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Mineral licks as a sodium source for Isle Royale moose

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Summary. Natural mineral licks and their use by moose (*Alces alces*) on Isle Royale National Park, Michigan, were studied during 1982–85. The distribution of known licks suggested that they occurred in association with glacial debris, primarily in the western portions of the island. Moose utilized mineral springs extensively during the spring-summer period, and at least 6 licks were used year-round. During summer, a pronounced diel pattern of moose visitation was apparent, with peak use occurring between 0400–0800 h. Although daytime lick use declined by late June, morning and evening use continued to be relatively high throughout the study period. Peak lick use coincided with leaf-emergence in spring. Moose continued to utilize mineral licks despite the availability of ponds containing aquatic plants. Sodium appeared to be the element attracting moose to licks where they ingest copious amounts of water. Observed sodium ingestion rates (0.35 g/min) at licks indicate that licks provide a more concentrated source of sodium compared to aquatic plants (0.023 g/min). Based on the data presented, we reject the conclusions of earlier workers that aquatic plants constitute the only significant source of sodium for Isle Royale moose.

Key words: Mineral licks – *Alces* – Sodium ingestion

Botkin et al. (1973) provided evidence of the relative scarcity of sodium (Na), an essential element for most vertebrates, in continental ecosystems throughout North America. Much of the supportive evidence provided for this hypothesis apparently came from studies of moose and their foodplants in Isle Royale National Park, Michigan (cf. Jordan et al. 1973). Subsequent investigations have further attempted to document the importance of Na to moose in this system and to examine the role of aquatic plants in moose-sodium dynamics (Belovsky and Jordan 1978; Aho 1978; Aho and Jordan 1979; Faaborg 1981). Models of resource use by moose have been constructed which identify the importance of Na acquisition (Belovsky 1978) while others offer explanations for reported moose population fluctuations based on Na limitations (Belovsky 1981).

Despite early evidence of extensive mineral lick use by moose on Isle Royale (Murie 1934), the potential significance of licks as an alternative source of Na to moose on the island has been largely ignored. Belovsky and Jordan (1981) considered Na concentrations at mineral licks on the island to be below levels detectable by moose. Furthermore, they felt that Isle Royale licks were not sufficiently widespread to be of importance to most moose on the island.

In this paper, we summarize results from our investigations of mineral licks and their use by moose on Isle Royale. We suggest that lick use by moose on Isle Royale is not inconsequential as claimed by previous workers (Botkin et al. 1973; Jordan et al. 1973; Belovsky and Jordan 1978, 1981), but instead is a significant activity of moose that has until now remained largely unknown.

Study area and methods

Isle Royale National Park (47°55′N, 89°W) is a 544 km^2 archipelago lying in the western portion of Lake Superior, 24 km southeast of the Canadian mainland. The island was formed by uptilted layers of basaltic lava with interbedded layers of sandstone and conglomerates, all of Precambrian age. Preglacial stream erosion and scouring by glacial ice has resulted in a series of parallel ridges and valleys with numerous lakes and streams. Shoreline regions are forested by a mixture of boreal species including balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*). Inland slopes are dominated by nonboreal species, especially sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*). Moose appeared on Isle Royale sometime between 1905 and 1913. The current population fluctuates between 600 and 1,200 animals.

During the period 1970–1984, researchers and field assistants hiked more than 11,000 km (>50% off-trail) on Isle Royale, and have spent more than 1,200 h in survey aircraft over the island during fall and winter. This field effort provides the foundation for our assessment of mineral lick distribution. During June, 1983, all known natural mineral licks on the island were "mapped" using ion conductivity meters to locate the source of mineral springs. Following recommendations of Fraser et al. (1980b), samples of lick water and water from a nearby control site (the nearest stream or pond to the lick) were collected and analyzed for concentrations of Ca, Mg, Na, K, NH_4, NO_3, PO_4, and SO_4 using an ion chromatograph (Dionex).

