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Browse Regrowth and Use by Moose After Fire in Interior Alaska

Abstract

This study was undertaken to estimate the short-term effects of fire on plant response and moose (*Alces alces* Miller) browse following the Rosie Creek fire near Fairbanks, Alaska. The fire consumed forests of quaking aspen (*Populus tremuloides* Michx.), paper birch (*Betula papyrifera* Marsh.) and white and black spruce (*Picea glauca* (Moench) Voss, *P. mariana* (Mill.) B.S.P.). The fire began in late May 1983, was hot and fast moving, and burned over 3,000 ha. Browse regrowth was abundant within two months. Regrowth was from root and stump sprouting of quaking aspen, paper birch, and willows (*Salix* spp.). Generally, aspen sites produced the most browse followed by white spruce, birch, and black spruce. Composition of the pre-fire plant community, which was directly related to stand age, strongly influenced browse regrowth. Seedling establishment of browse species was evident by the third growing season after the fire. Moose foraged in the burn the first winter after the fire. Browse use ranged from 1 to 46 percent and was greatest on willows. Estimates of browse use based on stem counts and biomass data were significantly correlated. Crude protein and mineral concentrations differed among browse species and decreased as time after the fire increased. This suggests that wildfire can have immediate benefits to moose by the production of substantial browse within a few months.

Introduction

Moose (*Alces alces* Miller) in Alaska are associated with habitats in early stages of plant succession (LeResche *et al.* 1974). These plant communities provide significant amounts of deciduous hardwood browse on which moose feed (LeResche and Davis 1973, Cushwa and Coady 1976). Fire is currently, and was historically, the most significant force creating early seral vegetation communities in interior Alaska (Viereck 1973).

Burning of old-growth forests leads to increases in the quantity and quality of moose browse (Oldemeyer 1974, Oldemeyer *et al.* 1977). Browse regrowth after fire is from root and stump sprouting, or from seed. Sprouting can result in extremely dense stands (Spencer and Hakala 1964, Wolff and Zasada 1979). Fire in old-growth stands results in a release of nutrients from slowly decomposing organic matter and from soil layers with permafrost (Viereck 1973). Increased quality of browse, however, may be related more to greater digestibility of younger plants than to increased nutrient concentrations in plants (Oldemeyer 1974, Irwin 1985).

The amount, species, and quality of browse regrowth after fire depends on several factors. The composition of the pre-fire plant community, which is often related to stand age, strongly influences species composition of burned sites. Time of year that a fire occurs is also important, as is fire intensity, size, and burn patterns (Viereck 1973, LeResche *et al.* 1974, Gasaway and Dubois 1985).

Land managers in interior Alaska are incorporating controlled burns, or "let burn" policies, into management plans to improve or maintain moose habitat. The useful life of a burn for moose has been estimated at less than 50 years with moose densities peaking 20-25 years after the burn (LeResche *et al.* 1974). Spencer and Chatelain (1953) estimated that three years elapsed before the 1947 burn on the Kenai Peninsula produced significant amounts of browse. Spencer and Hakala (1964) stated that plant communities from 5 to 20 years post-fire were optimum in terms of moose forage. These results suggest that in some habitats the immediate benefits of fire to moose may be negligible. Furthermore, managers may have to compensate for an initial short-term loss of moose habitat in burning programs. Prompt use of burns by moose has been observed, however. Peek (1974) reported increasing moose populations in the Little Sioux burn in Minnesota the first two winters after the fire. Gasaway and Dubois (1985) found that moose continued to occupy their traditional home range during and after a slow moving, patchy fire in interior Alaska.

Few data are available to provide estimates of browse regrowth and use by moose in Alaska

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less than three years after a burn (Wolff and Zasada 1979). This information is essential to assess the feasibility of fire as a management tool, select specific sites for burning, determine burn size and frequency, estimate short-term fire effects on moose, and to incorporate specific sites into wildlife and fire management plans.

