Minnesota Moose Research and Management Plan

Minnesota Department of Natural Resources

Final Plan Approved: December 21, 2011

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Executive Summary

Minnesota's moose *(Alces alces)* population, currently concentrated in the northeast corner of the state, is facing a decline where the cause is not understood. Aerial survey data indicate a declining population and hunter success rates have also declined over the past decade. While cow moose pregnancy rates are high in the northeast, recruitment of calves into the population is at low levels.

Since 2002, moose research and monitoring have been intensified in the region, and data suggest the northeast moose population decline is comparable to what was observed with northwest moose. That population decreased precipitously in the 1980s to early 2000s. That decline was correlated with increasing summer temperatures, although year-to-year variation was large. Both of these regional trends have been, and continue to be, troubling to the Minnesota Department of Natural Resources (DNR).

In response to the moose decline, the Minnesota State Legislature in 2008 directed the DNR to establish a Moose Advisory Committee (MAC) that would make recommendations to the DNR that would form the basis of a Moose Management and Research Plan. The MAC met during a period of one year and produced a detailed report with specific recommendations they believed would contribute to better understanding of moose and the steps needed to reverse the population decline if possible.

This plan attempts to address many of the points raised by the MAC and adopts the majority of their recommendations. It also contains information not discussed by the MAC, such as predation and tribal harvest.

This plan is organized with six primary objectives, their associated problems, and proposed DNR actions and strategies to address the objectives. The six objectives deal with moose hunting and its future; moose research; deer management and its relationship to moose populations; moose habitat across the animals' range; social considerations; and communications. These management proposals are summarized on pages 8-11.

A few highlights:

Hunting: Even though the population is declining, moose hunting in Minnesota is a social issue because the hunt is bulls-only and less than 2% of the population is removed annually. However, this report identifies biological thresholds for closing the moose-hunting season. The plan proposes closing the moose-hunting season if success rates fall below 20% for 3 consecutive years in zones outside the Boundary Waters Canoe Area Wilderness (BWCAW) or 10% in zones inside the BWCAW. Similarly, the DNR would close the moose season if bull:cow ratios fall

below 0.67 for 3 consecutive years. This plan incorporates thresholds to reopen moose seasons if the population increases.

Research: Wildlife research is an expensive and long-term endeavor but must be pursued to answer critical questions and address management issues. The DNR proposes to:

- Evaluate cause-specific mortality of adult moose,
- Examine the survival, recruitment, and cause-specific mortality of calf moose,
- Monitor disease prevalence and parasite loads as possible mortality factors, and
- Examine moose-habitat relationships to identify critical summer and winter habitats.

White-tailed deer management: White-tailed deer (*Odocoileus virginianus*) are implicated in predisposing moose to disease and/or parasites. While there is uncertainty regarding deer-moose interactions, this plan recommends keeping pre-fawn deer populations below 10 deer/mi^2 and banning recreational deer feeding in the primary moose range.

Quality moose habitat: Providing quality moose habitat is important, and this plan sets some broad guidelines for dealing with habitat issues, but does not constrain managers on the moose range to a single prescription.

Finally, there is no cookbook or prescription for reversing a declining moose population in Minnesota. The issue is decidedly complex, and the research needed to answer critical questions will take time and will be very expensive. The majority of work is currently funded by hunting-license dollars, but other funding sources such as the Environmental Trust Fund should be utilized for management-oriented research. Subsequent habitat development projects could ultimately be funded by Outdoor Heritage Funds.

As moose populations benefit all Minnesotans, it is critical that a broad funding source be developed because without sound scientific information, we may lose moose and never know why.

Background

In 2008, the Minnesota (MN) Legislature directed the Commissioner of Natural Resources to convene a panel of experts and individuals from interest groups to assist the Department of Natural Resources (DNR) with creating a moose management and research plan. Specifically, 2008 MN Legislative Chapter 368, Article 2, Section 76 states,

> The Commissioner of natural resources shall consult with research scientists, wildlife managers, tribal interests, other agencies with moose research and management expertise, and other key stakeholder groups on the development of a moose management and research plan for Minnesota. The plan shall address moose populations and habitats, including, but not limited to, the northwest Minnesota herd; likely causes of observed changes and trends; moose habitat and hunting management; and monitoring, research, and evaluation needs. The plan shall establish future moose management and research goals and strategies within the context of habitat and climate trends in Minnesota. By January 15, 2009, the Commissioner shall provide a progress report on the plan to the Senate and House of Representatives committees with jurisdiction over natural resource policy.

Moose Advisory Committee

Per the 2008 legislation, DNR convened a Moose Advisory Committee (MAC) to consult with regional authorities on moose biology and other stakeholders to thoroughly review options for moose management and research. Committee members were selected by the DNR to represent a cross-section of moose experts, land managers, wildlife managers, tribal staff, and other key stakeholders. The MAC was charged with the responsibility for making recommendations to the DNR and other stakeholders for moose management and research.

The MAC consisted of 18 members of diverse backgrounds, all with an interest in the future of moose in Minnesota. Several DNR employees served on the committee because of their professional expertise and specific knowledge of moose populations. In order to complete the assignment in a timely manner, several subcommittees were formed within the MAC to address specific areas of management and research. This plan loosely follows the subcommittee structure established by the MAC.

The MAC recommendations, to the extent practical, are incorporated into this management and research plan. In numerous instances, sections from the MAC recommendations document are used *verbatim* as the background work was extensive and contributed substantially to this plan.

Strategic Vision

The MAC identified a strategic vision that guided them through their recommendation process. That vision is extended to this plan as it is realistic, relevant, and timely:

> "*Moose have intrinsic value and are recognized for their importance to Minnesota. To the greatest extent possible, moose shall be managed for ecological sustainability, hunting, and viewing opportunities*".

Objectives, Problems, and Strategies

OBJECTIVE 1 - Hunting: Establish thresholds to close moose hunting or reduce impacts on the population. At some point, it may be necessary to determine a safe harvest and develop a structured process for allocating that harvest between State and Tribal hunters. Also, establish thresholds to re-open moose seasons where appropriate.

PROBLEM 1: Moose hunting may affect total population numbers. The DNR proposes these thresholds for closing the moose season for State hunters if any of these thresholds are met:

STRATEGY A: If the bull:cow ratio estimated during the aerial moose survey drops below 67 bulls/100 cows for three consecutive years.

STRATEGY B: If the harvest success of state hunters averages:

a) Less than 10% over 3 consecutive hunting seasons in the BWCAW.
b) Less than 20% over 3 consecutive hunting seasons in zones outside the BWCAW.

STRATEGY C: If hunter success (all units combined) drops below 30% for 3 consecutive seasons.

If any of the following thresholds are met, the moose season could be re-opened.

STRATEGY A: When the bull:cow ratio estimated on the aerial survey exceeds 67 bulls/100 cows for three consecutive years.

STRATEGY B: Give wildlife managers the option of reopening closed hunting zones after 3 years if adjacent zones remain open.

STRATEGY C: Reopen hunting season if the aerial survey indicates that the population increased above the number at closure and demonstrated an increasing trend for a minimum of 5 consecutive years.

OBJECTIVE 2 - Research: Use directed research to increase understanding of moose ecology and population dynamics.

PROBLEM 1: Adult non-hunting mortality rates are high and causing the population to decline; causes are largely unknown. The DNR proposes to:

STRATEGY A: Improve necropsy methods to determine cause-specific mortality.

STRATEGY B: Design a long-term study so the amount of annual variation inherent in most short-term research projects can be minimized.

STRATEGY C: Assess nutritional condition of animals spatially and temporally.

STRATEGY D: If cause of mortalities is identified, determine if management methods can be implemented to reduce mortality rates.

PROBLEM 2: Recruitment rates of calf moose are not sufficient to replace adult mortality. The DNR proposes to:

STRATEGY A: Continue monitoring pregnancy rates by measuring serum progesterone of adult females captured during research projects. Develop a survey methodology to determine range-wide pregnancy rates from progesterone in fecal pellets.

STRATEGY B: Design a research project to determine survival, recruitment, and cause-specific mortality of calves.

STRATEGY C: Assess habitat use by cow-calf pairs and use research results to build best management practices (BMPs) for moose habitat.

PROBLEM 3: Parasites and diseases may increase physiological stress and lead to adverse health conditions and mortality. The DNR proposes to:

STRATEGY A: Continue to monitor disease prevalence and parasite loads of individual moose

STRATEGY B: Continue to respond to public reports of sick moose to determine causes of clinical illness.

PROBLEM 4: Too little is known about moose-habitat relationships relative to climate change.

STRATEGY A: Determine the effect of ambient temperature on seasonal thermal cover needs.

STRATEGY B: Determine quality and quantity of forage availability of different habitats under varying environmental conditions. Use moose GPS telemetry data to analyze and characterize habitats that appear to be preferred.

PROBLEM 5: Data collection among studies is not standardized. The DNR proposes to:

STRATEGY A: Create a working group of moose research biologists to develop standardized data collection protocols. Use the working group to help guide projects that meet research and management objectives and ensure best use of limited resources. Attempt to ensure that results (especially related to habitat) have applicability for wildlife managers and foresters.

OBJECTIVE 3 – Deer Management: Integrate deer management as part of a comprehensive moose management strategy.

PROBLEM 1: Deer populations may prevent the growth and sustainability of moose population. Recreational deer feeding allows for densities that are higher than should be naturally maintained. In order to facilitate deer management within the northeast moose range, the DNR proposes to:

STRATEGY A: Maintain pre-hunt deer densities below 10 deer/mile^2.

STRATEGY B: Realign deer units to correspond to moose range to facilitate managing deer in the moose range.

STRATEGY C: Ban recreational deer feeding in the northeast moose range.

OBJECTIVE 4 - Habitat: Provide high quality habitat across the moose range.

PROBLEM 1: Focused management for high quality habitat may slow population declines and maintain or recover moose in appreciable numbers. The DNR proposes to:

STRATEGY A: Coordinate with the Minnesota Forest Resource Council and their partners to incorporate BMPs for developing and maintaining quality moose habitat into the MN Forest Resources Council's *Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines.*

STRATEGY B: Use readily available existing landscape level information to assess moose habitat distribution and quality. Where gaps exist, the MNDNR will consider forest management practices to improve habitat quality.

STRATEGY C: Implement the Subsection Forest Resources Management Plans (SFRMPs) for state forestland to achieve desired future forest conditions that are positive for moose habitat. When SFRMPs are updated, the MNDNR Division of Fish and Wildlife will utilize the

most up-to-date science-based moose habitat assessment to guide future SFRMP outcomes.

STRATEGY D: In the northeast moose range, focus resources in areas with existing high densities of moose as determined by the MNDNR's moose survey.

PROBLEM 2: Mixed ownership and management jurisdiction across the moose range complicates habitat management direction. Agencies' moose habitat management should be based on current knowledge and common landscape goals and objectives. The DNR Fish and Wildlife Section will:

STRATEGY A: Coordinate at least semi-annually, in a formal manner, with other land management agencies including the US Forest Service, tribal agencies, and counties to develop and discuss forest habitat projects that benefit moose.

STRATEGY B: Be an active participant in the Minnesota Forest Resource Council's Northeast Landscape Team process, and through this participation, ensure that Team members consider moose habitat needs in the primary moose range

OBJECTIVE 5 – Social Considerations: Integrate social science considerations into moose decision-making.

PROBLEM 1: Moose population dynamics and management are poorly understood by the non-hunting public. The DNR proposes to:

STRATEGY A: Solicit public input regarding the non-hunting values of moose, both economically and culturally.

STRATEGY B: Develop a public survey of attitudes towards Minnesota moose populations and management. The survey could include economic and cultural measures (e.g., attitudes towards hunting, willingness-to-pay, economic impact of moose-related tourism, acceptable levels of uncertainty).

STRATEGY C: Identify metrics for incorporating the cultural importance of moose (e.g., cultural identity, viewing opportunities) into DNR moose management.

STRATEGY D: Work to develop sustainable moose research and management funding sources based on a broader constituency of hunters and non-hunters.

OBJECTIVE 6 - Communication: Increase DNR's capacity to disseminate information that is critical to moose management decisions.

