Canada Lynx in the Great Lakes Region

2008 Report to Minnesota Department of Natural Resources

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Changes do not affect conclusions originally presented in Release 1.0

Summary

2008 was a year of transition for the Canada lynx project in Minnesota. It is the end of the 6th year of the project, and radiocollared lynx have been present in Minnesota for the entire project. Other than the study by Dr. L.D. Mech in the early 1970's in which 14 lynx were radiocollared and monitored for up to a year, this project remains the only radiotelemetry project on Canada lynx in the central portion of their range in North America. In part because Canada lynx were listed as a Threatened species under the Endangered Species Act, we also know more about Canada lynx in Maine, Montana, and Wyoming than was ever known before because of radiotelemetry projects in those states. Results from all of these studies are appearing in the peer-reviewed literature.

The project in Minnesota began when GPS collars became available that were light enough to be worn by lynx. We obtained over 15,000 locations of Canada lynx, and have technical reports, peer-reviewed papers, and annual reports both published and in preparation. We review these new papers and provide an update on the status of Canada lynx in Minnesota based on interpretation of historical records and data collected during this radiotelemetry project. Information contained in this update could be useful to MN DNR personnel currently deciding whether the status of lynx in Minnesota should be changed to endangered, threatened, or a species of special concern.

We will continue to monitor radiocollared lynx, and place new radiocollars on lynx with available funding. We had three animals radiocollared at the start of 2008 in Minnesota and by the end of 2008 only two male lynx in Minnesota had functioning transmitters. We could not locate the last transmitting radiocollared female in Minnesota (L31) after April 2008. There were two additional radiocollared lynx (one male and one female) with transmitting collars located in Ontario in May 2008.

We continued to count snowshoe hare pellets in spring 2008. Pellet counts showed continued presence of snowshoe hare at densities adequate to support lynx. The highest snowshoe hare densities are found in cover types that have a conifer component or have a brushy layer at the ground surface. These same cover types (Regenerating Forest, Upland Conifer, and Shrubby Grassland) are also selected by Canada lynx during daily movements within their home range.

Since 2003 the project has been supported by several agencies with common deliverables and with some deliverables that varied with agency. The report covers the lynx project in its entirety and we indicate specific deliverables in Appendix 2. We continue to use the project website (www.nrri.umn.edu/lynx) to provide information to biologists and the general public. This website is a historical record of the project, lists project goals and accomplishments, and is a source of publications available for download.

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Introduction

The Canada lynx (*Lynx canadensis*) is a 15 to 30 pound (7 to 12 kg) cat found in the boreal forests of Canada and the northern United States. Lynx populations in Canada increase and decrease with populations of the snowshoe hare (*Lepus americanus*) over an approximate 10-year period (Elton & Nicholson, 1942; Keith, 1978; Krebs *et al.*, 2001). Throughout this predator-prey cycle lynx populations lag 1-2 years behind hare populations (Brand *et al.*, 1976; O'Donoghue *et al.*, 1997; Poole, 1994; Slough & Mowat, 1996). Snowshoe hare densities in Minnesota are higher than the lowest hare densities in Canada, but are only about 10% of peak hare density in northern Canada (Moen *et al.*, 2008b).

Lynx occur at a density of < 3 / 100 km^2 during periods of hare scarcity in northern Canada and at densities > 30 / 100 km^2 during peak hare years (Poole, 1994; Slough & Mowat, 1996). For comparison, density of wolves is about 4 / 100 km^2 (Erb, 2008), and density of bobcats is about 4 / 100 km^2 in Minnesota bobcat range. If we assume that all of Cook, Lake, and St. Louis counties in northeastern Minnesota is suitable habitat, a density of 3 lynx / 100 km^2 would correspond to about 760 lynx (Moen *et al.*, 2008b). Much of Cook, Lake, and St. Louis counties is not suitable habitat, however, because of human development, lack of conifer understory, lakes, and because lynx are approaching the southern edge of their range. Approximately 25% of northeastern Minnesota contains areas of predicted higher quality hare habitat (McCann, 2006; McCann & Moen *in prep.*) that also roughly corresponds to area classified as better lynx denning habitat (Moen *et al.*, 2008a). A population of about 200 lynx could be supported at a density of < 3 / 100 km^2 if 25% of northeastern Minnesota is suitable habitat.

Minnesota is at the southern edge of Canada lynx range (McKelvey *et al.*, 2000). Declines in the snowshoe hare population have historically been followed by “invasions” of the U.S. by Canada lynx from the north (Adams, 1963; Mech, 1973). There is a record of harvest of lynx in Minnesota from 1929 to 1976 (Henderson, 1978). The harvest in Minnesota is correlated with harvest in Ontario and other provinces of Canada, although harvest peaks in Minnesota about 3 years after harvest peaks in Canada (McKelvey *et al.*, 2000). The increase in harvest during “invasion” years was too big to arise from what the MN DNR considered a small “population” of lynx in northeastern Minnesota (Henderson, 1978).

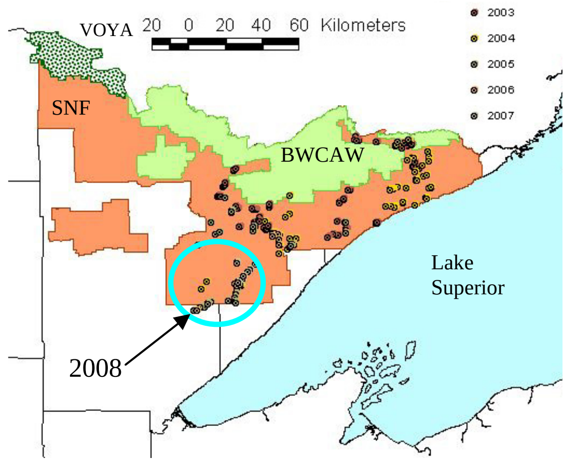
From an ecological perspective, many boreal species have the southern edge of their range in or near northeastern Minnesota. Forests in northeastern Minnesota are composed of aspen (*Populus tremuloides*), birch (*Betula papyrifera*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*). Other tree species include black spruce (*P. mariana*), white pine (*Pinus strobus*), red pine (*P. resinosa*), and jack pine (*P. banksiana*). Some mammals that have the southern edge of their range in or near northeastern Minnesota include the snowshoe hare, moose (*Alces alces*), and American marten (*Martes americana*). Bird species at the southern edge of their range include the Common Raven (*Corvus corax*), Gray Jay (*Perisoreus canadensis*), Northern Goshawk (*Accipiter gentilis*), Boreal Owl (*Aegolius funereus*), and Boreal Chickadee (*Poecile hudsonica*).

Should Canada lynx also be a part of this ecological assemblage in northeastern Minnesota? This question can be tested with historical records, GPS and VHF radiotelemetry data collected in this research project, and other information such as sightings and reported mortalities. The question is timely because a decision will be made in the next year on whether Canada lynx should be considered a species of special concern, a threatened species, or an endangered species in the state of Minnesota. The final report of the first phase of this project (Moen *et al.*, 2008b) provides background information on distribution, habitat use and requirements, abundance, prey availability, and monitoring the long-term persistence of lynx in Minnesota. This biological data was not available when the FWS made listing recommendations in the 1990's, and also was not available when the MN DNR commented on listing Canada lynx as a Threatened species under the federal Endangered Species Act. We begin with a description of radiocollaring effort, monitoring, and data analysis that has been part of previous annual reports. We end this report with a synthesis of information on Canada lynx that could be useful to the state listing process.

Radiocollaring Canada Lynx in Minnesota

Trapping and handling methods draw from protocols that have been used on the Maine and Montana lynx research projects (Vashon *et al.*, 2008; Squires *et al.*, 2008; Squires *et al.*, 2008). On the Minnesota lynx project we have used these techniques in 63 captures (Moen *et al.*, 2005; Moen *et al.*, 2006; Moen *et al.*, 2008b). Traps were only placed in the southwestern part of the study area in 2008 (Fig. 1).

Figure 1. Locations of Canada lynx traps in and near Superior National Forest in 2003 to 2008, with the extent of 2008 trap locations circled. Brown areas indicate Superior National Forest (SNF), and green areas are the Boundary Waters Canoe Area Wilderness (BWCAW). Voyageurs National Park is shown as stippled green area. We did not trap in the BWCAW even though at this map resolution it appears that a trap was placed in the BWCAW.



We had 5 lynx wearing transmitting radiocollars in 2008 (Table 1). We had low trapping effort due to reduced funding and due to less presence of lynx sign in areas where we have traditionally found lynx. We did not place radiocollars on any new animals in 2008, nor did we replace collars of previously collared lynx. We recaptured 2 radiocollared lynx during trapping when we were trying to capture offspring of L31 that were born in May 2007 (Moen *et al.*, 2008b) and other unknown animals. We released each radiocollared lynx because their collars would last at least another year according to collar specifications and collars did not show antenna damage. In spring 2009 we replaced the collar on L28 and placed new collars on a male yearling and a female kitten.

Table 1. A brief description of Canada lynx with transmitting radiocollars in 2008. Each lynx is referred to in the report by the ID indicated here. Numeric designations are not sequential. Additional details on each animal are on the project web site (www.nrri.umn.edu/lynx).

ID	Capture	Sex	Status
L28	3/1/05	M	Captured near Isabella, MN. Has worn both VHF and GPS.
L31	3/10/05	F	Captured north of the Sullivan Lake area. Has worn both VHF and GPS.
L32	3/11/05	F	Captured along the Gunflint Trail, fitted with a VHF collar. Last heard in Ontario.
L33	3/19/05	M	Captured west of Babbitt, MN and fitted with a VHF collar. Last heard in Ontario.
L43	3/13/06	M	Captured in the Sullivan Lake area, VHF collar. Eartagged as a kitten, L43 is a son of L07.

Survival and Mortality

There were no confirmed deaths of the 5 radiocollared lynx in 2008 and 1 death in 2009 (Table 1). Causes of death of lynx during this project were varied, with 13 of 17 deaths probably related to humans (Table 2). L43 was monitored for almost 4 years because he was eartagged as a kitten in May 2005, radiocollared in March of 2006, and then died in March 2009. L28 is a male who has been radiocollared for over 4 years.

Table 2. Current status of all radiocollared lynx in this project. If status is unknown it is because the collar stopped transmitting, the animal moved out of range, or was otherwise lost. Some animals were last located in Ontario and status can only be determined infrequently. Comments column gives a brief description of cause of death or other information. The LastLoc column indicates when the lynx was last located if status is alive or unknown. This table is an updated version of a table that appeared in the Final Report for phase 1 of this research project (Moen *et al.*, 2008b). In the 2008 and 2009 report we have added the column indicating known (Y) or probably human-caused (PH) mortality. "Natural Mortality" was changed to "Probable Natural Mortality" (i.e., N to PN) in version 1.1 of the 2008 report. After discussion between R. Moen and Ed Lindquist we do not "know" that a "Natural" mortality occurred because, for example, we haven't witnessed a predation event. Although "Probable Natural" may be preferred, general conclusions in text do not change.

