MINERAL LICK USE BY MOOSE IN THE CENTRAL ALASKA RANGE

A
Thesis

Master of Science

By
Nancy G. Tankersley, B.S.

University of Alaska
Fairbanks, Alaska
May 1981

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Presented to the Faculty of the University of Alaska
in Partial Fulfillment of the Requirements
for the Degree of

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RECOMMENDED:

Chairman, Advisory Committee

Chairman, Program of Wildlife & Fisheries

Director, Division of Life Sciences

APPROVED:

Vice Chancellor for Research and Advanced Study

Date

ABSTRACT

Natural mineral licks were studied to determine their ecological importance to moose and their use to wildlife managers in Alaska. Chemical analyses and observations of lick use indicated that licks are an important source of sodium for moose in early summer. Most lick use occurred in late evening, unlike the diurnal activity patterns of moose not at licks. Despite high densities of moose in lick areas during early summer, predators did not hunt there. Estimating the sex composition of moose population(s) at licks may not be feasible because there was a disproportionately high rate of lick use by bulls, and a seasonal offset in use by bulls and cows at the licks studied. Estimating the number of calves born each spring from counts at licks was not found to be feasible because calves did not always accompany their dams to the licks.

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INTRODUCTION

Ungulates in various parts of the world seek out mineral elements from sources known as mineral licks (Cowan and Brink 1949, Stockstad _et al_. 1953, Dalke _et al_. 1965, Knight and Mudge 1967, Henshaw and Ayeni 1971, Heimer 1973). Commonly, natural licks are wet muddy areas fed by springs where water or mud is consumed, but some licks are areas of relatively dry soil. Studies of moose (_Alces alces_) using natural mineral licks have been done in Canada and on Isle Royale, Michigan (Murie 1934, Peterson 1955, Jordan _et al_. 1973, Fraser and Reardon 1980). However, little is known about the ecological importance of natural mineral licks used by moose in Alaska.

Many studies have shown that the essential macro-element sodium (Na) is relatively abundant in licks and is selectively sought by ungulates (Dixon 1939, Stockstad _et al_. 1953, Denton and Sabine 1961, Dalke _et al_. 1965, Knight and Mudge 1967, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Fraser and Reardon 1980). But some studies have found relatively high quantities of various other elements in licks (Murie 1934, Cowan and Brink 1949, Peterson 1955, Wright 1956, Chamberlin _et al_. 1977, Gill 1978). Fraser _et al_. (1980b) stated that the inconsistencies in element content of lick water samples reported in the literature are probably due to sampling muddy water in the licks or areas that were contaminated by urine or other nonlick water. Samples of muddy water had higher trace element content (especially iron and manganese), and urine-contaminated puddles had lower levels of Na, chlorine, sulfate, calcium, and magnesium, than did filtered samples taken directly from spring sources (high in Na) in the licks (Fraser *et al*. 1980b).

Most researchers have reported that mineral lick use by ungulates is seasonal, occurring mostly in spring and early summer (Cowan and Brink 1949, Peterson 1955, Dalke *et al*. 1965, Hebert and Cowan 1971, Heimer 1973, Weeks 1978). This seasonal use may be due to Na loss in urine and feces from ingesting large quantities of potassium (K) and water in new-growth forage (Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Salter and Pluth 1980), from winter depletion of mineral reserves (Dixon 1938, Nikolaevskii 1961, Hyvarinen *et al*. 1977), and from increased mineral demand due to pregnancy and lactation (Jordan *et al*. 1973, Weeks 1978, Smith *et al*. 1978), molting (Dixon 1938, Hebert and Cowan 1971), and antler growth.

Predation was found to be high at licks used by mountain goats (*Oreamnos americanus*) in Jasper National Park (Cowan and Brink 1949), but other studies have found little evidence of predation at lick sites (Hebert and

Cowan 1971, Heimer 1973, Carbyn 1975).

Observations at lick sites may provide new wildlife management techniques. Counts of ewes and lambs taken at a Dall sheep (*Ovis dalli*) lick in Alaska have been considered an acceptable alternative to aerial estimates of annual lamb and ewe numbers in the sheep populations (Heimer 1974 and pers. commun.).

Wildlife managers in Alaska are interested in identifying and protecting areas of critical habitat for moose. My study was designed to evaluate the importance of natural licks to moose to determine if these areas should be designated as critical habitat, and the feasibility of determining sex and age composition of moose populations at licks.

Objectives of this study were to: 1) determine what chemical element(s) were relatively abundant in licks used by moose; 2) describe the seasonal and daily cycle of lick use; 3) examine differential use of licks on the basis of sex and age groups; 4) describe social behavior at licks; 5) identify ecological and physical factors affecting lick use; and 6) investigate levels of predation at lick sites.

METHODS

Study Area

An area of approximately 2 km^2 containing 4 natural mineral licks in Denali National Park (formerly Mount McKinley National Park) in Alaska was chosen for study (Fig. 1). The nearest known licks outside of the study area that are used by moose are 11 km away.

The area is underlain by the Cantwell Formation, which is composed of sandstone, shale and conglomerate. Licks 2 and 2a, separated by 30 m (Fig. 1), are located near an overlying glacial deposit, a remnant of earlier glacial activity in the Teklanika River Valley (Gilbert 1979).

Elevations in the study area range from 880 to 980 m, which is near treeline. The area is dotted with several small lakes and ponds and drained by several streams.

Vegetation types (Viereck and Dyrness 1980) include open white spruce forest (*Picea glauca*); open low shrubland, dominated by dwarf birch (*Betula glandulosa* and *B. nana*); open tall shrubland, dominated by feltleaf willow (*Salix alaxensis*); and sedge-grass types near ponds and lakes.

Well-worn game trails lead to the 4 licks, which are only known to be used by moose. The licks are muddy areas, riddled by depressions made by moose hooves. In June,

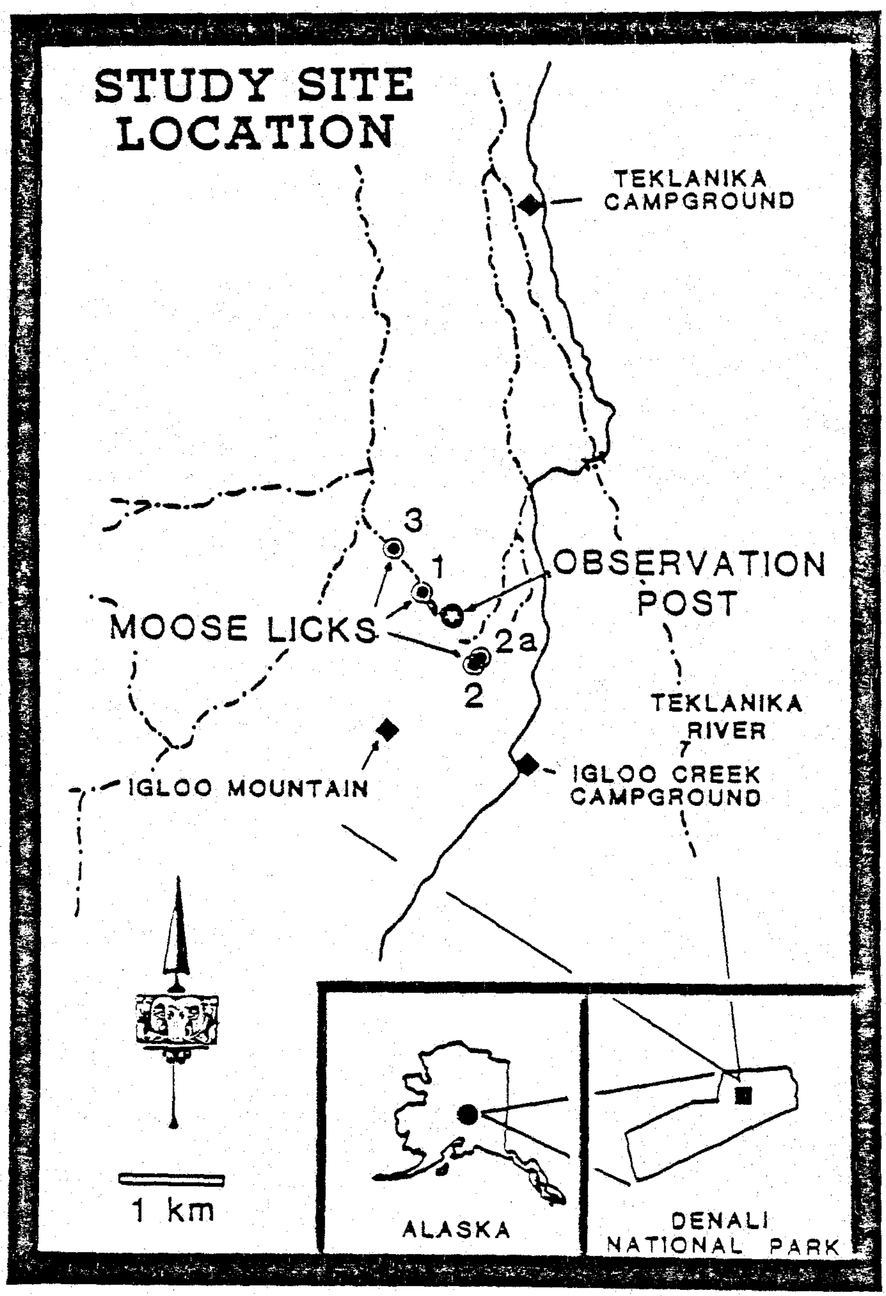

Fig. 1. Study area containing 4 mineral licks used by moose in Denali National Park. Three of the licks (Licks 1, 2, 2a) could be seen from the observation post.

obvious springs emerge in Licks 1 and 2. All the licks are located near the base of hills.

