Diet of Canada Lynx in Minnesota Estimated from Scat Analysis

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Summary

~~To~~We estimated winter diet composition of lynx in Minnesota~~, we collected~~ from 87 scats we collected while trailing lynx, from live-traps that were being used to capture lynx for a radiotelemetry study in northeastern Minnesota, and opportunistically while searching for lynx. We separated scats into a confirmed category (DNA analysis, collected from live traps or along trail of radio-collared lynx) and a probable category (no DNA analysis, tracks likely lynx but not certain or not found, scat dimensions and odor) for analysis. Scats were soaked, washed, and then undigested hair and bones from prey items and vegetation were identified. Undigested prey items were identified to species through comparison to a reference collection. We used the point-frame method for estimates of species composition in scats from hairs. Snowshoe hare (*Lepus americanus*) remains were present in 76% of scats. If scats in which only white-tailed deer (*Odocoileus virginianus*) hair was found were eliminated, snowshoe hare remains were found in 97% of scats. We believe most, if not all, deer hair found in lynx scats was from bait used during the radiotelemetry project. Over 80% of the diet of Canada lynx in other parts of the range has been snowshoe hare. We also found evidence of predation or scavenging on other species, including deer, marten, grouse, and other birds. We found one instance of scavenging and possible predation on another lynx. Vegetation was present in trace quantities in many scats and was identified in broad categories of conifer needles, deciduous leaves or grass, and bark, possibly consumed while lynx were eating snowshoe hares they had caught. Scat analysis indicated snowshoe hare are the most important component of Canada lynx diet in northeastern Minnesota in the winter.

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Introduction

Canada lynx (*Lynx canadensis*) range throughout the boreal forest region in Canada and Alaska, with portions of their range extending into the northern United States (DeVos 1964). The distribution of lynx coincides with the distribution of snowshoe hare (*Lepus americanus*) in North America (Aubry et al. 2000). Snowshoe hare is the primary prey of lynx in northern boreal forest regions (Mowat et al. 2000, Koehler 1990, Squires and Ruggiero 2007). Snowshoe hare and Canada lynx populations demonstrate a cyclic predator-prey relationship (Elton and Nicholson 1942). Although lynx feed primarily on snowshoe hare, at low points in the hare population cycle alternate prey species are used (Mowat et al. 2000). About 50% of kills recorded while snowtracking were snowshoe hare during a low in the hare cycle (Apps 2000), compared to up to 100% when snowshoe hare densities were high (Aubry et al. 2000). When body mass was considered, snowshoe hare would have accounted for over 80% of the diet even during a low in the hare population cycle (Murray et al. 2008).

Food habit studies can be based on tracking to predation sites, stomach and intestinal content analysis, and scat analysis. Scat analysis is the method primarily employed for studying carnivore diets (Goodbois et al. 2005). Scat collection can be non-invasive and cost-effective, while analysis of scat contents provides an accurate estimate of dietary habits (Ciucci et al. 1996, 2004). From 60 to 100 scats should be analyzed to detect prey species that comprise at least 5% of the diet (Trites and Joy 2005).

Alternative prey species could be of more importance in southern boreal forests because the density of snowshoe hare is similar to that of northern populations during cyclic lows (Squires and Ruggiero 2007). Small prey species eaten by lynx include red squirrel (*Tamiasciurus hudsonicus*), northern flying squirrel (*Glaucomys sabrinus*), ruffed grouse (*Bonasa umbellus*), marten (*Martes americana,*) and voles (*Microtus pennsylvanica*). Lynx can also kill deer *(Odocoileus* spp.) in deep snow conditions (Fuller 2004, Squires and Ruggerio 2007). Lynx will also scavenge on road-killed ungulates such as white-tailed deer *(O. virginianus*) and mule deer (*O. hemionus*) (Apps 2000, Mowat et. al 2000).

Because lynx are at the southern edge of their range, it is possible prey species other than snowshoe hare could be an important part of lynx diets in northeastern Minnesota. We identified prey remains present in scats to estimate diet composition of lynx in Minnesota. We compared estimates from scats confirmed to be from lynx against scats which may have been from lynx but not confirmed. Finally, we list prey species not detected in scats that we or others have observed in Minnesota while tracking lynx or through incidental observations.