PROBLEM 1: There is no formalized mechanism to communicate moose population, research, and management issues to the public. The DNR proposes to:

STRATEGY A: Develop a communications plan that guides information sharing, assures accuracy, and solicits public comments. Communicate about the biological challenges facing moose in Minnesota, particularly climate change impacts on projected moose population levels, real and perceived impacts of hunting, and the rationale for management actions.

STRATEGY B: Develop a mechanism to update policy-makers about moose management actions and needs that includes efforts to coordinate requests with ongoing DNR activities.

STRATEGY C: Work with other agencies and educational institutions to develop a website to communicate new information and background materials and develop other outreach materials and strategies for public education.

Introduction

There are 4 recognized subspecies of moose (*Alces alces*) in North America. The largest is the Alaska-Yukon (*A. a. gigas*), which grow to over 6' at the shoulders and can weigh over 1,200 pounds. The smallest sub-species is the Shiras (*A. a. shirasi*), which is found in the intermountain west, grows to about 5'6" – 5'9", and typically weighs under 1,000 pounds. The sub-species recognized in Minnesota is the Northwestern moose (*A. a. andersoni*), which is about halfway in size between the two other subspecies. The fourth subspecies, the Eastern moose (*A. a. americana*) occurs in New England and eastern Canada. While Minnesota is one of the few lower 48 states with a moose population, Minnesota moose are at the very southern edge of the North American range for their subspecies.

Historical evidence indicates that moose occupied northern Minnesota since at least the turn of the 20th century, but their numbers were low until the early 1950's. Since the 1950's, moose sightings expanded from the traditional boreal forest in the northeast to the prairie edge of northwest Minnesota. In 1982, DNR established a separate population survey between the two disjunct populations in northwest and northeast Minnesota (Figure 1). Over the last two decades, moose density declined dramatically in the northwest population, from at least 4,000 to fewer than 100 animals in the last survey (Figure 2). The northwest moose population is on the verge of extirpation. The precipitous decline in this population continued even after the cessation of hunting in 1997 and continuation of habitat improvement projects. During a period of intensive research in the late 1990s, annual adult moose mortality was high (21%) and moose pregnancy and recruitment rates were very low. Mortality was attributed to poor nutritional condition and parasitism. These health-related issues were correlated with increased summer and winter temperatures in recent decades, in an area of forest edge where tree cover is relatively sparse. Consequently, the majority of this plan addresses the northeast moose population, which at present is still viable.

Beginning in 2002, moose research and monitoring were intensified in northeast Minnesota through a cooperative effort by the DNR, tribal authorities, and federal researchers. Annual non-hunting mortality of adult moose in this population was found to be comparable to that of the northwest population during the 1990's study. Aerial survey information also revealed declines in moose calf recruitment. Fixed-wing aerial surveys conducted between the early 1980s and 2003 had revealed a generally declining population. In 2004, the survey method was changed to a helicopter and a new sightability model was developed so aerial survey information is not comparable between methods. Since the implementation of a helicopter survey, there has been an apparent decline in the population; however, the decline was not statistically significant until 2011 (Figure 3). The statistical decline supports population modeling, which indicates continued declines if the low levels of adult survival and calf recruitment continue. Research has also identified inverse correlations between annual and seasonal survival and various temperature metrics which suggests a link between moose populations and a warming climate.

To achieve a better understanding of what is driving this population downward; research should address critical deficiencies in our understanding of moose mortality and recruitment in the northeast. In addition, long-term monitoring of the population should continue and primary factors responsible for the population change should be identified. Only through this understanding can management actions be undertaken that may provide for a viable long-term moose population.

Research projects that identify cover and forage type selection by moose and data on moose responses to weather events are critical to understanding their long-term habitat needs. Ultimately, this information should provide guidance to land management agencies in Minnesota, aid in development of habitat management plans, and provide the basis for a comprehensive understanding of how moose use different vegetation types and their relative importance.

Research should also address some of the more long-term issues associated with moose in Minnesota. Climate change models predict that in the coming decade's impacts of ambient temperature on moose will increase in both summer and winter. Understanding how moose respond to warmer temperatures will help guide future habitat and moose management decisions here in Minnesota.

Figure 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.

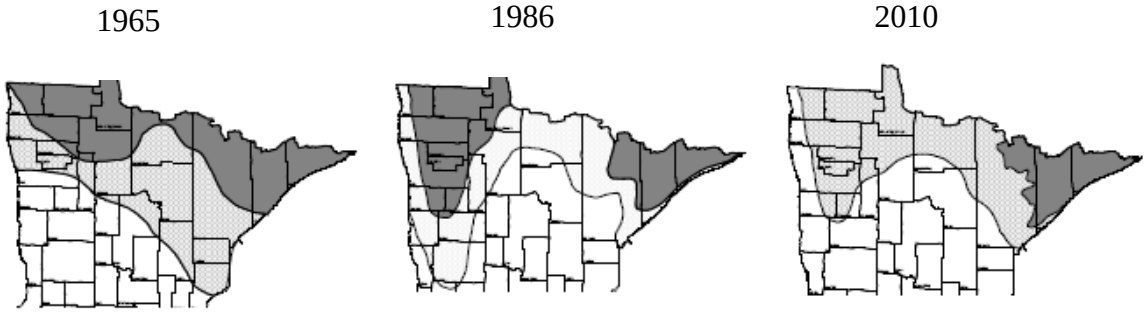


Figure 2. Estimated moose population in northwest Minnesota, 1983-2007. Error bars reflect 90% confidence intervals.

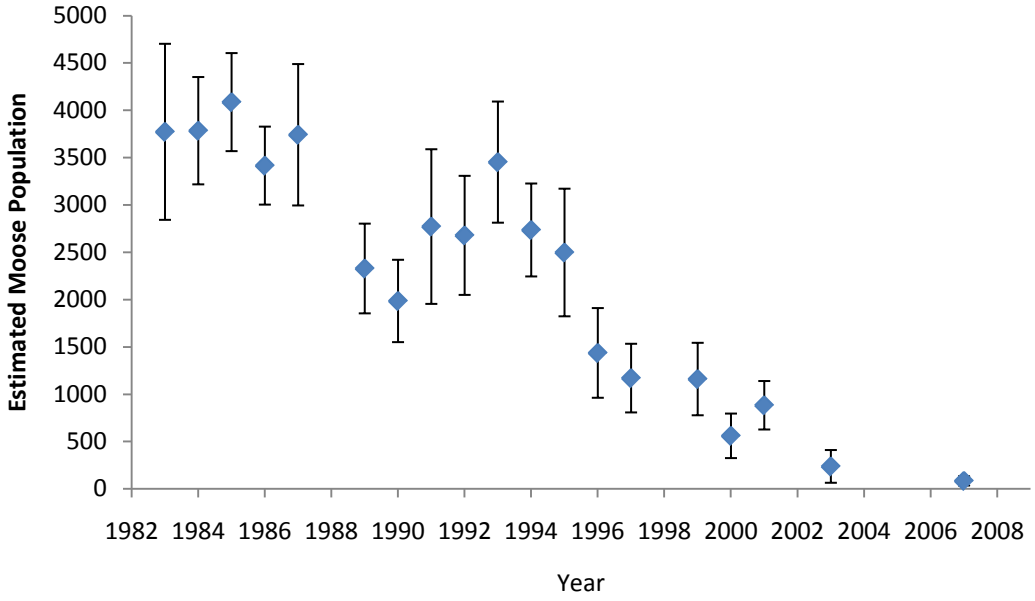
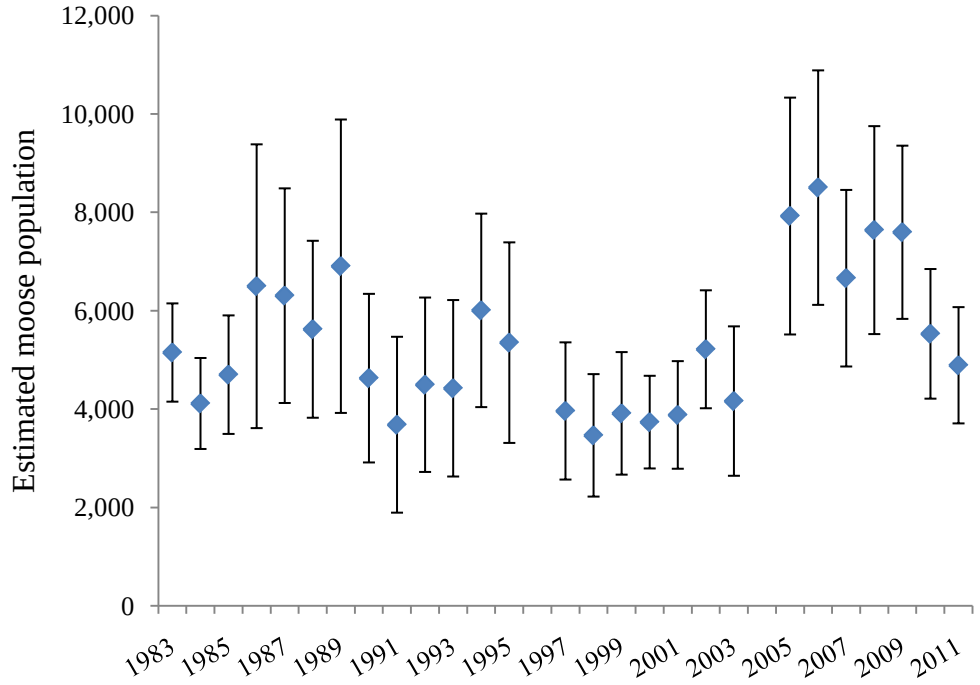


Figure 3. Estimated moose population in northeast Minnesota, 1983 - 2011. Error bars reflect 90% confidence intervals.



Note: Beginning in 2004, the DNR began using helicopters on the survey and corrected visibility bias using a "sightability model." Estimates prior to 2004 are not directly comparable with the new survey techniques.

Designation as State-Listed Species

Minnesota state law (Minnesota Statutes, 2007: Section 84.0895 Protection of Threatened and Endangered Species) provides for additional protection or monitoring for species designated as Endangered, Threatened, or Species of Special Concern. There was unanimous agreement among MAC members that it is inappropriate at this time to designate the moose as either *Threatened* or *Endangered* in Minnesota. With the northeast population numbering around 7,000 (at the time the MAC was in deliberation) and forested moose habitat secure at least in the short-term, the committee felt moose are neither in immediate danger of extirpation nor threatened with extinction statewide. Furthermore, a designation of "threatened" is incompatible with moose hunting, which the MAC considered appropriate. The MAC also acknowledged the current need for moose managers to deal differently with northeast and northwest moose so a state-wide designation as either *Endangered* or *Threatened* was not warranted.

There was considerable discussion within the MAC about whether or not a designation of Species of Special Concern was appropriate. This designation is provided for species that are on the periphery of their range or require unique or highly specific habitats, and thus need careful monitoring of their population status. Moose in Minnesota are on the periphery of their range, but that has been the case ever since moose recovered in the middle of the 20th Century from early overharvest. Moose are considered habitat generalists, without unique or highly specific habitat requirements, but in the context of climate change it is not known with certainty what habitats will be critical for moose survival. Prior to polling the full MAC, members considered the following:

Reasons *for* listing moose as a Species of Special Concern

- Moose are clearly intolerant of heat extremes and the southern edge of their distribution in North America is considered to be limited by prevailing temperature. The moose is on the periphery of its range in Minnesota and the extent of suitable range in the state has contracted because of climate change.
- On a *statewide* basis moose numbers have declined by over 30% since the mid-1980s even with closed seasons or conservative harvests.
- Annual mortality of moose in northeast Minnesota is currently comparable to that documented in northwest Minnesota during the chronic population decline there, and is correlated with mid-winter temperature.
- There have been long-term declines in calf recruitment and hunter harvest, consistent with anecdotal reports from the public that moose have declined in the northeast.

Reasons *against* listing moose as a Species of Special Concern

- There are still approximately 7,000 moose in Minnesota, and aerial surveys do not suggest a chronic population decline in the northeast (at the time of the MAC deliberation)*.
- While measured mortality rates since 2001 suggest ongoing population decline, these data come primarily from the southern portion of the moose range and might not apply throughout the northeast.
- Moose have existed on the periphery of their range throughout history.
- Listing of moose as a Species of Special Concern is not necessary at this time as the species is already being monitored carefully.

*Note – At the time of MAC deliberations, the moose population had not declined significantly. As of this plan, the population has declined significantly.

