Chapter 4: Moose

Introduction

Moose were abundant and widely distributed when Vermont was first settled by Europeans in the 1700s. At that time, Vermont was 95% forested and neither Native Americans nor the early European settlers likely had much impact on the population. As Vermont's European settler population grew, unregulated, year-round hunting undoubtedly took its toll. However, it was the loss of moose habitat from excessive clearing of forests that ultimately lead to extirpation. This clearing began around 1800 and had peaked by 1880 after which only 37% of the state remained forested. By the late nineteenth century, moose had become so rare that when a young bull was shot in March 1899 in Wenlock (now Ferdinand), newspaper reports called it "a strange animal" and "the last moose in Vermont."

During the twentieth century, forests gradually returned and, as they did, moose began to reappear; immigrants from New Hampshire and Maine. By the 1960s, 25 moose were thought to exist in Essex County. By 1980, forests covered 80% of the land area of the state, and moose numbers had increased to a point where they were regularly seen in Essex County. The absence of hunting or significant predation allowed rapid moose population growth. Moose started showing up in neighboring counties and eventually re-occupied appropriate habitat statewide.

Vermont's first modern moose season was a three-day hunt held in 1993 in WMU E. Continued, rapid growth eventually resulted in 78% of the state being open to either-sex moose hunting. By the early 2000s, the moose density in Essex county was estimated at more than 4 moose per square mile, which had exceeded biological carrying capacity and was causing significant damage to forest regeneration. This was detrimental to the moose population and also negatively affected other wildlife species that depend on low growing trees and shrubs for food and cover such as ground nesting birds like woodcock, grouse and various songbirds. Landowners too, especially large industrial forestland owners whose livelihood and investment depend on healthy forests, started expressing concern. Moose-vehicle collisions were increasing and, perhaps most telling, the 2007 Vermont Species Management Survey found a third of all Northeast Kingdom residents wanted the moose population to decrease.

2010-2020 Plan Accomplishments

ISSUE 1. Regional Population Goals

1.1 Maintenance of at least 25% of adult moose in age class 4 or greater was achieved every year (generally around 45%), as was the adult sex ratio goal of at least 40 bulls per 100 adults.

ISSUE 2. Moose Human Conflicts

2.1 Developed and implemented a policy for staff response to moose/human conflicts, including appointment of response teams, training on wildlife immobilization and relocations techniques, and acquisition of some equipment. Three moose that presented a risk to human safety were successfully chemically immobilized and relocated.

2.2 Continued to issue annual press releases to remind motorists during seasons of increased moose movements and continued to work with Vermont Agency of Transportation (VTRANS) to advise on road crossings where new signs were warranted or where old signs should be maintained.

2.3 Worked with VTRANS to develop a new standard for new bridges that allows for a more even walking surface under bridges. This change will positively impact moose and deer by allowing for easier under-the-road passage for all bridges built from here on out.

ISSUE 3. Moose Hunting Opportunities

3.1 Quality hunting opportunities continued in all WMUs, where feasible, and a separate early archery season with its own lottery system was instituted in 2011. The "bonus point" system of awarding an extra lottery chance to previous year non-winners, instituted in 2006, was continued until the low number of overall permits available in 2018 resulted in the suspension of the open lottery altogether.

3.2 Hunter access on large landholdings was widespread.

3.3 The department continued to provide information in each moose hunter's guidebook on how to donate moose meat to the *Hunter's Sharing the Harvest* program and/or local food shelves.

3.4 Significant outreach was conducted prior to the expected reduction in moose hunting permits as the planned density reduction was achieved in 2011. The hunting and general public seemed informed and annual proposals to issue reduced permits were well-received.

In response, the department initiated an effort to reduce the population in Essex and parts of Caledonia Counties (WMUs E and D2) and stabilize the population or allow for slow growth in the rest of the state. To accomplish this, the number of moose hunting permits doubled in 2004, increased to over 1,000 the following year, and it remained above 1,000 over the next four years. A separate antlerless-only season was also added.

