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 ($P < 0.01$, $R^2 = 0.68$), 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.

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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 sightability of moose into the population estimate, and maximized efficiency. Sample units were stratified according to observed

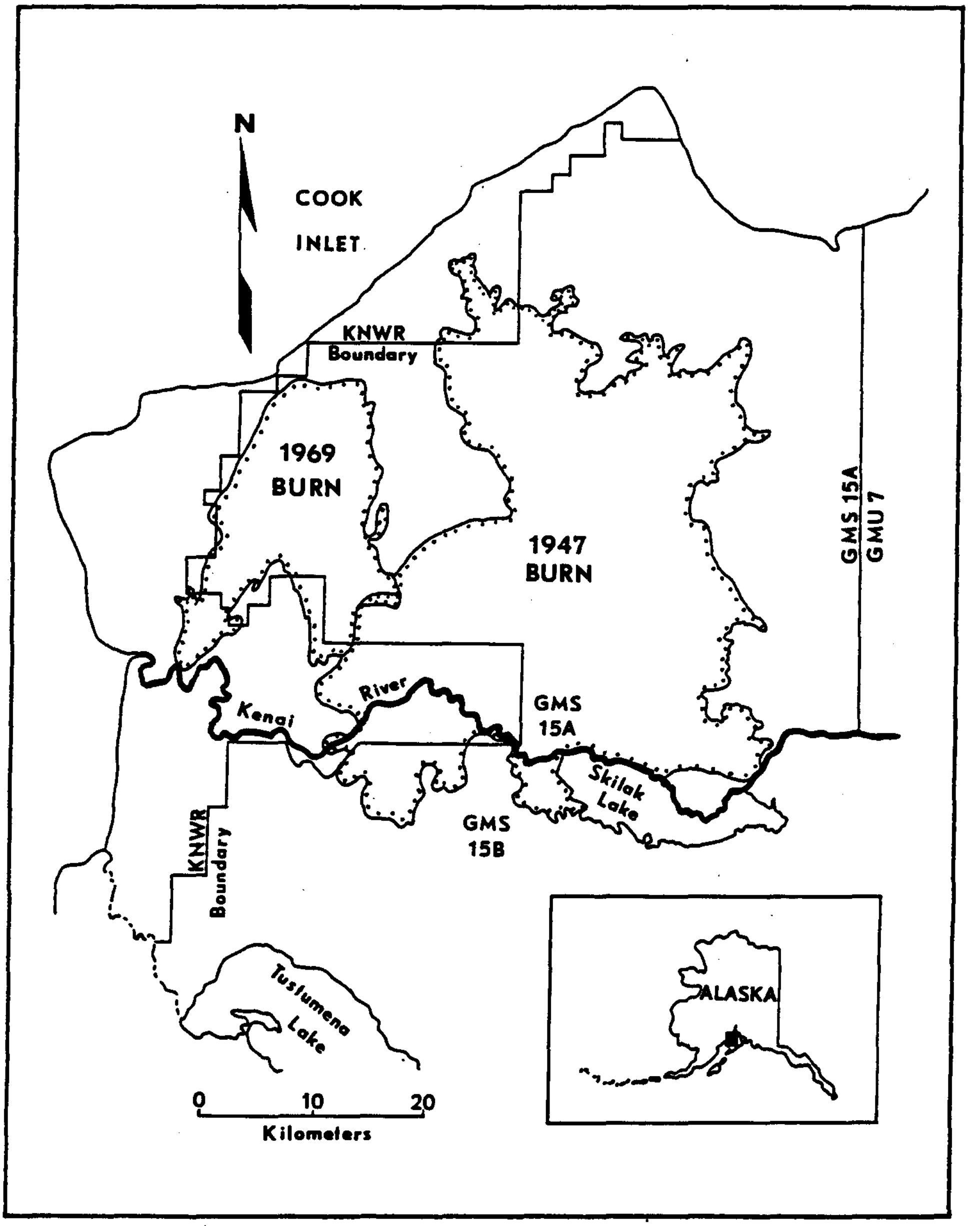

Fig. 1. Location of 1947 and 1969 burns in relation to Alaska Game Management Subunit 15A and the Kenai National Wildlife Refuge, Kenai Peninsula, Alaska.