Information about lick utilization by moose was gathered through direct observations during 1982–1985. With the exception of West Huginnin lick (WHL), observations of moose use of mineral licks were made opportunistically in conjunction with on-going studies. Use of WHL by moose (Fig. 1) was systematically sampled during June–Au-

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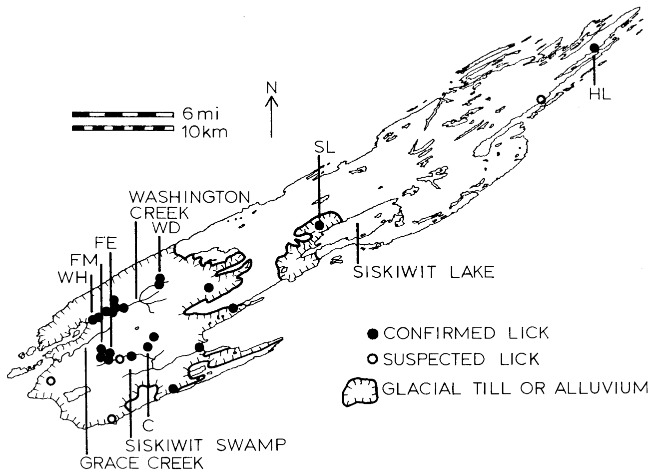

Fig. 1. Locations of mineral licks on Isle Royale National Park in relation to glacial debris (*C* Cabin Lick; *FE* Fingers-East Lick; *FM* Fingers-Middle Lick; *HL* Hidden Lake Lick; *SL* Siskiwit Lake Lick; *WD* West Desor Lick; *WH* West Huginnin Lick)

gust, 1984, and during April–May, 1985, in order to evaluate daily and seasonal changes in lick visitation patterns during spring and summer.

Observers generally sat quietly on the ground at strategic locations offering an unobstructed view of lick areas. At WHL, a canvas blind was erected approximately 10 m from the lick to permit close observation of moose while drinking. During watches, observers recorded the sex-age class, arrival and departure times, and whenever possible, the time spent drinking for each animal visiting the lick. No attempt was made to measure drinking times during night watches due to decreased visibility. In addition, details about antlers, bell shape, hair pattern or other distinguishing marking were recorded to aid observers in distinguishing individual animals. For this study, a visit was defined as the time a moose spent in the unvegetated opening or muddy wallow of the lick site. Repeated visits by recognizable individuals were counted separately if animals moved out of view for 15 min or more.

At WHL, lick use was sampled during three 8-h watches, representing morning (0000–0800 h), day (0800–1600 h) and evening (1600–2400 h) periods. Mean visitation rates during these periods were compared to determine temporal and seasonal use patterns.

Consumption rates

Rates of lick water consumption by moose were determined at Siskiwit Lake lick (SLL), located north of Siskiwit Lake in the middle portion of Isle Royale (Fig. 1). The spring creating the lick seeps from the base of a glacial moraine and water accumulates in a circular, 2 m-wide depression in gravel and sand. We measured, by removal, the volume of water in this natural basin relative to a graduated measuring stick placed in the puddle. After draining, the rate at which the basin refilled was measured and recorded. This process was repeated several times to insure accurate calibration. The mean refill rate was then used to calculate the amount of water seepage occurring during the draining process, and to correct volume-water level measurements.

Water consumption rates were determined by observers as moose entered and drank at the basin. Water levels on the graduated stick were noted before and after each moose visit, and the elapsed time between measurements and actual drinking time were recorded to the nearest second. Rate of lick water consumption (CR) in l/min was calculated using the equation:

$$\mathrm{CR} = \frac{dV + T_t(r)}{T_d}$$

where: dV = the change in water volume in the basin (l), T_t = elapsed time between volume measurements (min), r = mean refill rate (l/min), and T_d = actual time spent drinking (min).

Movement in relation to mineral licks

To evaluate the distances moose travelled to utilize mineral licks on the island, we compared centers-of-activity within summer home ranges of 14 animals to the locations of the 3 licks (Fingers Lick-East, Fingers Lick-West and Cabin Lick) at which they were radio-collared. Details of the immobilization and capture of these animals are reported elsewhere (Seal et al. 1985). Methods and equipment used to determine moose summer home ranges and to calculate centers-of-activity will be presented separately (Risenhoover and Peterson unpublished work).

