SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

MOOSE FOOD HABITS AND NUTRITIONAL QUALITY FORAGE IN THE MIDDLE SUSITNA RIVER BASIN, ALASKA

PREPARED BY

LGL

Alaska Research Associates

UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE

FINAL REPORT

MAY 1986
DOCUMENT No. 3422

Alaska Power Authority

Document No. 3422
Susitna File No. 4.3.3.2

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Report by
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Under Contract to
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Prepared for
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Final Report
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NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

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INTRODUCTION

The proposed Susitna Hydroelectric Project in the middle Susitna River basin of southcentral Alaska would permanently remove habitat used by wintering moose. In early 1983 the Alaska Power Authority made a decision to pursue assessment of proposed project impacts on moose habitat by developing estimates of loss of nutritional carrying capacity. Nutritional carrying capacity can be defined as the size of a healthy and productive population that the available food resources of a unit of land can maintain without permanently degrading habitat quality. A ruminant computer simulation model specific to moose being developed by the Alaska Department of Fish and Game (ADF&G) was to be used to develop nutritional carrying capacity estimates. This model integrates nutritional requirements of the animal with those forage nutrients supplied by the habitat. Forage nutrients generally considered most important (limiting) to ruminants are energy and nitrogen. For ruminants such as moose, digestibility of winter forages is also important. The ruminant simulation model was developed and tested by ADF&G on the Kenai Peninsula. Specific information was required to adapt the model to predict carrying capacity for the Susitna project area.

This report is divided into 2 sections. Section I documents the results of 2 studies designed to provide information specific to the project area. In the first study, winter food habits of moose in the middle Susitna River basin were determined from fecal pellet analysis. The second study documents seasonal nutritional quality and digestibility of those plant species eaten by moose during winter. The results of these 2 studies have been written in a format preparatory to their submission for journal publication, and are presented in that format. References to figures, tables, and literature citations within the text of each study in Section I are specific to the respective study only.

Section II of this report combines and summarizes the results of the 2 previous studies into meaningful inputs to the carrying capacity model. This section also provides justification, rational, and recommendations for certain related assumptions that will be made in the carrying capacity model simulation runs. References to figures, tables, and literature citations within Section II are specific to this section only.

SECTION I

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WINTER FOOD HABITS OF MOOSE IN THE MIDDLE SUSITNA RIVER BASIN, ALASKA

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Abstract: Winter food habits of moose (Alces alces gigas) in the middle Susitna River basin of southcentral Alaska were determined from microhistological analysis of fecal pellets. Pellet samples were collected from line transects and analyzed separately for 9 areas within

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the study area. Willow (Salix) was the dominant component in fecal samples, averaging 72% for all areas and ranging from 40-87%. Resin birch (Betula glandulosa) averaged 11% for all areas (range 3-16%). Mountain cranberry (Vaccinium vitis-idaea) was highest at 2 western sites (27% and 41%) but was relatively low in other areas. Other species were minor components of fecal samples. Regional abundance and distribution of willow appeared to influence diet composition. We were unable to calibrate fecal pellet analysis by differential in vitro digestion and microhistological fragment identification of residue for the major dietary components. Accuracy and reliability of data is in question whenever the microhistological technique is used.

KEY WORDS: Moose, Alces alces gigas, Susitna, southcentral Alaska, winter, food habits, diet, forage, willow, Salix, in vitro, digestibility, IVDDM.

Several studies on moose and their habitat in the middle Susitna River basin implicated woody browse species as the major component of winter diets. McKendrick et al. (1982) reported that willows were observed to be the most heavily browsed species in all vegetation stands sampled. Resin birch shrub communities were noted to have received moderate use, while only individual American green alder (Alnus crispa) plants appeared to be heavily browsed (McKendrick et al. 1982). Ballard et al. (1982) suggested that distribution of willow strongly influenced seasonal distribution of moose, and that willow distribution was useful in determining the importance of habitats to moose populations. Steigers et al. (1983) reported twig utilization by moose in 9

STUDY AREA

The study area was located in the middle Susitna River basin in southcentral Alaska (Fig. 1). Generally, the area was a broad U-shaped valley occupied by the Susitna River. Numerous tributaries drained into the river along its course. River elevations ranged from about 270 m on the western end of the study area to approximately 750 m on the east. Topography has been strongly influenced by glacial action and associated river and stream erosion. Extensive sedimentary terraces perched above the river channel were approximately 610-760 m in elevation, and made up a majority of the study area. The specific areas from which samples were collected generally bordered and paralleled the Susitna River for approximately 120 km along its east-west orientation.

Numerous plant communities characteristic of the northern boreal forest occurred in the study area. R.A. Kreig and Associates, Inc. mapped 92 vegetation types to levels III and IV of Viereck and Dyrness (1980; 1982 revision). Distribution of plant communities was strongly influenced by site topography, soils, and moisture regimes. Feltleaf willow (Salix alaxensis) was the predominant shrub growing along riverine and stream riparian zones and on disturbed sites. Steep, well-drained river channel slopes were dominated by communities of mixed paper birch (Betula papyrifera)-white spruce (Picea glauca) forests and open coniferous spruce forests. Terraces at higher elevations above the river were primarily shrub communities dominated by resin birch

on the drier sites, with white spruce forests on moderately drained slopes, and black spruce (Picea mariana) forests on wetter, poorly drained sites. Willows, primarily diamondleaf willow (Salix pulchra), grayleaf willow (S. glauca), and Richardson willow (S. lanata), dominated the shrub communities in wetter sites on upland slopes and intermixed with resin birch in coniferous forests. Alpine vegetation types occurred at the highest elevations.

METHODS AND MATERIALS

Winter fecal pellets of moose were collected along 32 line transects as part of another study (Helm and Mayer 1985) during early spring (late April through early May) 1983 (Fig. 1). At each of 9 areas, 2 non-randomly placed parallel transects approximately 100 m apart on either or both the north- and south-facing slopes of the Susitna River channel were walked by observers. Twenty-eight transects at 8 sites extended from the upland terraces downslope to the Susitna River or major tributary. Four transects at 1 site (Fog Creek) extended generally downslope parallel to a tributary located on a terrace above the Susitna River. Transects ranged in length from 1.2-1.6 km.

Fecal pellets were collected opportunistically from atop melting snow along the transects to ensure they had been reliably deposited during the winter months. Four pellets were randomly collected from each pellet group. Pellet samples were composited within each of the 9 areas. Because pellets were collected opportunistically, total sample size in the composite varied among areas. Fecal samples were forced-air oven-dried at 60 C for 48 hours, then ground once through a Wiley mill using a 1 mm screen (Holechek and Gross 1982). For each area, subsamples were taken equal to one-half (1 extra if a fraction) of the total number of samples in each composite.

Microhistological examination was used to identify food items in fecal pellets (Sparks and Malecheck 1968, Free et al. 1970, Dearden et al. 1975). This procedure has many advantages as discussed by Holechek et al. (1982). Three microscope slides were prepared from each subsample, which was considered to provide adequate sampling intensity for major species in the fecal pellets. Twenty valid microscope fields were read at 125x on each slide (Holechek and Gross 1982). A valid field had to contain at least 2 discernible plant fragments. A discernible plant fragment was defined by Johnson et al. (1983) as a fragment "having at least 2 distinct anatomical characteristics, such as silica bodies, trichomes, or stomates". Data was recorded as frequency of occurrence of discernible fragments in a field in relation to the total number of fields read. This has been called the "percent frequency addition" procedure by Holechek and Gross (1982), and was statistically evaluated in their study. Only the frequency of occurrence of discernible fragments in the microscope field were recorded. Discernible fragments included both known and unknown species. Ubiquitous fragments of plants such as xylem, protoxylem, and phloem were not recorded.

All plants were identified to species when technically possible. Forbs and graminoids were identified and compiled as life form categories. Every effort was made to identify to genera and species all unknown plant fragments that made up a substantial proportion of the sample composition. Viereck and Little (1972) was used as the vernacular authority for scientific and common names of plant species.

To calibrate for possible differential digestion of the major plant species found in the fecal samples, in vitro digestible dry matter (IVDDM) was determined for plant species alone and in combination as test diets. Current annual growth twigs of willow, resin birch, whole mountain cranberry plants (twigs and leaves), and moss (primarily

Sphagnum sp.) were collected during October from the study area, forced-air oven-dried for 48 hours at 60 C, and ground once through a Wiley mill using a 1 mm screen. For these analyses, 60:40 willow was composed of ground current annual growth twigs of diamondleaf willow and feltleaf willow, respectively, in a 60:40 ratio dry weight mixture. Five test diets each comprised of 60:40 willow, resin birch, mountain cranberry, and moss were prepared. Levels for each forage in the diet mixtures ranged over the approximate percentages observed from the fecal pellet analysis. Diet proportions were weighed using a Mettler electronic balance to the nearest 10^{-4} g. IVDDM was determined using the method of Tilley and Terry (1963) as modified by Goering and Van Soest (1970). IVDDM trials were run in triplicate using bovine rumen inoculum obtained from a mature Holstein dairy cow fed brome (*Bromus*) hay and dairy ration. All IVDDM analyses were run concurrently from the same inoculum source, and the data expressed as a percent of digested dry matter.

