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Moose (*Alces alces*) are strongly attracted to supplementary sodium (Na) during the spring and early summer in large parts of their North American range. This specific appetite appears to account for their attraction to mineral-rich springs (Fraser and Reardon 1980, Tankersley 1981) and may explain their remarkable fondness for Na-rich aquatic plants (Jordan et al. 1973).

In Quebec moose are attracted to roadside pools that have a high concentration of dissolved highway salt, and such pools are thought to contribute to the frequency of traffic accidents involving moose (Grenier 1974, 1980). The seasonal peak of moose-vehicle accidents in Ontario occurs in May-July, corresponding to the apparent peak in Na hunger, but not to the period of greatest vehicular traffic (Fraser 1979, 1980).

This study reports on moose activity and moose-vehicle accidents in relation to roadside salt accumulations on a section of Ontario highway.

STUDY AREA

The study area was a 156-km section of the Trans-Canada Highway (Highway 17) near Wawa, Ontario. Much of the terrain is rolling, with elevations of 200-460 m. The northern portion is boreal forest; the southern is Great Lakes-St. Lawrence forest (Rowe 1972). Moose, with an estimated density of 0.2/km^2, are the only large mammals commonly killed on the highway although black bear (*Ursus americanus*) and white-tailed deer (*Odocoileus virginianus*) are occasionally seen.

Most of the highway consists of a 2-lane asphalt surface 7 m wide with a sloping shoulder of packed gravel 0.5-4 m wide on each side. A section of loose gravel generally extends downward from the outer edge of the packed shoulder to a drainage ditch or other low roadside area. Traffic is about 1,400-2,700 vehicles/day throughout the year but climbs to 2,800-5,300 vehicles/day in summer. Because of icy conditions between November and April, rock salt (NaCl) is spread on the highway at an estimated rate of 30-40 tonnes/km of highway each winter.

Mean daily temperature in the study area typically increases from -13 C in January to 16 C in July (Atmospheric Environment Service). Daytime highs occasionally reach 30 C in May-July. Snow cover typically persists from 20 November to 20 April with maximum accumulations of 100-120 cm. In 1980 some leaves on browse-height shrubs had flushed (leaf blades unfolded and petioles exposed) by 19 May, and all had flushed by 29 May.

METHODS

To document the nature and distribution of roadside pools of salty water, locations were recorded for roadside pools found to be heavily trampled by moose in the study area in 1977-79. During early May

1980 all small roadside water bodies were inspected, and most were checked for specific conductance with a field conductivity meter and probe. (Specific conductance, expressed in µ/cm, is a measure of the electrical conductance of water, and is strongly influenced by dissolved solids.) Pools with specific conductance >500 µ were numbered and mapped. They were re-examined on 10-14 July 1980, and the accumulated amount of trampling by moose was scored subjectively from 0 (not used by moose) to 5 (heavily trampled). Grazing of cattails (*Typha latifolia*) and any wildlife trails leading to the site also were noted. Water samples were collected from 10 of the heavily trampled roadside pools and from 14 lakes in the study area. Samples were analyzed for major cations and anions at the Ontario Ministry of the Environment laboratory at Rexdale, Ontario, using standard analytic procedures (Ontario Ministry of the Environment 1975). Fifty-six pools selected for detailed observations (see below) were checked for specific conductance on 8 occasions between May and September 1980.

To compare moose activity at salty and fresh water, an inspection was made of all water bodies (pools, streams, lakes) within 50 m of the highway along a convenient 22-km section. In mid-July 1980, accumulated trampling by moose was scored subjectively from 0 to 5 at each site, and any wildlife trails leading to the site were noted. Notes were made at each water body on typical depth, specific conductance, and surface area of the water, location relative to the road, and whether the water was flowing perceptibly.

To establish the seasonal variation in moose activity at saltwater pools, detailed observations were made at 56 convenient pools, chosen to include the sites that appeared most heavily used by moose in previous years. Between 1 and 4 plots, mostly rectangles of 2-12m^2, were marked at each pool in areas where moose tracks could readily be seen and erased. One of 2 observers visited each site every 2nd day from 16 May to 10 August and from 14 to 22 September 1980 to record moose activity. All tracks of moose (calves excluded) in the plots were counted and obliterated, and fresh moose activity near the pool but outside the plots was scored subjectively from 0 (no tracks) to 5 (heavily trampled). Of the 56 pools, 18 were altered experimentally as described in part by Fraser and Hristienko (1982), leaving 38 unaltered pools used in the present study.

To further document moose activity and accident locations in relation to saltwater pools, all moose seen from a vehicle and all distances driven in the course of the study were recorded throughout the 1980 field season (3 May-11 August and 11-23 September). Most driving occurred between 0800 and 1900. During May-September of 1979 and 1980, locations of most moose-vehicle accidents in the area were inspected within 24 h of the occurrence. Accident locations could usually be identified precisely, and distances to nearby saltwater pools were measured by pacing.