The largest lick, Lick 1, was roughly 600 m^2 and was fed by at least 4 springs. Lick 2 was roughly 470 m^2 fed by 2 or 3 springs. Licks 2a and 3 were the smallest licks, roughly 20 m^2 and 40 m^2 in size, respectively. Lick 2a usually had standing water, and Lick 3 was often dry. No spring source was evident in either. I found a white precipitate on dried soil in the licks, especially before the summer rains began.

Observations

Three of the licks (Licks 1, 2 and 2a) could be observed from the top of a ridge approximately 0.5 km from each (Fig. 1). Roughly 2 km^2 of the surrounding hillside and valley could be seen. Observations of moose were aided by 7 x 26 or 7 x 35 binoculars and a 15-60X spotting scope.

Observations at the licks began on 18 May 1979 during spring thaw and continued regularly until 22 September. Aerial or ground checks of the licks were made when the licks were snow-covered on 25 January, 18 April and 3 May 1980. Intense observations resumed on 21 May 1980 and ended on 15 July 1980.

Between 18 May and 22 September 1979, the licks were observed for 660.25 hours. Continuous daylight in early summer permitted observations during all hours of the day (Fig. 2). Observation shifts varied from 1 to 49 hours in length, but most shifts (62%) were 8 hours or less and made by 1 observer. An additional 12% of these shifts were 2 contiguous 6-hour shifts with a different observer for each.

In 1980, the licks were observed for a total of 306.5 hours in 8-hour shifts including all hours of the day (Fig. 2). Occasionally the evening shifts (2100-0459) were shortened due to fog, high winds or problems with bears. Usually there were 2 observers per shift. Because approximately 50% of the lick activity occurred between 2100-0459 hours in 1979, observations were made during this 8-hour shift twice as often as the other 2 shifts in 1980. Two shifts from 0500-1259 were followed by 2 shifts from 1300-2059, with 4 evening shifts (2100-0459) completing an 8-shift "period." Each 8-hour shift occurred on a different day. Five 8-shift periods were completed in 1980: 21-31 May, 1-12 June, 13-23 June, 24 June to 6 July, and 7-15 July. For comparative purposes, data collected in 1979 were divided into similar periods, although the hours of observation in each period are not equivalent to the hours observed in 1980.

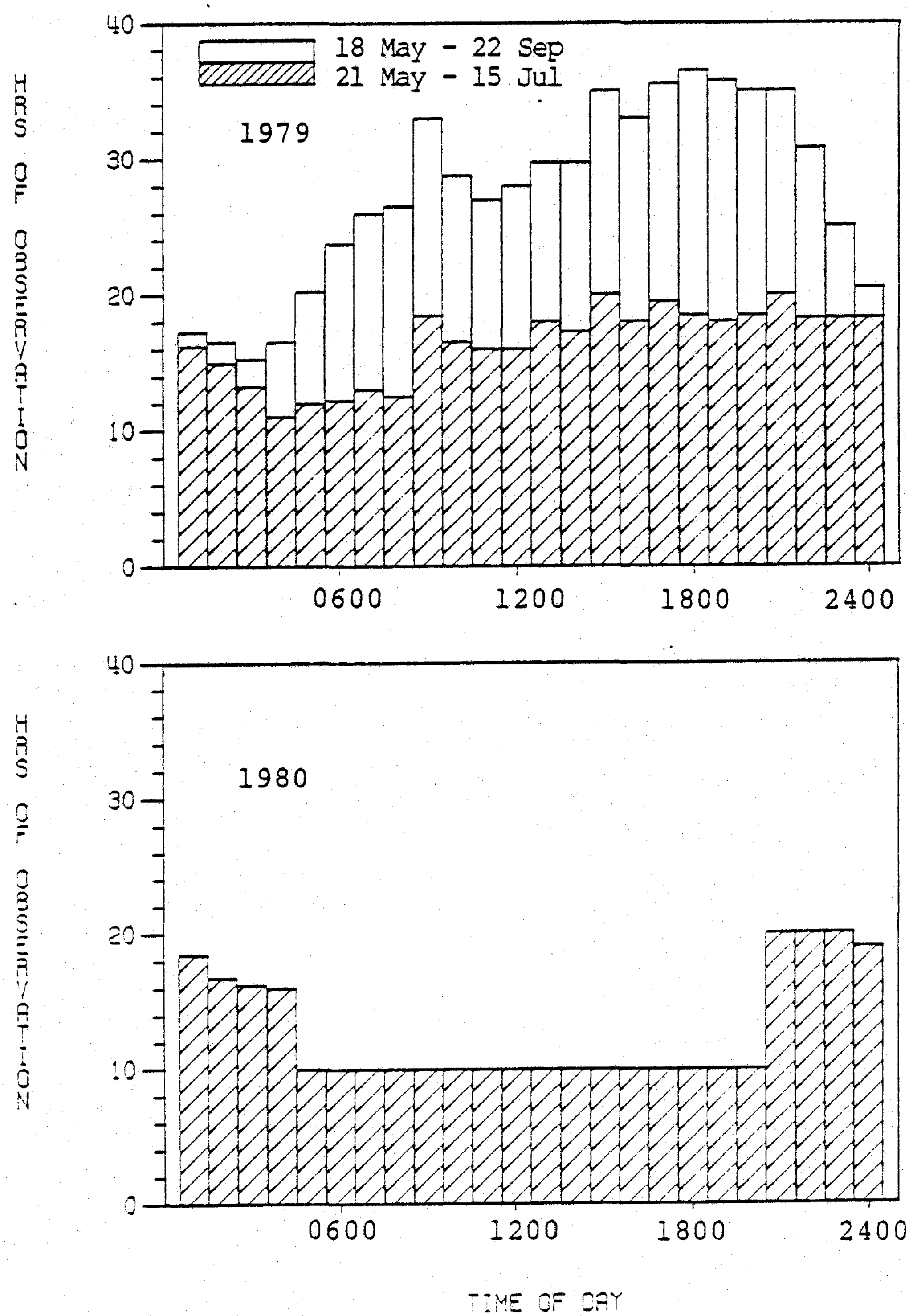

Fig. 2. The number of hours of observation at the licks in Denali National Park during each hour of the day in 1979 and 1980.

Activity Data Collection

Data were recorded at 15 minute intervals using the instantaneous scan sampling method described by Altmann (1974). Data were recorded in numerical codes to speed collection and to facilitate computerized analysis. For at least 3 minutes prior to every quarter hour, the study area was scanned for the location of moose. On every quarter-hour, the activity, location, sex and age category, and an identification number were recorded for each moose seen. Additionally, the date, time, weather conditions (precipitation, approximate wind speed, and in 1980 only, the percent of cloud cover), and wolves (Canis lupus) or grizzly bears (Ursus arctos) seen were recorded. Daily maximum and minimum temperatures were recorded from a max-min thermometer.

Entry and exit times for any moose using a lick were recorded to the nearest minute at any time during a shift. I named this span of time a "lick visit." Lick visits separated by less than 15 minutes were treated as 1 visit, with the actual number of minutes in the lick combined. Occasionally, the entry or exit time was recorded late, but these recorded times were usually not later than 2 or 3 minutes of the actual time. In 1979, this occurred for 33% of the visits, and in 1980, for only 10% of the visits. The time moose spent only licking (consuming water or soil) during a lick visit was also recorded to the nearest minute in 1980. The duration of feeding bouts in the lake adjacent to Lick 1 were also timed.

Moose were classified as bulls if they had antlers. Bulls were classified as adult if their antlers had a main palm and a brow palm, or like a few individuals, well-developed cervicorn antlers. Bulls were classified as subadult if they had only antler nubs, forks, or after mid-June, small spikes or small single palms (not divided into main palm and brow palm). Subadult bulls (mostly yearlings) were also distinguished by their smaller body size.

Moose were classified as cows if they showed no sign of antler development. If conditions of visibility permitted, the presence of a vulva patch was used to confirm the female classification. Only 1 subadult bull of 102 bull moose assigned identification numbers in 1980 had what appeared to be a small vulva patch. Moose not classified into one of the above categories were classified as "unknown age bull," "yearling unknown sex," or "unknown."

During each shift, all moose were given a unique identification number (IDN). Most moose seen were recognized individually throughout at least 1 shift. A sketch (adapted from D. Fraser, unpub.) of antler size and shape, bell shape, coloration, molting patterns and any other unique morphological features was drawn for each moose to facilitate repeated identification. Some moose, especially adult bulls, were recognized repeatedly, for up to 10 weeks. If a moose was recognized from a previous shift, it was given its previous IDN.

Chemical Sampling

Water samples from Licks 1, 2 and 2a as well as nearby control samples (from outside of the lick), were taken on 4 dates in 1979 for mineral element analyses. On 3 June, only Licks 1 and 2 were sampled, and there was no obvious spring source in either. On 3 July and 21 August, the springs were running in Licks 1 and 2, but no obvious flow was ever seen in Lick 2a.

