Colorado Division of Wildlife
July 2009–June 2010

WILDLIFE RESEARCH REPORT

State of:	Colorado	:	Division of Wildlife
Cost Center:	3430	:	Mammals Research
Work Package:	0670	:	Lynx Conservation
Task No.:	1	:	Post-Release Monitoring of Lynx
		:	Reintroduced to Colorado
Federal Aid Project No.	N/A		

Period Covered: July 1, 2009 – June 30, 2010

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ABSTRACT

In an effort to establish a viable population of Canada lynx (*Lynx canadensis*) in Colorado, the Colorado Division of Wildlife (CDOW) initiated a reintroduction effort in 1997 with the first lynx released in February 1999. From 1999-2006, 218 wild-caught lynx from Canada and Alaska were released in Colorado. Post-release monitoring was critical to assess and modify the release protocols as they were implemented to improve the survival of released individuals. Average monthly mortality rate in the reintroduction area during the first year post-release decreased with time in captivity from 0.205 [95% CI 0.069, 0.475] for lynx spending up to 7 days in captivity to 0.028 [95% CI 0.012, 0.064] for lynx spending > 45 days in captivity before release. Under the final release protocol, lynx were held in captivity and fed a high quality diet for a minimum of three weeks before release. Results suggested that keeping lynx in captivity beyond 5 or 6 weeks accrued little benefit in terms of monthly survival. We documented survival, movement patterns, reproduction, and landscape habitat-use through aerial (n = 11,580) and satellite (n = 29,258) tracking. Monthly mortality rate was estimated as lower inside the reintroduction area than outside the reintroduction area, and slightly higher for male than for female lynx, although 95% confidence intervals for sexes overlapped. Mortality was higher immediately after release (first month = 0.0368 [SE = 0.0140] inside the study area, and 0.1012 [SE = 0.0359] outside the study area), and then decreased according to a quadratic trend over time. Given the importance of adult survival in the dynamics of long-lived species, the long-term, high survival rates estimated for the reintroduced lynx both inside (0.9315, SE = 0.0325) and outside (0.8219, SE = 0.0744) the reintroduction area are promising for the establishment of a viable population of lynx in Colorado. From 1999-June 2010, there were 122 known mortalities of released adult lynx. Human-caused mortality factors were the highest causes of death with approximately 29.7% attributed to collisions with vehicles or gunshot. Starvation and disease/illness accounted for 18.6% of the deaths while 37.3% of the deaths were from unknown causes. Reproduction was first documented in 2003 with subsequent successful reproduction

in 2004, 2005, 2006, 2009, and 2010. No dens were documented in 2007 or 2008. Reproduction followed a pattern of good and bad years followed by a return to good years in both the reintroduction area and outside the reintroduction area suggesting there may be a cyclic pattern to reproductive output of lynx in Colorado. If the pattern of annual reproductive and survival parameters estimated to date for lynx within the core reintroduction area would repeat over the next 20 years, the population currently in the core reintroduction area would sustain itself at existing densities. To document the continued viability of lynx in Colorado beyond the reintroduction period, some form of long-term monitoring will be needed. A site-occupancy monitoring program using cost-effective, minimally invasive techniques is currently being developed to estimate the extent, stability and potential distribution of lynx throughout Colorado.

WILDLIFE RESEARCH REPORT

POST RELEASE MONITORING OF LYNX (*LYNX CANADENSIS*) REINTRODUCED TO COLORADO

TANYA M. SHENK

P. N. OBJECTIVE

The post-release monitoring of Canada lynx (*Lynx canadensis*) reintroduced into Colorado emphasized 5 primary objectives:

1. Assess and modify release protocols to ensure the highest probability of survival for each lynx released.
2. Obtain regular locations of released lynx to describe general movement patterns and habitats used by lynx.
3. Determine causes of mortality in reintroduced lynx.
4. Estimate survival of lynx reintroduced to Colorado.
5. Estimate reproduction of lynx reintroduced to Colorado.

Three additional objectives were emphasized after lynx displayed site fidelity to an area:

6. Refine descriptions of habitats used by reintroduced lynx.
7. Refine descriptions of daily and overall movement patterns of reintroduced lynx.
8. Describe hunting habits and prey of reintroduced lynx.

Information gained to achieve these objectives will form a basis for the development of lynx conservation strategies in the southern Rocky Mountains.

SEGMENT OBJECTIVES

1. Complete winter 2009-10 field data collection on lynx habitat use at the landscape scale, hunting behavior, diet, mortalities, and movement patterns.
2. Complete data collection for the pilot study designed to estimate lynx detection probabilities using non-invasive techniques.
3. Complete spring 2010 field data on lynx reproduction.
4. Summarize and analyze data and publish information as Progress Reports, peer-reviewed manuscripts for appropriate scientific journals, or CDOW technical publications (see Appendix I).
5. Complete field research on the post-release monitoring of lynx reintroduced to Colorado and prepare a final report describing status of the lynx reintroduction.

INTRODUCTION

The Colorado Division of Wildlife implemented the largest Canada lynx (*Lynx canadensis*), and one of the largest carnivore, reintroductions programs undertaken to date. Thus, evaluating success of this program is critical, and assessing the methods used may prove useful for other ongoing or future carnivore reintroductions. The reintroduction effort was begun in Colorado in 1997, with the first lynx released in the state in 1999. The goal of the Colorado lynx reintroduction program was to establish a self-sustaining, viable population of lynx in this state. The approach taken to reach this goal was to first establish a viable lynx population within a core reintroduction area in southwestern Colorado. From this core reintroduction area, it was hoped that lynx would remain in this area and disperse on their own into suitable habitat throughout the state. Thus, 218 wild-caught lynx from Canada and Alaska were reintroduced in the core reintroduction area from 1999-2006.

There were 7 critical criteria established for achieving a viable lynx population in Colorado: 1) development of release protocols that lead to a high initial post-release survival of reintroduced animals, 2) long-term survival of lynx in Colorado, 3) development of site fidelity by the lynx to areas supporting good habitat in densities sufficient to breed, 4) reintroduced lynx must breed, 5) breeding must lead to reproduction of surviving kittens 6) lynx born in Colorado must reach breeding age and reproduce successfully, and 7) recruitment must equal or be greater than mortality over an extended period of time. These criteria were evaluated incrementally over time to gauge whether the reintroduction effort was progressing toward success (Shenk and Kahn 2002). All seven criteria have now been met.

STUDY AREA

Byrne (1998) evaluated five areas within Colorado as potential lynx habitat based on (1) relative snowshoe hare densities (Bartmann and Byrne 2001), (2) road density, (3) size of area, (4) juxtaposition of habitats within the area, (5) historical records of lynx observations, and (6) public issues. Based on results from this analysis, the San Juan Mountains of southwestern Colorado were selected as the core reintroduction area, and where all lynx were reintroduced. Wild Canada lynx captured in Alaska, British Columbia, Manitoba, Quebec and Yukon were transported to Colorado and held at The Frisco Creek Wildlife Rehabilitation Center located within the reintroduction area prior to release.

Post-release monitoring efforts were focused in a 20,684 km^2 study area which included the core reintroduction area, release sites and surrounding high elevation sites (> 2,591 m). The area encompassed the southwest quadrant of Colorado and was bounded on the south by New Mexico, on the west by Utah, on the north by interstate highway 70, and on the east by the Sangre de Cristo Mountains (Figure 1). Southwestern Colorado is characterized by wide plateaus, river valleys, and rugged mountains that reach elevations over 4,200 m. Engelmann spruce/subalpine fir is the most widely distributed coniferous forest type within the study area. The lynx-established core area is roughly bounded by areas used by lynx in the Taylor Park/Collegiate Peak areas in central Colorado and includes areas of continuous use by lynx, including areas used during breeding and denning (Figure 1).

