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Supporting Document for Road Salts

ROAD SALTS AND WILDLIFE - AN ASSESSMENT OF THE RISK

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Assessment summary

There have been many documented cases of wildlife mortality along roadsides where salt has been applied. Mammalian and avian wildlife, especially herbivorous and granivorous species are attracted to salt, probably to satisfy a dietary need. Because mortality appears to be primarily a result of vehicle strikes, most authors have assumed that salt was only indirectly responsible for the deaths - a case of 'fatal attraction' to busy salted roads. While this is likely the case for mammals, especially large ungulates, repeated observations of apparent behavioural toxicity along roadsides, as well as new information on the toxicology of oral salt ingestion in birds, now suggest that salt toxicity per se is contributing to the vulnerability of small songbirds to road traffic and, perhaps, is a direct cause of mortality in some birds. The difficulty of retrieving bird carcasses and the low rate of reporting suggest that kills are probably more widespread and frequent than indicated by documented reports alone. Most known cases of songbird mortality have occurred within a group of birds collectively known as 'winter finches' and belonging to the subfamily Carduelinae. This may result from a higher probability of exposure for these species because of their diet and presence in the snow belt, but may also reflect a greater ease of detecting mortality incidents in species forming large feeding flocks. The very high attraction of salted roads for winter finches suggests that the roads' 'ecological footprint' is very large. We conclude that the importance of road salt as a mortality factor in these species has long been underestimated by wildlife managers and transport personnel.

1. Exposure characterization

Sodium is an indispensable component of the physiological processes of all vertebrates but is toxic when taken in excess. Typically, surplus sodium is removed by an increase in glomerular filtration rate and a decrease in the percentage of sodium reabsorbed by the kidneys. The avian kidney is less efficient than the mammalian kidney at removing sodium. Birds that live in saline environments (e.g. marine birds) have a developed nasal salt gland for excretion. Terrestrial birds, especially herbivorous and granivorous species, are more likely to be salt deficient and are poorly equipped to deal with excess sodium. Any animal attempting to satisfy a 'salt hunger' generally overshoots its deficit by a substantial amount, and the increase persists for some time after the deficit is replaced (Schulkin, 1991). Over-consumption of salt is in turn regulated via a feed back mechanism: the thirst response. The absence of a source of water therefore increases the toxicity of ingested salt (see section 2.1).

Some wildlife species actively seek out salt licks and mineral deposits. Sodium deficient wildlife are known to travel great distances to obtain and ingest salt and to visit roads where salt has been applied (Shulkin, 1991). One concern raised by this assessment is that the 'footprint' of a salted road may be quite large when highly mobile wildlife species are attracted from great distances.

1.1 Mammals

The most visible interaction between road salt and wildlife concerns the large ungulates, such as moose (*Alces alces*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*) , and bighorn sheep (*Ovis canadensis*). Road salt attraction has been identified as a main reason for kills of bighorn sheep and a minor reason for kills of Elk in Jasper National Park (Bradford, 1988). In May and July pools of salty snowmelt available along the roadsides are considered a major cause of moose-vehicle accidents in Northern Ontario (Fraser and Thomas, 1982) and Quebec (Jolicoeur and Crete, 1994). Remedial efforts have included partial drainage of pools (Jolicoeur and Crete, 1994), and the application of repellents (Fraser and Hristeinko, 1982). Apart from death and injury due to vehicle collisions, there is no record of moose or deer suffering from salt toxicosis. However, when moose are drinking salty water, they tend to lose their fear of humans and vehicles (Jones et. al. 1992) in contrast to moose not drinking salty water that move away from approaching humans. The only documented case of small mammals exhibiting signs of salt toxicosis is Eastern cottontail rabbits (*Sylvilagus floridanus*) reported during a severe winter in Wisconsin (Trainer and Karstad, 1960). Their symptoms were not described separately from those of affected birds but could have included " *loss of fear, depression*[1]*, tremors, torticollis*[2]*, retropulsion*[3]*, partial paralysis, and circling in one direction*". The role that road salt could play in the mortality of other wildlife species such as small mammals commonly killed by traffic is not known.

1.2 Birds

We were able to find twelve published reports of bird kills associated with salted roads (Appendix 1). Two incidents were formally diagnosed as salt poisoning (Martineau and Lair, 1995; Trainer and Karstad, 1960) and observations of potentially aberrant behaviour suggestive of toxicosis were made in several other cases. Sodium chloride was usually identified as the substance to which birds were exposed, although in one case the road salt applied was calcium chloride (Meade, 1942). Geographically, these kills occurred at several sites within the Canadian and U.S. snow belt from 1942 to 1999. One report originated from Germany. At least two reported kills were large, involving more than a thousand birds each. Given the difficulty of finding avian carcasses (Mineau and Collins, 1988), the high rate of scavenging reported from sites where birds are routinely killed at roadside (John Woods, Parks Canada, *pers. comm.*; Craig W. Benkman, New Mexico State University, *pers. comm.*) and the low rate of reporting for wildlife mortality events in general, the number of reports of bird mortality associated with the use of road salt is significant and suggests that kills are probably more widespread and frequent than indicated by documented reports alone. Supporting this view is the fact that other researchers and biologists, when contacted, were very familiar with kills of birds on salted highways even though their observations had not been published. In one location (Mount Revelstoke Park), mortality of siskins and other winter finches (see below) has been seen frequently enough over the last 25 years that they are called "*grill birds*" by the local inhabitants, in reference to their propensity to be collected by the front end of moving vehicles (John Woods,

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[1] Depression: General lethargy
[2] Torticollis: Abnormal head carriage
[3] Retropulsion: Spasmodic pushing out with the legs

Parks Canada, *pers. comm*.). The kills often occur in sections of the highway with curves or where there are many cracks and crevasses in the pavement where salt can accumulate although they may occur anywhere the roads have been sanded and salted. Baker (1965) stated that the inhabitants of one Maine community "*looked upon this bird slaughter as a natural and everyday occurrence*". Another researcher we contacted reported seeing "*hundreds of dead crossbills that were hit by vehicles while on the road eating salt*" (Craig W. Benkman, New Mexico State University, *pers. comm*.).