Density reductions in WMU E to 1.75 moose per square mile and in WMU D2 to 1.0 moose per square mile were achieved by 2011. Permit numbers were subsequently reduced but population estimates indicated moose numbers were continuing to decline. Similarly, the management strategies intended to allow slow growth in WMUs I, L, P, and Q, and stabilize them in other WMUs were not having the intended effect. A widespread decline was occurring which was being driven by something other than permit levels.

Winter tick infestations in the Northeast Kingdom and a higher incidence of brainworm are increasing the mortality rate, particularly in calves, and reducing reproduction. Both are linked, in part, to climate change, and both continue to significantly impact the moose population. As a result, by 2016, the statewide population estimate had dropped below 3,000 moose. By November 2018, the population was estimated at just under 2,000 moose.

2010-2020 Plan Accomplishments *(continued)*

ISSUE 4. Moose Viewing

4.1 One moose observation tower was constructed in 2010 on department-owned land in Ferdinand, overlooking a road-side salt lick on Vermont Route 105.

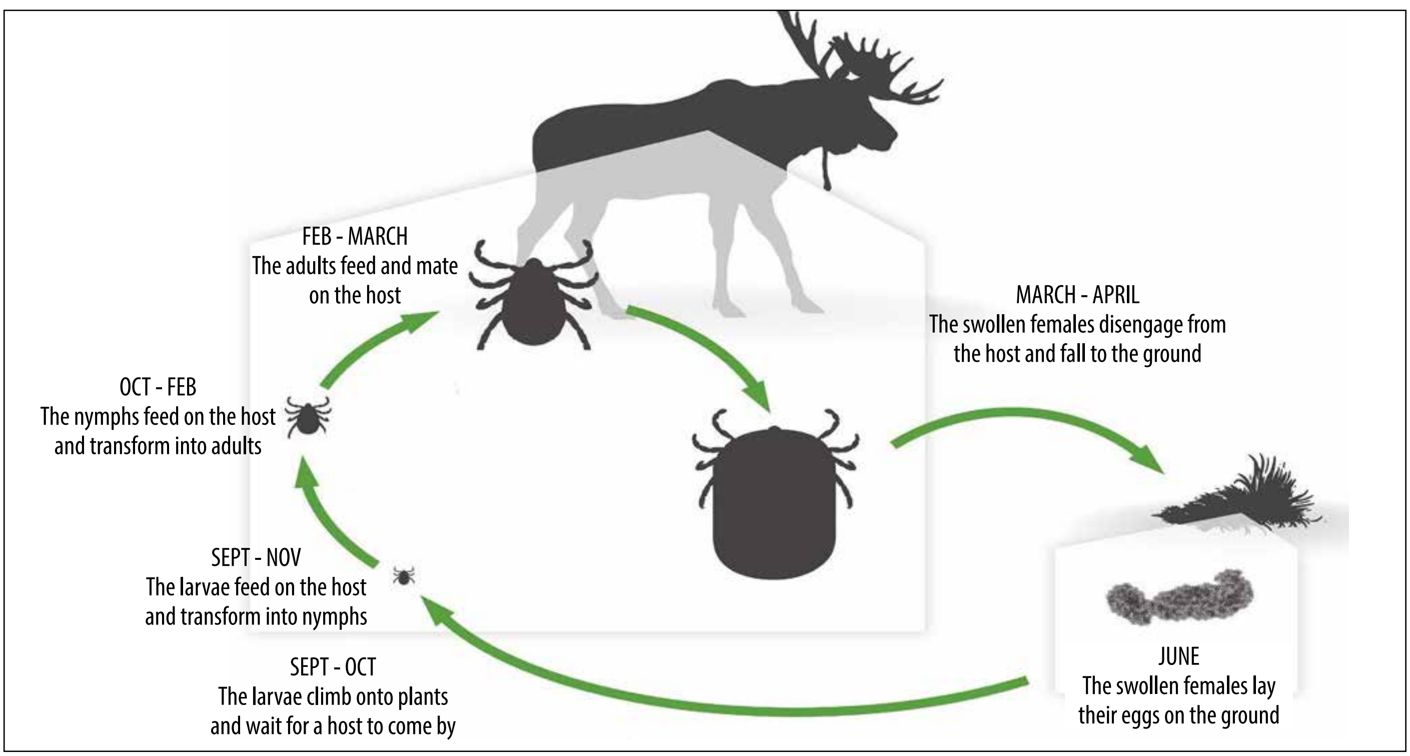
4.2 The department's website notes other locations around the state where people are more likely to spot a moose.