The MAC was unable to reach consensus for a Species of Special Concern listing; indeed, only a slight majority supported the designation (9 Yes: 8 No: 1 abstain). The MAC recognized there are important consequences associated with SSC designation, but committee members were largely guided individually by their understanding of moose status on a statewide basis, without trying to resolve all the legal issues associated with the language of the law.

The MAC was also concerned about the length of time necessary for designation as a Species of Special Concern. Even if the moose is not designated at this time, it is possible that evidence of chronic population decline might be forthcoming in the near future and listing as a Species of Special Concern would be desirable. There is increased potential for transmission of new diseases among wildlife populations and species, they believed the DNR needs a capability to review and change species status, at least on a provisional basis, without a review that extends for years. The federal government, through the Endangered Species Act, has a procedure for emergency listing of a species as either Threatened or Endangered. The MAC urged the DNR to take steps to eliminate undue delays in listing a species, recognizing that action by the legislature might be necessary.

As of March 2011, the new rule designating species as threatened, endangered, or special concern has not been finalized by the Division of Ecological and Water Resources. The draft rule, which has not completed full DNR review, recommends listing moose as a Species of Special Concern.

Moose Harvest

The statewide moose hunting season was closed in 1922 after the cumulative effects of settlement reduced northeast moose numbers to very low levels. With the increase in numbers since the 1950's and expansion in range, the hunting season was reopened in 1971 and limited numbers of hunters were issued permits to take moose in both northeast and northwest Minnesota. Although moose hunting was eliminated in the northwest in 1997, moose hunting has continued in northeastern Minnesota and over the last 10 years, state and tribal hunters have harvested an annual average of 184 moose. Since 2007, state-licensed hunters have been restricted to harvesting antlered bulls only. While the hunting season thresholds that are identified in this plan apply only to state licensed hunters, a section regarding tribal harvest is also provided.

Moose are harvested by both state-licensed hunters and tribal members under separate seasons and regulations (Table 1). Annually, an aerial survey is conducted in northeastern Minnesota to monitor moose numbers and identify population fluctuations. The primary objectives of the aerial survey are to estimate moose numbers and determine the calf:cow and bull:cow ratios. These data are used to determine population trends and set the harvest quota for the subsequent hunting season.

The public tends to view moose hunting in northeastern Minnesota as contributing to a population decline. However, the current bulls-only harvest removes only 2% from the fall population annually. While this level of harvest has a minor effect on the absolute number of moose in northeast Minnesota, the impact on the rate of population change is likely minimal. In some cases, individual bull moose in prime breeding condition can mate with several cows, but in forested habitats most evidence points to the evolution of an even sex ratio. Bull moose in Minnesota likely breed only a small number of cows each year and for that reason the bull:cow ratio needs to remain higher than in species such as white-tailed deer. Research in Quebec suggested that if the bull:cow ratio dropped below 0.67 bulls per cow, the pregnancy rate would decline. Until recently, the bull:cow ratio observed on the aerial moose survey in northeastern Minnesota has remained fairly stable but in the last 7 years, this ratio has trended downward and was below 0.67 in 2011 (Figure 4).

DNR is charged with managing the moose herd sustainably and has the responsibility of leading moose management efforts in the state. If moose are listed as a State Threatened or Endangered species, then legally, moose hunting must be stopped entirely. If moose numbers continue to decline, the DNR has recommended numerical thresholds to determine when moose hunting should be suspended. These thresholds are described under the DNR Strategies section of this plan.

Table 1. State-licensed hunter applications, bull harvest, success rates and total tribal harvest for northeastern Minnesota, 1993-2010.

Year	Party applicants	Permits	Bulls harvested	Bull hunter success	Total tribal harvest
1993	2,934	315	200	63%	96
1994	3,022	189	115	61%	74
1995	3,181	188	129	69%	77
1996	3,830	207	123	59%	63
1997	3,958	198	124	63%	66
1998	4,157	182	90	49%	71
1999	3,919	189	101	53%	68
2000			No hunt		63
2001	3,164	182	108	59%	62
2002	2,580	208	118	57%	79
2003	2,328	224	127	57%	63
2004	3,062	245	127	52%	61
2005	3,060	284	137	48%	67
2006	2,952	279	133	48%	48
2007	2,566	233	115	49%	47
2008	2,706	247	110	45%	40
2009	2,746	225	103	46%	42
2010	2,415	213	109	51%	36

Figure 4. Bull:cow ratio as estimated from aerial surveys in northeastern Minnesota. Estimate for 2003 was biologically impossible considering estimates in 2002 and 2004 and was omitted from trend analysis. Error bars reflect 90% confidence intervals.

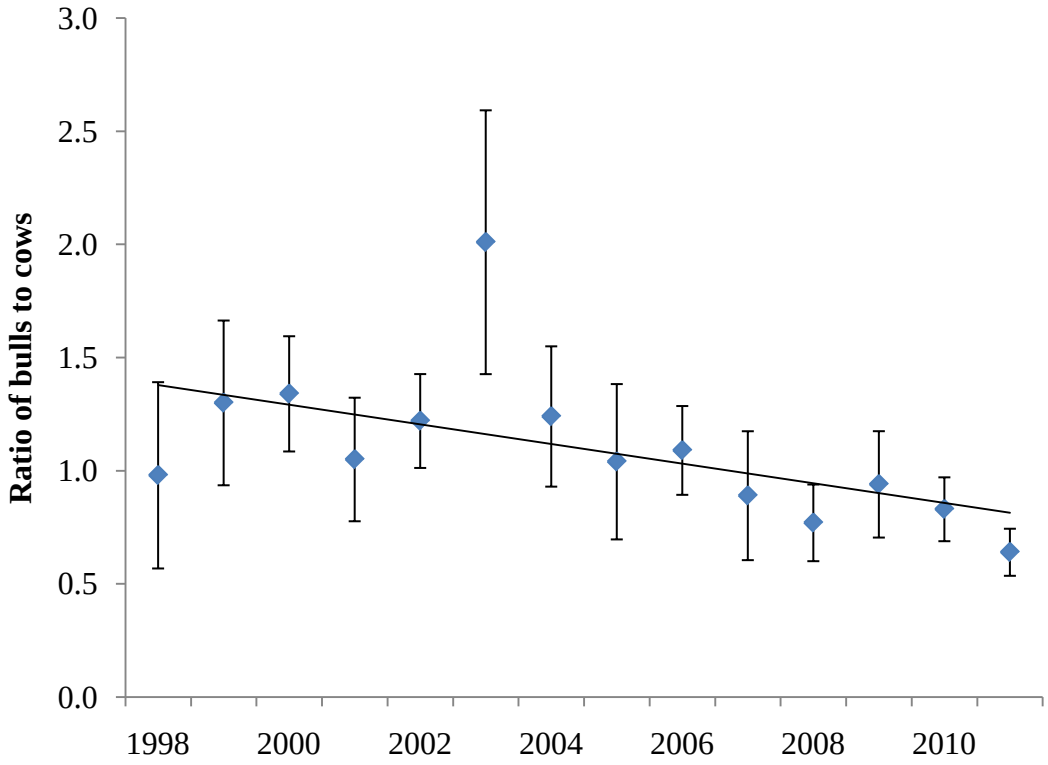
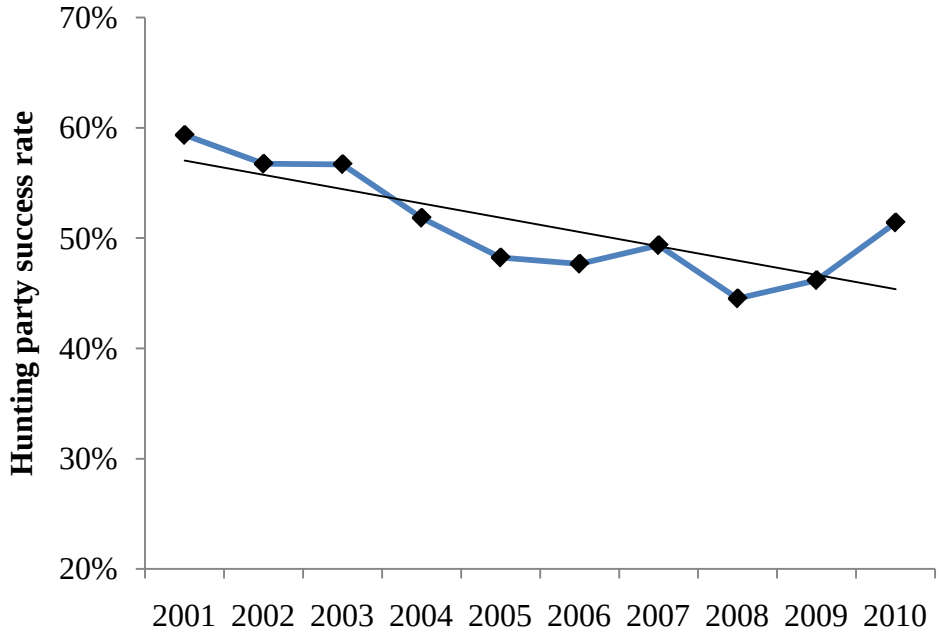


Figure 5. Hunter success at harvesting a bull moose in northeastern Minnesota, 2001-2010.



Tribal Harvest

In addition to state-licensed hunters, there are three Tribal governments that retain the rights to hunt moose in the northeastern moose range of Minnesota. The Grand Portage, Bois Forte, and Fond du Lac Bands of Lake Superior Chippewa all retain rights to hunt in the territory ceded under the Treaty of 1854. The Bois Forte and Grand Portage Bands are in an agreement with the State, which was established in 1988 that limits their exercise of those rights to fish and hunt outside state regulation in exchange for annual cash payments. Those two Bands regulate their harvest through an inter-tribal agency known as the 1854 Authority, which is charged with managing their off-reservation hunting rights. The Fond du Lac Band is not party to the negotiated agreement and manages its ceded territory moose harvest under a tribal code. Both the 1854 Authority and Fond du Lac hunt moose annually and neither are obligated to distribute their hunters according to the State's moose zones.

1854 Authority. Under the negotiated agreement, 1854 Treaty Authority moose seasons shall be the same as those established under state law and the Bands are authorized to take no more than 30 moose per each annual open season. Since 1994, 1854 Authority hunters have averaged 26 moose per year and the trend has been declining. In 2010, 1854 Authority hunters took 12 moose (8 bulls, 4 cows), which is the lowest ever recorded.

Fond du Lac. Harvest seasons are set under Band code and are not necessarily the same as State seasons. Since 1994, Fond du Lac hunters have averaged 34 moose per year and their harvest trend has also been declining. In 2010, Fond du Lac hunters took 23 moose (20 bulls, 3 cows).

State / Tribal Percentages. If the total allowable harvest of moose continues to decline, it will affect harvest by both State and Tribal hunters. While no cap on Band harvest share has been set by a federal court in Minnesota, similar federal treaty cases in other jurisdictions have limited Band harvest to no more than 50 percent of the allowable harvest of a particular species. Since 1994, Tribal moose harvest has averaged 29% of the total northeastern Minnesota moose harvest. During that time, the annual state harvest has always exceeded 100 moose (range 103 – 243) and the total band harvest has averaged 60 per year (range 28 – 79). If allowable moose harvest continues to decline and without commensurate harvest adjustments by Tribal authorities, the Band percentage of total harvest will increase. For example, in 2011 State hunters will be issued 105 licenses that are projected to result in a harvest of approximately 53 moose. The 2011 Tribal harvest projected by the Bands is 51, which could approach 50 percent of total harvest.

The State and Bands currently hold an annual joint technical meeting to set moose harvest quotas and allocations. If allowable harvests continue to decline, there may be a need for a more formal process of decision-making and dispute resolution around making those determinations.

Moose Predation

The two primary predators of moose in Minnesota are the black bear (*Ursus americanus*) and gray wolf (*Canis lupus*). Functionally, the effects of predation should be segregated between calves and adults. Black bears are likely not large enough to kill adult moose; however, they will opportunistically take calves. Studies have shown that black bears are effective predators of moose calves from 0 to 30 days of age. Research from the Kenai Peninsula in Alaska documented that 50% of calf mortalities were predation-related and black bears accounted for one-third of that mortality. In a similar study in east central Alaska, predators took up to 70% of moose calves but low densities of black bears were responsible for only 3%. In northwest Minnesota, research demonstrated that predation rates on neonates were lower than what had been reported in other studies, which indicated predators (both black bear and wolf) likely had little role in the decline of that population. In northeast Minnesota, black bear densities can be characterized as high (relative to the overall bear range); however, the effect of bears on moose calves in northeast Minnesota has not been quantified.