Residue from each replicate of the IVDDM trials for the 5 test diets were analyzed for dietary composition using the microhistological technique. Methods followed those previously described except 5 slides were read per residue sample. The same observer and reference slides were used for both the fecal and residue analysis. Neither composition or proportions of plant species in the IVDDM residue were known to the technical observer conducting the microhistological analysis.

RESULTS

Fecal Analysis

A total of 199 fecal samples were collected from pellet groups along transects at the 9 areas. Twenty-six samples were collected from

Devil Creek, 9 from Tsusena Creek, 31 from Fog Creek, 33 from Watana Creek, 14 from Watana Slide, 14 from Cassie Creek, 23 from Kosina Creek, 11 from Clarence Creek, and 38 from Oshetna River transects (Fig. 1). A total of 102 subsamples were prepared from the fecal samples.

Analysis of the winter fecal samples showed that willow was the dominant component for all areas sampled in the middle Susitna River basin (Table 1). Epidermal trichomes characteristic of the genera could not be used to distinguish among individual species of willow using the microhistological technique. Based on percent dry weight composition of identified fragments, willow ranged from a high of 87% at the Watana Slide area to a low of 40% at the Tsusena Creek area. Within the 7 areas in the eastern half of the study area bordering the Susitna River (Watana Creek to Oshetna River), percent composition of willow was 77%. These eastern transects generally traversed a greater proportion of upland benches and coniferous forests where willow forage biomass was higher than in the deciduous forests common in the western half of the study area (Devil Creek to Tsusena Creek) (Becker and Steigers 1986). Fecal composition of willow was lowest in the western half where it averaged 46% from the 2 areas (Table 1).

Composition of resin birch in fecal samples was 11% for all areas, ranging from 3-16% (Table 1). Excluding the lowest value at the Tsusena Creek area (3%), resin birch composed a fairly consistent but moderately low percentage of fecal samples over the entire study area.

Fecal composition of mountain cranberry was greatest in the 2 western areas (Table 1). Forty-one percent of the fecal samples collected at the Tsusena Creek area were composed of mountain cranberry. An increased component of mountain cranberry at the 2 western areas might have been related to the decreased availability of willow (Becker and Steigers 1986). Percent composition was low for all eastern areas except Cassie Creek and Kosina Creek, which had 11% and 15%, respectively (Table 1).

Similar to mountain cranberry, percent composition of graminoids was also greater at the 2 western areas (Table 1). Presumably, moose were foraging more at the dwarf shrub and ground layer vegetation levels in the western part of the study area where deciduous forests were more predominant and the primary food source of willow was less abundant (Becker and Steigers 1986). Percent composition of graminoids was relatively low in the fecal samples at all western areas (Table 1).

Paper birch was found to be present in fecal samples only at the Watana Creek area (Table 1). Quaking aspen (Populus tremuloides) alder, lichens, and forbs and other shrubs were minor components in fecal samples throughout the study area (Table 1).

Dietary Calibration

In the preliminary analysis of the fecal samples, moss was initially identified as both a consistent and relatively important component. Proportions of moss ranged from 12-23% over the 9 areas, averaging 18% for all areas. Prevalence of moss in fecal samples was not easily explained. Though it was the dominant ground-layer plant species in the study area (Steigers et al. 1983), it was not considered to be moose forage. Because the dwarf shrub mountain cranberry grew interspersed with the moss, it was conjectured that moss might have been inadvertently consumed in the process of foraging for mountain cranberry. Field observations of mountain cranberry foraged from craters dug in the snow by moose lended support for this argument.

However, mosses were reported to be "completely indigestible", highly fragmented, and easily identified in microhistological analysis by Dearden et al. (1975). Thus, calibration of differential digestibility, fragmentation, and fragment identification rate was undertaken to prevent overestimation of mosses and underestimation of other forages in our data.

Results of <u>in vitro</u> digestion showed mountain cranberry was the most highly digestible species, whereas moss was the lowest (Table 2). IVDDM for the 60:40 willow mixture (34.3%) was close to the predicted IVDDM from proportionalized individual values for diamondleaf willow and feltleaf willow (33.9%) (Table 2). IVDDM of moss (20.3%) was substantially higher than the "completely indigestible" of Dearden et al. (1975). IVDDM results closely paralleled those reported for the same study area by Steigers et al. (1986) using moose rumen fluid.

We were unable to calibrate results of the fecal sample microhistological analysis because reliable linear regression relationships could not be developed between true proportions and proportions resulting from analysis of IVDDM residue of the test diets (Table 3). High variation between true proportions and residue proportions, high variation among residue replications, and misidentification of species in IVDDM residues were the primary causes. Differences ranging to 67% IVDDM between true and individual replication proportions of residue were found in several test diets. Microhistological analysis of undigested fractions of the test diets yielded similarly variable results for many the same reasons (Table 3).

It was learned during the course of the microhistological analysis of IVDDM residue, however, that what had originally been identified as mosses were in fact stem structures (laticifers) of willows. Furthermore, it was learned that none of the species under study were exempt from misidentification using the microhistological technique.

Experimentally determined digestibility of the mixed test diets (determined IVDDM) was found to be very similar to the summation of digestibilities of the component diet items weighted by proportion (predicted IVDDM) (Table 3). There did not appear to be general trends between the 2 values as a result of changing proportions of the species in the test diets.

DISCUSSION

This study has shown that willows were the major component of winter diets of moose in the study area. The technique used to identify dietary fragments did not allow separation of the willows by species. However, other studies have shown that the species of willows that are dominant components of the vegetation communities of the study area all contribute to the forage resource. Studies conducted by Steigers et al. (1983) documented that diamondleaf willow, grayleaf willow, Richardson willow, and feltleaf willow were the most common willows in vegetation types where they occurred; diamondleaf willow was the most common of the willows. Diamondleaf willow had the highest current annual growth biomass of all willows in the study area (Becker and Steigers 1986). Other species of willows also grow in the study area, but they generally make up a small proportion of the willow biomass (Becker and Steigers 1986). Steigers et al. (1983) reported that individual species of willows were browsed by moose in approximate relative proportion to their stem density.

Pellets collected along line transects passed through numerous different vegetation types and along a continuum of elevational gradients. There was no definite means to determine exactly the area where the forage which was the source of the pellets was consumed. Pellet samples were grouped by geographic area primarily to represent possible variation in diets along the east-west orientation of the Susitna River drainage within the defined study area boundaries. The results indicate similar diets throughout the eastern half of the study area, with willow predominating. The western half of the study area had less willow biomass in the understory layer in the river canyon (Becker and Steigers 1986), and this was reflected in the fecal analyses.

Resin birch was a common shrub species in the study area. It was not considered a preferred forage species for moose, and was utilized only lightly in relation to its availability (Steigers et al. 1983). Availability of forage biomass of resin birch was not a factor limiting its intake by moose (Becker and Steigers 1986). However, it appears that moose will voluntarily consume resin birch up to approximately 15% of the diet. Murie (1944) reported that dwarf birch (Betula nana) was regularly browsed by moose in Denali National Park.

The frequency of occurrence of mountain cranberry in fecal pellets of moose was high in the Devil Creek and Tsusena Creek areas. Moose may have been expending more effort locating and consuming mountain cranberry growing at the dwarf shrub layer in the western part of the study area where willow was less abundant. While tracking moose through snow near the mouth of Tsusena Creek in March, it was observed that mountain cranberry was exposed directly beneath the canopies of spruce trees while between tree canopies it was covered by snow approaching 75 cm deep. Tracks led from tree to tree as moose were apparently feeding on the exposed mountain cranberry and other ground-layer vegetation. LeResche and Davis (1973) described similar cratering by moose for mountain cranberry on the Kenai Peninsula. On a depleted Kenai Peninsula winter range, mountain cranberry composed 51% of observed bite counts (LeResche and Davis 1973). Deep snow cover persists throughout most of the winter in the study area, making mountain cranberry, lichens, and other ground-layer plants of limited availability as moose forage. Mountain cranberry is only considered limited to a maximum of 20% of the average moose diet in the study area during the period January through April in winters of light or average snowfall and during the period December through April in winters with early, deep snowfall.