ISSUE 5. Moose Habitat

5.1 The department assisted the University of New Hampshire with a graduate thesis investigating the impact of moose browsing on forest regeneration in WMU E1 (Andreozzi et al. 2014). Field work consisted of browse measurements in 37 regenerating clearcuts in three age classes.

5.1 The department is currently cooperating with the University of Vermont to explore the use of recent (2017) lidar data, collared moose GPS locations, and winter tick indices to modify the Koitzsch Habitat Suitability Index (HIS) model (Koitzsch 2000) for application to WMUs E1 and E2. The resulting new model may be applicable to additional WMUs outside of the study area.

5.3 Moose habitat management guidelines for landowners and professional land managers were updated in 2014 and made available on the department's website.



ISSUE 1. Regional Population Goals

GOAL: Maintain a healthy moose population in Vermont's moose management regions.

Vermont's moose population has declined significantly since 2007, the last year a survey was conducted to assess public desire for regional population levels (fewer, stable, or more). This question was not asked in the 2019 Big Game Survey, as it was clear from recent public input that most Vermonter's want to increase the moose population above the current level. Instead, the public was asked questions to gauge their awareness of the issues facing moose. This included winter ticks, brainworm, the overall moose population decrease and climate change. In general, a majority of residents knew at least a little about these issues. Almost half knew a moderate amount to a great deal about the impact of winter ticks, while only a quarter said they knew a moderate amount to a great deal about brainworm with 41% knowing nothing at all. Compared to brainworm, winter ticks are a recent phenomenon but have been subject to intense department outreach as well as local and regional media coverage in the years prior to the survey. In addition, a strong majority (65%) of survey respondents also supported maintaining a smaller moose population through hunting if that reduced the number of moose that would die each year from winter ticks and reduce the number of winter ticks.

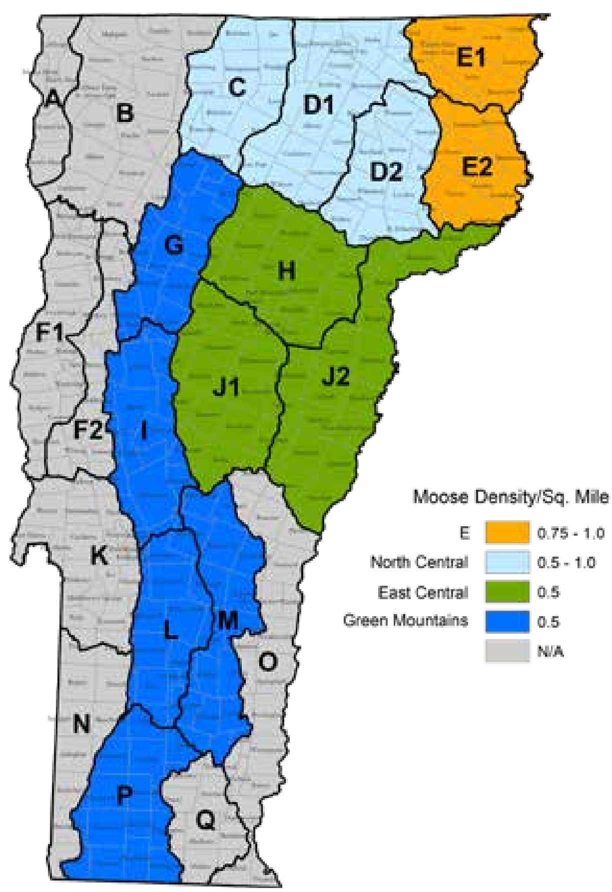
In 2018, 65% of residents strongly or moderately supported maintaining a smaller moose population through hunting, if it reduces the number of moose that die each year from winter ticks and reduces the number of winter ticks overall. Only 15% opposed. The remainder either didn't know (8%) or neither supported nor opposed (12%).