RESULTS

Nature and Distribution of Saltwater Pools

A total of 169 saltwater pools (specific conductance > 500 µ) were found in the 156 km of highway. By mid-July 1980 many of these pools appeared well trampled by moose (Table 1). Most pools rated ≥ 2 showed signs that cattails had been grazed, and most pools rated ≥ 3 had 1 or more wildlife trails leading to the site.

Water from roadside pools that were actively used by moose had extremely high levels of Na and Cl, high specific conductance, and rather high levels of other major cations and anions, compared with samples of lake water from the study area (Table 2). Lakes located < 100 m from the highway had higher levels of Na and Cl than other lakes. There was a strong linear relation between the Na content and the specific conductance of the water (r = 0.99, N = 24 samples). Specific conductance, therefore, was considered an adequate measure of salt content for roadside pools.

Table 1. Number of saltwater pools along a northern Ontario highway, ratings of accumulated trampling by moose from 0 (none) to 5 (heavily trampled), percentage of pools with wildlife trails, and percentage of pools with cattails grazed in mid-July 1980.

Rating of accumulated trampling	Pools[a] (N)	Pools with trails (%)	Pools with cattails grazed[b] (%)
0	16	0	0
1	40	0	35
2	53	25	86
3	36	83	100
4	13	92	67
5	4	100	100

[a] Seven of the 169 original pools were missed or could not be found.

[b] Based on pools in which cattails were present.

Table 2. Mean ± SE chemical composition (ppm) and specific conductance (µ) of water samples from roadside pools used by moose along a northern Ontario highway, and from lakes located near and further removed from the highway.

		Lakes	
Variable	Roadside pools	< 100 m from highway	> 200 m from highway
Na	336 ± 38	12.2 ± 4.5	1.9 ± 0.5
K	7 ± 1	0.6 ± 0.0	0.4 ± 0.1
Ca	67 ± 17	8.5 ± 1.7	8.4 ± 3.1
Mg	5 ± 1	1.3 ± 0.2	2.0 ± 0.8
Cl	608 ± 88	21.3 ± 8.4	0.4 ± 0.1
HCO_3	121.7 ± 31.2	21.4 ± 4.0	35.4 ± 15.3
SO_4	21 ± 3	8.9 ± 0.6	7.9 ± 1.1
Specific conductance	1,979 ± 245	126 ± 33	74 ± 25
No. of sites	10	10	4

Of the 56 pools examined repeatedly, 37 either never or rarely became dry in May-September 1980, while 19 became dry periodically. Specific conductance of the pool water showed little consistent pattern of change during the season.

Salty vs. Fresh Water

Along the 22 km of highway in which all water bodies were recorded, there were 13 major lakes and streams and 37 small pools. The 13 lakes and streams had water of low specific conductance ($\bar{x} \pm$ SE of 68 ± 7 µ) and no evidence of concentrated moose activity. Of the 37 small pools, 14 had a typical conductance > 1,000 µ. (salty pools), and 23 had lower conductance. (1,000 µ was considered a better cut-off point than 500 µ as used initially). The 14 salty pools had substantially higher ratings of moose activity (P < 0.001 by Mann-Whitney U test), and they were the only ones with wildlife trails. Most pools of high and low conductance did not differ in size, distance from the road, or elevation relative to the road. However, all but 2 salty pools appeared to be completely stagnant, and a few of the non-salty pools were apparently fed by run-off from adjacent forest areas rather than from the highway.

Seasonal Pattern of Activity

Moose activity as scored at pools increased from mid- to late May, fluctuated in June, and then declined throughout July to very low levels in August and September. During the peak period (May and June) moose appeared to use pools more on hot days, and the activity score was strongly correlated with average temperature in the study area ($r = 0.67$, $P < 0.001$). In July and August, however, moose activity showed a steady decline but no relation to daily temperature. Temporary reduction of activity at experimentally treated pools had little apparent influence on activity at sites included in this analysis.

Moose Sightings and Accidents

Of the 67 moose sightings made from a vehicle, the animal was in a known saltwater pool in 41 cases and within 100 m of such a pool in 11 cases. Sightings in and near pools were most common between mid-May and mid-June, but continued at a lower rate through mid-July. Moose were seen in lakes and wetlands in 8 cases, mainly from mid-June to mid-July.

The 23 pools where moose were seen had higher ratings of accumulated trampling ($\bar{x} \pm$ SE of 3.1 ± 0.2) than pools where no moose were seen (2.0 ± 0.2). The 7 pools with 3 or more sightings were all rated ≥ 3 for accumulated trampling.

