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BROWSE QUALITY AND THE KENAI MOOSE POPULATION

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ABSTRACT: The quality of moose (*Alces alces gigas*) forage on the northwestern Kenai Peninsula, Alaska was evaluated by determining digestibility (as *in vitro* dry matter disappearance) and levels of fiber, protein, and minerals for one winter and two summer collections. There were significant changes in all parameters between summer and winter in the major browse species - paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*), willow (*Salix* sp.), alder (*Alnus* sp.), and lowbush cranberry (*Vaccinium*

vitis-idaea) and significant differences among species within seasons. Considering all factors, alder and willow ranked as the best summer browse plants and lowbush cranberry as the poorest; in winter, aspen and lowbush cranberry ranked best and paper birch poorest. However, since the different species provide different nutrients, sufficient quantities of all five species could better meet the needs of moose than any one. The northern Kenai moose range, once multispecies habitat, is now dominated by paper birch; this is relatively poor winter forage, and the moose population is declining.

The quality of plants that wild ungulates eat has been given little scrutiny. Yet, on both summer and winter range, quality is as important as quantity in maintaining healthy ungulate populations. In a study of moose forage Cowan et al. (1950) recognized the relationships between range quality, carrying capacity, and the successional stage of the forest. They noted specifically that fats (ether extracts), total carbohydrates, and proteins in the vegetation of a 6- and a 20 to 30-year-old forest were superior to those of a 70 plus-year-old forest; and that the most nutritious forage was found in the younger forests. Klein (1970) discussed the relationships between quantity of high-quality plants and deer growth rate and body size, productivity and survival, and changes in age and sex ratio; he concluded that high-quality range is necessary for healthy deer populations.

Dietz (1970) defined a high-quality plant as one that is palatable to the animal, has adequate levels of necessary nutrients in the proper ratios, has a high apparent digestibility, produces desirable proportions of volatile fatty acids, has adequate levels of minerals and vitamins, and is efficiently converted into components required by the consuming animal. Some researchers have looked at one or several of these components of quality, but no one has looked at all of them with respect to wild ungulates. This paper presents data we have collected to compare and define the quality of the important browse plants eaten by moose in summer and winter on Alaska's Kenai Peninsula. The characteristics we used to describe browse quality were: *in vitro* dry-matter disappearance (IVDMD), fiber content, protein content, and the concentration of 18 mineral elements.

The study took place on the Kenai National Moose Range at the Kenai Moose Research Center, a cooperative research project of the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service. The Center is located in the northwestern lowlands of the Kenai Peninsula. About 40 percent of the lowlands were burned during a 125,455-ha fire in 1947. The land is rolling and covered by podsol soils that are glacially scoured and dotted with numerous lakes and bogs. Mature white spruce (*Picea glauca*), paper birch, and aspen remain as islands within the burn. Regrowth consists mostly of black spruce (*P. mariana*), paper birch, willow and aspen, with paper birch producing over 80 percent of the annual browse production. The major shrubs of the unburned stands are aspen saplings and highbush cranberry (*Viburnum edule*). Ground vegetation in both the burned and unburned stands is dominated by lowbush cranberry, bunchberry (*Cornus canadensis*), rose (*Rosa acicularis*), twinflower (*Linnaea borealis*), and fireweed (*Epilobium angustifolium*).

Although woody browse is poorest in quality of the year's food supply, it is the mainstay of the moose's winter diet. LeResche and Davis (1973) studied food selection by moose at the Kenai Moose Research Center and found that paper birch and lowbush cranberry were by far the most important species eaten during the winter on normally browsed range. Willow, aspen, alder, and dwarf birch (B. nana) are sparse and thus are not as important here as in interior Alaska (Coady 1973) or other parts of the range of moose (Peek 1974).