METHODS, RESULTS AND DISCUSSION

Development of Release Protocols

Post-release monitoring was critical to assess and modify the release protocols as they were implemented to improve the survival of released individuals (Shenk 1999). Under the final release protocol, lynx were held in captivity and fed a high quality diet for a minimum of three weeks before release. Thus, they were released in good body condition and one could expect that the longer the captivity, the lower the post-release mortality. This final protocol resulted in high initial post-release survival.

Later, detailed analysis of lynx mortality was completed to evaluate how the different release protocols affected mortality within the first year post-release. From this analysis, it was documented that the average monthly mortality rate in the reintroduction area during the first year post-release decreased with time in captivity from 0.205 [95% CI 0.069, 0.475] for lynx spending up to 7 days in captivity to 0.028 [95% CI 0.012, 0.064] for lynx spending > 45 days in captivity before release (Devineau et al. 2010a). The results also suggested that keeping lynx in captivity beyond 5 or 6 weeks accrued little benefit in terms of monthly survival. On a monthly average basis, lynx were as likely to move out (probability = 0.196, SE=0.032) as to move back on (probability = 0.143, SE=0.034) the reintroduction area during the first year after release. Mortality was 1.6x greater outside of the reintroduction area suggesting that permanent emigration and differential mortality rates on and off reintroduction areas should be factored into sample size calculations for an effective reintroduction effort. Our results will be useful in the development of release and post-release monitoring protocols for future lynx, as well as other carnivore, reintroductions.

Long-Term Survival

Viability of a reintroduced population requires long-term survival and site fidelity of individuals to the reintroduction area. Over a 10-year period of the reintroduction effort (1999-2009), monthly mortality rate was estimated as lower inside the reintroduction area than outside the reintroduction area, and slightly higher for male than for female lynx, although 95% confidence intervals for sexes overlapped (Devineau et al. 2010). Mortality was higher immediately after release (first month = 0.0368 [SE = 0.0140] inside the study area, and 0.1012 [SE = 0.0359] outside the study area), and then decreased according to a quadratic trend over time. Given the importance of adult survival in the dynamics of long-lived species, the long-term, high survival rates estimated for the reintroduced lynx both inside (0.9315, SE = 0.0325) and outside (0.8219, SE = 0.0744) the reintroduction area are promising for the establishment of a viable population of lynx in Colorado (Figure 2, Devineau et al. 2010b). The higher mortality outside the reintroduction area may have been influenced by habitat fragmentation, increased road density and more opportunities for human interactions.

From 1999-June 2010, there were 122 known mortalities of released adult lynx. Human-caused mortality factors are currently the highest causes of death with approximately 29.7% attributed to collisions with vehicles or gunshot. Starvation and disease/illness accounted for 18.6% of the deaths while 37.3% of the deaths were from unknown causes. Lynx mortalities were documented throughout all areas lynx used, including 31 (26.3%) occurring in other states.

Reproduction

Reproduction is necessary to achieve a self-sustaining viable population of lynx in Colorado. Reproduction was first documented from the 2003 reproduction season and again in 2004, 2005 and 2006. Lower reproduction occurred in 2006, although a Colorado-born female gave birth to 2 kittens, documenting the first recruitment of Colorado-born lynx into the Colorado breeding population. No reproduction was documented in 2007 or 2008. The cause of the decreased reproduction from 2006 -08 is unknown. One possible explanation would be a decrease in prey abundance. Reproduction was again observed in 2009 with 5 dens and 10 kittens found in Colorado. Litter size was smaller than previously documented with only 2 kittens found in each litter in comparison to a mean of 2.8 found in previous years. In addition, a sex bias towards female kittens was evident in 2009 which was not evident in prior years. Two litters found in 2009 had both parents born in Colorado, resulting in the first documented third generation Colorado lynx from the reintroduction. The percent of females having dens increased in 2010 to 33%, similar to the highest years documented in 2004-2005. The average number of kittens per litter also returned to the previously observed mean of 2.8. Breeding males and females in 2010 included Colorado-born lynx that have established territories and are now contributing to the breeding population.

Reproduction has followed a pattern of good and bad years followed by a return to good years in both the reintroduction area (Figure 3) and outside the reintroduction area suggesting there may be a cyclic pattern to reproductive output of lynx in Colorado. Such a pattern matches the classic Canada lynx-snowshoe hare (*Lepus americanus*) cycle (Elton 1942). Long-term studies spanning an additional10-20 years would be required to document such a cycle in Colorado.

Viability

The current lynx population in Colorado is comprised of surviving reintroduced adults, lynx born in Colorado from the reintroduced animals and their offspring and possibly some naturally occurring lynx. To achieve a self-sustaining, viable population of lynx, enough kittens need to be born and recruited into this population to offset the mortality that occurs and hopefully even exceed the mortality rate to achieve an increasing population. If the pattern of annual reproductive and survival parameters estimated to date for lynx within the core reintroduction area would repeat over the next 20 years, the population currently in the core reintroduction area would sustain itself at existing densities (Figure 4).

FUTURE DIRECTIONS

Research and monitoring efforts over the last 11 years, since the first lynx were released, have focused primarily on monitoring reintroduced animals through VHF and satellite telemetry and estimating demographic parameters of these animals. However, as more of these animals become unavailable for monitoring due to failed telemetry collars, death or movement out of the core reintroduction area, it becomes more difficult to accurately evaluate the status of the entire lynx population in Colorado, including the core reintroduction area.

To document the continued viability of lynx in Colorado beyond the reintroduction period, some form of long-term monitoring will be needed to determine viability for a period of time long enough to encompass possible snowshoe hare cycles. In addition, a challenge facing Colorado Division of Wildlife is how efforts should be allocated between monitoring persistence of lynx that have established within the core reintroduction area and lynx that may be pioneering and expanding into other portions of the state.

A site-occupancy monitoring program using cost-effective, minimally invasive techniques is currently being developed to estimate the extent, stability and potential distribution of lynx throughout Colorado (Shenk 2009, Appendix 2). The primary objectives of this monitoring program would be to document the distribution of lynx throughout Colorado and the stability, growth or shrinkage of this distribution over time, and to identify potential areas lynx may occupy in the future. Minimally invasive techniques (e.g., genetic identification, cameras) would be used to detect changes in lynx persistence and distribution as a foundation for assessing whether lynx continue to persist in Colorado. Such non-invasive techniques are widely desirable because they require minimal impact to the animals and are cost-effective. The protocols developed will also be made available to any other agencies or entities that want to monitor lynx. Methods to extend this monitoring effort to estimate lynx density are currently being pursued.

ADDITIONAL EFFORTS

Additional goals of the post-release monitoring program for lynx reintroduced to the southern Rocky Mountains included refining descriptions of habitat use and movement patterns of lynx once lynx established home ranges that encompassed their preferred habitat. This work is ongoing.

The program also investigated the ecology of snowshoe hare in Colorado. A study comparing snowshoe hare densities among mature stands of Engelmann spruce (*Picea engelmannii*)/subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*) and Ponderosa pine (*Pinus ponderosa*) was completed in 2004 with highest hare densities found in Engelmann spruce/subalpine fir stands and no hares found in Ponderosa pine stands (Zahratka and Shenk 2008). A study to evaluate the importance of young, regenerating lodgepole pine and mature Engelmann spruce/subalpine fir stands in Colorado by examining density and demography of snowshoe hares that reside in each was completed in 2010. Small lodgepole stands supported the highest densities of hares as well as the highest and most consistent recruitment rates. Hares survived best in spruce/fir stands while density and recruitment in these stands were intermediate. Thus, small lodgepole and mature spruce/fir likely provide the most important hare habitat in Colorado; while thinned, medium lodgepole stands appear to be relatively unimportant based on the density and demography measures in this study (J. Ivan, Colorado State University, unpublished data, Appendix 3). However, within the study area, small lodgepole stands occupied only 10% of the area covered by mature spruce/fir, and we suspect a similar pattern statewide. Additionally, the structure provided by mature spruce/fir stands is less transient than that provided by regenerating lodgepole. Thus, while density and recruitment estimates in spruce/fir stands were somewhat inferior to those collected in small lodgepole, the areal coverage and longevity of spruce/fir likely renders it as important, if not more important, to snowshoe hare and lynx management in Colorado as regenerating lodgepole (J. Ivan, Colorado State University, unpublished data, Appendix 3).

