EFFECTS OF FOREST SUCCESSION AFTER FIRE IN MOOSE WINTERING HABITATS ON THE KENAI PENINSULA, ALASKA

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ABSTRACT: Estimates of moose (Alces alces) density during winter in early seral forests created by human-caused wildfires and in older successional forests on the northern Kenai Peninsula were obtained using data from standardized aerial surveys conducted from 1964-1990. Wintering moose densities in the study area were highest within areas burned by wildfires in 1947 and 1969, reaching peaks of 3.6-4.3 moose/km². Density estimates for the 1947 burn were available 17-43 years post-fire. The relationship between moose density and forest age in the 1947 burn from 1964-1990 was highly significant (P < 0.01, R² = 0.68), and density declined at a rate of approximately 9 percent per year during this period. Highest densities, ranging from 2.0-3.6 moose/km², were recorded 17-26 years post-fire (1964-1973). Winter moose density in the 1947 burn and the area’s total moose population then declined abruptly. Favorable habitat created by the 1969 wildfire resulted in a major increase in total population by 1982, although wintering densities in the 1947 burn remained low. Moose density estimates in the 1969 burn following this increase were high and remained relatively constant 13-21 years post-fire (1982-1990), ranging from 3.6-4.4 moose/km². In older successional forests, wintering moose density was low throughout the study period, ranging from 0.1-0.8 moose/km². Forest succession in the 1969 burn will ultimately result in habitat capable of supporting wintering moose densities similar to those currently found in mid-successional and older forests. We predict the area’s moose population will decline in the absence of early seral forests.

The importance of early seral vegetation to moose (Alces alces) is well documented throughout its circumpolar range (Peterson 1955, Bishop and Rausch 1974, LeResche et al. 1974, Krefting 1975, Cederlund and Markgren 1987, Lavsund 1987). In Alaska, increased quantity and improved nutritional quality of browse used by moose are associated with early seral forests (Oldemeyer and Regelin 1987, Regelin et al. 1987, MacCraken and Viereck 1990). Reproductive performance of moose is apparently enhanced under favorable habitat conditions. Moose twinning rates were higher in a recent burn (13-14 years post-fire) than in an older burn (30-31 years post-burn) on the Kenai Peninsula in southcentral Alaska (Franzmann and Schwartz 1985).

Forest succession following human-caused wildfires in 1947 and 1969 has been a major factor influencing moose population dynamics on the northern Kenai Peninsula during the past 50 years (Spencer and Hakala 1964, Bishop and Rausch 1974, Bangs and Bailey 1980, Bangs et al. 1985, Schwartz and Franzmann 1989). Moose population irruptions followed both fires, which occurred primarily on lands within the Kenai National Wildlife Refuge (KNWR). Recognition of the importance of early seral forests to moose resulted in the implementation of a planned habitat management program on the KNWR. From 1956 to present, 6,640 ha (most within the 1947 burn’s perimeter) have been enhanced to benefit moose, primarily using mechanical tree crushing and prescribed burning (KNWR, unpubl. data).

In this paper, the relationship between recent dynamics of northern Kenai Peninsula moose populations and forest succession following fire in two major wintering habitats are discussed. We examine the timing, extent and rate of decline in winter moose densities in the 1947 burn from 1964-1990, 17-43 years
post-burn. We report recent winter moose densities in the 1969 burn, the lone remaining large contiguous block of early seral forest on the northern Kenai Peninsula. Finally, we examine trends since 1964 in winter moose densities in late successional forests and compare these with densities in early and mid-successional forests. This analysis provides a framework for predicting the near-future effects of forest succession in wintering habitats on the area's moose population. Implications to the KNWR habitat management program and other moose management activities by responsible agencies on the Kenai Peninsula are presented.

