

SUMMER DIET COMPOSITION OF MOOSE IN ROCKY MOUNTAIN NATIONAL PARK, COLORADO

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ABSTRACT: Summer diet composition of habituated adult moose (*Alces alces*) in Rocky Mountain National Park, Colorado, was determined using direct observations and fecal analysis. Direct observations determined moose ate 20 different plant species, including 6 willow (*Salix* spp.) species, which comprised 91.3% of the overall diet from June through mid-September. Geyer willow (*Salix geyeriana*) accounted for 45.1% of summer diets. Other species included mountain alder (*Alnus incana*, 2.5%), quaking aspen (*Populus tremuloides*, 1.1%), and bog birch (*Betula glandulosa*, 1.0%). Aquatic plants accounted for 1.9%, forbs 1.1%, and grasses 0.9%. Moose ate 11 different species of woody browse, which comprised 96.9% of the diet. Species diversity in the diet peaked in July with 18 different species, including 7 species of non-woody browse. Fecal analysis showed moose consumed 79.3% willow; 11.9% less than direct observations indicated. Fecal analysis identified *Carex* spp. as a major contributor to moose summer diets (8.7%); a genus not identified by direct observation. Fecal analysis could not identify forbs, willow, or other shrubs to the species level, but identified all major genera (> 1%) contributing to moose summer diets that were indicated by direct observations, except quaking aspen (1.1%).

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Historically, moose (*Alces alces shirasi*) were rare in Colorado and early sightings recorded in Colorado were believed to be moose that wandered into the state from northwestern Wyoming (Bailey 1944). The Colorado Division of Wildlife (CDOW) introduced two groups of 12 moose near the town of Rand, Colorado, in 1978 and 1979; 13 km west of Rocky Mountain National Park (RMNP). The objective was to establish a viable resident moose population in the area. In June of 1980, the first moose was observed within the park, and the first moose to winter in the park was recorded in 1985-1986 (Stevens 1988). Presently between 61-66 moose are estimated to summer in the park (J. Dungan, University of Idaho, Moscow, Idaho, unpublished data).

Large mammalian herbivores can cause

major changes in plant community composition and structure (Augustine and McNaughton 1998). Herbivory is a major concern of RMNP where large numbers of Rocky Mountain elk (*Cervus elaphus*) occur. Managers are particularly concerned about effects on riparian willow (*Salix* spp.) and upland shrub communities, based on visual appearance of short-hedged willow on elk winter range. In a recent study, elk herbivory was found to suppress heights, leader lengths, and annual production of willow, and herbaceous productivity of willow sites within the park (Zeigenfuss et al. 1999).

High densities of moose have also been shown to influence the dynamics and structure of ecosystems. Bark stripping by moose in Denali National Park, Alaska, may increase the rate of succession in aspen-spruce com-

munities by killing trees (Miquelle and Van Ballenberghe 1989). Similar results were found in Isle Royale National Park, Michigan, where high rates of moose browsing depressed nitrogen mineralization and net primary production of boreal forest ecosystems (Pastor et al. 1993). Furthermore, McInnes et al. (1992) showed that moose herbivory reduced tree biomass and production, and increased shrub and herb biomass at Isle Royale.

Winter food supply is generally considered the limiting factor in some moose populations (Crete 1989, Kufeld and Steinert 1990, MacCracken et al. 1997, Zheleznov-Chukotsky and Votashova 1998). Woody browse is usually the only food supply available for moose during the winter, and therefore moose diet and habitat studies have focused on use, availability, and quality of winter browse (LeResche and Davis 1973). Few studies have examined use of summer habitat, although summer diets are generally 1.5–3 times more nutritious than winter diets (Schwartz 1992), and summer is a key period in which moose build up fat reserves that take them through the winter. Knowledge of moose summer diets benefits resource managers in making decisions on managing moose habitat.

Peek (1974) reviewed 41 food habit studies in North America, of which 18 were from the intermountain west, but none as far south as Colorado. Five of the 18 studies included summer food habits, and revealed even greater variation between areas than those on the winter range (Peek 1974). Summer diet studies have increased (Joyal and Sherrer 1978, Butler 1986, Van Ballenberghe et al. 1989), but none have investigated the southern extent of the Rocky Mountains.

