77 Fed. Reg. 73,220, 73,221 (Dec. 7, 2012)).

These determinations that climate projections through 2100 represent the best-available science for assessing the "foreseeable future" threats of climate change provides a solid basis for applying the same foreseeable future timeline to the moose.

Perhaps more importantly, the time period the Service uses in its listing decision must be long enough so that actions can be taken to ameliorate the threats to the petitioned species and prevent extinction. *See Defenders of Wildlife v. Norton*, 258 F.3d 1136, 1142 (9th Cir. 2001) (quoting legislative history that notes the purpose of the ESA is "not only to protect the last remaining members of [a listed] species but to take steps to insure that species which are likely to be threatened with extinction never reach the state of being presently endangered"). Slowing and reversing impacts from anthropogenic greenhouse gas emissions, a primary threat to the moose, will be a long-term process for a number of reasons, including the long-lived nature of carbon dioxide and other greenhouse gases and the lag time between emissions and climate changes. The use of less than 100 years as the "foreseeable future" in this rulemaking would be clearly unreasonable, frustrate the intent of Congress to have imperiled species protected promptly and proactively, and fail to give the benefit of the doubt to the species as required by law. The Service must include these considerations in its decisions for the moose.

Throughout this threats analysis, it is important to remember that our current understanding of the causes of the decline in moose populations is limited and studies are ongoing. However, most scientists generally agree that the main driver of moose population decline likely is a result of the combination of climate change, *and* disease, *and* parasites, *and* habitat curtailment, with other factors likely exacerbating these problems.

A. The present or threatened destruction, modification, or curtailment of its habitat or range

Overall, habitat loss is not considered to be the primary reason for the most severe declines in *andersoni* moose (Minnesota Department of Natural Resources 2011, cited in Schrage 2014, p. 1). However, moose are threatened by the impacts climate change will have on its habitat and range. Managing moose habitat already requires a complex balance of maintaining young and old forests, and these complexities will grow in the face of climate change and human resource use.

1. Global Climate Change

Global climate change is happening at an unprecedented rate and threatens numerous species and their habitats. The IPCC, the world's leading authority on the assessment of climate change, published in its Fifth Assessment Report (AR5) "Summary for Policy Makers," which states:

> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased (see Figures SPM.1, SPM.2, SPM.3 and SPM.4) (IPCC 2013, p. 2.2, 2.4, 3.2, 3.7, 4.2–4.7, 5.2, 5.3, 5.5–5.6, 6.2, 13.2).

Scientists agree that these trends are largely human-induced, resulting from human activities that release greenhouse gases such as carbon dioxide into the atmosphere, where they accumulate and create a greenhouse effect.

Major changes in ecosystem structure and function are predicted if temperatures increase 1.5 to 2.5°C. Changes are expected in species' ecological interactions and geographical ranges, with predominately negative effects on biodiversity. The IPCC states with "virtual certainty" that there will be more frequent hot and fewer cold temperature extremes, and heat waves will occur in higher frequencies and duration (IPCC 2013, p. 20).

Species respond to climate change in many different ways depending on their sensitivity to environmental changes, the exposure they have in their range, and their adaptive capacities (Huey *et al.* 2012, cited in McCain and King 2014, p. 1766; Dawson *et al.* 2011, p. 53). Climate and extreme weather events are mechanistically linked to body size, individual fitness, and population dynamics of diverse species (Parmesan and Yohe 2003, p. 40). Moose are at more of a disadvantage than other animals because warmer climates tend to favor smaller body mass in many taxa, including mammals (Frelich *et al.* 2012, p. 2955).

McCain and King (2014) found that large bodied mammals, such as moose were more likely to rapidly respond to climate change, which indicates a higher extinction risk (p. 1768). To be sure, during the Pleistocene extinction, the largest range shifts detected were among large bodied mammals (McCain and King 2014, p. 1766). Though large mammals are more mobile than their small relatives, McCain and King's study showed that because large mammals are already contracting their ranges and reducing in abundance, there is a stronger negative impact of climate change than what could be solved by mobile response (2014, p. 1767). Large-bodied mammals are generally at higher risks of extinction due to the energy expended in their life-histories (reviewed in McCain and King 2014, p. 1767), but mammals that exist at higher latitudes and the southern limits of their range will experience more dramatic shifts in climate, putting them at even higher risks of extinction (McCain and King 2014, p. 1761, 1767).

Moose – large bodied mammals superbly adapted to cold climates and intolerant of heat – are faced with many challenges with the onset of climate change. Moose will lose crucial habitat, experience heat stress and malnutrition, and come into contact with more pathogens and winter ticks as a result of warmer, wetter winters and springs, a reduction in snow depth, and hotter summers (Rustad *et al.* 2012, p. 30-31).

a. Moose Habitat is Threatened by Global Climate Change

The pace of climate change is expected to exceed the rate of forests' natural ability to adapt (reviewed in Duveneck *et al.* 2014, p. 1). For example, climate change has already been linked to declines in quaking aspen that are occurring throughout North America (Worrall *et al.* 2013, cited in Duveneck *et al.* 2014, p. 1). In most cases, species' habitats have been projected to move north to higher latitudes. Tree species that are important to moose in eastern North America – including quaking aspen, paper birch, northern white cedar, balsam fir, and sugar maple – are likely to move completely north of the U.S. border (Hasen *et al.* 2001, p. 771).

The northern Great Lakes region is expected to experience faster rates of climate change than other regions in the country because it is not buffered by oceans (IPCC 2007, cited in Duveneck *et al.* 2014, p. 2). On the other hand, because of the unique regional features of the Great Lakes system, scientists have struggled to construct exact predictions on how global climate change will affect the region (Gregg *et al.* 2012, p. 6).

Average temperatures have been increasing in the Great Lakes region over the past few decades, especially in winter (Wuebbles and Parzen 2010, cited in Gregg *et al.* 2012, p. 10). Mean temperatures are expected to increase by 3-7°C in winter and 3-11°C in summer in the Great Lakes region by 2100 (Duveneck *et al.* 2014, p. 2). Winter temperatures are expected rise at twice the rate of summer temperatures, with the coldest day becoming 4-8°C higher than average (Gregg *et al.* 2012, p. 10-11). Summers are expected to be an average 2-3°C higher by mid-century (Frelich *et al.* 2012, p. 2957), and the frequency and duration of summer heat waves will increase (Gregg *et al.* 2012, p. 11). The number of hot days over 32.2°C will increase, and by the end of the century, the region will experience a larger number of extremely hot days over 37.8°C (Gregg *et al.* 2012, p. 11). The number of frost days per year will decrease and end 20 to 30 days earlier in the season (Gregg *et al.* 2012, p. 11).

A greater variability in precipitation is also expected (IPCC 2007, cited in Duveneck *et al.* 2014, p. 2). Rain is expected to fall more often than snow. Almost 75 percent of the winters have seen below average snowfall since 1980, and scientists believe climate change will result in 30 to 60 percent fewer snow days annually in the Great Lakes region by the end of the century, depending on emission scenarios (Gregg *et al.* 2012, p. 15).

Similarly, boreal species on which moose rely, including black spruce, paper birch, and northern white cedar, are expected to decline throughout most of the southern edge of their ranges (Iverson *et al.* 2008, Walker *et al.* 2008, cited in USDA 2012, p. 227). The boreal-temperate ecotone that currently exists in northern Minnesota, Michigan, and New York is expected to shift north by 150 to 200 kilometers (Galatowitsch *et al.* 2009, cited in Frelich *et al.* 2012, p. 2957). A warmer climate with dryer soils in the north is expected to favor oak species, and forested wetlands – an incredibly valuable type of habitat for moose – will likely disappear (USDA 2012, p. viii).