Lynx is listed as threatened under the Endangered Species Act (ESA) of 1973, as amended (16 U. S. C. 1531 et. seq.)(U. S. Fish and Wildlife Service 2000). Colorado is included in the federal listing as lynx habitat. Thus, an additional objective of the post-release monitoring program is to develop conservation strategies relevant to lynx in Colorado. To develop these conservation strategies, information specific to the ecology of the lynx in its southern Rocky Mountain range, such as habitat use, movement patterns, mortality factors, survival, and reproduction in Colorado have been and will continue to be provided to regulatory agencies.

SUMMARY

From results to date it can be concluded that the Colorado Division of Wildlife developed release protocols that ensured high initial post-release survival of lynx, and on an individual level, lynx demonstrated they can survive long-term in areas of Colorado. We also documented that reintroduced lynx exhibited site fidelity, engaged in breeding behavior and produced kittens that were recruited into the Colorado breeding population. Following the successful reproduction in 2010, we have now documented that if the population would repeat the reproduction and mortality patterns documented over the last 10 years the lynx population would continue into the future at sustainable numbers. Thus, the final criterion of a successful reintroduction, documenting recruitment necessary to offset annual mortality, is now supported. To build upon the success of this reintroduction effort, effective conservation and management strategies will need to be developed and implemented to ensure the long-term viability of Canada lynx in Colorado.

ACKNOWLEDGEMENTS

The Colorado Lynx Reintroduction Program required the continued efforts of numerous personnel in the Colorado Division of Wildlife, other agencies and the general public. Such sustained dedication has resulted in the successful reintroduction of this species to our ecosystems. Funding for the reintroduction program was provided by Colorado Division of Wildlife, Great Outdoors Colorado (GOCO), Vail Associates, Colorado Wildlife Heritage Foundation, Turner Endangered Species Foundation and the U.S.D.A. Forest Service.

LITERATURE CITED

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Devineau, O., T. M. Shenk, G. C. White, P. F. Doherty Jr., P. M. Lukacs, and R. H. Kahn. 2010. Evaluating the Canada lynx reintroduction programme in Colorado: patterns in mortality. Journal of Applied Ecology 47:524-531.

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Shenk, T. M. 2002. Post-release monitoring of lynx reintroduced to Colorado. Wildlife Research Report, July: 7- 34. Colorado Division of Wildlife, Fort Collins, Colorado.

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U. S. Fish and Wildlife Service. 2000. Endangered and threatened wildlife and plants: final rule to list the contiguous United States distinct population segment of the Canada lynx as a threatened species. Federal Register 65, Number 58.

Zahratka, J. L. and T. M. Shenk. 2008. Population estimates of snowshoe hares in the southern Rocky Mountains. Journal of Wildlife Management 72:906-912.

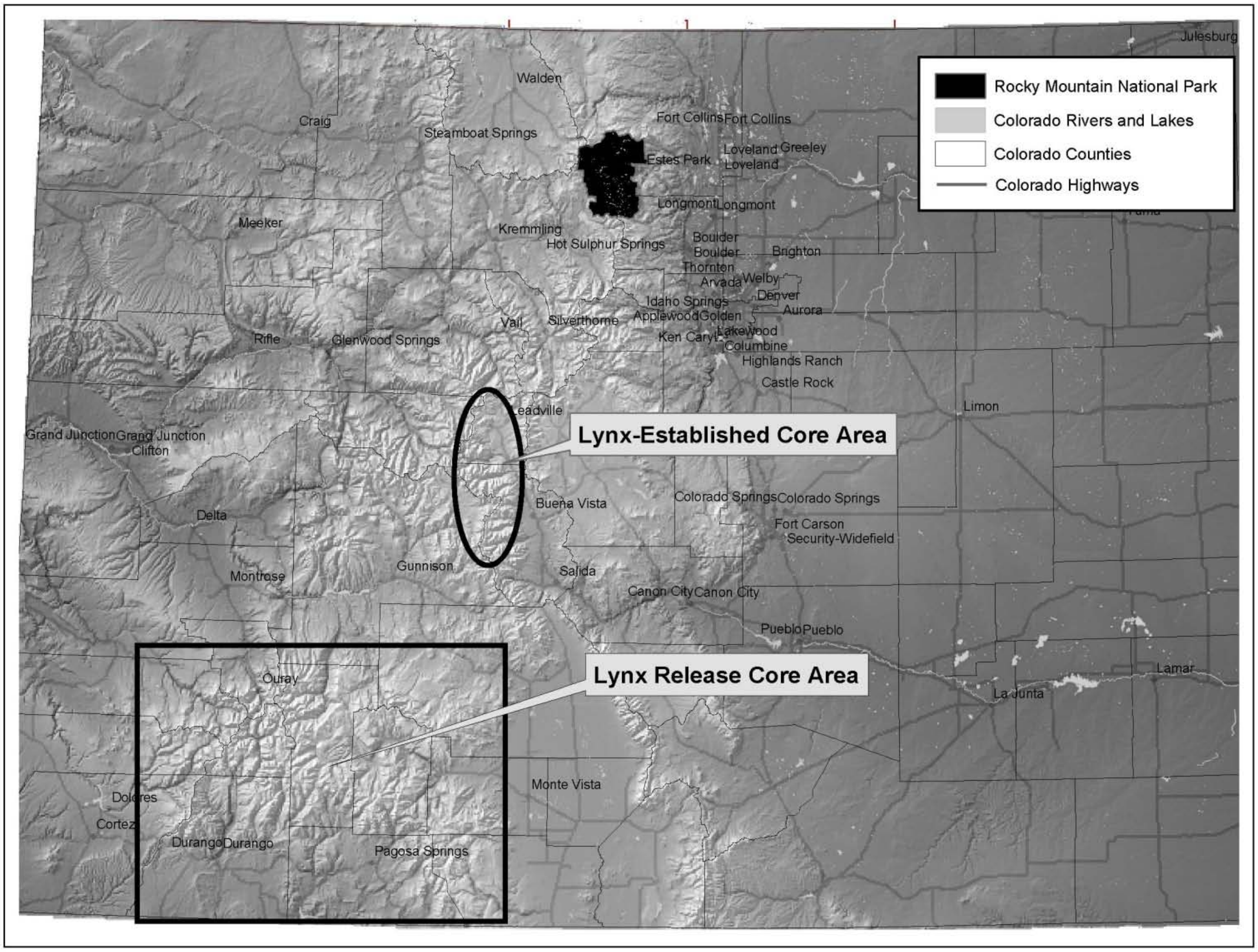

Figure 1. Lynx are monitored throughout Colorado and by satellite throughout the western United States. The lynx core release area, where all lynx were released, is located in southwestern Colorado (outlines in white). A lynx-established core use area has developed in the Taylor Park and Collegiate Peak area in central Colorado.

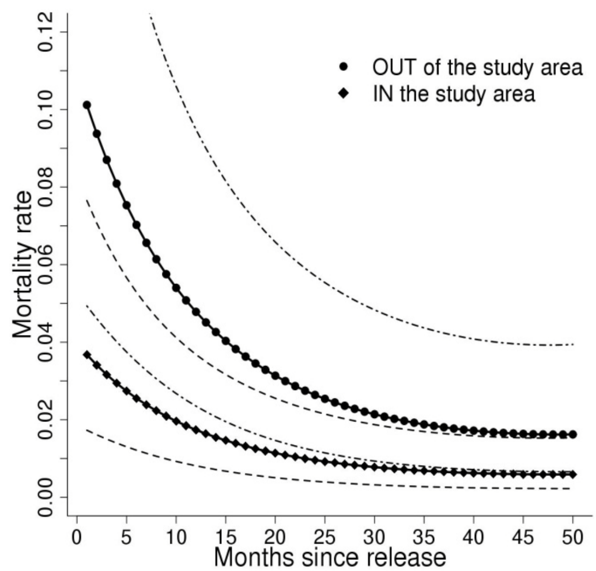

Figure 2. Variation of monthly mortality rate with time since release for Canada lynx reintroduced to Colorado, inside and outside of the study area, according to the best-AICc model (from Devineau et al. 2010). Only the first 50 months following release are shown.