Status	ID	Sex	Collar	LastLoc	DeathDate	Days	Human	Comments
Dead	1	M	03/14/03		11/26/03	257	Y	Trap, ON
Dead	2	M	03/14/03		04/20/05	768	Y	Car kill, MN
Dead	3	F	08/28/03		10/20/03	53	PH	Unknown, collar cut, MN
Dead	8	F	01/09/04		09/30/05	630	PN	Non-human caused, ON
Dead	9	F	01/09/04		10/22/04	287	Y	Incidental Trap, MN
Dead	10	M	01/13/04		06/01/05	505	PH	Unknown, near road, MN
Dead	11	F	02/12/04		11/13/06	1005	Y	Trap, Manitouwadge, ON
Dead	16	F	11/29/04		04/28/05	357	Y	Train, MN
Dead	19	F	03/01/05		11/02/05	545	Y	Shot, MN
Dead	20	F	04/03/05		07/15/05	435	PH	Unknown, near cabin, MN
Dead	23	M[a]			12/28/05		Y	Incidental Trap, MN
Dead	24	F	10/02/04		01/29/05	119	PN	Non-human caused, MN [b]
Dead	26	F	01/08/05		1/10/06	367	Y	Trap, ON
Dead	27	F	02/19/05		11/01/05 [c]	255	PH	Unknown, near road, MN
Dead	34	M	03/23/05		11/01/05	223	PH	Unknown, collar cut, ON
Dead	49	F	12/18/05		03/17/06	89	PN	Non-human caused, MN
Dead	43	M	03/13/06		03/03/09	1086	PN	Only collar found, MN
Alive	28	M	03/01/05	04/15/09		1505		
Alive	57	F	03/19/09	04/15/09		27		Just collared
Alive	58	M	04/06/09	04/15/09		10		Just collared
Unknown	32	F	03/11/05	04/30/08		1146		Last location in ON
Unknown	33	M	03/19/05	04/30/08		1138		Last location in ON
Unknown	31	F	03/10/05	04/30/08		1147		Last location Sullivan Lake, MN
Unknown	4	M	09/14/03	03/18/04		186		Last location near ON/MN border
Unknown	5	M	09/23/03	07/11/06		1022		Last location in ON
Unknown	6	M	12/09/03	08/23/05		623		Last location near Isabella, MN
Unknown	7	F	12/10/03	08/16/06		980		Last location in ON
Unknown	12	M	02/24/04	01/31/07		1072		Last location in ON
Unknown	13	F	03/25/04	08/24/05		517		Last location south of Toimi, MN
Unknown	14	F	03/29/04	06/02/05		430		Last location near Isabella, MN
Unknown	15	M	03/31/04	02/24/05		330		Last location in ON
Unknown	17	F	03/08/05	08/01/06		817		Last location Sullivan Lake, MN
Unknown	30	F	03/09/05	09/21/05		196		Last location in ON
Unknown	35	M	04/09/05	04/01/07		722		Last location near Isabella, MN
Unknown	36	M	04/02/05	01/31/07		669		Last location near Isabella, MN

[a] Not radiocollared, ear-tagged at den. Called L21 at least once previously but correct ID is L23
[b] Appeared to be non-human caused from evidence at site but cannot be certain
[c] Estimated date based on collar condition and location but cannot be certain

Location and Distribution

Locations and sightings in 2008 did not extend the range of lynx in Minnesota. Estimated lynx range in the 1970's included much of the area that was identified as quality lynx habitat (Fig. 2). We have not extensively searched parts of Koochiching, Lake of the Woods, and Beltrami counties identified as lynx range in 1977 (Fig. 2), thus we do not know if lynx are now present in the westward extension. There have been occasional sightings and reports of varying quality from these counties.

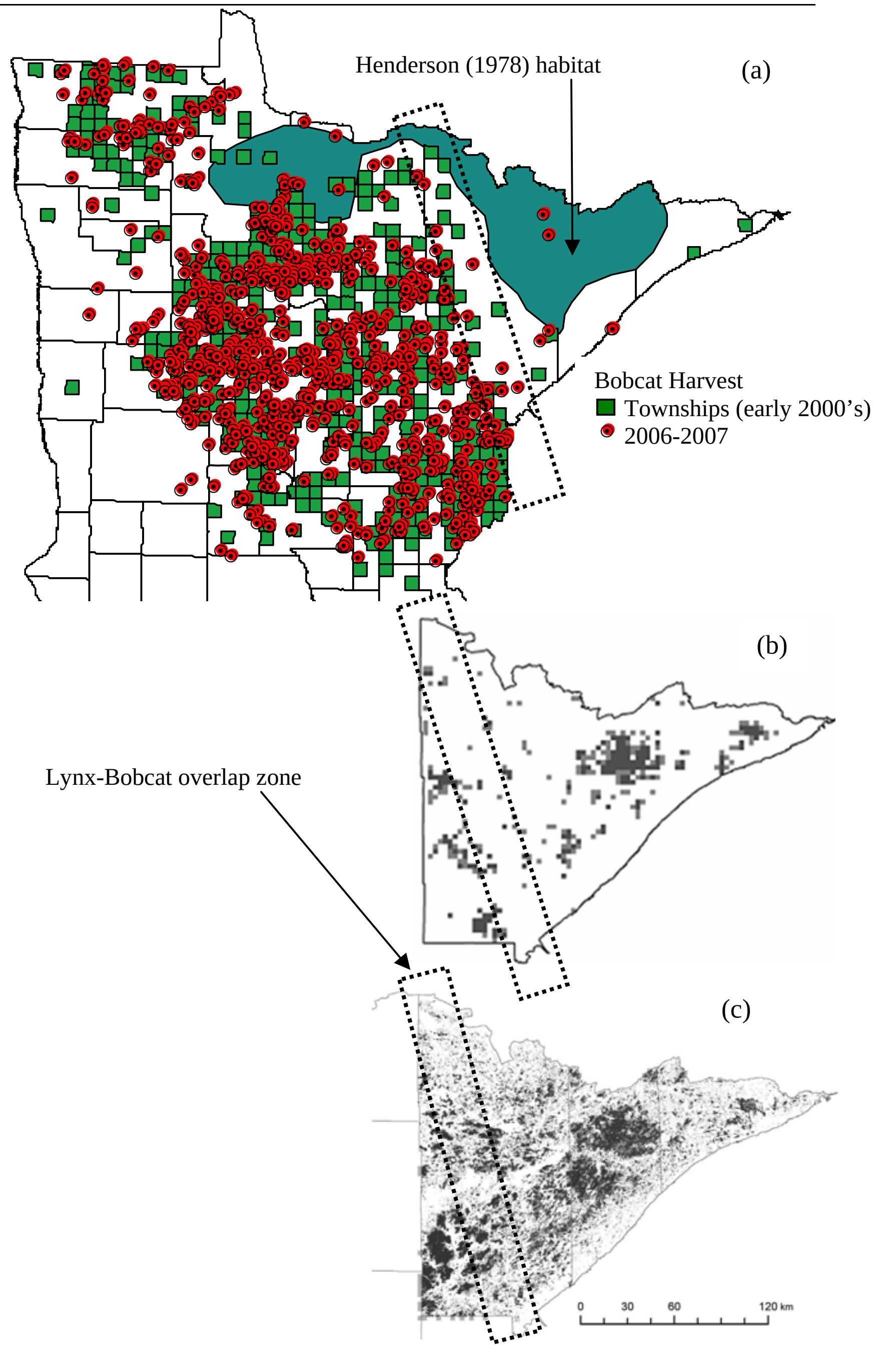
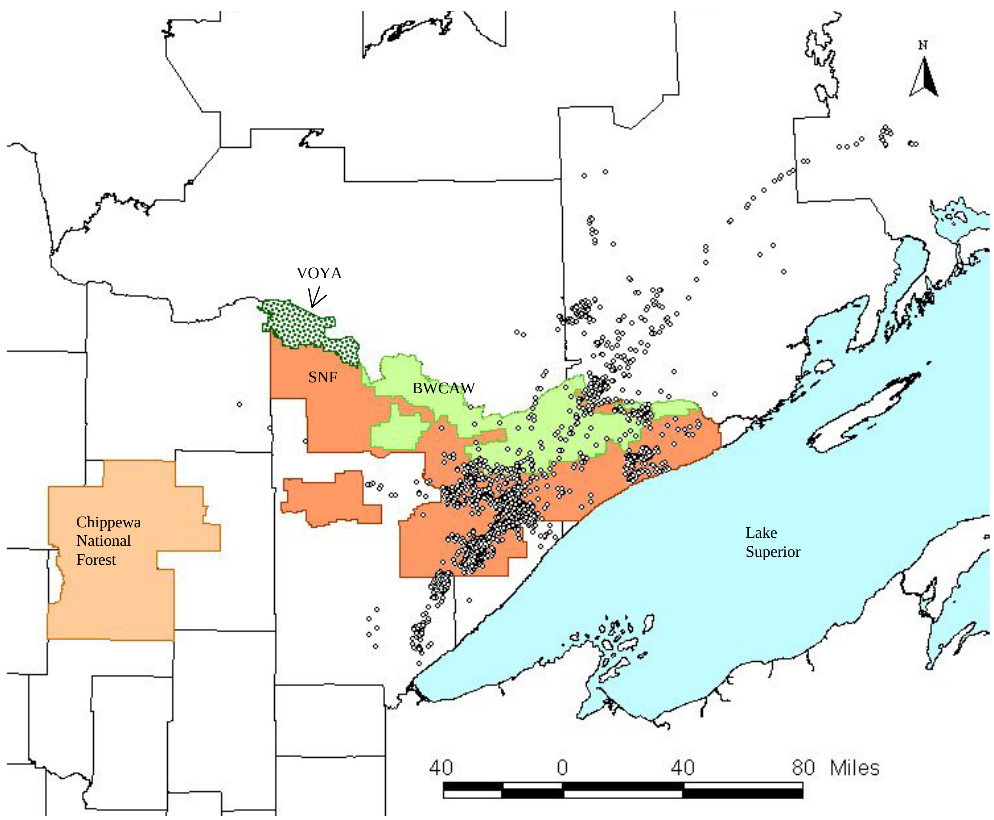


Figure 2. Possible habitat for Canada lynx (a) identified in 1970s based on sightings and trapping records (Henderson, 1978) and bobcat harvest in Minnesota with green squares indicating township level distribution of bobcat harvest in early 2000's and red circles indicating bobcat harvest in 2006 and 2007 (data courtesy J. Erb, MN DNR). In (b) predicted area of higher quality hare habitat (McCann & Moen, *in prep.*), and (c) predicted highest quality denning habitat based on satellite imagery (Moen *et al.*, 2008a). For (b) and (c), darker patches indicate higher quality habitats but do not indicate lynx presence or absence. Spatial distribution of high quality lynx habitat will change as forests age and disturbance occurs because lynx feed primarily on snowshoe hare which are found at highest densities in younger forests with a conifer component in the understory. The box with dashed lines in (a), (b), and (c) represents a zone of potential overlap between bobcats (*L. rufus*) and lynx (*L. canadensis*). It is probable that lynx presence to the south and west of that box is less likely due to interactions with bobcats. Habitat changes outside of Lake, Cook, and St. Louis counties mean that the habitat model cannot be extended to the west.