Moose on Isle Royale face an additional, unique threat as a result of warming temperatures. Ice bridges that connect the island to Canada and Minnesota have not been forming as frequently in the past – now forming only about once every 15 years, whereas bridges used to occur about every eight out of ten years (Barnes, MLive 11/7/2014). Experts that study the Isle Royale predator-prey system between wolves and moose fear the next ice bridge will be the last to ever form, permanently isolating the islands inhabitants (*id.*). If a disease wiped out the moose population – as one did the wolves, natural recovery would be impossible.

b. Moose are Intolerant to Heat

Along with food supply and habitat composition, climatic influences play a large, if not the largest, role in determining the limits of moose range (Kelsall and Telfer 1974, cited in McGraw *et al.* 2012, p. 51; Rustad *et al.* 2012, p. 30-31). It is well known that moose are highly sensitive

to above average temperatures due to their superb adaptations for cold weather (Renecker and Hudson 1986, p. 326; Renecker and Hudson 1990, cited in Lenarz 2010, p. 1013; Lenarz *et al.* 2009, p. 507-508; Haase and Underwood 2013, p. 50; McGraw *et al.* 2012, p. 45). The moose's large body size and insulating coat make them susceptible to heat stress (Feldhamer *et al.* 2003).

Heat stress has been defined as "the state at which mechanisms activate to maintain an animal's body thermal balance when exposed to intolerable (uncomfortable) elevated temperatures" (Marai and Haebb 2010, cited in Broders *et al.* 2012, p. 53). Renecker and Hudson (1986, p. 324) discovered that the temperature threshold for heat stress for moose in Alberta is -5°C in the winter and 14°C in the summer. Moose exhibit initial responses when temperatures exceed these thresholds such as panting and seeking shade (McGraw *et al.* 2012, p. 51). High temperatures are especially troubling for moose in early spring when they still have their winter coats (Lenarz *et al.* 2009, p. 503). Further increases in temperature and lack of refuges can lead to serious health complications, including increases in metabolic, heart, and respiration rates; reduced feed intake and body fat; increased susceptibility to parasitism and disease; and reduced productivity (Broders *et al.* 2012, p. 54; Belovsky and Jordan 1978, Renecker and Hudson 1986, 1990, Lenarz *et al.* 2008, p. 50; Lenarz 2010, p. 1013 and Haase and Underwood 2013, p. 50).

Moose reduce overall activity and seek shade or water when temperatures are high enough to cause stress (Peek *et al.* 1974, Renecker and Schwartz 2007, cited in Innes 2010), thereby changing daily activity patterns and limiting the use of high quality habitats (Feldhamer *et al.* 2003, Franzmann 1981, cited in Innes 2010). Because of their size, moose are unable to continue eating during summer warm spells (Frelich *et al.* 2012, p. Bishop 1988, Cowan *et al.* 1950, cited in Innes 2010). The energy loss and malnutrition that occurs from increased activity (seeking shade) and decreased feeding reduces moose's ability to resist pathogens (Lenarz *et al.* 2009, p. 508). Additionally, cattle exposed to heat stress had markedly reduced white blood cell counts (Morrow-Tesch *et al.* 1996, cited in Lenarz *et al.* 2009, p. 504) which suggests a further suppression of the immune system made worse by malnutrition, leading to further susceptibility to parasites (Hahn 1999, cited in Lenarz *et al.* 2009, p. 504). In Minnesota, Lenarz *et al.* (2009, cited in DeCesare *et al.* 2014, p. 46) was able to show that heat stress, based on Renecker and Hudson's thresholds (1986), accounted for more than 78 percent of the annual variability in moose survival. Murray *et al.* (2006, p. 24) also attributes the decline of moose in northwest Minnesota to heat stress, linking it to energy loss, malnutrition, and immunosuppression.

Impacts to moose from heat stress will only intensify as temperatures increase further from climate change (Lenarz *et al.* 2009, p. 503). Summer temperatures are expected to increase 1.5-2°C by 2025 and 3-4°C by 2100 (Kling *et al.* 2003, p. 17; IPCC 2007). As a result, there will be more and longer periods of time when the temperature exceeds the upper limit for moose (McGraw *et al.* 2012, p. 51). Regions that frequently exceed 27°C in the summer and do not have aquatic or shady microclimates cannot support moose populations (Demarchi 1991, cited in McGraw *et al.* 2012, p. 45). Increasing temperatures in the Midwest and Great Lakes regions will put *andersoni* moose populations in serious jeopardy.

c. Forest Disturbance Needed for Moose Habitat Is Being Altered

Maintaining favorable moose habitat in an increasingly populated world is challenging and complex. Moose can benefit from natural and human-induced forest succession because of the nutritional qualities new vegetation provides. Fire, logging, and insect outbreaks (plus the absence of predators) allowed moose to expand their range in the United States in the twentieth century (Innes 2010). However, natural disturbances such as fire are often suppressed while detrimental human disturbances such as logging have intensified, and climate change is adding to these threats. Cumulatively, these impacts are causing dramatic shifts in moose habitat in the Midwest and Great Lakes, eliminating safe refuges, mature forests needed for cover (Innes 2010), and important browse species. *Andersoni* populations will continue to plummet if these issues are not addressed.

i.   Logging and Fire

Logging and fire is generally believed to open up forests and provide good habitat for moose populations (Schrage 2014, p. 1). However, while appropriate timber harvest may create habitat that moose prefer, intensive exploitation may cause moose to avoid these areas (Mabille and Ouellet 2012, p. 975). Moose favor disturbance associated with clearcuts only during the 15 to 40 year period following the cut, avoiding recently cut areas (Eason *et al.* 1981, Girard and Joyal 1984, Eason 1989, cited in Courtois *et al.* 2002, p. 178). Roads created from logging operations open up the forests to hunters and predators, and biologists have recorded moose avoiding such areas and modifying their movements between patches of forest (Laurian *et al.* 2008, McLoughlin *et al.* 2011, cited in Mabille and Ouellet 2012, p. 975; Rempel *et al.* 1997, cited in Courtois 2002, p. 178). As expected, Courtois (2002) found that moose prefer clear cut areas that had matured to mixed stands over young, freshly cut areas. He also found that moose move from these areas to mature forests in winter to seek cover. Because of the limited time frame in which disturbed habitat is favorable to moose, excessive logging may reduce moose food and cover for longer periods of time than the population can withstand (Innes 2010).

Aspen communities require disturbance such as fire to regenerate and prevent succession (Smith *et al.* 2011, p. 159), but fire suppression in the twentieth century has allowed conifers to overtake and replace large areas of aspen forests (Rehfeldt *et al.* 2009, p. 2353). This, together with the decline of willow habitat in crucial winter ranges for moose (Harry 1957, Houston 1968, cited in Smith *et al.* 2011, p. 152), is also reducing the preferred habitat for moose in both quality and quantity (Smith *et al.* 2011, p. 152).

However, fire has not always had the positive effect on moose habitat as predicted, as can be demonstrated by the 1988 fire in Yellowstone which led to a local moose population crash (Tyers 2008, p. 9).

ii.   Forest Pests

In the northern states from Minnesota to Maine (Kucera and Orr, undated), outbreaks of the Eastern spruce budworm can provide forest disturbance favorable for moose (Crawford *et al.* 1993, Krefting 1974, cited in Innes 2010). These outbreaks create openings that can allow balsam fir and spruce saplings to grow, which provide nutrition to moose, but they could also create even-aged stands where moose no longer have important cover (Feldhamer *et al.* 2003,

Newton *et al.* 1989, Peek 2007, Krefting 1974, cited in Innes 2010). Thus, it is important to understand and prepare for outbreaks that may be too severe for forests and moose to withstand.

