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WILDLIFE RESEARCH REPORT

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ABSTRACT

In an effort to establish a viable population of 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. A total of 166 lynx were released from 1999-2004 and an augmentation of 38 additional animals (20 males:18 females) was completed in 2005 resulting in a total of 204 lynx reintroduced to southwestern Colorado. Each lynx was released with dual satellite and VHF radio transmitters to allow intensive monitoring of animals after release. Locations of each lynx were collected through aerial- or satellite-tracking to document movement patterns. Most lynx remain in the southwestern quarter of Colorado. Through documentation of lynx mortalities and causes of death, human-caused mortality factors, such as gunshot and vehicle collision, are currently the highest source of mortality for reintroduced lynx. Reproduction was first documented during the 2003 reproduction season with 6 dens and 16 kittens found. A second successful breeding season was documented in 2004 with 30 kittens found at 11 dens and an addition 9 kittens found after denning season. In 2005, 46 kittens were found at 16 dens with an additional den located but not visited for safety reasons. Data collected from snow-tracking indicate the primary winter prey species are snowshoe hare (*Lepus americanus*) and red squirrel (*Tamiasciurus hudsonicus*), with other mammals and birds forming a minor part of the winter diet. Site-scale habitat data collected from snow-tracking efforts indicate Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are the most common forest stands used by lynx in southwestern Colorado. Results to date have demonstrated that CDOW has developed release protocols that ensure high initial post-release survival, and on an individual level, lynx have demonstrated an ability to survive long-term in areas of Colorado. Reintroduced lynx have also exhibited site fidelity, engaged in breeding behavior and produced kittens. What is yet to be demonstrated is whether conditions in Colorado can support the recruitment necessary to offset annual mortality for a population to remain viable for several generations of lynx. Monitoring of reintroduced lynx will continue in an effort to document such viability.

WILDLIFE RESEARCH REPORT

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

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P. N. OBJECTIVE

The initial post-release monitoring of lynx reintroduced into Colorado will emphasize 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 will be emphasized after lynx display 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. Release additional adult lynx captured in Canada in southwestern Colorado during spring 2005.
2. Complete winter 2004-05 field data collection on lynx habitat use, hunting behavior, diet, mortalities, and movement patterns.
3. Complete winter 2004-05 lynx trapping field season to collar Colorado born lynx and re-collar adult lynx.
4. Complete spring 2005 field data on lynx reproduction.
5. Summarize and analyze data and publish information as Progress Reports, peer-reviewed manuscripts for appropriate scientific journals, or CDOW technical publications.

INTRODUCTION

The Canada lynx occurs throughout the boreal forests of northern North America. Colorado represents the southern-most historical distribution of lynx, where the species occupied the higher elevation, montane forests in the state. Little was known about the population dynamics or habitat use of this species in their southern distribution. Lynx were extirpated or reduced to a few animals in the state by the late 1970's due, most likely, to predator control efforts such as poisoning and trapping. Given the isolation of Colorado to the nearest northern populations, the CDOW considered reintroduction as the only option to attempt to reestablish the species in the state.

A reintroduction effort was begun in 1997, with the first lynx released in Colorado in 1999. To date, 204 wild-caught lynx from Alaska and Canada have been 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 if the reintroduction effort is progressing towards success. There are 7 critical criteria for achieving a viable population: 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 be equal to or greater than mortality.

The post-release monitoring program for the reintroduced lynx has 2 primary goals. The first goal is to determine how many lynx remain in Colorado and their locations relative to each other. Given this information and knowing the sex of each individual, we can assess whether these lynx can form a breeding core from which a viable population might be established. From these data we can also describe general movement patterns and habitat use. The second primary goal of the monitoring program is to estimate survival of the reintroduced lynx and, where possible, determine causes of mortality for reintroduced lynx. Such information will help in assessing and modifying release protocols and management of lynx once they have been released to ensure their highest probability of survival.

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 and describing successful hunting habitat once lynx established home ranges that encompassed their preferred habitat. Specific objectives for the site-scale habitat data collection include: 1) describe and quantify site-scale habitat use by lynx reintroduced to Colorado, 2) compare site-scale habitat use among types of sites (e.g., kills vs. long-duration beds), and 3) compare habitat features at successful and unsuccessful snowshoe hare chases. The program will also investigate the ecology of snowshoe hare in Colorado.