The purpose of this study was to estimate browse regrowth and use by moose two months to two years after a fire in interior Alaska. A second objective was to examine yearly trends in browse nutrient composition following the fire, as well as differences among species.

Study Area

This study was conducted in the 1983 Rosie Creek burn, about 40 km southwest of Fairbanks, Alaska. The fire began on 29 May and was brought under control in 17 days (Juday 1985). About 3,500 ha of upland forest and Tanana River valley bottomland was burned. Most of the burn was on upland sites with east, southeast, south or southwest aspect. Plant communities burned included 130- to 180-year-old (based on tree coring) white spruce (*Picea glauca* (Moench) Voss.), black spruce (*Picea mariana* (Mill.) B.S.P.), and paper birch (*Betula papyrifera* Marsh.) forest. Younger (63- to 72-year-old) white and black spruce and quaking aspen (*Populus tremuloides* Michx.) forest were also consumed, as well as some mesic bottomland herbaceous communities.

The fire was hot and fast moving (Juday 1985). A convective fire storm, which generated winds over 160 km/hour, uprooted 16 ha of mature (48 cm diameter breast height) white spruce forest. Although specific areas could be classified as light or heavily burned, the burn pattern was fairly uniform. Islands of unburned vegetation within the fire perimeter were rare. Preliminary results of research associated with this fire were reported in Juday and Dyrness (1985).

Vegetation of the area before the fire was typical for the Tanana River floodplain or Yukon-Tanana uplands. Quaking aspen stands had a closed canopy. The shrub layer was composed of high bushcranberry (*Viburnum edule* (Michx.) Raf.) and prickly rose (*Rosa acicularis* Lindl.). The low shrub layer was dominated by buffaloberry (*Shepherdia canadensis* (L.) Nutt.), twinflower (*Linnaea borealis* L.) and kinikinnick (*Arctostaphylous uva-ursi* (L.) Spreng.). Important herbaceous species were bluejoint (*Calamagrostis canadensis* (Michx.) Beauv.), bedstraw (*Galium boreale* L.), and horsetail (*Equisetum scirpoides* Michx.); leaf litter covered the soil surface. Some white spruce were also present.

Paper birch stands had well-developed, open canopies with scattered white spruce and quaking aspen. The understory was dominated by the tall shrubs; green alder (*Alnus crispa* (Ait.) Pursh.), prickly rose, and high bushcranberry. Important herbaceous plants were bluejoint, horsetail (*E. arvense* L.), and bunchberry (*Cornus canadensis* L.). Litter covered the soil surface.

The mature white spruce forests had open canopies with a few aspen and birch. The tall shrub layer was sparse with green alder, prickly rose, and high bushcranberry. Low shrubs included twinflower and mountain-cranberry (*Vaccinium vitis-idaea* L.). Herbaceous species included horsetail, wintergreen (*Pyrola secunda* L.), and *Geocaulon lividum* (Richards.) Fern. A well-developed moss-lichen mat covered the forest floor. Stair-step moss (*Hylocomium splendens* (Hedw.) B.S.G.) and chink moss (*Pleurozium schreberi* (Brid.) Mitt.) were most abundant. Lichens included *Peltigera* spp. and *Cladonia* spp.

A 70-year-old white spruce forest had a greater density of trees, but they were small in height and diameter. The tall shrub layer was dominated by Bebb willow (*Salix bebbiana* Sarg.).

The bottomland black spruce forest had an open canopy, and trees were small in height and diameter. Tall shrubs present were prickly rose and high bushcranberry with scattered willows (*S. glauca* L., *S. bebbiana*, and *Salix* spp.). The low shrub layer was dominated by Labrador tea (*Ledum groenlandicum* Oeder.), mountain-cranberry, and bog blueberry (*V. uliginosum* L.). Important herbs were bluejoint, horsetail (*E. silvaticum* L.), and *G. lividum*. A thick mat of moss (*Sphagnum* spp., *Hylocomium splendens*, *Polytrichum* spp., *Pleurozium schreberi*) and lichen (*Peltigera* spp., *Cladonia* spp.) covered the soil surface.