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METHODS

We collected plants at two periods of their annual life cycle. In order to sample nutrients present during the growing season, we collected current annual growth stems and leaves during early August 1973 and early July 1974. Two or three samples of each species were collected in 1973 and only one sample of each species was collected in 1974. All plants in these summer collections came from in or near the Moose Research Center, except for one sample of each species which came from the Kenai Mountains (elevation 610 m). To represent the dormant period, we collected six samples of each of five browse species in late January 1974 from sites in or near the Moose Research Center. The winter samples consisted of current-growth twigs except for the samples of lowbush cranberry. Because this shrub does not drop its leaves in winter and moose appear to browse it to near ground level, that sample consisted of all above-ground portions of the plant.

Since earlier studies (Oldemeyer 1974) showed little variation in IVDMD among individual plants of a species from the same collection site, all samples consisted of material clipped from several plants within a site until at least 100 grams were obtained. In all cases we attempted to obtain maximum diversity in cover, topography, and soils between collection sites.

After collection, the plants were oven-dried at 40C for 48 hours and ground to pass through a 30-mesh screen. Each sample was divided into three portions: One for in vitro digestion, one for fiber and protein analysis, and one for mineral determination.

Two series of IVDMD trials were conducted, one using moose inocula and one for comparison using inocula from a domestic ruminant. The trials using moose inocula began within 3 weeks of each forage collection and followed the procedure described by Tilley and Terry (1963) as modified by Pearson (1970). Duplicate or triplicate tubes were run of each sample. Six blank tubes and six tubes with a standard calf ration were run as standards. Rumen liquor inoculum was from moose captured in or adjacent to Moose Research Center enclosures; presumably their diet was the normal seasonal forage eaten by moose in that area. The rumen liquor was collected into a preheated vacuum bottle, by stomach pump from live moose or from freshly killed moose, and the trial began within 3 hours of the liquor collection.

The trials using inocula from a domestic ruminant were conducted at the Palmer Research Center. The inoculum source was a rumen fistulated

Holstein dairy cow on a diet of mixed grass hay and blended dairy concentrates. The two-stage Tilley and Terry (1963) procedure was modified by the use of a carbonate-limited buffer and direct acidification in lieu of centrifugation before second-stage digestion with pepsin (R. M. Meyer 1971, personal communication). These trials with dairy cow inocula followed those using moose inocula by 8, 4, and 0 weeks, respectively.

Fiber was analyzed by the procedure outlined in the USDA Agriculture Handbook #379 (Goering and Van Soest 1970). Crude protein was estimated by using the factor 6.25 to convert nitrogen determined by the Kjeldahl technique (A.O.A.C. 1970).

Plant samples for mineral analysis were sent to the Trace Element Center, Cleveland Metropolitan General Hospital. They were dried at 55C for 48 hours; then 100 mg of each sample was digested at room temperature by 10 ml of a 4:1 mixture of concentrated nitric and perchloric acids. After digestion the material was diluted with water and analyzed by atomic absorption spectroscopy.

RESULTS AND DISCUSSION

Digestibility

In the past, analyses of forage quality have almost solely concentrated on carbohydrates, fats, proteins, and minerals. While these indicate the potential value of the plant, determining its digestibility is an important additional step that gives a measure of the availability of those nutrients to the animal. We used IVDMD as an estimate of digestibility; it was within the range found by others working with mule deer (Odocoileus hemionus) and elk (Cervus canadensis) forage (Ward 1971, Dietz 1972) and similar to what

LeResche and Davis (1973) found with Kenai moose forage early in the growing season. During the summer, alder and lowbush cranberry were significantly more digestible than the other four plant species (Table 1). In the winter, aspen and lowbush cranberry were the most digestible, willow and paper birch were intermediate, and alder was least digestible (Table 1). Of the five species tested at both seasons, IVDMD of all but one (aspen) was greater in summer than in the winter. Dietz (1972) also observed better digestibility in summer and related it to lower acid-detergent fiber and lignin content at that time.