New one l Nalgene bottles were used to contain the sampled water. The sample bottles were cleaned with soap, rinsed with a mild nitric acid solution, and then rinsed 3 times with double distilled water before use. If a spring source was located, as much unmuddied water was obtained as possible, up to one l. No filtering device was used for collection. Unfiltered samples were also taken from standing puddles in the lick. Obvious urine-contaminated puddles (deep orange or wine color) or muddy puddles were avoided. Unfiltered water samples from outside the licks were taken as controls from a nearby stream or lake for comparison to lick samples. A few drops of nitric acid were added to each sample within 24 hours of collection to prevent formation of insoluable precipitates and adhesion of elements to the container's surface during storage.

The samples were filtered in the laboratory through a 0.45-μm filter unit before analyses. An atomic absorption spectrophotometer (precision within 3%) was used for analysis of the essential macro-elements Na and K. An inductively coupled plasma argon flame on a recording emission spectroscope (precision within 2%) was used for analysis of the essential macro-elements calcium and magnesium, and for 9 essential micro-elements (iron, copper, zinc, manganese, cobalt, molybdenum, selenium, chromium, and nickel). This method was also used for analysis of aluminum, cadmium, arsenic, mercury, and lead.

Data Analysis

Unknown age bulls, subadults of unknown sex, and other moose of unknown age or sex were not included in analyses involving differences of lick use on the basis of sex and age, but were included in other analyses. Data on adult and subadult bulls were usually segregated for data analyses, but were occasionally combined if the sample sizes in the 2 groups were too small for statistical tests.

Because of insufficient sample size, the last 4 periods of data from 1979 (16 July-22 September) were usually omitted from statistical tests comparing seasonality of use. The minutes spent licking per visit were sometimes combined from all lick visits for diurnal, seasonal, or sex and age class comparisons of the time spent licking per hour of observation. Also, the minutes spent in a lick per visit were combined for the same kind of comparisons. These combined times are referred to as combined time spent licking or combined time spent in the licks.

I used the Chi Square statistic to test for equal probability of lick use, homogeneity of lick use among sex and age classes, and in the Median Test to differentiate samples on the basis of different medians. The expected values for the equal probability tests were weighted by the number of hours of observation per cell. Multiple regression was used to determine the effects of weather and other factors on lick use. Some statistical analyses were aided by computer software available in the SPSS manuals (Nie _et al_. 1975, Nie and Hull 1977) and the BMDP manual (Dixon and Brown 1977).

RESULTS

Chemical Analyses

Sodium was the only element analyzed that was much higher in most of the lick samples than in the control samples (Fig. 3, Table 1). The Na levels in samples taken 3 June from Lick 2 are low probably because no spring source was available for sampling, and only standing, dilute water was taken (Table 1).

Lick 1 had the highest mean Na content of the 3 licks, and Lick 2a had the lowest, based on comparative samples taken on 21 August. Lick 1 was the largest of the 3 licks and was used the most. Lick 2a was the smallest lick and was used the least (Table 2).

General Characteristics of Lick Users

Moose often moved rapidly to one of the licks along one of the well-established trails. Usually moose would drink from the standing puddles or from a spring, often appearing to sniff several places before choosing where to drink. Places where the springs emerged did not appear to be preferred over the spring-fed puddles in the lick. Concentration of Na in some puddles was as high or higher than identifiable spring sources (Table 1). Sometimes the mud would be licked, especially on the sides of sedge tussocks where I sometimes found a white precipitate. Mud

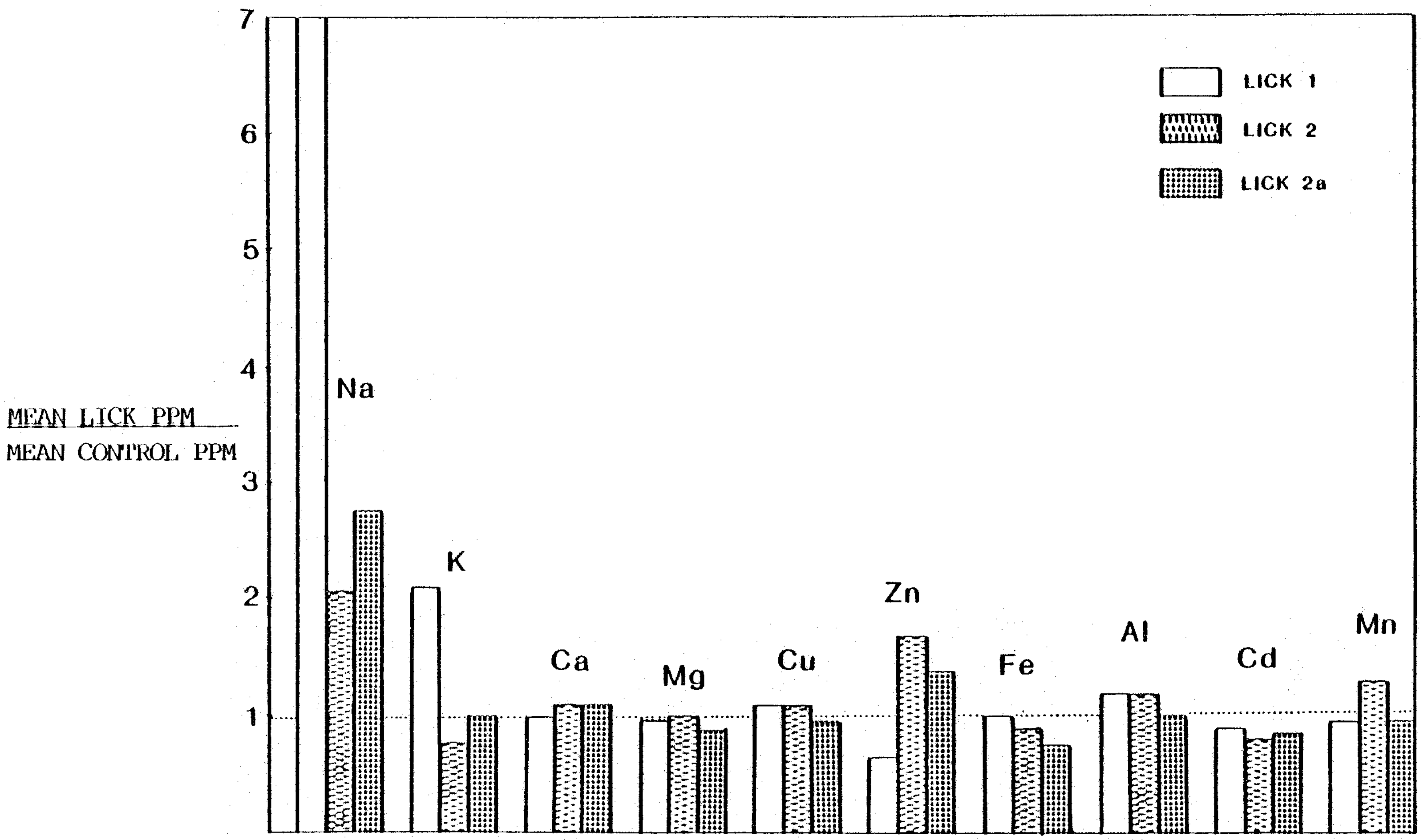

Fig. 3. Ratios of lick sample element content to control sample content based on all samples taken in 1979 from the 3 licks studied in Denali National Park. The dotted line is placed at the 1:1 ratio point.

Table 1. Chemical elements (ppm) in water samples taken from the 3 licks and control sites in Denali National Park during 1979.[a]

LICK 1		Na	K	Ca	Mg	Cu	Zn	Fe	Al	Cd	Mn
3 Jun	Above main spring	66	2.4	9.1	4.0	2.3	2.2	0.2	0.17	0.10	0.20
	Center puddle	307	3.8	5.7	6.5	0.7	1.6	0.4	0.12	0.13	0.22
	Mean	187	3.1	7.4	5.3	1.5	3.8	0.3	0.15	0.12	0.21
3 Jul	Main spring source	280	2.4	5.7	3.6	0.8	1.6	0.3	0.06	0.13	0.12
	Main spring source	294	2.1	6.7	5.7	0.9	1.9	0.4	0.13	0.20	0.26
	Above main spring	293	7.3	12.2	4.6	0.7	1.3	0.4	0.16	0.16	0.24
	Above main spring	253	2.6	8.9	3.4	0.8	1.4	0.6	0.19	0.15	0.20
	North side seep	52	5.3	5.6	3.4	0.6	2.0	0.3	0.15	0.09	0.13
	North side seep	45	6.0	8.5	4.3	0.8	2.7	0.2	0.17	0.17	0.10
	Below main spring	247	3.6	5.2	2.9	0.5	1.4	0.3	0.16	0.12	0.12
	Mean	209	3.8	7.5	4.0	0.7	1.8	0.4	0.15	0.15	0.17
21 Aug	Main spring source	205	8.7	6.2	4.6	0.7	1.2	0.2			
	North side seep	243	6.0	7.1	3.6	0.7	2.5	0.2	0.17	0.09	0.12
	North side seep	154	4.5	6.8	4.3	0.8	1.6	0.3	0.08	0.12	0.10
	Above main spring	203	2.1	10.4	3.7	0.8	2.4	0.3	0.09	0.17	0.16
	Mean	201	5.3	7.6	4.1	0.8	1.9	0.3	0.11	0.13	0.13
CONTROL SAMPLES - Lick 1											
3 Jun	Adjacent lake	31	1.4	6.6	3.9	0.5	1.8	0.3	0.18	0.17	0.23
3 Jul	Adjacent lake	36	3.5	6.3	3.8	0.7	3.1	0.3	0.08	0.11	0.16
21 Aug	Adjacent lake	20	1.4	9.7	5.2	0.9	4.0	0.3	0.11	0.18	0.13
Mean		29	2.1	7.5	4.3	0.7	3.0	0.3	0.12	0.15	0.17

Table 1 cont.