Wolves are effective predators of all age classes of moose and research in other states has suggested that wolf predation can limit moose population growth, especially at low numbers. Nearly every study from Alaska to Isle Royale has shown that wolves can and do regulate moose densities. With respect to adult moose, radio telemetry data in northeast Minnesota indicates that 10% of adult mortality was directly attributed to wolf predation. While it is likely that some of the unknown mortality is in fact wolf-related, the data suggests that wolves are not the most significant source of adult moose mortality in NE Minnesota. In addition, other studies have demonstrated differential predation effects based on alternate prey species. In Minnesota, white-tailed deer are the primary ungulate prey species; however, smaller prey such as beaver (*Castor canadensis*) and snowshoe hare (*Lepus americanus*) are also taken. It is unclear whether the presence of white-tailed deer either dilutes (deer are an alternative prey source) or amplifies (more wolves on the landscape because deer are abundant) the effects of wolf predation on calf moose.

There is ample evidence to suggest that predators can play a role in limiting population growth by killing young calves. Given the observed high pregnancy rates (>80%) and early summer calf production of radiocollared females (e.g., timeframe = May 2010; n = 24 cows; 1.13 calves/cow; 21% twins), it can be presumed that most adult females are getting pregnant and successfully giving birth to offspring. However, the winter aerial survey has revealed a significant decline in those same population metrics (e.g., timeframe = January 2011; n = 24 cows; 0.46 calves/cow; 5% twins) indicates a significant loss of calves in the first 6 months of life. The 2011 aerial survey revealed the lowest cow:calf ratio ever recorded (0.24). However, there is likely not a 1:1 relationship between wolf populations and calf mortality. In reality, the effect of wolf predation on moose calves in northeast Minnesota remains unclear because there may be other factors affecting calf recruitment. For example, starvation, disease, and parasitism (e.g., brainworm) are

all likely impacting calf recruitment; thus, without research directed specifically at calves, it is not possible to make any quantifiable statements about the effects of predators.

Since 1974, wolves in Minnesota have been afforded protection under the Endangered Species Act of 1973. At the time of Federal protection, there were an estimated 750 wolves occupying approximately 38,000 km^2. Over the previous 35 years, both the numbers and distribution of wolves have increased and the most recent survey (2007-08) estimated a population of 2,900 ± 730 wolves distributed over 88,000 km^2. Until wolves are delisted, the Federal Government retains control over management and the State cannot establish hunting and trapping seasons.

In 2001, DNR undertook an effort to develop a statewide wolf management plan that would guide decisions once wolves were delisted. The minimum wolf population objective identified in the DNR wolf management plan is 1,600 animals. The wolf management plan also identifies several population management options (e.g., hunting and trapping seasons) that would be available when wolves are delisted. The complete DNR wolf management plan can be found at, http://files.dnr.state.mn.us/natural_resources/animals/mammals/wolves/wolfplan2000.pdf.

Moose Research

Although an aerial survey is conducted annually to determine the status of northeastern moose, it is not sufficient by itself to understand the current population decline and identify management solutions that could help stabilize or increase the moose population. Additional research is needed on moose biology, survival, habitat requirements, and their relationship to climate change. While aerial survey results give an indication of population trends, research is necessary to explain proximate and ultimate causes of changes in the moose population.

Several lines of evidence indicate the moose population in northeastern Minnesota is declining. High mortality among adult radiocollared moose, low recruitment rates of calves, and anecdotal information (e.g., declining moose observations and hunter success rates) all indicate a likely problem. Moreover, population modeling that integrates the survival and recruitment rates found among radiocollared moose substantiates a declining population. Approximately 74% of adult mortality from the current research on moose in northeastern Minnesota is classified as unknown, of which 38% of that appears to be health-related**.** In addition, research has found a correlation between increasing seasonal ambient temperature and subsequent adult survival. There should be continued research that identifies proximate and ultimate causes of moose mortality.

The DNR has maintained a conservative hunter harvest level in the northeast and hunting was discontinued in the northwest in 1997. As long as bull:cow ratios are maintained above the threshold sufficient to sustain breeding rates, reducing or eliminating the bull harvest should not alter the potential annual population increment as reproduction would not be affected because fertile females are bred.

Current Moose Research Projects

Annual moose survey. Since 2004, an annual aerial helicopter survey (completed in collaboration between DNR, Fond du Lac, and the 1854 Authority) provides data on moose population trends and demographic characteristics. Global Positioning System (GPS) locations of moose observed, age class, and sex are recorded in the helicopter. Numbers of deer on survey plots have also been recorded in some years. Estimates of population size, sex, and age ratios are generated from this survey, and this information is used to understand causes of historical changes in populations and help model future changes.

Current efforts to monitor the northeast moose population rely on this survey. Presently, annual costs of the survey exceed $30,000. However, the information is fundamental to understanding changes in moose numbers and distribution, and is the basis for determining if management efforts undertaken on behalf of moose are effective.

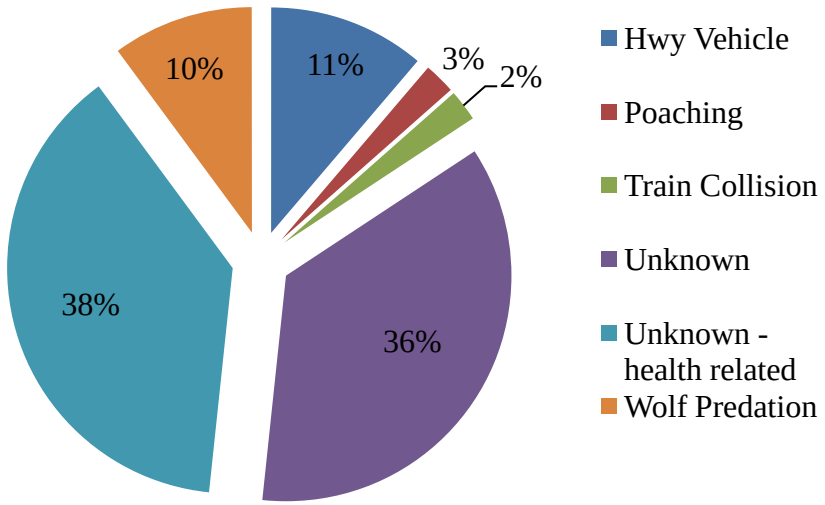
In northwest Minnesota, the aerial frequency of aerial surveys has been greatly reduced because of low moose numbers. Given the low moose density and high costs of aerial surveys, a 3-5 year survey period is appropriate at this time. If the moose population reveals an upward trend, an effort to develop and coordinate an annual low-cost alternative to the aerial survey in the northwest should be considered.

Moose Population Dynamics. A study using very high frequency (VHF) radiocollars began in 2002 as a cooperative project between the DNR, the U.S. Geological Survey (USGS), the 1854 Treaty Authority and the Fond du Lac Band of Lake Superior Chippewa in northeast Minnesota. Initial objectives of the research were to:

- Monitor trends in seasonal and annual rates of adult moose survival,
- Determine annual pregnancy rates and gross reproduction,
- Attempt to determine proximate causes of adult mortality,
- Determine calf survival to adulthood,
- Develop a sightability model for use in the aerial survey, and
- Determine movements and home range.

Between 2002 and 2008, 150 moose were captured and fitted with VHF collars. Current funding will allow monitoring of the remaining collared moose through February 2013. Results from this research improved the aerial survey, determined large-scale movements, home range sizes, and survival rates of adult moose and calves. The project has been less successful in determining causes of mortality, as about 74% of non-hunting adult mortality during the study was classified as "unknown," (Figure 6). In addition, the research found correlations between temperature metrics and subsequent annual and seasonal adult survival.

Figure 6. Cause-specific non-hunting mortality of 89 radio-collared moose, 2002-2010.



Global Positioning System (GPS) Telemetry Projects.

There are currently four research projects using GPS telemetry to study moose. While they are different projects, the studies share similar methods and should yield comparable results. The studies are, 1) Voyageurs National Park (VOYA), 2) Grand Portage (GP) Indian Reservation, 3) Quetico Provincial Park, and 4) Identification of critical habitats for moose (Figure 7). Study cooperators include the National Park Service, the Natural Resources Research Institute, Fond du Lac, 1854 Authority, Grand Portage Indian Reservation, Quetico Provincial Park, the Minnesota Deer Hunters Association (MDHA), and the US Geological Survey. The DNR has been providing in-kind veterinary and staff support during moose capture efforts but is not a participating partner.

During winter 2010, GPS collars were placed on 21 moose (Voyageurs and Grand Portage). During winter 2011, 65 moose were captured as part of all 4 projects. The collars collect location and activity data at 15-minute intervals. Vegetation types used by moose under different weather conditions will be identified and compared with estimates of temperature and activity recorded by the collar. Specifically, the research will:

- Quantify moose activity patterns and selection of vegetation or habitat types relative to ambient temperature,
- Evaluate consistency of habitat types used when ambient temperatures are high over time,
- Evaluate similarity of demography of moose populations in Voyageurs National Park and northeastern Minnesota in space and time, and
- Evaluate consistency of home ranges of moose between the northeast Minnesota VHF study and this research.

The project examining critical habitats for moose is being conducting in cooperation among the Natural Resources Research Institute, DNR, 1854 Treaty Authority, Fond du Lac Band, and the Minnesota Deer Hunters Association (Figure 8). It was recently funded by the Legislative-Citizen Commission on Minnesota Resources. The first year of radio-collars were placed on moose during winter, 2011. Specific objectives of the research are to:

- Use precise GPS locations to identify critical habitats, develop BMPs, and provide recommendations for protection of moose habitat,
- Use potential impact of climate change on moose as a teaching tool to increase understanding of how climate change could affect people and other species in MN, and
- Involve individuals, biologists, and organizations in a coordinated effort to determine if it is possible to slow or prevent a decline of the northeast Minnesota moose population.

The study has an educational component involving the Minnesota Zoo and a moose reporting website for the public at NRRI in cooperation with the MDHA. This research is intended to complement research from the VOYA and GP study sites, which are at the northern extremes of current moose range in northeastern Minnesota.

Figure 7. Locations where moose have been fitted with GPS radiocollars as part of various research projects.