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 techniques are comparable.

Estimates of wintering moose densities in the 1947 and 1969 burns and in older successional forest were obtained by interpolating data from aerial surveys of GMS 15A. The perimeters of the areas burned by wildfires in 1947 and 1969 provided the basis for classification of the mature forest and two seral forest habitats (1947 and 1969 burns) for which wintering moose densities were estimated. Moose survey sample units falling outside of the perimeter of the 1947 burn from 1964-1967, and outside of the perimeters of the 1947 and 1969 burns from 1971-1990 were classified as mature forest. Stand age in these older successional forests ranged from 60 years (in old burns) to 90+ years.

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 1969 burn in 1982, 1987 and 1990 (13-21 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.

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 approximately 9 percent per year during this period (Figure 2). Actual declines in wintering 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.

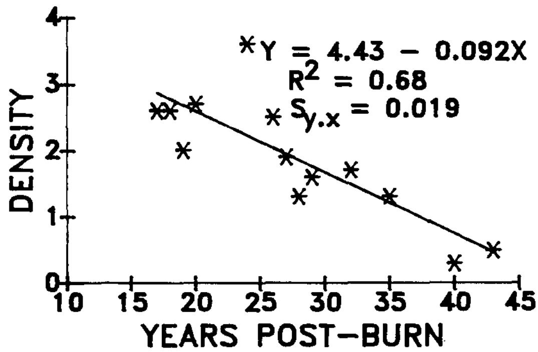

Fig. 2. Relationship between moose density (moose/km²) during winter and forest age in the 1947 burn, 1964-1990.

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 exellent habitat in the 1947 burn. Concurrently, winter moose densities in the 1947 burn reached their maximum levels, ranging from 1.9-3.6 moose/km² 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/km², recorded in

Table 1. Total and surveyed areas (mi^2) 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)[a].

	Survey area and stratum											
	GMS 15A			47 burn			69 burn			Mature forest		
Year/Variable	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
1964												
Total area	197	987	109	194	245	8	-	-	-	3	742	101
Area surveyed	28	38	4	28	10	0	-	-	-	0	28	4
1965												
Total area	155	1024	116	155	284	8	-	-	-	2	740	108
Area surveyed	22	51	4	22	9	0	-	-	-	0	42	4
1966												
Total area	170	854	277	167	269	11	-	-	-	3	585	266
Area surveyed	24	43	5	24	11	0	-	-	-	0	32	5
1967												
Total area	163	861	276	159	277	11	-	-	-	4	584	265
Area surveyed	23	42	6	23	7	0	-	-	-	0	35	6
1971												
Total area	136	737	418	136	288	13	-	-	-	0	449	405
Area surveyed	21	39	4	21	14	0	-	-	-	0	25	4
1973												
Total area	146	732	416	140	288	19	-	-	-	6	444	397
Area surveyed	28	42	3	28	19	0	-	-	-	0	23	3
1974												
Total area	104	579	602	96	303	38	-	-	-	8	276	574
Area surveyed	24	42	5	24	21	0	-	-	-	0	21	5
1975												
Total area	42	547	687	36	321	36	-	-	-	6	226	623
Area surveyed	11	42	12	8	30	1	-	-	-	3	12	11
1976												
Total area	32	537	705	27	320	90	-	-	-	5	217	615
Area surveyed	8	52	11	7	37	1	-	-	-	1	15	10
1979												
Total area	65	411	793	55	242	140	10	16	113	0	153	540
Area surveyed	11	59	10	11	31	2	0	2	4	0	28	4
1982												
Total area	75	453	740	32	300	105	45	62	32	0	91	603
Area surveyed	8	66	8	4	44	8	4	13	8	0	9	8
1987[b]												
Total area	193	454	632	0	151	300	160	0	0	0	94	322
Area surveyed	169	92	91	0	52	56	148	0	0	0	23	25
Total SU's	17	34	53	0	12	25	14	0	0	0	7	28
SU's surveyed	15	7	8	0	4	5	13	0	0	0	2	5
1990[b]												
Total area	216	345	718	32	119	342	148	0	0	0	56	361
Area surveyed	216	143	53	32	27	18	148	0	0	0	21	35
Total SU's	18	29	57	3	8	27	12	0	0	0	5	29
SU's surveyed	18	12	5	3	2	2	12	0	0	0	2	3

[a]Surveys from 1964-1982 used techniques described in Evans *et al.* (1966).
1987 and 1990 surveys used techniques described in Gasaway *et al.* (1986).