STUDY AREA

The Kenai Peninsula is located between Prince William Sound and Cook Inlet in southcentral Alaska (Lat. 60° N, Long. 150° W). The Kenai Lowlands are the predominant landform on the north-western part of the Peninsula. The Lowlands consist of ground moraine and stagnant ice terrain with low ridges, hills and muskeg. Relief ranges from 15-76 m and the area contains thousands of lakes and ponds. The study area consists of the lowland portion of the 3403 km² Alaska Game Management Subunit (GMS) 15A. Most of the study area lies within the boundaries of the KNWR (Figure 1).

A complete description of the region's vegetation is presented in Oldemeyer and Regelin (1987). Lowland habitats are predominantly forested with a mixture of white spruce (Picea glauca), black spruce (P. mariana), quaking aspen (Populus tremuloides) and paper birch (Betula papyrifera) (Oldemeyer and Regelin 1987). White spruce, often mixed with paper birch or aspen, is the climax species on well-drained soil and black spruce dominates on many poorly-drained sites. Approximately half of the forested areas on the Kenai Lowlands are in various successional stages due to wildfire. Regrowth stands of vegetation in burned areas vary in age from 21 to 75 years. Vegetation in these stands varies considerably with white and black spruce, paper birch, aspen and several species of willow (Salix spp.) comprising the major woody vegetation. Two large human-caused wildfires occurred on the Kenai Lowlands in GMS 15A during the past 50 years. The first burned 1250 km² in 1947, and the more recent burned 352 km² in 1969.

METHODS

Aerial surveys to obtain moose population estimates with known confidence intervals were initiated in 1964 on the KNWR, and were conducted in 13 years during the period 1964-1990. Alaska Game Management Subunit (GMS) boundaries were used to define survey areas for these fall (November-December) and winter (February-March) surveys. Survey effort was concentrated in GMS 15A and GMS 15B on the northern and central Kenai Peninsula, respectively. Various U.S. Fish and Wildlife Service and Alaska Department of Fish and Game (ADFG) personnel conducted the surveys.

The quadrat sampling method described in Evans et al. (1966) was used for surveys conducted from 1964 to 1982; methods in Gasaway et al. (1986) were employed for surveys conducted in 1987 and 1990. Both techniques employed stratified random sampling. Sample units for the former technique consisted of 2.6 km² sections denoted on 1:63,360 U.S. Geological Survey topographical maps. Sample units were placed into one of three strata according to moose density: High, Medium and Low density. Stratification was based on intuitive knowledge of moose distribution and overflights of the survey area. Surveys in 1987 and 1990 used larger sample units (22.8-38.1 km²), integrated the variance associated with sightings of moose into the population estimate, and maximized efficiency. Sample units were stratified according to observed
Fig. 1. Location of 1947 and 1969 burns in relation to Alaska Game Management Subunit 15A and the Kenai National Wildlife Refuge, Kenai Peninsula, Alaska.

Moose densities during overflights of the survey area immediately prior to the onset of the survey. The estimate of sightability was obtained by conducting an intensive search (>4.6 min/km²) of a randomly selected 2.6 km² portion of most surveyed sample units in the Medium density stratum and all surveyed sample units in the High density stratum. The sightability survey was flown immediately upon completing the standard search (1.5-2.7 min/km²) of a sample unit.

Although estimates of moose densities generated using the Evans et al. (1966) technique did not include a correction for sightability, search effort was intense (averaging 4.2-7.7 min/km²) and sightability was
probably high. In this paper, we assume that
the moose population estimates for GMS 15A
and density estimates for the three habitats
within GMS 15A generated by the two tech-
niques are comparable.

Estimates of wintering moose densities in
the 1947 and 1969 burns and in older success-

Fig. 2. Relationship between moose density
and forest age in the 1947 burn from 1964-1990
(17-43 years post-fire) was highly significant
($P < 0.01, R^2 = 0.68$). The linear fit indicated
that moose density declined at a rate of ap-
proximately 9 percent per year during this
period (Figure 2). Actual declines in winter-

The relationship between moose density
and forest age in the 1947 burn was tested
using simple linear regression (Snedecor and
Cochran 1967).