Methods

We collected scats as part of a lynx radiotelemetry project in northeastern Minnesota (Moen et al 2004, 2004, 2006). Lynx scats were collected from 2 January 2003 to 3 June 2007 and stored in paper bags or in desiccant at room temperature until analysis. We recorded length, maximum diameter, and air-dry mass for each dried scat. Scats were placed in a glass jar filled with water and soaked for 24 – 72 hours at 4^{o} C. To separate larger particles of undigested material, we washed scats through a Tyler standard screen scale with 0.589 mm mesh openings (W.S. Tyler Co., Cleveland, OH). After washing we placed the remaining material on a sheet of paper to air dry for ≥ 24 hours. We removed and weighed bones and bone fragments from the remaining scat contents.

We used point sampling to identify hair types present in each scat (Ciucci et al 2004). The closest hairs to 10 random points on a 6 mm by 6 mm grid were identified by comparison to a reference collection assembled from the UMD Department of Biology's mammalogy teaching collection. Unidentified hairs were labeled as unknown. We examined bones under a dissecting microscope if necessary and identified larger bones or bone fragments to species by comparison to the reference collection. Snowshoe hare bones were identified as teeth, ribs, claws, joints, vertebrae, or skull bone when possible. We also recorded if bone fragments too small to identify were present in the scat. We recorded if vegetation, gravel, feathers, or other bird remains were present in each scat.

We confirmed some scats were from lynx though DNA analysis by the Carnivore Genetics Laboratory, part of the Rocky Mountain Research Station's Wildlife Ecology unit located in Missoula, Montana (Mills et al. 2000, Schwartz et al. 2004). Scats were also identified as confirmed if we collected the scat from a live-trap in which a lynx was captured, or if we collected the scat from the trail of a radiocollared lynx (Burdett 2007). Scats that we identified as probable were collected while trailing unknown lynx or picked up opportunistically while searching for lynx on other parts of the radiotelemetry project, but were not confirmed by DNA analysis or physical evidence.

We used Statistix 9.0 for statistical analyses with $\alpha = 0.05$. We tested whether mass or composition of confirmed and probable scats differed with a *t*-test. We also tested whether snowshoe hare bone types found in confirmed and probable scats differed with a *t*-test. Values are presented as means ± SD. The animal handling protocol for the radiotelemetry project was approved by the Institutional Animal Care and Use Committee at the University of Minnesota (Codes 0301A39326 and 0602A81086).

Results

Scats were collected mainly from the central area of lynx locations in northeastern Minnesota (Fig. 1). We collected and analyzed 87 scats for this report. There was no difference in mass, length, or diameter between confirmed and probable lynx scats (Table 1). Mean mass was ~~higher~~ lower and mean length was ~~longer~~ shorter for confirmed scats, probably because a portion of these scats ~~was~~ had been sent in for analysis. Hair presence (% by mass) did not differ between confirmed and probable lynx scats, but there was more bone in probable lynx scats than in confirmed lynx scats. The increased bone content was snowshoe hare bones; there were no identifiable bones from other species in the probable lynx scats. We did find red-backed vole bones in a scat that was later identified as canid and excluded from analysis.

Table 1. Physical characteristics of lynx scats and results of unpaired t-tests testing for differences between confirmed and probable lynx scats. Confirmed scats are based on DNA analysis or physical evidence. Probable scats are believed to be from lynx but not confirmed. In all cases $n \geq 29$. Mass is air-dried mass, and percent hair and bone were calculated from air-dried mass.

	Confirmed	Probable	t	P	df
Mass (g)	7.7 ± 1.3	10.2 ± 1.13	1.41	0.16	68
Length (g)	12.2 ± 1.7	15.1 ± 1.2	1.47	0.15	68
Diameter (g)	1.9 ± 0.1	1.9 ± 0.0	-0.15	0.88	50
Hair (%)	49.2 ± 3.9	38.6 ± 4.2	-1.80	0.08	68
Bone (%)	0.9 ± 0.2	2.0 ± 0.4	2.65	0.01	44

Figure 1. Locations where lynx scats analyzed for prey species composition were collected in northeastern Minnesota. Green dots represent locations of Canada lynx from the telemetry study (Moen et al. 2006, Burdett et al. 2007).