It is difficult to predict how the Eastern spruce budworm will respond to climate change and how moose will respond to those changes in the forest. A study conducted by Candau and Fleming (2011) in Ontario estimated the changes in budworm outbreaks under six different climate scenarios from 2011-2040. They found that under all six conditions there will be a northward expansion of outbreak range while the southern range of budworm still persists (Candau and Fleming 2011, p. 1956, 1958). In the southern portion of range, additional warming is expected to increase the ratio of senescence to regeneration, which will result in the decline in host tree densities and eventually could cause the budworm – fir – spruce system to crash altogether and succeed to deciduous forest, shrubland, or grassland (Candau and Fleming 2011, p. 1958). The risk of fire may increase during this transient period as severe defoliation combines with higher temperatures and lower moisture (Fleming *et al.* 2002, cited in Candau and Fleming 2011, p. 1958). Resulting fire could decrease the long-term abundance of balsam fir and white spruce, (Candau and Fleming 2011, p. 1958), important forage and cover species for moose. Furthermore, a study conducted by Gray (2008) projected the changes in budworm outbreaks as they may occur from 2081-2100 under a climate scenario of carbon dioxide concentrations reaching 550 parts per million. He found that the outbreak may increase substantially in terms of both severity and duration (15 percent and six years, respectively) in the northern portion of his study area (Gray 2008, p. 377), thus potentially pushing moose even farther north into Canada.

Bark beetle outbreaks may benefit moose by opening the forest in the same manner as timber harvest or fire, but severe and persistent infestations may also reduce the habitat heterogeneity, browse, and cover species that moose prefer (Ritchie 2008, cited in Innes 2010; Samman and Logan 2000, cited in WGFD 2010b, p. 5-9). A study conducted in the southern Canadian Rocky Mountains concluded that a moderate amount of tolerance for mountain pine beetles combined with low and high intensity fires would allow a more diverse, open forest to develop (Dordel *et al.* 2008, p. 3570). However, concern among biologists today stems from the potential for bark beetle outbreaks to exceed a healthy threshold with the onset of climate change. Though not yet as prevalent in the Midwest as it has been in the Rocky Mountains region, excessive beetle populations threaten moose habitat.

Species such as the mountain pine beetle and the spruce beetle have the potential to spread into Midwest states and cause an epidemic in its forests such as what we have already witnessed in the western United States (Bentz *et al.* 2010, p. 607-608). Warmer temperatures mean that bark beetles are not dying off in the winter months, and warmer, dryer summers have reduced trees' abilities to resist the attackers (Carroll *et al.* 2004, cited in Dordel 2008, p. 3564). This "perfect storm" of fire suppression, drought, and large-scale bark beetle infestations is causing changes at a landscape-level in the West and is likely to spread east (WGFD 2010b, p. 5-8; Bentz *et al.* 2010, p. 611).

2. Land Ownership and Resource Development

Human activity changes moose behavior. Lykkja *et al.* (2009, p. 118) found that moose moved farther from areas of high human density, especially during peak activity hours. Moose habitat

must be managed in a way that allows for natural forest disturbance and mitigates the negative effects of climate change.

Much of the forested landscape in the northern Great Lakes is privately owned and managed for timber production (68 percent, compared to only 21 percent in the west; USDA 2012, p. 2, Bishop 1988, cited in Innes 2010). Timber harvest causes the most frequent land disturbance in the region, and intensive logging has resulted in denser, more homogenous stands than historically occurred (Karamanski 1989, Heinselman 1996, Hanberry *et al.* 2011, cited in Duveneck *et al.* 2014, p. 2). But the economic recession in the United States led to a decrease in aspen harvests in the region, which will result in a shift to more shade tolerant species if the trend continues. It is difficult to predict how land owners will act in the future, but increased disturbances brought on by climate change will likely further reduce habitat connectivity and corridors (USDA 2012, p. viii). Furthermore, education on climate-driven sustainable practices becomes more difficult when dealing with diverse motivations and values within privately owned lands (USDA 2012, p. 2, Bishop 1988, cited in Innes 2010).

In recent years, increased pressure to produce more precious metals, oil, and natural gas in the United States has further threatened important moose habitat. Within moose range in Minnesota and the Upper Peninsula of Michigan, hard rock mining pressures have been mounting. A cumulative effects analysis performed in 2006 for past, present, and reasonably foreseeable actions examined the total land loss and impacts on known wildlife corridors for sensitive species in NE Minnesota. It found that six of the 12 known wildlife corridors in the 100-mile mineral formation in the Mesabi Iron Range will likely become isolated, fragmented, or lost completely, and almost 9,000 acres of habitat will likely be destroyed by mining, economic development, and forestry practices (Emmons and Olivier Resources, Inc. 2006, p. 51). Moose were not included in this study because it was conducted before they were listed as a Species of Greatest Conservation Need, but impacts to other listed species were considered to be significant. It is reasonable to conclude that moose would likely be negatively impacted as well. In Michigan's U.P., mining has begun in Marquette County, where 29 moose were reintroduced from Ontario in "Operation Moose Lift." The site was selected due to its pristine habitat quality and remoteness from human activity.

The Environmental Protection Agency (EPA) named hard rock mining as the number one source of toxic pollution in the United States, releasing 3.4 billion pounds of toxic chemicals in 2000 – an estimated 47 percent of all toxics released by U.S. industries (Lovingood *et al.* 2004, p. 4). Hard rock mining involves the removal and beneficiation of metals and minerals, a process that results in huge amounts of waste in the forms of open mine pits, tailings ponds, ore stockpiles, and waste rock dumps – all of which are significant sources of toxic heavy metals such as cadmium and lead (*id.*).

Because of their herbivorous diets, moose are particularly susceptible to cadmium accumulation. Bioaccumulation of cadmium in moose livers and kidneys has been well documented (Crichton and Paquet 2000; Polluck 2005; Custer *et al.* 2004; Glooschenko *et al.* 1988; Crete *et al.* 1987). The effects of high concentrations of cadmium in moose are poorly understood (Polluck 2005, p. 22), butchronic cadmium toxicity tends to target the kidneys and bones of mammals and birds (Scheuhammer 1987, Alden and Frith 1991, cited in Polluck 2005, p. 22). Renal toxicity can

result in proximal tubular necrosis (Alden and Frith 1991, cited in Polluck 2005, p. 22), and an increase in cadmium concentrations disrupts calcium balance and reduces bone density (Taylor *et al.* 1999, cited in Polluck 2005, p. 22). Published studies that document these health problems are lacking for moose, but Crichton (unpubl. data, cited in Crichton and Paquet 2000, unpaginated) noted anomalous wear in moose in western Manitoba. Madden (1974) and Garrett (1994) also documented high levels of cadmium in a region where moose were frequently seen with worn teeth (Crichton and Paquet 2000, unpaginated).

Mining also causes acid mine drainage, which is highly toxic and a dangerous source of water pollution. Acid mine drainage is extremely difficult to control when it occurs, and it is responsible for contaminating an estimated 10,000 miles of rivers and streams in the United States (Lovingood *et al.* 2004, p. 4).

