FAILURE TO REDUCE MOOSE-VEHICLE ACCIDENTS AFTER A PARTIAL DRAINAGE OF ROADSIDE SALT POOLS IN QUÉBEC

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ABSTRACT: Salt pools along highways are considered a major cause of increased moose-vehicle collisions during June and July in Québec, Ontario and New Hampshire. About 60 moose are killed each year on the 189 km of Highways 175 and 169 which cross the Laurentides Wildlife Reserve in south central Québec. An attempt was made in 1979 to reduce accidents by drying up roadside salt pools. Some 71 % of salt pools found along a 52 km section of Highway 175 were treated by improving roadside ditch drainage or connecting marshy pools to water courses. In 1981 and 1982, 94 % of the treated pools were once again filled with water. Although mean pool depth was reduced, this did not result in the lowering of salinities or of the frequency of pool attendance by moose. Moose road mortality was not significantly modified by the drainage work. To be effective in reducing moose-vehicle collisions, roadside pools have to be completely and permanently eliminated. When it is not feasible or practical to drain all the water of a pool, other techniques tested elsewhere, like the covering of the pool with grates or diversion of a roadside stream through the salt pool to cause dilution, may be used in conjunction with drainage work. More research is needed to develop new techniques to keep moose away from hard-to-drain pools or to reduce pool salinity. These could include long-lasting repellents or replacement of NaCl by $CaCl_2$ as a road deicer.

RÉSUMÉ: Les mares saumâtres qui bordent certaines routes du Québec, de l'Ontario et du New Hampshire sont en majeure partie responsables de la hausse des accidents routiers impliquant des orignaux en juin et en juillet. Environ 60 orignaux se font ainsi tuer chaque année sur les 189 km de route qui traversent la réserve faunique des Laurentides, située au centre-sud du Québec. En 1979, nous avons tenté de réduire le nombre d'accidents en améliorant le drainage de 71 % des mares saumâtres qui bordaient une portion de 52 km de la route 175. Lors d'inventaires de suivi en 1981 et en 1982, nous avons constaté que 94 % des mares traitées étaient à nouveau remplies d'eau salée. Bien que le niveau d'eau dans les mares ait été abaissé par nos travaux, ni la salinité et ni la fréquentation de l'orignal n'ont subi de changements significatifs. Par conséquent, nos travaux n'ont pas eu d'impact sur la mortalité des orignaux au cours des années qui ont suivi le traitement. Pour être vraiment efficace au niveau de la prévention des accidents routiers, le drainage doit éliminer toutes les mares saumâtres présentes le long de la route ou d'une portion de celle-ci et être fait de la façon la plus permanente possible. Lorsqu'une mare ne peut être éliminée, on suggère d'utiliser des techniques qui ont fait leurs preuves ailleurs comme, par exemple, la couverture de la mare avec des troncs d'arbre pour empêcher les orignaux d'y accéder ou encore la déviation d'un ruisseau dans la mare pour diluer la teneur en sel de celle-ci. Des recherches sont nécessaires pour mettre au point d'autres techniques d'appoint, tels des produits répulsifs de longue durée ou le remplacement du NaCl par du $CaCl_2$ comme déglaçant principal, qui éloigneraient les orignaux des mares difficiles à drainer ou encore qui aideraient à reduire la salinité dans les mares.