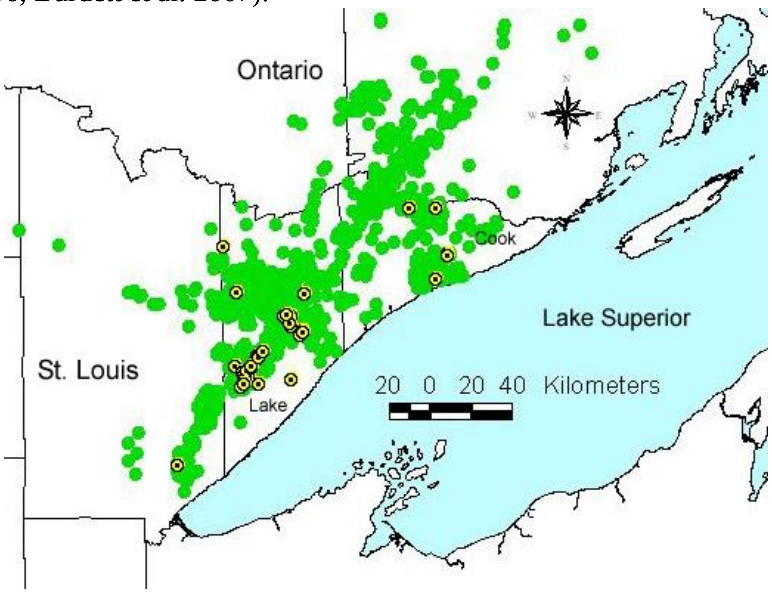
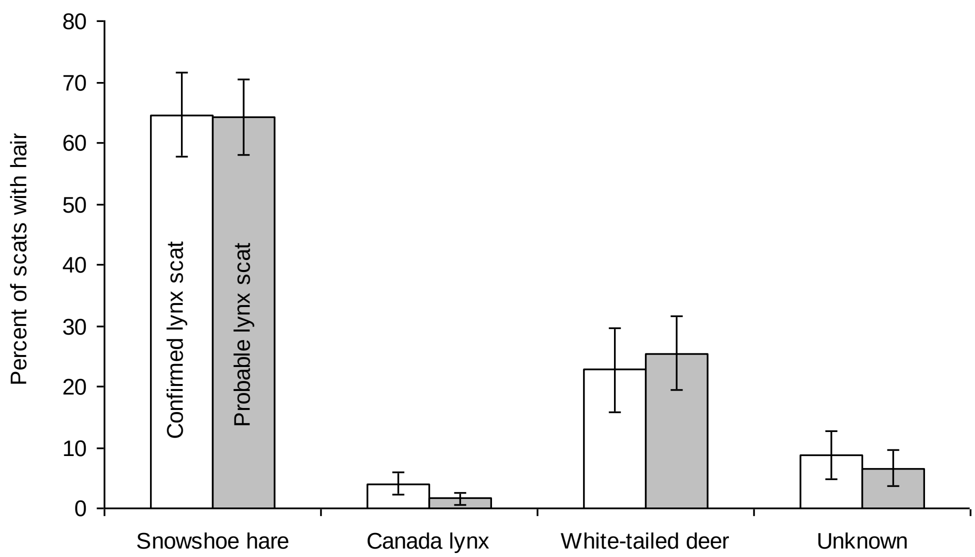


Figure 2. Point-frame sampling of hairs found in lynx scats collected in northeastern Minnesota from 2003-2007. White-tailed deer hair was likely consumed at bait sites that were being used for live-trapping lynx for the radiotelemetry project.