Radiotelemetry and GPS collar Locations

We obtained 60 locations or mortality checks of the 5 radiocollared lynx with functioning transmitters in 2008. We had 5 total locations of L32 and L33 because of limited resources to locate these lynx in Ontario. We also had few locations of L31, the only radiocollared female with a transmitting collar in MN in 2008. We lost the signal of L31 after a location on April 29th in 2008. Checks on the ground between May 1 and May 14 did not pick her signal up. The failure of an attempt to locate L31 from an airplane (range of 20-30 miles compared to about 1 mile on the ground) on May 15th was a definitive indication that we could not locate L31 in her typical area. We then searched twice from an airplane throughout northeastern Minnesota and into Ontario and were not able to locate L31. She was with a male during the 2008 breeding season and would very likely have had kittens in May 2008 if she was alive. Either she went to Ontario as L07 had done 2 years previously (Moen *et al.*, 2008b), was some other place where we could not pick up her signal, her collar failed, or she was killed and her collar destroyed.

Figure 3. VHF and GPS telemetry locations of lynx captured in this study as of 12/31/07. Many locations are obscured by other locations at this map scale, over 15,000 locations are plotted on this map. The light brown area in the west is the Chippewa National Forest. Voyageurs National Park is shown in stippled green.



Prey Species and Hare Pellet Plots

The primary prey of Canada lynx throughout its range is snowshoe hare (Aubry *et al.*, 2000; Mowat *et al.*, 2000; Squires & Ruggiero, 2007). We estimated prey species based on analysis of lynx scats (Hanson & Moen, 2008) and by snow-tracking (Burdett, 2007). Almost all identifiable remains from lynx scats found in Minnesota were from snowshoe hare (Hanson & Moen, 2008). Twenty-four of 26 kills found while snow-tracking were snowshoe hares; the remaining 2 kills included 1 ruffed grouse (*Bonasa umbellus*) and 1 spruce grouse (*Dendragapus canadensis*) (Burdett, 2007).

Hare fecal pellet transects consist of five 1 m^2 circular plots placed at 20 m intervals (McKelvey *et al.*, 2002; Murray *et al.*, 2002). In the first phase of this project plots were permanently marked with a 3/8" diameter reinforcing bar (rebar) stake and plots were remeasured each year. Some plots were missed each year, reducing the sample size, and some plots were added each year. After reviewing results we presented a method that we believe will accommodate permanent and nonpermanent plots in the phase 1 final report (Moen *et al.*, 2008b). We also presented results for plots done sequentially over time, and for all plots measured over the past 5 years of the project. We are incorporating the revised pellet count protocol into a manuscript to be submitted for peer review.

Persistence and Abundance of Lynx in Minnesota

Historical harvest and observation data sets provide an opportunity to evaluate the extent to which Canada lynx were present in Minnesota and contrast lynx presence in different states. It is also possible to use the historical harvest data to compare relative density of lynx in different states and the adjacent provinces. Finally, using biologically reasonable logic, it is possible to consider some alternative scenarios with respect to lynx harvest and distribution in different parts of Minnesota. These scenarios can be used to interpret current distribution and abundance of lynx in Minnesota.

The historical record of lynx harvest in Minnesota, and the reports of lynx harvest and observations from other states indicate that in years when the hare population crashes in Canada there are influxes of lynx into the U.S. (McKelvey *et al.*, 2000; Adams, 1963). These appearances of lynx have been called "invasions" or "irruptions" and the basis for these dramatic terms is clear when harvest records are compared, particularly in some states. For example, an average of 1 lynx was taken every 3 to 4 years in North Dakota in the 1900's prior to 1962. In the invasion year of 1962 about 200 lynx were trapped or shot in North Dakota, with one trapper taking 39 lynx (Adams, 1963).

Minnesota is unique among the contiguous 48 states in that recorded lynx harvest has been higher than any other state, and that there is a long record of harvest. Lynx harvest increased in Minnesota in the "invasion" year of 1962, when 387 were taken compared to 66 in 1961 (Henderson, 1978). However, there are only 2 years between 1930 and 1969 when reported lynx harvest in Minnesota was less than 16 animals (Henderson, 1978). No lynx were reported taken in DNR harvest data in 1950 and only 1 was reported taken in 1959. In every other year between 1930 and 1969 16 or more lynx were reported taken, and in more than 60% of those years over 50 lynx were reported in the harvest (Henderson, 1978).

Although interpretation of harvest records is limited by factors such as reporting accuracy, trapper effort, sampling bias, and uncertainty on where animals were harvested, harvest records are the best data available to help understand lynx abundance and population dynamics from 1929 to the 1970's. However, it is not possible to classify every harvest record as verified, or as documented (*sensu* (McKelvey *et al.*, 2008)) because of the nature of record collecting by the MN DNR (Henderson, 1978). It also would be inappropriate to classify every harvest record as anecdotal (*sensu* (McKelvey *et al.*, 2008)) with biologists identifying some of the harvested lynx. Correlations between harvest in Ontario and Minnesota (see below) support the general validity of Minnesota harvest records.

Harvest records provide a coarse index of relative population size across years rather than a direct measure of population size. Interpretation of 1970's harvest records is confounded by high pelt prices, a severe winter in 1969, harvest from both northern and southern Minnesota, unusually high harvest in Canada, and transition to managed furbearer status in Minnesota.

The average harvest in Minnesota from 1929-1969 of 177 lynx per year is at least 40 times higher than the average reported harvest or the verified records of every state south of Canada except Montana. From 1928 to 1964 an average of 4 lynx per year were harvested in New Hampshire (McKelvey *et al.*, 2000), compared to an average of 177 lynx per year in Minnesota in a similar time period (Henderson, 1978). New York has only 23 verified records of lynx in the 1900's (McKelvey *et al.*, 2000). Michigan has 38 verified records during the 1900's (many occurred during the 1962 "invasion"), and Wisconsin has 26 (McKelvey *et al.*, 2000). Montana is the only other contiguous state with continuous records of lynx harvest in the 1900's. Average harvest in Montana from the 1940's to the 1970's was about 80 animals per year (McKelvey *et al.*, 2000), about half as many lynx as were harvested in Minnesota during those years (Table 3).

Even though harvest is relatively large in Minnesota, harvest in the Canadian provinces is much larger. Lynx are on the southern end of their range in the contiguous 48 states and this is clear from harvest records in adjacent provinces. From 1919 to 1998 the average lynx harvest from Ontario, Manitoba, and Saskatchewan was over 5,000 lynx (McKelvey *et al.*, 2000). The average harvest in Ontario during this time period was about 1,700 lynx per year. In a similar time period the average harvest in Minnesota was about 170 lynx per year (Table 3).

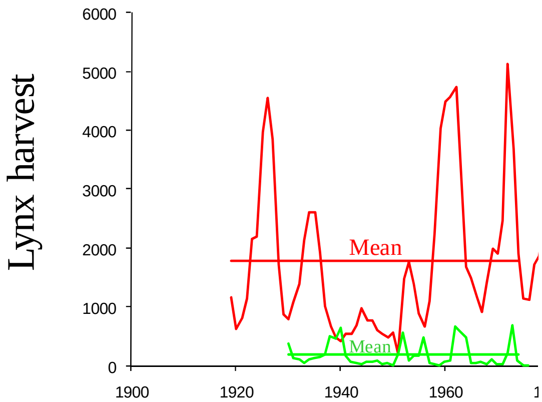
Table 3. Comparison of lynx harvest in Minnesota, Ontario, and Manitoba from 1930 to 1976 and other time periods used in comparisons above. Harvest data from (Henderson, 1978).

Region	**1930 - 1976**	**1930 – 1969**	**1945 - 1975**
Minnesota	177 ± 61	183 ± 64	168 ± 78
Ontario	1,670 ± 373	1,527 ± 383	1,917 ± 515
Manitoba	1,918 ± 641	1,678 ± 626	2,429 ± 888

Spatial Context of Lynx Harvest in Ontario and Minnesota

The difference between Ontario and Minnesota should be placed into a spatial context. Ontario lynx harvest is about 10 times the harvest of lynx in Minnesota, but the range of lynx in Ontario is also much bigger than the range of lynx in Minnesota (Fig. 4). Several factors confound a direct comparison between Ontario and Minnesota. There are no resident lynx in southern Minnesota. Much of the human population, and probably the lynx harvest, in Ontario is concentrated along the U.S. border. Historical lynx harvest / 1000 km^2 is surprisingly similar in Ontario and Minnesota (Table 4). Harvest rates (Table 4) are only a rough approximation because spatial distribution of harvest is unknown. However, if historical harvest in the 1977 counties (Table 4) was only 50% of the reported harvest in Minnesota, harvest / 1000 km^2 would still be somewhat similar to historical harvest in Ontario.

Figure 4. Lynx harvest in Ontario and Minnesota in the 1900's and a map of Ontario and Minnesota. Harvest data from Henderson (1978). Dark green counties include the estimated lynx range from Henderson (1978), and lighter green indicates counties in northern Minnesota where most lynx harvest would probably have occurred.



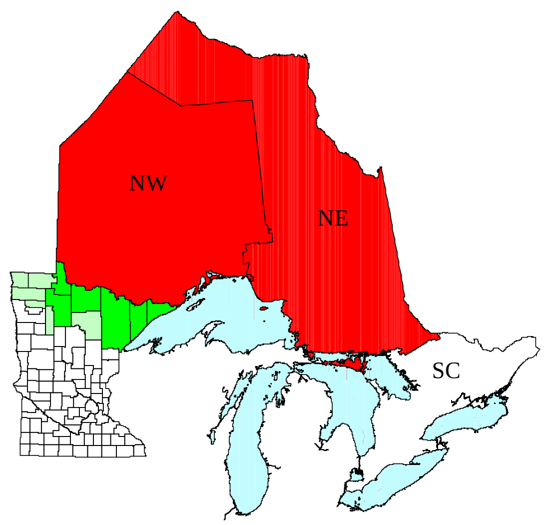


Table 4. Comparison of lynx harvest in Ontario and Minnesota. The text describes limits to the comparison based on human densities, harvest effort, and other reasons. This comparison is only made to show that harvest is similar in Ontario and northern Minnesota. Row colors are coded to Fig. 4.