Results

Distribution

We have mapped a total of 22 licks currently used by Isle Royale moose, plus 5 additional sites of uncertain status (Fig. 1). All but 3 of these 27 sites are located in the southwest portion of the island. Noteworthy concentrations of licks exist in an area of glacial drumlins north of the Siskiwit Swamp, and in the Washington Creek drainage. The water of Washington Creek is enriched by these licks to the point where Na levels in the creek are significantly higher than waters of nearby Grace Creek (Bowden 1981). Twenty of the 22 known licks currently being used by moose are within the area of glacial debris mapped by Huber (1973). Drumlins, in particular, tend to contain fine-grained glacial drift and often channel groundwater flow by the action of "hardpan" layers within them (McCabe et al. 1978; Whittecar 1983).

There are currently only 2 known licks in the northeast half of Isle Royale. Notably, none of the licks reported by Murie (1934) in this portion of the island are currently being used by moose. An additional site (Siskowit Mine), utilized during the 1960's and early 1970's, was also apparently abandoned for unknown reasons by 1980.

Chemical analyses of lick water

Chemical analyses of lick water indicate that Na is the primary attractant at moose licks, although we cannot dismiss the possible importance of sulphur (S) (Fig. 2). With all licks pooled, levels of both Na and S were significantly (two-sample *t*-Test, $P < 0.05$) higher in licks than in nearby controls. However, results for S were inconsistent since concentrations in licks were comparable to control samples in 3 of the 18 cases. In contrast, Na concentrations were higher in all lick samples compared to controls. Concentrations of Ca, Mg and K were often slightly higher in lick samples relative to controls, but we attribute this to stirring of the soil substrate into solution by moose traffic (Fraser et al. 1980b). The average Na concentration in Isle Royale licks was 91 ppm (range = 35-326, $N = 18$).

Lick use patterns

Moose approached licks along well-rutted trails and usually entered lick areas without hesitation. Occasionally, however, moose (usually subadults) stood alert at the edge of lick openings for extended periods, and would sometimes vocalize before entering to drink. Almost all drinking at licks occurred at specific locations. Moose were commonly observed moving through lick puddles with their heads low, and appeared to be sniffing at lick water before drinking. Mapping of lick areas indicated that these sites were usually near springs or seeps where electrical conductance was high relative to the rest of the lick. At several licks, moose were observed ingesting soil.

Moose of all sex-age classes were observed drinking at licks. We have observed up to 7 moose simultaneously using mineral licks, and have observed individual moose to visit licks as often as 5 times in 12 h. Although the duration of lick visits ranged from 1–150 min, the mean duration of visits was similar among the licks studied (Table 1). Although varying greatly (range = 0.25–25.3 min), the average time moose spent drinking per visit was also similar among licks. The highest recorded moose visitation rates (moose/h) were observed at West Desor, Hidden Lake and West Huginnin Licks. However, since observation dates and times varied between licks, these differences may reflect sampling procedures rather than moose preferences (see below). Observed moose visitation rates at licks were not well correlated ($r = 0.19$) with Na concentrations in water samples taken from the different licks studied.

Sex and age composition

The proportion of cows, calves, adult bulls and yearling bulls observed utilizing WHL were very different from proportions observed during fall aerial composition surveys conducted on Isle Royale in October, 1984 (Table 2). The proportion of yearling bulls in the sample of animals observed visiting WHL was 3 times the number expected. In contrast, adult bulls were rarely observed. These findings are in agreement with Fraser and Hristienko (1981) who reported a decline in lick use by adult bulls in Ontario by mid-June.

Diel and seasonal use

Observations at WHL indicated a pronounced diel pattern of use by moose at this site (Fig. 3). During June–August, 1984, moose visitation was greatest from 0400–0800 h in the morning and lowest from 1100–1700 h in the daytime period. This diel pattern was further apparent when lick visitation rates were compared by 8 h period (Fig. 4). Throughout the summer, moose visitation during the daytime period was low relative to morning and evening periods, and may reflect a reduction in moose activity during the warm periods of summer days (Risenhoover, unpublished data). Combined data suggest that 24-h moose visitation at WHL increased to a peak in June (1.6 moose visits/h) and appeared to coincide with spring leaf-flush on the island. Visitation rates remained relatively high through July, but declined by late August.