Point frame analysis indicated that hair from snowshoe hare was the largest component (Figs. 2, 3), whether hair from white-tailed deer was included or not. Hair from white-tailed deer was probably ingested while feeding on baits used to capture lynx in the box traps for the radiotelemetry project. There was no difference in percentage of snowshoe hare hair in scats between confirmed and probable scats for lynx (with deer hair: t_{85} = -0.04, P = 0.97, without deer hair: t_{65} = 0.37, P = 0.72). There was also no difference in the percentage of lynx hair in scats between confirmed and probable scats (with deer hair: t_{56} = -1.24, P = 0.22, without deer hair: t_{44} = -1.22, P = 0.22). Unknown hairs were dark bristles about 7 cm long, and thicker than deer hair (Fig. 4).

Figure 3. Point-frame sampling of hairs found in lynx scats collected in northeastern Minnesota from 2003-2007. White-tailed deer hair is not included in this figure because it was likely consumed at bait sites that were being used for live-trapping lynx for the radiotelemetry project.

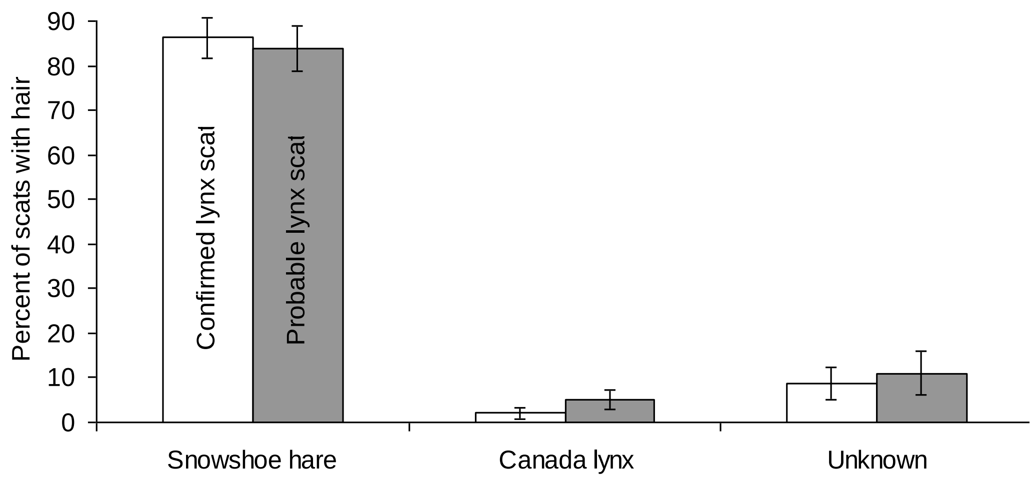
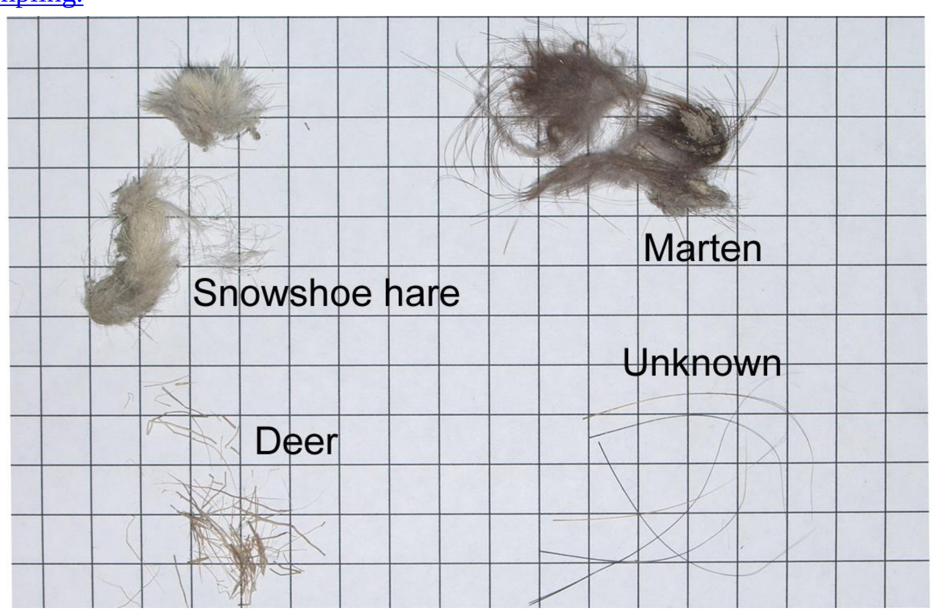


Figure 4. Pictures of hairs found in lynx scats and identified as snowshoe hare, American marten, and deer. Pictures of unknown hairs are in the lower right. Background squares are 1 cm. Deer hair has undergone physical or chemical decomposition. Marten hare was not picked up in point-frame sampling.