Paper birch as forage for moose occurs in the study area primarily as adventitious basal shoots from mature trees, and to a lesser extent in disturbed areas such as streambanks and slides (Steigers et al. 1986). Observations of only light browsing pressure on paper birch throughout the study area support the conclusion of low dietary composition found in this study. However, it is unknown whether this is a result of fewer numbers of moose utilizing the steeper canyon slopes where paper birch grows, or the possibility that the paper birch forage available to moose is in some way less palatable than regrowth available in other areas such as the Kenai Peninsula. Higher phenolitic resin content in adventitious basal sprouts than in mature tree crown twigs (Bryant 1981) may have inhibitory effects on digestibility of paper birch (Reisenhoover et al. 1985), thus affecting its rate of ingestion as forage by moose (Steigers et al. 1986). Paper birch as a dietary component in the study area is limited primarily by availability of forage biomass.

Quaking aspen occurred infrequently in the middle Susitna River basin. Alder was a relatively common species, but observations during previous studies (Steigers et al. 1983, Steigers and Helm 1984) documented that moose avoided browsing alders growing in dense stands. Certain individual alder plants, especially those with new twig regrowth following previous browsing and those growing on recently disturbed sites with a high willow:alder ratio, were occasionally browsed.

The inability to accurately and reliably estimate true proportions in test diets using the microhistological technique throws some doubt on the validity and accuracy of the original analysis of fecal samples. On one hand, we might partially explain the decrease in willow and increase in mountain cranberry at the 2 western areas by misidentification of species. On the other hand, other evidence on differential regional forage availability exists (Becker and Steigers 1986) that suggests there are viable reasons to support the results as presented. In our studies the technical observer was not informed of the species composition of the test diets; the results would likely have been less variable had the technician been informed. The technician did, however, use the same reference slide collection and knew they were winter test diets for moose.

Obviously, misidentification of identifying characteristics and the inherent difficulty in identifying fragments from woody tissue were the major problems encountered using the technique. Probably the greatest lesson learned though the analysis of IVDDM residue was that the microhistological technique should be used only to obtain probable species composition in diets and and generally broad ranges of percent composition. This technique is not a sufficiently reliable tool to use for dietary analysis other than to obtain gross estimates of composition. With the above guidelines in mind, we can document that the dominant component of moose winter diets in the middle Susitna River basin is willow. During mid- and late-winter (December through April), willow may comprise up to 90% of the diet. A maximum of 15-20% of the winter diet is resin birch. Mountain cranberry and graminoids are usually covered by snow during winter when forage availability becomes limiting; their use is probably governed by accessibility during the mid-and late-winter critical periods. Other species are minor winter dietary components.

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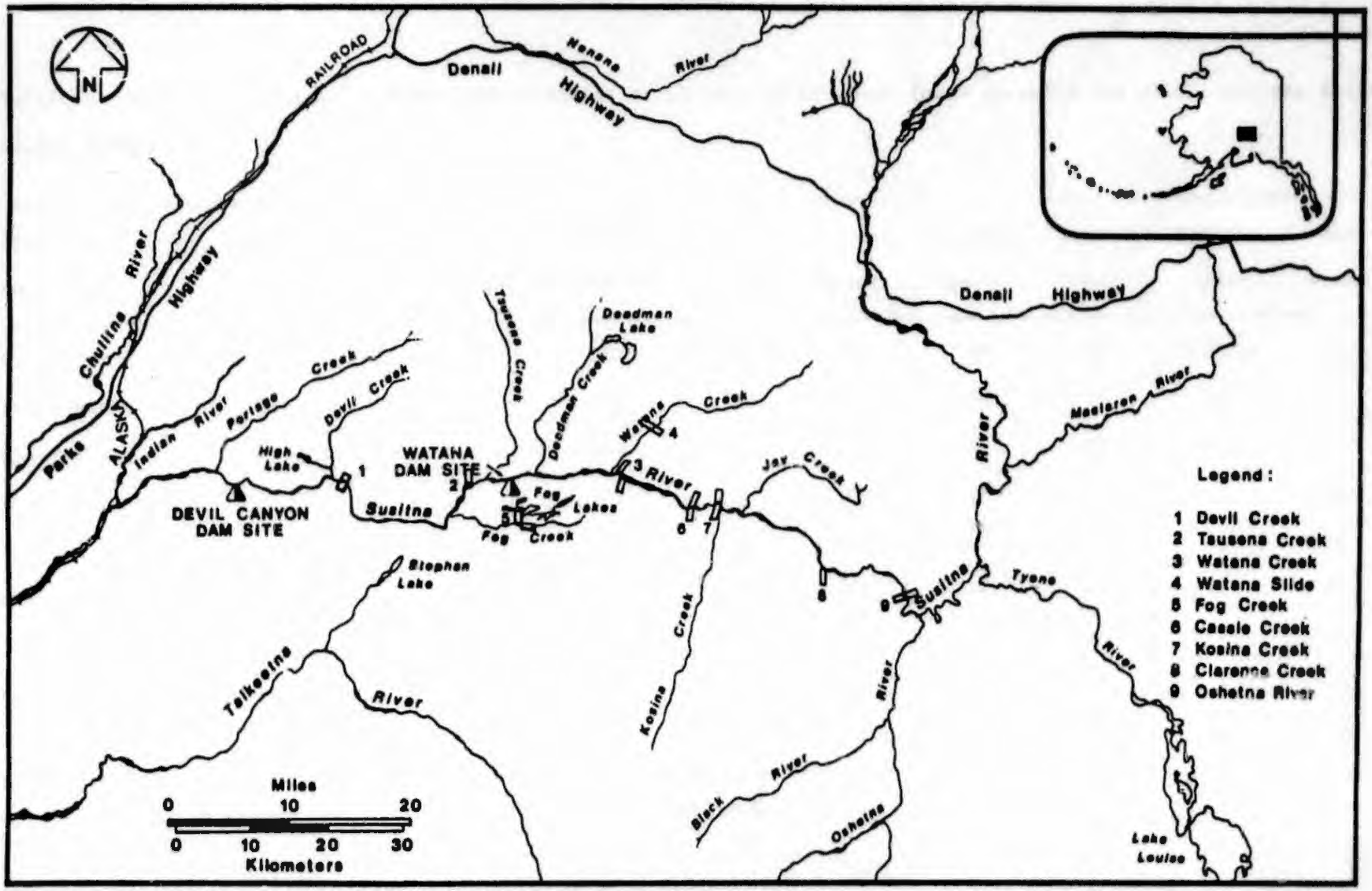

Figure 1. Transect locations for collection of winter moose fecal pellets for the moose food habits study.

Table 1. Percent dry weight[a] composition of winter fecal pellets of moose for 9 areas in the middle Susitna River basin, Alaska.

Dietary Component	Devil Creek	Tsusena Creek	Watana Creek	Watana Slide	Fog Creek	Cassie Creek	Kosina Creek	Clarence Creek	Oshetna River	All areas
Willow	49	40	71	87	80	80	69	84	80	72
Resin birch	10	3	14	7	9	7	10	9	16	11
Paper birch	--	--	4	--	--	--	--	--	--	1
Mountain cranberry	27	41	1	1	3	11	15	1	1	8
Quaking aspen	--	--	5	--	--	--	--	--	1	1
Alder	--	--	--	--	--	--	--	--	<1	<1
Lichen	--	1	--	<1	--	--	--	--	--	<1
Graminoid	12	14	2	3	5	<1	4	5	1	4
Forb & Other Shrub	2	2	3	3	3	2	2	3	2	2

[a] Due to rounding error, the dry weight may not total 100%.

Table 2. Percent IVDDM of individual plant species and species combinations in the middle Susitna River basin as determined using bovine rumen inoculum.

	IVDDM	
Species	$\bar{x}$	SD
Diamondleaf willow	39.8	--[a]
Feltleaf willow	28.0	--[a]
60:40 willow	34.3	1.3
Resin birch	27.8	0.6
Mountain cranberry	44.2	1.6
Moss	20.3	0.8

[a] 1 in vitro replication

Table 3. Percent dry weight composition and IVDDM using bovine inoculum of 5 test diets.