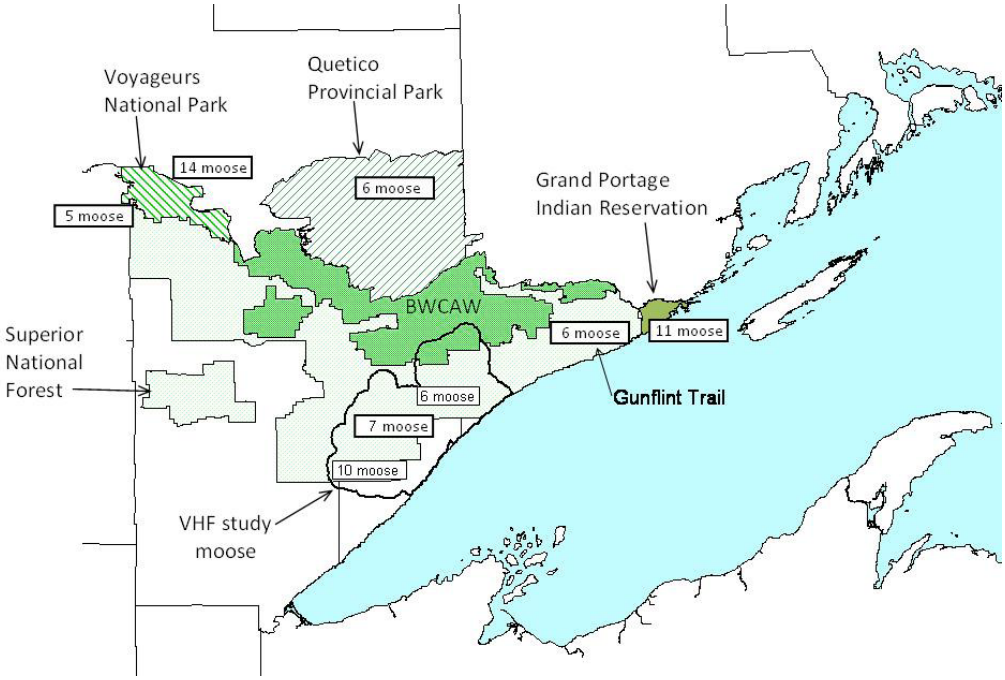
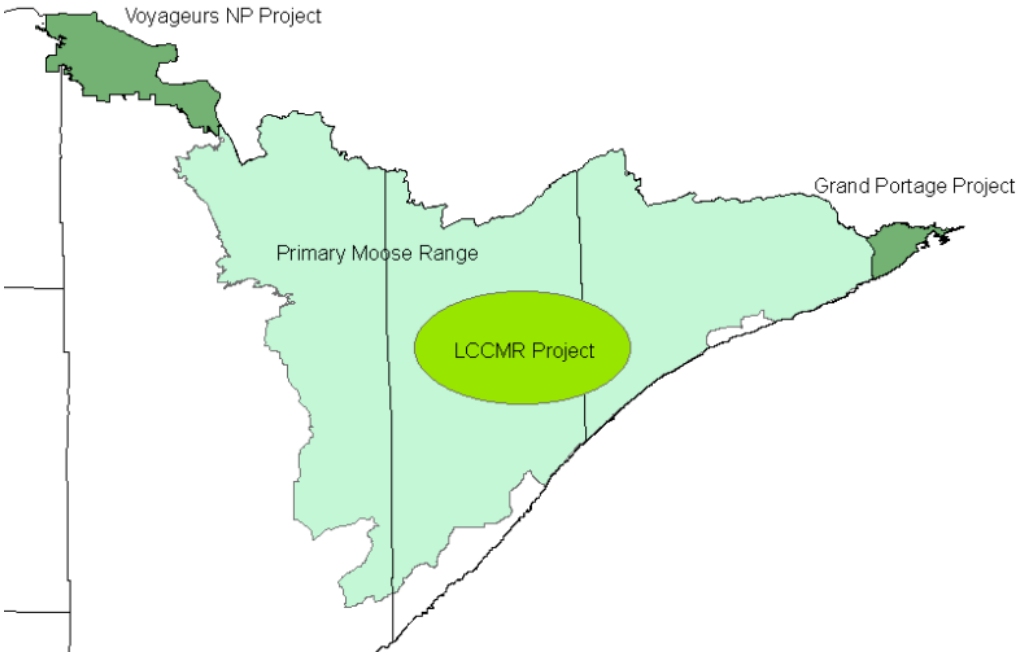


Figure 8. LCCMR project study site in relation to other GPS collar projects in Minnesota.



Disease Screening. During the 2007-2010 moose seasons, biological samples (e.g., liver, lung, feces, blood, hair, cranial lymph nodes, brain) were collected by DNR from hunter-harvested moose (both State and Tribal) and screened for a variety of disease agents. The results are intended to indicate which diseases the northeast Minnesota moose population are being exposed to as well as allowing for comparisons between similar testing completed on non-hunting moose mortalities from the same population. Positive results only indicate that the animal was exposed to the disease agent and do not necessarily mean the animal was sickened by the disease. While some of the test results may be all negative, this does not necessarily mean that the disease is not present or impacting the population. Some diseases cause death so quickly, or without an immune response, that finding a positive in a seemingly healthy animal would be extremely rare.

Over the first 3 years of this research (2007-2009), 368 moose from across the northeast were submitted for diagnostic screening (Figure 9; Table 2). In addition to blood and parasite screening, the University of Minnesota, Veterinary Diagnostic Lab examined whole brains (n = 47) and livers (n = 57) in 2008 and 2009. Of the brains examined, no lesions were found in 41, 5 had unspecified chronic inflammation, and 1 had larval meningeal worm tracts in the white matter. For the livers, 34 had no fluke lesions, 15 had mild infection, 6 had moderate infection, and 2 had marked infection.

The results of this work have identified exposure to disease agents as well as providing a baseline of "normal", which will allow for a better understanding of results from non-hunting mortalities and possible changes that may occur in the future.

Figure 9. Harvest locations of moose (n = 368) included in the 2007-2009 disease-screening data analysis.

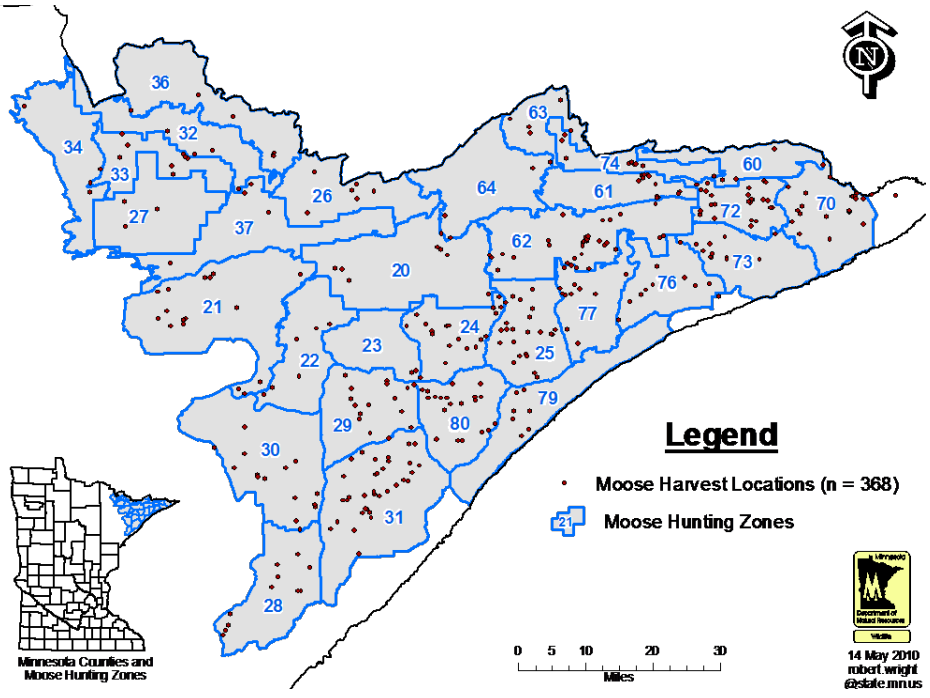


Table 2. Results of serologic testing of hunter-harvested moose, 2007-2009.

Serological Test	Number Tested	Number Positive	Percent Positive
Eastern Equine Encephalitis	330	20	6.1
West Nile Virus	330	115	34.8
Leptospirosis			
Leptospira bratislava	334	6	1.8
L. canicola	334	2	0.6
L. grippothyphosa	334	8	2.4
L. hardjo	334	3	0.9
L. interrogans serovar *icterohaemorrhagicae*	334	22	6.6
L. pomona	334	23	6.9
Johne's Disease (*Mycobaterium paratuberculosis*)	335	0	0
Malignant Catarrhal Fever	326	114	35
Anaplasmosis (*Anaplasma phagocytopila*)	319	1	0.3
Lyme Disease	319	73	22.9
Brucellosis	303	0	0
Blue Tongue Virus	334	0	0
Bovine Viral Diarrhea (Type 1 and 2)	333	3	0.9
Epizootic Hemorrhagic Disease	334	0	0
Neospora spp.	334	9	2.7
Bovine Herpes Virus 1	333	1	0.6
Parainfluenza Virus 3	335	1	0.3

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Moose Research Needs

Population Dynamics

Research is necessary to better understand the ultimate and proximate causes of the high mortality documented in the northeastern moose population. Without further research, we may never discover why moose are dying at such high rates in Minnesota. The roles of thermal stress, parasites, disease, and parasite and disease vectors need to be better understood. Potential geographic variation in mortality across Minnesota's moose range and better understanding of how local and regional environmental conditions may impact moose health, reproduction and mortality also must be investigated. Causes and rates of mortality may vary spatially and temporally and on-going monitoring is recommended.

The telemetry studies of northwestern (1995-2000) and of northeastern (2002 – 2010) moose have documented high mortality rates. Much of this mortality appears to be health-related and may be linked to heat stress. Research should focus on the seasonal nutritional condition of moose, on identifying potential agents and vectors of disease and parasites, their impact on

moose and how that impact may vary across moose range over time. For example, results from the northwest moose study indicated liver flukes were a common proximate source of mortality, likely contributing to 32% of deaths of collared moose; a much smaller proportion of moose were infected by liver flukes in the northeastern population. The reasons for this are not well-understood. Although probably not a proximate source of mortality, the role of heat stress in predisposing moose to other sources of mortality requires closer examination.

Cause-Specific Mortality

Recent study of the northeastern moose population has reported an annual non-hunting mortality rate of 5–35%, which was significantly higher than for other northern moose populations (8–12% per year) outside of Minnesota. That research suggested that a warming climate is at least partially responsible for the high mortality rates, hypothesizing that it acts as a contributing factor (i.e., ultimate cause of death). It is possible that moose are being physiologically stressed by warmer temperatures, rendering them more susceptible to disease, parasites, predation, or other direct (i.e., proximate) sources of mortality, but previous research had difficulty determining specific causes of non-hunting mortality or whether moose actually are physiologically stressed. Technology and cost constraints in earlier studies meant researchers were unable to respond to mortalities within a critical 24-hour period after death, often precluding definitive diagnoses and conclusions concerning causes of death in cases involving predators and/or health issues. Further, nutritional condition is centrally important to any assessment of ultimate cause of death, but thus far has been afforded limited attention. An LCCMR research proposal has been prepared to focus on determining, 1) specific proximate causes of non-hunting mortality of moose, and 2) on whether or not nutritional deprivation or physiological stress associated with increased ambient temperatures are implicated as ultimate causes of death.

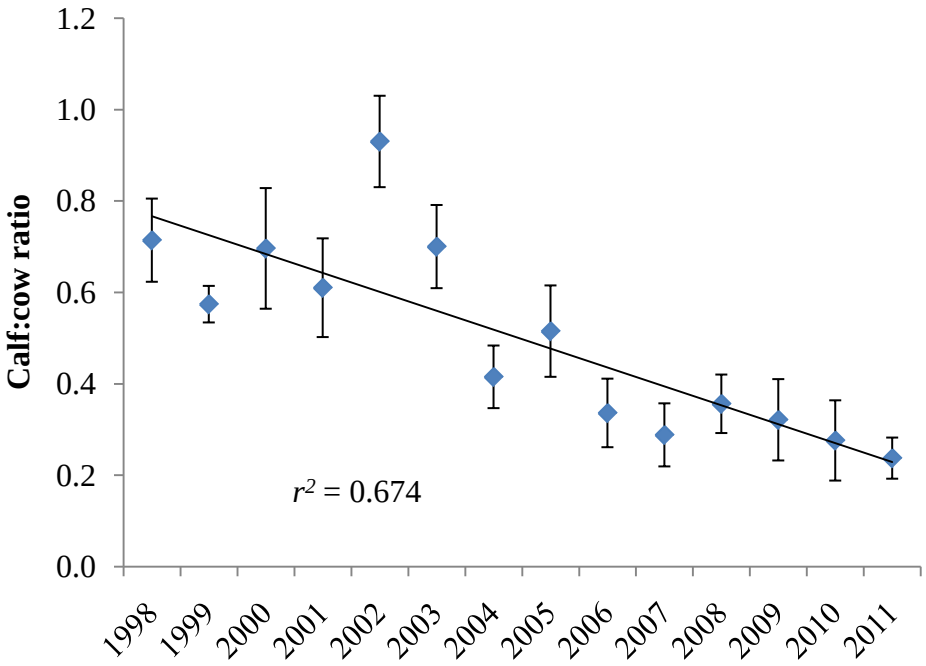
Calf Mortality

Our knowledge of age-specific survival and cause-specific mortality of calves from birth to one year of age is limited. Pregnancy rates of northeast moose are high (>80%) but the proportion of calves recruited into the population has been declining since the late 1990's (Figure 10). Research is needed to obtain a better understanding of pregnancy rates and calf mortality *pre-* and *post-partum*. Late winter condition of adult females has varied among study years in the northeast population, with lowest average fat reserves occurring during the year of lowest survival and pregnancy, whereas reserves of males though lower, were stable among years.