RESULTS

The relationship between moose density
and forest age in the 1947 burn from 1964-1990
(17-43 years post-fire) was highly significant
($P < 0.01, R^2 = 0.68$). The linear fit indicated
that moose density declined at a rate of ap-
proximately 9 percent per year during this
period (Figure 2). Actual declines in winter-

ing moose density in the 1947 burn occurred
after it reached 26 years of age (post-1973),
and the rate of decline since that time has been
even greater than when averaged over the
entire study period.

Moose population estimates for GMS 15A
during the study period were highest from
1964-1971, ranging from 3,849-5,298 moose
(Figure 3). These high moose populations
occurred in response to excellent habitat in the
1947 burn. Concurrently, winter moose
densities in the 1947 burn reached their
maximum levels, ranging from 1.9-3.6 moose/
km$^2$ from 1964-1973, 17-26 years post-burn
(Table 2). Up to 77 percent of the GMS 15A
moose population wintered in the 1947 burn
during this period. Peak winter moose density
in the burn was 3.6 moose/km$^2$, recorded in

Survey data were available for estimating
GMS 15A moose populations from
1964-1990, and for estimating wintering
moose densities in the 1947 burn from
1964-1990 (17-43 years post-fire), for the
years post-fire), and for mature forest from
1964-1990. Surveys conducted from
1971-1979 did not include adequate sampling
of the 1969 burn to allow estimating moose
density; most sample units in the burn were
placed in the Low density stratum during
these years.

Survey sample unit boundaries seldom
corresponded exactly to burn perimeters, and
total areas used to calculate moose densities
in the two burns and in mature forest (Table 1)
differed slightly from measureable areas of
these habitats. In addition, total areas used for
GMS 15A, the 1947 and 1969 burns and
mature forest habitats differed for pre- and
post-1982 moose density estimates because
sample unit boundaries changed in 1987 when
the Gasaway et al. (1986) survey technique
was adopted.
Table 1. Total and surveyed areas (mi²) and total and surveyed number of sample units (SU’s) used to calculate moose population estimates in Alaska GMS 15A and moose density estimates in the 1947 and 1969 burns and mature forest habitats (surveys from 1964-1982 used 1mi² SU’s, and total area = total SU’s, area surveyed = SU’s surveyed)*.