Test Diet	Treatment	60:40 willow	Resin birch	Mountain cranberry	Moss	Alder	Aspen	Determined IVDDM(SD)	Predicted IVDDM(SD)
1	True proportion	70	10	19	1	0	0	33.9(0.1)	35.4
	$\bar{x}$ Undigested	85	10	0	0	5	0		
	$\bar{x}$ Digested(SD)	69(4.7)	5(6.4)	26(1.7)	0	0	0		
2	True proportion	67	1	29	3	0	0	37.9(1.1)	36.7
	$\bar{x}$ Undigested	66	7	4	0	0	23		
	$\bar{x}$ Digested(SD)	59(1.7)	3(1.0)	38(2.0)	0	0	0		
3	True proportion	45	25	10	20	0	0	27.1(0.8)	30.9
	$\bar{x}$ Undigested	63	34	3	0	0	0		
	$\bar{x}$ Digested(SD)	66(5.1)	22(3.1)	6(7.4)	0	4(3.5)	2(4.0)		
4	True proportion	86	6	1	7	0	0	34.4(0.6)	33.0
	$\bar{x}$ Undigested	81	19	0	0	0	0		
	$\bar{x}$ Digested(SD)	85(13.3)	9(8.2)	1(1.7)	0	5(4.0)	0		
5	True proportion	25	15	50	10	0	0	33.8(1.0)	36.9
	$\bar{x}$ Undigested	59	21	20	0	0	0		
	$\bar{x}$ Digested(SD)	72(17.3)	5(0.6)	17(13.5)	0	6(6.0)	0		

QUALITY OF WINTER MOOSE FORAGE IN THE MIDDLE SUSITNA RIVER BASIN, ALASKA

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Abstract: Nutritional quality of winter forages of moose (Alces alces gigas) in the middle Susitna River basin of southcentral Alaska were evaluated for in vitro digestible dry matter (IVDDM) and crude protein content. Current annual growth twigs from 6 deciduous hardwood shrubs and leaves and stems from 1 evergreen dwarf shrub were collected during 2 winter sample periods. There was no significant difference in IVDDM between sample periods for the 7 species and no difference in crude protein between sample periodss for all species excluding paper birch. Crude protein was different between sample periods only for paper birch; differences were probably artifacts of sampling rather than changes over time. The dwarf shrub mountain cranberry (Vaccinium vitis-idaea) had the highest IVDDM but the lowest crude protein content of the 7 shrubs. IVDDM was not different among diamondleaf (Salix pulchra), grayleaf (S. glauca), and Richardson (S. lanata) willows, but feltleaf willow (S. alaxensis) was substantially lower. IVDDM of both paper birch (Betula papyrifera) and resin birch (B. glandulosa) was lower than any of the willows. Crude

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protein content was highest for paper birch and resin birch, and lowest for mountain cranberry. Diamondleaf willow had the highest, and grayleaf and Richardson willow the lowest, crude protein values of the willows. A significant inverse correlation was found when IVDDM and crude protein values were compared for the same species within December (r=-0.82) and March (r=-0.81) sample periods, and pooled across sample periods (r=-.75, excluding paper birch).

KEY WORDS: Moose, Alces alces gigas, Susitna, southcentral Alaska, winter, nutrition, forage, willow, Salix, in vitro, digestibility, IVDDM, crude protein, nitrogen.

The quality of forage is an important consideration when evaluating the capacity of rangelands to support wildlife populations. Forage quality has been commonly reported in terms of cellular constituents including fiber components and proteins. In vivo or in vitro dry matter digestibility of plants eaten by ruminant animals are also usually reported. Several workers (Short 1966, Brown and Radcliffe 1971, Robbins et al. 1975, Robbins and Moen 1975, Oldemeyer et al. 1977) have attempted with limited success to correlate dry matter digestibility with various nutritive parameters such as crude protein, organic material, energy digestion, crude fiber, cellulose content, other crude fiber constituents, and minerals.

Most workers (Morrison 1954, Bissell and Strong 1955, Dietz 1970, Oldemeyer 1974) consider dietary crude protein the most important plant nutrient because it provides nitrogen required by rumen microorganisms for digestion of carbohydrates, and is essential for ruminant body maintenance, growth, reproduction, and lactation. Crude protein is often the most limiting nutrient for wild ruminants, particularly during winter when woody plants which are low in protein dominate the diet.

Digestibility is also an important determinant of the quality of forage. An evaluation of forage digestibility determines the amount of nutrients utilized per unit consumed. Lower digestibility hardwood browse species often dominate wild ruminant diets in winter.

Several studies have reported on the quality of forage in Alaskan moose diets. Much of the work reported in Alaska has been on the Kenai Peninsula. LeResche and Davis (1973) described the in vitro digestibility and nutritional analysis of forages eaten by Kenai moose. Oldemeyer (1974) also reported the results of in vitro digestion of 3 browse species used on the Kenai. In vitro digestibility, nutrient content, and mineral composition of Kenai forages were described by Oldemeyer et al. (1977). Forage quality determined from rumen contents was reported for interior Alaska moose by Gasaway and Coady (1974). Crude protein content of willows was described for sites in interior Alaska by Milke (1969) and for both interior Alaska and the Kenai Peninsula by Machida (1979). Crude protein and in vitro digestibility of representative diets of Kenai Peninsula moose was described by Regelin et al. (1986).

These studies provided specific nutritional quality information on forage species used by moose in their respective areas of study. However, similar information was not available for the middle Susitna River basin where plant species composition and dietary proportions differed widely from results reported from other geographically distant studies (Steigers et al. 1986). The primary objective of this study was to provide area-specific information on the digestibility and crude protein content of winter forages used by moose in the middle Susitna River basin of southcentral Alaska. A secondary objective was to determine if digestibility and crude protein content of the dormant shrubs changed over the course of the winter. This information was required as part of a larger program to estimate nutritional carrying capacity of the study area.

R.H. Pollard of LGL Alaska Research Associates, Inc. (LGL) and M.G. McDonald, T.A. Otto, and R.W. Castle of the Alaska Department of Fish and Game (ADF&G) assisted with field collection of plant samples. L.D. Aumiller of ADF&G and R.H. Pollard of LGL prepared samples for laboratory analysis. M.E. Hubbert and C.C. Schwartz of ADF&G are thanked for their assistance in conducting in vitro digestion analyses. R.L. Fairbanks of Harza-Ebasco Susitna Joint Venture, R.G.B. Senner of LGL, and K.B. Schneider of ADF&G provided program support and critically evaluated the manuscript. Funding was provided by the Alaska Power Authority in support of the Susitna Hydroelectric Project.

STUDY AREA

The study area was located in the middle Susitna River basin in southcentral Alaska (Fig. 1). Generally, the area was a broad U-shaped valley occupied by the Susitna River. Numerous tributaries drained into the river along its course. River elevations ranged from about 270 m on the west to approximately 750 m on the east. Surrounding peaks of the Talkeetna Mountains ranged to 1,907 m at the top of Mt. Watana. Topography has been strongly influenced by glacial action and associated river and stream erosion. Extensive sedimentary terraces perched above the river channel were approximately 610-760 m in elevation, and made up a majority of the study area.

Numerous plant communities characteristic of the northern boreal forest occurred in the study area. R.A. Kreig and Associates, Inc. (Anchorage, Alaska) mapped 92 vegetation types to levels III and IV of Viereck and Dyrness (1980; 1982 revision). Distribution of plant communties was strongly influenced by site topography, soils, and moisture regimes. Feltleaf willow was the predominant shrub growing along riparian zones of streams and on disturbed sites. Steep, well-drained river channel slopes were dominated by communities of mixed paper birch-white spruce (Picea glauca) forests and open coniferous spruce forests. Terraces at higher elevations above the river were primarily shrub communities dominated by resin birch on the drier sites, with white spruce forests on moderately drained slopes, and black spruce (Picea mariana) forests on wetter sites. Willows, primarily diamondleaf willow, greyleaf willow, and Richardson willow, dominated the shrub communities in wetter sites on upland slopes and intermixed with resin birch in coniferous forests. Alpine vegetation types occurred at the highest elevations.

METHODS

Shrubs were collected from 15 sites along a 100 km stretch of the Susitna River (Fig. 1) during 2 winter sample periods: December 11-13, 1984 and March 5-7, 1985. Prior knowledge of general shrub species composition occurring at each site, the need to sample the east-west gradient of the study area, and helicopter access considerations guided selection of site locations. Target shrub species were sampled opportunistically at each site during the first sample period to maximize the number of sites represented by each species. Samples of 7 shrub species known to be major components of moose diets in the study area (Steigers et al. 1983, Steigers et al. 1986) were collected (Table 1). Shrub species originally collected during the December sample period were again sampled, if possible, when the site was revisited during March.

At each site, current annual growth twigs of shrubs were clipped at the bud scale scar and bagged by species. Only unbrowsed twigs were collected, when possible. Approximately 50-100 g wet weight of plant material was collectively accumulated from each species present at each site during each sample period. Approximately 15 twigs of diamondleaf willow, grayleaf willow, and Richardson willow, 20 twigs from resin birch, 10 twigs from paper birch, and 3 twigs from feltleaf willow were collected from each shrub. One or more handfulls of whole mountain cranberry plants were clipped at ground level from pits dug through the snow cover. A variable number of individual shrubs of each species were sampled in order to meet the minimum weight goal at each site.