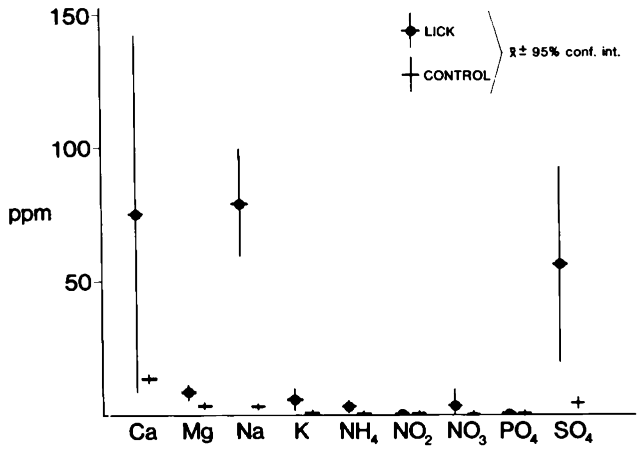

Fig. 2. Comparison of results from the chemical analyses of lick water samples and controls collected on Isle Royale

Table 1. Comparison of moose utilization of selected mineral licks on Isle Royale

Lick location	Na[a] (ppm)	Observation h	$\bar{x}$ Moose visits/h	$\bar{x}$ Duration of lick visits (min)	$\bar{x}$ Drinking time (min)
West Huginnin	327	191.0	1.24	27.5 ± 19.5	8.3 ± 5.7
Siskiwit Lake	64	82.2	0.63	27.2 ± 25.4	5.7 ± 3.8
Fingers-East	72	55.2	0.25	34.2 ± 12.9	9.0 ± 7.6
Fingers-West	33	31.6	0.92	32.5 ± 19.0	5.1 ± 1.7
Cabin Lick	45	20.8	0.96	24.0 ± 23.0	9.5 ± 7.1
Hidden Lake	69	10.5	1.81	43.6 ± 20.1	4.3 ± 1.0
West Desor	127	10.1	3.30	42.4 ± 26.3	6.7 ± 4.7

[a] Concentrations of Na were determined from a single measurement during June (see text)

Table 2. Comparison of the sex-age composition of moose visiting West Huginnin Lick and moose observed during fall aerial compositions surveys on Isle Royale

	Sample size	Yearling ♂		Adult ♂		Cows		Calves	
		N	(%)	*N*	(%)	*N*	(%)	*N*	(%)
Aerial Survey (October, 1984)	131	8	(6.1)	49	(37.4)	57	(43.5)	17	(13.0)
West Huginnin Lick	167	46	(27.5)	10	(6.0)	69	(41.3)	42	(25.1)

Periodic inspections of licks along Washington Creek during January–April, 1985, indicated that moose continued to visit several licks (including WHL) during winter. Other licks visible from aircraft were also examined periodically for evidence of use by moose. Based on these observations, it appears that a minimum of 6 licks are utilized by moose year-round on Isle Royale. These findings are not supportive of the assumption that Na is available to moose only during the 108 day summer period (Belovsky and Jordan 1978, 1981).

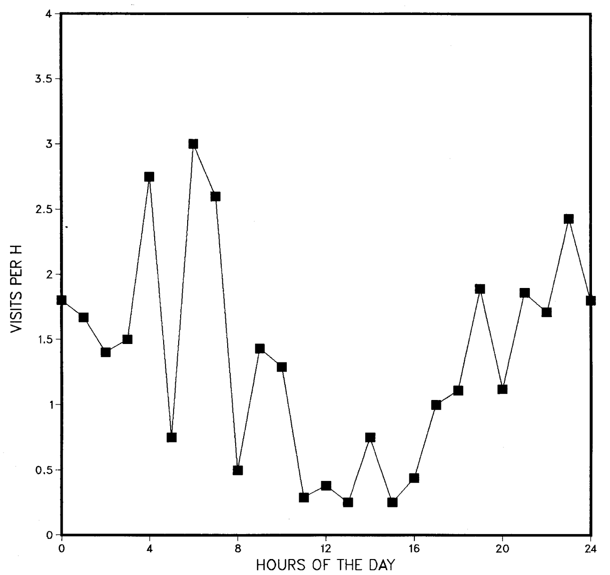

Fig. 3. Diel pattern of moose visitation at West Huginnin Lick during June–August, 1984

