SHIRAS MOOSE WINTER HABITAT USE IN THE UPPER YELLOWSTONE RIVER VALLEY PRIOR TO AND AFTER THE 1988 FIRES

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ABSTRACT: Fourteen radio-collared moose in the upper Yellowstone River drainage of Montana and Wyoming provided information on habitat use patterns during 1987-91. Two basic winter habitat use patterns were evident prior to the 1988 fires in the Yellowstone area. Moose either used willow stands in riparian areas that did not significantly overlap with elk winter range until snow forced them into mature conifer stands, or they used small patches of aspen and willow within elk winter range and retreated to mature conifer stands as these patches were depleted of available browse or covered by snow. Moose that stayed in Yellowstone National Park avoided hunting mortality but may have suffered nutritional penalties by sharing range with elk or by using higher elevation conifer stands with deeper snow. Moose outside the Park could avoid elk and deep snow more easily but were vulnerable to hunting and faced winter range reduction as mature conifer stands at moderate elevations were logged. Moose that exhibited the high elevation/mature conifer pattern survived extensive burning of their winter ranges by reducing movements and concentrating on small islands of unburned and lightly burned habitat or by shifting home ranges to unburned areas. Moose that shared winter ranges with elk survived the 1988 fires if they were able to avoid excessive movement and find unburned mature conifer stands with snow depths that discouraged elk use.

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Shiras moose (*Alces alces shirasi*) numbers in the Yellowstone ecosystem have remained relatively low in historic times (Houston 1968, 1982). Several ecological studies of moose in or near Yellowstone National Park (YNP) were conducted between 1940 and 1970 (McDowell and Moy 1942, Harry 1957, Houston 1968, Oldemeyer unpubl., Stephens 1970). By the mid-1980s conditions in the ecosystem had changed substantially (Houston 1982, Despain *et al.* 1986). Elk (*Cervus elaphus*) populations had increased at least 3-fold, extensive clearcuts were common, and winter recreation use in and adjacent to Yellowstone National Park (YNP) increased significantly. Moose survived the changes in their environment, but declines in hunting success and a low count in a 1985 horseback survey (Tyers 1993) suggested that moose numbers on the northern boundary of YNP had declined substantially since the 1940s. Concern with this apparent decline lead the Northern Yellowstone Cooperative Wildlife Working Group to authorize a study of moose associated with the winter ranges along the northern border of YNP. During the third year of the study, massive wildfires erupted in YNP burning close to 1/3 of the Park (Rothermal *et al.* 1994). We were able to use animals radiocollared for this study to describe responses of moose to changes in vegetation that occurred after the 1988 fires.

STUDY AREA

We radiocollared moose in 4 areas (Fig. 1) in and adjacent to YNP to sample as wide a range of available habitats, human activities, and elk densities as possible. The Soda Butte study unit included portions of YNP and the Gallatin National Forest (GNF) near Cooke City, Montana. Soda Butte had the highest elevations of the 4 study units and was located at the eastern extreme of ungu-