<table>
<thead>
<tr>
<th>Year/Variable</th>
<th>GMS 15A</th>
<th>47 burn</th>
<th>69 burn</th>
<th>Mature forest</th>
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<tr>
<td></td>
<td>High</td>
<td>Med</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>1964 Total area</td>
<td>197 987 109</td>
<td>194 245 8</td>
<td>- - -</td>
<td>3 742 101</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>28 38 4</td>
<td>28 10 0</td>
<td>- - -</td>
<td>0 28 4</td>
</tr>
<tr>
<td>1965 Total area</td>
<td>155 1024 116</td>
<td>155 284 8</td>
<td>- - -</td>
<td>2 740 108</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>22 51 4</td>
<td>22 9 0</td>
<td>- - -</td>
<td>0 42 4</td>
</tr>
<tr>
<td>1966 Total area</td>
<td>170 854 277</td>
<td>167 269 11</td>
<td>- - -</td>
<td>3 585 266</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>24 43 5</td>
<td>24 11 0</td>
<td>- - -</td>
<td>0 32 5</td>
</tr>
<tr>
<td>1967 Total area</td>
<td>163 861 276</td>
<td>159 277 11</td>
<td>- - -</td>
<td>4 584 265</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>23 42 6</td>
<td>23 7 0</td>
<td>- - -</td>
<td>0 35 6</td>
</tr>
<tr>
<td>1971 Total area</td>
<td>136 737 418</td>
<td>136 288 13</td>
<td>- - -</td>
<td>0 449 405</td>
</tr>
<tr>
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<td>21 39 4</td>
<td>21 14 0</td>
<td>- - -</td>
<td>0 25 4</td>
</tr>
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<td>1973 Total area</td>
<td>146 732 416</td>
<td>140 288 19</td>
<td>- - -</td>
<td>6 444 397</td>
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<tr>
<td>Area surveyed</td>
<td>28 42 3</td>
<td>28 19 0</td>
<td>- - -</td>
<td>0 23 3</td>
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<tr>
<td>1974 Total area</td>
<td>104 579 602</td>
<td>96 303 38</td>
<td>- - -</td>
<td>8 276 574</td>
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<tr>
<td>Area surveyed</td>
<td>24 42 5</td>
<td>24 21 0</td>
<td>- - -</td>
<td>0 21 5</td>
</tr>
<tr>
<td>1975 Total area</td>
<td>42 547 687</td>
<td>36 321 36</td>
<td>- - -</td>
<td>6 226 623</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>11 42 12</td>
<td>8 30 1</td>
<td>- - -</td>
<td>3 12 11</td>
</tr>
<tr>
<td>1976 Total area</td>
<td>32 537 705</td>
<td>27 320 90</td>
<td>- - -</td>
<td>5 217 615</td>
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<tr>
<td>Area surveyed</td>
<td>8 52 11</td>
<td>7 37 1</td>
<td>- - -</td>
<td>1 15 10</td>
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<tr>
<td>1979 Total area</td>
<td>65 411 793</td>
<td>55 242 140</td>
<td>10 16 113</td>
<td>0 153 540</td>
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<tr>
<td>Area surveyed</td>
<td>11 59 10</td>
<td>11 31 2</td>
<td>0 2 4</td>
<td>0 28 4</td>
</tr>
<tr>
<td>1982 Total area</td>
<td>75 453 740</td>
<td>32 300 105</td>
<td>45 62 32</td>
<td>0 91 603</td>
</tr>
<tr>
<td>Area surveyed</td>
<td>8 66 8</td>
<td>4 44 8</td>
<td>4 13 8</td>
<td>0 9 8</td>
</tr>
<tr>
<td>1987 Total area</td>
<td>193 454 632</td>
<td>0 151 300</td>
<td>160 0 0</td>
<td>0 94 322</td>
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<tr>
<td>Area surveyed</td>
<td>169 92 91</td>
<td>0 52 56</td>
<td>148 0 0</td>
<td>0 23 25</td>
</tr>
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<td>1990 Total SU’s</td>
<td>7 34 53</td>
<td>0 12 25</td>
<td>14 0 0</td>
<td>0 7 28</td>
</tr>
<tr>
<td>SU’s surveyed</td>
<td>15 7 8</td>
<td>0 4 5</td>
<td>13 0 0</td>
<td>0 2 5</td>
</tr>
</tbody>
</table>

*Surveys from 1964-1982 used techniques described in Evans et al. (1966).
1987 and 1990 surveys used techniques described in Gasaway et al. (1986).
Sightability correction factor (SCF) used (Gasaway et al. 1986).
1987 SCF for GMS 15A = 1.32.
1971.

A major decline in the GMS 15A moose population occurred between 1971 and 1975, when the population estimate fell by nearly 60 percent to 2175 moose (Figure 3). Severe winters and declining range conditions in the 1947 burn were believed primarily responsible for this decline (Bishop and Rausch 1974, Oldemeyer et al. 1977, Bailey 1978, Bangs and Bailey 1980). Winter moose density in the 1947 burn declined to 1.3 moose/km² by 1975.

Another moose population irruption in GMS 15A began approximately 10 years after the 1969 wildfire, again in response to the creation of favorable habitat (Bangs and Bailey 1980, Schwartz and Franzmann 1989). Estimates of moose density in the 1947 burn remained relatively stable during this increase, ranging from 1.3 to 1.7 moose/km² (Table 2), suggesting the burn could no longer support the high winter densities it had in the past. Moose density in the 1947 burn declined further to 0.3 moose/km² in 1987 and 0.5 moose/km² in 1990, indicative of the reduced carrying capacity during winter of mid-successional forests on the Kenai Lowlands.