Cardueline finches (Family Fringillidae, subfamily Carduelinae: crossbills, grosbeaks, and siskins) were involved in 11/12 published incidents. This group of seed eating birds, some of which are collectively known as 'winter finches' range throughout the boreal forest, moving to more southern latitudes only when seed yield is low. Although they will eat deciduous seed, insects, and berries, their primary diet, particularly in the winter consists of coniferous seeds. Their beaks are adapted to facilitate the cracking of nuts, or the extraction of seeds from cones (Runtz, 1996). They are small birds with body weights between 15 and 40 grams. They are transcontinental nomads, resident all year but moving between locations, in search of high seed yields. Birds may be absent in an area one winter and common the next, invading an area in a matter of weeks (Parker, 1973). The winter presence of these birds can be predicted by seed yield the previous summer (CraigW. Benkman, New Mexico State University, *pers. comm*.). They are social birds known to forage in flocks. Their attraction to salt is well known. Red crossbills (*Loxia curvirostra*) have been trapped using salt as bait (Dawson et al 1965), and cardueline finches were found to prefer sodium over other minerals regardless of grit size (Bennetts and Hutto 1984). They have been observed pecking in the damp soil near salt water roadside pools (Fraser, 1985), drinking sea water (Riddiford, 1994), and consuming mortar and cement from houses (Tozer, 1994, Frost, 1985, Sainsbury, 1978). Their attraction to road salt is so well known that it is mentioned in field guides (e.g. Ehrlich et. al., 1988). In Algonquin Park, pine grosbeaks (*Pinicola enucleator*) are no longer seen in large numbers at roadside once the snow has melted (Jim Bendell, University of Toronto, *pers. comm*.) although this may be because snowmelt comes at a time when winter flocks are breaking up. It has also been hypothesized that cardueline finches may be attracted to roadsides in order to ingest clays and minerals to detoxify the toxic elements in conifer seeds. (Craig W. Benkman, New Mexico State University, *pers. comm*.) All cardueline finches are protected species listed under the Migratory Bird Convention Act.

The information from reported kills and the behavioural/social characteristics of the cardueline finches suggest that this may be the group most at risk of acute salt toxicity from ingesting road salt. However, because the birds tend to travel and forage in large flocks in the winter, there is undoubtedly a bias for a higher detectability and reporting of kills. Trainor and Karstad (1960) reported Bobwhite quail (*Colinus virginianus*), Ring-necked pheasant (*Phasianus colchicus*) and feral dove (*Columba livia*) as well as Eastern cottontails being poisoned.

It is often assumed that salt is ingested in order to fulfill a physiological need associated with a largely vegetarian diet. However, the taking of salt crystals as grit cannot be ruled out. Grit is used to aid in the grinding of food and to provide supplementary minerals to bird species with low calcium diets (Gionfriddo and Best, 1995). Course foods such as seeds and chitinous insect parts require more grit for digestion than do softer foods (Gionfriddo and Best, 1995). Birds select grit on the basis of size, color and shape (Gionfriddo and Best, 1994; Gionfriddo and Best, 1996a; Gionfriddo and Best, 1996b). Crushed rock salt particles are multifaceted and irregular in shape and translucent to white in appearance. These characteristics were all preferred features in choice tests carried out with House sparrows, a granivore at the mid-point (28g) of the size distribution for cardueline finches. Continuing with the House sparrow model (Gionfriddo and Best, 1995), only 1 of 245 free-ranging sparrow gizzards was devoid of grit. The number of grit particles ranged from 0 to 3,204 with a mean of 580 and a median of 462. The average grit particle (based on a subsample of 60 gizzards) had a mean diameter of 0.5 mm and a maximum of 2.4 mm. Individuals compensated for smaller grit particles by ingesting higher numbers. Across species, grit size preferences are linearly related to bird size. Particle analysis from a salt mine in Ontario gave the following size distribution: 25-35%: 9.5 - 4.75 mm; 20-30%: 4.75 - 2.36 mm; 15-25%: 2.36-1.18 mm; and 5-10 %: 1.18-0.6 mm (The Canadian Salt Company Limited, 1991). Because salt particles applied to roads will undergo a gradual size reduction as they melt (Art Letts, Morton Salt, *pers. comm*.), salt particles will overlap broadly with the preferred grit size for any-sized bird from the time of application to some undetermined time after application. The large variation in the starting size of road salt particles ensures that a suitable size of grit will be available for an extended period.

2. Effects characterization

2.1 Acute Toxicity of sodium chloride

Incidents of vertebrate salt toxicity in domestic or captive stock fall under several main categories: accidental overdose in feed beyond a level that can be compensated by drinking more water (Sandals 1978, Khanna et al 1997, Wages et al., 1995, Howell and Grumbrell 1992, Swayne et al., 1986); exposure to saline drinking water (Franson et al. 1981), saline lakes (Windingstad et al 1987, Meteyer et al 1997), or the provision of salt supplements with deprivation of water (Trueman and Clague 1978, Scarratt et. al. 1985) . Reports of salt toxicosis in free-ranging vertebrate wildlife have been the result of exposure to road salt, drought, ice, hypersaline lakes and discharge ponds from various industries (Baeten and Dein, 1996).

Rats have an oral LD_{50} of 3,000 mg/kg, and mice an LD_{50} of 4,000 mg/kg (Bertram, 1997). Sodium chloride administered as a saturated water solution (approximately 2100 mg/kg) usually resulted in death within 24 hours (Trainor and Karstad, 1960). Repeated small doses of salt produced no illness if water was not restricted.

The Canadian Cooperative Wildlife Health Centre in Saskatoon and the National Wildlife Research Centre, Environment Canada recently conducted a joint study (Wickstrom *et al.* in prep.) on the acute effects of salt on wild caught house sparrows (*Passer domesticus*). The up-and-down method (OECD 1998) was used in a pilot study to estimate the approximate lethal oral dose of granular NaCl in birds that were non-fasted but without access to water for 6 hours post dose. Results indicated an approximate LD_{50} of 3000–3500 mg/kg, which is similar to the rodent values. A tentative no-effect level (mortality) was estimated to be 2000 mg/kg in this pilot study although mortality was seen at 1500 mg/kg in the subsequent phase of the study. As predicted, the availability of water influenced test outcome. The 2 birds given 3000 mg/kg both showed severe intoxication. One individual died while the other recovered 1-2 hours after water was made available again. Two supplemental birds given the same dose but with *ad lib* access to water showed only mild depression. Individuals dosed with a salt solution rather than with the dry crystals began showing overt signs of intoxication between 4000 and 6000 mg/kg regardless of whether drinking water was available or not. Limited testing also demonstrated that toxicity was more severe and the onset of overt signs much more rapid in individuals that had been fasted overnight. Observations from Mount Revelstoke Park (John Woods, Parks Canada, *pers. comm.*) suggest that pine siskins (the species most numerically affected at that site) are most likely to consume salt and grit in the morning when they are also likely to have an empty crop. Similar timing was observed in pine grosbeaks on Algonquin Park roadsides in Ontario (Jim Bendell, University of Toronto, *pers. comm.*) although some believe that feeding may occur before birds come to roads (Craig W. Benkman, New Mexico State University, *pers. comm.*).