We found bones or bone fragments from throughout a snowshoe hare skeleton in scats (Fig. 5). Teeth and leg bones were most common, with a larger percentage of both in the probable lynx scat category (Fig. 6).

Figure 5. Pictures of snowshoe hare bones found in Canada lynx scats collected in northeastern Minnesota from 2003-2007. Background squares are 1 cm.

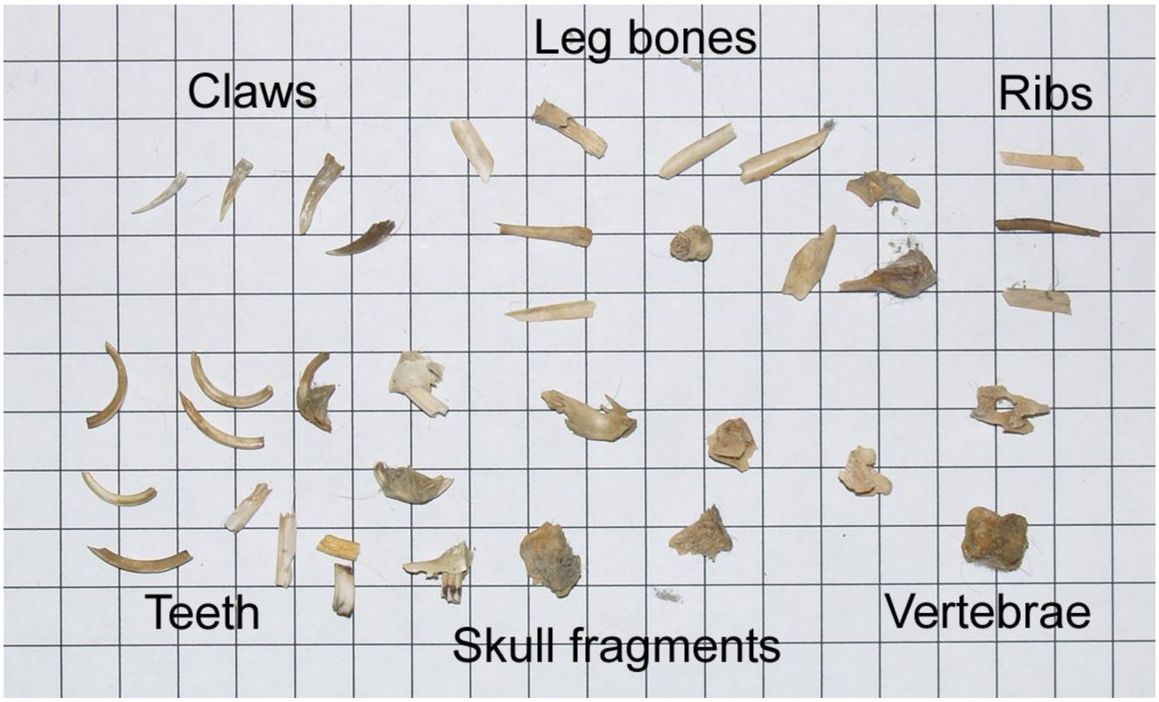


Figure 6. Bones from different parts of the skeleton found in Canada lynx scats collected in northeastern Minnesota from 2003-2007.