Upland black spruce forests had a more developed, open canopy and trees were taller and larger in diameter. The understory was similar to bottomland stands, except for the addition of green alder. Plant names follow those given by Hulten (1968), Viereck and Little (1972), and Crum (1976).

The density of moose on the study area was unknown. The Alaska Department of Fish and Game estimated an average of 0.97 moose/km^2 in Game Management Unit 20B, which encompasses the study area. Moose densities ranged from 3.8-0.2/km^2 in 20B, depending on locale. Moose density on the study area was considered low because of the area's proximity to Fairbanks and good access for hunters.

Methods

During June 1983, 10 study sites were established at random with respect to moose occurrence on the study area. Study sites were located in stands homogeneous with respect to pre-fire plant community and topography. Sites were chosen primarily for other fire ecology studies, and represented the variability in topography and stand age that occurred in the study area for each of the four major palnt communities burned. Two sites were in 70-year-old aspen forest on primarily south-facing slopes of 33 and 36 percent, respectively. A third site (70-years-old) was in a mixed aspen-white spruce stand on a moderate (18%) south slope, adjacent to the other aspen sites.

Two sites were located in 130- and 136-year-old paper birch forests. The younger site was on a ridge with a 5 percent slope of southwest aspect, while the other was on a steep (30%), southeast-facing hillside.

Three sites in white spruce forest were also studied. Two of these were in 190- and 180-year-old stands. The older stand was within the area of the fire storm. Aspect was south and the slope was 20 percent. The other site was on a southwest-facing slope of 27 percent. The 70-year-old white spruce stand studied was on an 18 percent slope with southwestern exposure.

Two black spruce stands were also sampled. One was on an old river terrace that also burned in 1914; the other was an upland site on a mid-slope bench. Trees at the upland site were about 140 years old and the area was primarily flat with little topographic relief on a 2 percent north-facing slope. Permafrost occurred only at the black spruce sites. Information on herbaceous and woody biomass for the first two summers after the fire was given in Viereck and Foote (1985).

At each site a grid system was established to define plot locations. Twenty points were delineated in a 50 x 40 m grid with points every 10 m. Grid configuration was modified at two sites to 100 x 20 m in order to remain within a uniform stand.

During the summers of 1983-85, browse density was estimated at each site in 20 circular plots. Plot size varied with stand density. In aspen stands, a 4-m^2 plot was used, but in birch and spruce stands, where browse regrowth was primarily from stump sprouts, we used either 10-m^2 or 50-m^2 plots. Browse density was estimated for each species by counting individual stems rooted within a plot.

During mid-May 1984 and 1985, before plant growth began, winter browse use by moose was estimated at each site. Browsed and unbrowsed stems were counted in each plot, providing an estimate of percent use. The basal diameter, height, and diameter at the point of browsing (DPB), if applicable, were also measured for each individual stem. Height was measured to the nearest centimeter with a steel tape, and diameters to the nearest 0.01 mm with a dial caliper.

In 1984, plots were examined in numerical order until 100 stems of each species were sampled. However, a modified sampling scheme was used in May 1985; five plots were chosen at random. The same measurements were made as in 1984, except that only 20 browsed stems per plot were measured for height and diameter. If 100 total stems were not counted or 50 browsed stems were not measured, additional plots were randomly sampled until those criteria were met. The number of twigs per stem was also recorded in 1985 because of extensive branching of some species.