The correlations of IVDMD as determined with moose inocula and dairy cow inocula seemed to improve when we decreased the time interval between trials. Pearson (1967) found that IVDMD of forage changed when inoculum collection was delayed. He concluded that inoculum-source animals should be grazing the kind of forage being tested and that trials should begin soon after forage collection. In August 1973, when the trial with cow inocula began 8 weeks after the one with moose inocula and almost 11 weeks after forage collection, correlation between the two inoculum sources was low ($r = 0.24$). We think it unlikely that the plants' digestibility changed radically while in storage, and since the Holstein's food supply was constant, we cannot explain the poor correlation. That winter, the trial with cow inocula began 4 weeks after the one with moose inocula, and the correlation was better ($r = 0.84$). The summer 1974 trials were run simultaneously so that the two inoculum sources could be directly compared, but the correlation did not improve ($r = 0.83$). As would be expected, moose inocula tended to digest woody material better and dairy cow inocula tended to digest the grasses and forbs of the summer 1974 trial better (Tables 1 and 2).

Fiber Content

Carbohydrates were analyzed by Van Soest's (1966) system. Rather than describing carbohydrates as nitrogen-free extract and crude fiber, this system uses the categories of cell-wall constituents, acid detergent fiber (ADF) and lignin; these reflect the value of carbohydrates to the animal. The cell contents (100 percent minus cell walls) are the more readily utilized nutrients and include protein, soluble carbohydrates, soluble minerals and lipids. Van Soest (1971) regarded the cell walls as the most important components of feeds of plant origin because they are related to net energy, to the efficiency ratio (net energy/total digestible nutrients), and to voluntary intake of feed by the animal. ADF is the ligno-cellulose portion of the plant, and its determination allows one to calculate hemicellulose (cell walls minus ADF) and cellulose (ADF minus lignin). Hemicellulose tends to be of greater benefit to the animal than cellulose, and lignin is the undigestible portion of the plant.

Table 1 shows the results of analyses for cell walls, ADF, and lignin. In all five species we examined during both seasons (Table 1), percent cell walls was greater in winter than in the summer, probably because we combined leaves with twigs. Aspen and willow had significantly higher percentage of cell walls in the winter than the other three species. Like Van Soest (1971), we found the percentage of cell walls greatest in grasses and lowest in forbs (Table 2). Percentage of cell walls was intermediate in shrubs.

Lignin content during the summer was higher in aspen than in the other species, and both aspen and willow had more lignin in the summer than in winter (Table 1). Interestingly, aspen had more lignin in leaves than in twigs during summer, which may explain its higher summer lignin content; however, willow did not follow that pattern (Table 2). The lignin content in the twigs and leaves of shrubs was higher than in any of the grasses, forbs, or aquatics. During the winter, paper birch had significantly more lignin than the other species we analyzed.

Protein Content

Most workers (Bissell and Strong 1955, Morrison 1954, Dietz 1970) consider protein the most important plant nutrient because it provides nitrogen required by rumen microorganisms for growth and is essential for body maintenance, growth, reproduction, and lactation. Except for lowbush cranberry, the plants we examined had considerably higher protein levels in summer than winter (Table 1). In summer, all plants but lowbush cranberry had more than 12 percent protein; in winter, none had as much as 10 percent protein and lowbush cranberry was lowest with 5.4 percent. The seasonal changes in protein levels of deciduous shrubs have been well documented (Bissell and Strong 1955, Tew 1970, Dina and Klikoff 1973) and apparently reflect differences in moisture and phenology. Because it is an evergreen shrub, lowbush cranberry apparently maintains a relatively uniform protein level year-round (Oldemeyer and Seemel 1976). Alder and paper birch had winter protein levels higher than the 7 percent Dietz et al. (1962) recommended as minimum for browse on good mule deer range. Milke (1969) reported winter protein levels of less than 7 percent in three of four species of Alaskan willow he analyzed; his values were not greatly different from ours.

Mineral Content

Kubota (1974) and Franzmann et al. (1975) discussed the importance of dietary minerals to the basic body processes and the difficulties of interpreting the results of forage mineral analyses. In our study, only eight elements consistently appeared in amounts over 1 ppm (Tables 1 and 2). Of the others, mercury and selenium consistently occurred in trace amounts (less than 0.05 ppm) in all species, lead consistently occurred in trace amounts in alder, cobalt occurred sporadically at trace levels in all species, and chromium, cadmium, nickel, molybdenum, arsenic, and aluminum were not detected.