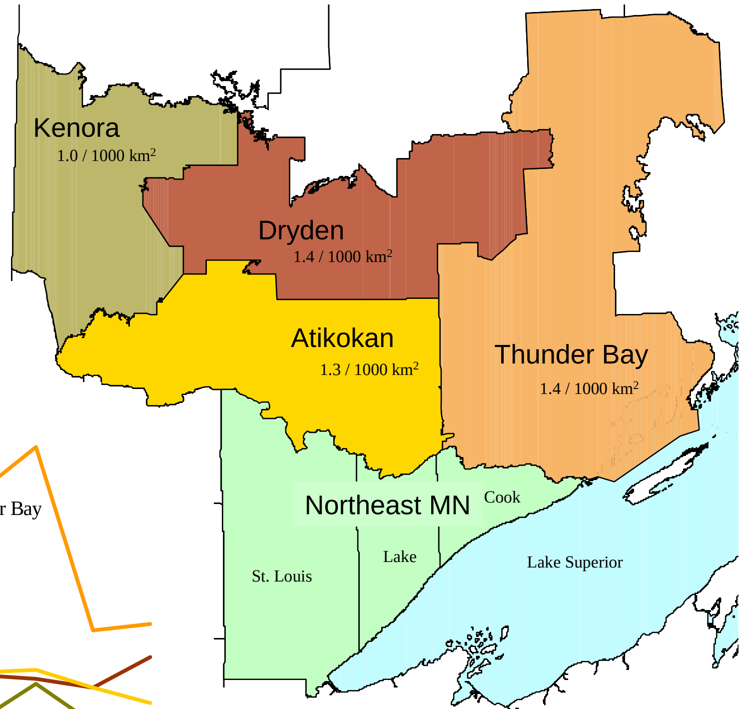
	Percent of		Harvest / 1000 km^2 1929 – 1983	
Region	**Harvest**[a]	**km^2**	**Mean**	**Maximum**
Ontario - NE and NW regions		909,192	1.88 [b]	5.72 [b]
All northern MN Counties	67%[a]	71,977	1.65	3.73
Counties 1977 range includes	50%[a]	48,224	1.84	4.15

[a] Assumes 67% and 50% of Minnesota harvest was in northern counties. Adjustment made because some harvest occurred in the southern MN counties, especially in "invasion" years.

[b] Assumes Ontario harvest spread across NW and NE regions, total includes some harvest in SC region.

We can refine the comparison in Table 4 by considering lynx harvest in OMNR regions adjacent to the Minnesota border. Lynx harvest in districts adjacent to Minnesota has been 1.0 to 1.4 lynx per 1,000 km^2 from 1993 to 2004 (Fig. 5). This harvest is lower than the long-term average for Ontario (Table 3), which is consistent with a decline in lynx harvest across Canada in the late 1900's (McKelvey *et al.*, 2000).

Figure 5. Harvest of lynx in OMNR districts adjacent to northeastern Minnesota from 1993 to 2004. OMNR harvest data courtesy of OMNR.



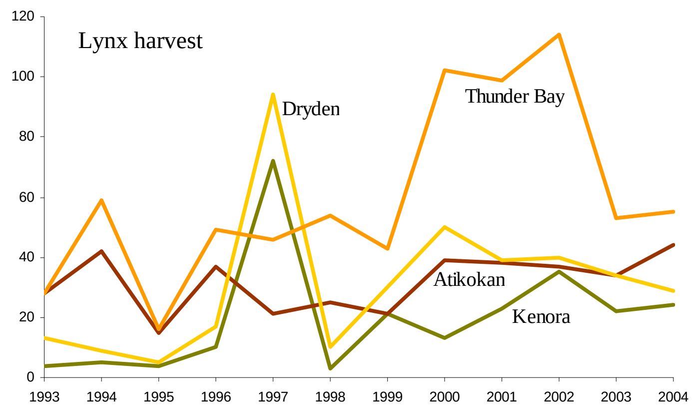


Table 5. Average harvest of lynx in OMNR districts adjacent to northeastern Minnesota from 1993-1994 to 2004-2005. In the last column, we indicate what hypothetical harvest in northeastern Minnesota would have been if Cook, Lake, and St. Louis counties were a OMNR district at the low and high harvest rates.

	Kenora	**Dryden**	**Atikokan**	**Thunder Bay**	***Hypothetical NE MN***
Harvest	20 ± 11	32 ± 5	31 ± 14	60 ± 17	*27 - 38*
km^2	19,850	22,860	23,624	43,257	*27,537*
Harvest/1,000 km^2	1.0	1.4	1.3	1.4	*1.0 – 1.4*

We can calculate what a hypothetical harvest would be in Northeastern Minnesota if we assume that Cook, Lake, and St. Louis counties were an OMNR district. Based on the land area in these 3 counties, about 27 – 38 lynx would be harvested in a hypothetical harvest (Table 4). The hypothetical harvest of 27 – 38 lynx is less than historical average of 177 lynx harvested per year in Minnesota (Table 3) for several reasons. Historical lynx harvest in Ontario from 1919 to 1983 was 1,810 ± 155 (mean ± SEM) compared to 871 ± 86 from 1984 to 2005 (McKelvey *et al.*, 2000). A similar decline from the historical Minnesota harvest would provide an expectation of 85 lynx harvested in Minnesota, rather than the historical average of 177 lynx (Table 3).

There also would probably be a reduction in harvest as the southern edge of lynx range is approached in Minnesota because of habitat and land use changes in southern St. Louis county. Only about 25% of northeastern Minnesota is the best quality lynx habitat and bobcats are present in part of this area (Fig. 2). The analysis is also being restricted to the land area in Cook, Lake, and St. Louis counties, while historical harvest was across a larger area, especially in “invasion” years (Henderson, 1978). If we assume that from 25% to 50% of historical lynx harvest occurred in Cook, Lake, and St. Louis counties, the expectation would be a hypothetical harvest of about 20 to 40 lynx. It may just be a coincidence that a harvest of about 20 to 40 lynx is similar to the hypothetical harvest estimate in Table 4, and a further coincidence that the average annual harvest of lynx in Minnesota when harvest was legal and regulated (1977-1983) was 23 (J. Erb, MN DNR, pers. comm.).

On the other hand, it may be more than a coincidence: the estimate of 27 – 38 lynx may be a rough maximum baseline for removal of lynx from Minnesota, where removal could be from illegal shooting, incidental catch, vehicle collisions, movement to Ontario, and other factors decreasing the number of lynx present in Minnesota. The baseline might need further adjustment for other reasons, including being conservative in estimating removal or disappearance from a small population.

The main point of this process was to present historical lynx harvest in Minnesota in a spatial and numerical context that would enable a biologically accountable analysis of lynx residency in northeastern Minnesota. We know the percentage of lynx harvested in northern Minnesota counties compared to southern Minnesota was not 0% and not 100%, but we will never know if the correct percentages for Table 4 are 50% or 67% or some other number. We also cannot know for certain whether lynx were misidentified as bobcats, or bobcats were misidentified as lynx, or if some of the registered lynx were harvested outside of Minnesota. While these harvest records cannot be considered verified (sensu (McKelvey *et al.*, 2008)) they are the only records that are available. These historical records enable a sensitivity analysis to create expectations of allowable mortality and emigration rates based on data from the past.

Legal Status of Canada lynx in Minnesota

Prior to the FWS listing of the Contiguous United States Distinct Population Segment (DPS) of Canada lynx as a Threatened species under the Endangered Species Act in 2000, the MN DNR submitted comments that indicated the state's position with regard to Canada lynx in 1998 (Letter from Commissioner Rod Sando to US FWS dated 9/25/1998). Among the points raised by the MN DNR were the importance of distinguishing between individual animals that could be dispersing from Canada and a resident population. The MN DNR also commented on the age distribution of lynx harvested in Minnesota from 1977 to 1983, on the low survival of lynx in Minnesota, and on the overharvest of lynx in Canada in the 1970s. Other comments addressed the adequacy of state regulations protecting lynx as a furbearer and indicated that there were only 2 documented incidental catches of lynx from 1984 to 1998. Despite the comments from the MN DNR, the Canada lynx was listed as a threatened species in 14 states south of Canada under the U.S. Endangered Species Act (ESA) in April 2000.

The Canada lynx is currently considered a furbearer under Minnesota law. However, the season has been closed since 1983, 17 years before lynx were listed at the Federal level. Harvest of lynx is prohibited under Minnesota DNR regulations because Federal ESA listing takes precedence over state status. Just as a species can be listed under the ESA at the federal level, Minnesota has a process to list species as threatened or endangered at the state level. Links to the Minnesota State website that has these statutes and rules are provided in Appendix 1. Unlike the federal listing process, in Minnesota every species is considered when the state list of the status of plant and animal species is revised. This process is a major undertaking that occurs approximately every decade.

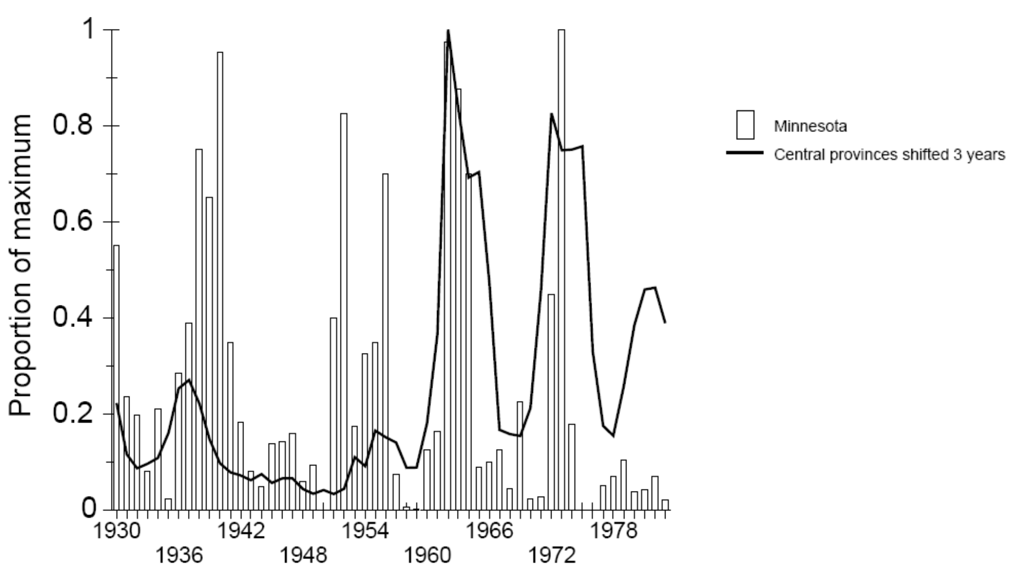
One such revision is underway now. Native species in Minnesota are considered for classification as endangered, threatened, or a species of special concern in the state. Endangered species are threatened with extinction throughout all or a significant portion of their range *in Minnesota* and Threatened species are likely to become endangered in the foreseeable future throughout all or a significant portion of their range *in Minnesota*. The italics emphasize that the listing decision is made solely based on a species range *in Minnesota*, even if the population of the species is high in adjacent states or provinces. Lynx are a species where this clause may apply: although rare in Minnesota, lynx are managed as a furbearer in Ontario and Manitoba.