While research suggests predators are likely not influencing adult survival (Figure 6), data are not available to make the same assertion regarding calf recruitment. Given the typically high pregnancy rates but low recruitment rates, any research that examines moose survival (and cause-specific mortality) and reproduction (calf production and survival), should include

components focused on assessing the health and nutritional condition of cows and the impacts of predation and health issues on calves.

Figure 10. Estimated calf:cow ratio from aerial moose surveys in northeastern Minnesota. Note: The calf:cow ratio is not adjusted for sightability and can be compared with estimates prior to adoption of the sightability model.



Habitat

Habitat research in Voyageurs National Park and the Grand Portage Indian Reservation, while valuable, may not address the range of variation in the managed forest environment across most of the northeast moose range. Moose across most of their range in northeastern Minnesota utilize a managed forest environment (except the Boundary Waters Canoe Area Wilderness) where the different strategies and priorities of county, state, federal, and private land managers create a mosaic of conditions. The Environment and Natural Resources Trust Fund-funded GPS research should begin to provide some of the fine-scale habitat use information.

Climate

Research has established that climate change is occurring in the Great Lakes region and predictions call for spring and summer temperatures to increase as much as 2°C in the next 25 to 50 years. Moose are superbly adapted to colder environments, but they are far less tolerant of summer heat, and even minor increases in temperature may affect their survival. Importantly, recently published research has suggested there is a link between rising temperatures and moose

survival in Minnesota. Moose in Minnesota likely can use a variety of habitat features to ameliorate the effects of warmer temperatures and such features would represent critical habitat to moose. The availability of this critical habitat is likely to become altered in response to natural forces (fire, wind), human activity (timber harvest), and climate change, and it is important to better understand how such changes will affect the moose population.

It will be necessary to monitor changes in causes and rates of moose mortality in order to evaluate the effectiveness of any management recommendations and the effects of climate change. Thus, research is necessary to develop a better understanding of how moose respond to their environment and use habitat to meet their thermal and foraging needs. Improved fine-scale monitoring of climate, habitat changes, and their impacts on population performance of moose across Minnesota is necessary. In addition, moose populations across the southern edge of their range in North America do not appear to be affected equally by climate change (e.g., stable populations in New England), but the reasons for this variation are unclear. Understanding geographic variation in moose response to climate change may assist wildlife managers in developing strategies to benefit moose.

Research is an open-ended process

Answers and management implications are not always immediately obvious and ongoing research frequently raises new questions and unexpected results. The value of long-term research projects to explain trends and differentiate the effects of short-term variation due to changes in weather, predator populations, hunter harvest, habitat or other sources of environmental variation cannot be overstated. For example, DNR has undertaken long-term studies of white-tailed deer in forested habitat and statewide bear population dynamics. This research has contributed to a deeper understanding of the biology of both species, while minimizing the variability typically associated with short-term research projects. Finally, wildlife managers and policy makers need to leave the door open for new research ideas to adapt to changing conditions and information.

Deer Management

Overview

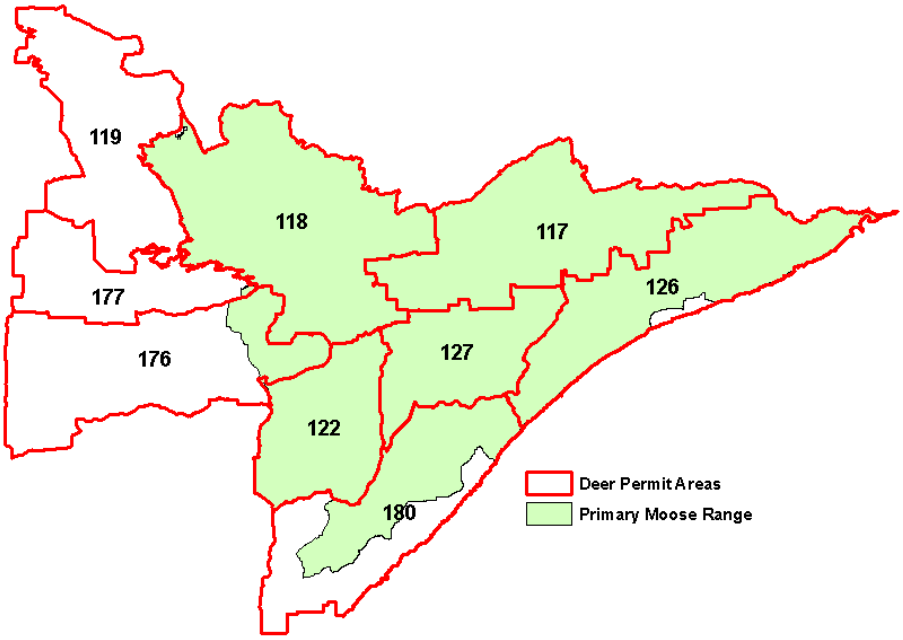
White-tailed deer occur across all of Minnesota's moose range and may carry parasites (e.g., liver fluke, brainworm) and possibly diseases (see Table 2) that can adversely impact moose. Little is known about the extent to which moose succumb to parasites and diseases that are maintained by the presence of deer on the landscape. Ultimate cause of moose death is often difficult to determine as many environmental factors likely contribute to mortality in individual cases. Although known to be potentially fatal to moose, the rate at which moose die from infections of parasites such as brainworm and liver flukes is also unclear.

Historical Deer Management

The State of Minnesota started managing deer populations through regulated hunting as early as 1858. Over the past century, deer populations have fluctuated throughout the State in response to changing habitat, varying winter severity, and harvest. These factors, especially the latter two, forced hunting season closures during the early 1940s and 1951. A statewide deer population crash occurred in the late 1960s, which prompted the most recent statewide season closure in 1971.

Historically, Minnesota allowed the harvest of one either-sex deer statewide, which may also have contributed to some of the 'boom and bust' that was observed in deer populations. After the 1971 season closure, a new system of management was developed that allowed for annual hunting seasons and growth of the deer population. To do this, hunters were allowed to harvest one buck per year and a finite number of either-sex permits were issued by deer permit area. These either-sex permits functionally turned a hunter's buck license into an either-sex license. In 2010, some deer permit area boundaries were adjusted so they largely fall either "in" or "out" of the northeast moose range (Figure 11).

Figure 11. Distribution of deer permit areas and moose hunting zones relative to the primary northeast moose range.



Minnesota's deer program has been a success based on hunter numbers, deer harvests, and population trends. For the last 30 years the current framework has brought stability to deer population management in Minnesota relative to previous decades where liberal seasons were often followed by season closures. Population management through season structure and regulation that began in the mid-1970s gradually increased the proportion of adult females in Minnesota's deer population. This, along with forest management practices and mild winter weather patterns, have been the most significant factors in growing and stabilizing Minnesota's forest deer populations.

Current Deer Population Status

Northeast Minnesota

Deer harvest and populations have fluctuated dramatically throughout the northeast moose range. However, after the severe winters in the mid-1990s, deer harvest has increased steadily. Total deer harvest throughout the moose range peaked in 2007 (10,838); however, it is important to note that buck harvest actually peaked in 2003 (6,196). With the changes to antlerless permitting, a proportion of the buck harvest was replaced with antlerless deer harvest, which peaked in 2007 (4,979; Figure 12). This shift in harvest has likely contributed to stabilization or reduction of total deer populations in that pre-fawn populations are estimated to have peaked in 2003 and, while still near historic highs, have generally decreased through 2009. The exception is deer permit area 180, which peaked in 2007 (Figure 13).

In adjacent areas of northwestern Ontario, two indices of deer population density (hunter-reported observations and deer recorded incidentally during moose aerial census flights) have likewise increased during the past decade. From this information we conclude that deer population density in the moose range has probably increased steadily in the past decade, a period when most winters were relatively short and of low severity for deer. That increase has been tempered by more aggressive antlerless deer management strategies consistent with the desire to lower total deer populations. Due to aggressive harvest management and increased winter severity in 2007-08 and 2008-09, modeled population estimates indicate the deer population has declined.

Figure 12. Registered deer harvest for deer permit areas in the northeast moose range, 1997 – 2009.

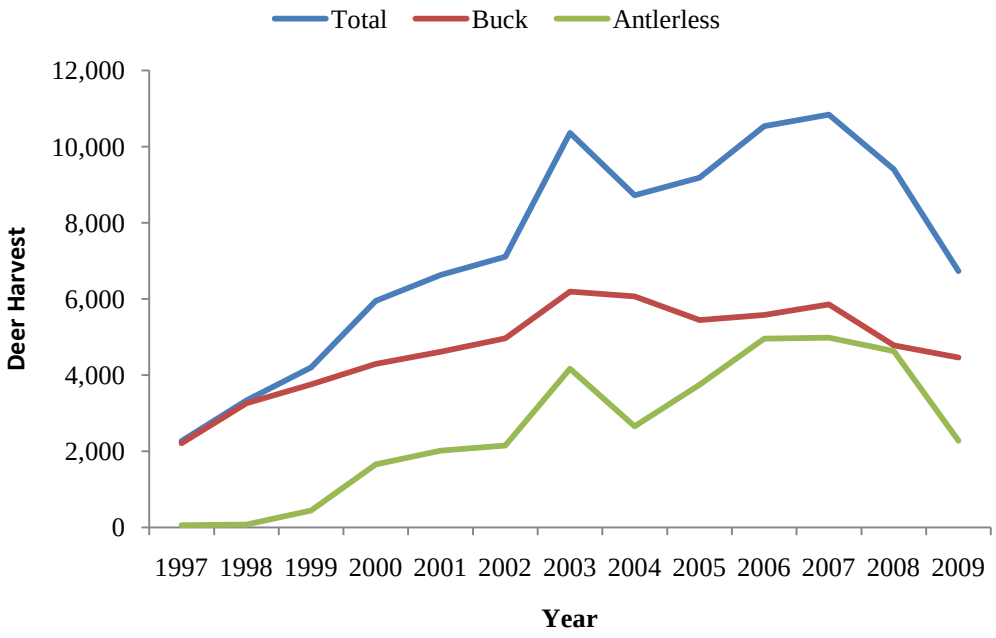
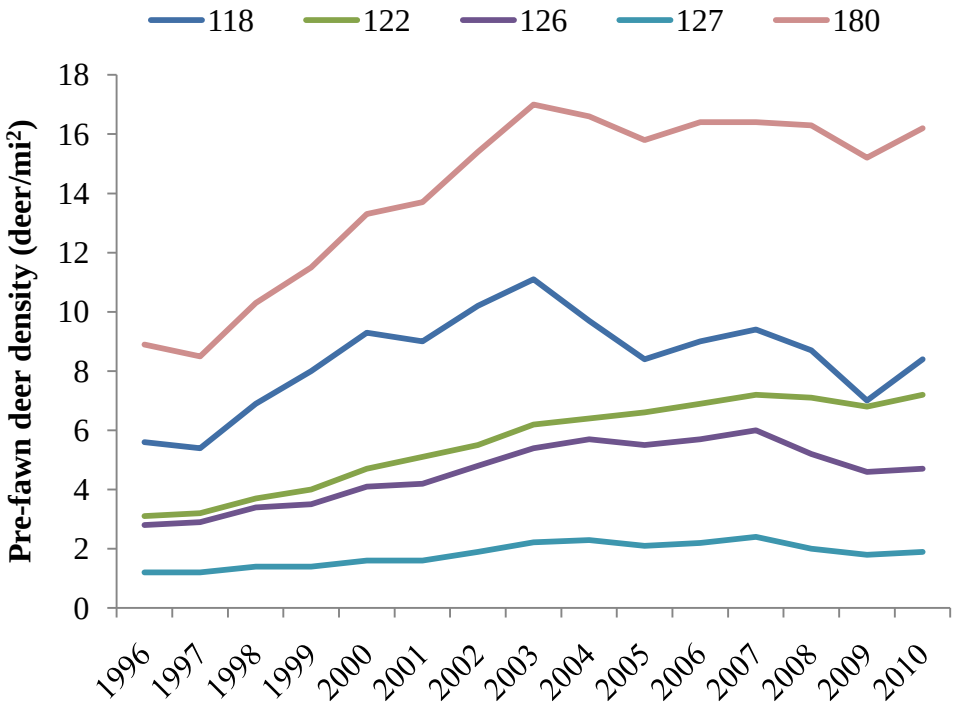