In North Park, willow was the most commonly selected habitat by moose in all seasons between 1991 and 1995 (Kufeld and Bowden 1996). Similarly, willow comprised about 80–85% of the diet of wild adult moose in Denali National Park during the summer (Van Ballenberghe et al. 1989). The long-

term effects of moose browsing on riparian communities from Alaska to RMNP, is not yet understood. The purpose of this study was to document summer diet composition of moose in RMNP.

STUDY AREA

This study was conducted in RMNP during the summers of 2003 and 2004. RMNP is located in north-central Colorado just west of Estes Park. RMNP covers an area of 1,075 km² and ranges from 2,389 m to 4,345 m in elevation. The park lies astride the continental divide and the west and east side differ in climate. Annual precipitation ranges from 37.6 to 51.7 cm. Temperatures range from highs in July and August of 24°C to lows in December–February of –17°C (Monello and Johnson 2003).

We conducted this study predominantly on the west side of the park within the Colorado River Drainage and within higher elevation meadows east of the Continental Divide. The study was conducted at 2 distinct elevational strata, below 3,000 m (low elevation sites) and above 3,000 m (high elevation sites), because of differences in plant species composition, distribution, and plant morphology. Lower elevation sites tend to be comprised of a greater variety of plant species. Plants tend to be more sparsely distributed, and to be taller with longer leader lengths and greater biomass, than plants at high elevation sites.

Low elevation riparian meadows are characterized by large stands of geyer willow (*Salix geyeriana*), mountain willow (*Salix monticola*), drummond willow (*Salix drummondiana*), plane-leaf willow (*Salix planifolia*), and smaller stands of whiplash willow (*Salix lasiandra*), and wolf willow (*Salix wolfii*). Other common species are beaked sedge (*Carex utriculata*), bog birch (*Betula glandulosa*), mountain alder (*Alnus incana*), marsh reed grass (*Calamagrostis canadensis*), white clover (*Trifolium repens*),

and strawberry (*Fragaria ovalis*). These areas are surrounded by stands of ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), quaking aspen (*Populus tremuloides*), and narrowleaf cottonwood (*Populus angustifolia*). High elevation meadows are characterized by large stands of plane-leaf willow, wolf willow, and bog birch. Surrounding trees include quaking aspen, lodgepole pine (*Pinus contorta*), and subalpine fir (*Abies lasiocarpa*) (Beidleman et al. 2000).

METHODS

Over 3 million people visit RMNP annually. Viewing wildlife is a major visitor activity and traffic jams result when large animals such as moose are visible from park roads. As a result, moose within RMNP are accustomed to people and their habituation enabled us to directly observe feeding behavior and estimate diet composition. From 1 June through 15 September we observed the feeding behavior of moose at distances between 5-20 m. We recorded feeding data using hand-held voice recorders. Feeding data were grouped into feeding periods (bouts) defined as any span greater than 15 minutes in which the moose fed continuously. Miquelle and Jordan (1979) reported more than 95% of all bites recorded occurred during such bouts. We counted individual bites taken by foraging moose, and bites were classified by plant species when possible. Individual moose were followed as long as possible, and each continuous span was considered a single observation set. Bite counts were not conducted at night for observer's safety and compliance with park regulations.

During feeding periods the sizes of all bites were recorded to estimate intake rates, and bites were classified as small (1-5 leaves), medium (5-10 leaves), or large (> 10 leaves). After each observation set, simulated moose bites were collected by clipping 10-20 samples/species in each of the three sizes as closely to the observed bite size as possible.

These samples were bagged, oven-dried at 60°C for 48 hours, and weighed in accordance with methods described by Renecker and Hudson (1985). Average dry weight per bite (g/bite) for each size and species was calculated. Diet composition was based on percentage dry weight of species consumed by moose. This was derived by multiplying the number of bites taken of each species in each size class by the average dry weight per bite (Van Ballenberghe et al. 1989).