[b]Sightability correction factor (SCF_0) used (Gasway *et al.* 1986).
1987 SCF_0 for GMS 15A = 1.32
1990 SCF_0 for GMS 15A = 1.21

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

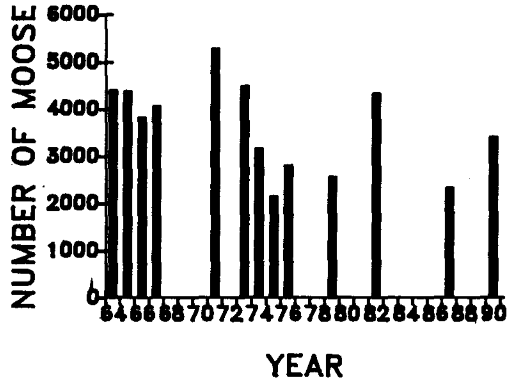

Fig. 3. Moose population estimates in Alaska Game Management Subunit 15A, 1964-1990.

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.

	1947 Burn			Mature Forest			1969 Burn		
Year	Density	80% CI	% 15A Pop.	Density	80% CI	% 15A Pop.	Density	80% CI	% 15A Pop.
1964	2.6	1.9-3.3	67.7	0.7	0.5-0.8	32.2	-	-	-
1965	2.6	1.6-3.5	67.6	0.8	0.5-0.9	32.4	-	-	-
1966	2.0	1.7-2.3	59.2	0.7	0.5-0.9	40.8	-	-	-
1967	2.7	2.0-3.2	72.9	0.6	0.3-0.8	27.1	-	-	-
1971	3.6	3.1-4.2	77.4	0.6	0.4-0.8	22.6	-	-	-
1973	2.5	1.9-3.0	63.5	0.7	0.3-1.1	36.5	-	-	-
1974	1.9	1.6-2.1	65.4	0.5	0.3-0.8	34.6	-	-	-
1975	1.3	0.9-1.	58.9	0.3	0.1-0.5	41.1	-	-	-
1976	1.6	1.3-1.8	62.4	0.4	0.2-0.6	37.6	-	-	-
1979	1.7	1.2-2.2	73.8	0.4	0.1-0.6	26.2	-	-	-
1982	1.3	1.0-1.6	34.1	0.7	0.3-1.1	29.1	4.4	2.7-6.0	36.1
1987	0.3	0.1-0.4	12.8	0.1	<0.1-0.3	6.6	3.5	3.3-3.7	61.8
1990	0.5	0.4-0.7	19.1	0.2	<0.1-0.4	8.2	3.8	3.7-4.0	42.9

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/km^2, 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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REFERENCES

BAILEY, T. N. 1978. Moose populations on the Kenai National Moose Range. Proc. N. Am. Moose Conf. Workshop 14:1-20.

BALLARD, W. B., and D. G. LARSEN. 1987. Implications of predator-prey relationships to moose management. Swedish Wildl. Res. Suppl. 1:581-602.

BANGS, E. E., and T. N. BAILEY. 1980. Interrelationships of weather, fire and moose on the Kenai National Moose Range. Proc. N. Am. Moose Conf. Workshop 16:255-274.

_______, _______ and M. F. PORTNER. 1989. Survival rates of adult female moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 53:557-563.

_______, S. A. DUFF and T. N. BAILEY. 1985. Habitat differences and moose use of two large burns on the Kenai Peninsula, Alaska. Alces 21:17-35.