Example of a stream contaminated with acid mine drainage. The U.S. Forest Service estimates that approximately 10,000 miles of river and streams have been contaminated by mining activity (Courtesy of Lovingood 2004, p. 4-5).
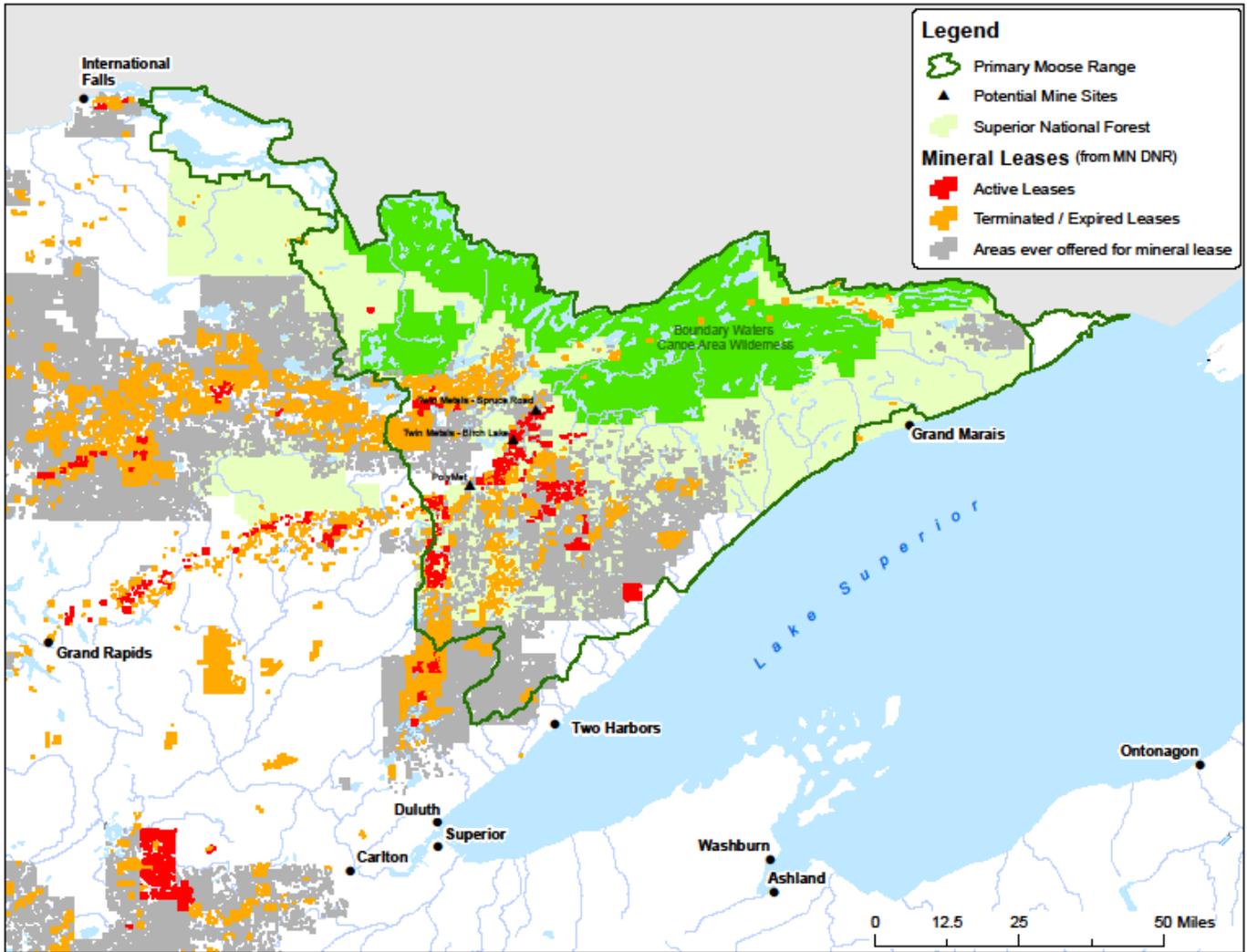
Figure 12: Mineral leases within the primary moose range in northeastern Minnesota.

Increased mineral and energy development within moose habitat will likely drive away these large cervids.

B. Overutilization for commercial, recreational, scientific, or educational purposes

Moose are prized big game species throughout their range in the United States and Canada. As such, moose hunting is carefully managed by the states. Minnesota cancelled their moose hunt in response to the decline in populations there, and other states followed suit reducing available moose permits. Despite this, overhunting was cited as a contributing factor to the decline of moose in North Dakota (Maskey 2008, thesis abstract; Smith and Maskey 2013, abstract). In addition, calf mortality has been an unfortunate and unintentional consequence of tracking moose for scientific study (Myers, Forum News Service 2/23/15), but it is unclear if these mortalities will have an impact at the population level as a whole. Nevertheless, Governor Dayton halted moose-collaring in Minnesota due to the high death rate (Marcotty, Star Tribune 4/28/15).

State managers adjust hunting permits yearly according to population trends, and they often rely on hunting data to understand how moose are doing from year to year. However, regulations for moose hunting do not always consider additive impacts of hunting in seasons when suitable habitat is less abundant (Brown 2011, p. 1296). Lowering the number of hunting permits after populations have already decreased might be a late response to a problem that is exacerbating the effects of intensive past hunting. Managers should study the shifts in climate patterns that affect the timing and quality of vegetation, and ultimately the nutrition of moose and population recruitment, to identify regional differences and predict appropriate hunting limits (Brown 2011, p. 1296). Additionally, in most states managers estimate their moose populations based on the seasonal catch per unit effort (CPUE) of moose hunts, but in a study conducted by Hatter (2001, abstract), this method of estimation was shown to underestimate the rate of population decline and overestimate the rate of increase in black-tailed deer and moose. Problems with using hunter success as a surrogate for population viability also surfaced in the Turtle Mountains of North Dakota where hunters had a 79 percent success rate in 2011 followed by a 29 percent success rate in 2012. The hunting season had to be closed in 2013 (Smith 2013, http://gf.nd.gov/magazines/august-september-2013/2013-hunting-outlook/big-game), and moose are now considered essentially extirpated from the Turtle Mountains, with overhunting a contributing factor (Smith and Maskey 2013, abstract).

C. Disease or Predation

North American ungulates are susceptible to numerous parasitic diseases, some of which can be fatal to moose. Climatic restrictions on vectors and environmental habitats usually keep animal diseases in check (Stem *et al.* 1989, DelGiudice *et al.* 1997, cited in Lenarz *et al.* 2009, p. 508), but climate change is likely to alter temperature and habitat regimes in favor of disease transmission, decreasing moose productivity and survival rates (Baker and Viglizzo 1998, cited in Lenarz *et al.* 2009, p. 508; Pickles *et al.* 2013, p. 2645). Dr. Rolf Peterson, Chair of the Minnesota Moose Advisory Committee, wrote that "the most important reason for moose decline in Ontario and Minnesota is likely an interaction between climate and parasites (especially brain worm) that moose acquire when they live in the presence of white-tailed deer" (Vucetich *et al.*

2013, p. 101). The combination of stressors brought on by climate change further reduces moose's ability to ward off pathogens, and management should consider the additive effects that heat stress, malnutrition, loss of habitat, and disease will have on moose. The following information details pathogens that are believed to be threatening moose populations currently or that may be exacerbated in the future.

1. *Parelaphostrongylus tenuis* ("brain worm" or the meningeal worm)

Parelaphostrongylus tenuis is a parasitic, meningeal worm, commonly known as the brain worm, which is lethal to moose. Terrestrial gastropods and white-tailed deer are the natural hosts for this parasite, but moose have experienced higher infection rates as a result of increased range overlap with the hosts. Scientists consider it to be a significant contributor to the periodic, prolonged moose declines in the Midwest and Northeast (Lankester 2010, p. 54; Schmitz and Nudds 1994, p. 91; Maskey 2008).

While the parasite will infect, develop, and reproduce within deer without ramifications, moose develop a number of motor and neurological problems when they are infected with *P. tenuis*. These include: toe dragging, stumbling, weakness in the hindquarters, involuntary flailing of legs, loss of fear of people, weight loss, and death (Lankester 2010, p. 63). Infected moose have been reported in New Brunswick, Nova Scotia, Quebec, Ontario, Manitoba, Maine, Vermont, New Hampshire, Michigan, Minnesota, North Dakota (Lankester 2001, cited in Lankester 2010, p. 55; Maskey 2008, cited in DeCesare *et al.* 2014, p. 45). Biologists are concerned about potential for the parasite to spread into other areas co-inhabited by moose and deer as well (DeCesare et al 2014, p. 45).

Ultimately, the prevalence of the meningeal worm depends on three key factors: (1) the number of deer within range, which depends on (2) the length and severity of the winter; survival, mobility, and abundance of gastropods; and (3) the suitability and length of a snow free period in which transmission is possible (Lankester 2010, p. 61). Climate change favors all of these conditions.

Pre-1900, a narrow band of habitat from the Atlantic to the Great Lakes to the edge of the central Great Plains was made up of mature forests, which marked the southern range of moose and caribou habitat (Lankester 2010, p. 54). But winter is becoming less severe and spring is arriving earlier, allowing temperate forests to migrate northward and replace southern boreal forests, thereby expanding the number and range of deer (Lankester 2010, p. 54; Groffman *et al.* 2012, p. 1061; Frelich *et al.* 2012, p. 2956; Lenarz *et al.* 2010, p. 1013). As the southern boreal forests continue to warm, white-tailed deer will likely become the dominant herbivore in the region over moose (Frelich *et al.* 2012, p. 2956).