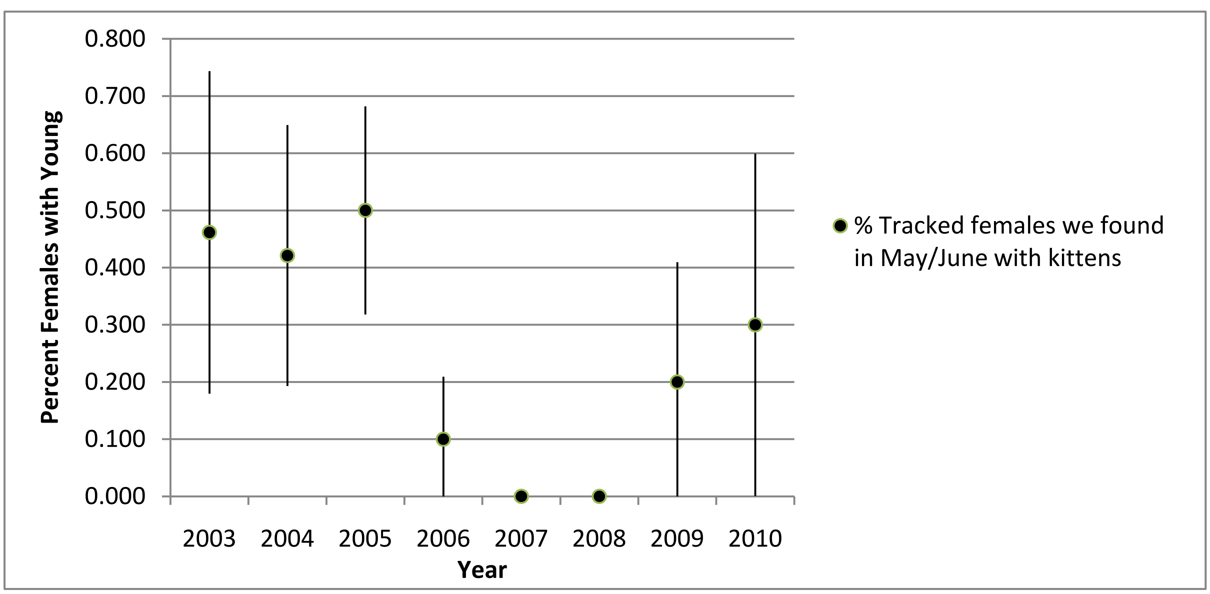

Figure 3. Percent of tracked Canada lynx females in the reintroduction area found with kittens in May or June from 2003 through 2010.

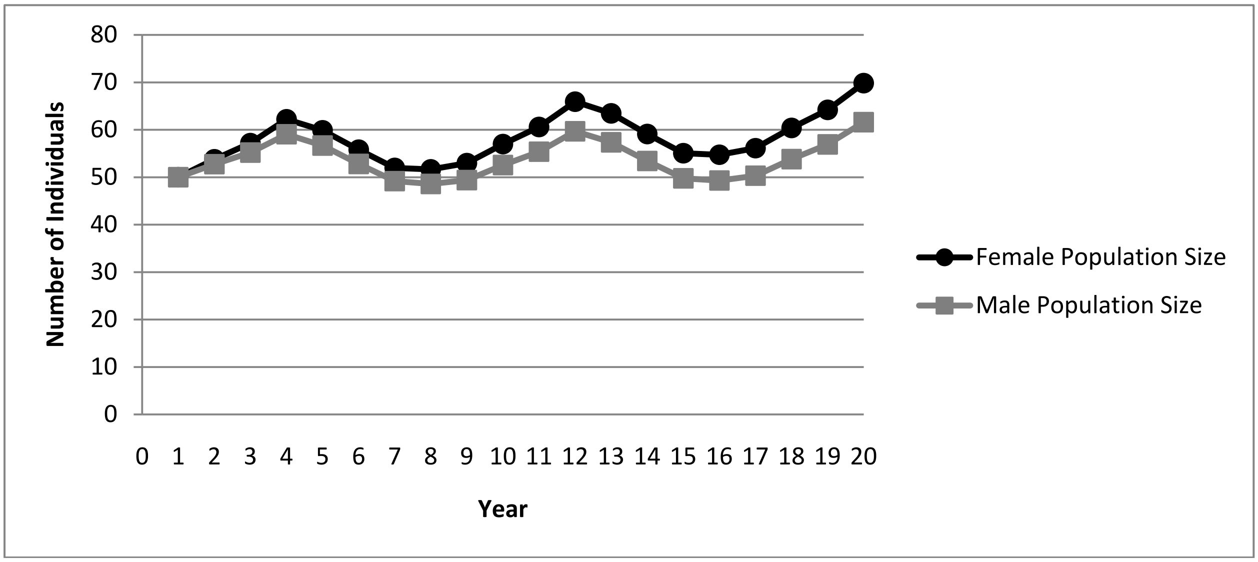

Figure 4. Projected Canada lynx population trend in the core reintroduction area over 20 years if the pattern of reproductive and survival parameters observed over the last 8 years would repeat. The initial population sizes of 50 males and 50 females for this projection was not based on a current population estimate, however, they are not unreasonable assumptions for the study area. Using alternative initial population sizes would not change the projected pattern.

Appendix I.

STATUS OF PUBLICATIONS ASSOCIATED WITH THE COLORADO LYNX REINTRODUCTION PROGRAM

Five papers have been published:

Devineau, O., T. M. Shenk, G. C. White, P. F. Doherty, Jr., P. M. Lukacs, and R. H. Kahn. 2010. Evaluating the Canada lynx reintroduction programme in Colorado: patterns in mortality. Journal of Applied Ecology 47:524–531.

Shenk, T. M., R. H. Kahn, G. Byrne, D. Kenvin, S. Wait, J. Seidel, and J. Mumma. 2009. Canada lynx (*Lynx canadensis*) reintroduction in Colorado. Pages 410-421 *in* A. Vargas, C. Breitenmoser, and U. Breitenmoser, editors. Iberian Lynx Ex situ Conservation: An Interdisciplinary Approach. Fundacion Biodiversidad, Madrid, Spain.

Shenk, T. M and, R. H. Kahn. 2009. Reintroduction of the Canada lynx (*Lynx canadensis*) to Colorado. *in* Proceedings of the Third Iberian Lynx Symposium. *eds*. A. Vargas, C. Breitenmoser, U. Breitenmoser, Fundacion Biodiversidad and IUCN Cat Specialist Group. Fundacion Biodiversidad, Spain.

Wild, M. A., T. M. Shenk, and T. R. Spraker. 2006. Plague as a mortality factor in Canada lynx (*Lynx canadensis*) reintroduced to Colorado. Journal of Wildlife Diseases 42:646–650.

Zahratka, J. L., and T. M. Shenk. 2008. Population estimates of snowshoe hares in the southern Rocky Mountains. Journal of Wildlife Management 72:906–912.

Five additional papers are currently in review:

Devineau, O., T. M. Shenk, P. F. Doherty, Jr., G. C. White, and R. H. Kahn. In review. Assessing release protocols used for the Canada lynx (Lynx Canadensis) reintroduction in Colorado: Recommendations for future efforts. Journal of Wildlife Management.

Devineau, O., T. M. Shenk, P. F. Doherty, Jr., et al. In review. Modeling known-fate and nest survival data within the multistate framework: increased flexibility for telemetry studies. Journal of Applied Ecology.

Wolfe, L. L., T. M. Shenk, B. Powell, and T. E. Rocke. In review. Safety of and serum antibody responses to a recombinant F1-V fusion protein vaccine intended to protect Canada lynx (Lynx Canadensis) from plague. Journal of Wildlife Diseases.