Species of Special Concern (SSC) is the final category of listed species in Minnesota. Species of Special Concern can be extremely uncommon in this state, but do not meet the definition of an Endangered or Threatened species. SSC may also have unique or highly specific habitat requirements and may need careful monitoring of status. Species on the periphery of their range that are not listed as threatened may be included in the SSC category, as can species that were once threatened or endangered but now have increasing populations or protected, stable populations. The DNR proposes a status for a species at the end of the review process, but the public can also recommend or petition for a change in status.

Hypotheses to Evaluate the Status of Canada lynx in Minnesota

One simple hypothesis is that lynx harvest in Minnesota is unrelated to lynx harvest in Ontario and the adjoining provinces. Harvest numbers in Minnesota are higher than any other contiguous state, but this hypothesis is not supported by harvest data (Fig. 6). An alternative hypothesis is that lynx harvest in Minnesota is driven by "invasions" of lynx from Canada. This has been suggested by the MN DNR previously (Henderson, 1978), reinforced in a letter from MN DNR Commissioner Sando to the FWS in 1998, and is supported by harvest data. Harvest records show peaks in Minnesota lynx harvest that roughly coincide with harvest in Ontario, Manitoba, and Saskatchewan 3 years earlier (Fig. 6).

Figure 6. Lynx harvest in Minnesota and harvest in Ontario, Manitoba, and Saskatchewan. Lynx harvest in Minnesota is shifted 3 years to the right to give the best correlation between Minnesota and provincial harvests. Figure is from (McKelvey *et al.*, 2000).



Ecological problems are rarely this simple, however, and an alternative explanation is possible because the two hypotheses are not mutually exclusive. For example, during the period 1929 to 1969, lynx were harvested in every single year except 1950 in Minnesota. In 60% of those years, harvest was more than 50 lynx. It is possible that during those years there was a resident population of lynx in Minnesota (Henderson, 1978), and that there were also periodic “invasions” which resulted in an increase in harvest of lynx in Minnesota. To test this more complex hypothesis, we used data on survival, reproduction, and habitat use of lynx in Minnesota from the radiotelemetry project (Moen *et al.*, 2008b). We also evaluated historical harvest data in the context of resident and invading populations. We considered the validity of several statements, which if true would support rejection of the hypothesis of a resident population and would support the hypothesis that lynx are in northeastern Minnesota only because of periodic “invasions” from Ontario (Table 6). Some of these statements cover basic biological data, other statements are a data-driven method to test statements in the public domain, and other statements represent a synthesis of existing knowledge. Collectively, these statements could support or reject the global hypothesis that lynx should be considered a resident species in Minnesota.

Table 6. Statements discussed in a hypothesis testing framework in this section.

Lynx in Minnesota are in poor physical condition
Lynx in Minnesota cannot reproduce
Lynx kittens born in Minnesota are not recruited into the population
Lynx in Minnesota cannot survive for more than 1 year
Lynx “invade” Minnesota and then either die or return to Canada
Most lynx mortalities in Minnesota are reported
Age structure of lynx in Minnesota is primarily young non-resident animals
Lynx reports are geographically consistent with historical “invasion” records
Lynx population biology is not comparable to bobcat population biology in Minnesota

Hypothesis: Lynx in Minnesota are in poor physical condition.

If lynx in Minnesota are generally in poor physical condition, this would support the hypothesis that lynx are not a resident species in Minnesota. This statement is not supported by measurements on lynx from 2003 to 2007. Lynx we radiocollared were in good physical condition and body mass of adults was similar to body mass elsewhere (Moen et al. 2010). Minnesota females were 9.2 ± 0.3 kg (range = 7.0 to 11.4) compared to a mean of 9.1 kg (range = 5.9 to 13.2) 30 years earlier (Mech, 1980). Minnesota males were 11.2 ± 0.3 kg (range = 7.2 to 15.2) compared to a mean of 10.6 kg (range = 6.8 to 13.2) 30 years earlier. Lynx carcasses examined for fat content in the 1970's at these body masses had either large or moderate amounts of fat reserves (Mech, 1980). One male weighed about 12 kg when he was incidentally snared at the age of 1 year and 8 months. There are no abnormal indications in blood chemistry data in blood samples taken during the latter years of the project (Moen et al., 2010).

There were only three lynx that did not appear to be in good physical condition in Minnesota during this telemetry project. The first was a male (L33) who had probably been caught in a foot-hold trap by the right front foot (Moen et al., 2010). Bone spurs were visible on the foot, and he did not appear to be in as good physical condition as other lynx. Despite the injury, after being captured and radiocollared near Babbit, MN, he lived in Ontario for at least 2 years after capture. His current status is unknown. The second was a lynx that was shot while killing a deer in a yard near Cook, MN in February 2008. Despite a subadult or adult-sized frame, this lynx weighed just over 6 kg and the pathologist report indicated very low fat reserves. The third was a lynx observed at a private residence near Ely. This lynx was first seen during a very cold spell in the 2008 winter. It appeared to have an injury to the right hind leg. This lynx was not captured and radiocollared, and current status is unknown.

Two of these three lynx in poor condition appeared to have injuries that could have contributed to their poor physical condition, but we have found no starvation mortality in radiocollared lynx in Minnesota. In contrast, initial estimates were that 36% of mortalities of radiocollared lynx were due to starvation in Maine (Vashon *et al.*, 2007), and about 33% of lynx mortalities in the radiotelemetry project in Montana have been from starvation (J. Squires, pers. comm.). During lows in the hare cycle in northern Canada, starvation is a common cause of death (Mowat *et al.*, 1996; Poole, 1994).

Hypothesis: Lynx in Minnesota cannot reproduce.

If lynx in Minnesota cannot reproduce, this would support the hypothesis that lynx are not a resident species in Minnesota. This statement is not supported by data. Every adult female lynx that we radiocollared had a litter in every year that we could monitor her (Moen *et al.*, 2008b). In one year we had a female bred at 22 months have kittens (Moen *et al.*, 2008b). During lows in the hare cycle, when lynx are in poor condition, lynx in the Yukon Territory and Northwest Territories fail to breed or have poor recruitment (Mowat *et al.*, 1996; Poole, 1994). Snowshoe hare density in Minnesota in recent years has not cycled as greatly as the difference between high and low hare densities during the hare cycle in northern Canada when these extreme responses in lynx reproduction are detected (Moen *et al.*, 2008b).

Average litter size in Montana was 3.25 for adult lynx (Aubry *et al.*, 2000), consistent with what we have measured in Minnesota (Moen *et al.*, 2008b). Litter size in northern Canada averages 4 to 5 kittens and nearly all adult females have kittens when hare density is high (Poole, 2003). In years of low hare density, there are no kittens by mid-June, even if adult females give birth (Mowat *et al.*, 1996). Reported litter sizes are 5.3 ± 0.9 (mean ± SEM) and 4.9 ± 0.6 (Mowat *et al.*, 1996) and 4.0 ± 0.6 (Poole, 1994). Female lynx in Minnesota have had litter sizes as large as 5, but average litter size is lower. Although litters appear to be lost within a month of parturition during years of low hare density, the loss of entire litters has not occurred in Minnesota except possibly for one female whose den was not located (Moen *et al.*, 2008a).

Hypothesis: Lynx kittens born in Minnesota are not recruited into the population.

If lynx kittens born in Minnesota all die in the den, or do not survive to adulthood, this would support the hypothesis that lynx are not a resident species in Minnesota. The hypothesis of lack of recruitment is supported by radiotelemetry data, but the reasons for recruitment failure are not known. We have documented lynx kittens with adult females through the winter in each year of the radiotelemetry project. Despite the birth of at least 33 kittens to radiocollared females, and documented survival to one year of several kittens, we are only aware of two kittens born in Minnesota that have survived to over 2 years of age. A female, L17, lived to be at least 2 years and 3 months and had a litter of kittens before we lost track of her; her current status is unknown. A male, L43, died at 3 years and 10 months in March 2009. Kittens are hard to capture and radiocollar in the first year of life. Causes of mortality of radiocollared young at dispersal age have all been human-related or probably human-related (Moen *et al.*, 2008b). Each year we have searched for tracks and scat of lynx in home ranges of radiocollared females but have not found sign of the previous year's kittens. None of the ear-tagged kittens have been reported by trappers in Ontario. Female kittens should be somewhat philopatric to the home range of their mother (Mowat & Slough, 1998) so we would expect some female kittens to be detected later in life if they survived (e.g., via DNA analysis of scat samples) because we and others have monitored lynx throughout the past 6 years.

Hypothesis: Lynx in Minnesota cannot survive for more than 1 year.

If lynx in Minnesota cannot survive for extended periods, this would support the hypothesis that lynx are not a resident species in Minnesota. This statement is not supported by radiotelemetry data. The median survival of a lynx after radiocollaring in this project was 623 days (517 days for lynx last located in Minnesota). L28, one of the lynx with a currently active radiocollar, has been wearing a collar for 1,475 days (over 4 years), and 5 of the 15 lynx that remained in Minnesota wore their radiocollars for more than 2 years. In contrast, when 14 lynx were radiocollared in 1972 and 1973 and harvest was not restricted by game laws, they survived from 2 to 359 more days (Mech, 1980). Because we have had radiocollars on only 33 animals we do not have an adequate sample size to calculate survival rates with precision. Longevity of individual animals and cause of death provide indirect information that can be used to infer survival of lynx in Minnesota.

Hypothesis: Lynx that "invade" Minnesota either die or return to Ontario

If lynx in Minnesota die or reappear in Ontario without establishing residence in Minnesota, this would support the hypothesis that lynx are not a resident species in Minnesota. This hypothesis is largely unsupported by survival and movement data. Less than 33% of lynx radiocollared in Minnesota were last located in Ontario, and over 75% of lynx that remained in Minnesota did so for at least a year. The historical record clearly indicates that invasions occur at approximately decadal intervals (Fig. 4, 6). It was assumed that "invading" animals were surplus animals that would die if they were not harvested. Prior to our study there was only one historical record of a lynx moving from Minnesota to Ontario (Mech, 1977). In this telemetry project we documented repeated movements between Minnesota and Ontario by some lynx (Moen et al., 2008b; Moen et al., *In prep.*).