Documenting reproduction is critical to the success of the program and lynx are monitored intensively to document breeding, births, survival and recruitment of lynx born in Colorado. Site-scale habitat descriptions of den sites are also collected and compared to other sites used by lynx.

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 is needed.

STUDY AREA

Southwestern 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. The Core Research Area is defined as areas bounded by the New Mexico state line to the south, Taylor Mesa to the west and Monarch Pass on the north and east and > 2900 meters in elevation.

METHODS

REINTRODUCTION

Effort

All 2005 lynx releases were conducted under the protocols found to maximize survival (see Shenk 2001). Estimated age, sex and body condition were ascertained and recorded for each lynx prior to release (see Wild 1999). Specific release sites were those used in earlier years of the project and were selected based on land ownership and accessibility during times of release (Byrne 1998). Lynx were transported from the Frisco Creek Wildlife Rehabilitation Center, where they were held from their time of arrival in Colorado, to their release site in individual cages. Release site location was recorded in Universal Transverse Mercator (UTM) coordinates and identification of all lynx released at the same location, on the same day, was recorded. Behavior of the lynx on release and movement away from the release site were documented.

Distribution and Movement Patterns

All lynx released in 1999 were fitted with Telonics™ radio-collars. All lynx released since 1999, with the exception of 5 males released in spring 2000, were fitted with Sirtrack™ dual satellite/VHF radio-collars. These collars have a mortality indicator switch that operated on both the satellite and VHF mode. The satellite component of each collar was programmed to be active for 12 hours per week. The 12-hour active periods for individual collars were staggered throughout the week. Signals from the collars allowed for locations of the animals to be made via Argos, NASA, and NOAA satellites. The location information was processed by ServiceArgos and distributed to the CDOW through e-mail messages.

To determine general movement patterns of reintroduced lynx, regular locations of released lynx were collected through a combination of aerial, satellite and ground radio-tracking. Locations were recorded in UTM coordinates and general habitat descriptions for each ground and aerial location were recorded.

Survival and Mortality Factors

When a mortality signal (75 beats per minute [bpm] vs. 50 bpm for the Telonics™ VHF transmitters, 20 bpm vs. 40 bpm for the Sirtrack™ VHF transmitters, 0 activity for Sirtrack™ PTT) was heard during either satellite, aerial or ground surveys, the location (UTM coordinates) was recorded. Ground crews then located and retrieved the carcass as soon as possible. The immediate area was searched for evidence of other predators and the carcass photographed in place before removal. Additionally, the mortality site was described and habitat associations and exact location were recorded. Any scat found near the dead lynx that appeared to be from the lynx was collected.

All carcasses were transported to the Colorado State University Veterinary Teaching Hospital (CSUVTH) for a post mortem exam to 1) determine the cause of death and document with evidence, 2) collect samples for a variety of research projects, and 3) archive samples for future reference (research or forensic). The gross necropsy and histology were performed by, or under the lead and direct supervision of a board certified veterinary pathologist. At least one research personnel from the CDOW involved with the lynx program was also present. The protocol followed standard procedures used for thorough post-mortem examination and sample collection for histopathology and diagnostic testing (see Shenk 1999 for details). Some additional data/samples were routinely collected for research, forensics, and archiving. Other data/samples were collected based on the circumstances of the death (e.g., photographs, video, radiographs, bullet recovery, samples for toxicology or other diagnostic tests, etc.).

From 1999–2004 the CDOW retained all samples and carcass remains with the exception of tissues in formalin for histopathology, brain for rabies exam, feces for parasitology, external parasites for ID, and other diagnostic samples. Since 2005 carcasses are disposed of at the CSUVTH with the exception of the lower canine, fecal samples, stomach content samples and tissue or bone marrow samples to be delivered by CDOW to the Center for Disease control for plague testing. The lower canine is sent to Matson Labs (Missoula, Montana) for aging and the fecal and stomach content samples are evaluated for diet.

