Canada Lynx in the Great Lakes Region

2005 Annual Report
to
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and
MN Cooperative Fish and Wildlife Research Unit
and
Minnesota Department of Natural Resources

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Executive Summary

We summarize the third year of a project on Canada lynx ecology in the Great Lakes region. The project is designed to address four major questions about this population of Canada lynx: distribution, habitat use, abundance, and persistence. In the first 33 months of this project we captured and deployed radiotelemetry collars on 32 Canada lynx. Each animal was located approximately biweekly after being collared when logistically feasible.

GPS collars have been deployed on 12 of the lynx in this project. Over 12,000 locations were obtained from GPS collars at the end of 2005. GPS collar locations will be fundamental to understanding movements and habitat use of Canada lynx. Ambient temperature and animal activity level is recorded by the collars indicating daily patterns in activity, and also shows how active an animal was when each GPS location was obtained.

Radiocollared females have had kittens in 2004 and 2005, and at least 5 of the 12 kittens known from den visits in 2005 survived until December 2005. Of the 2004 litters, 1 and possibly 2 of the known offspring were alive at the end of 2005. Of the 32 lynx radiocollared by December 31, 2005, 2 died in 2003 and no animals were recovered dead in 2004. We recorded the deaths of 14 radiocollared animals in 2005, one of which had died in 2004.

We finished the third year of surveys for snowshoe hare, the major prey species of Canada lynx. Permanent pellet plots were established throughout the SNF for snowshoe hare. Plots were distributed based on stratified random, systematic, and selective site selection strategies. Many stratified random plots had few or no pellets. The highest pellet density over two years of pellet surveys occurred in young red pine and young upland black spruce cover types. A mark-recapture experiment will make it possible to estimate density of snowshoe hares from pellet plots.

We continue to use the project website (www.nrri.umn.edu/lynx) to provide information to biologists and the general public. The website gets over 1,000 page requests per day. This website is a historical record of the project, lists project goals and accomplishments, and gives information and pictures of each lynx. The annual reports and other publications on the project are or will be available for download. Trail camera images were added to the website in 2005.

We begin the report with a brief chronological summary of Canada Lynx ecology in the Great Lakes region. The project has been supported by several agencies with some common deliverables and some deliverables that varied among agencies. To produce a cohesive, logically organized annual report, we describe the project in its entirety, and we indicate specific deliverables in Appendix 1. We first describe Canada lynx trapping and the deployment of radiotelemetry collars. The radiotelemetry program is very important because each of the major deliverables depends on telemetry data. Next, we address progress made on each of the major questions: 1) distribution, 2) habitat use, 3) abundance, and 4) persistence. Prey species surveys and other aspects of the project are also summarized.

We conclude main sections with the current status and future plans for each topic. Some of the questions will require several years of data collection which was built into the project master plan. With the number of Canada lynx now radiocollared and the number of locations available, data collected on this project were used to assist in management decisions in 2005.

Table of Contents

List of Figures

List of Tables

Introduction

Canada lynx (*Lynx canadensis*) was listed as a threatened species under the U.S. Endangered Species Act (ESA) in April 2000. The ESA provides for the conservation and recovery of listed species, directing all federal agencies to utilize their resources to carry out programs for the conservation of listed species, and to consult with the U.S. Fish and Wildlife Service (USFWS) to ensure that their actions do not jeopardize the continued existence of any listed species. Being listed as a threatened species creates a legal obligation to increase understanding of the ecology and natural history of the species throughout the conterminous U.S. range of lynx. Federal agencies, including the U.S. Forest Service (USFS), the National Park Service (NPS), and the USFWS must follow provisions in the ESA, the National Forest Management Act (NFMA), and the National Environmental Policy Act (NEPA) when management decisions could impact Canada lynx.

Under NEPA the actions of all federal agencies are analyzed to fully disclose the expected impacts to the environment such that an informed decision can be made. Without this study, analysis of the effects of proposed management actions in the Great Lakes region under NEPA might have been based on insufficient information because most studies on the ecology of lynx have been conducted in the western U.S. and Canada, which differs in climate, landscape, topography and vegetation. This project has begun allowing management and recovery efforts to use data that has been collected on lynx in the Great Lakes portion of the U.S. lynx population instead of assuming that results of studies done in other regions apply here.

Canada lynx populations in the lower 48 states were previously identified as western Great Lakes, eastern, and western populations (McKelvey et al. 2000, Ruggiero et al. 2000). Historically, Minnesota had the highest numbers of lynx among the states in the western Great Lakes population. Harvest data document the persistence of a lynx population in Minnesota through most of the 20th century (Henderson 1978, Loch and Lindquist, unpubl. manuscript). Yet relatively little is known about Canada lynx in Minnesota. The only previous estimates of home range size and demographic statistics on lynx in Minnesota are from a single field study in which 14 animals were radiocollared as part of an ongoing study on wolves (Mech 1980).

In the 33 months that have elapsed since obtaining regulatory approval for this project, 27 adult and yearling lynx and 5 individuals known to be kittens have been captured and radiocollared. Information that will contribute most effectively to the recovery and conservation of lynx in the Great Lakes region includes:

1. Distribution,
2. Habitat use and requirements,
3. Abundance, and
4. Monitoring the long-term persistence of the lynx population.

These needs could be subsumed under a more general heading of understanding the biology and ecology of Canada lynx in Minnesota and other states in the Great Lakes region. Work by the USFS, NRRI, and MN DNR has provided background information on distribution, a necessary precursor to determining abundance. Persistence of the Canada lynx population in this region can be addressed with genetic analyses and long-term monitoring. Habitat use is being determined with snow tracking, VHF telemetry, and GPS collar locations.

Literature Review

The Canada lynx is a medium-sized felid found in the boreal forests of Canada and the northern United States. Lynx populations increase and decrease with populations of the snowshoe hare (*Lepus americanus*) over an approximate 10-year period (Elton and Nicholson 1942, Keith 1963, Krebs et al. 2001). Throughout this predator-prey cycle, lynx populations lag 1-2 years behind hare populations (Brand et al. 1976, Poole 1994, Slough and Mowat 1996, O'Donoghue et al. 1997). Lynx occur at a density of less than 3 / 100 km^2 during periods of hare scarcity in northern Canada, but rebound to densities over 30 / 100 km^2 during peak hare years (Poole 1994, Slough and Mowat 1996).

Much of the past research on lynx has been conducted in Alaska and Canada, providing a large amount of comparative literature that can be used to efficiently increase knowledge of lynx ecology in the contiguous 48 states. This is helpful because little was known about lynx ecology in the contiguous U.S. at the time of federal listing of the Canada lynx under the Endangered Species Act (Ruggiero et al. 2000). As late as 2000, there were only seven studies in the contiguous 48 states that focused on lynx ecology, and two of these had bobcats as the primary species of interest (Squires and Laurion 2000). Lynx populations in southern areas seem to have characteristics similar to lynx populations in northern areas during lows in the lynx-hare cycle (Koehler 1990), driven by the relatively low hare densities in both cases.

There are at least three ongoing studies of lynx in the contiguous U.S. outside of Minnesota that began just prior to lynx being listed as threatened under ESA. These studies are still in progress, and information is available as annual reports (Vashon et al. 2002, Vashon and Crowley 2003, Crowley and Vashon 2004, McLellan and Crowley 2005), publications in chapters and popular magazines (Squires and Laurion 2000, Todd 2003), and websites (e.g., http://wildlife.state.co.us/species_cons/lynx.asp). The study in Montana has resulted in over 50 lynx being radiocollared, with about 30 animals being maintained in recent years (Squires and Laurion 2000). The study area is in the mountainous region of northwestern Montana. The collection and genetic analysis of hair and scat samples for identification of individual lynx was pioneered during this study (Schwartz et al. 2002), as was the development of the snow-tracking protocol for the National Lynx Survey (Squires 2002).