The new, wetter climate in this region has also boosted gastropod reproduction and activity levels (Lankester 2010, p. 61). Parasite transmission is made easier in warm, wet conditions that deer and gastropods favor. A study conducted in Ontario showed that snails and slugs in the wet areas of Navy Island were six times more likely to become infected with *P. tenuis* than those in the dryer habitat upland (Lankester and Anderson 1968, cited in Lankester 2010, p. 61). Additionally, *P. tenuis* is able to tolerate low temperatures, and *P. tenuis* larvae can shelter inside

their gastropod hosts, which protects them from extreme winter conditions (Pickles *et al.* 2013, p. 2652).

Although the prevalence of infected gastropods can be low (1/1000), transmission is incredibly efficient (Lankester 2010, p. 61). One species of slug (*Deroceras leave*) seems particularly important to *P. tenuis* due to its high mobility and longer active season. Most deer are infected at a young age and carry worms for life. Thus, where deer and gastropod populations rise, and there is sufficient moisture for transmission, so does the prevalence of infection in moose. As expected, low rainfall and low deer densities represent the westernmost limit of the disease (Lankester 2010, p. 63). But climate models predict an increase in habitat suitability for *P. tenuis* across North America from now through 2080, with the northern forest ecotone becoming particularly accessible (Pickles *et al.* 2013, p. 2650). Increasing temperatures will allow this parasite to move farther north, possibly as far Alberta or Labrador, where it currently does not exist (Pickles *et al.* 2013, p. 2652).

Predictably, there has been a direct correlation between the increase in deer and gastropod numbers and the decline in moose due to the contraction of *P. tenuis* (Lankester and Peterson 1996; Whitlaw and Lankester 1994; Timmerman *et al.* 2002; Maskey 2008; Beazley *et al.* 2006; cited in Lankester 2010, p. 54, 55, 61). White-tailed deer have been expanding their range north for the past 50 years in response to mild winters (Pickles *et al.* 2013, p. 2652; Côté *et al.* 2004, p. 116). In northern Minnesota, deer were absent or rare in the early 1900s (MN DNR), but they are abundant today. In the boreal forest of Ontario, adjacent to Isle Royale, deer have almost completely displaced moose over the past three decades (Whitlaw and Lankester 1994, cited in Frelich *et al.* 2012, p. 2958). Moose populations have declined dramatically in areas with a combination of warmer climates and a growing deer population. Declines in the Pembina Hills moose population of North Dakota were attributed to increased *P. tenuis* transmission due to higher densities of deer (Jensen, Minnesota Moose Summit 2008, slide 30). Other areas where this has occurred include the White Mountains of New Hampshire, Nova Scotia, northwest Ontario, and the Upper Peninsula of Michigan (Lankester 2010, p. 55; Frelich *et al.* 2012, p. 2956; Pickles *et al.* 2013, p. 2652; Groffman *et al.* 2012, p. 1061-1062).

An increase in suitable habitat for *P. tenuis* will cause a greater prevalence in infection rates in moose, exacerbating existing problems associated with rising deer populations (Pickles *et al.* 2013, p. 2652). A warmer climate and the transmission of meningeal worm by deer are thought to be the limiting factors for moose at the southern edges of their range (Telfer 1967, Lankester 2010, cited in Frelich *et al.* 2012, p. 2956).

2. *Fascioloides magna* (liver flukes)

Moose are threatened by giant liver flukes (*Fascioloides magna*) throughout the United States. Similar to *P. tenuis*, the transmission of liver flukes depends on the presence of host snails (genus *Lymnaea*), competent cervid hosts (white-tailed deer, *Odocoileus virginianus*; North American elk, *Cervus elaphus*; and caribou, *Rangifer tarandus*), and persistent wetland habitat (Maskey 2011, cited in Peterson *et al.* 2013, p. 359-360). Moose are considered abnormal hosts of *F. magna*, and infection leads to serious health complications (Lankester 2010, p. 64).

Infection of *F. magna* in moose results in bloody tracts and extensive fibrosis, leading to compensatory liver tissue hypertrophy (Lankester 2010, p. 64). Livers in infected moose have been found at twice their normal size (*id.*). The prevalence of infection among moose largely depends on the density of deer populations inhabiting the same space and, although less influential, the presence of wetland habitats that support snails as the intermediate hosts of the parasite (Peterson *et al.* 2013, p. 364; Lankester 2010, p. 64).

As discussed for *P. tenuis*, deer populations have risen as a result of climate change, now inhabiting areas that were once only accessible to moose. As a result, moose will become increasingly infected with *F. magna*. While there is debate among scientists as to whether or not the liver fluke has significant impacts on moose populations, it is clear that *F. magna* can be fatal to moose when combined with other stress factors, such as malnutrition or warmer temperatures (Pybus 2001, Lankester and Samuel 2007, cited in Lankester 2010, p. 64; Peterson *et al.* 2013, p. 360). Murray *et al.* (2006) believed the giant liver fluke was the primary cause of moose declines in northwestern Minnesota (Peterson *et al.* 2013, p. 360), responsible for up to 89 percent of all moose deaths in the area (Murray *et al.* 2006, p. 166).

3. Winter Ticks (*Dermacentor albipictus*)

Moose are threatened by a dramatic increase of winter ticks (*Dermacentor albipictus*). Winter ticks are ectoparasites that feed on a single ungulate host from their larval stage to adulthood (Addison and McLaughlin 1988, cited in Sine *et al.* 2009, p. 143). A trend in warmer and shorter winters has increased tick numbers by maximizing both their spring survival rates and autumn questing (a process in which a tick seeks out a host) (Lankester 2010, p. 65; Bergeron *et al.* 2013, p. 47; Bergeron *et al.* 2013, p. 47; DelGuidice *et al.* 1997; p. 900).

Moose, elk, and white-tailed deer are the main hosts of the winter tick, but moose are particularly vulnerable to tick infestations because of their ineffective grooming behavior and long hair (Musante *et al.* 2007, p. 101; Welch *et al.* 1991, cited in Sine *et al.* 2009, p. 143). In recent years, moose have been found infested with up to 150,000 ticks covering their bodies (Jarvis, Sentinel Source 5/9/11). Additionally, calves have higher relative tick numbers than adults, and as such experience age-specific impacts that could be detrimental to the population (Bergeron *et al.* 2013, p. 46; Sine *et al.* 2009, p. 145).

Moose infested with a high number of ticks experience severe hair loss, chronic weight loss, and reduced growth and fat stores (reviewed in Musante *et al.* 2007, p. 101; Lankester 2010, p. 65). Hair loss is evident in calves even in low tick years (Bergeron *et al.* 2013, p. 46), and thermal energy loss due to alopecia, combined with other effects, can be fatal (Sine *et al.* 2009, p. 143). Moose calves experience a blood loss of 64 to 112 percent of their normal volume during the eight week engorgement period of ticks (Sine *et al.* 2009, p. 143; Musante *et al.* 2007, p. 105). For comparison, recommendations for blood removal made by the Joint Working Group of Refinement (Morton *et al.* 1993, p. 18) suggest that a maximum of ten percent of blood volume can be removed every three to four weeks to maintain good health in an animal. When moose, especially calves, lose such high levels of blood, they also lose of 50 to 100 percent of their daily protein requirement (Sine *et al.* 2009, p. 143) and become anemic (Musante *et al.* 2007, p. 104).

In late winter moose rely on their fat stores to compensate for the low nutritional value in available browse, and they reduce their activity levels to keep their metabolism low. Moose suffering from a high number of ticks expend valuable energy by a natural increase in restlessness and grooming behavior (Lankester 2010, p. 65). The relative energetic cost to compensate for the amount of blood loss is particularly higher for malnourished calves, which have proportionally less body fat than adults, making them even more susceptible to late winter mortality (Musante *et al.* 2007, p. 105).