To estimate browse biomass eaten by moose, a sample was collected during May 1985 from unbrowsed stems representative of portions removed by moose. From each site, 10 individuals of each browse species were clipped at diameters within the range of DPB's measured in the stand. Clipped samples were oven-dried at 60°C for 48 hours and weighed to the nearest 0.01 g. From these samples, regression equations were developed to predict browse biomass eaten by moose (y) from DPB (x) (Telfer 1969, Grigal and Moody 1980, Oldemeyer 1983). Exponential equations [logn y = a(logn x)^b] described browse growth most accurately. Browse biomass eaten by moose was equal to mean biomass eaten per browsed stem multiplied by the density of browsed stems, and the mean number of twigs per stem at each site, for each species. Browse use was also estimated with biomass data. The percent of biomass used was equal to biomass eaten by moose divided by available biomass for each species.

Total browse biomass (standing crop) was sampled at each site in mid-July 1984 and 1985 after the cessation of twig growth. Procedures followed were similar to those used in estimating biomass eaten by moose. First, a browse-density estimate was obtained, then regression equations were developed to predict total browse biomass per individual stem based on stem basal diameter. A mean weight per individual stem was then multiplied by stem density. To develop these regression equations, 10 entire plants of each species were clipped during mid-July 1984-85, the leaves and woody materials separated, oven-dried, and weighed. Total browse biomass estimates include the biomass removed by moose during the previous winter.

Generally, available biomass is defined as the amount of material between maximum snow depth and the maximum reach of moose. Wolff and Zasada (1979) used 0.5 and 3 m, respectively. However, during this study, moose browsed as low s 20 cm and browse regrowth did not exceed 2 m. Furthermore, snow accumulation was not significant enough to effect moose foraging until late winter. Therefore, all biomass was potentially available to moose, and browse use was restricted primarily by characteristics of moose behavior, such as forage preference and maximum bite size. We estimated available biomass by multiplying the mean weight of browse eaten per stem by mean stem density and mean twigs per stem for each site in 1984 and 1985.

Browse samples were collected at seven sites in June 1983 and all 10 sites in May 1984 and 1985 for chemical analyses. Up to 100 twigs per species per site were collected for analysis. Plant samples were ground in a Wiley mill to pass through a 1-mm mesh screen. Samples were analyzed in duplicate by the Forest Soils Laboratory, University of Alaska Fairbanks, for crude protein (N x 6.25), phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K) according to A.O.A.C. (1970) procedures. Minerals (ppm), excluding P, were determined with an atomic absorption spectrophotometer; P was estimated with an auto-analyzer.

During early 1984 and 1985, snow depths were measured at random at representative sites for each plant community. Snow was measured to the nearest centimeter at 3 to 10 locations at each site sampled. Average maximum snow depth per site was estimated for each year.

Because each site selected for study was unique in topography or stand age, no statistical comparisons were made among sites. However, t-tests were used to compare mean snow depth between years (1984-85). A one-way ANOVA, followed by Tukey's mean separation procedure, was used to test for differences between years (1984-85) in protein and mineral concentrations. The same tests were also used to examine differences in nutrients among the major browse species using data from 1983-85. Statistical significance was accepted at $P < 0.05$.

Results

Browse regrowth after the fire was primarily quaking aspen, paper birch, and willows (*S. bebbiana*, *S. glauca*, and *Salix* spp.). These plants were the most important to moose in terms of forage production and use (Table 1). Prickly rose, green alder, high bushcranberry, and American red raspberry (*Rubus idaeus* L.) also came in after the fire but were not eaten by moose.

Browse Density, Biomass, and Use

Aspen regrowth was primarily from root suckers and resulted in dense stands (> 300,000 stems/ha at one site) within two months after the fire. Aspen density was highest in aspen stands followed by birch, white spruce, then black spruce stands. Aspen invaded black spruce sites through seedling establishment. Total biomass of aspen regrowth among sites followed a pattern similar to that of stem density (Table 1).

