Management and Conservation Article

Behavioral Adaptations of Moose to Roadside Salt Pools

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ABSTRACT Sodium has many fundamental physiological functions in animals but is rare in boreal ecosystems where moose (*Alces alces*) thrive. In Québec (Canada), sodium is readily available in aquatic vegetation and in salt pools that form along highways. We do not know if moose are adopting specific behaviors to access sodium sources or if they simply use the sodium sources they encounter during their movements. We tested the hypothesis that moose modify both space and habitat use to gather sodium from salt pools. We expected moose to use salt pools mostly in spring and early summer, when needs are greatest and before aquatic vegetation has fully developed. We fitted 47 moose with Global Positioning System telemetry collars and collected data for 2 to 36 months between 2003 and 2006. We rarely located moose at salt pools (0.12% among the 95,007 locations collected). As we expected, use of salt pools was highest in late spring and in early summer, and we observed a time lag between peak use of salt pools compared to use of lakes and waterways, indicating moose fulfilled their sodium requirements in salt pools before aquatic vegetation was available. Moose selected salt pools over lakes and waterways when these 2 sodium sources were present in their home range and moved rapidly over large distances to reach them. Our results were consistent with moose using salt pools when they are likely to be sodium deficient. Salt pools were less accessible, required long-distance movements, and were located in habitually avoided areas along highways. Elimination of roadside salt pools should be considered among strategies to reduce cervid–vehicle collision risks in boreal environments. (JOURNAL OF WILDLIFE MANAGEMENT 72(5):1094–1100; 2008)

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Sodium is an abundant element in organisms with fundamental roles in acid–base equilibrium and osmotic regulation. It also is necessary for other essential physiological functions such as intercellular exchange, neural transmission, muscular contraction, reproduction, lactation, growth, hair production, and maintenance of body mass and appetite (Church et al. 1971, Robbins 1993). Sodium, however, is a rare element in boreal ecosystems such as the boreal forest of North America, where it has even been considered a limiting factor for some species, including moose (*Alces alces*; Jordan et al. 1973).

Moose, the largest herbivores inhabiting the boreal forest, feed primarily on terrestrial vegetation with relatively low sodium concentrations. In spring and early summer, moose need large quantities of sodium to compensate for mineral deficiencies incurred during winter foraging (Jordan et al. 1973, Weeks and Kirkpatrick 1976, Belovsky and Jordan 1981, Staaland and Garmo 1987, Ohlson and Staaland 2001). During this transitional period, moose suffer from sodium deficiency because terrestrial chlorophyllous vegetation, when phenologically young, has a substantial ionic imbalance resulting in high potassium and water content (Weeks and Kirkpatrick 1976, Jordan 1987). The high potassium concentration in spring vegetation temporarily reduces sodium retention, which is at other times easily reabsorbed in the digestive tract (Ohlson and Staaland 2001). Moreover, moose lose weight during winter and need more sodium than is available by browsing to replenish mass and energy stores (Fraser et al. 1982). Moose appetite for sodium peaks in spring and early summer before decreasing steadily through the end of summer (Joyal and Scherrer 1978, Fraser et al. 1980*a*, Fraser and Hristienko 1981, Tankersley and Gasaway 1983, MacCracken et al. 1993).

Sodium is generally scarce in boreal environments, but its availability can vary dramatically over the year and from site to site. To fulfill their needs, moose eat aquatic vegetation (Joyal and Scherrer 1978; Fraser et al. 1980*a*, 1982, 1984; MacCracken et al. 1993; Ohlson and Staaland 2001) with a sodium concentration of 150 to 700 ppm (Fraser et al. 1980*b*, 1982, 1984). Moose also may drink brackish water at mineral springs when available (23 ppm to 200 ppm; Fraser et al. 1980*b*, 1982; Tankersley and Gasaway 1983; Couturier and Barrette 1988). In northern regions, moose can also find high sodium concentrations in roadside salt pools (>500 ppm; Grenier 1974, Fraser 1979, Fraser and Thomas 1982, Leblond et al. 2007). These pools are formed in poorly drained areas by the accumulation of de-icing salts (mostly composed of sodium chloride). Such an anthropogenic sodium source could be attractive to moose, especially in spring and early summer before aquatic vegetation is

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available. Jolicoeur and Crête (1994) and Leblond et al. (2007) tested the effectiveness of a roadside salt-pool management strategy in reducing moose–vehicle collision risks along highways.