We use methods similar to those used in Montana and Maine to obtain basic information that we can then compare directly to results from those states, although portions of our study differ because of differences in technology and management focus. Both Minnesota and Maine have southern boreal forest vegetation with many of the same tree species. Both areas are managed in part for timber harvest, although Maine forests are mainly privately owned, while most of the Minnesota study area is public land or public land with inholdings. Conditions encountered by lynx in Minnesota are probably more similar to conditions encountered by lynx in Maine than in Montana.

A large part of the current project is based on VHF and GPS telemetry, which makes it possible to determine habitat use and requirements of Canada lynx. Telemetry work also provides basic ecological information on distribution, abundance, residency, movement patterns, reproduction, and survival of lynx. At the end of 2004 we had about 3,000 GPS collar locations of lynx (Moen et al. 2004) while by the end of 2005 we had about 12,000 GPS collar locations (see below). Telemetry locations are augmented by snow tracking to provide insights into characteristics of habitats that lynx are using for movement and foraging. Tissue, scat, and hair samples collected from captured lynx and while snow tracking will provide baseline data for the question of persistence of the Canada lynx population in Minnesota.

Capture, Handling, and Radiocollaring of Canada Lynx

Trapping Methods

The trapping methods that we employ draw from protocols that have been used to capture and process over 75 Canada lynx on the Maine and Montana lynx research projects (Squires and Laurion 2000, Vashon et al. 2002). On the Minnesota lynx project we have used these techniques during more than 50 capture events. We have found it possible to capture lynx in both winter and summer in box traps. Traps are checked within 24 hours of being set. Records of trap setup and effort at each trap location are documented.

Captured lynx are anaesthetized by injection with a pole-syringe while the animal is in the box trap. Drug dosage follows standard protocol (Kreeger et al. 2002), and allows a 30-40 minute handling time. During processing, a hood or towel is placed over the head to protect the eyes. The rectal temperature is periodically monitored while the animal is under anesthesia. We began monitoring pulse rate and respiration in fall 2004. Anesthetized lynx are kept warm in cold weather with chemical hand warmers, blankets, and/or sleeping bags throughout handling. Antibiotics are injected intramuscularly prior to release. Data collected on captured animals includes sex, estimated age, body mass, and morphological measurements. Genetic material was collected from blood samples placed on Whatman filter cards, and a few hairs were collected as a reserve genetic material. Each animal is fitted with either a VHF collar (Vashon et al. 2002) or a GPS radiotelemetry collar before release.

Few non-target species were trapped in 2005. Incidental catch was reduced compared to previous years because we only used box traps and because we used trail cameras and other signs (e.g., tracks in snow) prior to setting traps. Non-target species that were incidentally trapped in 2005 included fisher (*Martes pennanti*), marten (*M. americana*), domestic dog (*Canis familiaris*), and a gray jay (*Perisoreus canadensis*). A bobcat (*Lynx rufus*) that was trapped in 2005 was radiocollared.

Trap Locations and Captures

In 2005 we had at least 1,036 trap nights in 175 different days of trapping (Table 1). Canada lynx were caught throughout the year. As in past years, we divide the trapping effort into three separate phases: (1) from January to April before kittens are born; (2) from July to November when there was no snow on the ground; and (3) December when there was snow on the ground. Snow is important because it allows us to search for tracks and set traps based on lynx locations.

The winter trapping season begun in January 2005 continued until early April 2005, 14 new animals were radiocollared. Animals were also retrapped to replace the GPS collar batteries, for a total of 27 captures (with processings) during this time period (Table 1). Traps were placed in the general areas of Isabella, Ely, Tofte, and Grand Marais (Fig. 1). Trapping in the first winter period resulted in about 1 lynx capture per 23 trap nights including all recaptures, or 1 lynx capture per 30 trap nights if all recaptures that were released without processing are excluded. This occurred when more than one lynx was in an area we were trapping and a previously captured lynx entered a trap.

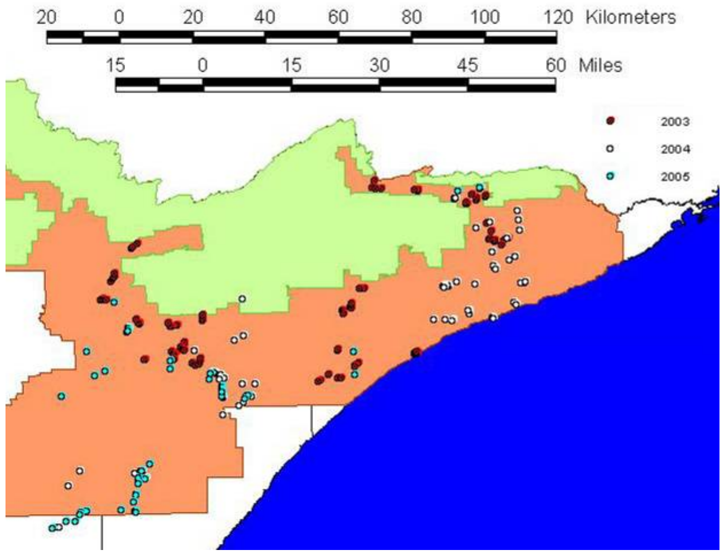
Table 1. Minimum trapping effort in and near Superior National Forest in 2005 from January 1 to December 31, 2005. Effort is broken down into three periods based on the type of trapping and the basis for trap locations, with counts representing minimum numbers for days trapped and trap nights.

	January to April	July to November	December	Total
Days trapped	110	45	20	175
Trap nights	789	190	72	1,036
Traps / day	7	4	4	6
Lynx processed	27	2	2	31
Lynx released w/o processing	8	1	0	9
Other species	15	5	0	39
Lynx / 100 Trap nights	3.4	1.1	2.8	3.0

Summer/fall trapping began in September, 2005 when L07's GPS collar began signaling in recovery mode, indicating that GPS locations were no longer being collected. From September until November 2005, with no snow cover on the ground, we retrapped and replaced GPS collars on L05 and L07. We attempted to retrap and replace GPS collars on L06, L13, and L14 but were not successful. Trapping effort was focused on the Isabella, Bassett, Babbitt, and Brimson areas. Trapping in the snow-free period resulted in about 1 lynx capture per 63 trap nights including all recaptures, or 1 lynx capture per 95 trap nights if all recaptures that were released without processing are excluded (Table 1).

In December 2005, with snow on the ground, L43 was recaptured and her kitten collar was replaced with a GPS collar, and L49 was captured near Isabella. Trapping was focused on the Isabella, Ely, and Bassett areas in December. Trapping in December resulted in 1 new lynx and 1 recapture and collar replacement, with 1 lynx capture per 36 trap nights (Table 1). There were no recaptures of non-targeted lynx during this time period.

Figure 1. Locations of Canada lynx traps in and near Superior National Forest in 2003 to 2005. Brown areas indicate Superior National Forest, and green areas are the Boundary Waters Canoe Area Wilderness.



In 2005 10 female and 5 male lynx were captured and radiocollared (Table 3), for a total of 13 male and 19 female Canada lynx fitted with radiotelemetry collars since the project began in 2003. Two male bobcats and 1 female bobcat have also been captured and fitted with radiotelemetry collars through 2005. Captures in 2005 were new captures, recaptures to download GPS collar data, or recaptures to place GPS collars on animals that had previously worn a VHF collar. Capture locations were similar to past years in extent, from Brimson to the Gunflint Trail, with some extensions beyond trapping locations used in the past (Fig. 1). For example, traps were set near Babbitt, and farther south from Isabella than we have set traps in previous years. Trapping effort was again lower than in 2003 based on trap-nights (Table 2), because increased effort was placed on the pre-trapping phase.