Because these lynx were radiocollared as adults, we do not know if they were born in Ontario, "invaded" Minnesota, and move back and forth, or if they were born in Minnesota. Given the low numbers of lynx observed in Minnesota in the late 1980's and 1990's, it is likely that at some point immigration from Ontario to northeastern Minnesota occurred.

Prey availability in areas of Ontario visited by some of these lynx was higher than prey availability in Minnesota (Moen *et al.*, 2008b). Even so, these lynx returned to Minnesota, suggesting that food resources in Minnesota were adequate in their home range in Minnesota.

Hypothesis: Most lynx mortalities or incidental captures in Minnesota are reported

If all mortalities or incidental captures in Minnesota were reported, then the small numbers of mortalities in the incidental take database would support the hypothesis that human-caused mortality of lynx is rare in Minnesota, and therefore lynx are either dying of natural causes or emigrating to other locations (e.g., Ontario). This hypothesis is not fully supported by data. If one assumes that all lynx mortalities and incidental captures in Minnesota are reported, incidental take incidents could be directly applied to estimate population level effects. Evidence from other carnivore species indicates that not all mortality events are reported. About half of grizzly bear (*Ursus horriblis*) mortalities would not have been discovered without radiotelemetry in British Columbia (McLellan *et al.*, 2000). Black bear (*U. americanus*) mortalities are not all reported in Washington (Koehler & Pierce, 2005). Wolf (*Canis lupus*) mortality is generally unreported in Wisconsin, and lack of reporting seems to be increasing (Wydeven *et al.*, 2007). Harvested bobcats (*Lynx rufus*) are transported illegally between management areas in Michigan (Millions & Swanson, 2006). Common sense would also indicate that not all incidental takes are reported because the person would not want to draw attention to himself or herself, especially if the action was illegal.

Incidental take has been reported in Minnesota, but the reporting rate is not known. We do have a small sample size from radiocollared lynx that were trapped, shot, or died from collisions with vehicles (Table 7). If reporting rates were similar between trapping, incidental shooting, and vehicle collisions, then we would expect a similar ratio of radiocollared lynx to uncollared lynx from each cause of death. It turns out that 1 in 6 lynx hit by car is radiocollared, and 1 in 5 lynx shot wore a radiocollar. For comparison purposes, we will conservatively assume a ratio of 1:5 is expected. There were 6 reported trapping incidents with radiocollared lynx in Minnesota, but only 9 additional incidents were reported. The expectation, based on a 1:5 ratio, would be 30 total incidental catch instances, which means that 15 incidental catches were not reported. Some of these 9 incidents were before any lynx were radiocollared, but we left them in these rough calculations. Similarly, for the "Unknown" cause of death category (Table 7) there were 9 deaths of radiocollared lynx, and only 12 reported when the expectation would have again been about 45 total incidents, which means that 33 incidents were not reported.

The sample size is small, but proportionately fewer non-radiocollared lynx in the Incidental Take database were reported compared to radiocollared lynx when the incident was "Trapping" or "Unknown". This would suggest that either (a) radiocollared lynx are reported at a higher rate than non-radiocollared lynx for "Trapping" and "Unknown" causes of death, or (b) there are more mortalities of uncollared lynx that are not reported when cause of death is “Trapping” or “Unknown.” The latter possibility (unreported take) is consistent with the literature reviewed above. However, with this sample size it is not safe to conclude that there have been an additional 15 lynx deaths or incidental captures due to “Trapping” and 33 additional lynx deaths from “Unknown” causes that have been unreported. It is probably safe to conclude that there have been somewhere between 10 and 60 lynx deaths or incidental takes for the “Trapping” and “Unknown” causes that have been unreported over the 5 year records of the Incidental Take database for incidental take factors other than railroad mortality.

Table 7. Causes of mortality or incidental take in the Incidental Take database maintained by the FWS in relation to whether lynx was radiocollared or not radiocollared.

	Radiocollared	Total	Percent Radiocollared
Railroad	1	2	50
Road kill	1	6	17
Shooting	1	5	20
Trapping	6	15	50
Unknown	9	12	75
Total	21	43	49

Because lynx are listed as threatened under the ESA, one factor that would lead to low motivation to report mortalities is the potential for being fined regardless of the cause of mortality. Further reduced motivation on the part of the trapping community would exist because of a fear that trapping in lynx range might be curtailed, and also because over the last few years there have been lawsuits against the MN DNR on trapping associated with species (Bald eagle, gray wolf, Canada lynx) listed under the ESA.

Hypothesis: Age structure of lynx in Minnesota is primarily young non-resident animals

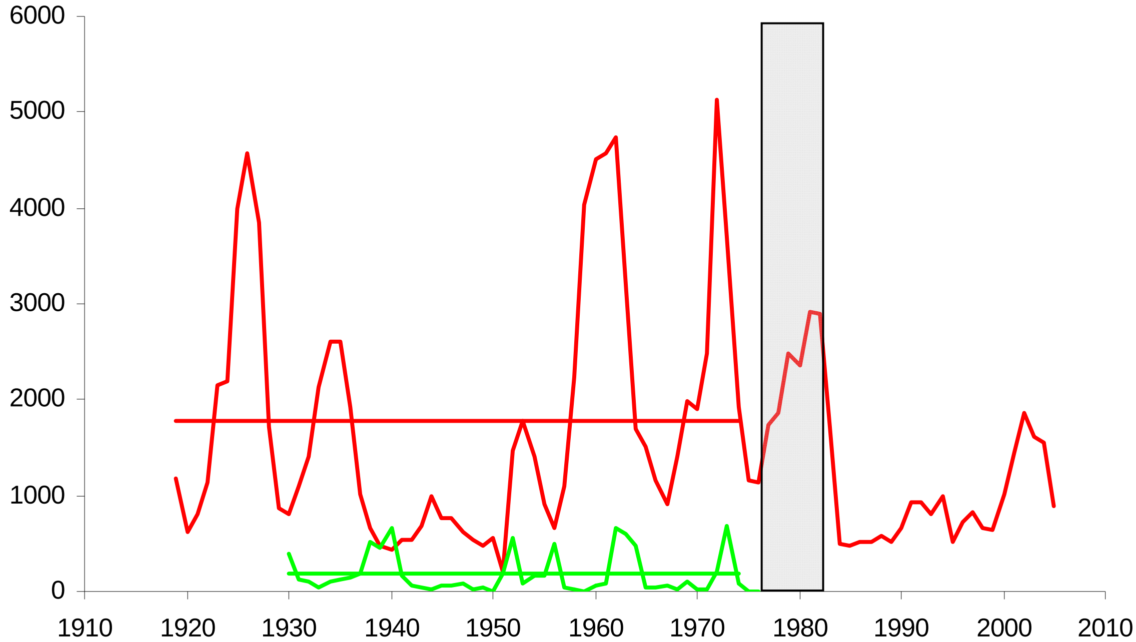
If lynx in Minnesota are all relatively young this would indicate immigration from Ontario, and support the hypothesis that lynx are not a resident species in Minnesota. This hypotheses is not supported by the data in the context of historical interpretation of age structure of the population. However, this statement is difficult to test because many of the lynx in the telemetry study or that have been incidentally taken have not been aged. In the letter from the MN DNR commissioner in 1998 is the following:

> " … *we collected age data directly from carcasses of harvested lynx during the last few years of Minnesota lynx trapping seasons (1977-1983). Of 49 carcasses examined, no animals were older than 3 ½ years. This age distribution is strikingly different from our resident bobcat population, in which 50% of the population is greater than 2.7 years old. If lynx were continuously resident in Minnesota, we would expect a sample of this size to contain at least a few animals older than 3.5 years. Conversely, if the "population" were composed of Canadian dispersers, we would expect exactly the skewed age structure we found. …*"

If we consider minimum ages of radiocollared lynx (assuming they were collared at 1.5 or 2.5 years based on body mass), the average age at death or last telemetry location was 3.4 ± 1.2 years, or for animals last located in Minnesota 3.3 ± 1.3 years, and 67% (18 of 27) were older than 2.7 years. Over 40% of the lynx were older than 3.5 years at death or last telemetry location.

It is also important to consider the Commissioner's statement in the context of the cycle of lynx "invasions" recorded in harvest record. The period which was quoted (1977-1983) includes the last real peak in lynx harvest in the 1900's (Fig. 7), and thus the later years of this time period would be expected to have a younger age distribution because harvest was influenced by lynx "invading" from Ontario. It would be impossible to obtain age data from periods such as 1945 – 1950, or from 1965 – 1970 (Fig. 7), but one could speculate that age structure of harvested lynx in those years, without the "invasion" effect, would have been more similar to age structure of the bobcat population. It would be possible, however, to further analyze the age and sex-structure of the harvested lynx. For example, 11 of the 49 lynx carcasses examined from 1977-1983 were kittens (J. Erb, MN DNR, pers. comm.). This has consequences for both reproduction of lynx in Minnesota and for age structure estimates.

Figure 7. Lynx harvest in Ontario and Minnesota (Henderson, 1978). Harvest in Ontario from 1977-1983 is shaded. We did not obtain the number of lynx harvested in each year from 1977 to 1983, but the average harvest was 23 lynx per year (J. Erb, MN DNR, pers. comm.).



Hypothesis: Reported take is geographically consistent with historical "invasion" records

If reported take was geographically consistent with historical "invasion" records, this would indicate that lynx were wandering through Minnesota rather than being concentrated in the northeastern part of the state. This hypothesis is not supported by the data. Lynx have historically been recorded in Iowa, South Dakota, and other states far outside of typical lynx range during "invasions". One analysis of data that would address this is whether there are consistencies between the geographical distributions of historical records (McKelvey *et al.*, 2000), the sightings database that was maintained by the Minnesota DNR, and recent known mortalities and incidental take records (Table 7). These records range from verified to documented to anecdotal (*sensu* (McKelvey *et al.*, 2008)) but may be consistent in their representation of lynx distribution. If recent lynx presence in Minnesota is the product of an "invasion," then we would expect historical records (McKelvey *et al.*, 2000) to be consistent with reported locations on the assumption that "invasions" produced remarkable conditions and broad dispersal that were likely to be recorded in newspapers or as museum specimens.

On the other hand, if recent lynx presence in Minnesota includes proportionately more resident animals, we would expect a higher proportion of locations in northeastern Minnesota. Records concentrated in Cook, Lake, and St. Louis Counties would support the hypothesis of a resident population. Observations of radiocollared animals are not included in this analysis because the telemetry study was restricted to NE MN. The resident population hypothesis is supported by the data, with between 75 and 80% of the incidental take and sightings reports from Cook, Lake, and St. Louis counties, compared to 47% of the historical records (Fig. 8, Table 8).