2.2 Sub-chronic toxicity

No mammalian studies of greater than 5 days exposure to sodium chloride were found. In birds, shell damage occurred when 60 day old laying hens were given water with 600 mg/L NaCl for 10 weeks (Balnav and Yoselewitz, 1987). One week broiler chicks given 0.5% NaCl for 7 days experienced expansion of blood volume, increased mortality from pulmonary hypertension and ascites, right ventricular atrophy and decrease in growth rate (Mirsalimi et. al., 1993). There was no effect on white leghorns in the same study. Day old broiler chicks tolerated up to 0.2% NaCl over four weeks. Mortality in the 0.5% group was 28.9%. Adverse reaction included decrease in body weight, increased water consumption (Afifi et. al., 1992).

Red crossbills were treated with NaCl in drinking water for 20 days. Their daily water intake at the lowest dose (0.1M) was similar to that of controls (approximately 6 ml/day), and increased thereafter with increasing dose beginning at 0.15 M. By day 10, the 0.25M group was consuming 40 ml fluid per day. Control plasma sodium concentrations (birds given tap water) averaged 161.2 mmol/l. Plasma sodium in birds receiving 0.25 M for 8 days averaged 194.7 mmol/l. Birds not receiving water over 2 days had an average plasma sodium concentration of 194.3 mmol/l. (Dawson et al., 1965). A sandhill crane died after consuming water with 1% NaCl over 10 days (Franson et al. 1981).

2.3 Sub-lethal effects of excess salt ingestion in birds

Several authors reporting wildlife incidents associated with road salt made note of behavioural deficits in exposed birds. The most common observation is that the birds appeared unusually fearless and could be approached easily (Meade 1942, , Trainor and Karstad 1960, Baker 1965, Theil 1979, Smith 1981, Woods *pers. comm.* 1999). Others described the birds as "*weak and slow*" (Martineau and Lair 1995), or appearing sick (Meade, 1942). Trainor and Karstad (1960) reported "*depression, tremors, torticollis, retropulsion, and partial paralysis*" for birds and mammals affected in one incident.

These signs are closely matched by observations made in the course of laboratory studies. Pheasants fed increased amounts of sodium in their mash exhibited signs of intoxication when the drinking water was restricted. These included depression, followed by excitement, tremors, torticollis, opisthotonus, retropulsion, complete incoordination, and coma (Trainor and Karstad, 1960). Not all signs were seen in the same animal. Frequent signs reported in poultry and in swine include salivation, diarrhea, a staggering gait, muscular spasms, twitching, and prostration. (Humphreys, 1978). In Wickstrom *et al.* (in prep.), following the pilot study reported above, House sparrows were dosed orally with granular NaCl at 0, 500, 1500, 2500, or 3500 mg/kg. Groups of three birds at each dose were euthanised at 1, 3, 6, and 12 hours after exposure, and samples collected for histopathology and brain and plasma electrolyte analyses. Overt clinical signs were observed at 1500 mg/kg or higher and included rapid onset (< 30 min) of depression, ataxia, and inability to fly or perch, with death in as little as 45 min. Birds which survived for 6 hours usually recovered. Plasma Na concentrations > 200 mmol/L were consistently associated with overt clinical signs. Lesions in the form of gizzard edema, were observed after 1 hour in most birds dosed with 500 mg/kg or higher, and brain stem vacuolation, also consistent with edema, was seen in some birds showing clinical signs.

<u>3. Risk characterization</u>

Because mortality has been documented and is thought to be much more frequent and widespread than is reflected by the published record, we believe the risk to cardueline finches and perhaps other bird species is significant. Locally, the risk to large mammals may also be high. In the latter case, any mitigation effort would have the added advantage of reducing the human hazard associated with collisions between vehicles and wildlife. The main uncertainty associated with this risk analysis is the extent to which salt toxicity contributes to vehicle collisions. Also, if salt toxicity is occurring, it is relevant to ask whether wildlife, cardueline finches in particular, could be killed by salt ingestion in the absence of a vehicle strike.

3.1 Estimating the contribution of salt toxicity to vehicle strikes

The severe behavioural impairments (depression, tremors, torticollis, retropulsion, and partial paralysis) observed at one site as well as the finding of elevated brain sodium level at another argue strongly for a contributory role of salt toxicity to roadside bird kills. The more common observation of unusual fearlessness documented in both birds and mammals could be an early symptom of intoxication or it could be the manifestation of animals under extreme salt hunger modifying their usual behaviour towards potential danger.

Although overt signs of intoxication were seen in the House sparrow at 1500 mg/kg and higher, the level of dosing at which a more subtle behavioural impairment could be manifest is not known. We estimated a lower limit for potential impairment, using the House sparrow as a model, as follows:

1. The distribution of normal sodium values in the plasma of the sparrows is very narrow (mean of 163.2 mmol/l, range of 158-168, n=12. Our assumption is that adverse effects (such as reduced coordination and weakness) may begin when sodium homeostasis is breached and elevated sodium levels are being delivered to target organs. Fig. 1 applies a linear regression model to the data of Wickstrom et al. (in prep.) for sparrows sampled one hour post dose, a time interval which corresponds to the appearance of overt intoxication at high doses. The regression of the dose response curve intersects the 95th percentile of the control distribution (167.45 mmol/l) at a projected dose level of 266 mg/kg body weight.

2. The next major uncertainty is the likely rate of intake of salt by a cardueline finch (or similar species) at roadsides where salt is present. Salt crystals could be consumed directly (as are grit particles); alternatively, surfaces could be licked or salty meltwater consumed. For this analysis, we assume that salt crystals are most likely to be picked up whole as are grit particles.

A finch trying to satisfy a salt hunger might pick up a granule of a size that it is 'comfortable' with. The maximum recorded size for grit in the House sparrow is 2.4 mm (Gionfriddo and Best 1995). Such a particle would have a volume of 7.24 mm^3 if spherical and 13.8 mm^3 if cubic. Given a specific gravity of 2.18 g/cc for rock salt (CRC Handbook), a particle of this size would represent 15.8 mg (spherical) or 30.1 mg (cubic) of sodium chloride assuming 100% purity. This allows us to estimate the number of particles that need to be ingested by birds in order to attain specific critical toxicological values (Table 1).

Table 1. Calculation of the number of particles of salt that need to be ingested in order to reach critical toxicological values assuming a model 28g House sparrow consuming particles at the upper end of its known preference range.