LICK 2		Na	K	Ca	Mg	Cu	Zn	Fe	Al	Cd	Mn
3 Jun	Muddy top puddle	39	2.5	7.0	3.6	0.7	1.7	0.4	0.12	0.18	0.25
	Puddle near top	21	3.6	8.1	4.3	0.9	1.8	0.4	0.16	0.09	0.24
	Center puddle	53	4.0	6.9	3.9	0.8	1.9	0.4	0.18	0.12	0.21
	Side puddle	59	4.2	9.8	7.2	1.3	1.6	0.4	0.17	0.15	0.26
	Mean	43	3.6	8.0	4.8	0.9	1.8	0.4	0.16	0.14	0.24
21 Aug	East side seep	203	2.8	5.6	5.2	0.9	1.8	0.3	0.10	0.11	0.11
	Middle seep	146	3.2	8.2	3.6	1.6	1.4	0.2	0.07	0.12	0.16
	West side seep	58	4.3	6.5	2.8	0.7	1.5	0.4	0.23	0.14	0.15
	Mean	136	3.4	6.8	3.9	1.1	1.6	0.3	0.13	0.12	0.14
LICK 2a											
21 Aug	Upper puddle	113	4.5	9.1	3.6	0.8	3.0	0.4	0.14	0.13	0.13
	Lower puddle	40	4.1	9.0	3.7	0.7	2.2	0.2	0.12	0.16	0.13
	Mean	76	4.3	9.1	3.7	0.8	2.6	0.3	0.13	0.15	0.13
20 Sep	Puddle	183	5.0	4.2	3.7	0.8	1.7	0.3	0.12	0.12	0.17
CONTROL SAMPLES - Licks 2, 2a											
3 Jun	Adjacent stream	65	6.7	5.5	4.8	0.6	1.7	0.2	0.14	0.17	0.23
3 Jul	Adjacent stream	34	3.0	7.1	5.1	0.9	1.5	0.4	0.13	0.13	0.14
"	Adjacent stream	38	3.2	4.3	3.5	0.8	1.3	0.4	0.12	0.16	0.12
21 Aug	Adjacent stream	23	5.2	8.3	3.9	0.8	1.7	0.4	0.14	0.16	0.12
Mean		40	4.5	6.3	4.3	0.8	1.6	0.4	0.13	0.16	0.15
1 l dist. water w/5 drops HNO_3		5	0.1	0.4	0.3	0.2	0.6	0.2	0.01	0.08	0.02

[a]The following elements were near or below detection limits (in parentheses) for all samples: As(0.001), Cr (0.001), Hg (0.001), Mo (0.001), Ni (0.01), Pb (0.005), Co (0.01), and Se (0.01).

Table 2. Number of lick visits (N), mean and SD of minutes spent in the lick per visit, and mean and SD of minutes spent licking per visit during 1979 and 1980.

	1979			1980			1980		
	Min spent in lick/visit			Min spent in lick/visit			Min licking/visit		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD
LICK 1	225	17[a]	10	231	22[a]	14	226	14[a]	11
LICK 2	127	13	8	66	10	6	66	7	4
LICK 2a	13	9	9	11	5	5	11	3	2

[a]Minutes spent in a lick per visit and minutes licking per visit were different at each lick ($P < 0.001$).

licking occurred more often in late May before the springs began to flow than later in the summer. Also, later in the summer, most calves chose to lick the mud rather than drink water in the lick.

Lick visit lengths averaged 15 minutes in 1979 and 19 minutes in 1980, ranging from 1 to 78 minutes. However, the time spent only licking (consuming water or soil) during a visit averaged 12 minutes during 1980, ranging from 1 to 74 minutes. The remainder of the time in a lick was generally spent pausing between drinks, or in an alert posture in response to another moose approaching or other noises. Therefore, the time spent only licking during a visit was considered a more accurate measurement of lick use than the total length of a lick visit.

The average amount of time individually identified moose were monitored was short (Table 3), perhaps because individual moose did not stay in the study area a long time, or because the moose were not re-identified often. The moose that were re-identified for the longest time were ones with unique physical features. But not all identifiable moose made frequent use of the licks (Table 4).

My study area had a high density of moose during the peak lick use season. Moose density in the eastern part of the Park is roughly 0.3 to 0.6 moose per km^2, based on

Table 3. The number of moose IDNs assigned (N) during 1979 and 1980, and the associated data compiled from them.

Year	N	No. shifts an IDN was seen		No. days between 1st & last record		No. lick visits/IDN		Total min in licks/IDN		Total min licking/IDN	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1979	304	1.3	0.85	1.9	5.3	1.8	1.48	28.2	26.8		
1980	201	1.5	0.99	2.2	3.9	2.3	1.46	41.9	39.6	26.9	27.7

Table 4. Lick use by some individual moose.

Year	IDN	Sex & Age	1st day identified	Last day identified	No. shifts seen	No. lick visits	Total min in licks	Total min licking	Comments
1979	28	Adult bull	2 Jun	5 Jun	3	1	12		Unique cervicorn antlers
1979	144	Adult bull	27 Jun	20 Aug	8	2	34		
1979	146	Adult bull	27 Jun	12 Jul	4	4	>65		
1979	180	Subad bull	11 Jul	15 Sep	8	7	>102		
1979	181	Subad cow	11 Jul	22 Jul	5	5	59		Possibly #180's twin
1979	200	Adult bull	16 Jul	13 Aug	5	0	0		
1979	76	Adult bull	7 Jun	11 Jun	5	11	>188		Made most visits/indiv in 1979
1980	29	Adult bull	2 Jun	5 Jul	5	0	0	0	Cervicorn antlers-possibly old bull
1980	11	Subad bull	27 May	30 May	4	5	242	218	Most time licking/indiv
1980	14	Subad bull	29 May	8 Jun	4	3	22	15	Re-identifiable in these 2 weeks
1980	35	Adult bull	3 Jun	23 Jun	6	7	131	>74	Light velvet streaks
1980	44	Adult cow	7 Jun	9 Jun	2	5	>91	>74	Distinctive when molting
1980	61	Adult bull	11 Jun	13 Jul	4	4	>96	>77	Light velvet patches
1980	66	Adult bull	11 Jun	27 Jun	6	6	72	37	Light velvet patches
1980	140	Cow w/2 calves	26 Jun	2 Jul	4	6	148	73	
1980	148	Cow w/2 yrlgs	28 Jun	29 Jun	1	0	0	0	With #146, #147
1980	146	Yrlg bull	28 Jun	29 Jun	1	2	49	23	Defended by #148
1980	147	Yrlg bull	28 Jun	29 Jun	1	2	69	34	Defended by #148
1980	189	Cow w/2 calves	7 Jul	13 Jul	3	5	53	>41	
1980	200	Subad bull	13 Jul	15 Jul	2	9	239	143	Made most visits/indiv in 1980

1974-80 aerial counts of moose per km^2 of moose habitat (below 1000 m). The number of different moose seen per 8-hour shift in my study area (2 km^2) in the early summer of 1980 varied from 2 to 19, with an average evening density of 5.0 moose per km^2. Because this density of moose did not continue year-round (Fig. 4 and Troyer 1980), it is likely that moose traveled to the study area in early summer to use the licks.

Seasonal Variation

Like other ungulates in North America, moose used the licks intensely in spring and early summer. Use of the licks commenced in mid-May after the spring thaw, peaked during June, and tapered markedly by late July (Fig. 4). In July when lick use was declining, moose spent more time eating aquatic plants than earlier in the summer (Table 5). No use of the licks was recorded during the winter of 1979-80, based on spot checks for tracks when the area was snow-covered in January, April and early May.