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Chemical analyses of lick water and "cafeteria" style studies have confirmed that sodium is the primary attractant at moose (*Alces alces*) licks (Fraser and Reardon 1980; Tankersley and Gasaway 1983; Couturier 1984; Couturier and Barrette 1988; Risenhoover and Peterson 1987). Use of mineral licks by moose is seasonal, reaching its peak in spring and early summer (Fraser and Hristienko 1981; Tankersley and Gasaway 1983; Couturier 1984; Couturier and Barrette 1988; Risenhoover and Peterson 1986, 1987). Different hypotheses related this increased sodium intake by moose to the need to allay a sodium deficiency induced by the winter depletion of mineral reserves (Jordan *et al.* 1973), by a reacclimation to warm weather (Fraser and Hristienko 1981) or by an increase in mineral demand for pregnancy or antler growth (Jordan *et al.* 1973). Na hunger can be also associated to an adjustment of the moose Na^+/K^+ equilibrium which has been temporarily changed by the ingestion of large quantities of water and potassium found in growing terrestrial vegetation (Weeks and Kirkpatrick 1976; Staaland *et al.* 1980). Such a seasonal variation of the Na^+/K^+ ratio has been illustrated by Stewart and Flynn (1978), and by Flynn and Franzmann (1987) in moose hair.

Na concentration at mineral licks varies from about 30 to 500 ppm (Fraser 1980; Tankersley and Gasaway 1983; Couturier 1984; Couturier and Barrette 1988; Risenhoover and Peterson 1986, 1987). Other major sources of Na (150-700 ppm in Ontario; up to 9 400 ppm on Isle Royale, Michigan) can be found in aquatic vegetation (Jordan *et al.* 1973; Belovsky and Jordan 1981; Fraser *et al.* 1982) and in certain salt laden pools (27-984 ppm; Grenier 1973; Fraser and Thomas 1982; Fraser *et al.* 1982; Miller and Litvaitis 1992; present study). Salt pools are formed along road embankments where undrained water is high in Ca^{++} and especially in Na^+ as a result of the winter spreading of calcium chloride ($CaCl_2$) and sodium chloride ($NaCl$) as road deicers (Grenier 1973, 1980).

In Québec, Ontario and northern New Hampshire, moose frequently visit roadside salt pools during the summer and, as a result, are often victims of vehicle collisions such as on the highways that cross the Laurentides Wildlife Reserve in south central Québec (Grenier 1973; Fraser 1979; Fraser and Thomas 1982; Miller and Litvaitis 1992). Grenier (1973) demonstrated that there were twice as many moose killed per km of road where pools were found along these highways than where there were no pools at all. No fatalities occurred during the study in the Reserve but material damage caused by moose-vehicle collisions reached $2,300 /accident, whereas 21% of injured drivers or passengers required medical assistance for cuts or bone fractures (Grenier 1980). In an attempt to reduce moose collisions, pools most frequented by moose were drained along the southern portion of Highway 175. Our goal was to evaluate the complete dry-up of the preferred pools, or at least the lowering of NaCl concentrations to levels less attractive to moose with a view to reducing moose road mortalities (Grenier 1980).

STUDY AREA

The Laurentides Wildlife Reserve, located 50 km north of Québec City, is a coniferous and mixed forest area covering 7 960 km^2 (Fig. 1), completely included within a high plateau (max. 1 000 m) of the Precambrian Canadian Shield. There are no known natural salt licks in the Reserve but lakes supporting substantial aquatic vegetation are numerous and well distributed throughout the Reserve.

Two year-round asphalt highways (Highways 175 and 169) transect the Reserve along its north-south axis (Fig. 1). Total length of these roads is 189 km. Mean summer traffic measured on Highway 175 at the southern limit of the Reserve remained constant during the study at about 5 000 vehicles/day (Trans-