_______, T. H. SPRAKER, T. N. BAILEY, and V. D. BERNS. 1982. Effects of increased human populations on wildlife resources on the Kenai Peninsula, Alaska. Trans. 47th North Am. Wildl. Nat. Resources Conf. 605-616.

BISHOP, R. H., and R. A. RAUSCH. 1974. Moose population fluctuations in Alaska, 1950-1972. Naturaliste can. 101:559-593.

CEDERLUND, G., and G. MARKGREN. 1987. The development of the Swedish moose population. Swedish Wildl. Res. Suppl. 1:55-62.

EVANS, C. D., W. A. TROYER, and C. J. LENSINK. 1966. Aerial census of moose using quadratic sampling units. J. Wildl. Manage. 30(4):767-776.

FRANZMANN, A. W., and C. C. SCHWARTZ. 1985. Moose twinning rates: a possible population condition assessment. J. Wildl. Manage. 49:394-396.

GASAWAY, W. C., R. D. BOERTJE, D. V. GRANGAARD, D. G. KELLEYHOUSE, R. O. STEPHENSON, and D. G. LARSEN. In press. Predation limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildl. Monogr.

_______, S. D. DUBOIS, R. D. BOERTJE, D. J. REED, and D. T. SIMPSON. 1989. Response of radio-collared moose to a large burn in central Alaska. Can. J. Zool. 67:325-329.

_______, _______, D. J. REED, and S. J. HARBO. 1986. Estimating moose population parameters from aerial surveys. Biol. Pap. Univ. Alaska No. 22. 108pp.

JACOBS, M. J. 1989. An initial population analysis and management strategy for Kenai Peninsula brown bears. M.S. Thesis. West Virginia Univ. Morgantown. 205pp.

KREFTING, L. W. 1975. Moose distribution and habitat selection in North Central North America. Naturaliste can. 101:143-178.

LAVSUND, S. 1987. Moose relationships to forestry in Finland, Norway and Sweden. Swed. Wildl. Res. Suppl. 1:229-244.

LERESCHE, R. E., R. H. BISHOP, AND J. W. COADY. 1974. Distribution and habitats of moose in Alaska. Naturaliste can. 101:143-178.

MACCRAKEN, J. G., and L. A. VIERECK. 1990. Browse regrowth and use by moose after fire in Interior Alaska. Northwest Science 64(1):11-18.

OLDEMEYER, J. L., A. W. FRANZMANN, A. L. BRUNDAGE, P. D. ARNESON, and A. FLYNN. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41:533-542.

_______, and W. L. REGELIN. 1987. Forest succession, habitat management and moose on the Kenai National Wildlife Refuge. Swedish Wildl. Res. Suppl. 1:163-180.

PALMER, L. J. 1938. Kenai Peninsula moose. Alaska. Research Project Report, Bureau of Bioological Survey - Sept.-Oct. 1938. Unpubl. Rpt. U.S. Fish and Wildlife Service. 37pp.

PETERSON, R. L. 1955. North American moose. University of Toronto Press, Toronto. 280pp.

PETERSON, R. O., J. D. WOOLINGTON, AND T. N. BAILEY. 1984. Wolves of the Kenai Peninsula. Wildl. Monogr. 88. 52pp.

REGELIN, W. L., C. C. SCHWARTZ, and A. W. FRANZMANN. 1987. Effects of forest succession on nutritional dynamics of moose forage. Swedish Wild. Res. Suppl. 1:247-263.

SCHWARTZ, C. C., and A. W. FRANZMANN. 1989. Bears, wolves, moose and forest succession, some management considerations on the Kenai Peninsula, Alaska. Alces 25:1-10.

_______, and _______. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. 113. 58pp.

SNEDECOR, W. G., and W. G. COCHRAN. 1967. Statistical methods. Sixth ed. Iowa State Univ. Press, Ames, Iowa. 593pp.

SPENCER, D. L., and J. B. HAKALA. 1964. Moose and fire on the Kenai. Proc. 3rd Tall Timbers Fire Ecol. Conf. 33pp.

VAN BALLENBERGHE, V. 1987. Effects of predation on moose numbers: a review of recent North American studies. Swedish Wildl. Res. Suppl. 1:431-460.