Spatial and temporal variations in sodium availability have been suggested to influence distribution of moose (Joyal and Scherrer 1978, Belovsky and Jordan 1981, Fraser and Hristienko 1981), white-tailed deer (*Odocoileus virginianus*; Weeks and Kirkpatrick 1976) and some African ungulates (McNaughton 1988). For instance, individuals were found to move toward sectors that are not commonly used in spring and summer to reach lakes or mineral licks (Belovsky and Jordan 1978, Joyal and Scherrer 1978, Fraser and Hristienko 1981, Tankersley and Gasaway 1983, Couturier and Barrette 1988). However, to date, all observations of ungulate behavior in relation to sodium sources were collected using direct observations or track surveys at mineral licks. Our understanding of the influence of sodium availability on ungulate behavior is limited because we do not know if individuals are adopting specific behaviors to access sodium sources or if they simply use sodium sources they encounter during their movements.

We tested the hypothesis that moose modify both space and habitat use to gather sodium in anthropogenic sodium sources, especially during spring and early summer when sodium needs are greatest and availability from aquatic vegetation is lowest. To overcome some limitations of previous studies, we used Global Positioning System (GPS) telemetry to obtain moose relocations in the boreal forest of Québec (Canada) where salt pools were available during the snow-free period. We expected that 1) salt pools would be visited by moose mostly in spring and early summer, and 2) moose would select salt pools over lakes and waterways during this period. We also expected that 3) moose would occasionally make directional trips to reach salt pools and, consequently, 4) moose using salt pools would have larger home ranges compared to other moose. These last 2 predictions are based on our previous observation that moose generally avoid highways and their surroundings up to $\geq$500 m (Laurian et al. 2006).

STUDY AREA

We conducted this study in the northern part of the Laurentides Wildlife Reserve (Québec, Canada; 71°24′W, 48°4′N), a 1,800-km^2 wild territory that is crossed by 2 provincial highways on a north–south axis. Forests in the study area were typical of the boreal region; coniferous stands with balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*) dominated on high plateaus, whereas low-lying areas and valleys were dominated by mixed and deciduous stands. Deciduous tree species were mostly white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), yellow birch (*B. alleghaniensis*), and maples (*Acer rubrum* and *A. saccharum*). Topography in the study area was gently rolling with several deep river valleys. Lakes and rivers were widespread throughout the study area and supported a substantial density of aquatic plants (Jolicoeur and Crête 1994).

The mosaic of young and mature stands resulted in high-quality moose habitat. Moose density was estimated in the entire Wildlife Reserve at 2.2 moose/10 km^2 during winter 1994 (St-Onge et al. 1995), but local density reached up to 8 moose/10 km^2 in the study area. Caribou (*Rangifer tarandus*), white-tailed deer, and black bear (*Ursus americanus*) were the other large mammals found in the study area. Potential predators of moose were gray wolves (*Canis lupus*) and black bear.

Winters were harsh in the Laurentides Wildlife Reserve, with among the highest total snow precipitation in the world (>550 cm in some areas). More than 100 metric tons of de-icing salts/km of highway were used each winter, favoring development of salt pools (Jolicoeur and Crête 1994). Maximal and minimal daily temperatures were, respectively, −9.0° C and −21.7° C in January, and 21.7° C and 9.5° C in July.

METHODS

We installed GPS telemetry collars (models 2200L and 3300L; Lotek Wireless Inc., Newmarket, ON, Canada) on 47 moose for 2 to 36 months between January 2003 and April 2006. We conducted captures following methods approved by the Animal Welfare Committee of Faune Québec (certificate no. 03-00-01). We captured and immobilized moose by darting them from a helicopter with carfentanil and xylazine (Delvaux et al. 1999). We captured an initial group of 30 adult moose (>2.5 yr; 22 F and 8 M) in January and February 2003. Between January and March 2004, we recaptured 17 of these moose to download GPS fixes and replace collar batteries. We also installed GPS collars on 12 new individuals (6 M and 6 F) to replace mortalities or defective collars. Between January and March 2005, we recaptured 18 moose (4 M and 14 F) and captured 13 new individuals (6 M and 7 F). We recaptured all moose to recover collars between January and April 2006. We equipped 55 individuals with a collar, but our sample was reduced to 47 moose because of collar failures. We had no information to determine whether calves accompanied females. We programmed GPS collars to record a location every 2 hours and obtained an average location success rate of 80% from May to September (i.e., our study period). We estimated location error to be <35 m, 95% of the time (Dussault et al. 2001).