Table 2. Trapping effort in and near Superior National Forest in 2004 from January 1 to December 31, 2004. Effort is broken down into three periods based on the type of trapping and the basis for trap locations, with counts representing minimum numbers for days trapped and trap nights. Direct comparison to 2003 trapping effort is not valid because of different methods.

	2003	2004	2005
Days trapped	177	164	175
Trap nights	2,732	2,066	1,036
Traps / day	15	13	6
Lynx processed	13	21	31
Lynx released w/o processing	5	9	9
Other species	66	39	20
Lynx / 100 Trap nights	0.5	1.0	3.0

Table 3. A brief description of 15 Canada lynx and 1 bobcat on which radiotelemetry collars were newly deployed in 2005. Each lynx is referred to in the report by the ID indicated here. Additional details on each animal, including those radiocollared in 2003 and 2004, are on the project web site (www.nrri.umn.edu/lynx).

ID	Date	Sex	Description
L26	Jan 08	F	Captured west of Babbitt, MN. This 11 kg female was fitted with a VHF collar.
L27	Feb 19	F	Captured north of Two Harbors, MN. This 5 kg female was fitted with a kitten-sized VHF collar.
L19	Mar 01	F	Captured in the Sullivan Lake area, L19 was a 6 kg female that we had ear-tagged as a kitten. She was fitted with a kitten-sized VHF collar.
L28	Mar 01	M	Captured near Isabella, MN. L28 was an 11 kg male that was fitted with a VHF collar. He was recaptured a month later and fitted with a GPS collar.
L29	Mar 02	F	Captured east of Ely, MN. L29 was an 8 kg female who was fitted with a VHF collar. She died within 24 hours of being released.
L17	Mar 08	F	Captured in the Sullivan Lake area, L17 was an 8 kg female that we had ear-tagged as a kitten. She was fitted with a kitten-sized VHF collar.
L30	Mar 09	F	Captured along the Gunflint Trail, L30 was a 9 kg female who was fitted with a VHF collar.
L31	Mar 10	F	Captured north of the Sullivan Lake area, L31 was fitted with a VHF collar.
L32	Mar 11	F	Captured along the Gunflint Trail, L32 was a 10 kg female who was fitted with a VHF collar.
L33	Mar 19	M	Captured west of Babbitt, MN, L33 was a 10 kg male who was fitted with a VHF collar.
L34	Mar 23	M	Captured near Brimson, MN, L34 was a 10 kg male who was fitted with a VHF collar.
L36	Apr 02	M	Captured south of Isabella, MN, L36 was a 5 kg male that we originally thought was a son of L14, the den we were not able to visit in the spring of 2004. He was fitted with a kitten-sized VHF collar.
L20	Apr 03	F	Captured near Brimson, MN, L20 was a 7 kg son of L13 who was fitted with a kitten-sized VHF collar.
L35	Apr 09	M	Captured south of Isabella, MN, L35 was a 12 kg male who was fitted with a VHF collar.
L49	Dec 18	F	Captured south of Isabella, MN, L49 was a 10 kg female who was fitted with a VHF collar.
B03	Feb 07	M	Captured near Brimson, MN, B03 was a 9 kg bobcat who was fitted with a VHF collar.

Because we began placing adult-sized VHF collars on individuals originally handled as kittens in a den ("Kxx" designation in previous reports), we renamed all lynx so that they have a "L" designation. For example, L17 originally was called K02 at the densite and in past annual reports. Appendix 2 gives a cross-reference of old and new names.

Den Site Visits and Kittens

2005 was the second year of the project in which we were able to monitor females during the denning season. Parturition occurs in early May. Localization of positions in early May indicate that a female has denned. The ideal time to visit a den is about 4-5 weeks after parturition mark each kitten with an ear tag. We visited each den when kittens were about five weeks old. During den visits we weigh kittens, take morphological measurements, obtain a blood sample for DNA analysis, and ear tag each kitten for later identification. Three of the 4 females (L7, L13, and L14) had denned in the previous year, and a fourth radiocollared female (L31) also had a den in 2005.

One female, L26, localized southeast of Ely for about 2 weeks in early May, 2005, but soon after that she began moving again. We believe that L26 lost her kittens to unknown causes. Two other females, L30 and L32, were radiocollared along the Gunflint Trail in far northeastern Minnesota. During the denning season they were in Ontario. We made two searches in Ontario and did not find kittens or a densite. Based on these movements, we believe that these females did not have litters with them in mid to late June of 2005.

There were 12 kittens at the 4 dens visited in 2005 (Fig. 2). L7's den was visited on June 3, 2005. We found 3 kittens in her den, the same number found in 2004. L13 had 4 kittens at her den, which was visited on June 2, 2005. There were 2 kittens at L14's den site, which was visited on June 7, 2005, and there were 3 kittens at L31's den site, visited on June 6, 2005. Vegetation measurements were taken at each den after the mother and kittens had left it and we were certain they were not going to return.

Sightings reports over the summer indicated that at least 2 of L13's kittens survived into September of 2005 and that all 3 of L07's kittens survived through December 2005. It is possible that L31 was seen with kittens in August 2005 (may have been L07 with kittens, their ranges overlap) but by December 2005 L31 did not have any kittens with her. The transmitter on L14's collar failed in late summer and we have no subsequent sightings reports of L14.

Figure 2. Images of kittens and den sites from the 2005 denning season. (a) handling kittens at L07 den site, (b) kittens of L07 in 2005, (c) den of L13 in 2005 was in the tangled branches of a downed tree, and (d) kitten of L14 in 2005 on leg after DNA sample collected. Additional images of the kittens and den sites are available on the project website (www.nrri.umn.edu/lynx).

Future Plans

Areas near Isabella, Brimson, Babbitt, Bassett, and Ely are being trapped this year. Lynx are present in the Grand Marais / Gunflint Trail area, but they are too far away to regularly monitor with VHF collars. One future direction this research project could go is understanding how lynx move across the border between Ontario and Minnesota, and how much time is spent in each country. Movements differ between males and females based on data that is already collected. We will keep GPS collars actively collecting data to the extent possible. We plan to replace GPS collars with VHF collars on known individuals. VHF collars will last for several years, and we will be able to continue monitoring survival of these animals.

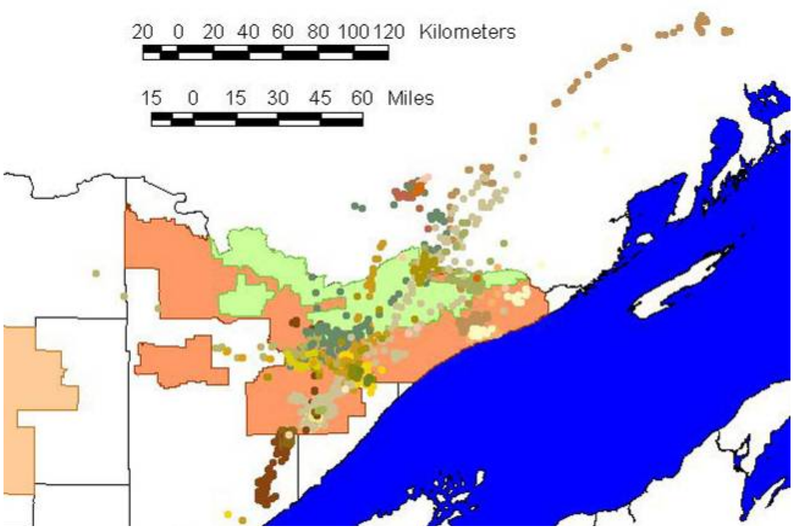
Location and Distribution

Telemetry locations were used to determine the location and distribution of Canada lynx wearing VHF telemetry collars and GPS collars. Locations of lynx were also obtained from snow-tracking and reports of sightings by USFS personnel and the general public.