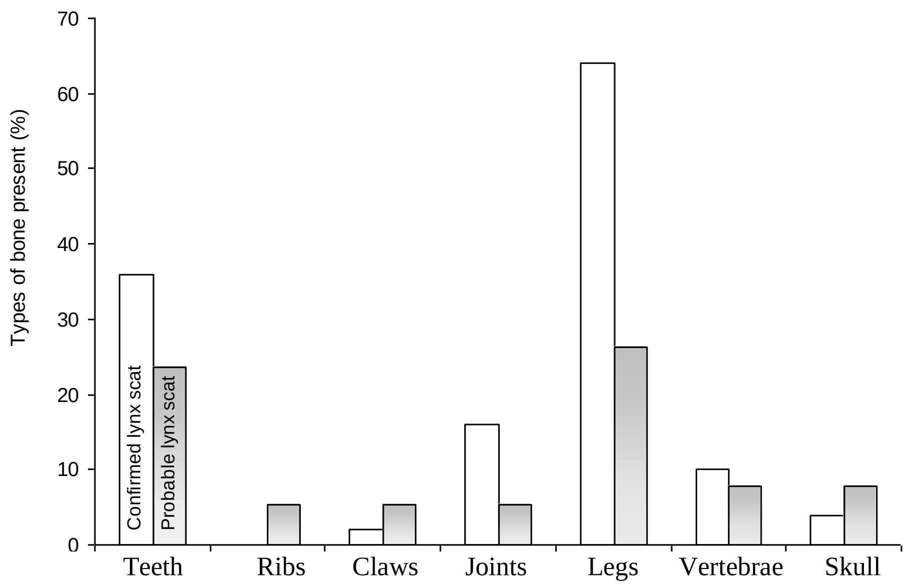
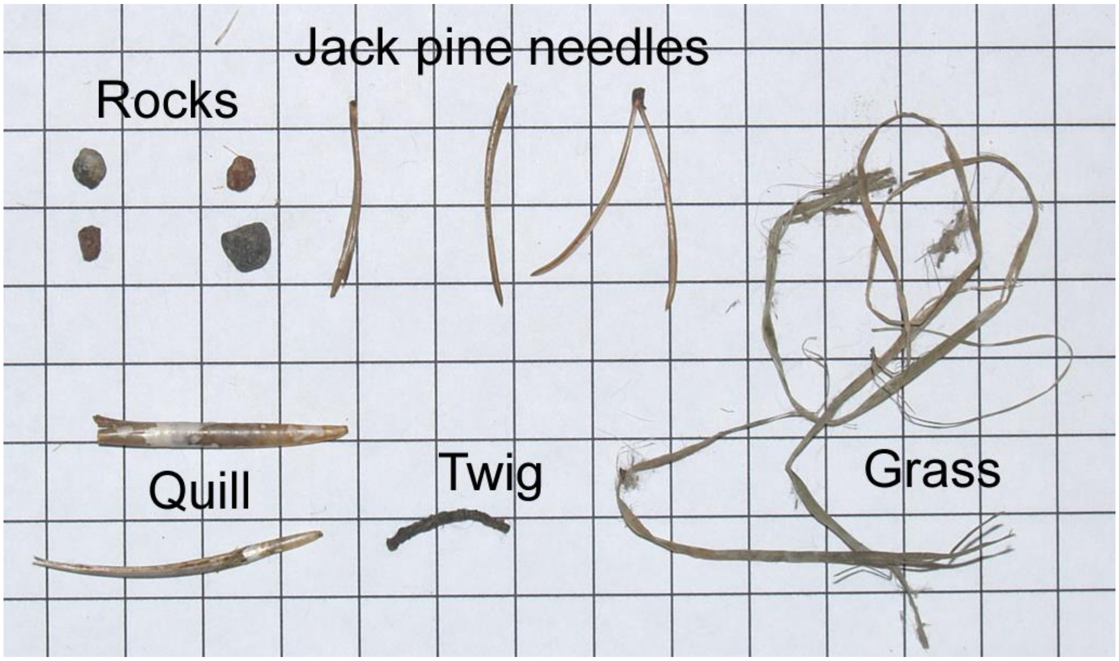
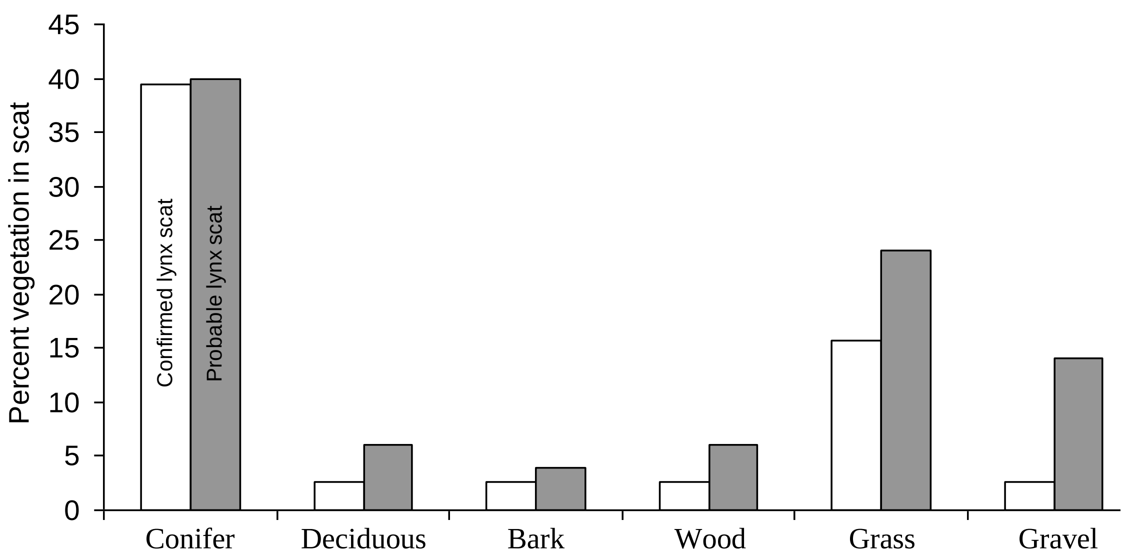