The seasonal differences in mineral concentrations (Table 1) were striking. For the five species collected at both seasons, calcium, potassium, and magnesium concentrations were 126 to 501 times higher in summer than in winter; copper, iron, and zinc were 9 to 129 times higher; and sodium was 2 to 3 times higher. Winter mineral levels, in general, were lower than those required by domestic cattle for optimum nutrition (Church 1971); but, most minerals attained acceptable levels during summer. Manganese was not detected in alder, aspen, and willow in summer 1973; in winter, manganese was present but extremely low (1 ppm). Rojas et al. (1965) observed deficiency symptoms in calves from cows fed less than 17 ppm manganese during gestation. In summer 1973 we found more than 17 ppm manganese only in lowbush cranberry, but the summer 1974 samples of paper birch, willow and lowbush cranberry contained much higher levels than in summer 1973 and in most cases, more than 17 ppm (Table 2). Kubota (1974) reported still higher manganese levels in birch (738 ppm), willow (309 ppm), and aspen (61 ppm) collected from the Kenai Peninsula.

Consistent differences in mineral concentrations were observed between twigs and leaves in the summer 1974 samples. Except for potassium and sodium, paper birch leaves had higher levels than twigs and the combined sample was intermediate. Aspen leaves had higher levels than twigs for all minerals, and willow followed that pattern except for copper and sodium.

Mineral values for other shrubs and some herbaceous plants browsed by moose in the summer are also listed in Table 2. Kubota et al. (1970) reported some mineral values for fireweed, bluejoint (*Calamagrostis canadensis*) and lupine (*Lupinus* sp.) from the Kenai Peninsula that differed substantially from ours. Since we have observed great differences in the same species between years even when many of the samples were collected from the same or nearby areas, the differences between our results and theirs may perhaps be explained as natural yearly variation.

Browse Quality

Others (Short 1966, Brown and Radcliffe 1971) have attempted to correlate dry-matter digestibility with various other nutritive parameters (cellulose content, organic matter, energy digestion) in an effort to better understand the meaning of IVDMD trials and more easily describe browse quality. For winter browse, we obtained low or insignificant correlation coefficients between IVDMD and percent cell walls ($r = 0.15$), ADF ($r = 0.04$), and lignin ($r = -0.44$). In summer 1974 we made an effort to collect a greater variety of plant types and observed better correlations between IVDMD and cell walls (r = -0.36), ADF (r = -0.54), and lignin (r = -0.51). While these showed real and expected relationships between digestibility and the factions of fiber, the relationships were not strong enough to warrant estimation through regression.

The precise determination of the highest quality forage species is probably impossible. For example there are complex interactions between a plant's components, their chemical dynamics, their digestibility, their efficient use by the animal, and the animal's minimum requirements. However, in an attempt to rank the species in terms of general quality, we used a Friedman Test. For each constituent (Table 1) we ranked the species from best (rank 1) to poorest, and summed those ranks over all the analyses performed. By this criteria, there were no significant differences among the species' ranks (α = .10).

Van Soest (1971), Walters (1971), and Ammann et al. (1973) discussed the relation between rate of digestion and voluntary intake of forage by ungulates. At low levels of dry matter digestibility, Ammann et al. (1973) found lower intake with lower-quality forage. Since low-quality forage is in the rumen longer, it probably undergoes more complete ligno-cellulose digestion but provides less available energy than high-quality forage which passes through the animal rapidly. Thus, the animal may not obtain enough energy from low-quality browse to meet its requirements. Crampton (1957) thought that if a forage were consumed in amounts to meet energy needs, it would normally meet the animal's needs with respect to protein, calcium, and phosphorus. While we have not investigated energy relationships between moose and their winter diet on the Kenai, paper birch, the most common and most used of the five major browse species ranked fourth in digestibility, had the highest lignin content, and ranked poorest overall as winter browse. Thus we suspect that the winter diet for moose on the Kenai is energy deficient.