A second aspect of the historical record is related to immigration from Ontario and may apply to recent records. There seem to be fewer lynx present in Minnesota now than there were a few years ago. One possible reason could be immigration of lynx from Ontario into Minnesota from 2000 to 2002. There is a 2-3 year lag between historical lynx harvest in Minnesota and peaks in harvest in Ontario (Fig. 6). There was a peak in harvest in the Thunder Bay district between 2000 and 2002 (Fig. 5). Many of the locations of radiocollared lynx in Ontario are in the Thunder Bay district (Fig. 3). Perception of a higher lynx density in the period between 2003 to 2005 or 2006 in Minnesota could be in part affected by the correlation lag that had been noticed previously (McKelvey *et al.*, 2000). A peak in lynx presense in 2003-2006 is consistent with a 3-year lag. While the historical record and recent harvest data from the Thunder Bay district provides some support for this reasoning, it is also important to consider documentation of mortality and emigration in explaining changes in the Canada lynx population in Minnesota.

Figure 8. Map of take (recent mortality or incidental take) records on non-radiocollared lynx, the MN DNR sightings database, and historical records (McKelvey *et al.*, 2000).

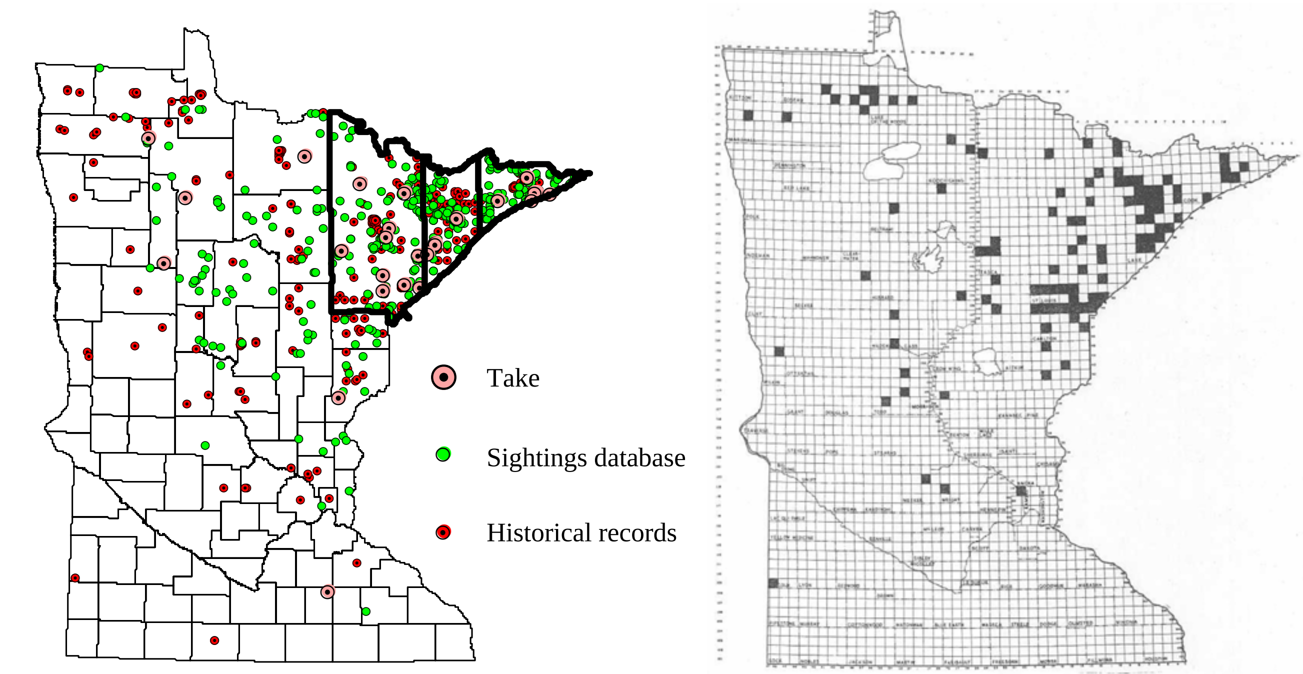


Table 8. Geographic distribution of incidental take records on non-radiocollared lynx, the MN DNR sightings database, historical records (McKelvey *et al.*, 2000), and township resolution data on Canada lynx reports from 1971-1974 during a lynx "invasion" (Henderson, 1978). The number of lynx reports from a township was not given in the Henderson report, only the presence or absence of a occurrence in a township.

	Cook, Lake, and St. Louis Counties	Minnesota	Percent in Cook, Lake, and St. Louis Counties
Incidental Take	23	29	79
Sightings Database	310	403	77
Historical Records	164	351	47
1971-1974 Reports	65	107	61
Estimated 1971-1974[a]	192	256	75

[a] Estimated 1971-1974 assumes reports in townships to the south and west were individuals, while reports in NE MN townships represent multiple occurrences. Further analysis of this data is possible if the original data still exists.

Hypothesis: Lynx population biology can be compared to bobcat population biology in Minnesota

If population biology of lynx and bobcats is similar enough, it would be possible to use the population model used for bobcats in Minnesota now to estimate lynx populations in Minnesota in the past. This indirect estimate of historical population size of lynx in Minnesota can be derived by applying ratios from the model used to simulate bobcat population trends in Minnesota to historical lynx harvest data. The estimated population size of bobcats was 2,800 in spring 2006 and 4,100 in Fall 2006 (Erb 2007), with a harvest of about 1,000 bobcats (about 36% of the spring population and 24% of the fall population). Kitten production of adult females was 2.9 (Erb 2007), similar to kitten production of lynx in Minnesota (Moen *et al.,* 2008b). Historically, the average lynx harvest in Minnesota was 177, and we can hypothesize that the relationship between harvest and population size is similar for bobcat and lynx. If we assume that 36% of the historical lynx population could be harvested each year, then there would have been about 177 ÷ 0.36 = about 500 lynx present in Minnesota each spring. If reproduction were similar in all years, there would be 177 ÷ 0.24 = about 740 lynx in the Fall. However, in years with “invasions” there would probably be less reproduction, and the predicted number of lynx in the fall would be lower.

This simple calculation does not take into account the increased harvest of lynx from Ontario during “invasion” years. If we assume that half of the lynx harvested in Minnesota were “invading” lynx, there would still be a spring population of about 250 lynx (half of 500) on average during the period from 1929 to 1969 in Minnesota. Coincidentally, this is similar to a previous estimate of about 200 – 250 lynx being supportable by present habitat conditions in Minnesota (Moen *et al.*, 2008b) and also the estimate based on land area (Page 11).

Susceptibility to human-caused mortality

In this section I attempt to provide a context for causes of mortality in Canada lynx. The radiotelemetry study documented that lynx can live to be at least 5 years old in Minnesota, and that about 75% of mortalities of radiocollared lynx were related to humans (Moen *et al.,* 2008b). Human-caused mortality is often the largest cause of death of *Lynx* spp. In Norway, 81% of known deaths of *L. lynx* were associated with humans (Andren *et al.*, 2006). In Spain, at least 85% of Iberian lynx (*L. pardinus*) deaths were human-caused (Rodriguez & Delibes, 2004). In Switzerland, human-related mortality of *L. lynx* was 70% (Breitenmoser-Warsten *et al.*, 2007). Bobcats (*L. rufus*) are another *Lynx* species that is hunted and trapped in Minnesota which showed a high level of human-caused mortality. Of 14 known mortalities in a radiotelemetry study, 71% were legal harvest, 14% were illegal harvest, and 14% were non-human related (Fuller *et al.*, 1995).

In some cases human-related mortality is not the largest cause of death in *Lynx* spp. Differences could be due to reporting bias, human access, or biological conditions. In the Maine radiotelemetry study preliminary results were that 33 out of 60 radiocollared lynx had died by the end of 2006 (Vashon *et al.*, 2007). Of these deaths, 12 were due to starvation, 5 from predation, 3 were illegally taken, 4 were legally harvested in Canada, and 8 died of unknown causes. This means that 7 of 24 (28%) of known mortalities were human-caused in Maine when lynx were a protected species.

For Canada lynx (*L. canadensis*) causes of mortality vary with stage of the snowshoe hare cycle and with accessibility of an area to humans (Poole, 2003). During lows in the hare cycle starvation can be an important cause of mortality if lynx are not trapped. In one study 80% of radiocollared lynx were trapped in a single year (Bailey *et al.*, 1986). Trapping-caused mortality was much lower (8 to 31%) when mortality estimates were based on population modeling from harvest data in Alberta (Brand & Keith, 1979) instead of from survival of radiocollared animals.

Lynx are easy to trap relative to other species (Mowat *et al.*, 2000; Poole, 2003). Lynx caught in the Mech (1977, 1980) study were caught in traps set for wolves. Incidental take in Minnesota that was reported in the last few years has often occurred with target species being red fox (*Vulpes vulpes*) or coyotes (*Canis latrans*). However, there are probably also more trappers targeting red fox and coyotes than other species. Trapping effort is one potential data source for increased understanding of lynx population dynamics in Minnesota that has not been fully analyzed.

There is no evidence that lynx in Minnesota would be less susceptible to human-caused mortality. Half of the 14 animals radiocollared in the 1970's were shot or trapped and all recorded mortalities were associated with humans (Mech, 1980). At that time lynx could be taken all year without restriction because they were not classified as a game animal until 1975 in Minnesota (Henderson, 1978). From 1971 to 1974 there were 125 documented lynx mortalities in Minnesota (Henderson, 1978). Car kills accounted for 4% of the mortality and the rest of mortality was split evenly between trapping and shooting. Lynx were not hunted as a specific target species. Lynx that were shot appeared to be taken opportunistically by grouse hunters, deer hunters, or landowners. Behavior is one reason why lynx can be opportunistically shot: many of the sightings reported to the lynx hot line indicate the animal stood or sat instead of running off.

Unreported mortality may be partially responsible for low lynx densities in Minnesota. Emigration may also be a cause of low lynx densities. The effects of either factor on lynx densities in Minnesota cannot be answered definitively without further research.

The Future of Canada lynx in Minnesota

Our results generally support the presence of a resident population of Canada lynx in Minnesota during the 1900's, and generally reject the hypothesis that lynx are in northeastern Minnesota only because of periodic "invasions" from Ontario. The historical record assembled by the MN DNR (Henderson, 1978), density estimates from Minnesota and adjacent Ontario, genetic documentation of individuals (Moen *et al.*, 2008b), reproduction, age of lynx, animal condition, and survival of lynx with radiotelemetry collars all indicate conditions are currently suitable for lynx to be residents of northeastern Minnesota. The lack of recruitment into the adult population does not support the hypothesis of a resident population. Because kittens survive through the summer and into winter, there may be reasons for lack of recruitment other than low food resources.