The highest post-1969 wildfire population estimate for GMS 15A was the 1982 estimate of 4,352 moose (Figure 3), indicating the population had doubled since the mid-1970’s. Winter moose densities in the 1969 burn remained high from 1982-1990, 13-21 years post-fire, when estimates ranged from 3.5-4.4 moose/km² (Table 2). Although comprising only 10 percent of the total land area in GMS 15A, the excellent habitat in the 1969 burn supported 36-62 percent of the wintering moose population from 1982-1990.

Moose density during winter in older successional forest was low. Moose densities in

<table>
<thead>
<tr>
<th>Year</th>
<th>1947 Burn</th>
<th>Mature Forest</th>
<th>1969 Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Density</td>
<td>80% CI</td>
<td>% 15A Pop.</td>
</tr>
<tr>
<td>1964</td>
<td>2.6</td>
<td>1.9-3.3</td>
<td>67.7</td>
</tr>
<tr>
<td>1965</td>
<td>2.6</td>
<td>1.6-3.5</td>
<td>67.6</td>
</tr>
<tr>
<td>1966</td>
<td>2.0</td>
<td>1.7-2.3</td>
<td>59.2</td>
</tr>
<tr>
<td>1967</td>
<td>2.7</td>
<td>2.0-3.2</td>
<td>72.9</td>
</tr>
<tr>
<td>1971</td>
<td>3.6</td>
<td>3.1-4.2</td>
<td>77.4</td>
</tr>
<tr>
<td>1973</td>
<td>2.5</td>
<td>1.9-3.0</td>
<td>63.5</td>
</tr>
<tr>
<td>1974</td>
<td>1.9</td>
<td>1.6-2.1</td>
<td>65.4</td>
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<tr>
<td>1975</td>
<td>1.3</td>
<td>0.9-1.1</td>
<td>58.9</td>
</tr>
<tr>
<td>1976</td>
<td>1.6</td>
<td>1.3-1.8</td>
<td>62.4</td>
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<tr>
<td>1979</td>
<td>1.7</td>
<td>1.2-2.2</td>
<td>73.8</td>
</tr>
<tr>
<td>1982</td>
<td>1.3</td>
<td>1.0-1.6</td>
<td>34.1</td>
</tr>
<tr>
<td>1987</td>
<td>0.3</td>
<td>0.1-0.4</td>
<td>12.8</td>
</tr>
<tr>
<td>1990</td>
<td>0.5</td>
<td>0.4-0.7</td>
<td>19.1</td>
</tr>
</tbody>
</table>

Table 2. Estimates of wintering moose density (moose/km²) and percentages of total moose population in two recent burns and mature forest in Alaska Game Management Subunit 15A, Kenai Peninsula, Alaska, 1964-1990.
mature forest appeared related to overall moose population dynamics in GMS 15A. Estimates were highest while moose populations were peaking from 1964-1971 and in 1982, and were lower from 1974-1979 following the moose population decline in GMS 15A (Table 2). In 1987 and 1990, moose density in mature forest was the lowest recorded since 1964 at 0.1 and 0.2 moose/km², respectively.

Recent estimates of the GMS 15A moose population suggest a declining trend since 1982. The 1990 estimate was 3,400 moose. Lowered moose density estimates in the 1947 burn and mature forest account for most of the difference between the 1982 and 1990 population estimates.

DISCUSSION

Moose density during winter in the 1947 burn in GMS 15A was correlated with forest age. The decline in winter moose densities in the burn became pronounced 26+ years post-burn. Declining habitat quality in the 1947 burn concurrent with four consecutive severe winters resulted in an abrupt moose population decline from 1971-1975. The impacts of the 1947 burn’s reduced carrying capacity for moose on the overall moose population in GMS 15A were obscured in the late 1970’s when favorable early seral forest habitat created by the 1969 wildfire became available. The GMS 15A moose population rebounded even though winter densities in the 1947 burn remained low. A recent declining trend in the GMS 15A moose population has apparently been manifested in a further decline in winter moose densities in mid-successional (1947 burn) and mature forest habitats.