CONCLUSIONS

Data on the productivity of the Kenai moose population support our conclusion that this area is poor winter range. The effects of high and low quality ranges or diets on deer productivity and growth have been clearly demonstrated (Cheatum and Severinghaus 1950, Klein 1964, Verme 1965). Klein (1970) reported that deer on a poor quality range weighed less. The average weight of 18 adult moose of both sexes trapped outside the Kenai Moose Research Center during the fall, winter, and spring 1973 was 385 kg, compared with 409 kg for 19 adult moose from the Tanana Valley near Fairbanks where Coady (1973) felt the weights and growth of moose indicated favorable range conditions. Klein (1970) reported that deer on poor quality ranges have lower fertility and poorer fawn survival. Franzmann and Arneson (1973:23, 1974:16) reported low pregnancy rates for cow moose they examined between January and April at the Moose Research Center. In 1973, 62 percent of 21 cows in Center enclosures and 76.5 percent of 34 free-ranging cows were pregnant; and in 1974, 50 percent of 10 enclosed cows and 64 percent of 14 free-ranging cows were pregnant. In contrast, Houston (1968) in Wyoming and Rausch and Bratlie (1965) in Alaska reported pregnancy rates near 90 percent. Finally, the Kenai moose population is decreasing. Mid-winter aerial surveys showed that the moose population on the northern two-thirds of the Kenai National Moose Range decreased from an estimated 7,900 in 1971 to 3,500 in 1975 (Kenai National Moose Range files).

Dead moose are commonly observed in winter and necropsy indicates starvation; the logical conclusion is that the winter range is not sufficient in quality or in quantity to support the population. If the Kenai range supported a larger population 5 or 10 years earlier, why won't it do the same now? Are nutrients deficient? Our data show low winter levels of protein in all plant species, as well as low levels of manganese and several other trace elements, but we see no reason to presume that these levels are greatly different from what they were several years ago. The only change that is apparent on the northwestern Kenai is the change in plant species composition. We now have a winter range dominated by paper birch where once there was a multispecies range of birch, willow, aspen, and perhaps some alder.

The results of our analyses demonstrate the importance of browse variety in the diet of moose. For example, alder and paper birch supply higher winter levels of protein, whereas willow and lowbush cranberry are better digested and contain higher winter levels of calcium. Sufficient quantities of five winter browse species can more adequately meet the nutritional needs of moose than one species, however abundant.

Spencer and Hakala (1964) have estimated that the productive life of a burn as good moose range is 20 years. By now the 1947 burn on the Kenai National Moose Range is probably marginal moose range; low-quality winter browse predominates and the moose population is declining.

Table 1. Quality of moose browse collected in August 1973 and January 1974. Analysis of variance with Scheffe's test was performed within seaso means followed by the same superscripts were not different (α = 0.1).