Plant samples were frozen until immediately prior to processing. Samples were oven-dried at 60 C for approximately 72 hours. Dried leaves and other litter were removed from the twigs of all species except mountain cranberry, which is a dwarf evergreen shrub that retains its leaves during winter. Samples were ground once through a Wiley mill fitted with a 1 mm screen. Equal proportions of ground material from all collection areas were composited by species for each sample period.

Composite samples were evaluated for in vitro digestible dry matter (IVDDM) using rumen inoculum from a wild moose collected on the Kenai Peninsula Moose Research Center (MRC). IVDDM analyses were conducted at MRC facilities following the method outlined by Pearson (1970). IVDDM replicates were run in triplicate for each sample, and the data expressed as percent of digested dry matter. Crude protein analyses determined by the block digestor technique (Isacc and Johnson 1976) were conducted in duplicate on the same composite samples by the Palmer (Alaska) Plant and Soils Analysis Laboratory. Crude protein was estimated by using the factor 6.25 to convert nitrogen.

Analysis of variance (ANOVA) 2-factor factorial design using species and sample periods as factors was used to detect statistical differences. Multiple comparison of means was conducted using a protected LSD procedure. Significance level for all statistical tests was set at alpha = 0.05.

RESULTS

There was no significant difference (P>0.36) in IVDDM between sample periods for any of the shrub species sampled (Fig. 2). No significant (P>0.06) 2-way interactions between species and sample periods were detected, which allowed pooling across sample periods (Table 2). Elimination of mountain cranberry, sampled only during December, did not affect the results of the analysis.

Mountain cranberry had the highest IVDDM among the 7 species sampled; deep snow precluded its collection during the March sample period (Table 2; Fig. 2). There were significant differences in IVDDM pooled across sample periods among the 7 shrub species. Multiple comparison of sample means showed that IVDDM was not different among diamondleaf, grayleaf, and Richardson willows, but feltleaf willow had significantly lower digestibility than the other willows. IVDDM of both paper birch and resin birch was significantly lower than all of the willows with the exception of feltleaf willow. IVDDM of paper birch was significantly different from that of resin birch (Table 2).

There was a significant ($P<0.004$) 2-way interaction for crude protein between species and sample periods when paper birch was included in the ANOVA. When paper birch was excluded, there was no significant ($P>0.42$) interaction and no difference ($P>0.15$) between sample period means for crude protein of the remaining 6 species. Elimination of mountain cranberry, sampled only during December, did not affect the results of the analysis. Crude protein was pooled across sample periods for comparison of sample means for all species except paper birch (Table 3).

Average crude protein content was highest for resin birch, and lowest for mountain cranberry (Table 3). Crude protein levels for paper birch were similar to those for resin birch in both sample periods (Fig. 3). Diamondleaf willow had the highest, and grayleaf and Richardson willow the lowest, crude protein values of the willows (Table 3, Fig. 3). There were significant differences in crude protein levels among the 6 shrub species pooled over sample period (Table 3). With the exception of grayleaf willow and Richardson willow, which were similar in growth form and size of current annual growth twigs, the means of all other species were different.

There was high correlation ($r=0.95$) between crude protein values of the same species (excluding mountain cranberry) compared between December and March sample periods, but trends over time were not consistent (Table 3). Crude protein values for paper birch, resin birch, and grayleaf willow increased from December to March, while values for diamondleaf willow, feltleaf willow, and Richardson willow decreased (Table 3, Fig. 3).

A significant inverse correlation was found between IVDDM and crude protein values compared for the same species within December ($r=-0.82$) and March ($r=-0.81$, using December value for mountain cranberry) sample periods, and when pooled across sample periods ($r=-0.75$, excluding paper birch).

DISCUSSION

In vitro digestibilities of individual willow species reported in this study were similar to those reported by other researchers. Oldemeyer (1974) reported IVDDM using moose rumen inoculum averaged 34.5% and 37.3% for littletree willow (_Salix arbusculoides_) collected on the twigs from juvenile plants contain more digestion-inhibiting substances. Both Klein (1977) and Bryant (1981) reported that high resin content of basal shoots of paper birch deterred browsing by snowshow hare (*Lepus americanus*). Basal shoots from birch trees (*Betula pendula* and *B. pubescens*) were shown to receive lower browsing pressure from mountain hare (*Lepus timidus*) in northern Sweden (Danell and Huss-Danell 1985).

Most of the paper birch available as browse in the study area is basal shoots arising from over-mature trees. Twig samples collected for this study were essentially all from basal shoots. The preponderance of these lower digestibility basal shoot twigs in the samples may explain the apparent discrepancy in IVDDM between this study and results reported from the Kenai Peninsula and interior Alaska where shrub-sized paper birch plants were important in moose diets (LeResche and Davis 1973), though our results are nearly identical to those of Regelin et al. (1986). *In vitro* digestion of paper birch and resin birch twigs may also be lower than the "open flow" system of rumen digestion where removal or dilution of toxic resins may enhance digestibility (Person et al. 1980).

Mountain cranberry had the highest digestibility of the seven species tested. Several other studies have also suggested that digestibility of mountain cranberry was consistently high in relation to other woody forages eaten by moose during winter. For exan[illegible]sche and Davis (1973) reported 50.1% IVDDM using bovine inoculum, and Oldemeyer et al. (1977) found 41.8% using moose rumen fluid and 40.8% using dairy cow inoculum on the Kenai Peninsula where mountain cranberry was an important winter forage particularly when snow was not deep. Our observations suggest that moose in the middle Susitna basin study area cratered through light snow cover (<25 cm) in December to reach mountain cranberry. But by March, when snow depths had accumulated to over approximately 60 cm, cratering for this low-growing dwarf shrub was rare. Oldemeyer (1974) reported lower IVDDM values for mountain cranberry than other studies: 36.0% and 37.4% using moose rumen inoculum for February and March samples, respectively.

Dietz et al. (1962) recommended a minimum of 7% crude protein for browse on good condition mule deer (Odocoileus hemionus) winter range. Similarly, Regelin et al. (1986) recommended that winter requirements to maintain nitrogen balance of adult moose should be met by dietary crude protein levels of 6.5%. Three of 4 willow species and mountain cranberry all had crude protein levels lower than the recommended 6.5%. The crude protein values for the shrub species investigated during winter in this study were generally comparable with other published information. Average crude protein content of 7.0% was reported for feltleaf willow in interior Alaska (Milke 1969) compared to our 6.24%. Diamondleaf willow in interior Alaska ranged from 5.4-5.6% (Machida 1979), which was lower than the average of 6.92% crude protein in our study area. Crude protein averaging 5.4% was found for mountain cranberry by both LeResche and Davis (1973) and Oldemeyer et al. (1977) on the Kenai Peninsula, compared to 5.25% during December in the Susitna basin. Because it is an evergreen shrub, most studies have shown that mountain cranberry maintained a low but relatively uniform crude protein level year-round (Oldemeyer and Seemel 1976, Regelin et al. 1986). In contrast, Scotter (1965, cited in Oldemeyer 1974) found higher levels of crude protein in mountain cranberry of northern Saskatchewan; 7.9% and 6.3% in September and March, respectively. Oldemeyer et al. (1977) reported 8.5% crude protein in paper birch during January, and cited Kenai National Moose Range (Kenai National Moose Refuge narrative report: May-August, 1963. Kenai, Alaska. 25pp.) as having a winter average of 7.5% on the Kenai Peninsula. Cowan et al. (1950, cited in Oldemeyer et al. 1974) found crude protein levels averaging 6.1% during winter compared to 8.25% in our study.

It is possible both crude protein and digestibility could vary over time as a result of changes in availability of different plant parts. As winter progresses, fewer current annual growth twigs remain to be browsed. Those twigs which do remain can be of lower nutritional quality if they have been previously browsed. Browsed twigs have a larger remaining diameter and lack terminal buds, which contain the highest protein content (Cowan et al. 1970, Wolff

1977) and are more digestible. If this was the case, then a consistent declining trend over time would be expected. Our data do not show this trend. Our selection of predominantly unbrowsed twigs in both sample periods would tend to artificially suppress this trend over the twigs a moose might choose. Though statistical tests showed a significant increase in crude protein content between sample period means for paper birch, it is our conclusion that the detected difference was an artifact of field sampling and low sample size and do not represent real changes through time that would directly influence nutrition of foraging moose. We know of no biological reason why crude protein content of paper birch would increase during the winter dormancy period. Further support for the conclusion that crude protein levels probably did not change in the interim between December and March comes from Bailey (1967) and Laycock and Price (1970) who found that crude protein content of browse does not change appreciably during the non-growing season.