Fanson, K., T. M. Shenk, et al. In review. Patterns of testicular activity in captive and wild Canada lynx. General and Comparative Endocrinology.

Fanson, K., T. M. Shenk, et al. In review. Patterns of ovarian and luteal activity in captive and wild Canada lynx. General and Comparative Endocrinology.

One paper is in the process of being submitted for publication and requires no additional work from CDOW personnel:

Fanson, K., T. M. Shenk, et al. In prep. Patterns of stress physiology in reintroduced Canada lynx and implications for reintroduction success. General and Comparative Endocrinology.

Six publications are currently in preparation and require the continued efforts of Tanya Shenk and/or Jake Ivan to complete:

Theobald, D., and T. M. Shenk. In prep. Lynx habitat use at site-specific and landscape scales.

Shenk, T. M. In prep. Lynx denning habitat and reproduction in Colorado.

Ivan, J. S., G. C. White, and T. M. Shenk. In Prep. Using telemetry to correct for bias: an approach to estimating density from trapping grids. Ecology.

Ivan, J. S., G. C. White, and T. M. Shenk. In Prep. Comparison of methods for estimating density from capture–recapture data. Journal of Applied Ecology.

Ivan, J. S., G. C. White, and T. M. Shenk. In Prep. Density and demography of snowshoe hares in west-central Colorado. Ecological Monographs.

Ivan, J. S., G. C. White, and T. M. Shenk. In Prep. Daily and seasonal movements of snowshoe hares in west-central Colorado. Journal of Mammalogy.

Appendix 2

PROGRAM NARRATIVE STUDY PLAN
FOR MAMMALS RESEARCH
FY 2010-11

State of:	Colorado	:	Division of Wildlife
Cost Center:	3430	:	Mammals Research
Work Package:	0670	:	Lynx Conservation
Task No.:	4	:	Estimating Potential Changes in Distribution of
		:	Canada Lynx in Colorado: Initial Implementation in the Core Lynx Research Area
Federal Aid Project No.	N/A		

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STUDY PLAN APPROVAL

Prepared by:	__________	Date:	________
Submitted by;	__________	Date:	________
Reviewed by:	__________	Date:	________
	__________	Date:	________
	__________	Date:	________
Biometrician Review	__________	Date:	________
Approved by:	__________	Date:	________
	Mammals Research Leader		

PROGRAM NARRATIVE STUDY PLAN
FOR MAMMALS RESEARCH
FY 2010-11

Estimating the Extent, Stability and Potential Distribution of Canada Lynx (*Lynx canadensis*) in Colorado: initial implementation in the core lynx research area

A Research Proposal Submitted By

Jacob S. Ivan, Wildlife Researcher, Mammals Research
Tanya M. Shenk, Landscape Ecologist, National Park Service

A. Need:

The Canada lynx (*Lynx canadensis*) occurs throughout the boreal forests of northern North America. While Canada and Alaska support healthy populations of the species, the lynx is currently listed as threatened under the Endangered Species Act (ESA) of 1973, as amended (16 U. S. C. 1531 et. seq.; U. S. Fish and Wildlife Service 2000) in the conterminous United States. Colorado represents the southern-most historical distribution of naturally occurring lynx, where the species occupied the higher elevation, montane forests in the state (U. S. Fish and Wildlife Service 2000). Thus, Colorado is included in the federal listing as lynx habitat. Lynx were extirpated or reduced to a few animals in Colorado, however, by the late 1970's (U. S. Fish and Wildlife Service 2000), most likely due to multiple human-associated factors, including predator control efforts such as poisoning and trapping (Meaney 2002). Given the isolation of and distance from Colorado to the nearest northern populations of lynx, the Colorado Division of Wildlife (CDOW) considered reintroduction as the only option to attempt to reestablish the species in the state.

Therefore, a reintroduction effort was begun in 1997, with the first lynx released in Colorado in 1999. To date, 218 wild lynx were captured in Alaska or Canada and released in southwestern Colorado. The goal of the Colorado lynx reintroduction program is to establish a self-sustaining, viable population of lynx in this state. Evaluation of incremental achievements necessary for establishing viable populations is an interim method of assessing the success of the reintroduction effort. There were 7 critical criteria established for achieving a viable lynx population in Colorado: 1) development of release protocols that lead to a high initial post-release survival of reintroduced animals, 2) long-term survival of lynx in Colorado, 3) development of site fidelity by the lynx to areas supporting good habitat in densities sufficient to breed, 4) reintroduced lynx must breed, 5) breeding must lead to reproduction of surviving kittens 6) lynx born in Colorado must reach breeding age and reproduce successfully, and 7) recruitment must equal or be greater than mortality over an extended period of time. These criteria were evaluated incrementally over time to gauge whether the reintroduction effort was progressing toward success (Shenk and Kahn 2003). All seven criteria have now been met and a Canada lynx population currently exists in Colorado (Shenk and Kahn 2010). To document sustained viability of the Canada lynx population in Colorado, some form of long-term monitoring must be implemented.

Lynx were released in a core reintroduction area in the San Juan Mountains of southwestern Colorado. It was hoped lynx would become established in this area and then disperse on their own throughout suitable habitat in the state. Research and monitoring efforts over the last 11 years, since the first lynx were released, have focused primarily on monitoring reintroduced animals through VHF and satellite telemetry and estimating demographic parameters of these animals (e.g., Devineau et al. 2010). However, as more of these animals become unavailable for monitoring due to failed telemetry collars, death, or movement out of state, it has become impossible to accurately evaluate the status of the lynx population in Colorado, including the Core Research Area.

A minimally-invasive monitoring program is needed to estimate the distribution, stability, and persistence of lynx. Occupancy estimation, the use of presence/absence survey data to estimate the proportion of survey units occupied within a study area, is appropriate for such a program. In the past, biologists referred to presence/absence as present/not detected, because absence cannot be absolutely determined. This term, however, confuses the status of being present or not present with the activity of either detecting or not detecting an animal. This monitoring program proposed here adopts the term presence/absence with the argument that although absence cannot be determined, it can be estimated statistically using a known or estimated detection probability. The indicator used to determine the distribution of occurrence of lynx is Ψ, the proportion of primary sampling units (PSU's) (MacKenzie et al. 2006) with lynx presence. A PSU is a square sampling unit of $75km^2$, the approximate mean size of a lynx winter home range as estimated by a 90% kernel utilization distribution (Shenk 2007).

In order to design the most efficient statewide monitoring program, we first evaluated the detection probabilities and efficacy of 3 methods of detection (Shenk 2009) via survey work in areas where lynx were known to occur. The most efficient methods of detection were snow-tracking (daily detection probability = 0.70) and camera surveillance (daily detection probability = 0.085). Hair snares were found to be ineffective in detecting the presence of lynx (daily detection probability = 0).
In addition to identifying purported lynx tracks, snow-tracking implemented at the maximum effort should also include backtracking until scat or hair samples can be collected. Such samples are used to validate that the discovered tracks were indeed lynx tracks. Furthermore, such an approach allows for individual identification (from scat only), which could be used to monitor individual movement patterns across PSU's, reproduction, social structure and possibly apparent survival rates. A genetic library of most lynx released during the reintroduction program (some samples were missing) and most kittens found in Colorado (some samples were insufficient for individual identification) has been established and is housed with USGS Conservation Genetics Lab in Fort Collins, Colorado. This genetic library will be used to identify individuals from the scat samples collected during the monitoring program.

Below we outline the objectives and approach for the estimating the distribution of lynx in the Core Research Area. Results from this study will enable us to design a larger-scale monitoring program to detect changes in lynx persistence and distribution throughout Colorado. The primary objectives of a statewide monitoring program would be to document the annual distribution of lynx throughout Colorado, the stability, growth or shrinkage of this distribution over time, and to identify potential areas lynx may occupy in the future

A statewide monitoring program based on our pilot study (below) will not provide a means of estimating total population size in the state because detection of a lynx may represent a single territorial animal, a breeding pair or a family unit. To obtain a statewide lynx abundance estimate, further efforts would be needed to establish the actual or estimated number of lynx in a PSU. Furthermore, the occupancy estimation approach outlined below is not designed to provide information on reproductive success or to estimate survival.