Figure 7. Picture of vegetation and other materials in lynx scats.



We found trace amounts of vegetation in 54% of scats collected (Fig. 7), split about equally between confirmed and probable lynx scats (Fig. 8). Vegetation was found even though most scats were collected in the winter months when snow was on the ground. The presence of rocks was most surprising.

Figure 8. Percentage of different vegetation types found in confirmed and probable lynx scats.



Although alternate prey sources were not found in lynx scats other than hair from a marten and some quills from feathers, lynx predation on several additional prey species in northeastern Minnesota was documented during the radiotelemetry project (Table 2). As in previous studies of Canada lynx, alternative prey species are used much less than snowshoe hare, whether on the basis of number of kills or prey biomass.

Table 2. Observations of predation events on non-typical prey species by Canada lynx in northeastern Minnesota.

Common name	Latin name	Notes
Blue jay	*Cyanocitta cristata*	Predation near a bait site for Canada lynx, with only lynx tracks in area. Observed by R. Moen, March 2008.
Ruffed grouse	*Bonasa umbellus*	One out of 26 documented predation events while snow-tracking (Burdett 2008)
Spruce grouse	*Dendrapagas canadensis*	One out of 26 documented predation events while snow-tracking (Burdett 2008)
Various songbirds	--	Predation attempts on passerines reported to the lynx project website, in one case when a lynx waited near a bird feeder for birds to appear. R. Moen, Unpublished.
Marten	*Martes americana*	Killed 2 m from a bait site for Canada lynx, but not consumed. Only lynx tracks in area. Observed by R. Moen, March 2008.
Flying squirrel	*Glaucomys sabrinus*	Evidence for predation found while trailing lynx. Observed by Dave Grosshuech and Tim Catton, USFS, March 6 2008.
Red-backed vole	*Clethrionomys gapperi*	Found along lynx trail, track evidence indicated lynx moved vole. Observed by R. Moen, January 2004.
Deer	*Odocoileus virginianus*	Roadkills eaten in winter 2004 and reported to Minnesota Canada lynx project. Pictures on lynx website (www.nrri.umn.edu/lynx). Trailing indicated predation on up to 4 deer in deep snow near Isabella, MN in April 2005 (Chris Burdett, Pers. Comm.). Lynx feeding on carcass was L06, a male. Deer hunters reported a lynx consuming part of a gut pile removed from a harvested deer in Fall 2006 (R. Moen, pers. obs.).