Sample size: 600 residents

Source: Vermont Residents' and Hunters' Attitudes Toward Big Game Hunting and Management, 2019

The department informally adjusted the target moose density for Region E (WMUs E1 and E2) from 1.75 to 1.0 moose per square mile to reflect the current reality of increasing frequency of winter tick epizootics. Previous research in New Hampshire and Maine, and more recent studies in Vermont, indicate that moose densities likely need to be no higher than 1.0 moose per square mile, and possibly less than 0.75 moose per square mile, to avoid further population declines caused by high winter tick infestations. If the climate in northeastern Vermont continues to warm, winter ticks may persist at high levels even if their host (moose) remains at lower densities. This plan formalizes the new target for Region E and WMU D2 at 0.75 to 1.0 moose per square mile while recognizing that these targets may need to be lowered if tick levels remain high over the next few years. Target densities throughout the rest of occupied moose range in Vermont remain at 0.5 moose per square mile.

Moose Target Density Objective by Region



Management Objectives and Strategies

1.1 Maintain target densities in North Central, East Central and Green Mountain moose management regions.

1.2 Provide quality hunting opportunity in all WMUs when appropriate.

1.3 Improve current and explore new population monitoring methods. They may include expanding annual deer hunter effort surveys, developing a camera trap network and monitoring snow urine (urea nitrogen/creatinine ratio) to gauge the impact of winter ticks on moose health.

ISSUE 2. Hunting Permit Thresholds

GOAL: Establish moose density thresholds in Wildlife Management Units that would dictate hunting closures or re-openings.

Density thresholds should be established where moose hunting in management regions and/or individual WMUs would be shut down or re-opened. Hunt thresholds have already been created by the New Hampshire Fish & Game Department and have been well-received by their citizens. Due to the average confidence interval of population estimates, it is recommended that no hunting permits should be issued for any Region or WMU in which the moose population estimate falls below 75% of the target density for 2 consecutive years. Conversely, if the population estimate grows to within 25% of the target for 2 consecutive years, hunting permits could again be proposed.

Management Objectives and Strategies

2.1 Hunting Permit Thresholds

- No permits if less than 75% of target density for 2 consecutive years.
- Resume permits if within 25% of target density for 2 consecutive years.

ISSUE 3. Disease

GOAL: Better understand and address the impacts of parasites and disease on the long-term viability of moose in Vermont

Recent moose studies in New England and the Midwest have documented a number of diseases and parasites, including lungworm, tapeworm and liver flukes (Jones et al. 2019, Murray 2006). The most serious diseases in New England appear to be two parasites, winter tick and brainworm. White-tailed deer are the normal hosts for these parasites, and land-use changes after European settlement allowed deer to spread north, bringing them into contact with moose. Moose, however, are abnormal hosts, and, unlike deer, are not well adapted to dealing with these parasites and are severely affected when infected with them. As climate change continues to increase average seasonal temperatures and reduce winter severity, deer abundance will likely be higher, even in northeastern Vermont. This will increase moose exposure to brainworm.

Winter Tick

The winter tick (*Dermacentor albipictus*) attaches to moose in the autumn as a tiny larva but soon molts into a nymph and then again into an adult. The adult female grows to the size of a small grape as they feed on moose blood during the winter before dropping off in the spring to lay their eggs in soil. With 30,000 or more winter ticks on one moose, they can cause extreme stress, reduced food intake, and cause anemia due to blood loss. In an often-futile attempt to dislodge the irritating ticks, moose will scratch with their rear hooves and rub against trees, breaking off their long winter guard hairs in the process. For calves especially, even if total blood loss isn't high enough to directly cause death, loss of their winter coat may cause death by exposure (Samuel and Barker 1979). Tick density can be quite variable from year to year, with prolonged severe outbreaks causing widespread mortality observed when moose densities are relatively high. Longer snow-free periods (shorter winters) also lead to higher tick numbers. The autumn questing period for larvae can be extended many weeks if the first snowfall is late, and fecund female ticks dropping off moose onto bare ground in April have higher survival rates (Samuel 2007).