During the summer of 1979, the number of lick visits observed and the relative number of moose seen (the number of IDNs) in the study area had the same pattern ($P > 0.10$) until late summer ($P < 0.001$). The relative number of moose seen increased in September, but a proportional rise in the number of lick visits or in the combined time spent

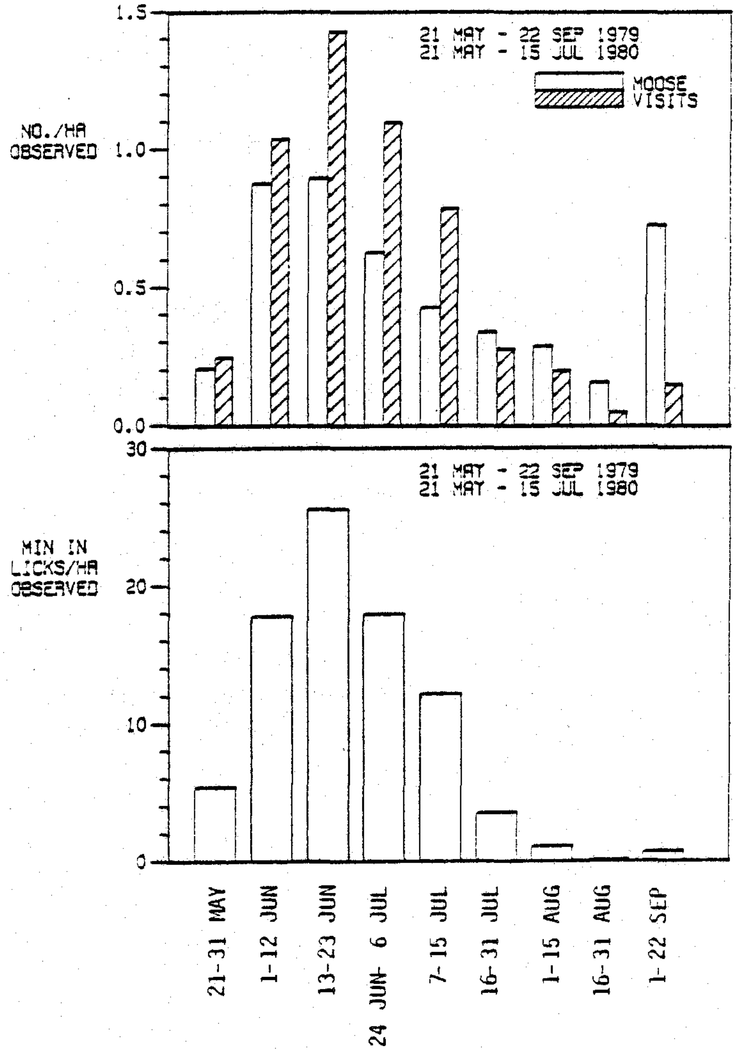

Fig. 4. Relative number of moose seen (based on IDNs), number of lick visits, and combined time (in minutes) spent in the licks per hour of observation during 9 periods of the summer in Denali National Park.

Table 5. Hours of observation, aquatic feeding, and lick use by sex and age groups during summer periods of 1979 and 1980.

Dates	21-31 May	1-12 Jun	13-23 Jun	24 Jun-6 Jul	7-15 Jul	16-31 Jul	1-15 Aug	16-31 Aug	1-22 Sep	TOTAL
Hrs obs 1979	77.25	123	40.25	90.75	63.75	74	66.25	44	33	612
1980	64	61.5	61.5	64	55.5					306.5
Aquatic feeding min/hr										
1979	0.0	0.91	0.0	4.4	20	11	2.4	0.95	1.6	4.7
1980	0.0	0.80	0.44	3.0	13.0					3.2
No. visits/ hrs obs										
1979										
Adult bulls	0.04	0.42	0.67	0.18	0.09	0.07	0.0	0.0	0.03	0.18
Subad bulls	0.06	0.29	0.4	0.13	0.08	0.03	0.08	0.0	0.0	0.13
Lone cows	0.04	0.20	0.27	0.56	0.38	0.16	0.03	0.05	0.12	0.22
Cows with calves	0.0	0.0	0.05	0.08	0.11	0.03	0.09	0.0	0.0	0.04
All bulls	0.12	0.73	1.1	0.26	0.17	0.09	0.08	0.0	0.03	0.31
All cows	0.04	0.20	0.32	0.64	0.49	0.19	0.12	0.05	0.12	0.26
Total	0.18	1.0.0	1.5	0.95	0.67	0.28	0.20	0.05	0.15	0.60
1980										
Adult bulls	0.14	0.41	0.34	0.16	0.09					0.23
Subad bulls	0.19	0.28	0.44	0.36	0.14					0.28
Lone cows	0.02	0.37	0.60	0.70	0.50					0.24
Cows with calves	0.0	0.0	0.0	0.09	0.18					0.05
All bulls	0.33	0.68	0.78	0.52	0.23					0.51
All cows	0.02	0.37	0.60	0.80	0.68					0.49
Total	0.34	1.1	1.4	1.3	0.92					1.0

Table 5 cont.

Dates	21-31 May	1-12 Jun	13-23 Jun	24 Jun-6 Jul	7-15 Jul	16-31 Jul	1-15 Aug	16-31 Aug	1-22 Sep	TOTAL
Min in licks/hr obs										
1979										
Adult bulls	0.63	8.0	14	1.7	1.7	0.82	0.59	0.0	0.33	3.2
Subad bulls	0.75	4.4	9.9	1.7	1.4	0.35	0.0	0.0	0.0	2.1
Lone cows	0.52	2.9	4.6	7.1	4.4	2.3	0.11	0.09	0.39	2.8
Cows with calves	0.0	0.0	0.35	0.79	0.83	0.12	0.41	0.0	0.0	0.29
All bulls	1.4	13	24	3.8	3.1	1.2	0.59	0.0	0.33	5.4
All cows	0.52	2.9	5	7.9	5.3	2.4	0.51	0.09	0.39	5.1
Total	2.0	17	29	12	8.4	3.6	1.1	0.09	0.73	8.9
1980										
Adult bulls	2.8	8.8	7.4	3.1	1.4					4.7
Subad bulls	6.5	4.4	7.1	9.3	4.3					6.4
Lone cows	0.16	6.2	8.3	12	6.1					6.5
Cows with calves	0.0	0.0	0.0	2.8	4.6					1.4
All bulls	9.4	13	14	12	5.7					11
All cows	0.16	6.2	8.3	15	11					7.9
Total	9.5	19	23	27	17					19
Min licking/hr obs										
1980										
Adult bulls	2.2	5.2	4.9	1.5	0.81					3.0
Subad bulls	5.4	3.1	4.2	4.6	2.5					4.0
Lone cows	0.16	3.9	6.2	6.8	3.5					4.1
Cows with calves	0.0	0.0	0.0	1.3	2.8					0.78
All bulls	7.6	8.4	9.1	6.0	3.3					7.0
All cows	0.16	3.9	6.2	8.2	6.2					4.9
Total	7.8	12	15	14	9.5					12

in the licks did not occur (Fig. 4).

Cow and bull moose had different seasonal patterns of lick visits, of combined time spent in the licks, and of combined time spent licking ($P < 0.001$). In general, bulls used the licks earlier in the season than the cows did (Fig. 5). There was no consistent seasonal trend of lick use by adult bulls compared to that of subadult bulls in both 1979 and 1980 (Table 5). Cows that brought calves to the licks were observed only after mid-June (Table 5).

The time spent licking per visit did not vary during 1980 for cows ($P > 0.25$), or bulls ($P > 0.20$) among the 4 periods of 1980 after 31 May. The means of time spent licking per visit for bulls are longer during 21-31 May than during any other period (Fig. 6), but the sample sizes for this period were insufficient to test statistically against later periods of the summer.

Diurnal Variation

Lick use by moose had a marked diurnal pattern, with a peak around midnight and a low in mid-day for both 1979 and 1980 (Fig. 7). More lick visits were made per hour of observation during 2100-0459 than for either of the other 2 8-hour periods of the day ($P < 0.001$).

In both 1979 and 1980, adult bulls, subadult bulls, and cows had the same ($P > 0.25$) pattern of lick visits

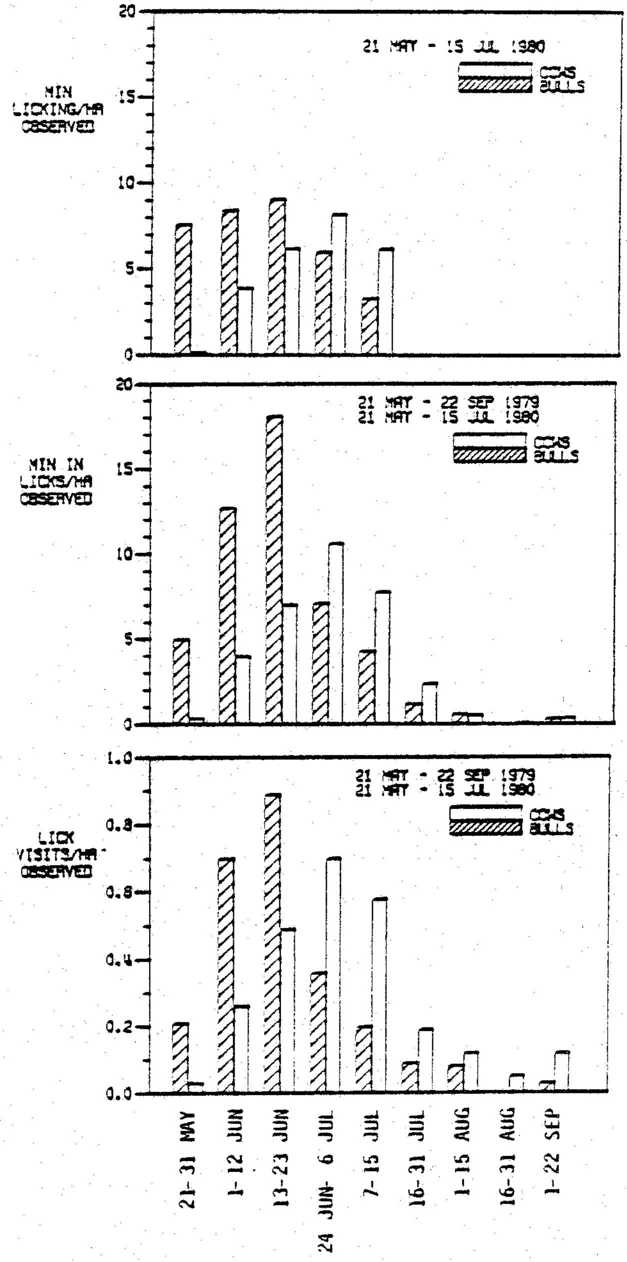

Fig. 5. The number of lick visits, the combined time (minutes) spent in the licks, and the combined time (minutes) spent licking for cows and bulls per hour of observation during 9 periods of the summer in Denali National Park.