Jordan et al. (1973) showed that terrestrial vegetation contains an average sodium concentration of 10 ppm and that browse only supplies for about 6% of moose annual requirements. Significantly higher sodium concentrations (>10-fold) in the study area, however, were available in 3 settings: 1) lakes and waterways in the form of aquatic vegetation, 2) roadside salt pools along highways, and 3) a series of man-made salt pools, referred to as compensation salt pools, that are managed by the Québec Ministry of Transportation to keep moose away from highways, thus reducing moose–vehicle accident risk. Based on studies by

Peterson (1955) and Fraser et al. (1982) in Ontario, Canada, and on our experience in the study area, we considered aquatic vegetation to be available in lakes and rivers from mid-May to late September. Compensation salt pools were located from 100 m to 1,500 m from highways in small standing water pools where approximately 3 tons of de-icing salts were dumped each spring. Similar to aquatic vegetation, sodium in roadside and compensation salt pools was available from early May, immediately after snowmelt, to late September, at the onset of freezing period.

The location of all lakes and waterways was available on the 1:20,000 digital maps of the study area that we assembled in ArcMap 9.2. We started by creating a map showing all sites supporting aquatic vegetation in lakes and waterways. We interpreted aerial photographs taken during summer and delineated all visible concentrations of macrophytes in lakes, rivers, and streams. In July 2005, we validated that map by flying over 73 randomly selected lakes or rivers at reduced altitude with a helicopter. Two observers drew the aquatic vegetation they saw. From this, we concluded that photo interpretation underestimated macrophyte availability. Aquatic vegetation was available in substantial quantities in all surveyed lakes and waterways. We subsequently considered all lakes and waterways in the study area as a potential source of sodium for moose.

We also conducted a census along the 2 highways in the study area to geo-reference all roadside salt pools using a GPS. We traveled along highway shoulders at very low speed in both directions (total distance = 198 km in each direction). We defined roadside salt pools as water-filled or muddy areas with obvious signs of use by moose. These pools were available from early May to late September and were maintained by rain. Mean sodium ($\pm$SE) concentration in these pools was 886 ppm $\pm$ 81 ($n = 12$). Finally, we used a handheld GPS to record the position of each compensation salt pool in the study area. We also collected water samples in 6 compensation pools and estimated sodium concentrations at $>$1,000 ppm. Because roadside and compensation pools were similar in terms of sodium content and size, we grouped them to study their influence on moose behavior. We will thus use the designation salt pool to refer to both salt and compensation pools hereafter, unless otherwise stated.

We pooled telemetry locations by individual to calculate habitat selection ratios (Manly et al. 2002). We calculated selection ratios to assess the selection of moose towards the 2 sodium sources available in the study area (i.e., salt pools and lakes and waterways) as the proportion of locations at salt pool or in lake and waterway divided by proportion of salt pools or lakes and waterways available in a moose home range. Because salt pools were small ($<$50 m^2) and only represented by a point in space, we considered that moose located $<$50 m from a roadside or compensation salt pool had indeed visited that pool (i.e., pool surface + location error), which is further justified because moose visits to salt pools are of short duration (Leblond et al. 2007). To assess frequency of use of lakes and waterways, we considered all moose locations falling within their boundaries to be a visit. We calculated availability of salt pools as proportion of salt pools, including a 50-m buffer zone, in moose home ranges. We estimated availability of lakes and waterways within each home range as the proportional area of lakes and waterways $<$20 m from the shoreline. We calculated seasonal moose home ranges using the minimum convex polygon method (MCP; Mohr 1947) with all locations recorded between May and September and Hawth's Analysis Tools (Beyer 2004). We selected the MCP method because a preliminary examination of the data indicated that visits to salt pools almost always occurred at the boundary of moose home ranges and that, in most cases, other home-range estimation methods excluded those locations. We calculated separate home ranges for individuals that we followed for $>$1 year.