Paper birch regrowth was exclusively from stump sprouts in 1983. By 1985, birch seedlings were becoming established in some spruce and aspen stands. Maximum density of birch was 10,240 stems/ha at a birch site. White spruce stands had the next highest density of birch followed by black spruce and aspen stands (Table 1).

TABLE 1. Mean (SE) density, biomass, and use estimates of browse regrowth in four plant communities after the Rosie Creek fire in interior Alaska. Sampling occurred in 1983-85.

Pre-fire Plant Community and Species	Stems/ha	%[a] Use	Total Biomass (kg/ha)	Available Biomass (kg/ha)	%[b] Use	Biomass[c] eaten by moose (kg/ha)
Quaking aspen						
Quaking aspen	125,218 (45181)	7 (6)	1,667 (478)	177 (72)	11 (6)	19 (16)
Paper birch	367 (367)	0	1 (1)	1 (1)	0	0
Paper birch						
Quaking aspen	2,289 (2111)	34 (1)	54 (53)	4 (3)	50 (23)	2 (2)
Paper birch	8,886 (1354)	38 (5)	58 (8)	8 (1)	38 (4)	3 (1)
Willow	2 (2)	0	Tr	Tr	0	0
Black spruce						
Quaking aspen	1,199 (189)	0	3 (2)	2 (1)	0	0
Paper birch	404 (17)	0	0 (7)	6 (3)	0	0
Willow	1,557 (1484)	30 (30)	18 (18)	5 (5)	40 (9)	2 (2)
White spruce						
Quaking aspen	3,031 (1634)	1 (1)	61 (59)	9 (7)	2 (2)	Tr
Paper birch	2,280 (2131)	23 (10)	42 (35)	4 (3)	20 (9)	1 (1)
Willow	10,882 (10882)	47 (12)	395 (395)	12 (12)	50 (19)	6 (6)

[a]Based on density estimates.
[b]Based on biomass estimates.
[c]Calculated as mean weight per twig browsed x twigs per stem x stem density.
Note: Tr = less than 0.1.

Willow regrowth was from root crowns immediately after the fire and was highest (10,000 stems/ha) at the 70-year-old white spruce stand (Table 1). The only other site with a significant amount of willow was the younger black spruce stand. In 1985 willow seedlings were established at the upland black spruce site.

Trends in total biomass of browse regrowth among stands and species were similar to patterns in stem density (Table 1). Total biomass of all browse species combined averaged 1,668(470) [$\bar{x}$(SE)] kg/ha at aspen sites, 498(398) kg/ha at white spruce, 111(61) kg/ha at birch, and 25(22) kg/ha at black spruce sites.

Available biomass of aspen averaged 66(40) kg/ha in 1984 and 48(25) kg/ha in 1985. Willows followed a similar trend; 32(18) kg/ha compared to 10(8) kg/ha in 1984 and 1985, respectively. Available biomass of birch was 3(1) kg/ha in 1984 and 10(3) kg/ha in 1985.

Browse use was highest on willows followed by birch, then aspen (Table 1). Trends in browse use among stands were directly related to use patterns among species. Moose foraged in the burn the first winter after the fire. Use of aspen, averaged over all sites with aspen and based on stem counts, was 11(4) percent during winter 1983-84. Use of paper birch averaged 47(8) percent during the first winter. Use of willows averaged 46(12) percent over the two sites with willows in winter 1983-84.

Browse use patterns changed at aspen sites during winter 1984-85. Stands browsed the first winter were not used in 1984-85 and vice versa. Use of birch was more consistent between the two years in that most sites browsed the first winter were browsed the next, and use of willow remained the same [47(11)%] each winter.

Browse use estimates based on biomass figures were similar to those based on stem counts (Table 1). A rank-order correlation (Snedecor and Cochran 1967:193) showed a significant positive relationship ($r_s = 0.89$, $P < 0.01$) between the two methods.