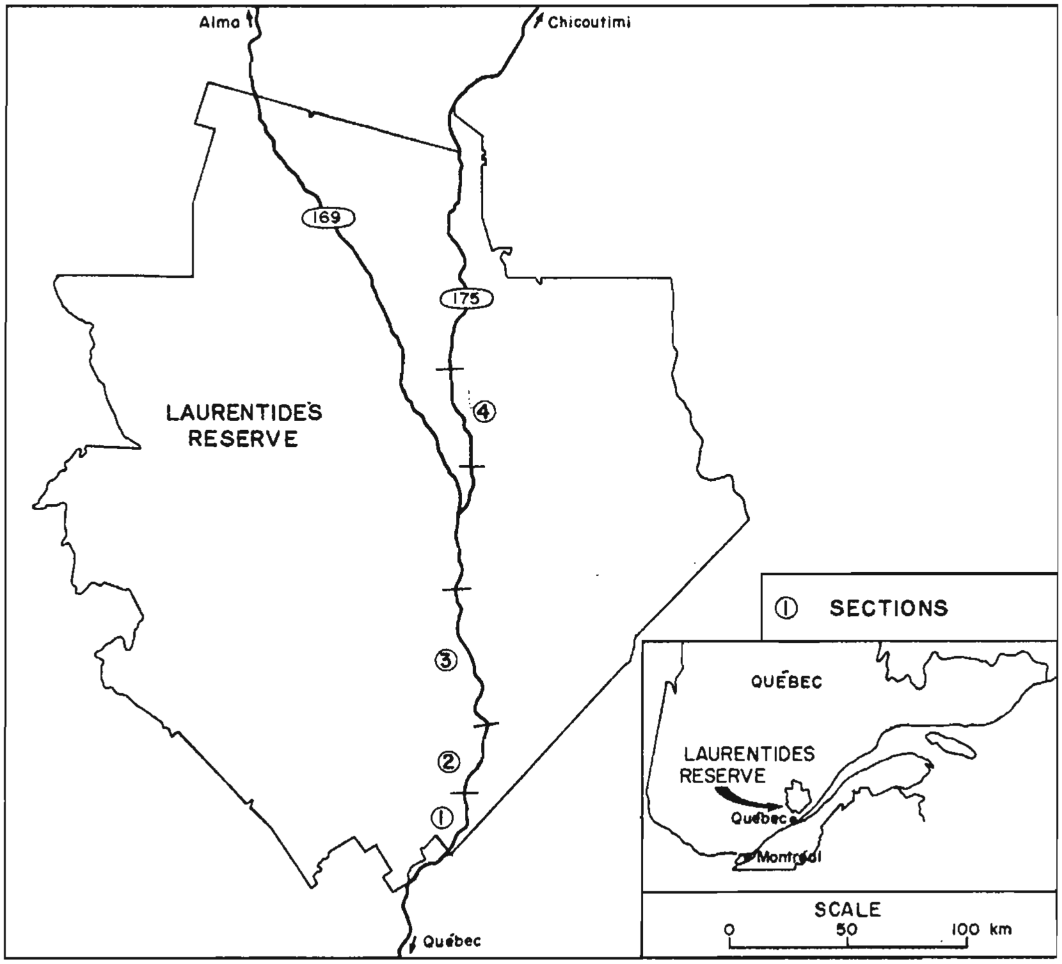

Fig. 1.The location of the Laurentides Wildlife Reserve, of Highways 175 and 169, of the treated sections (1, 2, 3) and the control area (4).

port Québec 1984).

Due to the altitude, the Reserve's climate is relatively harsh for southern Québec. The mean temperature in January is -15°C whereas that for July is +15°C. Snowfalls over the Reserve varies from 300 to 500 cm (Wilson 1971). Mean annual length of the growing season is 140 days starting May 20, one month later than the surrounding Québec region (Wilson 1971). Each winter, between 70 and 80 tonnes of NaCl, 60 tonnes of sand containing NaCl, and two tonnes of $CaCl_2$ are spread over each km of the highway for deicing (G. Dubé, Transport Québec, pers. comm.). Those quantities are higher than the 30-40 Tonnes of NaCl/km used on most other roads in Québec and Ontario (Fraser and Thomas 1982).

Large mammals commonly found in the Reserve include moose (density about 0.3 moose/km^2), caribou (*Rangifer tarandus*), black bear (*Ursus americanus*) and wolf (*Canis lupus*). There is a controlled moose hunt each autumn (Bouchard and Moisan 1974). Approximately 60 moose (0.32/km) are killed each year by vehicles on Highway 175 and Highway 169 within the Reserve. Mortality is high during the June to August period with a peak from mid-June to mid-July (Grenier 1973). By September, the collisions fall off sharply. Sightings of moose along the highways by patrolmen of the *Sûreté du Québec*, at work 24 hours a day, show the same trend (H. Jolicoeur, unpubl. data).