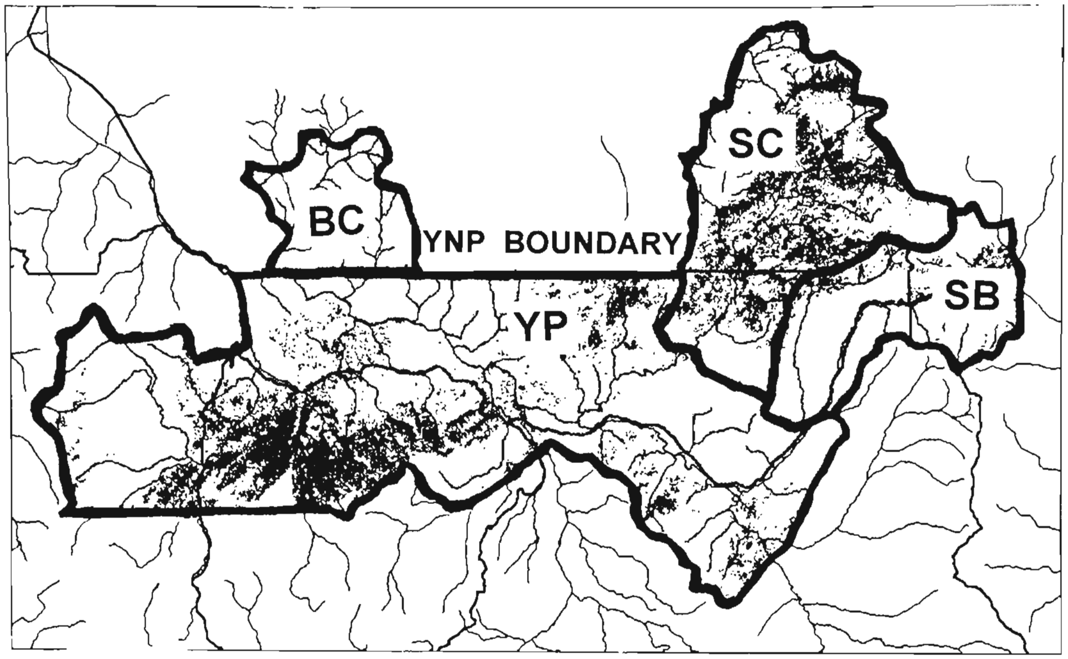

Fig. 1. A map of the study area showing unit boundaries (BC = Bear Creek, YP = Yellowstone Park, SB = Soda Butte, SC = Slough Creek). Areas in which forest canopy was severely burned in 1988 are indicated by dark stippling.

late wintering ranges in the Yellowstone system. Most of the area was covered by lodgepole pine (*Pinus contorta*) and subalpine fir (*Abies lasiocarpa*) forests in 1986. Well-developed willow (*Salix* spp.) stands and spruce (*Picea engelmannii*) forests occurred along drainages. Snowmobile recreation was the most intrusive human use of moose habitat. An extensive system of roads and trails dating to mining in the late 1800s provided access to the non-wilderness portion of the unit. Very few elk wintered in this unit. Soda Butte had the highest wintering moose density of the 4 study units. The hunting quota in 1986 was 15. Approximately half of this unit burned in 1988 (Fig. 2).

Winter ranges in the Slough Creek study unit were at slightly lower elevations than those in the Soda Butte Creek unit. The lower portions of the drainage were in YNP, and the upper reaches were in the Absaroka-Beartooth Wilderness of the GNF. Open meadows and willow stands were most abundant in riparian

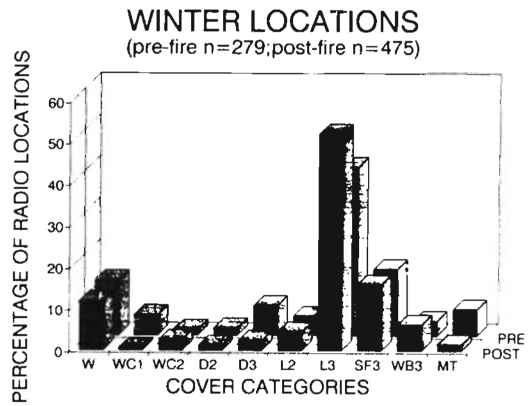

Fig. 2. Frequency of cover type use during winter prior to and after the 1988 fires for 14 radio collared moose wintering in 4 study units in the upper Yellowstone River drainage. Cover type codes are: W = willow; WC1 = willow - young (<100-year-old) conifer mixes; WC2 = willow - midage (100-300-years-old) conifer mixes; D2 = midage Douglas fir; D3 = mature (>300-years-old) Douglas fir; L2 = midage lodgepole pine; L3 = mature lodgepole pine; SF3 = mature spruce - fir; WB3 = mature whitebark pine; MT = minor types (types used <5% in all study units).

areas along the lower reaches of Slough Creek. Fir, spruce, and pine forests dominated mountain slopes and the upper reaches of the drainage. Human activity in this unit was limited to trail riding, fishing, hiking, and hunting. Elk winter range was restricted to the lower portions of the drainage. The moose population was lower than in the Soda Butte drainage, and the 1986 hunting quota was 10 moose. Over 70% of the unit and almost all of the area identified as moose winter range burned in the 1988 fires.