Mortality due to winter ticks has been observed at the highest scale in the northeast, but it is a widespread concern in the Great Lakes and Rocky Mountains regions as well. In a study conducted by Musante *et al.* (2010) in New Hampshire, 41 percent of radio-collared moose died from tick related complications (cited in Bergeron *et al.* 2013, p. 46). The decline in body weight and corpora lutea (CL) counts in yearling females from 1988-2009 in New Hampshire and Vermont supports the hypothesis that higher than average tick loads reduces the fecundity and fitness of young moose and is a significant contributor to the decline in moose populations (Bergeron *et al.* 2013, p. 45-47; Sine *et al.* 2009, p. 143). Wildlife biologists in Wyoming, Idaho, Washington, Isle Royale, Minnesota, and Montana have all expressed concern over their moose populations and the elevated risks associated with higher tick survival rates (Kilpatrick 2011, p. 15; DeCesare *et al.* 2014, p. 45; Landers, Seattle Times 4/7/2014; Vucetich, "Wolves and Moose of Isle Royale"; McDonald, New York Times 3/5/14). Even in Maine, where populations appear to be high and stable, the CL counts, body weight, and productivity in yearlings is alarmingly low due to winter tick infestations (Bergeron *et al.* 2013, p. 46).

The parasites discuss above are known to infect the DPS of *andersoni* moose in the United States. Other parasites and diseases, such *Elaeophora schneideri* (Elaeophorosis) (Henningsen *et al.* 2014, p. 35-36; LeVan *et al.* 2013, p. 666; DeCesare *et al.* 2014, p. 45) and Chronic Wasting Disease (Baeten *et al.* 2007, Williams and Young 1980, Williams and Young 1982, cited in Sigurdson 2008, p. 1-2; Miller 2008, p. 430), have been documented to threaten moose in other regions of the United States. It is possible that those parasites could impact Midwest moose in the future, especially given the increased ease of transmission and spread of the disease as a result of climate change (Henningsen *et al.* 2014, p. 41-42; Sigurdson 2008, p. 2).

4. Malnutrition

Malnutrition and nutrient deficiencies have been observed in North American moose. In most cases where malnutrition has been a factor in moose mortality, it is unclear which driving agent (malnutrition or disease) caused nutrient deficiencies, emaciation, and death. Mostly, pathogens and nutritional status closely interact. Malnutrition leads to immunosuppression, which leads to infection and disease, while disease leads to energy depletion and tissue damage (Murray *et al.* 2006, p. 23). Confounding factors such as climate change, heat stress, habitat degradation, and disease have likely led to emaciation and low bone marrow fat, but it is suspected that starvation and malnutrition is a cause of moose mortality (Murray *et al.* 2006, p. 23).

Various nutrient deficiencies have been documented in declining moose populations. Copper (Cu) deficiency has been associated with declines in moose populations in North America and

Sweden (Frank *et al.* 1994, cited in Custer *et al.* 2004, p. 84), and it is known to cause blood disorders, growth problems, cardiovascular defects, faulty keratinization, and neonatal ataxia in domestic ruminants (Underwood 1977, cited in Custer *et al.* 2004, p. 84). In moose, it is known to decrease productivity through anemia, blood disorders, and cardiac abnormalities (Underwood 1977, Flueck 1994, cited in Murray *et al.* 2006, p. 23). Clinical signs of Cu deficiency include: emaciation, weakness, lesions in the digestive tract, and atrophied lymphoid organs, but these symptoms also coincide with pathogenic conditions (Murray *et al.* 2006, p. 23).

Copper deficiency can result from a low Cu diet or an increase in molybdenum (Mo) or sulfur (S), both of which reduce the absorption of Cu (Gooneratne *et al.* 1989; Suttle 1991, cited in Custer *et al.* 2004, p. 85). Copper deficiencies could be a result of habitat degradation. In northwestern Minnesota, willow (*Salix* spp.) and bog birch (*Betula pumila*) have dwindled and been replaced by low-quality aspen (*Populus tremuloides*) and black spruce (*Picea mariana*) (Custer *et al.* 2004, p. 85-86). As expected, Cu concentrations in livers of moose from that region were comparable to moose from Alaska and Sweden where Cu deficiencies have been reported (Custer *et al.* 2004, p. 84). Copper deficiency has also been considered a factor in the decline of moose in Wyoming (Becker 2008, p. 169). Malnutrition was found to be the cause of 60 percent of female mortality from 1995-2004 in Jackson Hole, which was linked to habitat degradation. Since a strong relationship exists between nutrition and recruitment in moose, poor habitat and diet results in an overall declining population (Berger 2004, Boerje *et al.* 2007, Becker 2008, cited in Smith *et al.* 2011, p. 152).

Molybdenosis (the dietary intake of excessive Mo) was thought to be the most plausible cause of the "mysterious wasting disease" of Swedish moose and some North American moose in Minnesota and Nova Scotia (Frank *et al.* 2004, p. 90), though further study contradicted this conclusion (p. 96). Frank *et al.* (2004) showed that cobalt and vitamin B12, which is a crucial component to many metabolic functions of ruminants, might actually be a significant contributing factor of moose declines in northeastern America (p. 97). A collection of liver samples from sick moose in Nova Scotia showed half suffered from Co deficiency (Frank *et al.* 2004, p. 97). Further research is needed to understanding the key components of malnutrition in moose and how it relates causes of mortality.

D. Inadequacy of Existing Regulatory Mechanisms

1. Regulatory Mechanisms Addressing Greenhouse Gas Pollution and Climate Change are Inadequate

Existing international and U.S. regulatory mechanisms to reduce global greenhouse gas emissions are clearly inadequate to safeguard the moose against extinction resulting from climate change.

a. *National and international emissions reductions are needed to protect the moose*

The best-available science indicates that the atmospheric concentration of CO_2 must be reduced from the current level of ~390 ppm to at most 350 ppm to protect species and ecosystems from anthropogenic climate change. Numerous scientific studies indicate that climate change resulting

from greenhouse gases currently in the atmosphere already constitutes "dangerous anthropogenic interference" (DAI) with regard to species and ecosystems (Warren 2006, Hansen *et al.* 2008, Lenton *et al.* 2008, Jones *et al.* 2009, Smith *et al.* 2009). Climatic changes experienced so far – including a ~0.7°C temperature increase and a 30 percent increase in ocean acidity since the pre-industrial era – have resulted in significant changes in distribution, phenology, physiology, demographic rates, and genetics across taxa and regions, which have led to population declines and species extinctions (Walther *et al.* 2002, Parmesan and Yohe 2003, Root *et al.* 2003, Walther *et al.* 2005, Parmesan 2006, Warren 2006, Walther 2010).

Moreover, the impacts to biodiversity from greenhouse gases currently in the atmosphere have not been fully realized. Due to thermal inertia in the climate system, there is a time lag between the emission of greenhouse gases and the full physical climate response to those emissions. The delayed effects from existing emissions are known as the "climate commitment." Based on the greenhouse gases already emitted, the Earth is committed to additional warming estimated at 0.6°C to 1.6°C within this century (Meehl *et al.* 2007, Ramanathan and Feng 2008), which commits species and ecosystems to further impacts.

Greenhouse gas emissions are continuing to occur at a rapid rate – tracking the most fossil-fuel intensive emissions scenario of the Intergovernmental Panel on Climate Change (IPCC) (Raupach *et al.* 2007, Richardson *et al.* 2009), further jeopardizing species and ecosystems. The IPCC warned that 20 to 30 percent of plant and animal species will face an increased risk of extinction if global average temperatures increase more than 1.5 to 2.5°C (relative to 1980-1999), with an increased risk of extinction for up to 70 percent of species worldwide if the global average temperature increase exceeds 3.5°C relative to 1980-1999 (IPCC 2007). Thomas *et al.* (2004) projected that 15-37 percent of species will be committed to extinction by 2050 under a mid-level emissions scenario, which the world has been exceeding (abstract).