Critical toxicological value (CTV)	Rationale	No. 2.4mm diameter sperical salt particles to attain CTV in 28g bird	No. 2.4mm diameter cubic salt particles to attain CTV in 28g bird
266 mg/kg	Breach of homeostasis	0.47	0.25
500 mg/kg	Oedematous lesions in the gizzard	0.88	0.47
1500 mg/kg	Overt signs of toxicity. Mortality first recorded.	2.6	1.4
3000 mg/kg	Approximate median lethal dose	5.2	2.8

This calculation suggests that birds could be sublethally impaired following ingestion of a single salt particle and could be killed by as few as 2 particles.

The average size of grit ingested by the House sparrow was 0.5 mm (Gionfriddo and Best 1995). Assuming birds were intent on picking up salt particles of this 'preferred' size for digestion the above calculations were repeated for average-sized grit. (In fact, this average grit size is likely an underestimate because it is based on 'worn' grit extracted from sparrow gizzards. The average also encompasses very fine mineral particles which are probably inadequate as grit but which are ingested accidentally along with food.) These results are given in table 2.

Table 2. Calculation of the number of particles of salt that need to be ingested in order to reach critical toxicological values assuming a model 28g House sparrow consuming particles of average size.

Critical toxicological value (CTV)	Rationale	No. 0.5 mm diameter salt particles to attain CTV		No. salt particles as proportion of average gizzard grit count (580 particles as in Gionfriddo and Best 1995)	
		Spherical particles	Cubic particles	Spherical particles	Cubic particles
266 mg/kg	Breach of homeostasis	52	27	9.0%	4.7%
500 mg/kg	Oedematous lesions in the gizzard	98	51	17%	8.8%
1500 mg/kg	Overt signs of toxicity. Mortality first recorded	294	154	51%	27%
3000 mg/kg	Approximate median lethal dose	587	307	101%	53%

Although the number of particles that need to be ingested to reach CTVs is much higher than that calculated in table 1, this number of particles can easily be ingested if compared to average grit counts. Therefore, birds in need of replenishing their grit supply may easily achieve doses that would be toxicologically relevant.

4. Conclusions and remaining uncertainties:

1. Our assessment concludes that road salt increases the vulnerability of birds to car strike and may poison some birds directly. It is clear that, even without road salt, some birds would be coming to highways for grit, and possibly clays. The relative contribution of road salt as an attractant is therefore impossible to estimate for songbirds although road salt is thought to be the primary attractant for mammals. In our opinion, what differentiates road salt from, for example, sand which is also used on highways, is the impairment and possible poisoning of exposed birds.

2. Is the House sparrow a suitable toxicological model for cardueline finches? We have not applied any interspecies extrapolation factors in calculating the risk of deleterious effects to native bird species. However, the House sparrow has Middle-Eastern origins. Species in arid environments have a higher tolerance to salt. House sparrows may therefore be genetically predisposed to be more salt tolerant than cardueline finches. On the other hand, consumption rates of grit may be high in House sparrows relative to other bird species (Gionfriddo and Best

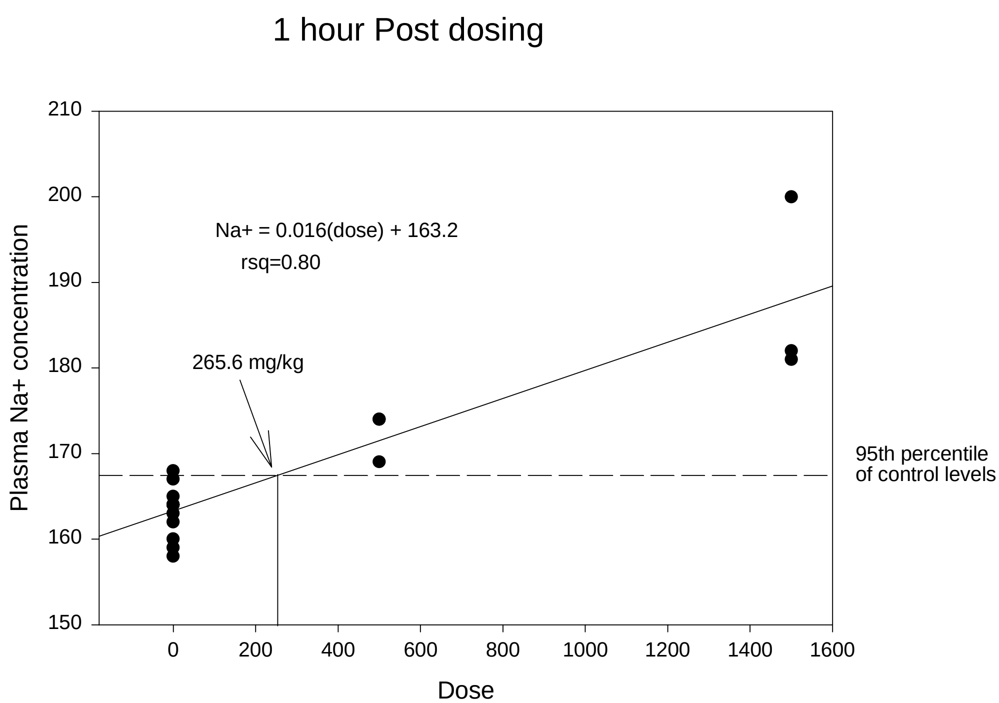
1995). The scenarios we presented above assumed a consumption of salt based on grit need (table 2) as well as on optimizing salt intake (table 1). The likely solution is likely intermediate between those two scenarios. Regardless of the exact particle size taken, salt deprived birds could ingest very large quantities before feedback mechanisms reduce the desire for salt.

3. Will birds at roadside have access to water? It is likely birds will be at higher risk of salt toxicosis when water availability is reduced during severe winters (Trainer and Karstad 1960). Birds have been observed eating snow, catching snowflakes during a storm, and chipping ice to obtain water (Wolfe, 1996). Oeser (1977) reported that crossbills were eating snow in the reported German kill incident. The negative energetic consequences of snow ingestion in response to salt over-consumption need to be assessed. Melted snow on the roads may be the most obtainable source of water. Depending on the concentration of salt, consumption of such water may compound the problem

4. Will kills be frequent? The overlap between the distribution of winter finches and the Canadian road system receiving road salt is extensive (Appendix 2). The data needed to assess kill frequency (whether fatal attraction, toxicosis-induced car strikes or lethal ingestion) is not available. Also, how long is the applied salt retained on or near the road surface (e.g., in the soil) where it could create an artificial "lick" attractive to both birds and mammals even after granules have disappeared?

Despite these remaining uncertainties, we argue that the importance of wildlife kills and the contribution of road salt to this mortality have long been underestimated by wildlife managers and transport officials.