IMPLICATIONS

These results have shown that digestibility and crude protein content of major food items available as forage for moose wintering in the middle Susitna River basin vary by species. Neither digestibility or crude protein content probably vary once the plants have become dormant in the fall; thus a single winter-long average should be obtained for each species using the data from both sample periods. The results suggest that digestibility among diamondleaf, grayleaf, and Richardson willows were not different; they could be combined and a single average digestibility (35.2%) used. However, differences in crude protein content among the willow species suggests that values should be individually determined. An average crude protein content (5.94%) could be used for grayleaf willow and Richardson willow. Mountain cranberry had the highest digestibility but the lowest crude protein content of the species tested Its dwarf growth form makes it of limited availability as forage in the study area during the period January through April in winters of light or average snowfall and December through April in winters with early, deep snowfall.

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FIGURES

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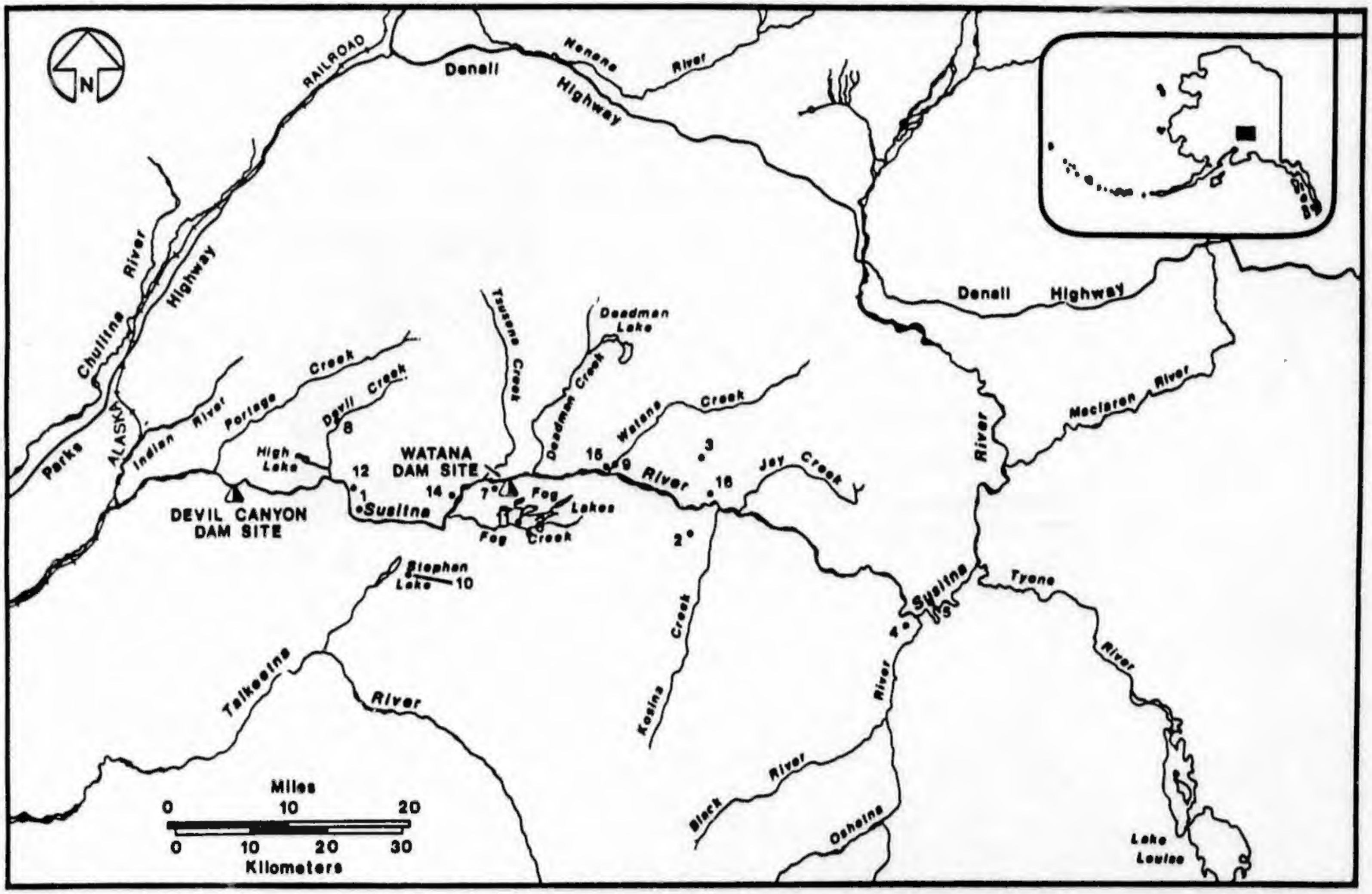
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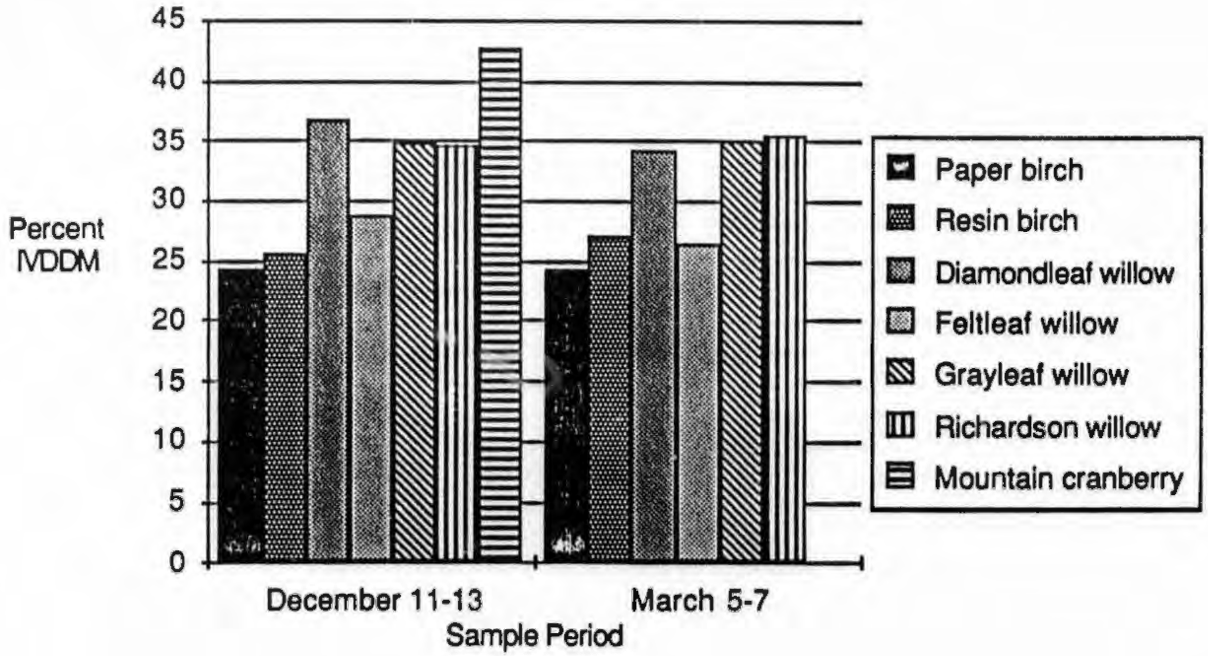
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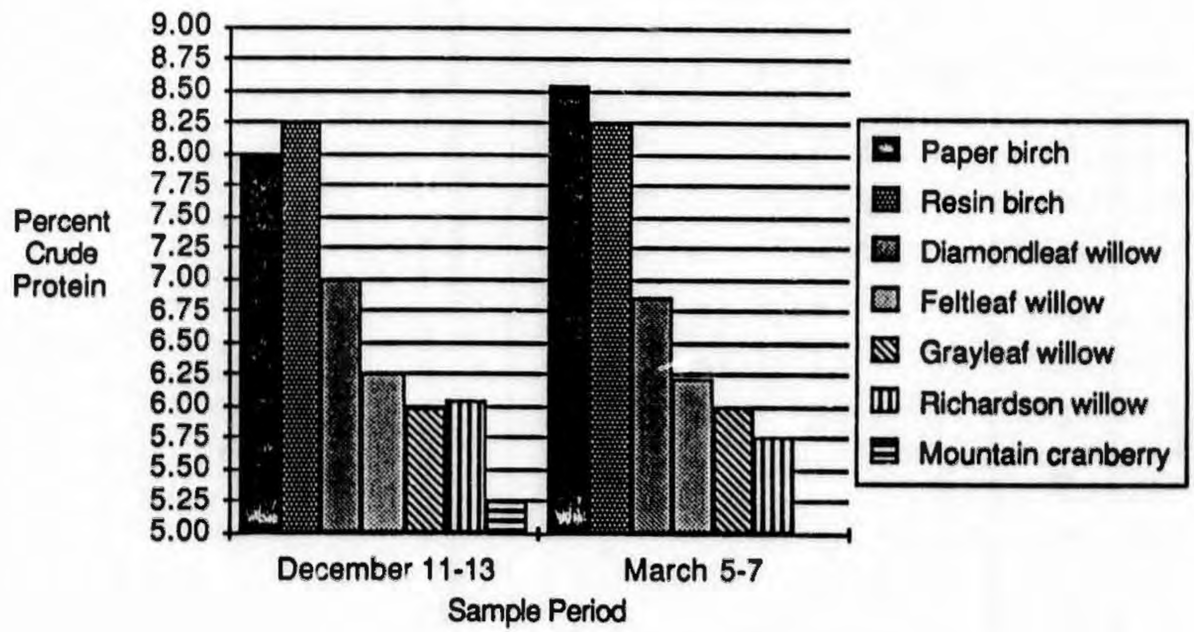
Resin birch
Diamondleaf willow
Feltleaf willow
Grayleaf willow
Richardson willow
Mountain cranberry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Percent Crude Protein
December 11-13
March 5-7
Sample Period
Paper birch
Resin birch
Diamondleaf willow
Feltleaf willow
Grayleaf willow
Richardson willow
Mountain cranberry