Season, species and number of sites sampled		IVDMD (%)		Fiber (%)			Protein (%)	Macroelements (ppm)				Microelements (ppm)				Sum of rank
		Moose	Dairy Cow	Cell Walls	ADF	Lignin		Ca	K	Mg	Na	Cu	Fe	Mn	Zn	
Summer																
Alder	3	48.0^{a}*	34.6^{b}	33.4^{a,b}	26.9^{b}	10.9^{b}	15.8^{a}	6063^{a,b}	5913^{a}	2022^{a,b}	66.7^{a}	17.5^{a}	87.3^{a}	ND*	23.3^{a,b}	36.0
Dwarf Birch	2	41.4^{a}	34.2^{b}	29.4^{b}	23.3^{b}	13.9^{b}	14.9^{a}	3920^{b}	5550^{a}	1730^{b}	55.0^{a}	11.3^{a}	60.5^{a,b}	4.9	45.0^{a,b}	50.0
Paper Birch	3	37.7^{a}	30.8^{b}	37.4^{a}	30.5^{a,b}	13.9^{b}	13.7^{a}	4608^{b}	6520^{a}	2038^{a,b}	66.7^{a}	7.5^{a}	82.7^{a,b}	12.3	69.2^{a}	46.0
Aspen	3	40.8^{a}	42.1^{a}	38.2^{a}	39.3^{a}	21.8^{a}	12.5^{a}	8672^{a}	7217^{a}	2147^{a}	65.0^{a}	5.2^{a}	51.0^{b}	ND	50.0^{a,b}	50.0
Willow	5	42.2^{a}	40.3^{a}	32.4^{a,b}	33.8^{a,b}	16.1^{a,b}	14.0^{a}	8759^{a}	5906^{a}	2100^{a,b}	65.0^{a}	14.9^{a}	85.0^{a,b}	ND	41.0^{a,b}	37.5
Lowbush cranberry	3	50.7^{a}	39.1^{a}	33.1^{a,b}	29.3^{b}	12.6^{b}	5.7^{b}	4920^{b}	4383^{a}	1328^{c}	55.0^{a}	5.8^{a}	51.3^{b}	17.6	8.3^{b}	53.5
Winter																
Alder	6	29.6^{c}	28.1^{c}	41.2^{b}	33.5^{c}	14.7^{b}	9.6^{a}	19^{b}	26^{b}	5^{b}	22.8^{a}	0.3^{a}	5.6^{a}	0.9^{c}	0.2^{c,d}	41.5
Paper Birch	6	33.8^{b,c}	25.8^{c,d}	47.1^{b}	38.7^{b}	18.4^{a}	8.5^{b}	11^{c}	22^{b}	5^{b}	22.7^{a}	0.3^{a}	5.3^{a}	1.4^{b}	0.7^{a}	45.5
Aspen	6	44.8^{a}	42.0^{a}	52.9^{a}	39.8^{a,b}	14.2^{b}	6.1^{c,d}	17^{b}	58^{a}	6^{a}	23.2^{a}	0.3^{a}	5.9^{a}	0.7^{c}	0.6^{a,b,c}	31.5
Willow	6	34.7^{b}	32.2^{b}	51.1^{a}	44.5^{a}	13.8^{b}	6.4^{c,d}	21^{b}	37^{b}	4^{b}	22.7^{a}	0.3^{a}	5.1^{a}	0.8^{c}	0.6^{a,b,c}	40.0
Lowbush cranberry	6	41.8^{a}	40.8^{a}	37.7^{b}	31.9^{c}	13.2^{b}	5.4^{d}	27^{a}	30^{b}	5^{b}	22.8^{a}	0.2^{a}	3.2^{a}	1.9^{a}	0.3^{b,c,d}	36.5

* IVDMD = *in vitro* dry-matter disappearance; ND = not detected.

Table 2. Quality of moose forage collected during July 1974.

	IVDMD (%)		Fiber (%)			Protein (%)	Macroelements (ppm)				Microelements (ppm)		
	Moose	Dairy cow	Cell walls	ADF	Lignin		Ca	K	Mg	Na	Cu	Fe	Mn
Grass													
Bluejoint	48.1	55.9	69.8	37.8	3.7	9.8	617	9799	1481	74	22.3	58	30.9
Carex sp.	41.4	53.8	78.4	33.4	5.9	9.9	2107	8330	2056	93	33.1	70	38.7
Forbs													
Menyanthes trifoliata	92.3	85.9	30.4	16.1	3.6	13.9	1080	10954	1007	718	19.1	113	36.6
Fireweed	62.2	64.7	23.8	19.3	5.4	11.9	4588	7863	2008	76	12.2	62	23.7
Lupine	56.9	84.4	23.1	18.8	3.7	24.3	11425	7413	1052	75	20.6	119	7.1
Potamogeton sp.	73.1	80.7	32.2	17.7	2.4	17.1	5690	10032	1072	3919	24.2	130	28.2
Shrubs													
Paper birch													
Leaves	43.1	47.6	29.0	19.5	8.3	16.9	1543	7273	2128	23	20.9	105	181.8
Twigs	25.8	23.5	56.1	43.2	16.8	9.0	586	4905	1842	81	16.6	67	62.8
Combined	42.6	38.6	38.3	26.0	11.0	13.9	773	7479	1892	63	16.7	78	141.0
Dwarf birch	42.6	38.1	36.5	27.3	14.5	16.8	631	5503	646	74	15.2	86	109.1
Aspen													
Leaves	56.8	57.6	36.3	29.9	17.6	13.8	2377	10478	1997	100	14.5	96	31.3
Twigs	64.1	56.1	46.2	36.5	13.4	8.3	791	7492	1286	88	11.3	78	9.4
Combined	-	57.4	36.8	28.6	14.4	12.6	2126	7516	1818	106	11.9	81	15.1
Willow													
Leaves	54.8	41.2	27.6	22.2	11.6	13.5	2613	8519	1891	93	15.8	115	66.2
Twigs	42.6	43.3	44.9	40.6	18.2	6.9	1198	3878	714	110	20.3	87	13.0
Combined	57.8	41.7	26.6	23.9	12.7	13.2	788	5055	893	105	22.7	92	21.9
Lowbush cranberry	44.3	38.5	50.5	44.6	23.8	7.6	699	3691	1426	72	13.8	44	111.8
Highbush cranberry	52.8	64.4	37.8	28.2	13.1	10.3	3284	10798	2112	106	21.0	50	24.4