Lynx also periodically "invade" Minnesota from the adjacent Canadian provinces when the snowshoe hare population crashes. In past decades the "invasion" resulted in increased harvest of lynx in Minnesota, and also increased harvest of lynx in Ontario. Harvest peaks in Canadian provinces indicate that "invading" lynx are harvested in the provinces as well as in Minnesota. These invasions could augment the lynx population in Minnesota if invading lynx survived, but whether lynx could persist as a standalone population in Minnesota without invasions has not been tested (and probably cannot be tested).

There is a biological population of lynx that moves across a political boundary without consideration of the management implications and legal issues that are being raised because a species has the southern edge of its range straddling the U.S.-Canada border. Movement data from the radiotelemetry project (Moen et al., 2008b; Moen et al., *In prep.*) indicate that at least some lynx move freely across the border between Ontario and Minnesota each year. If generalizations can be drawn from small sample sizes, then two can be made: (1) male lynx tended to move between Ontario and Minnesota from 0 to 4 times per year with movements of 50 – 100 km, and (2) if female lynx moved, they move 150 to 200 km once and then did not return to Minnesota. There were no radiocollared lynx in Ontario from which we might have picked up a movement from Ontario to Minnesota.

A listing decision at the state level is sure to cause some controversy, just as there are varying opinions on the desirability of listing the Canada lynx as a threatened species under the ESA at the federal level. There may be parallels with the listing of wolves under the ESA in the 1970's, but with less vocal polarization. I have presented the results of the Canada lynx study at least 50 times. These presentations have been at public Critical Habitat Meetings, at professional meetings, and to groups as diverse as the Duluth Audubon Society, the Minnesota Trappers Association, and the Sigma Xi society chapter in Rochester, Minnesota. It is clear that some people support lynx as a resident species of the state of Minnesota, others support lynx presence but without the legal context of laws and regulations associated with the ESA, and some others would prefer that there were no lynx in Minnesota. Motivations for these feelings are based on economics and emotions. For some there is a fear of critical habitat designation by the FWS. For others, there is the desire to see lynx in their natural habitat, or to just know that lynx are present.

It seems like a natural place to start would be to let the state listing process proceed. There are clear statements in the law as written (Appendix 1) that provide guidance to the process. I recommend that the process be carried out from a cooperative rather than an antagonistic perspective, and that litigation be avoided. It would benefit lynx, the listing process, and the critical habitat designation process to consider facts and consequences from a logical rather than an emotional perspective. Some readers can probably remember issues surrounding the ESA listing of the gray wolf in the 1970's. Reasonable accommodations on all sides would be more likely to result in a win-win situation for both humans and lynx than an adversarial relationship in the courts. For example:

1. Trapping. Causes of mortality were evenly split between trapping and hunting in the 1970's in Minnesota (Henderson, 1978). This does not mean that trapping and hunting will come to an end in northeastern Minnesota if Canada lynx are a listed species at both the state and federal level. The ITP plan being written by the MN DNR (DelGiudice *et al.*, 2007) is an example of accommodation required by law. Furbearer regulations could be further modified to reduce the risk of lynx incidental take even more, and trappers could even work to limit incidental take as a matter of professional pride.

2. Incidental Shooting. A proactive campaign to reduce or eliminate incidental shooting could be beneficial. An example of this is an article on the radiotelemetry project that appeared in White-tales, the publication of the Minnesota Deer Hunters Association, just before the 2008 deer season (Moen, 2008). Another example is including information about lynx in the MN DNR hunting regulations.

3. Development. Designation of Critical Habitat was ordered by courts. Critical Habitat actually adds little additional protection to Canada lynx. While this seems to be a paradox, it is true. Other sections of the ESA requiring consultation with the FWS are already triggered without Critical Habitat Designation whenever federal funds or federal agencies are involved in a project. Because both consultations are habitat-based and use the same input data, there really is little additional protection added by the Critical Habitat designation.

4. Logging. Education would also help to correct some misperceptions that persist about lynx. One misperception is that lynx can be used to shut down logging in northeastern Minnesota. Results of the telemetry project, and lynx biology actually support exactly the opposite conclusion! In parts of northeastern Minnesota logging is creating the early successional forests that snowshoe hare live in. Without logging or other forest disturbances, the prey resource that lynx depend on would not be present. One consideration with logging is that there must be some conifer regeneration in harvested sites to provide cover for snowshoe hare.

5. Wilderness. Some of the original research indicated that lynx were dependent on mature forests, but later research indicates that lynx are more flexible in habitat requirements (Murray *et al.*, 2008). There is also perhaps a romanticized notion that lynx are shy animals that cannot co-exist with humans. It may be more appropriate to say that lynx can survive in the wilderness, but they are also adaptable enough to survive in areas where humans are present.

6. Tourism. The plant and animal species assemblages in northeastern Minnesota are unique, and a main component of the tourism industry is seeing and experiencing what cannot be seen elsewhere in Minnesota. Lynx could be further developed as one of the "charismatic megafauna" species along with wolves and moose to enhance the tourism industry in northeastern Minnesota.

A model for the way forward could be the Moose Advisory Committee which was convened by the MN DNR with support from the Minnesota Legislature. With a combination of education and regulation, there could be benefits to all stakeholders interested in Canada lynx. Biologically, there is evidence for Canada lynx being a resident of northeastern Minnesota. Ultimately, it is the citizens of Minnesota and the U.S. that will determine whether lynx persist in Minnesota. Education and regulation can provide the basis for decisions to be made that can be broad in scope, such as an agency charged with implementing the law, or narrow in scope, such as when an individual carrying a gun sees a Canada lynx.

Website, Public Involvement, and Canada Lynx Sightings

The lynx project website at www.nrri.umn.edu/lynx continues to serve as a conduit of information for interested professionals and the general public. Lynx sightings can still be reported to the NRRI toll-free "hotline" (800-234-0054) or by email (lynx@nrri.umn.edu). Some of the sightings reports include pictures that have been included on the project website.

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Shedd, and Steve Mighton with the USFS. Dr. Michael Nelson, of the USGS BRD, has obtained almost all of the aerial locations while locating moose, deer, and wolves for other studies, with recent locations by Al Buchert (MN DNR) through in-kind assistance from Mike Schrage (Widlife Biologist, Resource Management Division, Fond du Lac Band of Lake Superior Chippewa) . Dr. Pat Zollner with North Central Research Station of the USFS helped by providing GPS collars. David Danielsen was a part of the project from 2003 to 2006. Steve Loch is no longer associated with this project but he worked for the project in 2004 and put in many hours as a Forest Service volunteer. Hard work by students, interns, volunteers, and technicians have helped bring this project to its current level. Funding support for the project (also on project website) has been provided by the U.S. Forest Service, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the University of Minnesota Duluth, the Natural Resources Research Institute, Defenders of Wildlife, the Minnesota Department of Natural Resources, the National Council on Air and Stream Improvement, Inc., Potlatch Forest Holdings, Inc., the Minnesota Zoological Garden in Apple Valley, the Minnesota Trappers Association, and several individuals who donated funds through the project website.

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Appendix 1. Minnesota Listing Rules Website Links

These are links to the Minnesota State laws relevant to listing of species as Endangered, Threatened, or Species of Special Concern. The links are included here in case anyone would like to see the actual text of these laws:

https://www.revisor.leg.state.mn.us/statutes/?id=84.0895

https://www.revisor.leg.state.mn.us/rules/?id=6134

(relevant rules within this chapter are 6134.0100-0400)

https://www.revisor.leg.state.mn.us/rules/?id=6212

(relevant rules within this chapter are 6212.1800-2300)

Appendix 2. Deliverables Listing

Deliverables for DNR Supplemental Funding:

1. Continue to obtain relocations for all currently radioed animals. We obtained locations on animals with functioning radiocollars 32 times during the 5 month contract period of 5/1/08 to 9/30/08
2. Trap and radiocollar additional animals as practical, given availability of transmitters and personnel for obtaining relocations. Contract period began just at parturition date so we did not trap in the early portion of the contract period. There were no lynx reports during the contract period that would have been feasible to trap on.
3. Collect tissue samples for genetic analyses from all trapped animals. Not applicable given Results from Objective 2.
4. Obtain genetic analysis of samples that are potentially Canada lynx. Not applicable given Results from Objective 2. We did assist in obtaining genetic analysis of a lynx incidentally killed near Rochester, MN.
5. Investigate possible reproductive events as evidenced by telemetry results. We attempted to investigate den site of L31 in May 2008. As discussed in report above, her collar failed or she left the area just prior to parturition.
6. Conduct snowshoe hare pellet counts to continue monitoring prey availability in 2008. This was done and is briefly reviewed in this report, as well as in the final report for the first phase of the project (Moen et al. 2008).
7. Prepare manuscripts for submission in peer-reviewed journals. We have a paper on blood chemistry accepted into the Journal of Wildlife Diseases pending minor revisions. We also have four additional manuscripts nearly ready for submission or resubmission:

   Moen, R., J. Rasmussen, C.L. Burdett, and K. Pelican. 2010. Hematologic and serum chemistry values of Canada Lynx in Northern Minnesota. Journal of Wildlife Diseases *in press*.

   Palakovich Carr, J.A., R. Moen, and G. Niemi. *In revision*. Interpreting activity counts in GPS collars worn by Canada lynx.

   Burdett et al. *In revision*. Fine scale winter habitat selection of Canada lynx. Chapter 2 of dissertation which will be submitted to journal to be decided.

   Moen, R.A., M.E. Nelson, C.L. Burdett, and G.J. Niemi. Long-distance movements of GPS collared Canada lynx. To be submitted to Journal of Mammalogy or Canadian Journal of Zoology.

   McCann et al. *In preparation*. Density of hare pellets in different cover types in Minnesota. Chapter 2 of M.S. thesis which will be submitted to Ecological Modelling.

   Moen, R. and C. Burdett. 2009. Den sites of radiocollared Canada Lynx in Minnesota 2004-2007. NRRI Technical Report No. NRRI/TR-2009-07.

   Minor revisions made on:

   Hanson, K. and R. Moen. 2008. Diet of Canada lynx in Minnesota estimated from scat analysis. NRRI Technical Report No. NRRI/TR-2008-13.

8. Prepare report for submission on 12/31/08. This is the report.

Appendix 3. Release Notes

Release 1.1 was completed 3/14/2010.

Added cover picture which will be standard on reports for the future

Changed “Natural Mortality” to “Probable Natural Mortality”, see Table 2.

Changed numbers and text associated with Table 7.

Alternative interpretations are possible in determining cause of death. By classifying as “Probably Natural Mortality” we are changing the level of certainty. Even if the causes of mortality on some individual animals were altered, there would be no effect on general conclusions regarding causes of death at the level of the project.

Therefore, alternative interpretations or changes made in Release 1.1 do not affect conclusions originally presented in Release 1.0.

Occasional typographical errors were also corrected.

For those that are interested, Release 1.0 is still available for download from the website.