Hansen *et al.* (2008) presented evidence that the CO_2 level at that time – 385 ppm – "was already too high to maintain the climate to which humanity, wildlife, and the rest of the biosphere are adapted," recommending a reduction to 350 ppm while also noting the ultimate target "probably needs to be lower" (p. 16). Hansen *et al.* (2008) found our current CO_2 level has committed us to a dangerous warming commitment of an additional ~2°C temperature rise and is already causing serious changes today: the rapid loss of Arctic sea-ice cover; a 4 degree poleward latitudinal shift in subtropical regions, which is leading to increased aridity in many regions of the earth; the near-global retreat of alpine glaciers affecting water supplies during the summer; accelerating loss of Greenland and west Antarctic ice sheets; and increasing stress to coral reefs from rising temperatures and ocean acidification. Hansen *et al.* (2008) emphasized that the overall maximum target of 350 ppm CO_2 must be pursued within decades, finding that paleoclimatic evidence and ongoing changes show it would be "foolhardy to allow CO_2 to stay in the dangerous zone for centuries" (p. 16).

To reach a 350 ppm CO_2 target or below, numerous studies indicate that global CO_2 emissions must peak before 2020 followed by rapid annual reductions that bring emissions to or very close to net zero by 2050. The IPCC found that to reach a 450 ppm CO_2 target, emissions from the United States and other developed countries must be reduced by 25 to 40 percent below 1990 levels by 2020 and by 80 to 95 percent below 1990 levels by 2050 (Gupta *et al.* 2007); thus

reductions to reach a 350 ppm CO_2 target must be more stringent. Baer and Athanasiou (2009) outlined a trajectory to reach a 350 ppm CO_2 target by 2100 that requires global emissions to reach 42 percent below 1990 levels by 2020, with emissions reaching zero in 2050. Negative emissions options make such a pathway more feasible. Baer and Athanasiou (2009) concluded that emissions from developed countries must be more than 50 percent below 1990 levels by 2020 and reach zero emissions in 2050 (Baer and Athanasiou 2009).

With current atmospheric carbon dioxide at ~390 ppm and worldwide emissions continuing to increase by more than 2 ppm each year, rapid and substantial reductions are clearly needed immediately to protect moose from increasing temperatures.

b. United States Climate Initiatives are Ineffective

The United States is responsible for approximately 20 percent of worldwide annual carbon dioxide emissions (U.S. Energy Information Administration 2010), yet it does not currently have adequate regulations to reduce these emissions. The U.S. Department of Interior acknowledged this in the final listing rule for the polar bear, which concluded that regulatory mechanisms in the United States are inadequate to effectively address climate change (73 Fed. Reg. 28, 12, 28,287-88 (May 15, 2008)). Executive branch agencies have the authority to regulate and reduce greenhouse gas emissions under the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act, and other existing laws, but the political will to enact such measures has not matched the urgent action needed to prevent mass extinctions and ecosystem shift.

The EPA released a draft rule on June 2, 2014, to reduce existing emissions from coal-fired power plants to 30 percent below 2005 levels by 2030, which is the equivalent of a 7.7 percent reduction from 1990 levels. This is nowhere close to the 25 to 40 percent reduction by 2020 that the IPCC and other experts warn is necessary to avoid global climate catastrophe. While full implementation of flagship environmental laws, particularly the Clean Air Act, could provide an effective and comprehensive greenhouse gas reduction strategy, the existing regulatory scheme as implemented is inadequate to protect moose from further effects of climate change.

c. International Climate Initiatives are Ineffective

The primary international regulatory mechanisms addressing greenhouse gas emissions are the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. In the final 2008 listing rule for the polar bear, the FWS acknowledged the original Kyoto commitments were inadequate to effectively address climate change (73 Fed. Reg. at 28,287-28,288). Although the Kyoto Protocol was amended and extended to 2020, the amendment addresses only about 15 percent of global greenhouse gas emissions (C2ES 2012, p. 2). And although the signatory nations have agreed to produce a treaty in 2015, that treaty would not go into force until 2020 *(id.)*. Furthermore, it remains unclear that the international community will actually be able to reach the anticipated agreement. Parties to the UNFCCC agreed that future global warming should be limited to less than 2° C, but there is no consensus on how to reach that goal.

Of perhaps even greater concern is the virtual certainty that the goal itself is inadequate. As one group of climate scientists put it, "2°C global warming would have consequences that can be described as disastrous." (Hansen *et al.* 2013, p. 15). Even if countries did meet their voluntary pledges, the collective national pledges to cut greenhouse gas emissions are inadequate to hold global warming to below 2°C. In light of these deficiencies and uncertainties in international agreements, international regulatory mechanisms must be considered inadequate to protect moose from climate change.

2. Regulatory Mechanisms are Inadequate to Protect Moose from Other Threats

a. Existing Federal Laws Do Not Protect Moose Habitat

The National Environmental Policy Act (NEPA) requires federal agencies to consider the effects of their actions on the environment and wildlife. However, NEPA does not prohibit an agency from choosing alternatives that will negatively affect moose. The National Forest Management Act (NFMA) regulations state that "Fish and Wildlife habitat shall be managed to maintain viable populations of existing native and desired nonnative vertebrate species in the planning area" (36 C.F.R. § 219.19), but does not prohibit the Forest Service from carrying out actions that harm species or their habitat, stating only that "where appropriate, measures to mitigate adverse effects shall be prescribed" (36 C.F.R. § 219.19(a)(1)).

For example, two sulfide mine proposals in Minnesota – the NorthMet project by PolyMet Mining Corporation, a Canadian company that has never actually operated a mine, and the Twin Metals Minnesota Project, which is now fully run by a Chilean company – would have significant impacts on moose. The proposed locations are within important moose habitat near the border of the Boundary Waters Canoe Area Wilderness. Construction and operation of these mines would not only directly destroy viable moose habitat, but it also would lead to disastrous impacts to moose if toxins leached into rivers and streams. Acid mine drainage kills almost all aquatic life. Moose rely on aquatic plants for their high nutritional value, and they frequently use riparian areas as thermal refuge from heat stress in the summer (Innes 2010). The Draft Environmental Impact Statement for the NorthMet Mining Project prepared jointly by the Minnesota DNR, U.S. Army Corps of Engineers, and U.S. Forest Service is virtually silent on the impacts on moose, even though the project would destroy at least 2,775 acres of moose habitat (MNDNR *et al.* 2013, p. 5-377). The Forest Service proposes to facilitate the project by trading away 6,650 acres (more than ten square miles) of public land within the identified moose range, while 72 percent of the land it will receive in return (5,086 out of 7,075 acres) is located outside the moose's range (MNDNR *et al.*, 2013 p. 3-160). Minnesota's moose population is in such extremity that any loss of habitat or habitat fragmentation is potentially significant, and needs to be carefully scrutinized.

Mining companies have applied for more than 100 permits for exploratory drilling on federal public lands (Friends of the BWCA, http://www.friends-bwca.org/issues/sulfide-mining/) in Minnesota. Similar pressures are mounting in Michigan (Alexander, Bridge Magazine, Nov. 3, 2011); the Kennecott Eagle Minerals project has already been approved right in the middle of moose habitat. Areas the moose inhabits in North Dakota are also experiencing a boom in oil and gas extraction, with little or no consideration of the impacts that project location or operations

will have on moose (McEnroe and Sapa 2011, p. 2; Vaidyanathan, EnergyWire 7/9/11). Hebblewhite (2008, p. 1-125). Future threats to moose and moose habitat posed by mining and energy development are unlikely to be addressed without being listed on the Endangered Species Act.