The Bear Creek study unit (Fig. 1) was entirely on GNF land. This unit had the lowest elevation and the driest climate of the 4 study units. Lower elevations were sage grasslands. Moose winter range (The upper 2/3 of the Bear Creek drainage) was covered by pine, fir, spruce, and Douglas fir (*Pseudotsuga menziesii*) forests. Small willow and aspen stands were scattered through the forest. This unit had been extensively modified by human activity. Roads, homesteads, and mines disrupted native vegetation in the late 1800s. Extensive logging during the past 30 years in the middle portion of the drainage increased open areas and roads. The upper third of the Bear Creek drainage remained relatively pristine and was incorporated into the Absaroka-Beartooth Wilderness in 1978. The lower portions of the drainage form a major wintering area for elk and mule deer (*Odocoileus hemionus*). The moose density in this unit was lower than that in the Soda Butte and Slough Creek units, and hunting was limited to an annual quota of 2. The Bear Creek Unit was not burned in the 1988 fires.

The YP unit (Fig. 1) was based on ungulate winter range distribution rather than a specific drainage and was located entirely in the Park. The unit encompassed rolling terrain at moderate to low elevations and included a wide variety of grass, shrub, and conifer communities. Aspen and willow communities were small, scattered, and heavily affected by ungulate browsing. Human activities were limited to hiking, fishing, and auto-based tourism. This unit included some of the most heavily used elk winter range in YNP. Moose population density was the lowest of the 4 units, and moose were not hunted. The 1988 fires burned a large portion of this unit, but the pattern was very patchy in distribution and intensity.

METHODS

In 1987-88, 14 moose were immobilized using dart-delivered drugs (Succostrin n=3; M99 n=1; Carfentinil n= 4, and Telazol n=6) and fitted with radio-transmitters (166-167 mhz, Telonics, Mesa AZ). Radiocollared moose were located on winter range 1-2 times per month from fixed-wing aircraft and 1-3 times per month from the ground using trucks, snowmachines, or skis during January 1987 through April 1990. We attempted to separate locations by at least 5 days to maximize independence of locations . All locations were made during daylight hours.

Home range sizes and boundaries were calculated using the Convex Minimum Polygon method (Mohr 1947, White and Garrott 1986) in the MCPAAL analysis package (Stuwe and Blowhowiak 1985). Home rang-

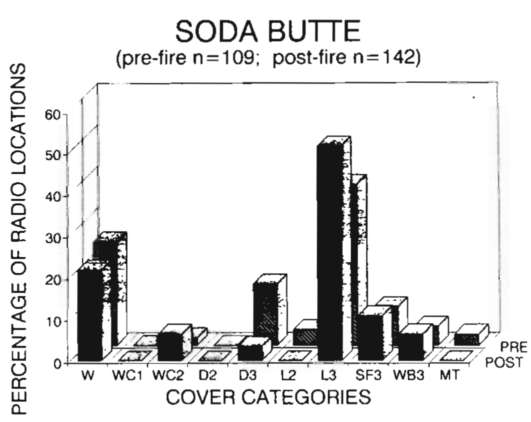

Fig. 3. Frequency of cover type use during winter prior to and after the 1988 fires for 4 radiocollared moose wintering in the Soda Butte study unit. Cover type codes are defined in Figure 2.

es were calculated for winter ranges (November - April relocations) during the pre-fire period and post-fire period when 10 or more locations were available. Differences in home range size between males and females were evaluated using a Student's t-test (Lund 1989).

All radiocollared moose legally killed by hunters were reported to MDFWP and examined to determine age and condition. All radiocollared animals that died from other causes during the study were located as soon as feasible and examined to determine cause of death. Starvation was assigned as the cause of death in carcasses that showed no evidence of predation. bullet wounds, fire-related injuries, or obvious disease symptoms; had femur bone marrow visually classified as "red and jellylike" (Cheatum 1949); and exhibited light to moderate tooth wear.

Radio relocations were classified by vegetation cover. The 166 climax and seral vegetation categories recognized by GNF and/or YNP were reduced to 20 classes (Tyers 1993) of which 9 (willow; willow-young conifer mixes; willow-mature conifer mixes; mid-successional [100-300-year-old] Douglas fir and Lodgepole pine types; and mature [>300-year-old] Douglas fir, lodgepole pine, whitebark pine, and spruce-fir types) were commonly used by radiocollared moose. Differences in pre- and post-fire use patterns and use patterns among study units were analyzed using chi-square tests (Lund 1989) in conjunction with the Bonferonni z-test statistic as described by Marcum and Loftsgaarden (1980).