MATERIALS AND METHODS

An inventory was carried out in June 1979 of all the roadside pools (or ditches) situated alongside the southern 52 km of Highway 175, the road section with the highest moose-vehicle collision rate in the Reserve. The pools were classified as salty when conductivity was $\geq$250 µhos, corresponding to a salinity of approximately 180 mg/l (or ppm), a level considered attractive to moose (Grenier 1980; Fraser and Reardon 1980). Based on the extent of moose trampling at the pool and the past incidence of accidents in the vicinity, 35 of the 76 pools classified as salty were selected and drained during the summer of 1979 (Grenier 1980). Ditch beds were cleaned using a backhoe, and slopes were increased. In marsh areas, drainage canals were dug also with a backhoe linking the pools to the nearest water course. To demonstrate the effect of pool drainage on the rate of moose accidents, pool drainage was undertaken in different degrees along the length of the study area. The 52 km of highway were divided into three sections, each having a different degree of drainage (Table 1). An additional control section of 26 km was situated north of the study area (Fig. 1).

The effect of the drainage work was evaluated based on two different indices; (1) the number of moose killed within each section of highway was compared for the three years prior to and following drainage work (data from 1979 were not included as the extensive drainage work that year may have modified moose behaviour along the road side); (2) salinity, depth and moose trampling (an index of visitation) at each pool were noted twice during the summer for 2 years following drainage work (1981-1982). Pool conductivity was evaluated using a YS1-33 portable conductometer. Conductivity measurements were then adjusted to 25°C and converted to their corresponding NaCl concentrations using the following linear regression equation (eq.1):

$$[1] \quad Y = 0.2X - 11.5$$

derived from conductivity-NaCl measurements of water samples taken from 20 different pools ($r = 0.98$; $P < 0.01$).

Water salinity and depth between treated and untreated pools, sections, summer periods and years were compared using ANOVA (Nie *et al.* 1975). Analyses pertaining to moose visitation and moose mortalities were performed with chi-square (Nie *et al.* 1975). The null hypothesis was rejected when $P < 0.05$.

Table 1. Moose road mortality, prior to (1976-78) and after (1980-82) roadside pool drainage, in relation to drainage treatment intensity.

Sections	Length of highway sections (km)	Pools drained in each section		No. moose-vehicle collisions	
		%	n	Before drainage	After drainage
1	12	83	12	14	12
2	12	53	15	7	20
3	28	37	46	19	13
4	26	0	0	21	17

RESULTS

Pool Visitation by Moose and Road Mortalities in Relation to Drainage Work

Moose use, judged from trampling, differed significantly ($P = 0.004$) between the three treated road sections. However, the difference was not due to drainage work. Section one, where the drainage was the most intensive, had the highest level of use by moose with 68 % of the pools being trampled. Sections two and three had equal levels of visitation with 45 % of the pools having moose tracks close or directly in the water. Overall, for the three experimental sections, the percentage of pools frequented by moose was 48 % in 1981 and 52 % in 1982 ($P = 0.47$). In general, the intensity of use by moose declined between the beginning (57 %) and the end of the summer (40 %; $P = 0.02$). Finally, there was no significant change ($P = 0.83$) between the 3-year periods prior to and after drainage in the number of moose killed on the 52 km stretch of highway (Table 1). Along the control stretch, moose mortality showed insignificant changes between the two periods (Table 1).

Effect of Drainage Work on Pool Salinity and Depth

There was no significant difference in the mean salinity of drained and undrained pools ($P = 0.78$), between sections ($P = 0.07$) or between years ($P = 0.58$; Table 2). However, on average, salinity declined close to 50 % between the beginning and the end of the summer ($P < 0.001$; Table 2). For the two study years, average salinity ranged from a high of 693 mg/l at the beginning of the summer to a low of 333 mg/l at the end of the summer, the overall mean being 508 ± 31 mg/l.