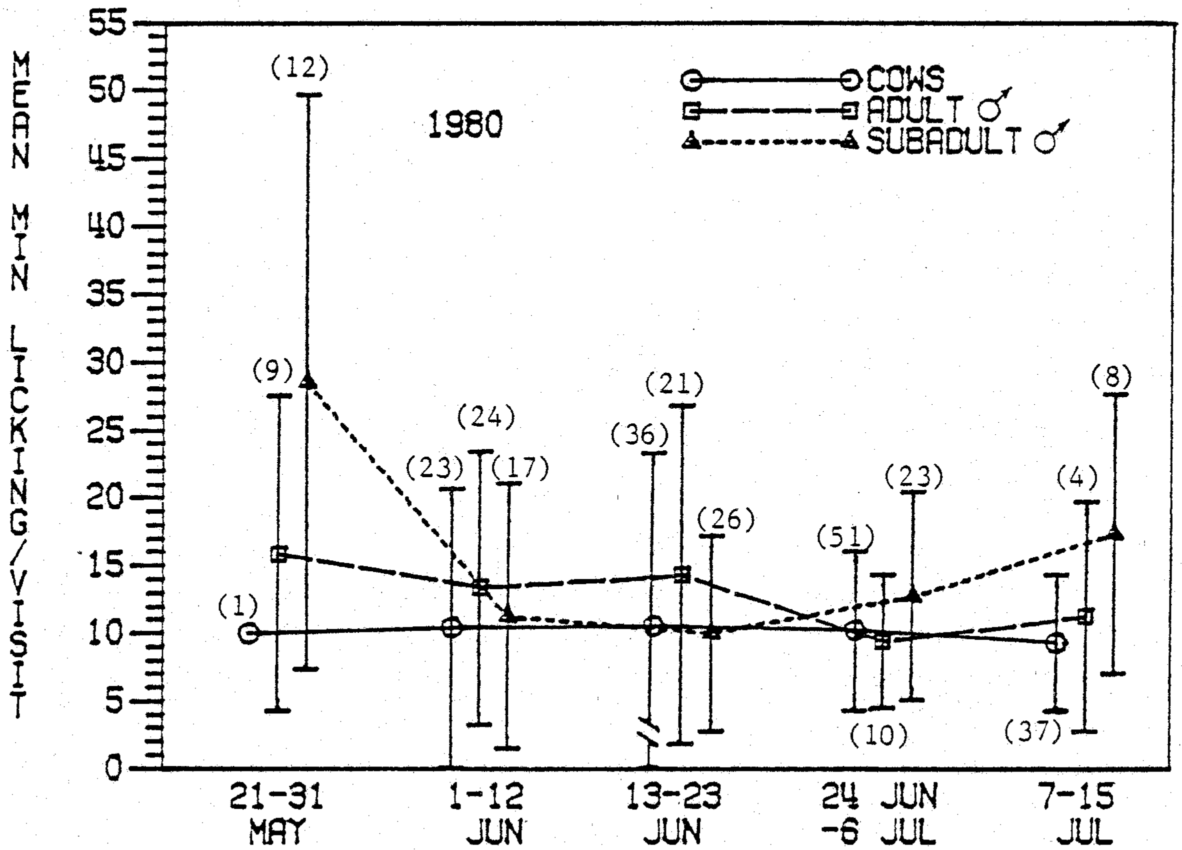

Fig. 6. Mean time spent licking per visit ± SD (in minutes) for lick visits made by cows, adult bulls, and subadult bulls during 5 periods of 1980. The number in parenthesis is the number of lick visits for that sample.

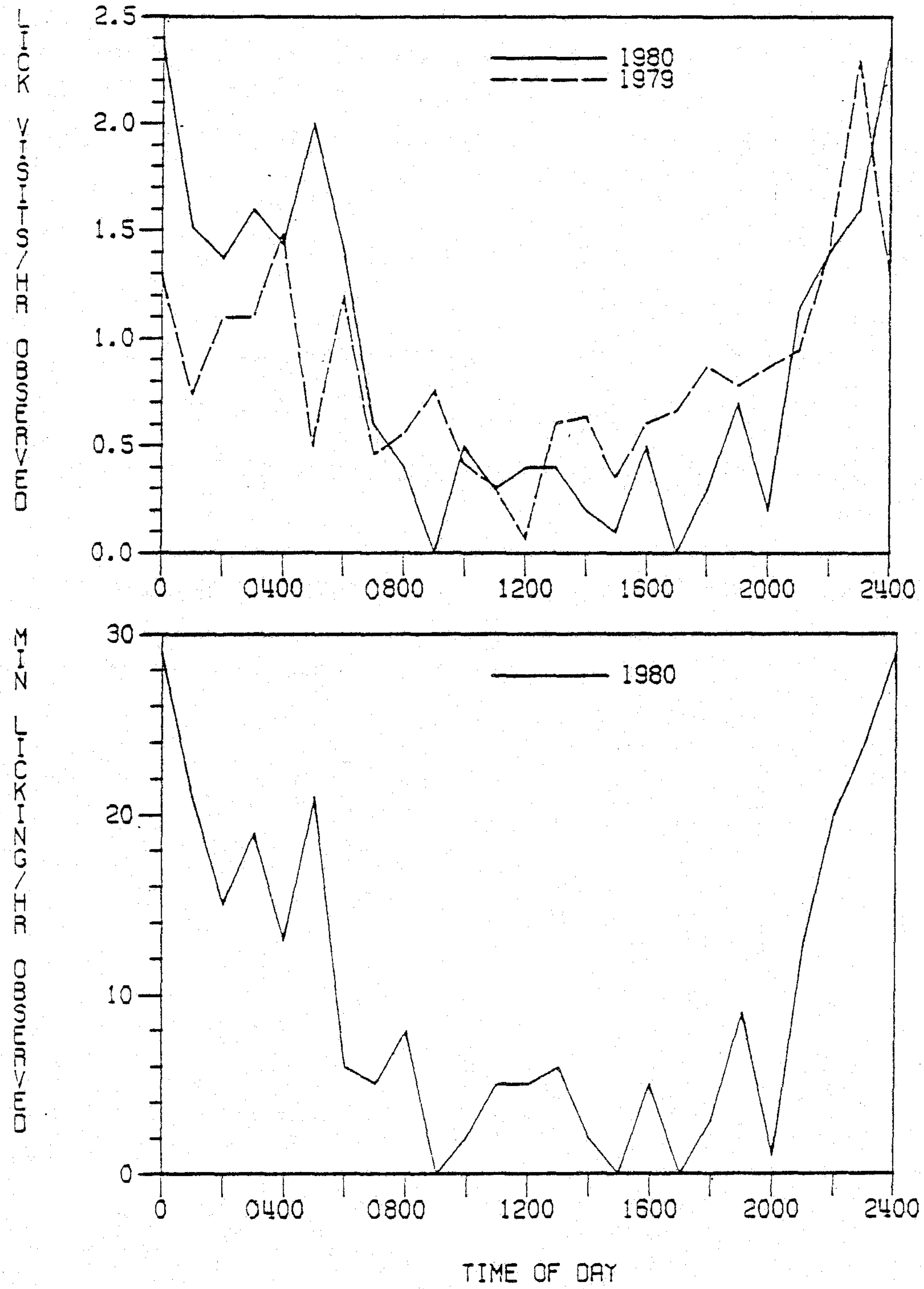

Fig. 7. Diurnal pattern of lick visits and combined time (minutes) spent licking per hour of observation.

during the 3 8-hour periods of the day. However, during 1980, the 3 groups had different ($P < 0.001$) diurnal patterns of combined time spent licking. The difference was mostly due to the adult bulls spending more time licking than expected during 0500-1259. Adult bulls had the highest mean time spent licking per visit during 0500-1259, whereas cows and subadult bulls had their lowest mean during this time (Fig. 8). However, there was no strong indication of a significant difference among these 3 groups ($P = 0.088$) during that time period.

Among the 3 periods of the day, there was some indication that the time spent licking per visit for cows differed ($P = 0.055$), but the times for adult and subadult bulls combined did not differ among the 3 periods ($P > 0.10$).