Radiotelemetry and GPS collar Locations

We used aerial telemetry and ground-based telemetry to obtain animal locations. Almost all of the aerial locations were obtained by Dr. Michael Nelson (USGS, wolf-deer project out of Ely). Locations were determined with a GPS unit on board the plane after the animal was located. Ground-based telemetry was done by project crew members. It was logistically difficult to obtain locations simultaneously with two observers (Squires and Laurion 2000), but we did use as short an interval as possible between triangulation locations. Ground-based telemetry locations were calculated with LOAS v. 2.10 (Ecological Software Solutions, www.ecostats.com).

Figure 3. VHF and GPS telemetry locations of lynx captured in this study as of 12/31/05. Each animal is color coded with a different symbol. Many locations are obscured by other locations at this map scale. Brown areas indicate Superior National Forest, and the green area is the Boundary Waters Canoe Area Wilderness within the Superior National Forest.



Captured lynx have been located from the northeastern tip of Minnesota west to Little Fork, MN (Fig. 3). The southernmost location of a radiocollared lynx is of L19, who moved from Brimson to near Twig, approximately 16 miles northewest of Duluth, before being shot. We also do not know how far into Ontario some of these animals may have gone because it is cost-prohibitive to fly into Ontario regularly. Thus, the locations shown represent minimum distances over which radiocollared animals have ranged. General locations of individual animals are available on the project website (www.nrri.umn.edu/lynx).

Male and Female Home Range Sizes

Male lynx range more widely than female lynx (Fig. 4b). Females with kittens tended to have an even smaller area of use than females without kittens (Fig. 4a). The home ranges of adult females with kittens tended to be smallest, while males had the largest home ranges (Table 4). Females with kittens did not move far in any season, maintaining site fidelity in relatively small areas (Fig. 5).

Figure 4. Examples of 50% and 95% kernel home ranges for radiocollared Canada lynx. Kernel home ranges are essentially contour maps showing areas representing a percentage of an animal's home range. The smallest home ranges (a) are used by females with kittens. Intermediate size home ranges are usually from smaller females and males, while larger home ranges such as those in (b) are from adult males.

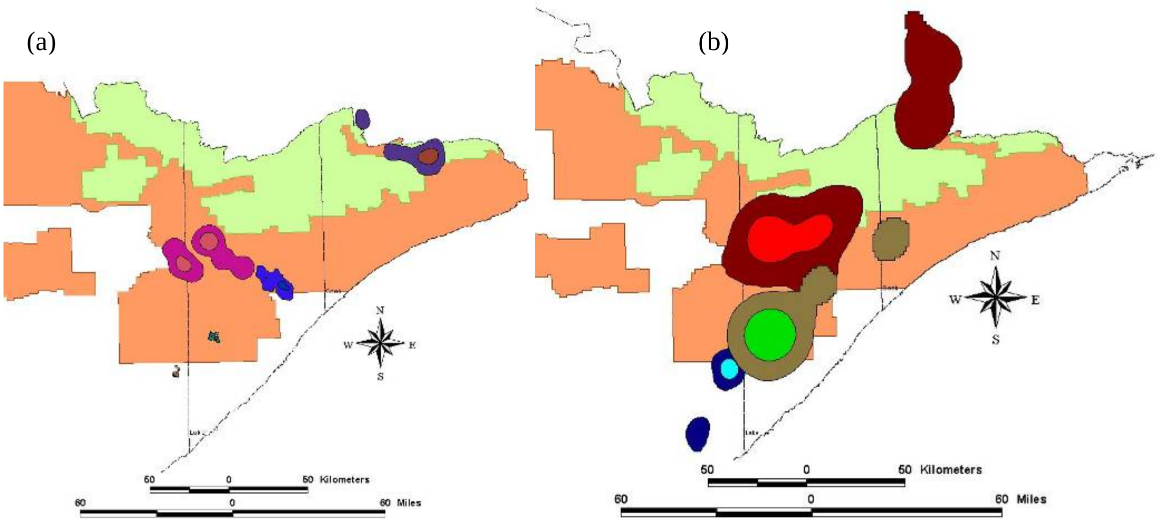
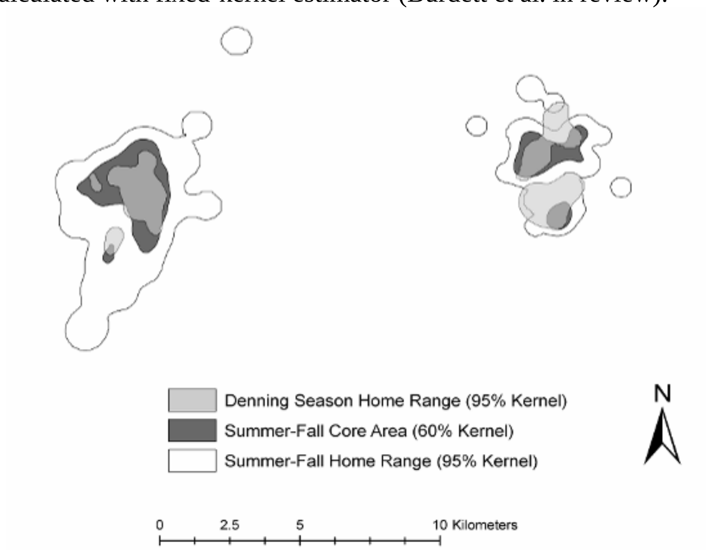


Figure 5. Overlap among snow-free season 95% home range, 60% summer-fall season core area, and 95% denning season home range for two reproductive female lynx in northeastern Minnesota, 2004-2005. Home ranges and core area calculated with fixed-kernel estimator (Burdett et al. in review).



Home range size of male lynx in Minnesota may be larger than other reported home range sizes. The weighted mean home range size of other studies is 87 km^2 (Table 4), much smaller than the 307 km^2 home range size of males in this project. In contrast, the 68 km^2 weighted mean home range size of females in other studies is much greater than the 21 km^2 home range of females in this project. Methodological differences limit direct comparisons among studies. Most studies, including this project in Minnesota, have had < 5 animals collared, making home range sizes in the Poole (1994) and Slough and Mowat (1996) studies influential in the calculation of weighted means.

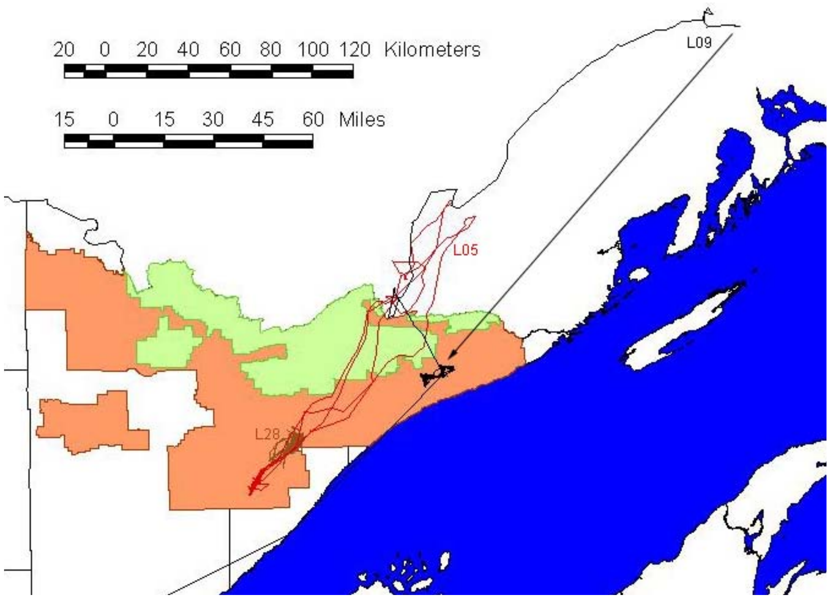
Table 4. Mean home range sizes (km^2) for Canada lynx. Home range size from literature estimates of past projects. Comparisons should be interpreted with caution due to differences in methodologies and analyses.