Figure 1: Sodium plasma concentrations in house sparrow, 1 hour post dosing.



Appendix 1: Published incidents involving wildlife and road salt arranged chronologically

DATE/LOCATION	SPECIES	COMMENTS	REFERENCE
1942,Sarnac, NY.	approx 1000 red crossbills and pine siskins	Killed by traffic on road after they settled to consume salt (calcium chloride). Birds were not scared by horns and appeared sick. A second incident was reported to the editor of Auk involving same area, time and species.	Meade, 1942
1958-9 Wisconsin	10 cottontail rabbits, 2 bobwhite quail, 1 ring-necked pheasant, 1 domestic free-ranging pigeon	Wildlife presented for diagnosis on one or more of following conditions: loss of fear, depression, tremors, torticollis, retropulsion, partial paralysis and circulating in one direction. Numerous additional reports also received. Disease ruled out. Gut contents of several animals contained blue-stained ingestia. Road salt (NaCl) in area was stained blue. Diagnosis was toxic encephalitis caused by excessive amounts of road salt.	Trainor and Karstad, 1960
1963, Maine	white-winged crossbills, pine siskins	after a large snowfall, white-crossbills and pine siskins were observed flocking to the middle of roads in bare areas. The birds were oblivious to traffic and decimation was enormous. Although efforts were made to force the birds off the roads, including shouting, whistling, honking of the car horn, and flashing of car lights, nothing was successful. “The local inhabitants for the greater part looked upon this bird slaughter as a natural and everyday occurrence.” The author suggested that chemicals used to melt snow could be involved.	Baker, 1965
February 9-28, 1974, Germany	common crossbills	Common crossbills were observed on a highway in Germany, gathered on building walls, an ashpile or on the “road salt” treated highway. They were attracted to the area because of the abundance of cones in the area. Dead birds were found in areas with highest traffic speed. The birds were observed to “swallow snow and water and pick up grains of salt and other solid materials.” A chemical analysis of the road salt was found to be pure NaCl.	Oeser, 1977
March 1975, Adams County Idaho	red crossbills	Flocks of red crossbill noted along sections of highway. Author noted approx 20 dead at the side of the road. Snow was on the ground but roads were clear. A salt and sand mixture is used by the State to control ice and snow.	Clark, 1981

1975-76, Manitoba	white-winged crossbill	Author observed a white-winged crossbill invasion of southeastern Manitoba between October 1975 and April 1976. Although the focus of the study was on diet and general condition of the birds, specimens for study were obtained from road side kills with reference to Meade 1942 and Baker, 1965, inferring the kills were road salt related.	Sealy et. al., 1980
1979, Juneau County, Wisconsin	red crossbills	birds observed eating minerals from cracks in road, did not get away from car and run over. Author found more birds at same sites on different days. Tried to speculate on why but could not find an obvious reason based on environment in area. Happened in Nov. Week before there had been snow and drizzle. No indication on whether road had been salted, although good probability there was.	Theil 1979
1980, Manning park, BC	1000 evening grosbeaks and 3 pine siskins	Killed while consuming grit and salt on roadway. Submitted for pesticide analysis. No results available.	Wilson et al, 1995
1980, B.C.	1000+ evening grosbeaks and pine siskins	Birds could be approached within 6-8 metres before they took flight. Further inquiries indicated that these kills had been occurring in the area for at least two weeks. The author also stated that he had seen similar large kills involving red crossbills, white-winged crossbills, pine siskins and pine grosbeaks in the same area, occurring in winter, on plowed and sanded roads in sub-alpine forest areas . May refer to same incident as Wilson et al 1995.	Smith, 1981
Mar-May 1989, Larmier and Jackson Counties	red and white-winged crossbills	Birds observed to be attracted to salt and grit along road. Numbers of crossbills dead at side of the road.	Leatherman, 1989
1995, CFB Valcartier, QC.	21 white-winged crossbills	Living birds were reported to be weak and slow. Analysis of one brain was 2.98 mg/g sodium.	Martineau and Lair, 1995
Quebec, date not specified	crossbills and others	In a report of common crossbills observed drinking sea water on Fair Isle, Shetland the editors commented as follows; “Crossbills commonly eat salt, when it has been sprayed on roads in icy weather, and also regularly visit piles of salted grit at roadsides. Some other finches (Fringillidae) that feed on conifer seeds do the same. In Quebec, I have seen many Common and Two-barred Crossbills L. leuoptera dead on roadsides, having been struck by cars when coming down to eat salt.”	Riddiford, 1994

Appendix 2: Spatial analysis of the overlap between winter finch distribution and salt use on the Canadian road network

A qualitative analysis of the spatial overlap between the winter distributions of six species of winter finches and the frequency of salt application on the Canadian road network was done by visual inspection. The species were chosen on the basis of reported kills associated with road salt and their relative importance as nomadic seed eaters which travel in flocks during winter in Canada. These include: the White-winged Crossbill, the Red Crossbill, the Pine Siskin, the Pine Grosbeak and the Evening Grosbeak. The layers of information considered include: (1) the network of two lane highways and associated data on the frequency of application of salt, (2) the winter range of the five species of finches, and (3) the relative abundance of the same five species as measured by the numbers of birds counted during the North American Christmas Bird Count.

Analytical approach

There are four main factors that are influence the choice of the analytical approach:

- Birds are irruptive and nomadic during winter; that is their relative abundance changes spatially within a season and between years.
- Salt is attractive to birds and will draw them to the roads from a distance that is not determined.
- The road network illustrated under-estimates the full network of smaller municipal roads salted during winter; thus the network of salted roads is actually much more complex although its extent probably does not go beyond the edges of the network illustrated in the map.
- The amount of salt applied in one pass is such that salt will not be limiting to birds as it exceeds by far the amounts needed to cause intoxication. Thus what is most relevant to exposure probabilities will be the frequency of application and not the total volume applied.

These three points preclude a formal quantitative approach to quantifying the probability of exposure to the population as a whole. This would require much more information on the movement of birds during winter, the proportion of the population moving through populated regions of Canada, and the actual extent of salt use on the full road network. We can conclude however from these points that part of the populations encountered within the boundaries of the road network is highly likely to encounter roads due to their nomadic habits. Thus if the majority of the birds' winter range is encountered within the boundaries of the road network then we can assume a higher likelihood of exposure to salt then if the winter range encompasses a large area of northern Canada where there are practically no roads.