B. <u>Objectives</u>:

The primary objectives of this study are to:
1. Estimate the distribution of lynx in the Core Research Area.
2. Further refine detection probabilities of snow-tracking and camera surveillance methods in detecting lynx.

2. Develop a standardized, valid monitoring protocol for estimating the distribution, stability and persistence of Canada lynx throughout Colorado.

C. Expected Results or Benefits:

The methodologies developed during this pilot study will be used to develop a valid, non-invasive or minimally invasive inventory and monitoring program to estimate the distribution of Canada lynx in Colorado. The monitoring program will provide information on the annual winter distribution, extent and habitat relationships of these parameters as well as their long-term trend which will be evaluated every 5 years. The protocols developed will be made available to any other agencies or entities that want to monitor lynx. The proposed methodology to estimate and monitor trends in lynx distribution throughout Colorado is designed to make use of technologies (e.g., genetic identification) reliant only on non-invasive or minimally invasive techniques. Such non-invasive techniques are widely desirable because they require minimal impact to the animals and because of their cost efficiencies.

D. Approach

The primary objective of the pilot study is to evaluate the efficacy of the proposed sampling techniques for detecting lynx presence. However, the pilot study will also include qualitative evaluation of all design methods that will be employed in a future, larger research area and statewide monitoring efforts, (i.e., the complete sampling frame).

Sampling Frame and Primary Sampling Unit Selection

The sampling frame will be the Core Research Area, a 20,684 km^2 study area which included the core reintroduction area, release sites and surrounding high elevation sites (> 2,591 m). The area encompasses the southwest quadrant of Colorado and is bounded on the south by New Mexico, on the west by Utah, on the north by interstate highway 70, and on the east by the Sangre de Cristo Mountains (Figure 1). The sampling frame will be randomly overlayed with a contiguous grid of 75 km^2 squares. The size of the square reflects a mean annual home range size of a reproducing lynx in Colorado (Shenk 2007) and is similar to home range estimates obtained for lynx in Montana (Squires and Laurion 1999). If a grid square meets the following criteria it will be identified as a PSU:

1. If ≥ 50% of the grid is located within the Core Research Area,
2. If ≥ 50 % of the grid contains conifer or montane/alpine habitat, as identified by the SWReGAP LandCover Dataset (http://earth.gis.usu.edu/swgap/swregap_landcover_report.pdf) and
3. If ≥ 50 % of the grid is located on public land (tribal, NGO and city and county lands are considered private) as determined by COMaP (Theobald, D.M., G. Wilcox, S.E. Linn, N. Peterson, and M. Lineal. 2008. Colorado Ownership, Management, and Protection v7 database. Human Dimensions of Natural Resources and Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO, www.nrel.colostate.edu/projects/comap).

Each grid will be assigned a random number based on a spatially balanced randomized sample (RRQRR; Theobald et al. 2007) and then stratified by accessibility in winter (accessible or not accessible). An accessible grid is defined as one that can be easily and safely reached in winter by truck or snowmobile. The grids with the lowest 30 random numbers for each stratum will then be identified as the grids to be sampled for this study. Should a grid be found to have been placed in the wrong accessibility strata once approached in the field, its designation will be changed and the next lowest random numbered grid will replace it.

The assumptions that must be met in estimating occupancy are 1) surveyed sites can be occupied by the species of interest throughout the duration of the study, with no sites becoming occupied or unoccupied during the survey period (i.e., the system is closed), 2) species are not falsely detected, but can remain undetected if present, and 3) species detection at a site is assumed to be independent of species detection at other sites (MacKenzie et al. 2006). For study, there will be 2 different methods of detection (snow-tracking and camera surveillance).

<u>Field Methods</u>

Temporal aspects of the sampling design

In order to verify that the detection methods being evaluated in this pilot study are effective at detecting lynx when they are present, we need to conduct the study while we have active radio collars on lynx. Currently, we are continuing to monitor lynx with the Core Research Area for data on the demography and movement patterns of the reintroduced lynx. Thus, completing this study at the same time that active monitoring is being conducted in the research area eliminates the need for future radio-collaring efforts to conduct this study.

Camera data collection will be conducted from September- June, although only photos obtained from October-March will be used in the analysis because this time period is when lynx typically maintain fidelity to a winter home range and when breeding occurs, the period of interest for document long-term persistence of lynx. All snow-tracking data will be collected from January – March, meeting the period of interest for occupancy.

Lynx Detection Data Collection

Two methods will be used to document the presence of lynx, based on winter accessibility of the PSU. These methods include 1) documenting the presence of lynx tracks in the snow coupled with a DNA sample collection (hair or scat found through snow-tracking) in PSU's that are accessible in winter or 2) a photograph of a lynx captured by a surveillance camera in PSU's that are inaccessible in winter. Camera work or snow tracking will be focused in areas of a selected PSU that a lynx would most likely use. Based on lynx habitat use in Colorado (Shenk 2005), focus areas will include mature Engelmann spruce-subalpine fir forest stands with 42-65% canopy cover and 15-20% conifer understory cover, mean slopes of 16° and elevations above 2591 m. In addition, selection of specific camera detection stations will be based on natural travel routes or the presence of lynx sign (i.e., tracks or scat). Chances of detecting lynx at these locations will be further enhanced by placing scent and visual lures at these sites. Other feline species may be attracted to these same lures, however, the probability will be low as the study will be conducted in winter and the deep snows at these elevations should preclude species such as mountain lion (*Puma concolor*) and bobcat (*Lynx rufus*) from using these areas.

<u>Establishing Detection Stations & Travel Routes</u>. – To eliminate bias, any known lynx locations in the selected PSU's will be withheld from field technicians as they select camera station locations and snowmobile/snowshoeing routes. Field personnel will, however, be provided commonly available information to select camera locations and survey routes that are feasible and most likely areas to detect lynx within a PSU (see above).

<u>Snow-Tracking.</u> –Searches for tracks will be attempted by snowshoeing, driving, or snowmobiling in the PSU once enough snow has accumulated. Once tracks are observed, personnel will follow the tracks for up to 1km or until either lynx hair or scat are found and collected. All hair found in day beds or a single scat will constitute a sample. Because lynx are a federally listed species, which can result in regulatory protection, we will eliminate doubt about the presence of lynx by submitting hair or scat sampled to a conservation genetics lab to confirm species identification (see McKelvey et al. 2006). All hair and fecal samples will be submitted to the USGS Conservation Genetics Lab in Fort Collins, Colorado for identification to species and individual, if possible. The distance a track is followed will be limited to 1

km to increase efficiency in lynx detection within the PSU (i.e., it will be assumed it is quicker to find a new lynx track to follow to locate hair or scat than to pursue a single track for more than 1 km; see McKelvey et al. 2006). To evaluate the efficiency of this method and better estimate detection probability, we will record the total distance searched before a track is encountered for each day of survey effort, along with the total distance each lynx track is followed to collect a scat or hair sample.

All selected accessible PSU's will be snow-tracked for a maximum of 3 days. However, once a track has been found in a PSU detection efforts will stop. Snow-tracking will be conducted in a minimum of 25 accessible PSU's. If time permits, up to 30 accessible PSU's will be surveyed.

Camera Traps. – Digital infrared surveillance cameras (RECONYX RapidFire™ Professional PC85) will be placed at 4 randomly selected detection stations among those that appear the most likely places where lynx would encounter them within the PSU, as defined above. Commercial scent lures and visual lures (e.g., CD's, waterfowl wings) will be used at each camera detection station to enhance the probability of drawing a lynx into the station. Cameras will be strategically placed at microsites least likely to be effected by accumulating snow (e.g., we will use large trees with broad canopies that will form "tree wells" during winter).