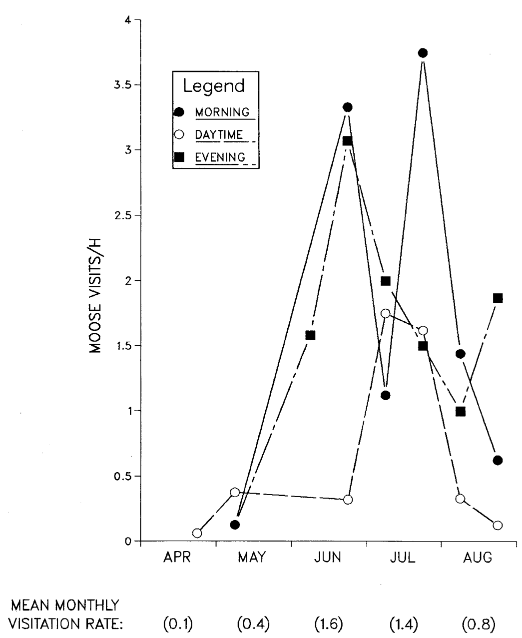

Fig. 4. Seasonal comparison of moose visitation rates at West Huginnin Lick during morning, daytime and evening periods, spring-summer, 1984–1985 (see text for definitions). Data points represent mean values for 15-day intervals

During mid-April, spring run-off inundated WHL and other licks along Washington Creek making them unavailable to moose during this time. However, by late April, creek water levels had receded, and moose again began using these licks. Observations at WHL during late April and early May indicated that moose visitation rates during this period were low relative to rates observed during June-August (Fig. 4).

Consumption of lick water and sodium intake

Observations and measurements at SLL indicate that moose consume copious amounts of lick water while at licks, at a rapid rate. Moose consumed an average of 33.9 (SD = 12.7, $N = 8$) l of lick water per visit at a mean rate of 5.4 (SD = 1.5, $N = 8$) l/min. This estimate is below drinking rates reported by Schmidt-Neilsen (1964) for donkeys (8.2 l/min) and camels (10.4 l/min).

The concentration of Na in water samples from SLL was 64 ppm (Table 1). Based on the observed rates of intake of lick water at SLL, we estimate that moose are ingesting an average of 2.17 g of Na per visit to this lick, at an average rate of 0.35 g/min.

Although moose have been observed drinking from other water sources, no attempt was made during this study to document use of non-lick sites by moose.

Moose movements in relation to mineral licks

Best et al. (1977) documented extensive spring movements to mineral springs by moose in Alberta. Observations of home range patterns of 14 radio-collared moose (Risenhoover, unpublished data) indicate that moose in the southwest portion of Isle Royale did not have to travel extensively to visit mineral licks during spring and summer. Distances between the center-of-activity within a moose's summer range and the licks visited in spring ranged from 1–7 km. During periodic monitoring of lick use in 1984, three radio-collared moose were observed drinking at two licks 8.2 km apart, and five radioed animals were observed at two or more of the licks being studied during May–August, 1984.

At WHL, individually recognizable animals were re-observed frequently during May–August, 1984. An identifiable yearling bull was observed visiting the lick 7 times during watches on 3 consecutive days, and was observed at least once during each of the 10-day sample periods extending from June through August. In addition, a marked cow and her twin calves were reobserved at WHL at least once during June, July and August.

On Isle Royale, moose may travel great distances during the course of the year. During winter 1984–1985, 2 radio-collared bulls traveled over 75% of the length of the island, but returned to mineral licks at the southwest end of the island by spring (Risenhoover, unpublished data). Such mobility would suggest that moose over a large area have greater access to mineral licks than suggested by Belovsky and Jordan (1981).

Discussion

Mammalian "salt hunger" exhibited primarily in spring has been attributed to a seasonal need for Na in response to leaf emergence. High concentrations of potassium (K), present in young, rapid-growing leaves, can result in a flushing of Na from the mammalian body (Weeks and Kirkpatrick 1976). An alternative explanation is that a chronic depletion of Na reserves occurs during winter when moose feed exclusively on woody browse, and must be replaced each spring and summer (Jordan et al. 1973; Belovsky and Jordan 1981).