Average pool depth during the study was 10.3 ± 0.5 cm. In contrast with the salinity, pool depth was significantly modified by the drainage work ($P < 0.001$; Table 3). The mean depth of treated pools was 6.0 ± 0.6 cm whereas that of untreated pools was twice that figure, at 12.5 ± 0.7 cm. Neither the period of the summer, the section of the highway, nor the year had an effect on the level of water in pools (Table 3).

Table 2. Mean pool salinity (mg/1 ± SD) in relation to drainage, road section, summer period, and year.

		Drained Pools						Undrained Pools					
		May-June			Aug.-Sept.			May-June			Aug.-Sept.		
Section	Year	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1	1981	659	179	9	489	148	7	411	88	8	189	69	9
	1982	502	710	2	488	152	8	107	151	2	343	111	8
2	1981	669	118	8	214	68	7	270	119	9	140	60	8
	1982	984	288	8	378	104	8	362	259	9	167	95	8
3	1981	783	137	16	318	67	14	775	107	47	358	66	44
	1982	390	120	14	248	52	16	897	160	38	394	70	43

Note: *F* Value (degree of freedom)
Drainage treatment: 0.09(1) not significant
Section: 2.52(2) not significant
Summer period: 39.96(1) $P < 0.001$
Year: 0.08(1) not significant

Table 3. Mean pool depth (cm ± SD) in relation to drainage, road section, summer period, and year.

		Drained Pools						Undrained Pools					
Section	Year	May-June			Aug.-Sept.			May-June			Aug.-Sept.		
		$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1	1981	6.0	0.6	8	6.2	1.0	7	11.7	3.2	7	14.5	5.9	9
	1982	5.4	2.1	8	5.2	2.7	4	17.8	8.2	7	23.1	9.1	4
2	1981	5.8	0.7	8	6.8	1.4	7	15.3	4.2	8	8.9	2.9	9
	1982	6.9	1.7	8	2.7	0.6	7	9.7	3.8	9	8.4	3.1	8
3	1981	6.1	1.9	15	6.4	1.7	15	11.7	1.4	45	15.4	1.9	46
	1982	6.9	3.6	17	5.9	1.4	17	10.3	1.4	47	12.1	1.4	47

Note: F Value (degree of freedom)
Drainage treatment: 32.29(1) $P < 0.001$
Section: 1.0(1) not significant
Summer period: 1.12(1) not significant
Year: 1.15(2) not significant

DISCUSSION

According to Grenier (1980), the pool drainage work resulted in the complete elimination of 71 % (25/35) of the salt pools, immediately after the treatment in the summer of 1979. The incomplete drying up of the other pools was attributed to inadequate drainage slopes and the occurrence of bedrock outcroppings or earth slides which acted as dams, retaining water. In 1981, two years after the drainage work, 94 % (33/35) of the previous pool areas were once again filled with water and used by moose. Although the drainage work diminished the mean depth of the treated pools, this change did not result in the intended salt-dilution effect. Even at the end of the summer, after several months of being flushed by rain, pool salt concentrations, although reduced by 50 %, remained at levels twice that established to serve as our basis for considering a pool salty (180 mg/l). Fraser and Thomas (1982) postulated that the concentration of NaCl in roadside soil is so high that a small amount of rain water is sufficient to reestablish pool salinity. That could explain why the drainage work failed to lower the pool salinity under the level considered as attractive for moose and consequently to reduce moose mortality along the experimental stretch.