LITERATURE CITED

Ammann, A. P., R. L. Cowan, C. L. Mothershead, and B. R. Baumgardt. 1973. Dry matter and energy intake in relation to digestibility in white-tailed deer. J. Wildl. Manage. 37(2):195-201.

Association of Official Analytical Chemists. 1970. Official Methods of Analysis. 11th Ed. Washington, D. C. 1015 pp.

Bissell, H. D. and Helen Strong. 1955. The crude protein variations in the browse diet of California deer. Calif. Fish and Game 41(2):145-155.

Brown, D. C. and J. C. Radcliffe. 1971. Prediction of in vivo dry matter, organic matter, and energy digestibilities of silage by in vitro digestion techniques. Aust. J. Agri. Res. 22(5):787-796.

Cheatum, E. L. and C. W. Severinghaus. 1950. Variations in fertility of white-tailed deer related to range conditions. Trans. No. Amer. Wildl. Conf. 15:170-190.

Church, D. C. 1971. Digestive physiology and nutrition of ruminants. Vol. 2. Oregon State Univ. Bookstores. Corvallis. 401 pp.

Coady, J. W. 1973. Interior Moose Studies. Alaska Dept. of Fish and Game. P-R Proj. Rept. W-17-4&5. 54 pp.

Cowan, I. M., W. S. Hoar and J. Hatter. 1950. The effect of forest succession upon the quantity and upon the nutritive values of woody plants used as food by moose. Can. J. Res. 28 Sect D.(5):249-271.

Crampton, E. W. 1957. Interrelations between digestible nutrient and energy content, voluntary dry matter intake, and the overall feeding value of forages. J. Anim. Sci. 16(3):546-552.

Dietz, D. R. 1970. Animal production and forage quality. Pages 1-9 in H. A. Paulson, Jr. and E. H. Reid, Cochairmen. Range and wildlife habitat evaluation - a research symposium. U.S. Dept. Agric. Misc. Publ. No. 1147. 220 pp.

Dietz, D. R. 1972. Nutritive value of shrubs. Pages 289-302 in C. M. McKell, Chairman. Wildland shrubs - their biology and utilization. U.S. For. Serv. Tech. Rep. Int-1. 494 pp.

Dietz, D. R., R. H. Udall, and L. E. Yeager. 1962. Chemical composition and digestibility by mule deer of selected forage species, Cache la Poudre Range, Colorado. Colorado Game and Fish Dept. Tech. Publ. 14. 89 pp.

Dina, S. J. and L. G. Klikoff. 1973. Effect of plant moisture stress on carbohydrate and nitrogen content of big sagebrush. J. Range Manage. 26(3):207-209.

Franzmann, A. W. and P. D. Arneson. 1973. Moose Research Center Studies. Alaska Dept. of Fish and Game. P-R Proj. Rept. W-17-6. 117 pp.

Franzmann, A. W. and P. D. Arneson. 1974. Moose Research Center Studies. Alaska Dept. of Fish and Game. P-R Proj. Rept. W-17-6. 68 pp.

Franzmann, A. W., J. L. Oldemeyer, and A. Flynn. 1975. Minerals and moose. 11th N. Amer. Moose Conf. and Workshop, Proc., Winnipeg, Manitoba, Can. (in press).