Fresh fecal samples were collected from observed moose during foraging bouts. Sample size ranged from 6 to 17 per month, and included pellets collected in October and November, while walking low elevation transects, to look at early winter diets. These samples were frozen and sent to the Wildlife Habitat Lab at Washington State University for microhistological analysis. Sub-samples of each fecal pellet group were combined with others from the same month and year. Fecal samples were blended with water, washed on a fine wire screen (200 mesh), and stained with a lactophenol blue stain. Relative cover (Korfhage 1974, Davitt 1979) of plant cuticle and epidermal fragments were quantified for 25 randomly located microscope views on each of four slides (total 100 views) per month. A 10 square x 10 square grid was used to measure area covered by each positively identified fragment observed at 100x magnification, and measurements of area covered were recorded by plant genus and species. Percent diet composition was calculated by dividing cover of each plant by total cover observed for all species, then multiplying by 100.

We compared differences in percentages of major plant species between years, elevations, months, and sexes for bite count data using a 1-way ANOVA. *Salix* species were pooled, and all percentages were Arcsine transformed in accordance with Krebs (1999). Experimental units were observations ($n = 54$), and pair-wise differences were located

Table 1. Summary of moose feeding data collected in Rocky Mountain National Park, Colorado from June 1st through September 15th, 2003 and 2004.

Month	Site (Elevation)	Observations	Female	Male	Feeding Bouts	Bites
June	Low	15	4	11	27	9,807
July	Low	17	4	13	60	20,324
	High	3	0	3	15	11,013
August	Low	7	3	4	32	15,277
	High	4	0	4	17	10,544
September	Low	6	0	6	21	7,692
	High	2	0	2	5	2,322
Totals		54	11	43	177	76,979

using the Tukey HSD procedure. Differences were considered significant at $\alpha < 0.05$, and all statistics were performed using SAS 8.3 (SAS Institute Inc., Cary, North Carolina) statistical software.

RESULTS

We recorded feeding data on 11 female and 43 male moose for a total of 54 observation sets (Table 1). Over 75,000 bites were counted during 177 feeding bouts (Table 1). Data from direct observations showed no difference between sexes and elevations ($P > 0.05$), but showed a significant difference ($F = 3.51$; $df = 3, 48$; $P = 0.02$) among months for mountain alder. Moose consumed significantly more mountain alder in late summer (September) than early summer (June). Likewise, a significant difference was found between years for western dock (*Rumex aquaticus*) ($F = 4.15$; $df = 1, 48$; $P = 0.04$) and triangular leaf Senecio (*Senecio triangularis*) ($F = 5.71$; $df = 1, 48$; $P = 0.02$). Moose ate significantly more western dock in 2003 and significantly more triangular-leaf Senecio in 2004. Other than the forementioned species, moose ate similar diets among months ($P > 0.05$) and years ($P > 0.05$). All bite count data were therefore pooled, for all animals, sexes, months, and years to estimate summer diet composition (Table 2). Moose consumed 11 different species of woody browse, which comprised 96.9% of the diet. Six willow species comprised 91.3 % of moose summer

diets. Geyer willow accounted for 45.1% of summer diets followed by plane-leaf willow (22.7%), mountain willow (11.7%), and drum-

Table 2. Percentage of plant species consumed by moose from June 1st through September 15th 2003 and 2004 in Rocky Mountain National Park, Colorado. Percentages were based on 76,979 bites classified to species and their associated weights, measured in grams/bite.

Species	Diet %
<i>Salix geyeriana</i>	45.10
<i>S. planifolia</i>	22.70
<i>S. monticola</i>	11.70
<i>S. drummondiana</i>	9.90
<i>Alnus incana</i>	2.50
<i>S. wolfii</i>	1.50
<i>Aquatic spp.</i>	1.30
<i>Populus tremuloides</i>	1.10
<i>Betula glandulosa</i>	0.97
<i>Grasses</i>	0.91
<i>Cirsium spp.</i>	0.71
<i>Rumex aquaticus</i>	0.47
<i>Senecio triangularis</i>	0.32
<i>S. lasiandra</i>	0.29
<i>Nuphar lutea ssp. Polysepala</i>	0.21
<i>Pentaphylloides floribunda</i>	0.16
<i>Psychrophila leptosepala</i>	0.03
<i>Mentha spicata</i>	0.02
<i>Pincus contorota</i>	Trace ¹
<i>Shepherdia canadensis</i>	Trace ¹