Sex and Age Composition

Bulls had higher rates of lick use than did cows (Table 5), either due to more lick visits made per bull or proportionately more bulls using the licks than were in the population. The proportion of cows, adult bulls, and subadult bulls seen in the study area (based on the IDNs assigned) were similar in 1979 and 1980 ($P > 0.10$) but were distinctly different from expected ratios ($P < 0.001$), based on the fall aerial composition count taken in 1980 in

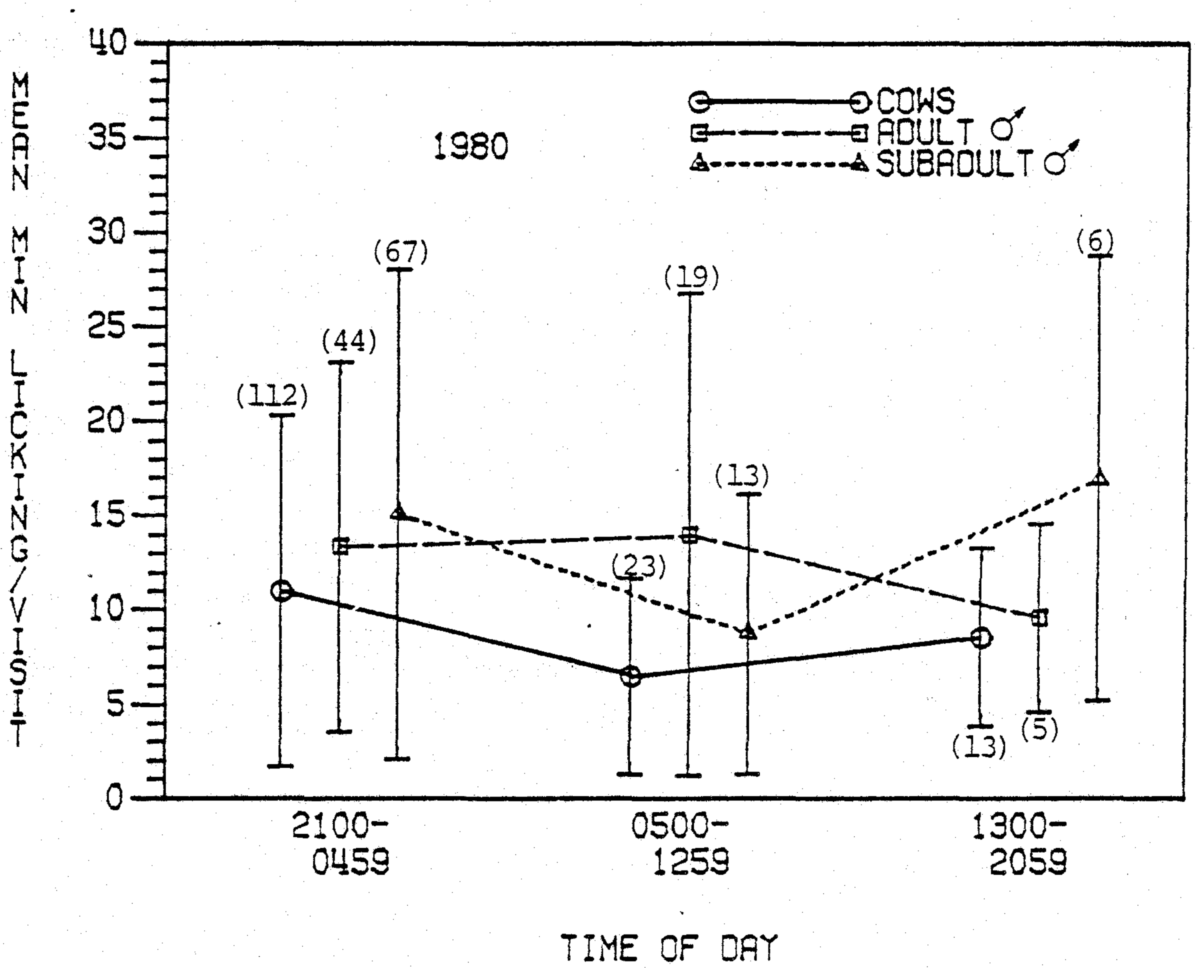

Fig. 8. Mean time spent licking per visit ± SD (in minutes) for cows, adult bulls, and subadult bulls during 3 periods of the day. The number in parenthesis is the number of lick visits for that sample.

the eastern portion of the Park (Troyer 1980). The fall aerial count was not completed in 1979. Bull to cow ratios from aerial composition counts in November or December from 1974 to 1980 in eastern Denali National Park have ranged from 25.8 to 44.6:100 (Troyer 1980). Yet, the sex ratio from my 1979 data on moose IDNs was 121:100; during 1980, it was 107:100. Most of the disparity between my bull counts and aerial bull counts is due to the numbers of subadult bulls. In 1980, only 3% of the moose seen in the aerial count were subadult bulls, but 29% of my IDNs were subadult bulls. My relatively high bull ratios may even be an underestimate as it is likely that the IDN ratios have inflated cow counts (see Methods).

There was some indication that the time spent licking per visit differed among the cows, adult bulls, and subadult bulls ($0.10 > \underline{P} > 0.05$). Subadult bulls had the highest mean time (14.3 minutes ± SD 12.4, n = 86), adult bulls had the next highest (13.3 ± SD 10.4, n = 68), and cows had the lowest mean time (10.1 ± SD 8.6, n = 148).

The first calf seen in the study area in 1979 was sighted on 24 May. Although moose calves are born in Denali National Park from mid-May to mid-June, very few calves were seen until 22 June, when cows were first seen bringing their calves to the licks. The same general trend was true in 1980 when on 8 June the first calf was seen in the study area, and on 26 June, calves were first seen using the licks. The time spent licking by calves was often difficult to observe because of their small size. Cows with calves did not always bring their calves to the licks, but when they did, the time spent licking by the calf per visit was usually less than that of the dam's (Table 6).

Effects of Weather and Other Factors

In 1980, the number of lick visits observed in each 8-hour shift varied from 0 to 27. Similarly, the combined time spent licking by moose recorded from each shift varied from 0 to 353 minutes. Certain weather variables were investigated to explain this variation. Two simple linear regression models were constructed, using maximum and minimum daily temperature, average cloud cover, total precipitation and maximum wind speed, with the dependent variable being either the number of lick visits observed or the combined time spent licking. Maximum wind speed per shift was the only significant weather factor ($P < 0.01$) that explained some of the variation in either dependent variable, lick visitation or combined time spent licking.

Maximum wind speed was not the only important recorded variable affecting lick use per shift, however. A forward stepwise regression procedure using maximum wind speed per

Table 6. Lick use in 1980 by cows known to have calves.

Date	Hour	IDN	No. calves present in lick	Min licking by cow	Min licking by calf(ves)
26 Jun	1300	140	2	10	>5 / >7
26 Jun	1400	140	2	5	5 / >5
26 Jun	1800	140	0	10	
26 Jun	1900	140	0	21	
27 Jun	1300	140	2	6	4 / 5
29 Jun	2400	140	0	21	
29 Jun	2100	160	2	12	5 / 5
30 Jun	2100	161	1	14	<1
1 Jul	2300	161	1	7	<1
2 Jul	0100	161	1	6	2
8 Jul	0600	189	0	8	
8 Jul	0700	189	0	4	
12 Jul	2200	189	2	9	unknown
12 Jul	2300	189	2	20	unknown
13 Jul	0900	189	2	unknown	unknown
9 Jul	1500	193	1	2	2
9 Jul	1600	193	1	3	unknown
14 Jul	0400	193	1	13	unknown
12 Jul	2100	197	0	17	
12 Jul	2200	198	1	11	unknown
13 Jul	2000	198	1	9	6
13 Jul	2100	199	1	6	unknown
13 Jul	2300	199	1	10	>4
14 Jul	0400	199	0	17	
14 Jul	2000	199	0	14	
14 Jul	2200	199	0	8	
14 Jul	2200	199	0	11	

shift and other variables affecting lick use ($P < 0.01$) revealed that 63% of the variation in lick visitation was explained by the time of the shift (39%), maximum wind speed (15%), and a quadratic expression of date (9%), in that order of entry into the regression equation. There was some evidence ($0.05 < P < 0.10$) that minimum temperature affected the variability of visits per shift, explaining an additional 3% of that variation. The variation in the combined time spent licking was also analyzed by a forward stepwise regression and 53% of the variation was accounted for by the time of the shift (42%), and maximum wind speed (11%), in that order of entry. These were the only 2 significant independent variables ($P < 0.01$) in this procedure.

In general, evening shifts (2100-0459) had a higher number of lick visits ($r = 0.62$) and moose spent more time licking then ($r = 0.65$) than during the 2 daytime shifts (0500-1259, 1300-2059). Maximum wind speeds greater than 30 km/hr (measured from the observation post) reduced the number of lick visits ($r = -0.52$) and the combined time spent licking per shift ($r = -0.47$). The date determined the peak of lick use (Fig. 4).

Certain weather factors, along with other variables, were also investigated in a forward stepwise regression procedure to explain the large variation in lick visit lengths and in the time spent licking per visit (Figs. 6 and 8). The 3 weather conditions measured during a lick visit (precipitation, wind speed, and cloud cover) did not explain a significant amount (*P* < 0.01) of the variation in either the time spent licking or the time spent in a lick per visit. Of the other factors measured, 18% of the variation in time spent licking per visit was explained by a quadratic expression of date (6%), a quadratic expression of time of day (2%), and which lick was used (10%), in that order of entry.