Table 1. Sites where current annual growth twigs from 7 shrub species were collected during December 11-13, 1984 and March 5-7, 1985 in the middle Susitna River basin, Alaska.

Forage Species	Site															Sample Size	
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	Dec.	Mar.
Paper birch	B[a]	--	--	--	--	--	--	--	--	--	--	B	B	B	B	5	5
Resin birch	--	B	--	B	B	--	B	--	--	B	--	--	--	--	--	5	5
Diamondleaf willow	--	B	--	B	B	--	B	--	--	B	B	--	--	--	--	6	6
Feltleaf willow	--	B	B	--	--	--	--	B	B	--	B	--	--	--	--	5	5
Grayleaf willow	--	--	--	B	B	D	D	--	--	--	--	--	--	--	--	4	2
Richardson willow	D	B	D	D	D	--	B	--	--	--	--	--	--	--	--	6	2
Mountain cranberry	D	--	--	D	--	--	D	--	--	--	--	--	--	D	D	5	0

[a] B = Both sample periods; D = December 11-13 sample period only.

Table 2. Average % *in vitro* dry matter digestibility of current annual growth twigs (whole plant for mountain cranberry) of 7 shrub species collected during 2 winter sample periods in the middle Susitna River basin, Alaska.

Forage Species	December 11-13		March 5-7		Both Periods		
	Mean	SD	Mean	SD	Mean		SD
Paper birch	24.4[a]	3.0	24.4	0.9	24.4	A[b]	1.7
Resin birch	25.5	0.5	27.0	1.4	26.3	BC	1.2
Feltleaf willow	28.8	1.6	26.5	1.1	27.7	C	1.8
Greyleaf willow	34.9	2.3	35.1	0.3	35.0	D	1.5
Richardson willow	34.7	1.5	35.4	0.5	35.1	D	1.1
Diamondleaf willow	36.8	0.4	34.3	1.0	35.5	D	1.5
Mountain cranberry	42.6	0.6	--	--	42.6[c]	E	0.6

[a] Pooled means within column followed by a different letter are significantly different.

[b] Only 2 replications.

[c] December sample period only.

Table 3. Average % crude protein content of current annual growth twigs (whole plant for mountain cranberry) of 7 shrub species collected during 2 winter sample periods in the middle Susitna River basin, Alaska.

Forage Species	December 11-13		March 5-7		Both Periods	
	Mean	SD	Mean	SD	Mean	SD
Mountain cranberry	5.25	0.0	--	--	5.25[a] A[b]	0.0
Richardson willow	6.03	0.04	5.75	0.27	5.89 B	0.23
Grayleaf willow	5.97	0.23	6.00	0.0	5.99 BC	0.13
Feltleaf willow	6.25	0.08	6.22	0.04	6.24 D	0.06
Diamondleaf willow	7.00	0.08	6.85	0.05	6.92 E	0.11
Resin birch	8.25	0.0	8.26	0.18	8.25 F	0.10
Paper birch	7.97	0.04	8.53	0.04	--[c]	--

[a] December sample period only.

[b] Pooled means within column followed by a different letter are significantly different.

[c] Significant 2-way interaction between species and sample periods.

SECTION II

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SECTION II - MODEL INPUTS

Monthly Diet Composition, Digestibility, and Crude Protein

Results from the food habits study (Section I) documented the genera, and in some cases species, of plants dominant in the diets of middle basin moose. There was variation in proportions of each food item among areas, though the basic food items were present in all areas sampled. Laboratory calibration of diet proportions through differential digestion and fragment identification was not successful primarily because of misidentification of species using the microhistological technique. Though these results highlighted the imprecision of this technique, they still provided needed quantitative insight into the presence or absence of major dietary items and gross dietary percent composition.

To arrive at monthly dietary composition from dietary information summarized over the entire project area was an exercise in combining both documented data and undocumented field observations into a best educated estimation. Willow made up the largest proportion of the average moose diet in the project area. The major willow species present and browsed by moose were diamondleaf willow, grayleaf willow, Richardson willow, and feltleaf willow. Diamondleaf willow was most abundant, while feltleaf willow was the tallest growing and provided a mid- to late-winter forage resource growing along riparian streams. These 4 willows were used in preparing the willow component of the average monthly winter moose diet in the project area (Table 1). Percentages of each willow species were estimated based on known availability, abundance, distribution patterns, observed patterns of use by moose, and height structure. The dietary proportion of resin birch was established as a maximum but consistent 15% throughout the winter and spring months (October through May) (Table 1). Mountain cranberry was stabilized at 20% of the diet during the October through December period, decreased to 10% during the winter months with deeper snow (January through March), and then increased again during April (15%) and May (25%) reflecting progressive melt of the snow pack and its availability as browse prior to spring plant phenological development (Helm and Mayer 1985) (Table 1). Primarily because of its low availability and limited distribution, paper birch was limited to a maximum of 4% of the diet during mid-winter (Table 1).

Average digestibility and percent crude protein values used for calculating predicted values from the sum of the component forages are also shown in Table 1. Nitrogen was calculated from percent crude protein for direct input to the carrying capacity model. Calculated results for average monthly diet digestibility and crude protein content are summarized in Table 2. Diet digestibility and crude protein values for the summer months (June through September) were obtained from studies conducted on the Kenai Peninsula (Regelin et al. 1986) and are also shown in Table 2.

Digestibility values were calculated from entire current annual growth twigs clipped at the bud scale scar. The average digestibility values assume, in theory at least, complete utilization of the entire twig at one time. When utilization levels are less than 100%, (e.g., 50%), it is probable that average digestibility of the terminal portion of the twig ingested may exceed average digestibility obtained from the entire twig. Moen (1985) has documented that red maple (Acer rubrum) twigs are more highly digestible (up to 164%) at the distal terminal bud than at the proximal bud scale scar.

Field observations have suggested that, in a high-use area, moose browse twigs of feltleaf willow progressively shorter through the winter rather than consuming an entire twig during a single feeding. However, for the shrub species we have used in average monthly diets (Table 1), only feltleaf willow has sufficiently long twigs that an upward adjustment in average digestibility and crude protein levels could be considered necessary. The other 3 willow species and both paper birch and resin birch all have small current annual twigs that are usually almost entirely removed in a single bite. The entire mountain cranberry plant is also consumed in the same manner. Observations of the degree of utilization of feltleaf willow in the project area suggest that this species is very heavily browsed, with almost the entire current annual growth twig having been removed by spring. Moose consuming higher quality terminal buds in December would subsequently be consuming the lower quality proximal end of the twig in March and April. This would result in an average digestibility and crude protein content over the winter similar to that calculated for the entire twig, but a decreasing digestibility curve over the course of the winter.

The digestibility and crude protein values reported in the Susitna studies (Section I, Forage Quality study) were comparable to those reported by other researchers in Alaska. Diet digestibilities calculated from sums of the component forage items were very close to those experimentally determined (Section, Food Habits study). In vitro digestibilities using bovine rumen inoculum also compared well with those obtained from moose rumen inoculum. Because the willow species were combined for forage biomass calculations (Becker and Steigers 1986) and the above arguments, it is not recommended that a correction factor be applied to monthly diet digestibility or crude protein values calculated in Table 1.