Reproduction

Females were monitored for proximity to males during each breeding season. We defined a possible mating pair as any male and female documented within at least 1 km of each other in breeding season through either flight data or snow-tracking data. Females were then monitored for site fidelity to a given area during each denning period of May and June. Each female that exhibited stationary movement patterns in May or June were closely monitored to locate possible dens. Dens were found when field crews walked in on females that exhibited virtually no movement for at least 10 days from both aerial and ground telemetry.

Kittens found at den sites were weighed, sexed and photographed. Each kitten was uniquely marked by inserting a sterile passive integrated transponder (PIT, Biomark, Inc., Boise, Idaho, USA) tag subcutaneously between the shoulder blades. Time spent at the den was minimized to ensure the least amount of disturbance to the female and the kittens. Weight, PIT-tag number, sex and any distinguishing characteristics of each kitten was also recorded. Beginning in 2005, blood and saliva samples were collected for genetic identification.

During the den site visits, den site location was recorded as UTM coordinates. General vegetation characteristics, elevation, weather, field personnel, time at the den, and behavioral responses of the kittens and female were also recorded. Once the females moved the kittens from the natal den area, den sites were visited again and site-specific habitat data were collected (see Habitat Use section below).

Recaptures

Recaptures were attempted for either lynx that were in poor body condition or lynx that needed to have their radio-collars replaced due to failed or failing batteries or to radio-collar kittens born in Colorado once they reached at least 10-months of age when they were nearly adult size. Methods of recapture included 1) trapping using a Tomahawk™ live trap baited with a rabbit and visual and scent lures, 2) calling in and darting lynx using a Dan-Inject CO_2 rifle, 3) custom box-traps modified from those designed by other lynx researchers (Kolbe et al. 2003) and 4) hounds trained to pursue felids were also used to tree lynx and then the lynx was darted while treed. Lynx were immobilized either with Telazol (3 mg/kg; modified from Poole et al. 1993 as recommended by M. Wild, DVM) or medetomidine (0.09mg/kg) and ketamine (3 mg/kg; as recommended by L. Wolfe, DVM)) administered intramuscularly (IM) with either an extendible pole-syringe or a pressurized syringe-dart fired from a Dan-Inject air rifle.

Immobilized lynx were monitored continuously for decreased respiration or hypothermia. If a lynx exhibited decreased respiration 2mg/kg of Dopram was administered under the tongue; if respiration was severely decreased, the animal was ventilated with a resuscitation bag. If medetomidine/ketamine were the immobilization drugs, the antagonist Atipamezole hydrochloride (Antisedan) was administered. Hypothermic (body temperature < 95^{o} F) animals were warmed with hand warmers and blankets.

While immobilized, lynx were fitted with replacement Sirtrack™ VHF/satellite collar and blood and hair samples were collected. Once an animal was processed, recovery was expedited by injecting the equivalent amount of the antagonist Antisedan IM as the amount of medetomidine given, if medetomodine/ketemine was used for immobilization. Lynx were then monitored while confined in the box-trap until they were sufficiently recovered to move safely on their own. No antagonist is available for Telezol so lynx anesthetized with this drug were monitored until the animal recovered on its own in the box-trap and then released. If captured and in poor body condition lynx were anesthetized with Telezol (2 mg/kg) and returned to the Frisco Creek Wildlife Rehabilitation Center for treatment.

HABITAT USE

Gross habitat use was documented by recording canopy vegetation at aerial locations. More refined descriptions of habitat use by reintroduced lynx were obtained through following lynx tracks in the snow (i.e., snow-tracking) and site-scale habitat data collection conducted at sites found through this method to be used by lynx.

Snow-tracking

Locations from aerial- and satellite-tracking were used to help ground-trackers locate lynx tracks in snow. Snowmobiles, where permitted, were used to gain the closest possible access to the lynx tracks without disturbing the animal. From that point, the tracking team used snowshoes to access tracks. Once tracks were found, the ground crew back- or forward-tracked the animal if it was far enough away not to be disturbed. Back-tracking generally avoided the possibility of disturbing the lynx by moving away from the animal rather than towards the animal. However, monitoring of the lynx through radio-telemetry was used to assure that the ground crew was staying a sufficient distance away from the lynx in the event the lynx might double back on its tracks. Radio-telemetry was also used in forward-tracking to make sure the team did not disturb the animal. If it appeared the lynx began to move in response to the observers, the observers stopped following the tracks. If the lynx began to move and the movement did not appear to be a response to the observers, the ground crew continued following the track.