During 1980, 19% of the variation in the time spent in a lick per visit was accounted for by a quadratic expression of date (2%), a quadratic expression of time of day (2%), and which lick was used (15%), in that order of entry. In 1979, 19% of the variation in length of a lick visit was accounted for by a quadratic expression of date (8%), the number of other moose in the lick (3%), which lick was used (5%), and the sex and age group of the lick user (3%), in that order of entry.

In 1979, an increase in the number of moose using a lick at one time was associated with an increase in the length of a lick visit ($r = 0.23$). The other factors influencing length of lick visits and the time spent licking per visit (date, time of day, and which lick was used) are discussed in other sections.

Social and Behavioral Aspects

The lick area may have been used as a meeting place for moose, especially at the beginning of the rut in mid-September. In mid-September, sparring, Flehmen, naso-genital testing, and other rut activities by a group of 8 moose were observed near Licks 2 and 2a, but they did not use the licks much (Fig. 4). Only a few cows in this group used the lick briefly at that time.

Earlier in the summer, moose would meet in a lick, then exit and browse together for a period of time. Yearling moose seemed especially eager to associate with other moose in early summer, probably because of recent abandonment by their dams.

Few aggressive encounters were observed among moose at the licks. The number of moose in a lick at one time varied from 1 to 7 during 1979, and 1 to 6 during 1980. During 204 lick visits in 1979 when more than 1 moose was present, only 10 aggressive encounters were seen. In 1980, only 11 aggressive encounters occurred during 196 lick visits when more than 1 moose was present. In each year, 8 of these encounters were initiated by cows, 4 of which appeared to be protecting their own calf or yearling. Most of these encounters were brief and most ended with all moose present sharing the lick.

Predation

In 1979 and 1980, grizzlies were sighted 27 times and lone wolves twice. The correlation between predator sightings and the number of moose seen per 8-hour shift in 1980 was extremely low ($r = 0.057$). Even though grizzly bears are common in Denali National Park and an active wolf den was located within 2.5 km of the study area, no incidents of predators hunting moose in the lick area were observed. In addition, no remains of dead moose were discovered near the licks.

DISCUSSION

Sodium seems to be the element sought at the licks. Sodium was the only element that was relatively abundant in all of the licks, with the exception of some samples taken from standing puddles which may have been diluted by precipitation or contaminated by urine. The lick with the highest amount of Na was used the most, which supports other mineral selection experiments with ungulates (Packard 1946, Stockstad et al. 1953, Ueckermann 1968, Fraser and Reardon 1980) and reports of preferred areas in licks containing more Na (Dalke et al. 1965, Hebert and Cowan 1971, Heimer 1973, Weeks 1978). Anions associated with the Na ion (e.g. Cl^-, SO_4^{-2}, HCO_3^{-2}) are not selectively sought by moose (Fraser and Reardon 1980).

The extreme variability in lick visit lengths and time spent licking per visit that is not explained by the weather conditions and other measured factors may be due to how many previous visits an individual has made (Heimer 1973), individual variation in mineral demand, or other unknown factors. The data on moose that were re-identified indicate that lick use may be highly variable among individuals. Perhaps this is because salt appetite may exceed the need in some moose, similar to that found for domestic sheep by Denton and Sabine (1961). The data set on lick use by individual moose is incomplete however, due to lack of re-identification of all moose, not obtaining information on use of Lick 3 (thought to be minor because of its small size and dryness) and possibly other licks used by these moose, and not observing lick use 24 hours each day.

The seasonal use of the licks is not just because the springs are unfrozen in the summer, because lick use declined in July even though 2 of the licks had active springs through September. And, even though there was an influx of moose into the study area in September, the licks were not used much then. Rather, seasonal use of the licks is probably due to a Na deficiency in early summer. Appetite for Na is known to increase during a deficiency (Denton and Sabine 1961). Bud break of willow (*Salix* spp.)

and dwarf birch (*Betula nana* and *B. glandulosa*) occurred in late May in 1979 and 1980, providing new succulent forage for the moose. Higher levels of K and water in spring and summer forage, relative to Na levels, reduce Na retention (Suttle and Field 1967, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Salter and Pluth 1980). Ratios of K:Na in willow and other browse species eaten by moose are 44 to 101 times higher in summer than in winter on the Kenai Peninsula, Alaska (Oldemeyer *et al*. 1977). Franzmann *et al*. (1975) found that the lowest levels of Na in hair taken from live moose on the Kenai Peninsula, Alaska, occurred in August, reflecting the diet of the preceding 2 months. The peak lick use season also coincided with moose calving (mid-May to mid-June), molting and antler growth, which require Na as well as other elements. Summer molt occurred from late May to mid-July, which was initiated and completed first by adult bulls, and lastly by cows, especially cows with calves. This sequence paralleled the seasonal sex and age sequence of lick users. The decline of lick use in July occurred when levels of K drop in *Salix pulchra*, *Betula nana*, and other plants in Alaska (Whitten and Cameron 1980, Chapin *et al*. 1980) and when moose increased their rate of aquatic feeding, which was noted by Peterson (1955). Aquatic plants eaten by moose are a good source of Na (Botkin *et al*. 1973, Fraser *et al*. 1980*a*).

The delay of lick use exhibited by cows may not be due to a differential timing of Na hunger between bulls and cows, but rather due to the cows' delay in traveling to a lick. Hebert and Cowan (1971) reported that female mountain goats delay movement to lick sites until after parturition.

The marked peak of lick use around midnight may be due to the preference of moose to use open areas during the darkest time of the day. This activity pattern differed from the bimodal or trimodal daily activity patterns of moose not at licks in other areas of Denali National Park in early summer (Linkswiler, pers. commun.).

The higher rates of lick use by bull moose may be because more bulls came to the area, although there is no known differential sex distribution of moose in Denali National Park. Otherwise, individual bulls could be making more lick visits than individual cows. The mean time spent licking per visit for bulls was also slightly higher than those of the cows'. Other published studies have reported a higher use by pregnant or lactating female ungulates, such as elk (*Cervus canadensis*) (Carbyn 1975), caribou (*Rangifer tarandus*) (Dixon 1939, Calef and Lortie 1975), and Dall sheep (Dixon 1939, Heimer 1973). Weeks (1978) reported a sex and age composition of white-tailed deer (*Odocoileus virginianus*) using licks that was similar to that of the whole population.

Several authors have found only minor lick use by young cervids (Peterson 1955, Jordan et al. 1973, Best et al. 1977, Weeks 1978). But, use of the licks by the moose calves I observed was fairly substantial, especially considering their small body size. Undoubtedly, some lick use was only in imitation of the dam, but some of my observations of calves avidly licking indicate that calves also may have a need for supplementary Na. Calves begin foraging regularly at 2 weeks of age (Franzmann 1978) and would be subject to high ratios of K:Na in summer forage too, as well as mineral demands of growth and molting.

It is surprising that the wolves denning nearby and grizzly bears did not appear to hunt moose concentrated near the licks in early summer. Grizzly bears in Alaska have killed 1 moose or caribou per 6 days of observation during summer and fall; 30% of these were adult moose, 57% were calf moose (Ballard et al. 1981). Adult moose are a staple food of wolves in northern Alberta in the summer (Fuller and Keith 1980). Predation at my study site may have been low because moose and caribou calves, Dall sheep lambs, and small mammals in other areas of the Park were easier prey at that time.

Management Implications

Natural lick sites should be designated as critical habitat for moose in Alaska because it appears that licks are an important source of Na in early summer. The high density of moose seen in the study area in early summer indicates that the lick areas attract moose from other areas of the Park. Dall sheep and moose are known to travel out of their way to visit a lick during movements from winter to summer range, and they return to the same licks annually (Heimer 1973, Best et al. 1977). Licks should be protected from disturbance or destruction so that moose can readily obtain needed mineral elements from traditional sites. Also, the influx of moose into the lick area in September may indicate that licks are important socially, providing meeting grounds for rutting moose. Murie (1934:23) stated that licks were "trysting places for the moose."

Artificial sources of salt may be used as a management tool for influencing the distribution of moose in spring and early summer. Use of salt blocks to influence movement patterns of elk in Idaho during winter and late summer was not successful (Dalke et al. 1965). But in Sweden where natural licks are unknown, moose avidly lick salt (96% NaCl) from blocks in the early spring, which are supplied by hunting groups (K. Borg and G. Markgren, pers. commun.).

Fraser (1979) suggests that managing roadside accumulations of highway salt in spring may be a way to reduce moose-vehicle accidents in Ontario. Placement of salt away from salted roadways has been successful in reducing moose-vehicle accidents in some areas of Sweden (K. Borg, pers. commun.). Also, placement of granular salt in some areas of Ontario has enhanced public viewing of moose in spring and early summer (D. Fraser, unpub. report).

It does not seem feasible to determine the sex and age composition of the moose population from the licks studied. The sex composition of lick users did not reflect aerial counts, and there was a seasonal difference in use by bulls and cows. Estimating the number of calves born each year from counts at the licks that I studied is not feasible because cows did not always bring their calves to a lick, and it is unknown whether cows with calves came to the lick area in proportion to their population numbers. Also, calves were not seen using the licks until late June, a time when substantial calf mortality has already occurred (Ballard et al. 1981, Van Ballenberghe 1979). Most of the lick activity occurred in late evening, and dim light and precipitation sometimes hindered observations. This would also restrict viewing of moose at licks by visitors in Denali National Park. Optimum viewing would occur during early summer evenings with little wind.

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