Estimates of biomass removed by moose ranged from a high of 51 kg/ha for aspen to a low of 0.1 kg/ha for birch and are summarized in Table 1. During the first winter, moose removed 13(13) kg/ha of aspen over all sites, but only 2(1) kg/ha during winter 1984-85. Biomass of birch removed was 1(1) kg/ha in 1983-84 and 3(1) kg/ha the second winter. Willows followed a similar pattern, ranging from 17(12) kg/ha removed to 24(19) kg/ha from one winter to the next.

Snow Depths

During winter 1983-84, maximum snow depth (averaged over all sites measured) was 39(6) cm, but during winter 1984-85, average maximum snow depth was 81(1) cm (t = 5.85, P < 0.0005).

Browse Composition

Protein and mineral content of browse varied among sites (Table 2). However, no clear trends were apparent in this data.

There were some differences in protein and mineral concentrations in the three browse species between 1984 and 1985 (Table 3). Concentrations of K were greater in 1984 than 1985 for aspen (F = 4.00, P < 0.05), (birch F = 7.72, P < 0.05), and willows (F = 7.45, P < 0.05). Furthermore, protein (F = 8.76, P < 0.01) and P (F = 17.17, P < 0.01) levels were greater in 1984 than 1985 in birch samples.

Differences among species in protein and mineral levels were also evident (Table 3). Paper birch samples had greater (F = 5.26, P < 0.01) levels of crude protein than aspen or willows. Aspen was higher (F = 7.51, P < 0.01) in K than birch, and both aspen and willows had greater (F = 9.52, P < 0.01) Ca concentrations than birch.

Discussion

The Rosie Creek fire occurred in early spring while plants were still dormant and root reserves were unused. This allowed for rapid regrowth of the three major browse species within two months after the fire. Browse was well established by the end of the summer, which provided moose with abundant forage that winter.

Pre-fire stand age played a significant role in browse response to fire. The aspen, white spruce, and black spruce stands that had burned in 1914 (70-year-old) produced 10-times as much browse as the older (130- to 180-year-old) birch, white spruce, and black spruce stands combined. This was largely due to the high production of aspen stands. In addition, when contrasting young and old black spruce or white spruce stands, three-times as much browse was produced in the younger stands.

Moss and organic surface layers were burned off at many sites exposing mineral soil which is

TABLE 2. Mean (SE) concentration of protein and four elements in browse species collected from four plant communities in the Rosie Creek burn in interior Alaska. Plants were sampled in June 1983 and May 1984-85.

Pre-fire Plant Community and Species	Crude Protein (%)	Macroelements (ppm)			
		P	Ca	Mg	K
Quaking aspen					
Quaking aspen	3.5 (0.1)	950 (50)	4,833 (416)	1,033 (117)	5,067 (377)
Paper birch					
Paper birch	7.5 (0.6)	1,384 (17)	3,200 (326)	734 (36)	3,450 (150)
Quaking aspen	5.0 (1.8)	733 (133)	4,100 (462)	1,167 (120)	5,167 (684)
Black spruce					
Paper birch	6.6 (1.3)	1,400 (212)	2,750 (300)	775 (25)	4,350 (495)
Willows	3.9 (0.7)	900 (153)	4,767 (696)	767 (176)	3,833 (940)
Quaking aspen	4.5 (0.9)	1,200 (82)	8,400 (903)	1,300 (201)	6,200 (401)
White spruce					
Quaking aspen	4.9 (0.8)	1,400 (231)	6,033 (848)	1,200 (104)	5,800 (737)
Paper birch	4.7 (0.3)	1,067 (260)	3,517 (584)	700 (100)	3,367 (400)
Bebb willow	3.3 (0.4)	900 (58)	6,067 (410)	533 (219)	5,067 (1386)

TABLE 3. Mean (SE) concentration of protein and four elements in twigs of three browse species collected from four plant communities in the Rosie Creek burn. Sampling occurred in June 1983 and May 1984-85.