Collared moose studies in New Hampshire and Maine have indicated epizootic levels of winter ticks several times over the past 15 years, resulting in winter calf mortality as high as 74% in New Hampshire (2015). Tick counts conducted on harvested bull moose in Vermont, initiated in 2013, had often been 1/2 to 1/3 of identical counts in New Hampshire and Maine. The proportion of yearlings in Vermont's harvest (19 to 25 percent of adults) also suggested satisfactory winter survival of calves over the past decade. However, the percentage of yearlings in the 2016 harvest dropped to an all-time low of 7%. This suggested that calf mortality in the winter of 2015-16 may have been well above what had been experienced in the preceding decade, or that there was poor calf production in 2015. Although sample sizes have been small in recent years due to fewer hunting permits, average body weight and productivity of Vermont cows has continued to decline, a trend also being observed in New Hampshire and parts of Maine and attributed primarily to winter tick epizootics.

Vermont initiated its own mortality/recruitment study in January 2017, when 30 calves and 30 cows were radio-collared in Moose Management Region E. The study continued for three consecutive years, with an additional 30 calves collared in both 2018 and 2019. Data from this study, combined with past and concurrent research in neighboring states, will provide further insight into the host (moose) density at which parasite (winter tick) density can be reduced and maintained below epizootic levels. Final results were compiled and evaluated in 2020. However, the average overwinter survival rate was 90% for cows but just 48% for calves. Typical overwinter calf survival in the absence of severe winter tick infestation is around 85% (Keech et al. 2000, Testa 2004, Ballard et al. 1991, Gasaway et al. 1992). The moose density in Region E has been estimated at roughly 1 moose/mi2 throughout the study, suggesting it may be necessary to lower moose densities further to reduce winter ticks to levels that do not cause epizootic mortality.

Brainworm

A small nematode (*Parelaphostrongylus tenuis*), commonly referred to as brainworm, can also be fatal to moose. Brainworm is a two (2)-host parasite, living their larval stages in land snails and adult stages in herbivorous mammals. It is commonly carried by white-tailed deer, but with limited negative effects. When deer and moose ranges overlap, however, brainworm can infect moose. It travels along the spinal cord to the brain, causing inflammation and tissue damage along the way. The moose will usually show symptoms such as loss of balance, circling, lack of fear, blindness, and paralysis. The parasite, which often causes the eventual death of moose, has been linked to population declines in several studies, especially in areas where deer density exceeds 10/mi2 (Whitlaw and Lankester 1994).

The first moose death attributed to brainworm in Vermont occurred in 1984, and over the next quarter-century 233, or 5%, of all known incidental mortalities were from suspected brainworm. Although it didn't have a significant impact on population growth for the two decades following the first case, Vermont's deer population is now larger due to some of the mildest winters on record and occur in higher densities in habitat previously more suitable for moose. The increasing overlap between moose and deer is thought to be causing more cases of brainworm. Over the past 8 years, the portion of incidental mortalities attributed to brainworm has averaged 16%, or 3 times the previous average.

Most suspected brainworm cases in moose occur in central and southern Vermont. Moose densities are much lower in these areas and deer densities are markedly higher. However, it is worth noting that the proportional growth of the state's deer population is lower than the observed increase in suspected brainworm cases. This suggests the warmer and wetter weather caused by climate change may also be increasing density of land snails, the intermediate host. It is also possible that a portion of the suspected brainworm cases are actually from some other disease-causing encephalitis. Host-parasite disease dynamics are complex and related to larger factors such as climate and habitat change as well as wildlife distribution and movement. As a result, changes in the occurrence of brainworm cases are difficult to tie to single factors. Therefore, the department is focused on monitoring the presence of brainworm, particularly where there are influencing factors that the department can manage such as high deer densities or habitat in which deer concentrate.

The department attempts to confirm the presence of brainworm when it is suspected, especially when a moose requires euthanasia. A less complicated blood "ELISA" is under development and research is underway which should make confirmations of brainworm in moose simpler, less expensive and less labor intensive.