Cameras will be attached to a tree with a Master Lock ™ Python™ cable lock and powered by 12 AA lithium batteries which should ensure functionality for the duration of the study. Cameras will be placed in a minimum of 25 PSU's. If time permits, up to 30 PSU's will be surveyed.

Cameras will be collected in May and June when access to the PSU's are feasible. Only photos of lynx taken from October 1 – March 31 will be considered a detection.

Data Analysis

We will estimate the occupancy of lynx within the Core research Area. Further evaluation of each of the detection methods will be completed to refine detection probabilities (p) using data from the continued monitoring of lynx with active radio collars to document presence of lynx in some of the sampled PSU's. A final monitoring protocol will be developed and published for use on a statewide or rangewide basis.

Project Schedule

Aug. 2010

- Complete sampling frame and selection of primary sampling units.
- Purchase and test equipment.
- Hire fall field crews.

Sep. – Oct 2010

- Set up camera detection stations
- Hire winter field crews.

Jan.–Mar. 2011

- Conduct lynx snow-tracking surveys.
- Process and submit all genetic samples collected during surveys to the USGS Conservation genetics Lab.

May-Jun 2011

- Collect cameras.
- Data entry.

Jul-Sep 2011

- Data analyses and complete report.

Personnel:
Project Co-Leader: Jake Ivan, Wildlife Researcher, CDOW
Project Co-Leader: Tanya Shenk, Landscape Ecologist, NPS
Responsibilities: Design study, work with research associate to implement and complete field work and data entry, complete analysis, write report.

Crew Leader:
Responsibilities: Assist in study design and selection of PSU's, supervise field technicians, complete all data entry, and perform other duties associated with the post-release monitoring program and the reproduction study.

Field Technicians
Responsibilities: Establish camera detection stations, conduct all snow-tracking and collect cameras.

Data Analysis:
Jake Ivan, Wildlife Researcher, CDOW
Tanya Shenk, Landscape Ecologist, NPS
Paul Lukacs, Biometrician CDOW
Gary White, Professor Emeritus, CSU
Paul Doherty, Associate Professor, CSU

Estimated Budget:

September 2010 – June 2011	
Salary (Tech III)	$ 43,500
Salary (6 Field Technicians Fall, Tech I)	$ 32,500
Salary (6 Field Technicians, Winter, Tech II)	$ 35,000
Salary (4 Field Technicians Spring, Tech I)	$ 14,000
Misc. Supplies/Operating	$ 8,000
Equipment Repair, maintenance (snowmobiles)	$ 9000
Detection cameras (30 @$1000 each)	$ 30,000
Processing of genetic samples collected during monitoring	$ 2,000
Vehicles (6)	$ 8,000
total	**$182,000.00**

E. Location:

Southwestern and central Colorado is characterized by wide plateaus, river valleys, and rugged mountains that reach elevations over 4200 m. Engelmann spruce-subalpine fir is the most widely distributed coniferous forest type at elevations most typically used by lynx (2591-3353 m). The Core Reintroduction Research Area is defined as areas >2591 m in elevation within the area bounded by the New Mexico state line to the south, Taylor Mesa to the west and Monarch Pass on the north and east (Figure 1). Project headquarters will at the Fort Collins CDOW Research Center.

F. Literature Cited:

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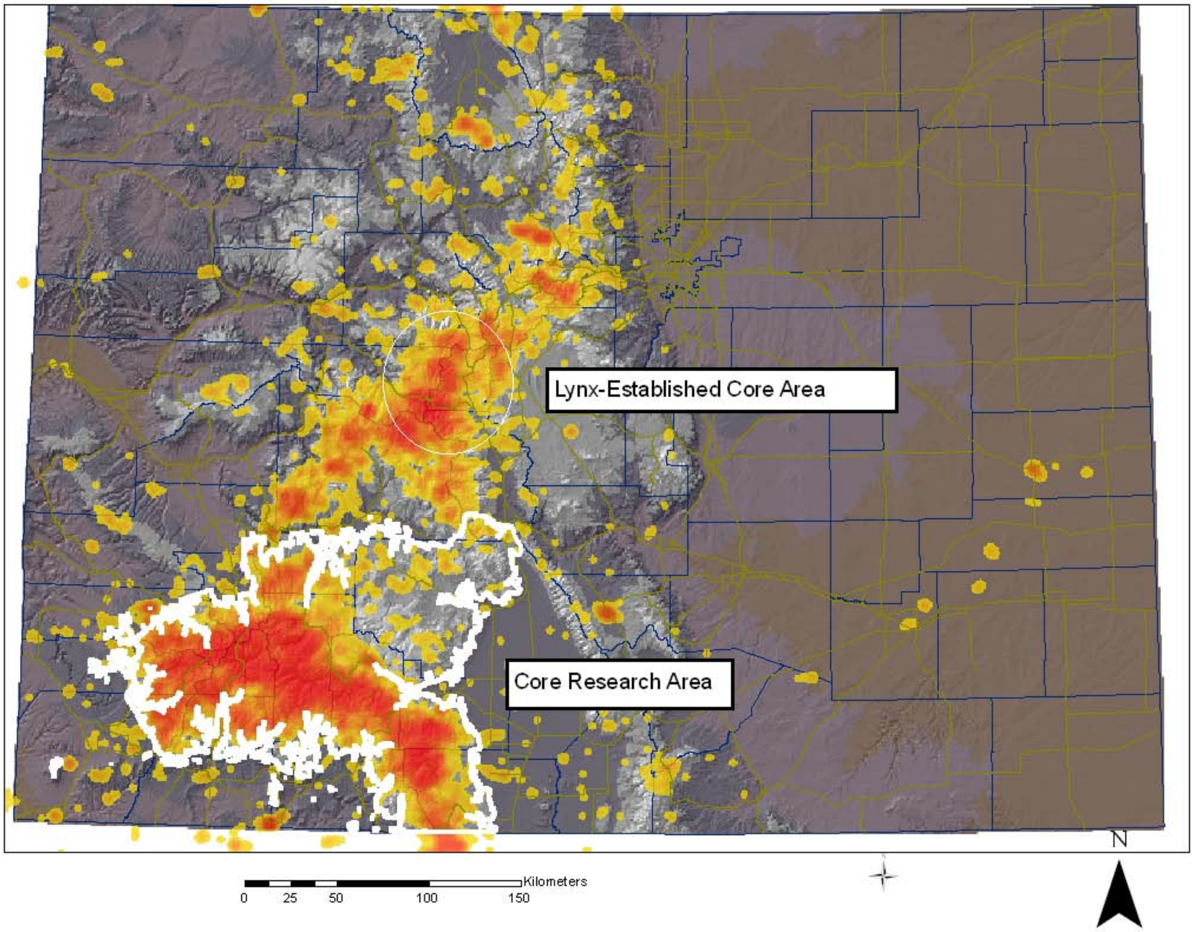

Figure 2. Study area depicting the Core Research Area, Lynx-established Core Area and relative lynx use (red is high intensity use, yellow is low intensity use).

Appendix 3

Colorado Division of Wildlife
August 2009
WILDLIFE RESEARCH REPORT

State of __________Colorado_________	________Division of Wildlife______________
Cost Center_______3430_____________	________Mammals Research______________
Work Package_____0670_____________	________Lynx Reintroduction_____________
Task No.___________2______________	___Density, Demography, and Seasonal __ Movements of Snowshoe Hare in Colorado ___

Federal Aid Project:__N/A__**:**

Period Covered: July 1, 2009- June 30, 2010

Author: J. S. Ivan, Ph.D. Candidate, Colorado State University

Personnel: Dr. T. Shenk of CDOW and Dr. G. C. White of Colorado State University.

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the author. Manipulation of these data beyond that contained in this report is discouraged.