Table 1. Numbers of individuals, mean numbers of locations per individual, and mean Convex Minimum Polygon estimates of winter (November - April) home range size for radio collared moose in 4 study units in the Yellowstone area prior to (1987-88) and after (1988-90) major fires. Standard deviations (SD) for mean home range sizes are given in the table.

	Pre-fire			Post-fire		
	Number of individuals	Mean locations	Mean home range size in km^2 (SD)	Number of individuals	Mean locations	Mean home range size in km^2 (SD)
Soda Butte						
Male[a]						
Female	3	27	4.1 (1.5)	3	40	6.1 (2.8)
Slough Cr.						
Male[b]				1	42	66.0
Female[a]				1	42	65.8
Bear Cr.						
Male[a]	1	28	5.4	2	35	8.7 (8.2)
Female	1	27	13.9	1	54	22.0
Yellowstone						
Male[a]				1	13	110.0
Female[b]	1	10	65.7	2	51	73.9 (51.0)
All units						
Male	1	28	5.4	4	31	48.3 (49.4)
Female	5	24	18.4 (26.8)	7	45	36.2 (39.3)

[a]Does not include 1 individual located <10 prior to fires.
[b]Does not include 2 individuals located <10 times prior to fires and 1 after the fires.

RESULTS

Eleven of the 14 moose captured were located 10 or more times during winter (November - April) prior to and/or after the 1988 fires (Table 1). Average pre-fire winter home range size for 5 female moose was 18.4 km². The only male moose located >10 times prior to the fires had a home range of 5.4 km². Post-fire winter home range size for 7 females averaged 36.2 km² and for 4 males averaged 48.3 km². We were unable to detect differences in post-fire winter home ranges between males and females ($t = 0.42$, $p = 0.69$).

Radiocollared moose were relocated 754 times during the 4 winters of the study. Ninety-five percent of the locations were in 9 vegetation categories (Fig. 2). The 3 most frequently utilized vegetation categories were mature (>300-year-old) lodgepole pine (47% of locations), mature spruce-fir (16% of locations), and willow communities (12% of locations). The distribution of locations among vegetation classes differed before and after the 1988 fires (Chi-square = 42.57, $p < 0.01$), but the only individual categories that showed significant changes after the fires (Bonferonni z-test, $p < 0.05$) were a decline in use of mixed willow - young conifer (<100-year-old) stands, an increase in use of mature lodgepole pine stands, and a decrease in use of minor cover types.

Pre-fire use patterns differed ($p < 0.05$) in only 2 pairwise comparisons between study units: Bear Creek differed from Soda Butte (Chi-square = 24.93. $p < 0.01$) and Yellowstone Park from Soda Butte (Chi-square = 24.13; $p < 0.01$). All pairwise comparisons between units differed significantly after the 1988 fires (Chi-square range = 27.56 to 53.14, $p < 0.01$).

Soda Butte

Four moose were collared in the Soda Butte unit. Two females survived through the project. One female and 1 male were killed legally by hunters. Two of the females were located a sufficient number of times for home range calculation. The mean winter home range for these moose (5.1 km²) was the smallest of the 4 study units (Table 1). Post-fire winter home ranges were slightly larger than pre-fire winter ranges.

Marked moose in this unit wintered in mature forests and tall willow stands at elevations above elk winter range prior to the 1988 fires. Approximately half of this unit burned in 1988, but only 1% of post-fire winter locations were in burned stands. Pre- and post-fire habitat use differed (Chi-square = 14.83, $p = 0.01$), but Bonferonni z-tests indicated only 1 category in which use changed significantly ($p < 0.05$); use of mature Douglas fir declined after the fires. Moose generally shifted to unburned areas within winter ranges and used the same vegetation types they had prior to the fires.

Slough Creek

Three moose were collared in the Slough Creek drainage. One survived the study; 1 was killed by a hunter; and 1 apparently died from malnutrition following the 1988 fires. We had too few locations of radiocollared moose prior to the 1988 fires to calculate

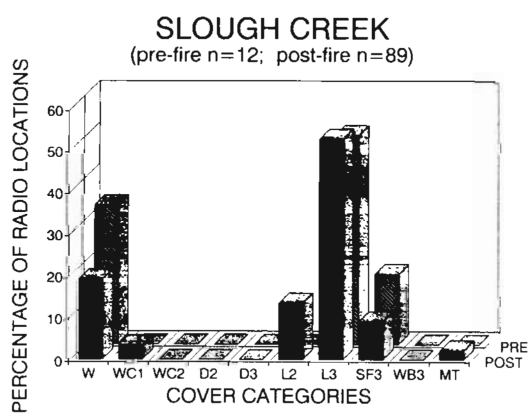

Fig. 4. Frequency of cover type use during winter prior to after the 1988 fires for 3 radiocollared moose wintering in the Slough Creek study unit. Cover type codes are defined in Figure 2.

winter home ranges, but the post-fire winter home ranges were much larger than those in the Soda Butte unit (Table 1).