We broke down paths of moose that traveled into steps, which corresponded to the straight-line segment between successive locations at 2-hour intervals (Turchin 1998, Fortin et al. 2005). To determine if moose modified their movement patterns to gain access to salt pools, we calculated movement rates (i.e., Euclidean distance between locations [m]/time elapsed between locations [hr]) for the movement steps recorded prior to, during, and after movement steps leading to the sodium source (Fig. 1).

We used separate repeated-measures analyses of variance (ANOVAs; PROC GLM, SAS Institute, Cary, NC), with month, sex, and their interaction as factors, to determine if proportion of moose locations at salt pools and at lakes and waterways varied both between spring and summer months and between males and females. We also used repeated-measures ANOVAs, with sex, sodium source (i.e., salt pool or lakes and waterways), and their interaction as factors, to test the hypothesis of no difference in selection index between salt pools and lakes and waterways. For this last analysis, we used only moose having both sources of sodium available in their home range.

We used a repeated-measures ANOVA followed by post hoc comparisons with Bonferroni-adjusted probabilities to determine if movement rates differed between the 3 movement step categories (prior to, during, and after the movement step leading to a salt pool) using sex as a factor. For this last analysis, we only considered relocations that were spaced 2 hours apart to prevent a potential bias related to the nonlinearity between movement rate and time elapsed between fixes. We compared home range area between moose that visited $\geq$1 salt pool and other moose, using an ANOVA with home range area as the dependent variable, and with sex, presence of pool, and their interaction as independent variables. We also included in the latter analysis individual moose identification as a random factor to consider the nonindependence of repeated measurements on some individuals across years and the number of locations used to compute the home range as a covariate to adjust home range area for inter-individual differences in location success rate.

We performed all statistical analyses using SAS version 9.1

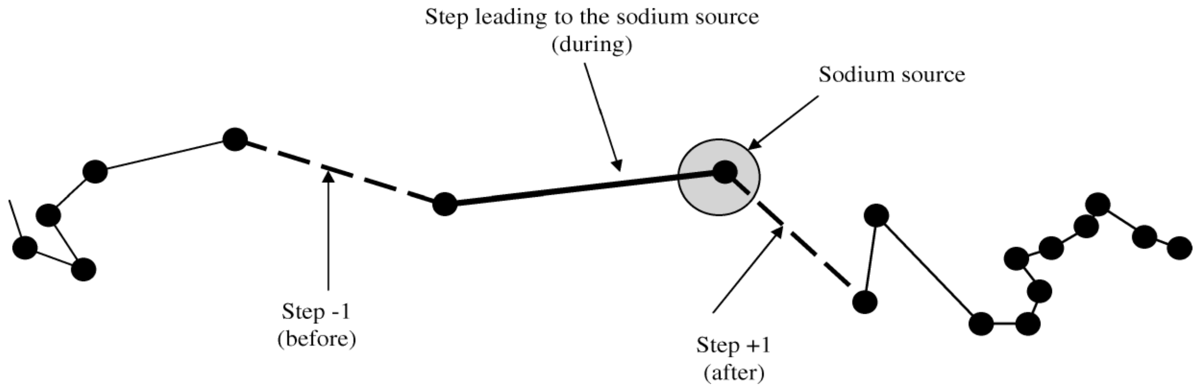

Figure 1. Schematic representation of a path traveled by moose to reach a sodium source in the Laurentides Wildlife Reserve, Québec, Canada, between 2003 and 2005. We broke down paths that moose traveled into steps, which corresponded to the straight-line segment between successive locations at 2-hour intervals. To study moose movement patterns relative to sodium sources, we identified 3 categories of movement steps: the step preceding movement towards the sodium source (before), the step leading to the sodium source (during), and the step leaving the sodium source (after).

(SAS Institute, Cary, NC) with an a priori $\alpha = 0.05$. We log-transformed dependent variables when needed to render residuals normally distributed.