Source and description of maps

I. Base maps
   A. Political boundaries for Canada:
      Provincial and international borders (Environmental Systems Research Institute Inc. basemap of Canada; 1:7,000,000 scale)

B. Lakes:
Large lakes of Canada (Environmental Systems Research Institute Inc. basemap of Canada; 1:7,000,000 scale)

II. Roads:
Two lane highways of Canada obtained from Commercial Chemicals Branch, Environment Canada. Attributes includes total salt applied per winter by stretch of highway at the municipal level. The latter were combined with the application rate by province to calculate the number of applications per winter for each stretch of two-lane highway. The data were classified into 4 categories using natural breaks in the data.

III. Species ranges:
Winter ranges for the five species were obtained from the project WILDSPACE™ of Ontario Region, Environment Canada. These represent the most current information on the presence of species in Canada during the winter.

IV. Winter relative abundance:
Maps of the relative abundance of the five species in winter were obtained from the US Geological Survey through their web site (http://www.mbr-pwrc.usgs.gov/bbs/) . The maps were copied as images and digitized to provide the outline of the largest and most important areas. These maps are smoothed relative abundance for species observed on Christmas Bird Counts. The CBC is a single day count of birds observed within a 24 km radius of a fixed site. The count occurs on any day within a two-week period around Christmas. The relative abundance (birds/100 party hours) is averaged over the interval 1966- 1989.

All maps were projected to an Albers Equal-Area Conic Projection.

Discussion

Figures 1 to 5 illustrate the overlap between species range, abundance and the frequency of salt applications. The latter layer shows how the most frequent applications occur in southern Ontario and Québec, and Nova Scotia.

Visual inspection of the overlays leads to grouping the five species into three groups based on the patterns observed:

1. <u>Winter range extends well beyond road network</u>
   For the White-Winged Crossbill (Figure 1) and the Pine Grosbeak (Figure 2) the recorded winter range extends far north to the tree line. If birds are distributed uniformly across this range then we could conclude that overlap with roads will occur only in less than half the range and would lead to exposure of less than half the birds. If the birds migrate further south in some years as they track cone seed production then, in these years, the proportion of birds exposed to salt will increase. The areas which show highest relative abundance and the

highest application frequency are Northern Ontario (north of Lake Superior) and the area east and north-east of Georgian Bay.

2. High overlap of road network with winter range but low overlap with areas of highest abundance
   For the Red Crossbill (Figure 3) and the Pine Siskin (Figure 4) la large proportion of the winter range overlaps with the road network indicating a high potential for all birds to be exposed to road salt. The areas of highest relative abundance, however, correspond to areas where the road network appears to be the least dense. Red Crossbills appear in greatest abundance in British Columbia, both on the coast and in the interior were roads are few. The Pine Siskin shows similar pattern but with the areas of highest concentration including the rocky Mountains, eastern Manitoba, northern Ontario and the area east and north-east of Georgian Bay. For this species it appears that the areas of highest abundance and application frequency occur in Ontario.

3. High overlap of road network with winter range and high overlap with areas of highest abundance
   For the Evening Grosbeak (Figure 5) the road network extends across most of its a range, with areas of greatest relative abundance corresponding to areas of highest application frequency. These areas of greatest exposure probabilities correspond to the St-Lawrence and Great Lakes lowlands where the road network reaches its highest density.

Conclusion

This spatial analysis offers a simplistic look at areas where the likelihood of exposure to road salt is the greatest. The analysis indicates that in Canada, for the Evening Grosbeak, and perhaps the Red Crossbill and the Pine Siskin, areas exist where road salt is applied frequently and the birds can be abundant. These areas correspond mostly to southern Ontario and Québec, from the city of Québec to Toronto, and to the region east and north-east of Georgian Bay. This does not imply that the risk is significantly less for the other species since, as noted above, in some years birds will migrate further south in search of food. For instance White-winged crossbills were involved in a third of the incidents reported in Appendix 1. These incidents occurred outside areas of highest relative abundance for this species.

It is important to realise that, where human population density is greatest, the road network illustrated here probably underestimates the spatial extent over which salt is applied. Furthermore traffic volume, not discussed here, may also influence exposure and risk. Areas where traffic volume is lower may have a lower risk since the probability of vehicle strikes is lower. Alternately the risk of lethal poisoning may increase since the birds can now access the salt without the disruption associated with high traffic.

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Figure 1. Winter range of White-winged Crossbill