Many moose populations exist in national forests and should be protected by federal laws. Using Minnesota again as an example, the northeast moose population exists mostly in and around the Superior National Forest, and 61 percent of the moose's range in the state exists on federal land (MNDNR 2011, p. 40). Land and resource management affecting moose in the Superior National Forest is governed by the Land and Resource Management Plan for the Superior National Forest (USFS 2004) (Forest Plan). The Forest Plan specifically addresses the habitat needs of several sensitive and/or indicator species and provides prescriptive requirements for all management activities. However, the moose is not addressed in the Forest Plan, and there are no specific guidelines for protecting or restoring moose habitat.

b. State Regulations Do Not Protect Moose

State laws and regulations afford little protection for the moose as well. North Dakota does not have a state endangered species law. Moose are listed a state "species of special concern" in Michigan and Minnesota, but this status does not afford them any sort of binding legal protection within those states. Even still, these two state endangered and threatened species laws would only protect moose from direct take and do little to protect its habitat.

Minnesota listed moose as a Species of Special Concern (SSC) in 2013 – four years after the Moose Advisory Committee recommended that it do so (Moose Advisory Committee 2009, p. 6). The state's moose population plummeted in the four years between the committee's recommendation and when the moose was listed, dropping from approximately 7,000 to 4,000 individuals – a 57 percent decline. Even with its SSC status, the moose remains in jeopardy in Minnesota due to the inadequate laws and regulations in the state.

The Minnesota Administrative Rules state that "species designated as species of special concern are not protected by Minnesota Statutes, section 84.0895 (Protection of Threatened or Endangered Species) or rules adopted under that section" (Minn. R. 6134.0150). Indeed, the only tangible benefit of a "Special Concern" listing is that the state's Department of Natural Resources (DNR) must reconsider the listing every three years to determine whether the listing should be changed to threatened or endangered (Minn. Stat. § 84.0895, subd. 3(c)). And even if the listing were to be upgraded, Minnesota law is less protective than federal law. For example, the DNR may issue permits for taking a listed species it if finds that "the social and economic benefits of the permitted act outweigh the harm caused by it, provided that the killing of a specimen for these purposes will be permitted only after all other alternatives have been evaluated and rejected" (Minn. R. 6212.2100(C)). Additionally, the Moose Advisory Committee's recommendations in the Moose Research and Management Plan are already included in many of the state and federal documents that guide forest land management (MDNR 2011, p. 43). Most of these considerations are not obligatory, particularly in regard to considering moose habitat needs in specific actions (e.g, timber sales or prescribed burns).

Without federal or state threatened or endangered listing, Minnesota could reopen the moose hunt. This is exactly what is happening in Michigan; allowing hunting of moose is being considered despite its protective status (Moose Hunting Advisory Council 2011, p. 2-3). Without federal protection, Michigan could go forward with a hunting season, which would threaten the state's population.

The explosion in oil and gas extraction in North Dakota also continues with little or no consideration of the impacts that project locations or operations will have on moose (McEnroe and Sapa 2011, p. 2; Vaidyanathan, EnergyWire 7/9/11). Moose outside of National Wildlife Refuges are not a concern for the FWS without a federal listing status. The North Dakota Game and Fish Department publishes a list of recommended management practices, but notes that "these recommendations are largely voluntary and are not necessarily comprehensive in nature" (North Dakota Game and Fish Dept. 2012, unpaginated). A 2011 report on the potential impacts of oil and gas development on North Dakota wildlife did not address moose (Dyke 2011).

E. Other Factors

1. Vehicular Collisions

Vehicular collisions with moose are often cited as a concern for human safety. But collisions are not only dangerous to people, they are also threatening moose populations. In some parts of North America, roadkills are the second largest cause of moose mortality behind hunting (Del Frate and Spraker 1991, cited in Rea 2003, p. 82). Many ungulates take advantage of the early green-up and late senescing of roadside forage and consequently are put at a higher risk of being hit by a car (reviewed in Rea 2003, p. 83). Moose also take advantage of salty pools that are formed beside roads after the snow melts (Leblond *et al.* 2007, p. 2304) And they forage at dusk and dawn to remain concealed, which effectively hides them motorists as well (Rea 2003, p. 83). Most measures to reduce collisions with moose and other ungulates have been ineffective or too costly (Rea 2003, p. 83).

According to the Minnesota Moose Management Plan, vehicle or train collisions were responsible for 13 percent of all deaths of radio-collared moose, a larger number than attributed to wolf predation (MDNR 2011, p. 25). Not surprisingly, researchers have found a strong correlation between increased traffic and increased moose-vehicle collisions (Seilor 2004, p. 310; Belant 1995, p. 1). Belant (1995, p. 4) also found that 70 percent of the moose-vehicle collisions during his study period happened at night. An increase in exploratory drilling, full-scale mining, and other development activities will increase the volume of traffic in many areas of the moose's range, including nighttime traffic because these activities occur around-the-clock.

2. Small Populations and Fragmentation

Small, isolated populations of moose are subject to increased extinction risk from stochastic environmental, genetic, or demographic events (Shaffer 1981, p. 131; Brewer 1994, p. 616). Loss of genetic diversity can lead to inbreeding depression and an increased risk of extinction due to the loss of genetic viability and reduced population growth rate (Allendorf and Luikart 2007, p. 338–343). *Andersoni* moose have undergone dramatic declines in some areas, while shifting

range into unusual habitat in others. In most cases, the majority of moose are expected to shift north. Small populations left behind will not be considered viable and will be at an increased rate of extinction. Even seemingly large populations of moose in some regions have been determined unviable. For example, in Nova Scotia, Snaith and Beazley (2002, p. 199) found that 5,000 moose and 100,000-200,000 km^2 of habitat were required for a healthy, long-term viable population. That is more than five times the number of moose there now and double the area Nova Scotia has to offer (*id.*). They recommend that habitat connectivity with neighboring populations are reestablished to maintain the genetic heterogeneity needed for a viable population (Snaith and Beazley 2002, p. 199-200).

Although some are increasing, none of North Dakota's or Michigan's populations of moose are large enough to act as a source population for moose recovery over the long-term if the Minnesota population fails. Isle Royale is both too small and too isolated to serve as a source population to ensure the long-term viability of *Alces alces andersoni* in the United States. The maximum carrying capacity of the island, which is 535 km^2, is between 1,000 and 2,000 animals. The distance of the island from the mainland is such that there is no movement of moose to and from the island. Keller *et al.* (2002, p. 1392) points out that a metapopulation can provide the requisite genetic variation to maintain viability at lower numbers if it is not totally isolated. The required influx is one reproductively successful migrant per generation (Snaith and Beazley 2002, p. 197). This influx does not occur on Isle Royale. Thus although the island population has proven viable over the short-term, its viability over the long-term is still uncertain.

At 450 animals, the moose population in Michigan's Upper Peninsula (U.P.) has not yet grown to a size where its viability is assured even for the short-term, particularly in light of the declines that are affecting populations in nearby areas. If the population declines as other populations have, it would be a matter of only two or three years before the population was essentially gone. The western U.P. population is also effectively isolated; wildlife managers do not believe there is any migration into the population (Beyer *et al.* 2011, p. 8). Primary moose habitat area of the western U.P. is comprised of only approximately 3,700 km^2, and wildlife managers do not expect this to expand *(id.)*. The only other *andersoni* population is in western North Dakota, which is currently exhibiting unusual habitat selection, and individuals exist in very low densities (0.02-0.06/mi^2) (Smith, Moose Management in ND, slide 19).

VI.   Conclusion

For all the reasons discussed above, Petitioner Center for Biological Diversity requests that the FWS list the U.S. population of northwestern moose (*Alces alces andersoni*) as a threatened or endangered species because it is in danger of extinction or likely to become so in the foreseeable future in all or a significant portion of its range. The U.S. population is threatened due to habitat destruction, the increasing effects of climate change, related effects on forests and disease transmission, and other threats. No existing regulatory mechanisms are adequate to ensure the survival of *andersoni* moose in the contiguous United States. Based on this information, the U.S. population of *andersoni* moose qualifies for and should be listed as threatened under the Endangered Species Act.

On behalf of all parties,

Tara Easter
Scientist
Center for Biological Diversity
PO Box 11374
Portland, OR 97211
teaster@biologicaldiversity.org

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