An attempt was made in Season 1 (February-May 1999) and Season 2 (December 1999-April 2000) to snow-track each lynx. In Season 3 (December 2000-April 2001), we attempted to snow-track all lynx within the Core Research Area. In tracking Season 4 (December 2001-April 2002), Season 5 (December 2002-April 2003), Season 6 (December 2003-April 2004) and Season 7 (December 2004-April 2005) we attempted to track all accessible lynx in the Core Research Area and some lynx north of the Core Research Area. Ground crews were instructed to track lynx only where it was safe to travel. Restrictions to safe travel included avalanche danger and extremely rugged terrain. Ground crews worked in pairs and were fully equipped for winter back-country survival.

Data Collection

For each day of tracking the date, lynx being tracked, slope, aspect, UTM coordinates, elevation, general habitat description, and summary of the days tracking were recorded. Aspect was defined as the direction of 'downhill' or 'fall line' on a slope. This is the direction along the ground in a dihedral angle between the horizontal and the plane of the ground surface. Units were compass degrees. Slope was defined as the dihedral angle between the horizontal and the plane of the ground surface (e.g., 45").

Once a track was located there were 2 types of 'sites' that were encountered. Site I areas needed documentation but either did not reflect areas lynx selected for specific habitat features, or were sites that occurred too frequently to measure each in detail. These sites included the start and end of the track being followed, the location of scat, and short-duration beds defined as being small in size (approximating an area a lynx would crouch), and with little ice formed in the bed indicating little time spent there. Site II areas included areas that might reflect specific habitat features lynx selected for and included locations where the following were found: kills, start of chases, territory marks (e.g., spray sites, buried scat, scat placed on prominent locations), long-duration beds (encompasses an area where a lynx would have lain for an extended period, iced bottom), and road crossing (both sides of road). In addition, habitat plots were conducted along lynx travel routes if no other sites sampled in last hour.

At each of the 2 types of sites the date, lynx tracked, slope, aspect, forest structure class, UTM coordinates, and elevation were recorded. Forest structure classes included grass/forb, shrub/seedling, sapling/pole, mature, and old growth as defined in Table 1. For Site I areas, the only additional data that was collected was identification of what the site was used for (e.g., short-duration bed), and a brief description of the site. Habitat plots (see below) were conducted at Site II areas.

Description of the Habitat Plot

The habitat plot consisted of a 12 m x 12 m square defined by a series of 25 points placed in 5 rows of 5 with the center point being on the object that defined the site (e.g., a kill)(Figure 1). Each point was 3 m apart. The 12 m x 12 m sampling square exceeded the minimum requirement of 0.01 ha. recommended by Curtis (1959) for sampling trees.

Measurements taken at each of the 25 points included:

1. Snow depth - measured vertically by an avalanche probe marked in cm.

2. Understory - measured from top of snow to 150 cm above snow in a column of 3-cm radius around the avalanche probe. Because understory measurements were influenced by vegetation outside the perimeter of the 25 sampling points (12 m x 12 m) the area used for estimating undersory cover was 15 m by 15 m. At each point, crews recorded all shrubs, trees and coarse woody debris (CWD) that fell within this column and was visible above the snow. Crews also recorded number of branches of each species that fell within the column at 3 different height categories (0-0.5 m, 0.51-1.0 m, 1.01-1.5 m).
3. Overstory: measured at 150 cm above snow with a sighting tube. The tube was made of PVC pipe, with a curved viewing end and a crosshair made of wire on the opposite end. The sighting tube was attached to the avalanche probe used to measure snow depth. Species that hit the crosshair were recorded at each of the 25 points in the vegetation plot. Ganey and Block (1994) found this method of measuring canopy cover (with 20 sample points per plot; Laymon 1988) provided greater precision among observers.
4. Species composition: all the different species of tree or shrub that hit the crosshair of the sighting tube at each of the 25 points were recorded.
5. Tree composition of the vegetation plot was recorded by species and diameter at breast height (DBH). Snow depth was used in conjunction with this recorded DBH to estimate true DBH. Within the 12 m x 12 m square all conifers and deciduous trees were recorded by DBH size class (A = 0-6 in, B = 6.1-12 in, C = 12.1 -18 in, D = 18.1-24 in, E = > 24 in). Area for the tree composition analysis was 12 m x 12 m.