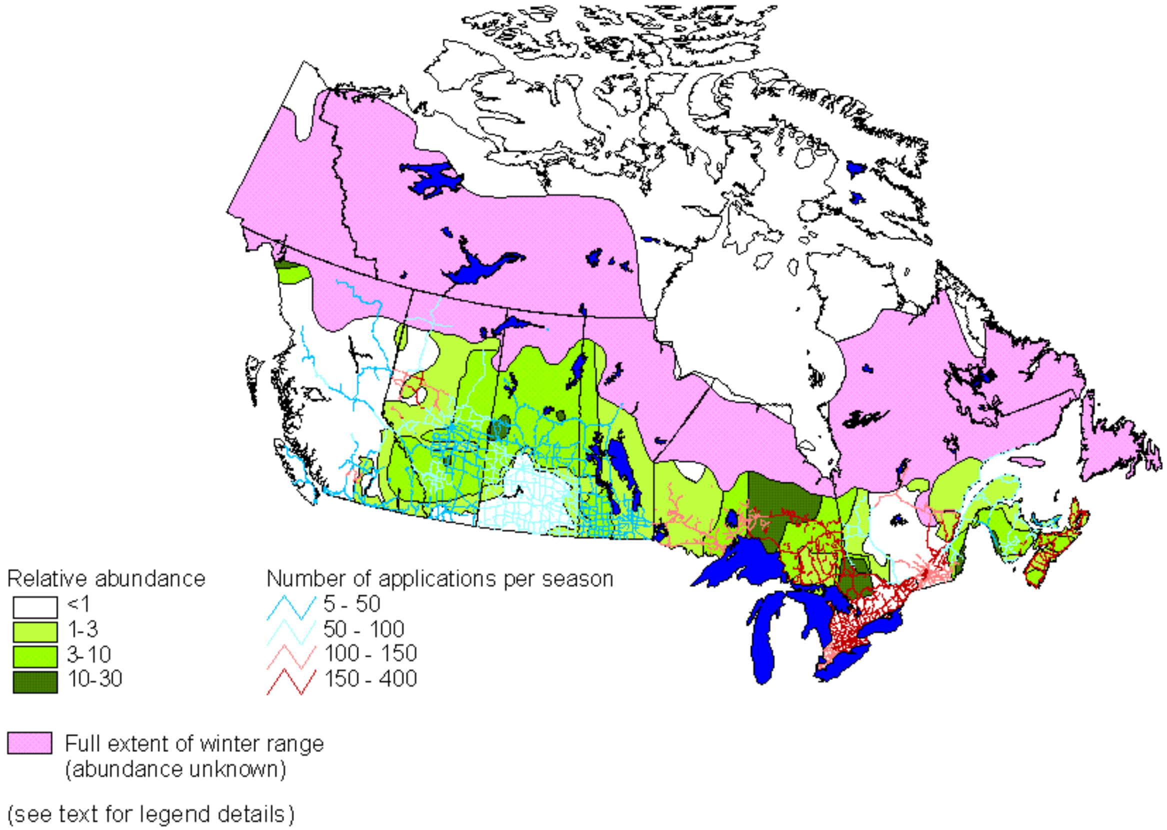


Figure 2. Winter range of Pine Grosbeak

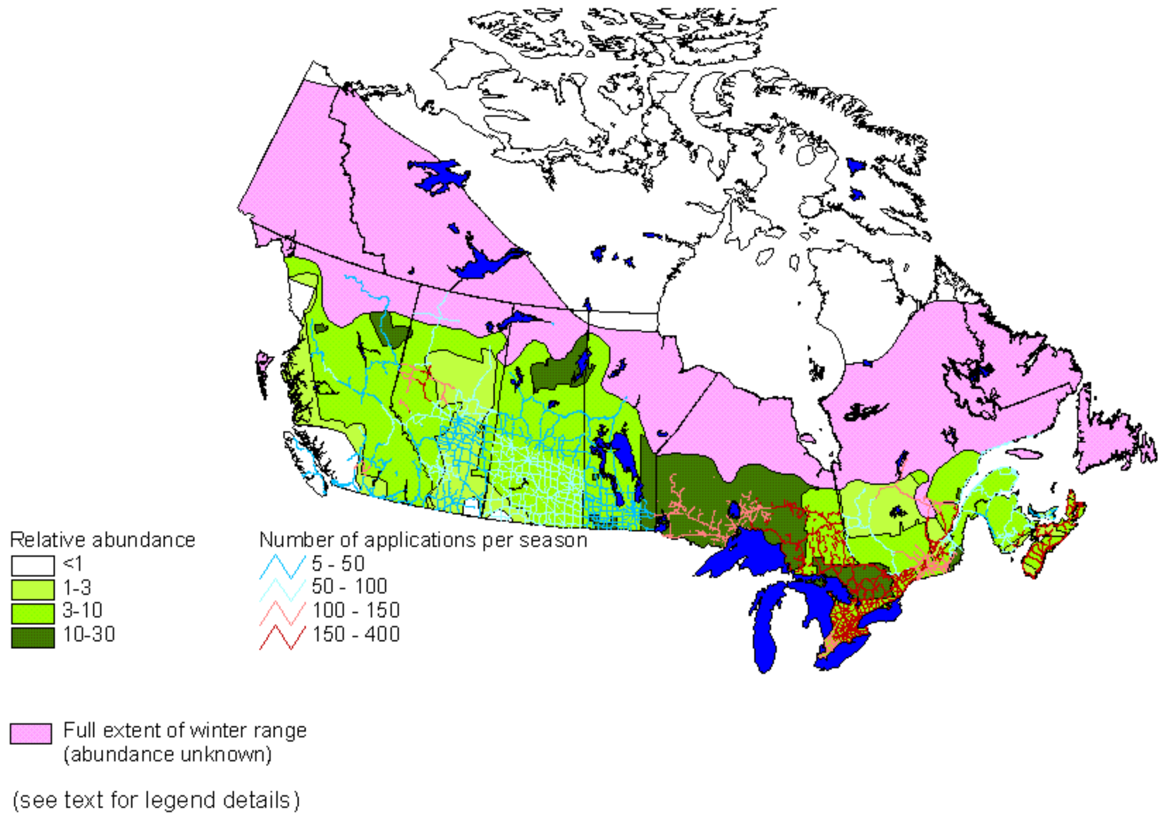


Figure 3. Winter range of Red Crossbill

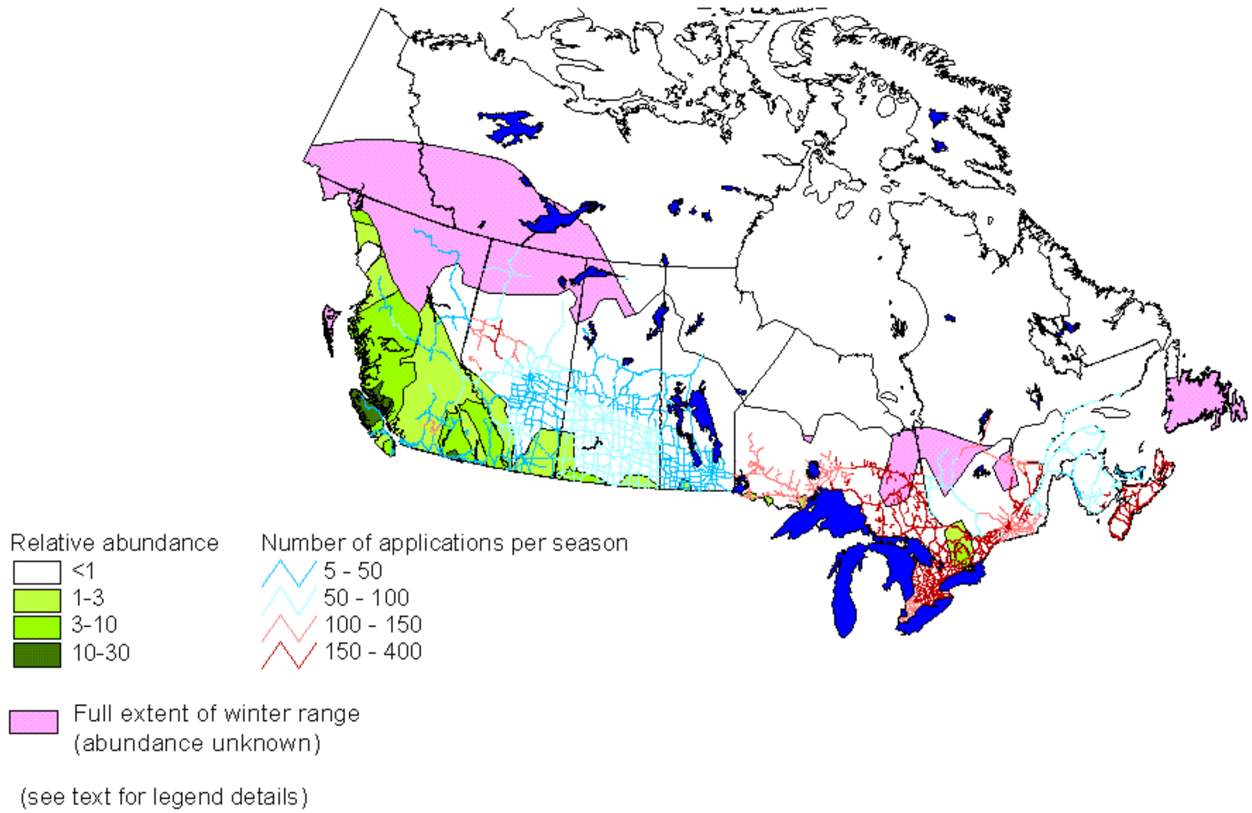