The pre-fire sample of radio relocations in the Slough Creek unit (n=12) was too small for viable analysis, but 76% of the locations after the fires were in the 3 types used by radiocollared moose prior to the fires (Fig 4.). Winter locations prior to and after the fires were at higher elevations than areas commonly used by elk in winter. Although >90% of the area we identified as primary moose winter range in the unit burned in 1988, only 32% of post-fire locations were in burns. Two marked moose, 1 male and 1 female, returned to their winter ranges after the fire and survived winter by feeding on plants in lightly burned patches when available and burned conifer twigs when unburned browse was exhausted. The male moved to a different winter range in unburned lodgepole at higher elevations the second winter after the fire. The female remained on the burn but foraged in lightly burned patches and did not utilize burned twigs. The third moose, an adult male, moved to a higher elevation, unburned area the first winter after the fire. He starved before spring.

Bear Creek

Two males collared in the Bear Creek unit were killed by hunters by 1991. The collared female survived until the end of the study. Winter home ranges averaged 11.4 km^2. Pre-fire home ranges were slightly smaller than post-fire home ranges (Table 1).

The moose we marked in this unit wintered in the non-wilderness portion of the drainage. They avoided logged areas throughout the winter and concentrated most of their activity in large, uncut blocks of mature conifer forest (Fig. 5). The proportions of types used prior to the 1988 fires differed from those used after the fires (Chi-square = 17.49, $p < 0.01$) even though none of the Bear Creek unit burned. Bonferonni z-tests did not identify any individual categories that varied significantly. Elk use of areas where marked moose were located was light. Radiocollared moose in this unit apparently selected small pockets of willows within conifer forests when snow depth allowed.

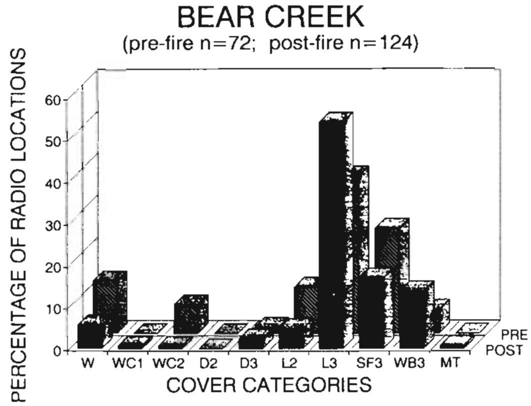

Fig. 5. Frequency of cover type use during winter prior to and after the 1988 fires for 3 radiocollared moose wintering in the Bear Creek study unit. Cover type codes are defined in Figure 2.

Yellowstone Park

Two females collared in the Yellowstone Park unit survived while 1 male and 1 female died of malnutrition following the 1988 fires. Although we only had enough locations to calculate 1 pre-fire home range and 3 post-fire home ranges (Table 1), the pre-fire home range was the largest calculated for any study unit during winters prior to the 1988 fires, and 2 of the post-fire home ranges were the largest calculated for winters following the fires .

Most of this unit burned in 1988. The patchy distribution and varying intensity of fires left a complex mosaic of burned, partially burned, and unburned areas. Pre- and post-fire habitat use patterns differed (Chi-square = 16.22, p = 0.02), but the only individual category that changed significantly (Bonferonni z-tests, $p < 0.05$) was a decrease in use of willow stands after the fire. Mature lodgepole and spruce-fir forests (Fig. 6) were