¹Trace species represented less than 0.01 % of the diet.

mond willow (9.9%). Geyer willow ranked first each month except in August 2003 when it ranked third behind mountain willow and drummond willow. Other woody species included mountain alder (2.5%), quaking aspen (1.1%), and bog birch (1.0%). Aquatic species accounted for 1.9%, forbs 1.1%, and grasses at 0.9%. Species diversity peaked in July with moose eating 18 different species, including 7 species of non-woody browse.

Monthly fecal analysis for 2003 showed moose relied more heavily on species other than willow in June, most notably *Carex* spp. (46.4%, Table 3), then increased willow consumption in July with a peak in August at 90%. In September, willow consumption began to decrease and early winter diets included species other than willow, most notably conifer needles (34.1%), shrubs (18.1%), and *Carex* spp. (11.6%, Table 3).

Fecal analysis data were pooled for all months and years, with the exception October/November 2003, to show summer moose diet composition (Table 4). Fecal analysis showed moose consume 79.3% willow, which is 11.9% less than direct observations indicated (Table 4). Fecal analysis identified *Carex* spp. as a major contributor to moose summer diets (8.7%), and was not identified by direct observation. Fecal analysis was not able to identify forbs, willow, or shrubs to the species level, but identified all major genera (> 1%) identified by direct observations with the exception of quaking aspen

(1.1%, Table 4). With the exception of *Carex* spp., both techniques showed similar results (Table 4).

DISCUSSION

Moose summer diets in RMNP consisted of 11 different species of woody browse, which accounted for roughly 97% of the overall diet. These results are similar to those found by Van Ballenberghe et al. (1989) in Denali National Park, Alaska, where woody species made up 96% of moose summer diets, and Joyal and Scherrer (1978) in Mont-Tremblant Park, Quebec, where moose summer diets consisted of 100% woody browse. Moose in RMNP use riparian willow communities during the summer, which contain little aquatic vegetation or forbs. Moose were observed eating 9 different non-woody species. Studies in less mountainous habitats have found moose consume larger proportions of forbs (25%, LeResche and Davis 1973; 70.6%, Knowlton 1960) and aquatics (9.3%, McMillan 1953) than those in RMNP. Forbs and aquatics may contain higher concentrations of important minerals (Belovsky 1978), and have higher digestibility levels than woody browse (LeResche and Davis 1973). Forbs and aquatics only accounted for 2.4% of the overall summer diet of moose in RMNP.

Moose ate 6 willow species comprising 91.3% of their summer diets, with geyer willow accounting for 45.1%. Results were similar to those found by McMillan (1953) for

Table 3. Percent of major plant species consumed by moose in Rocky Mountain National Park, Colorado per month for 2003, and by year for 2004, as indicated by fecal analysis.

Plants	Jun-03	Jul-03	Aug-03	Sep-03	Oct/Nov 03	2004
Grasses	2.10%	0.00%	0.60%	0.80%	8.90%	7.70%
<i>Carex</i> spp.	46.40%	5.00%	0.10%	3.80%	11.60%	3.60%
<i>Salix</i> spp.	48.00%	88.20%	90.00%	82.90%	25.30%	81.40%
Shrubs	0.40%	6.00%	9.30%	11.50%	18.10%	6.90%
Conifer needle	0.70%	0.00%	0.00%	0.00%	34.10%	0.20%
Forbs	2.40%	0.60%	0.00%	1.00%	2.00%	0.00%
Sphagnum Moss	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%
Insect	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%

Table 4. Percent diet composition of major plant species consumed by moose in Rocky Mountain National Park, Colorado from June 1st through September 15th, 2003 and 2004, using direct observations and fecal analysis. All months and years were pooled for both techniques.