ABSTRACT

A program to reintroduce the threatened Canada lynx (*Lynx canadensis*) into Colorado was initiated in 1997. Analysis of scat collected from winter snow tracking indicates that snowshoe hares (*Lepus americanus*) comprise 65–90% of the winter diet of reintroduced lynx in most winters. Thus, existence of lynx in Colorado and success of the reintroduction hinge at least partly on maintaining adequate and widespread hare populations. Beginning in July 2006, I initiated a study to assess the relative value of 3 stand types for providing hare habitat in Colorado. These types include mature, uneven-aged spruce/fir forests, sapling lodgepole pine forests ("small lodgepole"), and pole-sized lodgepole pine forests ("medium lodgepole"). Estimates and comparisons of survival, recruitment, finite population growth rate, and maximum (late summer) and minimum (late winter) snowshoe hare densities for each stand will provide the metrics for assessing these stands.

Snowshoe hare densities on the study area are low compared to densities reported elsewhere. Within the study area, hare densities during summer were generally highest in small lodgepole stands, followed by mature spruce/fir and medium lodgepole, respectively. Absolute hare densities declined considerably in summer 2007 and rebounded only slightly during summer 2008. Hare density in small and medium lodgepole stands equalized during winters. However, as with summer, overall density was much lower during the second winter compared to the first and rebounded somewhat during the last winter.

Hare survival from summer to winter was relatively high whereas winter to summer survival is quite low. Survival does not appear to differ between stand types or years, although a much more thorough analysis that will include known-fate telemetry data is forthcoming. This combined analysis will provide a final winter-summer estimate, will bring much more information to bear on the estimation process, and should increase precision of all estimates by a fair amount.

WILDIFE RESEARCH REPORT

DENSITY AND SURVIVAL OF SNOWSHOE HARES IN TAYLOR PARK AND PITKIN

JACOB S. IVAN

P. N. OBJECTIVE

Assess the relative value of 3 stand types (mature spruce/fir, sapling lodgepole, pole-sized lodgepole) that purportedly provide high quality hare habitat by estimating survival, recruitment, finite population growth rate, and maximum (late summer) and minimum (late winter) snowshoe hare densities for each type.

SEGMENT OBJECTIVES

1. Complete mark-recapture work across all replicate stands during late summer (mid-July through mid-September) and winter (mid-January through March).

2. Obtain daily telemetry locations on radio-tagged hares for 10 days immediately after capture periods, as well as monthly between primary trapping sessions.

3. Locate, retrieve, and refurbish radio tags as mortalities occur.

SUMMARY

Snowshoe hares (*Lepus americanus*), their famous 10-year population cycle, and close association with Canada lynx (*Lynx canadensis*) have been well-studied in boreal Canada for decades. Snowshoe hare range, however, extends south into the Sierra Nevada, Southern Rockies, upper Lake States, and Appalachian Mountains. Ecology of snowshoe hares in these more southerly regions is not as well understood, though hare research in the U.S. Rocky Mountains has accelerated over the past decade. Through this recent work, biologists have identified stands of young, densely-stocked conifers and those of mature, uneven-aged conifers as primary hare habitat in the region. Both stand types are characterized by dense understory vegetation that provides both browse and protection from elements and predators.

From 1999 to 2006, Canada lynx were recently reintroduced into Colorado in an effort to restore a viable population to the southern portion of their former range. Snow tracking of released individuals and their progeny indicated that the majority of lynx winter diet in Colorado was comprised of snowshoe hares. Thus, long–term success of the lynx reintroduction effort hinges, at least partly, on maintaining adequate and widespread populations of snowshoe hares in the state.

To improve understanding of snowshoe hare ecology in the southern portion of their range, and enhance the ability of agency personnel to manage subalpine landscapes for snowshoe hares and lynx in Colorado, I conducted an observational study to evaluate purported primary hare habitat in the state. Specifically, I estimated snowshoe hare density, survival, recruitment, and movement indices in mature, uneven-aged spruce/fir and 2 classes of young, even-aged lodgepole pine: 1) “small” lodgepole stands, which were clear cut 20–25 years prior to this study and had regenerated into densely stocked stands trees 2.54–12.69 cm in diameter, and 2)

“medium” lodgpole pine stands (tree diameter = 12.70–22.85 cm) which were clear cut 40-60 years prior to this study and pre-commercially thinned ~20 years prior. I used a combination of mark-recapture and radio telemetry to estimate parameters. I sampled during both summer and winter to cover the range of annual variation in parameters.

Animal density is one of the most common and fundamental parameters in wildlife ecology and was the first metric I used to evaluate the stand types. However, density can be difficult to estimate from mark-recapture data because animals can move on and off of a trapping grid during a sampling session (i.e., lack of geographic closure), which biases abundance estimates and makes them difficult convert to density. Before estimating snowshoe hare density, I developed a density estimator that uses ancillary radio telemetry locations, in addition to mark-recapture information, to account for lack of geographic closure resulting in relatively unbiased estimates of density. I derived the variance for this estimator, showed how individual covariates can be used to improve its performance, and provided an example using a subset of my snowshoe hare data.

Next, I completed a series of simulations to test the performance of this “telemetry” estimator over a range of sampling parameters (i.e., capture probabilities, sampling occasions, densities, and home range configurations) likely to be encountered in the field. I also compared the percent relative bias of the telemetry estimator to two other commonly used, contemporary estimators: spatial explicit capture-recapture (SECR), and mean maximum distance moved (MMDM). The telemetry estimator performed best over most combinations of sampling parameters tested, but was inferior to SECR at low capture probabilities. The telemetry estimator was unaffected by home range configuration, whereas performance of SECR and MMDM was dependent on home range shape.

Density is an important metric of habitat quality, but it can be misleading as some habitats with high animal density may function as population sinks. A complete assessment of habitat quality requires estimation of habitat-specific demographic rates in addition to density. I used the telemetry estimator to estimate snowshoe hare densities in each stand type during summer and winter, 2006-2009. I then combined mark-recapture and telemetry data to estimate survival via the Barker robust design model as implemented in Program MARK. Finally, I used age- and habitat-specific density and survival estimates to estimate recruitment in each stand type. Snowshoe hare densities were generally <1 hare/ha. During summer, hare densities were highest in small lodgepole pine, lowest in medium lodgepole pine, and intermediate in spruce/fir. During winter, densities became more similar between the 3 stand types. Annual survival of hares varied from 0.11 to 0.20. Survival tended to be higher during summer-winter intervals than during winter-summer, and higher in spruce/fir compared to the 2 lodgepole stands. Recruitment of juvenile hares occurred during all 3 summers in small lodgepole stands, 2 of 3 summers in spruce/fir stands, and in only 1 of 3 summers in medium lodgepole.

In addition to density and demography, movement is an informative aspect of animal ecology as well. Timing, extent, and frequency of movements can reflect predation pressure, food scarcity/abundance, availability of mates, or seasonal changes in any of these parameters. I used telemetry data to assess movement patterns of snowshoe hares at 3 scales (daily, within-season, between-season) in all 3 stand types. Hares in mature, uneven-aged spruce/fir stands made daily movements at the same scale as within-season and between-season movements in that habitat type, indicating they routinely traversed their entire home range over the course of a day. Conversely, hares in small and medium lodgepole stands appeared to use their home range in a more stepwise fashion (especially hares in medium stands), making smaller movements on a daily basis, but using larger areas over longer time frames. Additionally, hares in both lodgepole stands made large movements between seasons, possibly reflecting the patchy distribution of lodgepole landscapes in the study area and the variable value of patches as mediated by snow depth.

In summary, snowshoe hare density, survival, and recruitment were relatively low in medium lodgepole stands compared to spruce/fir or small lodgepole. Furthermore, hares in medium lodgepole stands made relatively large movements which may reflect poorer quality habitat. Thus, while hares occur in these stands, they do not appear to be capable self-sustaining hare populations and are probably less important than mature spruce/fir and small lodgepole. Management for snowshoe hares (and lynx) in central Colorado should focus on maintaining the latter. Given the permanent nature of spruce/fir compared to small lodgepole, and the fact that such stands cover considerably more area, mature spruce/fir may be the most valuable stand type for snowshoe hares the state.