The decline in winter moose densities in the 1947 burn, attributed to forest succession, has significant management implications for the GMS 15A moose population. The 21 year-old 1969 burn is currently the major moose wintering habitat in GMS 15A and its last large contiguous block of early seral forest. Schwartz and Franzmann (1989) suggested that reduced reproductive performance by moose in the 1969 burn in the late 1980’s was due to already declining habitat quality in the burn. We predict wintering moose densities in the 1969 burn will naturally decline over the next 25+ years. The timing, rate and extent of the decline in moose densities documented for the 1947 burn provide general guidelines for predicting this upcoming decline. Unless new early seral forests are created by wildfires or a planned habitat management program, the loss of wintering habitat with forest succession in the 1969 burn will result in an overall moose population decline in GMS 15A. The decline in population could be abrupt, as was the case between 1971 and 1975, should several severe winters occur.

Some loss of seral forests and lower moose densities in GMS 15A in the future appears likely for several reasons. The length of the natural fire cycle on the Kenai Peninsula is unknown, but natural wildfires occur infrequently on the Peninsula compared to other areas in Alaska because lightning strikes for ignition are rare and fuel moisture conditions are seldom dry enough to carry a wildfire. Improved fire suppression capabilities have decreased the likelihood of large escaped wildfires, either natural or human-caused, on the Kenai Peninsula. In addition, recent habitat management activities on the KNWR, primarily using prescribed burning, have been restricted by several factors. Conditions for ignition of the relatively heavy fuels present occur infrequently and often for short periods of time, and in some years, not at all. The fire prescription window is further narrowed by concerns for fire containment and smoke management. Favorable burning conditions on the Kenai Peninsula often coincide with wildfire occurrence in other parts of Alaska, resulting in the unavailability of the required suppression personnel to carry out a prescribed burn. Finally, successful implementation of a prescribed burning program on the KNWR is
unlikely to match total areas of early seral forests created by recent wildfires because of land status classifications and land ownership which restrict active management in some areas and the practical constraints of limited personnel and funding.

Should solutions addressing the current constraints on the habitat management program for moose on the KNWR be found, the success of this program may depend on the timing of its implementation. Moose use of manipulated areas and moose population responses to improved habitat could be limited where moose densities are low because of traditional movement patterns and lack of random searching for better habitat by most moose (Gasaway et al. 1989). Potential for success of habitat management is greater while moose densities remain relatively high in GMS 15A due to the still-favorable habitat conditions in the 1969 burn.

A tradition of intensive hunting for moose developed around the periodic high density moose populations on the Kenai Lowlands which occurred following the 1947 and 1969 wildfires. Recently, hunter numbers in GMS 15A averaged 1,460 annually from 1980-1990 (ADFG, unpubl. data). Annual harvest of bull moose averaged 268 from 1980-86, and declined to 133 bulls annually under more restrictive regulations from 1987-1990 (ADFG, unpubl. data). Future declines in the GMS 15A moose population may require further restrictions as current harvest levels might not be sustainable. Opportunities for viewing and photography of moose are major attractions for many visitors to the Kenai Peninsula. Dissatisfaction among user groups will undoubtedly grow should moose densities on the northern Kenai Peninsula decline substantially.

Several systems in North America in which moose populations appeared regulated at low densities for long periods by lightly exploited populations of copredators (wolves and bears) have been described (Ballard and Larsen 1987, VanBallenberghe 1987, Gasaway et al. (in press)). Predator populations on the Kenai Peninsula, including wolves (Canis lupus), black bears (Ursus americanus) and brown bears (U. arctos), are under varying degrees of exploitation and are heavily influenced by other human activities [Peterson et al. (1984), Jacobs (1989), Schwartz and Franzmann (1989) and (1991)]. Whether these predator populations could regulate the moose population in GMS 15A at low densities when the 1969 burn is no longer productive moose habitat is unknown. Should this occur, habitat management alone may not be sufficient to increase moose densities (Schwartz and Franzmann 1989), predator and scavenger populations which depend on moose as a major food source will ultimately decline, and increased controversy over predator and moose management will develop.

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