Species	Fecal Analysis	Bite Count
<i>Salix</i> spp.	79.3	91.3
<i>Carex</i> spp.	8.7	-
Shrubs	6.8	3.6 ¹
Grasses	4.3	0.91
Aquatics	0.11	1.98 ²
<i>Populus tremuloides</i>	-	1.12
Forbs	0.51	1.08 ³
Conifer needles	0.19	Trace ⁴
Insects	0.02	-

¹Shrubs consisted of *Alnus incana*, *Betula glandulosa*, *Pentaphylloides floribunda*, and *Shepherdia Canadensis*.

²Aquatics consisted of *Aquatic* spp., *Nuphar lutea* spp. *Polysepala*, and *Rumex aquaticus*.

³Forbs consisted of *Cirsium* spp., *Mentha spicata*, *Psychrophila leptosepala*, and *Senecio triangularis*.

⁴Trace species represented less than 0.01 % of the diet.

moose in Yellowstone National Park (willow 88.5%) and Van Ballenberghe (1989) in Denali National Park (81.5%). Similarities of diet composition of moose in RMNP and moose in Denali National Park suggest use of very similar habitats during the summer. Willow habitats not only provide a high quality woody browse for consumption (LeResche and Davis 1973) but are also used extensively for cover (Kufeld and Bowden 1996).

Fecal analysis showed moose rely more heavily on grasses, sedges, and forbs (50.9%) in early summer than woody browse (49.1%). Peek (1974) found that grasses and sedges were seldom consumed other than in spring, when digestibility and nutrient content are high. Consumption of willow species increased in July, peaked in August, and started to decline in September. Both techniques

showed the same trend, with exception of June bite count data, suggesting moose eat willow when available biomass and nutrients are high (Stumph 2005) and rely less heavily on willow in spring and fall when available biomass and nutrients are lower. Early winter fecal analysis showed willow comprised only 25.3 % of the diet, whereas conifer needles made up 34.1%, and grasses, forbs, and sedges made up 22.5 %. Forbs and grasses comprised relatively larger percentages of fall diets than winter diets (Peek 1974). During both years we observed moose moving out of the lower riparian willow communities, with the onset of the rut, and moving into higher more heavily forested areas of the park, possibly giving a reason for the large percent of conifer needles in early winter diets. In a study conducted from December 1991 to November 1995, moose from North Park, Colorado, tended to winter at lower elevations and move to higher elevations during spring, summer, and fall (Kufeld and Bowden 1996). Winter transect data showed little use of low elevation riparian willow communities from October through December for both years. Willows were the primary forage plants in 5 out of 6 winter diet studies reviewed by Peek (1974), and Risenhoover (1987) reported that willow comprised 94.3% of winter diets in Denali National Park. Stevens (1970) reported timber types received 82% of total use during the winter in the Gallatin region of Montana. October/November fecal analyses coupled with winter transect data suggest that willow may not constitute a large proportion of moose winter diets in RMNP, although a comprehensive study of winter diets has not been performed.

Similar results were achieved using bite count data and fecal analysis. Direct observations failed to detect the large amount of sedges consumed by moose in early summer, which was largely affected by adult movements during June. Older, more habituated moose had not yet moved to summer range from

winter range, necessitating that our sample be focused on younger, less habituated moose. This caused us to miss a large proportion of feeding data per day, which could account for some of the variation. Grasses were also slightly higher (3.4%) in fecal analysis than direct observations. Consumption of grasses and sedges is hard to observe because of their low growth form, and bites were not recorded when species could not be identified, a factor which could also lead to differences between the two techniques. Wallmo et al. (1973) reported bite count methods estimated more use of shrubs as a class and less use of grass and forbs than actually occurred for mule deer (*Odocoileus hemionus*).

Fecal analysis could not differentiate willow, forb, or shrub species, and failed to detect *Populus tremuloides*. Other species not detected by fecal analysis included *Cirsium* spp., *Rumex aquaticus*, *Senecio triangularis*, and *Nuphar lutea* ssp. *Polysepala*, but these species were less than 1 % of the observed diet. Monthly fecal sample size was smaller than similar studies, which could have contributed to not detecting these species.

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