Species and year	Crude Protein (%)	Macroelements (ppm)			
		P	Ca	K	Mg
Quaking aspen					
1983	7.1 (2.1)	1,700 (182)	6,200 (450)	5,900 (700)	1,300 (100)
1984	4.6 (0.5)	1,100 (71)	6,000 (286)	5,700 (464)	1,200 (71)
1985	3.6 (0.4)	700 (45)	4,000 (409)	4,100 (364)	900 (182)
Paper birch					
1983	8.6 (0.9)	1,700 (150)	3,600 (150)	3,300 (273)	900 (91)
1984	5.8 (0.7)	1,200 (77)	4,400 (400)	3,300 (280)	900 (80)
1985	3.9 (0.5)	800 (100)	2,800 (150)	3,000 (550)	600 (150)
Willows					
1983	4.5 (0.4)	1,000 (71)	3,200 (71)	5,100 (213)	700 (1)
1984	3.8 (0.4)	1,100 (71)	6,800 (1064)	6,100 (142)	1,000 (142)
1985	2.6 (0.1)	700 (71)	3,400 (709)	5,100 (1631)	300 (213)

necessary for seedling establishment (Viereck 1973). By the third growing season after the fire, seedlings of the three major browse species were present at many sites. Seedlings were primarily of the dominant species at each site, but each browse species invaded some sites, most notably black spruce stands. If invading seedlings survive, the poorer sites in terms of browse regrowth may become good foraging habitat for moose.

Browse use by moose in the Rosie Creek burn was scattered and locally concentrated. The large area burned and low pre-fire moose population was responsible for this use pattern. Moose were able to forage away from the most accessible areas of the burn and salvage-logging operations. In addition, moose did not use browse in the area of the firestorm. The large-diameter trees that were uprooted by the firestorm formed a physical barrier excluding moose.

Differences in snowfall between winters also affected use patterns at aspen sites. The above-normal snowfall of the second winter laid down and buried many aspen suckers, especially those on steep slopes. Many birch stems were also buried. In comparison, willow stems which were over 1 m tall were used at the same rate each winter.

We found a significant ($P < 0.05$) positive correlation in estimates of browse use when derived from stem counts or biomass sampling. Regelin (1987) reported similar findings when estimating use of paper birch and suggested that labor intensive biomass sampling be redirected toward counting more twigs and thus increasing sample size, and the precision of use estimates. Our results add further support to this conclusion.

Generally, protein and mineral concentrations in the browse species that we examined were greatest in 1984 and some nutrients declined significantly ($P < 0.05$) in 1985. It appears that most nutrients made available by fire are quickly absorbed by resprouting plants, and that this benefit of fire is relatively short-lived compared to the increase in browse biomass.

Schwartz *et al.* (1987) reported that moose need a minimum dietary crude protein content of 6.8 percent to meet maintenance needs. Paper birch samples in this study exceeded that amount at all but one site. However, aspen and willows were all below 6.8 percent. Contrariwise, K and/or Ca levels were greater in aspen and willows than birch. The minimum requirements of these minerals for moose are unknown. However, these results support the suggestion of Oldemeyer *et al.* (1977) that moose may use a variety of browse species to meet their nutritional needs.

The results of this study and others conducted in interior Alaska provide land managers with information that should be incorporated into burning programs designed to improve moose habitat. Burning should be done in early spring as soon as the area will carry a fire. A hot fire will burn off moss and organic layers providing a good seedbed, yet still allow for sprouting of trees and shrubs. A mosaic of burned and unburned vegetation will allow moose to remain in the immediate area during the burn (Gasaway and

Dubois 1985). A variety of plant communities should be burned to provide immediate and long-term browse regrowth, as well as diversity of browse species (Wolff and Zasada 1979). Aspen and willow provide immediate and abundant browse after a fire. Younger stands that may currently be good moose foraging habitat should be burned because these stands are the most productive and will result in the greatest immediate success of the program.

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