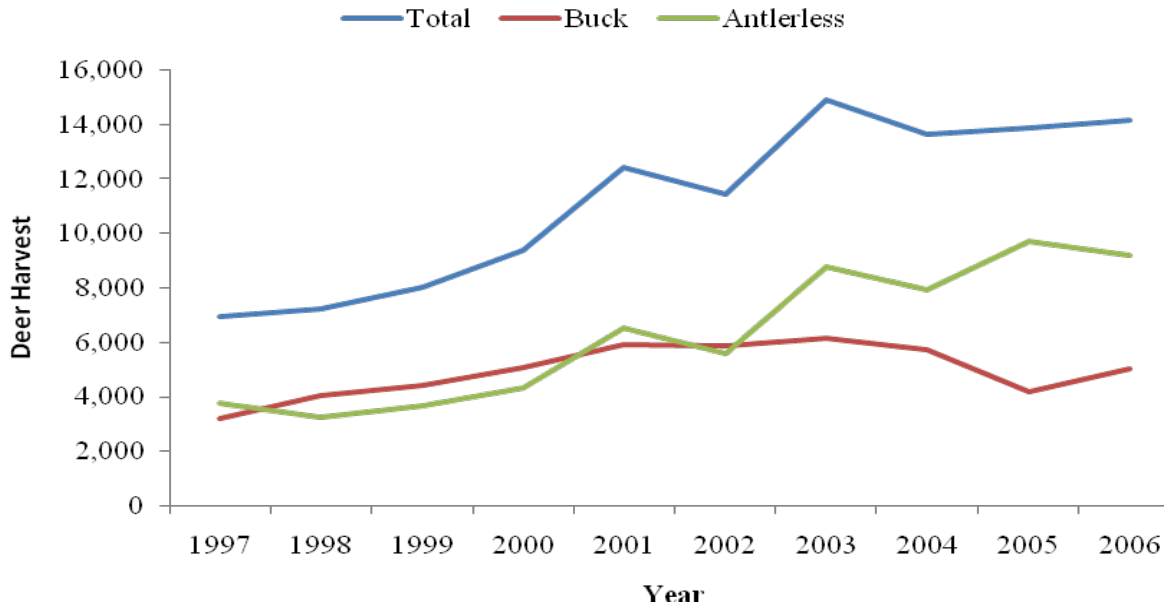
Figure 13. Estimated northeast Minnesota pre-fawn deer population density in 5 northeast deer permit areas, 1996 – 2010.



Northwest Minnesota

Deer harvest in northwest Minnesota has generally exhibited an upward trend with an increasing proportion of the total harvest being antlerless (Figure 14). Buck (n = 6,140) and total harvest (n = 14,930) peaked in 2003, while antlerless harvest (n = 9,723) peaked in 2005 (Figure 14). Much of northwestern Minnesota has been designated as either 'early antlerless' or 'intensive', which are the two most aggressive deer management strategies. Given the emergence of bovine tuberculosis and the aggressive deer management that has been occurring, deer populations in northwestern Minnesota are lower than the 10 deer/mi^2 identified as a threshold in this plan.

Figure 14. Registered deer harvest for deer permit areas in the northwest moose range, 1997 – 2006. Note: Deer permit area boundaries were changed in 2007 so the data are not comparable.



Deer Feeding

A portion of the public believes that deer should be provided with supplemental feed when winter is severe and mortality may occur. Beyond the discussion as to the merits of feeding deer in severe winters, there are individuals who feed deer simply to increase their probability of over-winter viewing. Recreational deer feeding is a controversial issue in many states and more negative than positive attributes have been described. For example, deer can be classically conditioned to visit feeders through a learning process, thus congregating them around a food source. This congregation around artificial feeding locations creates a host of problems including the increased risk of spreading disease (e.g., bovine tuberculosis, chronic wasting disease), destruction of native vegetation, and disruption of natural migratory patterns. Previous studies have shown that supplemental feeding may also increase overwinter deer survival or population productivity.

It is known that supplemental feeding can improve survival and productivity of wildlife including deer. Research in northeast Minnesota has shown some deer herds migrate many miles from summer to winter range. Often these winter ranges are near developed areas where supplemental food sources are available. These supplemental food sources serve to improve deer survival and productivity. The summer ranges are remote (such as the BWCAW) and hunting pressure light or nonexistent. Supplemental feeding can serve to offset the impacts of winter severity on deer populations and further increase deer numbers especially in less severe winters. Moose and deer range in northeast Minnesota is characterized by large blocks of dense forest often with limited or difficult access. Controlling deer numbers through hunter-harvest as a means to benefit moose will be increasingly difficult if, as predicted by many sources, severe winters occur less and less often. Intervals between severe winters may see higher deer numbers due to supplemental feeding with possible negative impacts on moose.

Moose - Deer Relationships

Overview

Infection with the brainworm (*Parelaphostrongylus tenuis*) is generally fatal to moose but seldom affects white-tailed deer. It is commonly assumed that increased deer density will result in higher infection rates of moose. This relationship, however, is not well understood and warrants investigation. Moose exhibiting clinical signs of infection have been reported in Minnesota as far back as 1912, but it was not until the early 1960s that brainworm was identified as the cause for these symptoms.

The Brainworm Cycle

The brainworm parasite normally occurs in white-tailed deer in eastern North America. The parasite is generally considered absent west of the 100th meridian (central Dakotas to central Texas). The adult worms reside in the cranium of the host deer and lay eggs into the blood stream. The eggs eventually lodge in the lungs where first stage larvae develop. The larvae are coughed up and then swallowed and eventually are passed back out on the surfaces of the deer's feces. Research has shown that larvae could survive for several months on feces and in the surrounding soil due to their resistance to drying and freezing. Eventually, the larvae penetrate one of several species of gastropods (snails and slugs) and develop through additional stages. The parasite is passed to deer (or moose) when the gastropod is consumed during foraging. The larvae penetrate the stomach wall, enter the nervous system and complete their development into adults. Although many infected deer shed no larvae because they are infected with only a single sex of brainworm, adult worms are long-lived and may pass eggs for many years. Deer appear to suffer few ill effects; however, symptoms of brainworm infection in moose may include circling, weakness in the hindquarters or inability to stand as well as turning of the neck and head to one side, lethargy, apparent blindness, loss of fear, and rapid eye movement.

Connections between deer and moose. It is well documented in Minnesota and other jurisdictions where deer and moose range overlap across eastern North America that moose are subject to brainworm-related mortality. What is less clear in the literature and subject to debate among scientists is the degree to which deer are responsible for historic declines in moose. Although a few authors present evidence indicating a correlation between increasing deer and decreasing moose numbers, other authors argue the evidence is inconclusive and there is no basis to conclude that changes in deer numbers can significantly impact moose numbers via transmission of brainworm.

There are few published papers that documented the proportion of mortality apparently caused by brainworm. In a Michigan study, researchers found brainworm to be the leading cause of mortality in moose accounting for 38% of all deaths. At the time deer were estimated at 13 deer/mi^2. In a retrospective evaluation of the effects of brainworm on moose populations, researchers in northwestern Ontario suggested that moose populations declined when deer density increased above 13 deer/mi^2.

Determining Maximum Threshold Deer Densities

The relationship between moose, deer and brainworm is more complex than is often believed and requires additional study. There is no consistent and conclusive evidence on the percentage of moose dying from brainworm in Minnesota. Therefore, the conclusions are unclear as to what extent, if any, reducing deer numbers will have on improving moose numbers. Although there may be less opportunity for moose to become infected if deer numbers are lower, it may not substantially improve moose survival in Minnesota. Results of several research projects indicate

moose in Minnesota likely face a host of health issues, and reducing deer numbers in the absence of a more comprehensive moose management strategy may not lead to significant and sustained recovery of moose numbers. Until we have more definitive research results, it may be prudent to maintain pre-fawn deer density within moose range below 10 deer/mi^2. Currently, only one deer permit area (180) exceeds a pre-fawn density of 10 deer/mi^2.

Habitat Management

Overview

Previous research in Minnesota over the last 4 decades has identified moose habitat throughout northern Minnesota. In general, moose habitat in Minnesota can be characterized as:

- Young forest stands,
- Older forest stands with gaps of regenerating forest,
- Wetlands, muskeg, and marsh,
- Riparian areas,
- Brushlands with abundant deciduous browse within reach of moose, and
- Adequate winter and summer thermal cover.

Functionally, habitat provides forage and cover. Moose forage includes a primarily deciduous browse component and a seasonal aquatic component. Cover has several potential components for moose: protection from heat, protection from deep snow, moderation of cold temperatures, predator avoidance and presence of calving locations. In addition to the functional aspects of habitat, spatial distribution of habitat must also be considered at a variety of scales (from home range to the landscape level).

As moose are increasingly challenged by warmer temperatures and changing precipitation patterns, changes in land ownership and forest management practices that occur within the moose range have the potential to significantly affect the quantity, quality, and distribution of moose habitat. Examples include but are not limited to: habitat fragmentation due to expected and occurring ownership changes and shifting landowner objectives, changes in the extent of forest management due to national and state economic effects on the primary wood- using industry in Minnesota, and increased harvesting of smaller diameter trees and brush used by moose for browse, as the demand for woody biomass increases.

There are important differences between the plant communities and moose habitat requirements of northwest and northeast Minnesota. Northwest moose habitat is a mixture of public and private lands that are dominated by brushlands interspersed with mesic hardwood forests, aspen parkland, peat lands, agriculture, and prairie. Northeast moose habitat can be described as near-boreal forest dominated by large blocks of public land.

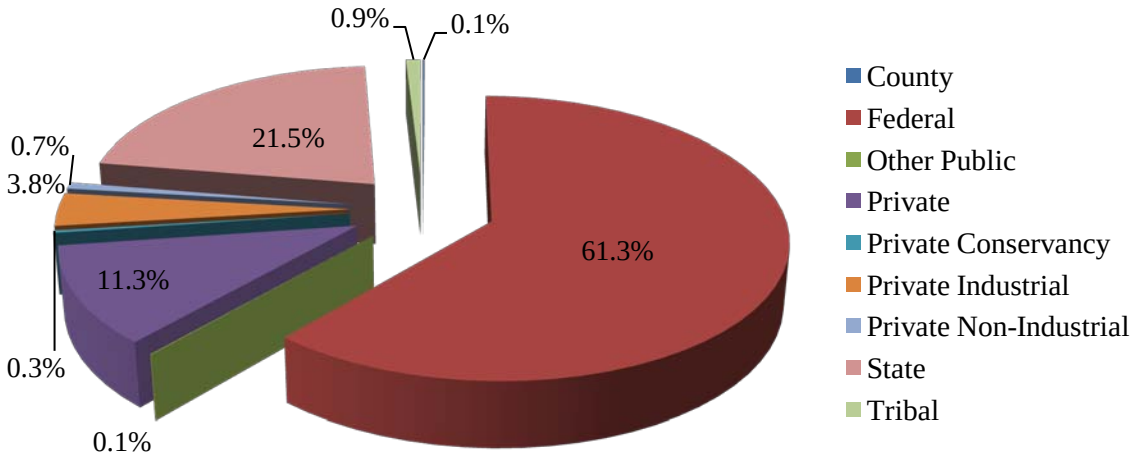
Habitat Quality and Impact on Moose Numbers

There is no recent historic evidence to suggest that habitat alone has limited moose numbers across their full range in Minnesota. However, habitat quality, including the spatial arrangement of cover types can limit moose numbers within smaller geographic areas. Focused management to provide high quality habitat (forage and cover) may be necessary to slow population declines and maintain or recover moose in appreciable numbers in Minnesota. However, very significant investments in direct moose habitat management by the DNR in northwest Minnesota, mainly browse regeneration in extensive brushlands, did not prevent the near extirpation of moose in this region.

Moose Habitat Guidance for Minnesota

In Minnesota most moose habitat management is achieved through commercial timber management activity. Mixed forestland ownership and management jurisdiction across the northeast moose range has resulted in multiple forest management guidance and planning documents that address moose habitat management via timber management (Figure 15).

Figure 15. Calculated land ownership within the northeast Minnesota moose range.