Table 3. Number of moose-vehicle accidents on a northern Ontario highway in May-September of 1979 and 1980. Accidents are classed according to distance from roadside pools rated 3 or higher for accumulated trampling by moose. Locations of 50 randomly-chosen points are given for comparison.

	Accidents			
Distance from pool (m)	1979	1980	Total	Random points
0-100	7	10	17	4
101-200	2	1	3	6
201-300	0	1	1	4
> 300	7	11	18	36

Between May and September of 1979 and 1980, 39 moose-vehicle accidents in or near the study area were accurately located and inspected. Seventeen accidents occurred within 100 m of a heavily-used pool (accumulated trampling rated 3, 4, or 5), and 4 others occurred 100-300 m from such a pool (Table 3). In several cases, tracks showed that the animal had been at the pool before the accident, but in other cases tracks were obliterated or difficult to interpret. Eighteen accidents occurred > 300 m from a heavily used pool, but in 3 cases the animal had been at or near a pool rated 2. To check for a chance association between accidents and pools, random numbers were used to select 50 points (based on 0.1-km intervals) along the 156 km of highway. Most of these points fell > 300 m from a pool rated 3, 4, or 5 (Table 3).

DISCUSSION AND MANAGEMENT IMPLICATIONS

Saltwater pools were a major attraction for moose. Many such pools were well trampled and had distinct wildlife trails. Most sightings of moose near the highway and about 1/2 of the moose-vehicle accidents occurred at or near actively used pools.

Moose-vehicle accidents are 1 of many social and environmental costs of highway deicing with NaCl. Others include corrosion of vehicles, damage to highway structures, effects on vegetation, and contamination of water supplies (Adams 1973). The various concerns have stimulated considerable research on means of reducing use of chemicals and a search for less harmful deicers.

A reduction in the use of NaCl might have various benefits, but would not likely eliminate salt-related accidents involving moose. Even small quantities of salt can attract ungulates in an Napoor environment. For example, on 1 highway that was sanded in the winter, the small amount of salt used to prevent clumping of sand apparently was sufficient to attract ungulates (Fraser 1979).

A number of alternative highway deicers have been used in areas with special needs (Zenewitz 1977), and others appear to have potential for the future (Dunn and Schenk 1979). However, only 3 compounds appear to be widely used in North America under severe winter conditions.

Urea is commonly used as a deicer in Canada and the U.S. at airports where corrosion associated with chloride salts cannot be tolerated. However, urea is about 10 times more expensive than NaCl and is effective only down to -10 C. Furthermore, urea would probably fertilize roadside vegetation which in turn might attract wildlife.

Liquid deicers based on ethylene glycol are effective at lower temperatures than urea and are gaining popularity at some airports in the U.S. (L. Vipond, Federal Aviation Administration, U.S. Dep. of Transport, Washington, DC, pers. commun.). They are probably too expensive to be considered for highway use, except in areas with special needs, and their use on highways has given mixed results (Zenewitz 1977).

Calcium chloride (as $CaCl_2$ or $CaCl_2 \cdot 2H_20$) is used on highways, usually in combination with NaCI, in some areas with severe winter weather. In Ontario, calcium chloride is about 5-8 times more expensive than NaCI. However it is effective at much lower temperatures (down to -34 C, rather than -12 C) and could probably be used at lower rates of application. Substitution of calcium chloride for NaCI would probably cause a large reduction in moose-vehicle accidents, but would be economical only if much smaller amounts of deicer could be used. In areas where bare pavement is not required, sand could be freeze-proofed with calcium chloride rather than NaCI, at a more modest increase in price.

Management of roadsides might help to eliminate accumulations of salty water. Some major pools might be drained successfully (Grenier 1980), but this would be difficult in many low-lying areas. Our experience suggests that some pools are repeatedly replenished with brine when rain percolates through the salt-laden shoulder of the highway. If the shoulder near such pools were made impermeable to water, perhaps by asphalt or a plastic fabric buried beneath the gravel surface, the pools would presumably be flushed with fresh water at each rainfall. The initial saltwater deposits from the spring thaw should then become progressively more dilute. For pools that cannot be treated permanently, a cervid repellent could be applied during the peak accident season as discussed by Fraser and Hristienko (1982).

With the great abundance of salty water in our study area, elimination of heavily used pools might serve only to encourage moose to use other roadside pools. Therefore, any management of roadsides might best be combined with establishing artificial salt sources distant from the highway. This idea is not entirely without precedent. In a rarely cited study in Michigan, a high frequency of deer-vehicle accidents was attributed to salt used to settle dust, and the placing of salt well away from the highway was followed by a reduction in accidents. That report came from Aldo Leopold (1933). As often happens in wildlife studies, Leopold recognized the germ of the idea a disconcertingly long time ago.

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