Males	Mean	Range	Animals collared	Reference
NWT	31	3 - 68	30	Poole 1994
Yukon	76	12 - 498	46	Slough and Mowat 1996
Alberta/B.C.	277	224 - 357	3	Apps 2000
Alaska	424	64 - 783	2	Bailey et al. 1986
Washington	69	56 - 99	5	Koehler 1990
Montana	238	20 - 534	5	Squires and Laurion 2000
Wyoming	137	-	1	Squires and Laurion 2000
Minnesota	194	145 - 243	2	Mech 1980
Minnesota	307	96 - 439	5	This project
All studies	*87*			*Weighted mean of all males*
Females				
Yukon	29	7-43	2	Ward and Krebs 1985
NWT	32	7-91	24	Poole 1994
Yukon	79	3 - 775	51	Slough and Mowat 1996
Alberta/B.C.	135	44 - 276	3	Apps 2000
Alaska	70	25 - 70	2	Bailey et al. 1986
Washington	39	38 - 41	2	Koehler 1990
Montana	115	15 - 164	3	Squires and Laurion 2000
Wyoming	114	-	1	Squires and Laurion 2000
Minnesota	87	51 - 122	2	Mech 1980
Minnesota	21	12 - 23	2	This project
All studies	*21*			*Weighted mean of all females*

Long Movements By Males and Females

Some adult males make long-distance moves of at least 40 to 80 km (Fig. 6). The time before return to their normal areas in Minnesota could be months in the case of L12 and L15, or days in the case of L06. For the first time we had a GPS collar on a male who made a long-distance movement, L05 twice went into Ontario in the summer of 2005 (Fig. 6). Other animals, such as L09, moved north and then returned, whereas some (e.g., L01) were legally harvested by trappers in Ontario.

Figure 6. Long-distance movements of Canada lynx wearing GPS collars. L05 is an adult male who made 2 trips into Ontario in 2005, L28 is an adult male who did not make long-distance movements, and L09 was a younger female whose GPS collar functioned during the trip north but stopped recording GPS locations before she returned to Minnesota.



Survival and Mortality

After 2 deaths of radiocollared lynx in 2003, and 1 death in 2004, there were 11 deaths in 2005. The increase in mortalities is partly due to having more animals radiocollared. At the end of 2004 17 lynx had been radiocollared and about 20% were dead, while at the end of 2005 32 lynx had been radiocollared and about 40% were dead. Through 2004 only 1 of 17 collared lynx was known to be less than 2 years old, while at the end of 2005 5 of 32 collared lynx were known to be less than 2 years old. Mortality of young animals was high, 3 of 5 were dead by the end of 2005. Thus, the increase in mortality in 2005 was due to several factors: the age structure of the collared population; a larger collared population; and also a higher rate of mortality. There were 0.6 deaths per 1,000 radiocollar days in 2004 compared to 1.3 deaths per 1000 radiocollar days in 2005. Causes of death were varied, although many deaths could be related to humans in some way (Table 5).

Table 5. Current status of all radiocollared lynx in this project. If status is unknown it is because the collar appears to have stopped transmitting. 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.

ID	Date collared	Days collared	Status	Date of Death	Comments
L01	03/14/03	257	Dead	11/26/03	Legally trapped in Ontario
L02	03/14/03	768	Dead	04/20/05	Hit by car near Isabella, MN
L03	08/28/03	53	Dead	10/20/03	Unknown but human involvement suspected, collar recovered west of Cook, MN
L04	09/14/03	186	Unknown		Televilt GPS collar not recovered
L05	09/23/03	830	Alive		
L06	12/09/03	753	Unknown		Lotek GPS collar, transmitter failure
L07	12/10/03	752	Alive		
L08	01/09/04	630	Dead	09/30/05	Non-human caused mortality in Ontario
L09	01/09/04	287	Dead	10/22/04	Incidentally caught in trap in MN
L10	01/13/04	505	Dead	06/01/05	Unknown but human involvement suspected, near Brimson, MN
L11	02/12/04	688	Alive		
L12	02/24/04	676	Alive		
L13	03/25/04	646	Unknown		Lotek GPS collar, transmitter failure
L14	03/29/04	642	Unknown		Lotek GPS collar, transmitter failure
L15	03/31/04	640	Alive		
L16	11/29/04	150	Dead	04/28/05	Hit by train in Minnesota
L17	03/08/05	604	Alive		
L19	03/01/05	246	Dead	11/02/05	Shot in Minnesota
L20	04/03/05	103	Dead	07/15/05	Unknown but human involvement suspected, west of Brimson, MN
L21	n/a	0	Dead	12/28/05	Incidentally caught in snare in MN
L24	10/02/04	119	Dead	01/29/05	Non-human caused mortality in Minnesota
L26	01/08/05	357	Alive		
L27	02/19/05	255	Dead	11/01/05	Unknown, bones found south of Grand Marais with radiocollar
L28	03/01/05	305	Alive		
L29	03/02/05	1	Dead	03/03/05	Unknown, died with 24 hours of release after radiocollaring.
L30	03/09/05	297	Alive		
L31	03/10/05	296	Alive		
L32	03/11/05	295	Alive		
L33	03/19/05	287	Alive		
L34	03/23/05	223	Dead	11/01/05	Probably illegal kill in Ontario, collar recovered under ice, belting was cut with knife
L35	04/09/05	266	Alive		
L36	04/02/05	604	Alive		
L49	12/18/05	13	Alive		

Habitat Use

From the 32 lynx that have been radiocollared, we have about 12,000 GPS telemetry locations and about 800 VHF telemetry locations from which to infer habitat use. Habitat use in last year's annual report indicated about 40% of use based on the 50% and 95% home range MCP was in brushy cover types (Moen et al. 2004). GPS collar data already collected shows its value in better understanding habitat use. For example, we can compare the cover types in the home range (an area) with the cover types identified from GPS collar locations (a point estimate) as in Table 6. In the denning period, the surrounding area and the 50% MCP both had about 12% of the area in shrub cover types, and 71% of the 50% MCP was the aspen/white birch cover type (Table 6). However, the GPS collar locations showed a much different picture of habitat use, with about 40% of locations in shrub cover types, and only 27% in the Aspen/White Birch cover type.

Table 6. Proportional utilization of different cover types by Canada lynx L07 from December 2003 to March 2004. The satellite imagery and cover type definitions are from the LULC satellite imagery and the animal locations were taken with a Lotek GPS collar. The listed cover types comprise 82 to 95% of area in these sites.

Cover Type	Surrounding Area	Area in den site 50% MCP	Den site GPS collar	Winter Area in 50% MCP	Winter GPS collar
Grassland	0	0	2	0	1
Upland Shrub	**5**	**5**	**19**	**7**	**15**
Lowland Deciduous Shrub	**7**	**6**	**20**	**6**	**14**
Water	3	0		2	
Sedge Meadow	1	0	1	0	1
Jack Pine	6	0		1	4
Red Pine	4	1		3	1
White Pine mix	0	0	1	0	0
Balsam Fir mix	5	1		3	7
Upland Black Spruce	1	0	1	0	0
Lowland Black Spruce	**10**	**7**	**16**	**7**	**4**
Stagnant Black Spruce	4	4	8	4	4
Tamarack	1	1	3	1	1
Lowland Northern White-Cedar	3	1	1	2	1
Aspen/White Birch	**45**	**71**	**27**	**62**	**45**
Red/White Pine-Deciduous mix	4	1	2	1	0

Future Plans

GPS collar data gives habitat use on a fine temporal and spatial scale. The first chapter in Christopher Burdett's dissertation has been submitted (Burdett et al. in review), other chapters are being written developing models of resource utilization functions that address habitat use in a predictive manner.