Figure 4. Winter range of Pine Siskin

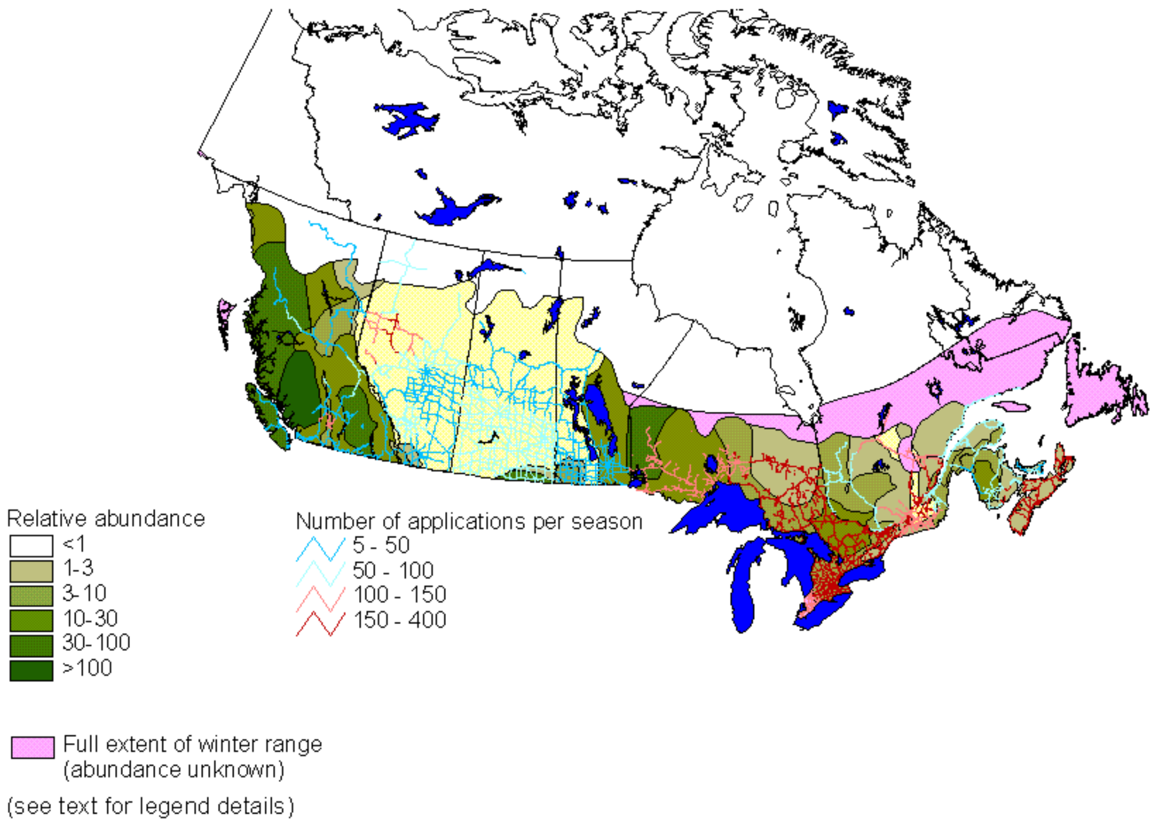
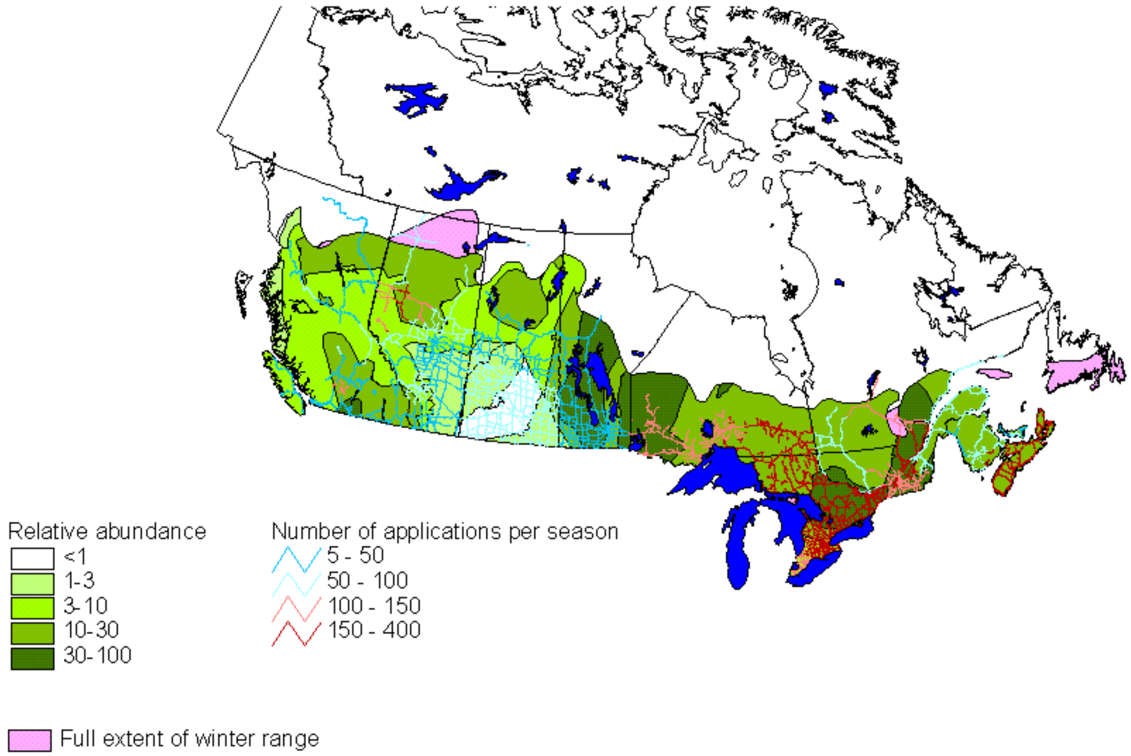


Figure 5. Winter range of Evening Grosbeak



(see text for legend details)