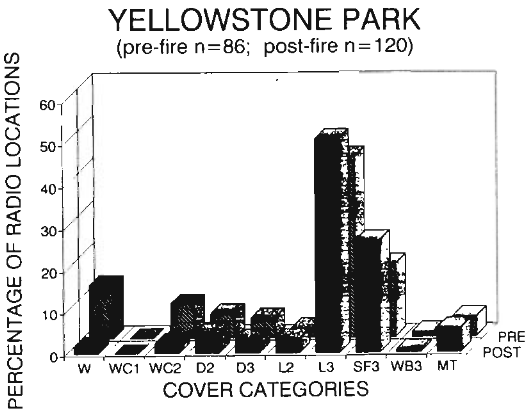

Fig. 6. Frequency of cover type use during winter prior to and after the 1988 fires for 4 radiocollared moose wintering in the Yellowstone Park study unit. Cover type codes are defined in Figure 2.

the most frequently used vegetation categories in both pre-and post-fire winters. Moose winter range overlapped elk winter range in much of this unit.

Habitat use patterns differed markedly among the 4 radiocollared animals. Prior to 1988, 1 female began winter in the Soda Butte unit then moved to large conifer stands above most elk winter range in the Yellowstone Park unit. When these stands burned, she returned to the same area, moved between small unburned patches, and survived through the study. Two of the collared moose (1 male and 1 female) utilized browse in patches scattered through elk winter range prior to the fires. Winter ranges of both animals were extensively burned. They evidently increased their winter range sizes after the fires, and both died of malnutrition by spring 1989.

The fourth moose, a female, used a smaller home range than the others. Before the 1988 fires, she spent early winter in aspen and willow patches within elk wintering areas and slowly moved upslope as winter progressed into conifer stands not used by elk. Most of her winter range burned in 1988. In the 1988-89 winter, she survived by moving to a large unburned lodgepole pine stand early in winter and remaining in this stand through the winter.

DISCUSSION

Moose winter habitat in the Upper Yellowstone Valley consists of mesic deciduous and coniferous plant communities. Both types of habitat have been extensively modified in the past 30 years. Elk use of lower-elevation willow and aspen stands has decreased height, density, and possibly total acreage (Despain *et al.* 1986, Kay 1990, Singer *et al.* 1994). Logging outside YNP and the fires of 1988 have decreased the overall area covered by mature conifer forests. These changes are likely linked to reported declines in moose numbers in the area over the past decade (Tyers, 1993).

We noted 2 basic winter habitat use patterns for radiocollared moose in the upper Yellowstone area prior to the 1988 fires. Moose either used riparian areas above elk winter range until snow forced them into mature conifer stands or they used small patches of mesic deciduous tree communities within elk winter range and retreated to mature conifer stands as these patches were depleted of available browse or covered by snow. The number of individuals monitored was too small to adequately test for sexual differences in habitat use (Miquelle *et al.* 1992). Moose that stayed in YNP avoided hunting mortality but may have experienced nutritional penalties by sharing range with elk (Kay 1990, Singer *et al.* 1994) or by using higher elevation conifer stands with deeper snow (Ballard *et al.* 1991, Miquelle *et al.* 1992). Moose outside YNP could avoid elk and deep snow more easily but were vulnerable to hunting and faced winter range reduction as mature conifer stands at moderate elevations were logged.

Moose that wintered in mature conifer stands at high elevations survived extensive burning of their winter ranges by reducing movements and concentrating on small islands of unburned or lightly burned habitat or by shifting home ranges to unburned areas. Moose that shared winter ranges with elk survived the 1988 fires if they were able to avoid excessive movement and find unburned mature conifer stands with snow depths that discouraged elk use.

The survival of nearly half the moose we marked for the duration of the study demonstrates that some moose have successfully adapted to current habitat conditions in the Yellowstone ecosystem. The declines in moose numbers noted in horseback surveys (1985-92) and aerial surveys (1987-92) (Tyers 1993) and the mortality we observed in marked animals indicate that the extensive fires of 1988 were not beneficial to moose in this system, at least during the early post-fire period. Some burned areas produced excellent summer forage for moose in the first 5 years after the fires (Knight 1994), but replacement of forest canopies that effectively intercept snow on winter ranges may take 200 years. Efforts to slow or reverse the apparent moose population decline should concentrate on minimizing loss of unburned mature forest and careful management of hunting. We did not attempt to measure competition between moose and elk, but the overlap in winter use of willow stands in areas where moose and elk were sympatric indicates that manipulation of elk numbers and/or distribution should also be considered as a mechanism to improve conditions for moose.

ACKNOWLEDGMENTS

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