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analysis. Agr. Handbook 379. U.S. Govt. Print. Off. 20 pp.

Houston, D. B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Nat. Hist. Assoc. Tech. Bull. No. 1. 110 pp.

Klein, D. R. 1964. Range-related differences in growth of deer reflected in skeletal ratios. J. Mammal. 45(2):226-235.

Klein, D. R. 1970. Food selection by North American deer and their response to over-utilization of preferred plant species. Pages 25-46 in A. Watson, ed. Animal populations in relation to their food sources. Brit. Ecol. Soc. Symp. 10. Blackwell Sci. Publ., Oxford. 477 pp.

Kubota, J. 1974. Mineral composition of browse plants for moose. Naturaliste Can. 101(1):291-305.

Kubota, J., S. Rieger, and V. A. Lazar. 1970. Mineral composition of herbage browsed by moose in Alaska. J. Wildl. Manage. 34(3):565-569.

LeResche, R. E. and J. L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37(3):279-287.

Milke, G. C. 1969. Some moose-willow relationships in the interior of Alaska. M.S. Thesis. Univ. of Alaska, College. 79 pp.

Morrison, F. B. 1954. Feeds and feeding. 21 ed. The Morrison Publ. Co. Ithaca, N.Y. 1207 pp.

Oldemeyer, J. L. 1974. Nutritive value of moose forage. Naturaliste Can. 101(1):217-226.

Oldemeyer, J. L. and R. K. Seemel. 1976. Occurrence and nutritive quality of lowbush cranberry on the Kenai Peninsula, Alaska. Can. J. Bot. ~~(In press)~~. 54(9):966-970.

Pearson, H. A. 1967. Effect of delays in inocolum collection on artificial rumen digestibilities. J. Range Manage. 20(5):332-333.

Pearson, H. A. 1970. Digestibility trials: *in vitro* techniques. Pages 85-92 *in* H. A. Paulson, Jr. and E. H. Reid, Cochairmen. Range and wildlife habitat evaluation - a research symposium. U.S. For. Serv. Misc. Publ. No. 1147. 220 pp.

Peek, J. M. 1974. A review of moose food habits studies in North America. Naturaliste Can. 101:(1):195-216.

Rausch, R. A. and A. Bratlie. 1965. Annual assessments of moose calf production and mortality in southcentral Alaska. Ann. Conf. W. Assoc. State Game and Fish Comm. 45:140-146.

Rojas, M. A., I. A. Dyer, and W. A. Cassett. 1965. Manganese deficiency in the bovine. J. Animal Science. 24(3):664-667.

Short, H. L. 1966. Effects of cellulose levels on the apparent digestibility of feeds eaten by mule deer. J. Wildl. Manage. 30(1):163-167.

Spencer, D. L. and J. B. Hakala. 1964. Moose and fire on the Kenai. Tall Timbers Fire Ecol. Conf. 3:11-33.

Tew, R. K. 1970. Seasonal variation in the nutrient content of aspen foliage. J. Wildl. Manage. 34(2):475-478.

Tilley, J.M.A. and R. A. Terry. 1963. A two-stage technique for the *in vitro* digestion of forage crops. J. Br. Grassl. Soc. 18(2):104-111.

Van Soest, P. J. 1966. Nonnutritive residues: a system of analysis for the replacement of crude fiber. J. Assoc. Off. Agric. Chem. 49(3): 546-551.

Van Soest, P. J. 1971. Estimations of nutritive value from laboratory analysis. Proc. 1971 Cornell Nutrition Conf. Pages 106-117.

Verme, L. J. 1965. Reproduction studies on penned white-tailed deer. J. Wildl. Manage. 29(1):74-79.

Walters, R.J.K. 1971. Variation in the relationship between in vitro digestibility and voluntary dry-matter intake of different grass varieties. J. Agric. Sci. 76(2):243-252.

Ward, A. L. 1971. In vitro digestibility of elk winter forage in southern Wyoming. J. Wildl. Manage. 35(4):681-688.