Abundance

At this point we are still able to consider abundance from the perspective of the minimum number of individuals that have been identified. Since 2002, over 70 individual lynx have been identified in Minnesota from DNA analysis. In the final report for this project we will analyze the number of individuals identified each year. It is impossible to identify all of the Canada lynx in Minnesota, however. There are some animals that we attempted to radiocollar but to date have failed to trap. There are also other lynx sightings that have been reported that are likely not collared animals, either because pictures were taken of the animal, reports from individuals that saw the animal, or because we know the locations of radiocollared animals.

Persistence

Persistence in the context of this project is the ability of the Canada lynx population present in Minnesota to persist through a complete lynx-hare cycle. Data collected in the first few years of this project will help determine whether the population does persist at low densities during the low in the lynx-hare cycle. Demographic data from collared animals will allow us to predict survival and fecundity of the Canada lynx population and build initial population models. Continuous observations of lynx would support the concept of persistence, but only genetic data or telemetry locations will make it possible to confirm presence of the same individuals in Minnesota over time.

The question of persistence is important because it is unknown whether lynx are present at low population densities during lows in the lynx-hare cycle. It is possible that lynx are sometimes extirpated from Minnesota during the lows in the lynx-hare cycle and then recolonize from Ontario. Even 33 years ago the appearance of lynx in Minnesota during highs in the lynx-hare cycle was hypothesized to result from dispersal of lynx from Canada into Minnesota (Mech 1973). Genetic evidence suggests that at least some of this dispersal results in gene flow between widely separated lynx populations (Schwartz et al. 2002). The dispersal hypothesis does not require that lynx be extirpated from Minnesota during lows in the lynx-hare cycle.

Persistence of the lynx population can be determined over a multi-year period. However, we should be able to use information from genetic analysis of hair, scat, blood, and tissue samples and survival of collared individuals to provide an initial estimate of persistence. An existing collection of genetic samples collected under the auspices of Superior National Forest can be used as a starting point (Loch and Lindquist, unpubl. manuscript). NRRI project personnel will ship over 25 Canada lynx tissue, scat and hair samples collected in 2005 for analysis, and other scat, hair, and tissue samples will be sent to the Carnivore Genetics Laboratory by SNF personnel. In the short-term, at least, there appears to be the potential for persistence because reproduction and survival of kittens has been documented in this population.

Future Plans

We will continue to collect scat, hair, and tissue samples for genetic analysis. By the end of this year we should have enough genetic samples analyzed when the historic data samples are included so that we can at the very least develop a genetic picture of the existing Canada lynx population in the SNF, including parent-offspring relationships.

Website, Public Involvement, and Canada Lynx Sightings

The lynx project website at www.nrri.umn.edu/lynx, continues to generate positive support for the project, and serve as a conduit of information for interested professionals and the general public. The Canada lynx site continues to be one of the most visited websites on the NRRI server, receiving over 1,000 page requests per day in 2005. We do not monitor unique visitors, so we do not know if this is many people looking at a few pages, or a few individuals thoroughly looking at the site. Whichever is the case, the site is relatively heavily used. Lynx sightings are still being reported to the NRRI toll-free “hotline” (800-234-0054) or to an email address established because it would be easy for members of the public to remember (lynx@nrri.umn.edu). Some of the sightings included pictures that have been included on the project website.

The SNF and NRRI continued to jointly issue press releases on the lynx project in 2005. In addition, several other sightings of Canada lynx were reported by USFS personnel—in some cases USFS personnel had seen the animal themselves, in other cases the sighting had been reported by the public. Some of the sightings reports were used as locations to set up scent stations and traps for Canada lynx, and three of the sightings ultimately resulted in the radiocollaring of a study animal. Sightings that have been reported to NRRI address are forwarded to the Minnesota D.N.R. sightings database (link on www.nrri.umn.edu/lynx) and followed up on by DNR personnel.

Future Plans

We will continue to receive lynx sightings at the lynx “hotline” and on the lynx email address. These sightings will be used to continue building the Canada lynx sightings database, and may also be used to help determine where and when to put trapping effort.

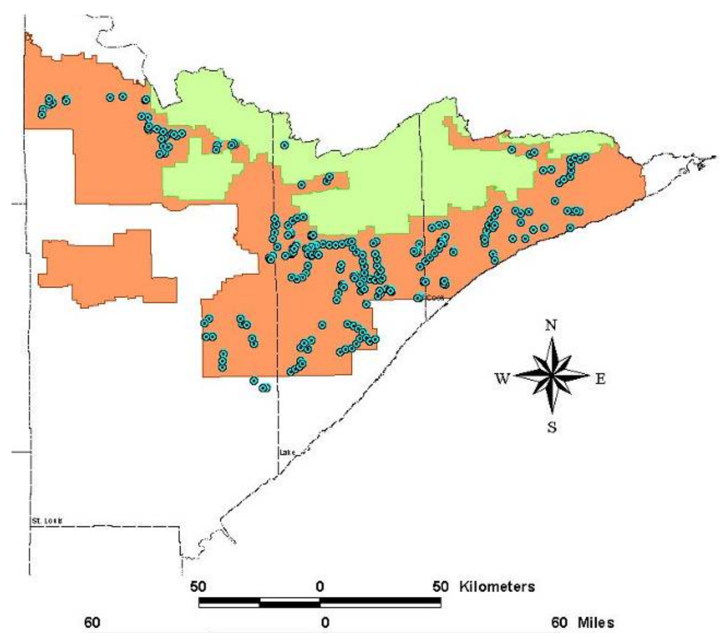
Prey Species Surveys

The primary prey of Canada lynx in this geographic region is snowshoe hare (Aubry et al. 2000). Nick McCann, a M.S. student at the University of Minnesota Duluth will be calibrating pellet counts with actual snowshoe hare density for his project. Grouse, other small mammals and carrion seem to be less important components of the lynx diet (Aubry et al. 2000), although project personnel have found at least one kill of ruffed grouse (*Bonasa umbellus*). We continue to conduct surveys for snowshoe hare to develop an index for estimating prey availability. Data collected on prey species abundance will be analyzed independently of lynx data, and will also be a part of Canada lynx habitat analyses.

Hare Pellet Survey

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). Plots were permanently marked with a reinforcing bar (rebar) stake at 3/8" diameter and revisited each May-June for the duration of the project. All fecal pellets within the plot boundary were counted and removed. 50% of the pellets found directly on the plot boundary were counted (McKelvey et al. 2002). Vegetation obscuring pellets was moved but pellets deeply incorporated into the organic layer of the forest floor were not counted.

Figure 7. Hare pellet survey plots established in the SNF on existing plots that are surveyed every spring. Brown areas indicate Superior National Forest, and green area is the Boundary Waters Canoe Area Wilderness.



Snowshoe hare pellet plots were placed throughout the SNF. Over 180 permanent transects were established in the spring of 2003 following the methods described above. An additional 54 transects were established in the spring of 2004. Hare pellet plots were randomly placed in habitats according to availability as part of an existing plot network (Hanowski and Niemi 1994, 1995), systematically placed in known lynx home ranges, or selectively placed in habitats with a high snowshoe hare density. This plot placement provided a broad overview of hare density in SNF, a basis for comparison to hare density in areas where Canada lynx had an established home range, and also a basis for comparison in an area that had high hare density based on human observations.