Discussion

Snowshoe hare is the most abundant component of the winter diet of Canada lynx in northeastern Minnesota based on scat composition, consistent with diet composition of lynx in other parts of North America (Apps 2000, Mowat et al. 2000, Squires and Ruggiero 2007). Snowshoe hare ~~were~~ also comprised 92% of predation events ~~the most important prey species~~ from predation sites found while snow-tracking in Minnesota~~; 92% of predation events were snowshoe hare~~ (Burdett 2008). Even though snowshoe hare density in Minnesota is similar to density at low parts of the cycle in northern hare populations (McCann 2007), the importance of alternative prey species in lynx diet has not increased relative to what has occurred in other lynx populations (Aubry 2000). Stable isotope content of lynx, snowshoe hare, and red squirrel hair indicated that snowshoe hare may represent only 63% of lynx diets in Minnesota (Roth et al. 2007), but these samples were from museum specimens which may not have been collected concurrently from the same geographic area.

Lynx killed and consumed or cached other prey species in Minnesota at low frequencies. We found the foot of a grouse species and feathers in one lynx scat, and snow-tracking documented predation on 1 ruffed grouse (*Bonasa umbellus*) and 1 spruce grouse (*Dendragapus canadensis*) in 26 predation events over >78 km of snow trails (Burdett 2008). This predation rate on grouse is similar to the predation rate on spruce grouse in Alaska, 1 of 22 predation events (Kesterson 1988). In the Alaska study, snowshoe hare remains were found in every scat collected. Studies in other southern boreal forest regions have found alternative prey species such as red squirrel (*Tamiascurius hudsoniscus*) and northern flying squirrel (*Glaucomys sabrinus*) included in the diet occasionally (Apps 2000, Squires and Ruggiero 2007). The rarity with which we found evidence for lynx killing other prey species with snow-tracking or scat analysis indicates that alternative prey would not be a significant component of Minnesota lynx diets in winter.

Canada lynx can kill ungulates, but this seems to occur at snow depths more than 0.5 m when prey mobility would be reduced, whether the prey is white-tailed deer, mule deer (*Odocoileus hemionus*), dall sheep (*Ovis dalli*), or caribou (*Rangifer tarandus*) (Fuller 2004, Mowat and Slough 1998, Stephenson et al 1991, Squires and Ruggiero 2007). Eurasian lynx

(*Lynx lynx*) diets are higher in larger prey, in part because Eurasian lynx are much larger than Canada lynx (Tumlison 1987). Roe deer (*Capreolus capreoulus*), reindeer (*R. tarandus*), and domestic sheep represented 81% of the diet of Eurasian lynx in Norway (Sunde et al 2000). Even though we found white-tailed deer hair in many lynx scats we believe most if not all of the deer hair can be attributed to bait from the radiotelemetry project because scats usually were collected from known individuals and none of these scats were associated with the possible predation events on deer documented by Chris Burdett (pers. comm.).

Presence of small amounts of vegetation in lynx scats that we found has not been previously reported to our knowledge. Because vegetation was present in confirmed and probable lynx scats in similar proportions, it is not an artifact of data collection or handling. We analyzed scats deposited during the winter months when snow was on the ground, so needles and leaves would not have attached to scat after defecation. It is possible that the trace amount of vegetation present in hare stomachs was ingested inadvertently by lynx.

We have not collected lynx scats that were deposited in the summer, so we are able to say little about lynx diet during months when snow is not on the ground. The literature indicates from scat analysis that reliance on snowshoe hare is reduced during the summer (Mowat 2000, Aubry et al. 2000). However, most reports indicate snowshoe hare still comprise 40 to 60% of prey items in summer and, as with winter months, there have been reports of predation on many prey species including ducks, ground squirrels, songbirds, and carrion.

We found that lynx diet in the winter months in northeastern Minnesota was predominantly snowshoe hare, consistent with Canada lynx diets throughout North America. Diet analysis, and the techniques used in the radiotelemetry trapping program, indicate that lynx are opportunistic and will also scavenge on food items such as road-kills if available. There is still little information available on lynx diets in summer months. Stable isotope analysis (Roth et al. 2007) may be the only solution for estimating diet in summer months.

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