In 1985, the MNDNR produced the Forestry-Wildlife Guidelines to Habitat Management. This document contains chapters for moose in the northeast forest, and the transition zone. A moose habitat suitability index model (HSI) for the Lake Superior region was developed by the University of Minnesota in 1987. In 1988 the US Forest Service used this HSI to develop their General Technical Report *Integrating habitat needs of moose with timber management in northeastern Minnesota.* Also in 1988 the Ontario Ministry of Natural Resources published its *Timber Management for Moose Guidelines.* A common theme in these guidelines was the use of

timber management to achieve moose habitat needs. Much of the information contained in these documents has been incorporated into broader, forest management guidance and planning documents for both landscape and site level considerations. These newer documents generally embrace the practice of ecological silviculture to mimic ecological processes that have shaped our forests for thousands of years. This ecological approach strives to create forest structures and functions that promote diverse and healthy forests beneficial to moose and all native biodiversity.

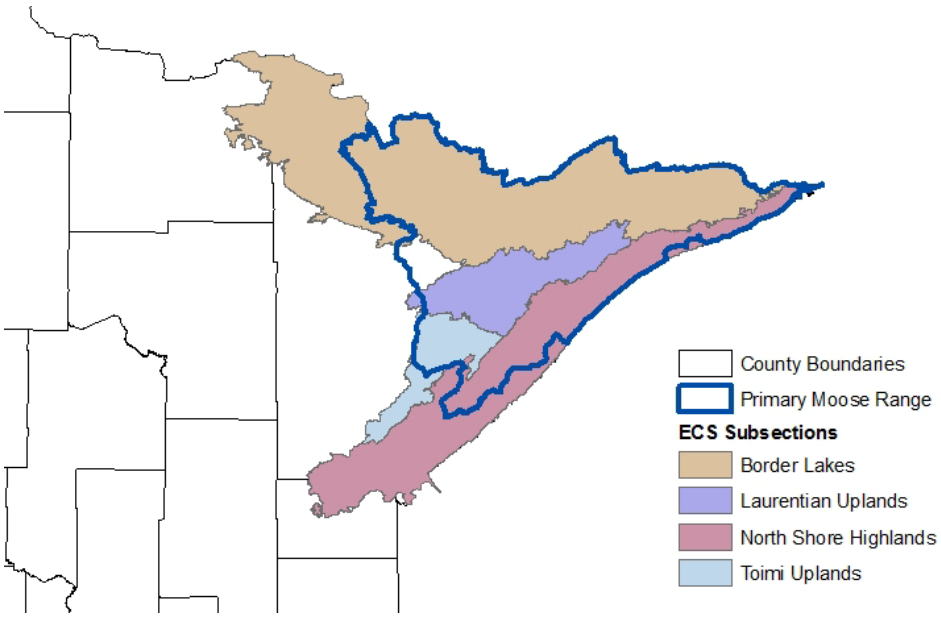
Long-term (50 years) for vegetation composition and age class distribution and short-term (10 years) vegetation management (e.g., harvest plans) on MNDNR-administered forestlands is planned through SFRMPs (Figure 16). SFRMPs are the primary tool for determining the mix of values and products (such as wildlife habitat, rare features, timber) that will be provided and sustained through management. SFRMPs are vegetation management plans for Forestry and Fish and Wildlife lands, they are not wildlife-specific plans. However, since forest management greatly influences the type of forest habitat on the landscape, wildlife populations are affected by these plans.

Similarly, the Minnesota Forest Resource Council (MFRC) NE Landscape Plan, the US Forest Service Superior National Forest Plan, and the Lake County Working Draft Forest Management Plan are key planning documents that address moose habitat needs (Table 3). Ontario's moose habitat guidelines are now incorporated into the broader *Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales* and the nearly completed *Forest Management Guide for Boreal Landscapes*.

The MFRC *Sustaining Minnesota Forest Resources- Voluntary Site-level Forest Management Guidelines* (Site-Level Guidelines) have landscape and site level implications. Wildlife habitat is specifically addressed in the guidelines.

The application of Site-Level Guidelines at the site of the individual timber stand treatment can further address moose habitat needs through considerations of timber sale design. Key guidelines and considerations with implications to moose habitat management include conifer retention and regeneration, patterns of cutting including size and type of timber harvest, protection of aquatic resources, legacy patches, and riparian guidelines. However, one cannot presume that implementing site-level guidelines will have a population level effect on Minnesota's moose. In fact, Ontario tested the hypothesis that its Moose Habitat Guidelines mitigated the negative population level affects of unmodified clearcuts, but their analysis actually found the rate of population growth was less in the moose management areas where the guidelines were implemented.

Figure 16. Key SFRMP plans containing Minnesota's primary moose range.



Northeast DNR wildlife managers plan and coordinate vegetation management to enhance moose habitat on state administered forestlands, and on lands managed under coordination agreements with federal and county agencies. These projects enhance browse (mowing, shearing or hand release) or cover (site preparation and/or conifer planting) on up to 200 acres per year. Sites are chosen to have proximity to all aspects of critical habitat needs (e.g., enhanced browse in proximity to thermal cover). While these projects provide enhanced habitat in targeted areas, they do not address a significant portion of the NE moose range. Rather, they contribute to long-term efforts to improve habitat in the moose range.

MAC Habitat Recommendations

The Moose Advisory Committee recommended the following moose habitat management considerations:

- Increase stand complexity, promote shrub production and diversity, and maintain thermal cover components by the use of variable thinning, use intermediate and partial harvests as a means to mimic varied disturbance patterns such as stand decline due to age, fire, wind-throw, and insect and disease outbreaks.
- Promote regeneration techniques that encourage mixed stands similar in composition, age and size to those existing under the range of natural variation and discourage the establishment of stands uniformly dominated by a single species.

- Utilize forest management/habitat management techniques that will promote browse production and diversity while maintaining juxtaposition of winter and summer thermal cover and aquatic feeding areas.
- In order to protect desirable browse species as much as possible while reducing competition with conifer seedlings, the use of mechanical treatment, spot chemical treatment or hand release should be encouraged.
- Promote a more regular use of wild and prescribed fire where appropriate to treat fuel loads and/or prepare forest stands for regeneration. Fire improves the quantity and quality of moose browse and may serve to remove or reduce populations of winter ticks (*Dermicentor albipictus*) and gastropods, which are direct parasites or parasite vectors for moose.
- Upland brush communities should be identified, protected and maintained by mechanical treatment and/or prescribed fire to provide moose browse.
- Protect and enhance summer thermal cover adjacent to and in close proximity to aquatic feeding areas.
- Increase rotation age of aspen stands to increase understory browse component while retaining summer thermal cover.

Table 3. Illustration of forest plans that have considerations similar to those recommended by the Moose Advisory Committee.

MAC Recommendation	North Shore SFRMP	Border Lakes SFRMP	MFRC Northeast Landscape	Superior National Forest	Agassiz Lowlands SFRMP	Aspen Parklands SFRMP	Lake County Working Draft Plan
NE							
Increase stand complexity	X	X	X	X			X
Mimic varied natural disturbance patterns	X	X	X	X			X
Encourage mixed stands	X	X	X	X			X
Use of mechanical treatment, spot	x	X		X			
chemical treatment or hand release should be encouraged.							
Promote a more regular use of wild and prescribed fire			X	X			
Upland brush communities should be protected and maintained		X					
Protect and enhance summer thermal cover	X	X	X				
Increase rotation age of aspen stands	X	X		X			X
Identify key moose management areas	X						
Encourage important browse species	X	X		X			
NW							
Use prescribed fire, timber harvest and mechanical treatment					X	X	
to create early successional habitats							
Manage for patches of mature aspen					X	X	

Social Dimensions

Increasingly, DNR has been attempting to integrate biological recommendations with social considerations for most harvestable species. While a substantial amount of work has been conducted on white-tailed deer, there has been little (if any) work regarding integrating biology and social science relative to moose management and decision-making.

Management decisions regarding the future of moose in Minnesota are inherently influenced by social factors related to perceptions about a moose population decline, the value of moose to local economies, and the symbolic nature of moose. In particular, future hunting seasons for moose must be reviewed in relation to biological, social, and legal criteria. Social concerns about hunting a declining moose population may at some point contradict a biologically-based rationale for continuing hunting. This is due to the high profile of moose in the state and their importance for non-hunting purposes. Given the complexity of the issue and the level of scientific uncertainty, acknowledging the role of social concerns in the decision-making process is critical to the success of moose management.

Observations and reports from Tribal representatives, hunters, non-consumptive users, Chambers of Commerce, resort owners, community members, and tourists indicate that moose are a critical component of the cultural identity and economy of northern Minnesota. Economically, the "value" of moose can be measured in terms of how much moose hunting contributes to local economies through trip-related expenditures and through the reinvestment of hunting license dollars for moose management. While no definitive study on the economic value of moose has been conducted, a 2006 DNR survey of 279 moose hunters yielded an estimate of 3,675 moose hunting days expended. From the perspective of license revenues, nearly $90,000 was generated in application and license fees in 2010, which was deposited into the Game and Fish Fund. Moose also contribute substantially to local economies through purchases of related souvenirs, travel to and within the region for the opportunity to view moose, and related lodging receipts. Many communities use moose as a trademark or advertising tool to promote or sell the area in which they live—the Minnesota Secretary of State website identifies more than 300 registered businesses with "moose" in their name.

The value of moose to Minnesota residents is difficult to quantify but is assumed to be substantial. Incorporating broad measures of the value of moose into state management plans, beyond economic impacts, is necessary to capture intrinsic value and ensure decisions made on behalf of moose incorporate an appreciation and sensitivity to them as a cultural symbol.

A broad constituency of hunters and non-hunters alike is necessary to provide balanced public input, assist with monitoring efforts, and to support management actions necessary to maintain viable moose populations. Moose management is disproportionately paid for by hunting license fees even though moose are important to state tourism and recreation and to the non-hunting public. Because the value received from investments in moose management benefits the public

as a whole, it is important that additional sources of financial support be obtained by building a broad constituency among hunters and non-hunters. A broad constituency may help diversify funding support as well as to incorporate the ideas of various interests, including fielding requests from the legislature.

Communication

Because moose are a high-profile species, a communications plan directed at informing the public of pertinent management decisions would have long-term benefits. The communications plan would provide accurate and up-to-date information about on-going research, as well as transparent information about the solicitation and use of public input in making management decisions. The purpose of a communications plan would be to convey the intent and scope of management actions taken and provide consistent and accurate information to the public. The plan would prioritize the types of media outlets and information for different publics (e.g., brochures, press releases, websites, mailings, public meetings).

Public meetings and targeted press releases are an important component of a communications plan. In addition, web links devoted to new releases of information are useful to a transparent decision-making process. Web links could provide key information about complex issues that might inform the public on certain aspects of moose management (e.g., hunting, species listing, and population dynamics).

In addition to a communication plan, a series of educational outreach materials that could be used in the classroom, presentations to community groups and for general public consumption would aid in information dissemination. Moose biologists from different agencies could be encouraged to present these talking points and educational materials to community groups. There is also an opportunity to use the public to assist with statewide monitoring including voluntary reporting of moose observations. Such an endeavor is currently being undertaken by the University of Minnesota Duluth through a website (http://www.nrri.umn.edu/moose) and the LCCMR project.

Conclusions

The moose in Minnesota is a species that is held in high regard by countless individuals. Their existence transcends the economic value derived from hunting and non-consumptive viewing opportunities. As an icon of the boreal forest, they have both intrinsic and existence values as well. Concern over moose populations becomes more prominent as the population declines and no causes can be identified.

Unfortunately, this plan cannot be viewed as a cookbook or prescription for reversing a declining moose population in Minnesota. With the loss of the northwest population and the continued decline in the northeast, much work must be done to determine if trends can be reversed. Simply advocating for wolf harvest or completing a handful of habitat projects will not recover the moose population. The issue is decidedly more complex and the research that is needed to answer these questions will take time and will be very expensive. The majority of work is funded by hunting license dollars and other funding sources such as the Environmental Trust Fund should be utilized for management-oriented research. Subsequent habitat development projects could ultimately be funded by Outdoor Heritage Funds. As moose populations benefit all Minnesotans, it is critical that a broad funding source be developed because without sound scientific information, we may lose moose and never know why.

Priorities and Timelines

Many of the sections in this plan are open-ended; however, timelines can be constructed for some problem statements. The evaluation of metrics identified in this plan will be ongoing and DNR staff will reevaluate sections as needed with the goal of revisiting the entire plan in 5 years.

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