RESULTS

There were 86 roadside and 23 compensation salt pools along highways 169 and 175. Among 47 collared moose, we found 34 to have ≥1 salt pool within their home range with an average of 5.0 salt pools/individual (range = 1–21, $n = 34$; Table 1). Moose having salt pools within their home range did not necessarily use them. We recorded ≥1 visit to a salt pool (i.e., moose locations within 50 m of these sites) for 14 of 19 (73.7%), 9 of 15 (60.0%), and 11 of 18 (61.1%) of the moose having ≥1 salt pool within their home range in 2003, 2004, and 2005, respectively (Table 1). We recorded 39, 27, and 45 visits to salt pools from May to September in 2003, 2004, and 2005, respectively (i.e., 0.12% among the 95,007 fixes collected during the 3 yr of the study). Number of visits by moose and year ranged between 0 and 15 and averaged 2.1 ($n = 52$ moose-yr; Table 1).

The proportion of moose relocations at salt pools varied among months ($F_{4,127} = 3.97$, $P = 0.005$) but not between sexes ($F_{4,35} = 1.93$, $P = 0.171$), and there was a weak month × sex interaction ($F_{4,127} = 2.10$, $P = 0.084$). Moose use of salt pools peaked in June and declined until the end of September (Fig. 2). In comparison, use of lakes and waterways varied among months ($F_{4,169} = 3.15$, $P = 0.016$) as well as between sexes ($F_{1,44} = 19.45$, $P < 0.001$), but there still was no month × sex interaction ($F_{4,169} = 0.91$, $P = 0.461$). Globally, females were located more often than males in lakes and waterways (mean proportion of locations ± SE = 0.067 ± 0.016% for F and 0.010 ± 0.003% for M; Fig. 2). For females, use of lakes and waterways was highest from July to August, whereas it peaked in July for males but was also relatively high during June.

Moose selection index was higher for salt pools ($\bar{x} \pm$ SE = 3.98 ± 1.25) than for lakes and waterways ($\bar{x} \pm$ SE = 0.19 ± 0.04; $F_{1,92} = 90.82$, $P < 0.001$). Moose selection index was not influenced by month ($F_{4,92} = 0.05$, $P = 0.996$), sex ($F_{1,92} = 0.03$, $P = 0.875$), or any interaction ($P \geq 0.367$).

Movement rates of moose that were approaching, arriving at, or leaving a salt pool differed ($F_{2,295} = 7.70$, $P < 0.001$; Figs. 1, 3), being higher during the movement step arriving at a salt pool compared to the previous ($t = -3.90$, $P < 0.001$) and following steps ($t = -2.35$, $P = 0.02$). Movement rates did not differ between sexes ($F_{1,295} = 0.13$, $P = 0.715$) and the step category × sex interaction was not significant ($F_{2,295} = 2.89$, $P = 0.057$; Fig. 3).

Moose home ranges were on average 32.5 ± 2.2 km^2, and home range size was not influenced by sex ($F_{1,35} = 2.57$, $P = 0.118$) or the presence of ≥1 salt pool in the home range ($F_{1,35} = 0.45$, $P = 0.507$).

DISCUSSION

We hypothesized that moose would modify their habitat- and space-use patterns to fulfill their sodium needs from anthropogenic sodium sources, especially before aquatic vegetation was fully developed. Our results indicate that moose seek anthropogenic sodium sources periodically but that overall frequency of visits to these sites is low. One striking and unexpected result that we must emphasize is the extraordinarily large sampling effort that was necessary to reach such a conclusion: nearly 200,000 GPS locations obtained from 47 different individuals over a 3-year period. Although moose were rarely located at sites where sodium was readily available (0.12% of the time in salt pools and 0.25% in lakes and waterways), we observed behavioral adaptations of moose in accessing salt pools, relative to habitat and space use. Among other findings, moose moved large distances rapidly to reach salt pools (i.e., 300–500 m between successive locations spaced 2 hr apart when accessing a salt pool vs. an average of 150 m for all movements recorded between May and Sep). Moose that visited salt pools, however, did not have larger home ranges than other moose, which was surprising considering that salt pools were often located at the fringe of home ranges, in areas usually avoided (Laurian et al. 2006). Nonetheless, our results indicate that salt pools are often located at home-range boundaries and that moose make purposeful movements to reach them.

Table 1. Number of visits to salt pools between May and September, and number of salt pools within the annual home range for moose followed with Global Positioning System telemetry from 2003 to 2005 in the Laurentides Wildlife Reserve, Québec, Canada. (ID = identication no.).