One option for addressing impacts to moose from winter ticks is to address the tick population directly. There are many possible options for controlling ticks directly, either by treating the landscape or by treating the moose (as one would treat a pet or livestock). There are many logistical challenges as well as ethical and environmental considerations to treating wild animals across a large, natural landscape, but this option should not be ignored. The department will continue to support research into the development and application of biopesticides that could help control winter tick density.

Continued monitoring of the impact of winter tick-related mortality on moose will be important. In the absence of radio-collared animals, it will be necessary to find alternative means of detecting and assessing the impacts of winter ticks. One potential option is using urine collected from snow to determine the physical condition of moose in winter, which is related to the severity of tick infestation.

Management Objectives and Strategies

- 3.1 Implement a density goal of 1 moose per square mile, or lower, for any WMU where winter ticks persist at epizootic levels or are driving population decline by lowering calf survival to an unsustainable level.
- 3.2 Support research into biopesticides for application to free ranging moose.
- 3.3 Explore the use of snow urine to monitor nutritional status.

3.4 Monitor tick load and hair loss on all incidentally or legally killed moose, when available, and consider other options, such as assessing hair loss via salt-lick camera traps, when appropriate.

3.5 Evaluate methods to supplement and improve population model estimates. These could entail using camera traps, comparing trends in deer hunter moose sighting rates, assessing calf-cow ratios, using genetic information to estimate population trends, and considering various trend estimation time frames (i.e. yearly, every three years, etc.).

3.6 Submit blood serum from euthanized sick-acting moose for ELISA testing, and consider the same from all incidental moose mortalities and harvested moose for brainworm screening.

3.7 Evaluate the need and feasibility of field necropsies of all incidental moose mortalities.

3.8 Maintain WMU E1 and E2 deer density at 10 per square mile or fewer.

ISSUE 4. Moose–Human Conflicts

GOAL: Minimize motor vehicle/moose collisions and other forms of damage caused by moose.

Even at low population densities, moose can cause big problems. In Vermont, the most common include motor vehicle collisions, over-browsing of commercially valuable trees and damage to Christmas tree plantations, livestock fencing and maple sap tubing. They can also pose a threat to human safety when they linger in farmyards, backyards, urban settings, or near highways, sometimes due to brainworm infection.

The frequency of moose/human conflicts has declined with the moose population. The number of motor vehicle collisions, for example, has dropped over 50% from the peak in 2004 - 2007 when the state was averaging 200 accidents annually. Regardless of how uncommon they are now, each moose collision has the potential to be catastrophic for those involved. Compared to hitting a deer, there is a much greater chance of a severe injury, and 19 human fatalities have occurred in moose-vehicle collisions in Vermont since 1985. Consequently, the department must continue to work with the Vermont Agency of Transportation to identify moose crossings and alert the public of peak times for collisions.

During years of greater abundance, killing a moose doing damage or euthanizing one as a safety risk was generally accepted by the public. With the current herd, there is more interest internally, and likely externally, to revisit the Board rule regarding moose doing damage that allows landowners to kill moose that continue to substantially damage sap tubing, livestock fencing and Christmas tree plantations. In addition, the department's approach to moose lingering in developed areas has also changed. A revised moose/human conflict protocol now calls for tranquilizing and relocating moose that are healthy (i.e., not infected with brainworm or some other serious malady) but posing a risk to human safety. This includes training, staffing and equipment necessary to relocate moose under certain circumstances.

Management Objectives and Strategies

4.1 Continue to improve the protocol for responding to moose/human conflicts.

4.2 Consider revising the moose doing damage rule in the light of the declining moose population (i.e. sap tubing damage only during sugaring season).

4.3 Continue to work with VTRANS to erect and maintain warning signs at traditional moose highway crossings.

4.4 Continue to work with VTRANS in implementing roadside brush-clearing projects to improve visibility at the most dangerous moose crossings, when feasible.

4.5 Cooperate with VTRANS to investigate the use of new technology that may help reduce moose/vehicle collisions.

4.6 Cooperate with VTRANS on the installation of wildlife crossing culverts or travel lanes during interstate and Vermont highway bridge replacements when feasible.