Hare presence is patchy in SNF when considered on the random availability of habitats. As in past years, about 90% of hare survey pellet plots did not have hare pellets. While negative information, this is useful because it suggests there are cover types that are not likely to be used by Canada lynx, and also because it identifies cover types where Canada lynx are more likely to be present based on prey density. Hare pellet plots are cleared every year that they are run (McKelvey et al. 2002). The total pellet count per transect was highest in 2004, and similar in 2003 and 2005. If hare numbers are declining then pellet counts should be lower in 2006.

Snowshoe hare pellet density can also be examined based on cover type and stand age. The highest hare pellet counts have been found in cover types that were defined as red pine pole and saw timber, jack pine saw timber, and upland black spruce regeneration (Table 7). The pellet plots will be repeated this spring, and we will determine whether hare densities are consistently highest in these cover types. Pellet counts were highest in younger red pine and black spruce stands in both years, and there were a few shifts that may be due to movements by the hare population. For example, the Aspen-White spruce pole timber and Jack Pine saw timber cover types had higher numbers of pellets in 2003, and then no pellets in 2004 or 2005. In 2005 the bigtooth aspen cover type suddenly had high numbers of pellets, indicating that hares may have moved into this area. However, because this increase is due to 5 plots on one transect, extrapolation to all examples of this cover type is not warranted.

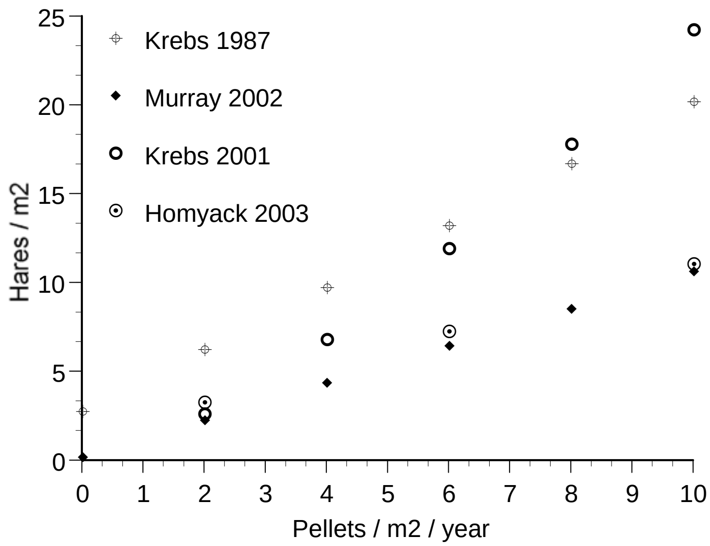
Table 7. Snowshoe hare pellet densities per plot index. The number of plots and density of snowshoe hare pellets (pellets / m^2) in each of the cover types in the randomly-located plots that were stratified on the basis of habitat availability. The top 25% of pellet counts are indicated by bolded text. The number of plots is approximate (some plots are not completed in some years).

Cover type	Stand Age	~ *n*	2003	2004	2005
Aspen/white spruce	pole	5	**1.00**	0.00	0.00
Bigtooth aspen	saw	5	0.00	0.00	**9.00**
Black spruce	pole	20	0.10	0.00	0.00
	saw	5	0.00	0.00	0.00
Cedar	pole	5	0.00	0.00	0.00
	saw	20	0.70	0.00	0.00
Fir/aspen/PB	regeneration	20	0.45	0.05	0.00
	pole	45	0.33	0.08	0.00
	saw	30	**1.13**	**0.50**	**1.97**
Jack pine	regeneration	30	**0.63**	**0.42**	**0.19**
	pole	20	0.30	0.15	0.00
	saw	10	**3.40**	0.00	0.00
Maple/beech	saw	5	0.00		0.00
Mixed swamp conifer	pole	15	0.00	0.29	**1.00**
	saw	10	0.00	0.00	0.00
Open		5	0.00	0.00	0.00
Paper birch	pole	25	0.20	0.04	0.00
	saw	5	**0.20**	**1.00**	0.00
Quaking aspen	regeneration	85	**0.98**	**0.84**	0.03
	pole	30	0.07	0.07	0.00
	saw	45	0.49	0.00	0.09
Red pine	regeneration	9	**0.78**	**0.63**	**0.17**
	pole	5	**6.00**	**6.00**	**0.60**
	saw	35	**2.80**	**0.43**	**0.37**
Sugar maple	pole	10	0.00	0.00	0.00
	saw	5	0.00	0.00	0.00
Upland black spruce	regeneration	5	**7.40**	**9.80**	**7.00**
	pole	5	0.00	**0.40**	0.00
White pine	pole	10	0.80	**1.10**	**0.50**

Relationship Between Pellet Density and Snowshoe Hare Population Density

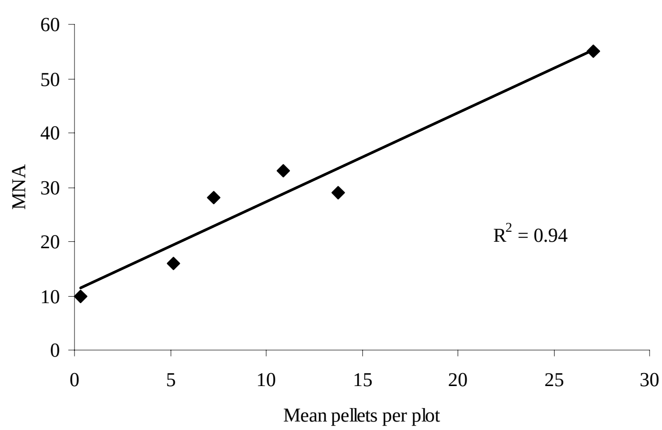
Correlations between snowshoe hare fecal pellet density and snowshoe hare mark-recapture population estimates have been demonstrated in several areas (Fig. 8) in Canada and the northern U.S. (Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002, Litvaitis et al. 1985). Pellet density increases with hare density, and we expect that a similar relationship exists in northern Minnesota. Fecal pellets were counted from sixty $1m^2$ plots at ten 13.25-hectare sites in Fall 2004, Spring 2005, Fall 2005, and will be Spring 2006. Sites that were selected fell within or near known Canada lynx use-areas that were identified by radio-locations from collared lynx within the SNF.

Figure 8. Relationship between pellet density and snowshoe hare population density in published literature. Ongoing work will determine where the Superior National Forest snowshoe hare population regression line would fit.



Mark-recapture efforts were conducted in 2005 at six of these sites and each site was trapped for 8-10 days. Overall, 170 individual snowshoe hares were marked and released and 298 recaptures were recorded. An additional mark-recapture period is planned in February--March of 2006 at 5 study sites. Preliminary results indicate a strong relationship between fecal pellet density and the minimum number of snowshoe hares utilizing each site (Figure 9).

Figure 9. The relationship between spring 2005 mean fecal pellet counts and the minimum number of snowshoe hares alive in winter 2005 at six SNF study sites. Five additional points will be added in 2006.