Monthly Diet Substitution

In computing carrying capacity, total available forage biomass of all subject species is offered for consumption over the specified time period (e.g., 100 days) the moose are expected to be on their winter range (proposed impoundments). Allocation of forage biomass resources is constrained by maximum percentages of each species allowed in the diet. When the upper limit of the allowable dietary proportion is reached for diet item A, diet item B is substituted until its upper limit is also reached, and then diet item C is substituted, etc.

Maximum allowable contributions of each diet item for project area moose were derived from the literature and from field experience. The 3 plant species requiring estimates of upper limits were paper birch, resin birch, and mountain cranberry. The contribution of willow in the diet is considered limited only by availability of total forage biomass once allowances have been made for environmental limitations such as snow depth.

Research on the Kenai Peninsula has suggested that a reasonable maximum contribution of paper birch in the diet of wintering moose is about 70% on a nearly monotypic paper birch study area (LeResche and Davis 1973). There is evidence that at higher percentages rumen activity may be inhibited by the resin content of paper birch (Reisenhoover et al. 1985). Paper birch is limited in abundance and is sparsely distributed in the project area. The 70% maximum dietary contribution was used for paper birch even though project area moose could not likely achieve this level for those very reasons.

Resin birch was not sampled for forage biomass in the project area because of its rather ubiquitous distribution and virtually unlimited abundance of forage biomass. Information from the food habits study (Section I) identified a maximum dietary contribution of 16%, averaging 11% over the entire project area. Murie (1944) reported that resin birch was regularly browsed by moose during winter in Denali National Park, though LeResche and Davis (1973) and Spencer and Hakala (1964) considered resin birch of minor dietary importance. For the Susitna project area, we recommend a maximum but consistent dietary percentage of 15% resin birch throughout the period October through May.

Mountain cranberry has been reported to comprise up to 51% of the winter diet of moose on a depleted range on the Kenai Peninsula (LeResche and Davis 1973). However, on a normal quality range on the Kenai Peninsula the maximum winter dietary proportion of mountain cranberry was 21% (LeResche and Davis 1973). On the depleted range but not on the normal range, mountain cranberry made up nearly half of the diet (LeResche and Davis 1973). Cushwa and Coady (1976) also noted that frequency of mountain cranberry in moose rumen samples was higher during spring than during winter on the Kenai Peninsula, but that it was nearly absent from samples taken from the interior near Fairbanks. Deeper and more persistent snow accumulations in the interior make mountain cranberry less available that on the Kenai Peninsula.

The Susitna project area is in a transitional zone between the interior and southcentral coastal climatological zones. Average snow depths exceed those on the Kenai Peninsula (compare Steigers et al. 1986 and LeResche and Davis 1973), but are less than those in the interior near Fairbanks. Thus mountain cranberry is considered to be available for a shorter period during the winter than on the Kenai Peninsula. Dietary composition in the Susitna project area ranged from 1-41%, averaging 8% over the entire area (Section I, Food Habits study). Mountain cranberry is considered to be at its lowest availability during the January through April period. For purposes of diet substitution, a maximum winter diet contribution of 15% is considered to be reasonable for project area moose. Mountain cranberry as a dietary component is not limiting in total biomass production, but rather solely because of limitations in availability.

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Table 1. Monthly diet composition and percent digestibility, protein, and nitrogen contributions to the winter diets of moose in the middle Susitna River basin, Alaska.

Month = October			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		64	64					
Diamondleaf	65		41.6	35.5	14.77	6.92	2.88	0.004606
Grayleaf	10		6.4	35.0	2.24	5.99	0.38	0.000613
Richardson	10		6.4	35.1	2.25	5.89	0.38	0.000603
Feltleaf	15		9.6	27.7	2.66	6.24	0.60	0.000958
Paper Birch		1	1	24.4	0.24	8.25	0.08	0.000132
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		20	20	42.6	8.52	5.25	1.05	0.001680
TOTALS		100	100		34.62		6.61	0.010573

Month = November			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		64	64					
Diamondleaf	65		41.6	35.5	14.77	6.92	2.88	0.004606
Grayleaf	10		6.4	35.0	2.24	5.99	0.38	0.000613
Richardson	10		6.4	35.1	2.25	5.89	0.38	0.000603
Feltleaf	15		9.6	27.7	2.66	6.24	0.60	0.000958
Paper Birch		1	1	24.4	0.24	8.25	0.08	0.000132
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		20	20	42.6	8.52	5.25	1.05	0.001680
TOTALS		100	100		34.62		6.61	0.010573

Month = December			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		64	64					
Diamondleaf	50		32	35.5	11.36	6.92	2.21	0.003543
Grayleaf	10		6.4	35.0	2.24	5.99	0.38	0.000613
Richardson	10		6.4	35.1	2.25	5.89	0.38	0.000603
Feltleaf	30		19.2	27.7	5.32	6.24	1.20	0.001917
Paper Birch		1	1	24.4	0.24	8.25	0.08	0.000132
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		20	20	42.6	8.52	5.25	1.05	0.001680
TOTALS		100	100		33.87		6.54	0.010468

Month = January			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		72	72					
Diamondleaf	40		28.8	35.5	10.22	6.92	1.99	0.003189
Grayleaf	10		7.2	35.0	2.52	5.99	0.43	0.000690
Richardson	10		7.2	35.1	2.53	5.89	0.42	0.000679
Feltleaf	40		28.8	27.7	7.98	6.24	1.80	0.002875
Paper Birch		3	3	24.4	0.73	8.25	0.25	0.000396
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		10	10	42.6	4.26	5.25	0.53	0.000840
TOTALS		100	100		32.19		6.66	0.010649

Month = February			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		71	71					
Diamondleaf	35		24.85	35.5	8.82	6.92	1.72	0.002751
Grayleaf	5		3.55	35.0	1.24	5.99	0.21	0.000340
Richardson	5		3.55	35.1	1.25	5.89	0.21	0.000335
Feltleaf	55		39.05	27.7	10.82	6.24	2.44	0.003899
Paper Birch		4	4	24.4	0.98	8.25	0.33	0.000528
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		10	10	42.6	4.26	5.25	0.53	0.000840
TOTALS		100	100		31.31		6.67	0.010673

Month = March			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		71	71					
Diamondleaf	30		21.3	35.5	7.56	6.92	1.47	0.002358
Grayleaf	5		3.55	35.0	1.24	5.99	0.21	0.000340
Richardson	5		3.55	35.1	1.25	5.89	0.21	0.000335
Feltleaf	60		42.6	27.7	11.80	6.24	2.66	0.004253
Paper Birch		4	4	24.4	0.98	8.25	0.33	0.000528
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		10	10	42.6	4.26	5.25	0.53	0.000840
TOTALS		100	100		31.03		6.65	0.010634

Month = April			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		67	67					
Diamondleaf	35		23.45	35.5	8.32	6.92	1.62	0.002596
Grayleaf	10		6.7	35.0	2.35	5.99	0.40	0.000642
Richardson	10		6.7	35.1	2.35	5.89	0.39	0.000631
Feltleaf	45		30.15	27.7	8.35	6.24	1.88	0.003010
Paper Birch		3	3	24.4	0.73	8.25	0.25	0.000396
Resin Birch		15	15	26.3	3.95	8.25	1.24	0.001980
Cranberry		15	15	42.6	6.39	5.25	0.79	0.001260
TOTALS		100	100		32.44		6.57	0.010516

Month = May			Diet		IVDMD		Protein	Nitrogen
Diet Item		% Diet	% Comp.	% IVDMD	% Contr.	% Protein	% Contr.	Contr.
Willow		59	59					
Diamondleaf	70		41.3	46.5	19.20	9.73	4.02	0.006430
Grayleaf	10		5.9	46.5	2.74	9.73	0.57	0.000919
Richardson	15		8.85	46.5	4.12	9.73	0.86	0.001378
Feltleaf	5		2.95	39.0	1.15	9.73	0.29	0.000459
Paper Birch		1	1	33.5	0.34	11.08	0.11	0.000177
Resin Birch		15	15	34.5	5.17	12.53	1.88	0.003007
Cranberry		25	25	42.6	10.65	6.43	1.61	0.002572
TOTALS		100	100		43.37		9.34	0.014942

Note: IVDMD and CP values for May are Susitna winter values plus 1/2 the difference between Susitna and Oldemeyer et al. (1977; 537, Table 2) July values.

Table 2. Average monthly percent digestibility and crude protein content of calculated moose diets to be used for carrying capacity model estimates for the middle Susitna River basin, Alaska.

Month	Digestibility	Crude protein
September[a]	42.00	13.38
October	34.62	6.61
November	34.62	6.61
December	33.87	6.54
January	32.19	6.66
February	31.31	6.67
March	31.03	6.65
April	32.44	6.57
May	43.37	9.34
June	53.10	18.75
July	53.10	15.63
August	44.70	15.63

[a] Values for June through September were from the Kenai Peninsula.