4.7 Issue annual press releases to remind motorists of moose hazards during seasons of increased moose movement.

ISSUE 5. Moose Habitat and Carrying Capacity

GOAL: Maintain necessary habitat to support regional moose density objectives.

Moose are a forest-dwelling species and research suggests their biological carrying capacity, as determined by food resources, is maximized when 40-50% of their range is comprised of young, regenerating forests (0 to 20 years old). Throughout most of Vermont, where public desire calls for maintaining moose density below the biological carrying capacity, adequate browse can be provided, for deer and moose combined, with 10-15% of young forest. Currently, winter ticks and brainworm, and perhaps other parasites and diseases along with a warming climate, are likely the limiting factors for moose across much of the state. Still, the percent of young forests in Vermont has declined over recent decades, and improvement in habitat suitability could help moose better sustain moderate levels of winter tick infestation, while also improving growth and productivity of moose in areas of the state (central and southern Vermont) where ticks do not currently occur at harmful levels.

However, regional studies, including Vermont's collared moose study, could indicate that winter tick epizootics can only be avoided, or at least minimized, by managing for moose densities well below what the habitat can support. As a result, a revised definition of the biological carrying capacity, regardless of habitat quality, would have to include the impact of parasite loads so that moose can simply exist on the landscape. These new, sustainable densities may be so low that moose hunting opportunity might be very limited, but at least some moose viewing opportunity, which surveys have shown is very important to many Vermont residents, could continue, and moose would still play some role, however minor, in the ecological systems of Vermont's forests and wetlands.

Analysis of data from Vermont's moose study is ongoing and the department will continue to learn from this as well as other ongoing studies in the region. If research indicates that lowering moose density further is the best option, any adjustments to moose population objectives will be discussed at length among department staff and with the public before being implemented.

Management Objectives and Strategies

5.1 Enhance moose habitat on State and Federal lands, especially in regions where young forest comprises less than 10% of forestland.

5.2 Support and monitor research into moose and parasite dynamics.

References

Andreozzi, H.A., P.J. Pekins, and M.L. Langlais. 2014. Impact of moose browsing on forest regeneration in northeast Vermont. Alces Vol. 50: 67-79.

Ballard, W.B., Whitman, J.S. & Reed, D.J. 1991: Population dynamics of moose in south-central Alaska. Wildlife Monographs 114: 1-49.

Casalena, M. J., M. V. Schiavone, A. C. Bowling, I. D. Gregg, and J. Brown. 2016. Understanding the new normal: wild turkeys in a changing northeastern landscape. Proceedings of the National Wild Turkey Symposium 11:45-57.

Côté, S. D., T. P. Rooney, J.-P. Tremblay, C. Dussault, and D. M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology Evolution and Systematics 35:113–147.

DeCalesta, D. S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. Journal of Wildlife Management 58:711–718.

Dunfey-Ball, K.R. 2017. Moose density, habitat, and winter tick epizootics in a changing climate. M.S. Thesis, University of New Hampshire, Durham, USA.

Eriksen, R.E., T. W. Hughes, T. A. Brown, M. D. Akridge, K. B. Scott, and C. S. Penner. 2015. Status and distribution of wild turkeys in the United States: 2014 status. Proceedings of the National Wild Turkey Symposium 11:7-18.

Gasaway, W.C., Boertje, R.D., Grandgard, D.V., Kellyhouse, K.G., Stephenson, R.O. & Larsen, D.G. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs 120: 1-59.

Gregonis, M. A., B. C. Tefft, B. J. Hiller and R. E. Eriksen. 2011. Assessment of wild turkey-human conflicts throughout the United States and Canada. Tenth National Wild Turkey Symposium 10:31-39.

Healy, W. M., and S. M. Powell. 1999. Wild turkey harvest management: biology, strategies, and techniques. United States Fish and Wildlife Service, Biological Technical Publication BTP-R5001- 1999.

Jones, H., P. Pekins, L. Kantar, I. Sidor, D. Ellingwood, A. Lichtenwalner, and M. O'Neal. 2019. Mortality assessment of moose (Alces alces) calves during successive years of winter tick (*Dermacentor albipictus*) epizootics in New Hampshire and Maine (USA). Canadian Journal of Zoology 97:22-30."