Moose ID	Sex	No. of visits to salt pools[a]			No. of salt pools in annual home range			No. of fixes[a]
		2003	2004	2005	2003	2004	2005	
L01	F	1	[b]		4			1,727
L03	F	0	1		5	4		2,979
L06	F	1	4	1	1	1	1	4,087
L07	M	0			4			349
L11	F	2			3			1,606
L12	M	7	2		1	1		2,656
L13	M	0			7			1,172
L18	F	0	0	0	7	0	0	2,933
L19	F	2	0	0	4	0	4	3,422
L20	F	1			9			1,574
L21	F	3		0	8		3	1,742
L22	M	2			3			1,767
L23	F	5			2			1,655
L25	F	1			1			1,100
L26	M	0			3			1,720
L27	F	1	2	7	5	7	7	4,831
L28	F	5	0		7	7		2,298
L29	M	1		8	5		3	2,876
L30	F	7	5	15	4	8	4	5,015
L32	M		0			2		1,655
L33	M		1			2		1,573
L35	F		1	0		5	4	1,925
L37	F		9			6		1,675
L38	F		0			13		1,632
L40	F		0	0		7	5	3,494
L42	F		2	0		1	6	2,511
L43	M			3			1	1,211
L45	M			1			5	1,128
L46	F			3			5	1,582
L47	M			1			21	1,545
L50	M			1			1	1,684
L51	F			4			5	1,834
L53	F			0			3	458
L54	F			1			15	1,614

[a] From May to Sep.
[b] A blank field means we did not sample that moose during that yr.

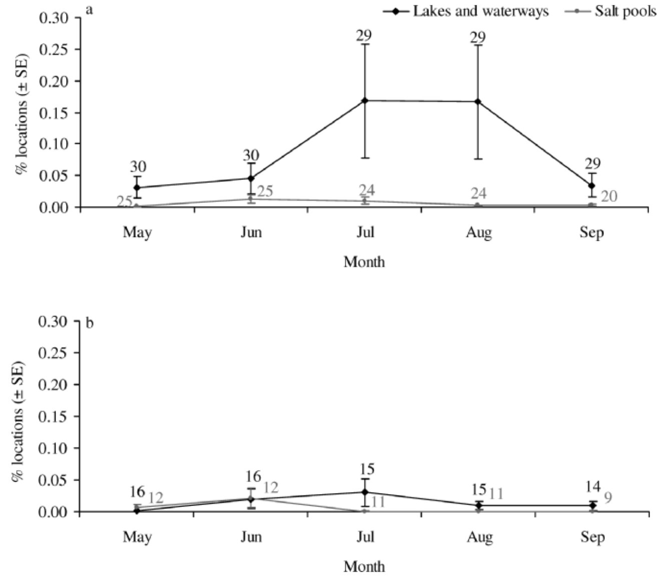

Figure 2. Mean proportion (±SE) of moose locations at sodium sources by month in the Laurentides Wildlife Reserve, Québec, Canada, between 2003 and 2005. We graphed results for females (a) and males (b) separately. Numbers of individuals used in estimations are indicated above data points.

As we expected, moose mostly visited salt pools when they likely were severely sodium deficient and before aquatic vegetation was fully developed (Fraser and Hristienko 1981, Tankersley and Gasaway 1983, Jordan 1987), which was consistent with previous studies conducted in Ontario and Québec (Fraser and Reardon 1980, Fraser and Hristienko 1981, Jolicoeur and Crête 1994). Further, we observed a time lag between peak use of salt pools compared with lakes and waterways, which was consistent with our hypothesis that anthropogenic sodium sources fulfilled moose requirements before aquatic vegetation was fully developed. Nevertheless, it is noteworthy that moose also visited lakes and waterways in May and June, before aquatic vegetation was available. Many reasons other than aquatic vegetation consumption have been proposed to explain water body use by moose, such as avoidance of biting insect harassment (Wolfe 1974), thermoregulation enhancement (Dussault et al. 2004), and predator avoidance (Ballard and Van Ballenberghe 1998). It can be inferred from the visit-frequency decrease to sodium sources in our study that sodium consumption declined from mid- to late summer, consistent with previous studies (Grenier 1980, Fraser et al. 1982, Jolicoeur and Crête 1994).