Fraser and Hristienko (1981) argued that available evidence supported the spring plant phenology hypothesis (Weeks and Kirkpatrick 1976) since moose did not appear to utilize available sources of Na (i.e. mineral licks, roadside pools rich in highway salt) prior to leaf-emergence. On Isle

Royale, lick use was most intense during the period coinciding with leaf-emergence, and would, therefore, appear to be related to spring phenology. However, moose also utilized mineral licks year-round, indicating that moose retained their hunger for Na throughout the year. Therefore, the data presented here would appear to be supportive of both hypotheses.

Fraser and Hristienko (1981) reported moose activity at licks declined sharply by late June, when aquatic plants in the area became common. However, observations of lick use in their study were limited to daylight periods. On Isle Royale, daytime lick use also declined after June, but morning and evening use remained relatively high through August. Tankersley and Gasaway (1983) also found a pronounced diel pattern in moose lick visitation in Alaska.

In contrast to the findings of Fraser and Hristienko (1981), it is clear that moose on Isle Royale continue to utilize mineral licks in spite of the availability of nearby ponds containing aquatic plants. This may be due to the fact that licks provide a more concentrated source of Na that can be rapidly ingested, and that does not become depleted. Based on moose Na requirements estimated by Belovsky (1978: 112), a 358 kg non-lactating animal must ingest an average of 1.34 grams of Na per day during summer (108 days) to meet its annual maintenance requirements. This would require a moose to locate and ingest 7,570 g (454 g dry weight) of aquatic vegetation per day if it were its only source of Na (Belovsky 1978). By comparison, moose at SLL ingested this amount of Na after drinking at the lick for only 3.9 min. Observed Na ingestion rates (0.35 g/min) at licks indicate that licks provide a more concentrated source of Na compared to aquatic plants (0.023 g/min; Belovsky 1981). The time and energy saved by obtaining Na requirements from mineral licks could be spent in other activities or in energy acquisition. Despite claims by Belovsky and Jordan (1981) that the increased water intake resulting from drinking at licks would reduce the Na retention ability of moose, available evidence (Bott et al. 1964; Jones et al. 1967; Gordon 1972; Weeks and Kirkpatrick 1976; Vander et al. 1980) suggests that mammals are very efficient at reducing Na loss through urination.

The average Na concentration in Isle Royale licks (91 ppm) was only about half the Na levels reported for moose licks studied in northern Ontario (Fraser et al. 1980b) and in Alaska (Tankersley and Gasaway 1983). Belovsky and Jordan (1981) reported that licks they evaluated on Isle Royale contained only 10–50 ppm Na. However, we believe these values may be flawed by inadequate sampling, which has been a common problem in lick studies (Fraser et al. 1980b).

Although it has been demonstrated that aquatic plants can be an important source of Na for moose during the summer period (Botkin et al. 1973; Jordan et al. 1973; Fraser et al. 1980a), moose use of aquatic sites may not be solely related to moose Na requirements as suggested by Belovsky and Jordan (1978, 1981), and may be motivated by other factors such as insect harassment or heat stress. We have observed moose visiting ponds without feeding on aquatic plants. Thermoregulation can pose a serious problem for moose during summer. Renecker and Hudson (1986) observed that moose went off feed and initiated thermal panting when ambient temperatures rose above 14° C.

The predictions of models of moose foraging behavior and population fluctuations presented by Belovsky (1978, 1981) were strongly influenced by the key assumption that the annual sodium requirement for moose could only be met by feeding on aquatic plants during their brief period of availability in summer. This assumption appears to have been based on the deductions of Botkin et al. (1973) and Jordan et al. (1973). Although provocative, we are aware of no firm evidence demonstrating that Na is a limiting nutrient for moose on Isle Royale. The proposed "balance sheet" presented by Jordan et al. (1973) and by Belovsky and Jordan (1981) is based on a number of unvalidated assumptions and calculations, and on a circular argument (c.f. Hanley 1980).

Therefore, we are in agreement with Weeks and Kirkpatrick (1976) that our present knowledge of Na dynamics in natural systems in not sufficiently detailed to allow the construction of a realistic Na budget for moose on Isle Royale. While our data confirm that Na is a much sought-after element by moose, especially during spring, there is yet no convincing evidence to suggest that it is a limiting nutrient for this well-known ungulate population.

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