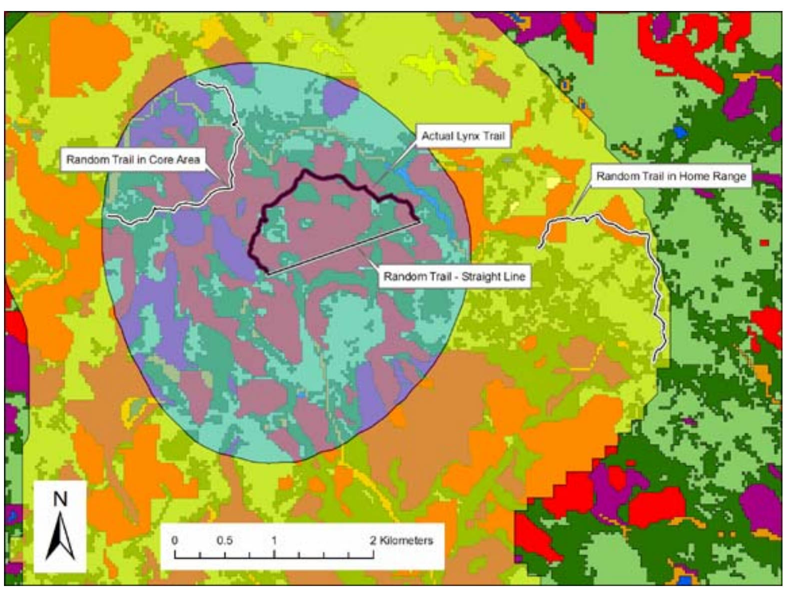
Snow Tracking

Snow Tracking Individual Animals

GPS telemetry locations and VHF telemetry locations are typically made at intervals of hours to days. These point locations indicate where an animal was, but provide no information on the path it took to get from one location to another. Even within a 6-hour interval between GPS collar locations there will be different activities. This is one reason to record movement trails of lynx through the snow with a GPS unit. We recorded 41 trails totaling over 60 km on 8 lynx wearing GPS collars. Trail distances varied from 508-3364 m (mean = 1716, S.D. = 765).

These trails were buffered by 25 m to calculate variables depicting the composition (cover-type) and configuration (edge density, number of patch types) of habitat along our lynx movement paths. Analysis will contrast actual lynx trails to multiple random trails created at a hierarchy of spatial scales. Spatial scales include the straightline distance between actual start and endpoints of a trail and multiple random trails distributed in the core area, the 95% home range (Burdett et al. *in review*), and outside the home range (Fig. 10). We will use matched pairs case-control logistic regression to model the habitat selected by lynx along their movement paths.

Figure 10. Sample analysis procedure for a lynx snow track. Cover type and other habitat characteristics will be compared for the trail, a straight-line between start and end points, and randomly placed trails in the core area, the home range, and outside of the home range.



Projects and Cooperative Studies

In addition to informal cooperation with other lynx projects, we have begun more formal collaboration with three other collaborators. Dr. Pat Zollner, with the North Central Research Station at Rhinelander, Wisconsin, is working on very fine-scale movement patterns of the GPS collared animals. Kerry Fanson, a PhD student out of Purdue University, is studying the utility of fecal hormone analysis. We also tested the activity counters in the Lotek GPS collars on captive lynx at the Wildlife Science Center in Forest Lake, Minnesota (www.wildlifesciencecenter.org).

Graduate Students

Three graduate students on the project will be completing several manuscripts in 2006. Chris Burdett, Ph.D. student in the Conservation Biology Program on the Twin Cities campus of the University of Minnesota has completed one chapter (Burdett et al. in review) and will be writing 2 more manuscripts in 2005. Nick McCann, an M.S. student in the Biology Department at the University of Minnesota Duluth will be writing 2 manuscripts, one on mark-recapture population estimates of snowshoe hare and correlation with pellet counts, and a second on the interpretation of pellet counts throughout northeastern Minnesota (Table 7 in this report). Julie Palakovich, also an M.S. student in the Biology Department at the University of Minnesota Duluth, will be writing one manuscript on validation of activity counts in GPS collars against lynx activity, and a second manuscript interpreting lynx activity in relation to habitat type in northeastern Minnesota.

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We would also like to thank the many individuals who have reported sightings or helped the project in other ways. In addition, some individuals have contributed greatly to this research project. Project management assistance was provided by Ed Lindquist 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. Dr. Pat Zollner with North Central Research Station of the USFS helped by providing GPS collars. David Danielsen has been a part of the project since 2003. Steve Loch worked for the project in 2004, and also 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, and Defenders of Wildlife. In 2005 support was also received from the Minnesota Department of Natural Resources with a Section 6 U.S. Fish and Wildlife Service grant, the National Council on Air and Stream Improvement, Inc. and Potlatch Corporation.

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Appendix 1. Deliverables Listing

The funding agreement between FWS Coop Unit and NRRI required an annual report in which progress made on identified topics was reviewed. Progress made is in this annual report. Other deliverables were met by actions during the first year of the project but are not listed here. For example, the purchase of a freezer in 2003 and the use of project personnel and NRRI facilities for use as a temporary storage facility for lynx carcasses and/or body parts was called for in the agreement between the Fish and Wildlife Service and the University.

A second funding agreement between the USFS and NRRI required an annual report in which progress made on identified topics was reviewed. There was some overlap between the deliverables for Agreement 1 (1.x in the table below) and Agreement 2 (2.x in the table below).

A third funding agreement between the Minnesota Department of Natural Resources and NRRI adds deliverables which are also described in this report. These deliverables are associated with radio telemetry directly (2.1) and indirectly with 1.1, 1.2, and 1.3 in the table below. A second deliverable of winter track surveys was partially designed in 2005, and then implemented in 2006.

1.1	Location and distribution	Reviewed in annual report in the Radiocollaring section (p. 4) and also in the Location and Distribution section (p. 10). Portions also covered in the Lynx Sightings section (p. 17).
1.2	Persistence	Reviewed in annual report in the Persistence section (p. 16).
1.3	Habitat use	Reviewed in annual report in the Habitat Use section (p. 18).
1.4	Prey species surveys	Reviewed in annual report in the Prey Species Surveys section (p. 18).
2.1	Capture and radiocollaring of lynx	Reviewed in annual report in the Capture and Radiocollaring of lynx section (p. 4).
2.2 2.3	Locations and suitable lynx habitat Development of lynx sampling framework	Reviewed in annual report in the Location and Distribution section (p. 10). Portions also covered in the Lynx Sightings section (p. 17) and the Snow Tracking section (p. 22).

Appendix 2. Numeric designation of lynx

Animals with the "K" designation (for kitten) were renamed prior to this annual report with an "L" designation. We will no longer use "K", all lynx will be identified with an L designation. This table provides a cross-reference for the old and new names. "B" indicates bobcat.

Change	New Name	Old Name	Date Radiocollared	Sex
	B01	B01	03/26/04	F
	B02	B02	03/29/04	M
	B03	B03	02/07/05	M
	L01	L01	03/14/03	M
	L02	L02	03/14/03	M
	L03	L03	08/28/03	F
	L04	L04	09/14/03	M
	L05	L05	09/23/03	M
	L06	L06	12/09/03	M
	L07	L07	12/10/03	F
	L08	L08	12/11/03	F
	L09	L09	01/09/04	F
	L10	L10	01/13/04	M
	L11	L11	02/12/04	F
	L12	L12	02/24/04	M
	L13	L13	03/25/04	F
	L14	L14	03/29/04	F
	L15	L15	03/31/04	M
Yes	L16	K01	11/29/04	F
Yes	L17	K02	03/08/05	F
Yes	L19	K03	03/01/05	F
Yes	L20	K05	04/03/05	F
	L21[a]		12/28/05	M
	L24	L24	10/02/04	F
Yes	L25[b]	L10		
	L26	L26	01/08/05	F
	L27	L27	02/19/05	F
	L28	L28	03/01/05	M
	L29	L29	03/02/05	F
	L30	L30	03/09/05	F
	L31	L31	03/10/05	F
	L32	L32	03/11/05	F
	L33	L33	03/19/05	M
	L34	L34	3/23/2005	M
	L35	L35	4/9/2005	M
Yes	L36	K04	04/02/05	M
	L49	L49	12/18/2005	F

[a] L21 was a male kitten of L13, he was incidentally caught in a snare by a trapper, not radiocollared.

[b] L25 was actually L10, he was caught after his GPS collar dropped off. Even though we suspected he was L10, we waited for genetic analysis for confirmation.