As we expected, individuals having access to the 2 sodium sources selected salt pools over lakes and waterways, though it must be noted that the latter were much more abundant and widely distributed. The higher selection of moose for salt pools persisted throughout the study. Lakes and waterways, however, were visited more frequently than salt pools in mid-summer, although not necessarily for sodium acquisition. Because salt pools were relatively scarce, situated in habitually avoided areas, and required long-distance movements, we concluded that they were an important source of sodium to moose. In addition, it is likely that our selection index underestimated the importance of salt pools

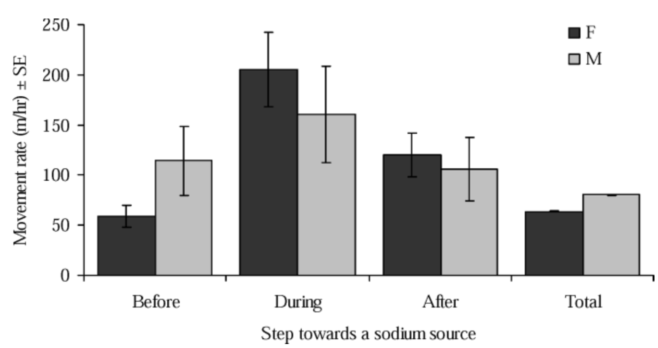

Figure 3. Mean moose movement rates (±SE) during the step preceding a movement towards a sodium source (before), the step leading to a sodium source (during), and the step leaving a sodium source (after) in the Laurentides Wildlife Reserve, Québec, Canada, between May and September from 2003 to 2005. We also calculated average movement rate for the entire study period (total) as a basis for comparison. Sample sizes are $n = 17$ for females and $n = 9$ for males.

relative to lakes and waterways as a sodium source. Indeed, although sodium availability likely was the only resource attracting moose to salt pools, moose may have, as detailed above, used lakes for reasons other than sodium acquisition. Second, we considered only the first 20 m along the shoreline of lakes and waterways to be available for aquatic vegetation consumption, which was conservative based on our field surveys. We do not think, however, that our results were influenced by a fix-rate bias because location success was high (80%) and both salt pools and lakes and waterways borders were relatively open areas (Dussault et al. 1999, Graves and Waller 2006).

We hypothesize that because moose fulfill their sodium needs very rapidly in salt pools, and because there is no other benefit acquired at these sites, moose leave them rapidly. Leblond et al. (2007) found moose visits to salt pools usually lasted <15 minutes in the same area where we conducted our study, whereas Joyal and Scherrer (1978) observed that moose in western Québec spent more time in lakes ($\bar{x} = 54$ min/visit). Use of salt pools can be valuable to moose because they increase sodium intake rate (×15 relative to aquatic vegetation; Belovsky 1978, Miller and Litvaitis 1992). In addition, although the sodium:potassium ratio is higher in aquatic than terrestrial vegetation, it is much higher in the brackish water of salt pools, which lacks potassium. Drinking brackish water in salt pools may be advantageous to moose, allowing them to obtain high quantities of sodium while minimizing losses (Couturier 1984).

Movement rates of moose were higher when moving toward a salt pool than during the previous and following movement steps, which suggests that moose were making purposeful directional movements to reach these sodium sources, probably following a stimulus (e.g., appetite for sodium). These long movement steps likely result in increased energetic costs that might be compensated by the nutritional benefits of sodium consumption (Belovsky 1978, Jordan 1987).

MANAGEMENT IMPLICATIONS

Salt pools should be considered a nonnegligible feature of a moose habitat. In attracting moose near highways, salt pools increase moose–vehicle collision risks (Dussault et al. 2006, 2007). Our results provide an explanation to the generally observed temporal pattern of moose–vehicle accidents in North America, with accidents peaking in late spring and early summer (e.g., Fraser and Thomas 1982, Dussault et al. 2006) at the time when moose are seeking sodium and aquatic plants that are still unavailable. Our findings, therefore, suggest that an effective way to mitigate moose–vehicle collision risk would be to render sodium unavailable along the roads. Use of a de-icing salt other than sodium chloride, such as calcium chloride or calcium–magnesium acetate, could be considered, but its application over large areas would be cost-prohibitive. Elimination of roadside salt pools, however, was found to reduce moose visit frequency to salt pools (Leblond et al. 2007) and should be considered among alternatives to reduce cervid–vehicle collision risks in boreal environments.

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