Keech, M.A., Bowyer, R.T., Ver Hoef, J.M., Boertje, R.D., Stephenson, T.R. & Dale, B.W. 2000: Life-history consequences of maternal condition in Alaskan moose. Journal of Wildlife Management 64(2): 450-462.

Klopfer, M., 2017. Identifying potential causes of the trends in wild turkey populations in the Northeast. Unpublished report prepared by Pond and Property, LLC for the Northeast Upland Game Bird Technical Committee of the Northeast Wildlife Administrators Association, 70 p.

Koitzsch, K.B. 2000. Application of a moose habitat suitability index model to wildlife management units in Vermont. M.S. Thesis, University of Vermont, Burlington, Vermont. 84 pp.

Marquis, D. A., R. L. Ernst, and S. L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies. United States Forest Service, Northeast Forest Experiment Station, Radnor, Pennsylvania, USA. General Technical Report NE-96. 108 pp.

McGhee, J. D., J. M. Berkson, D. E. Steffen, and G. W. Norman. 2008. Density-dependent harvest modeling for the eastern wild turkey. Journal of Wildlife Management 72:196–203.

McGraw, J. B., and M. A. Furedi. 2005. Deer browsing and population viability of a forest understory plant. Science 307: 920–922.

McShea, W. J., and J. H. Rappole. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. Conservation Biology 14:1161–1170.

Miller, J. E., B. C. Tefft, R. E, Eriksen, and M. A. Gregonis. 2000. Turkey damage survey: a wildlife success story becoming another wildlife damage problem. Proceedings of the Wildlife Damage Management Conference 9:24-32.

Murray, D.L., 2006. Pathogens, nutritional deficiency, and climate influences on a declining moose population. Wildlife Monographs 166: 1–30.

Robinson, K. F., A. K. Fuller, M. V. Schiavone, B. L. Swift, D. R. Diefenbach, W. F. Siemer, and D. J. Decker. 2017. Addressing wild turkey population declines using structured decision making. Journal of Wildlife Management 81(3):393-404.

Romano, M. A., S. P. Romano, and C. W. Kilpatrick. 2007. Report on genetic analyses of Vermont wild turkey populations. Unpublished report prepared for the Vermont Chapter of the National Wild Turkey Federation by the Department of Biological Sciences, Western Illinois University, Macomb, IL and the Department of Biology, University of Vermont, Burlington, VT 22 p.

Samuel, W. M. 2007. Factors affecting epizootics of winter ticks and mortality of moose. Alces 43:39-48.

Tefft, B. C., M. A. Gregonis, and R. E. Eriksen. 2005. Assessment of crop damage by wild turkey in the United States and Ontario, Canada. Wildlife Society Bulletin 33 (2):590-595.

Testa, J.W. 2004: Population dynamics and life history trade-offs of moose (*Alces alces*) in south-central Alaska. Ecology 85: 1439-1452

Thomas, J. M., A. B. Allison, E. C. Holmes, J. E. Phillips, E. M. Bunting, M. J. Yabsley, and J. D. Brown. 2015. Molecular surveillance for lymphoproliferative disease virus in wild turkeys (*Meleagris gallopavo*) from the eastern United States. PloS one, 10(4), p.e0122644.

Timmins, A. A., 2003. Seasonal home range, nesting ecology, and survival of eastern wild turkeys in northern New Hampshire. M.S. Thesis, University of New Hampshire, Durham, 87 p.

USDA Forest Service, Forest Inventory and Analysis Program. 2019. Forest Inventory EVALIDator web-application Version 1.8.0.00. U.S. Department of Agriculture, Forest Service, Northern Research Station, St. Paul, MN [Available only on internet: http://apps.fs.usda.gov/Evalidator/evalidator.jsp]

Vermont Department of Health https://www.healthvermont.gov/disease-control/tickborne-diseases/lyme-disease

Whitlaw, H.A., and M.W. Lankester. 1994. The cooccurrence of moose, white-tailed deer, and *Parelaphostrongylus tenuis* in Ontario. Canadian Journal of Zoology, 72(5), 819-825.