Demonstrations of attachment to a Na source may suggest that Na is of prime importance for moose in late spring and early summer and may confirm the hypothesis of a salt drive (Jordan 1987). Couturier (1984) noted that moose alertness at a lick (measured by the number of times the animal raises its head and stays still with ears in the same direction for at least 3 seconds) is less pronounced during the June-July period than during the late summer – early fall period. The time spent drinking at each visitation was also greater in the first part of the summer as were aggressive interactions between individuals (Couturier 1984). Other researchers noted that moose are more tolerant to the approach of human when feeding on aquatic plants (Joyal and Scherrer 1978; Belovsky and Jordan 1981) or when drinking at salt pools (Fraser 1979; Miller and Litvaitis 1992). Specific movements to mineral licks were also observed in Alberta (Best *et al.* 1973) and inferred in Alaska (Tankersley and Gasaway 1983). In New Hampshire, moose having their home ranges along a 25 km section of Route 3 made quick and direct trips to the nearest roadside salt pools throughout the summer and fall. One female covered a distance of 7.5 km in less than 8 hours to drink at a roadside salt pool (Miller and Litvaitis 1992). Several weeks after the initial drainage work, Grenier (1980) noted moose digging at the soil of drained sites and use of incompletely drained pools as small as 25 cm in diameter. This continued interest in the sites may also be interpreted as another form of attachment to Na source and may suggest that moose visitation at the pools sites will continue as long as salty water will remain in the pool.

Fraser *et al.* (1982) stated that moose progressively desert diluted salt pools when more Na–rich aquatic vegetation becomes available. This roadside abandonment by moose should normally result in decreased opportunities of moose-vehicle accidents. In the Laurentides Wildlife Reserve, moose sightings and mortalities do not decline sharply in July when moose feeding on aquatic vegetation reaches its highest level (Bouchard 1967). With salinities ranging from 107 to 984 mg/l (mean = 508 mg/l), roadside salt pools of the Laurentides Wildlife Reserve offer Na concentrations at least comparable to those found in the aquatic vegetation of Ontario (Fraser *et al.* 1982). As a result, there may be no need for the moose population living along the road to shift to other sources of sodium. Similar findings were made in the Wawa area in Ontario where roadside pool salinity reached 600 ppm as compared to 100 ppm elsewhere in that province (Fraser *et al.* 1982). In New Hampshire, moose visitation to roadside licks continued during the summer despite the availability in the study area of ponds containing aquatic vegetation (Miller and Litvaitis 1992).

In conclusion, roadside pools are a non-negligible source of Na for the moose population of the Laurentides Wildlife Reserve and constitute an easy way to satisfy the summer salt need of moose having their home-range along these roads. As sodium seems to be an important element for moose in late spring-early summer and as the effect of a Na deficiency on moose is not known (Jordan 1987), the drainage work must be designed to encourage moose to use natural source of Na such as those found in aquatic plants. Roadside drainage of salt pools is difficult to accomplish and labour intensive but until we find evidence to the contrary, we still consider this treatment as a method of reducing moose-vehicle accidents. To be successful, the drainage work has to eliminate all pools in an area and the treatment must be as permanent as possible. In Ontario, a similar treatment started by draining only heavily used pools, encouraged moose to move to nearby pools with lower conductivity. The complete elimination of all pools $\geq 200\,\mu$mhos finally reduced moose mortalities by 80% on a 10 km experimental stretch of road (G. Eason, pers. comm.). Treating 35 of 76 pools with conductivity $\geq$ 250 μhos, as we did in our study, still allows 41 of them to be used. Under these conditions, it is understandable that moose road mortality was not reduced by this partial pool drainage. When it is not possible or practical to drain a pool, other techniques could be used in combination with drainage work. Most promising techniques recently tested in Ontario include the covering of pools with grates made of poles cut at the site, impeding moose drinking into the ditch and trampling their sides. The diversion of roadside streams through some salt pools causing a dilution of salty water can also give good results (G. Eason, pers. comm.). More research is needed to study other techniques to keep moose away from hard-to-drain pools, for instances long-lasting repellents. The replacement of NaCl by $CaCl_2$, as road deicer, could also help to reduce moosecar collisions through lowering of pool salinity.

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