Understory was estimated as: 1) percent occurrence within the vegetation plot (number of points with understory/total number of points surveyed) and 2) mean percent occurrence and variance by species and height category over the total points sampled within the vegetation plot.
Overstory was estimated as percent occurrence over the vegetation plot (number of points with overstory/total number of points surveyed).

DIET AND HUNTING BEHAVIOR

Winter diet of reintroduced lynx was estimated by documenting successful kills through snow-tracking. Prey species from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed. Scat samples were collected wherever found and labeled with location and individual lynx identification. Only part of the scat was collected (approximately 75%); the remainder was left in place in the event that the scat was being used by the animal as a territory mark. Site-scale habitat data collected for successful and unsuccessful snowshoe hare kills were compared.

RESULTS

REINTRODUCTION

Effort

From 1999 through 2004 166 lynx were reintroduced into southwestern Colorado. An additional 37 lynx were released in April 2005 (17 females and 20 males), one female was released in June 2005. This brings the total number of lynx released in Colorado to 204 (Table 2). These lynx released in 2005 were captured in Quebec, British Columbia and Manitoba. All lynx were released in the Core Research Area of southwestern Colorado at or near previously used release sites in southwestern Colorado. Lynx were released with dual VHF/satellite radio collars so they can be monitored for movement and mortality. The CDOW plans to release up to 15 lynx annually from 2006-2008.

Distribution and Movement Patterns

A total of 7421 aerial VHF locations for all 204 reintroduced lynx have been collected to date. An additional 14,788 satellite locations have been collected. Most lynx released remained in the southwestern quarter of Colorado. The majority of surviving lynx from the entire reintroduction effort continue to use areas from New Mexico north to Gunnison, west as far as Taylor Mesa and east to Monarch Pass. Most movements away from the Core Research Area were to the north.

Numerous travel corridors have been used repeatedly by more than one lynx. These travel corridors include the Cochetopa Hills area for northerly movements, the Rio Grande Reservoir-Silverton-Lizardhead Pass for movements to the west, and southerly movements down the east side of Wolf Creek Pass to the southeast through the Conejos River Valley. Lynx appear to remain faithful to an area during winter months, and exhibit more extensive movements away from these areas in the summer. Such movement patterns have also been documented by native lynx in Wyoming and Montana (Squires and Laurion 1999).

Survival and Mortality Factors

Of the total 204 adult lynx released from 1999-2005 there are 66 known mortalities. Of these 66 mortalities, 26 are from the 1999 releases, 24 are from the 2000 releases, 5 are from the 2003 releases, 8 are from the 2004 releases, and 3 are from the 2005 releases. Causes of death are listed in Table 3. Starvation was a significant cause of mortality in the first year of releases only. Mortalities occurred throughout the areas through which lynx moved.

As of June 30, 2005, CDOW was actively tracking 110 of the 138 lynx still possibly alive. There are 29 lynx that we have not heard signals on since at least June 30, 2004 and these animals are classified as ‘missing’ (Table 4). One of these missing lynx is a mortality of unknown identity, thus only 28 are truly missing. Possible reasons for not locating these missing lynx include 1) long distance dispersal, beyond the areas currently being searched, 2) radio failure, or 3) destruction of the radio (e.g., run over by car). CDOW continues to search for all missing lynx during both aerial and ground searches. Two of the missing lynx released in 2000 are thought to have slipped their collars.

Reproduction

2003.-- Nine pairs of lynx were documented during the 2003 breeding season (March and April). In May and June, 6 dens and a total of 16 kittens were found in the lynx Core Research Area in southwestern Colorado (Table 5). At all dens the females appeared in excellent condition, as did the kittens. The kittens weighed from 270-500 grams. Lynx kittens weigh approximately 200 grams at birth and do not open their eyes until they are 10-17 days old.

The dens were scattered throughout the Core Research Area, with no dens found outside the core area. All the dens were in Engelmann spruce/subalpine fir forests in areas of extensive downfall. Elevations ranged from 3240-3557 m. Field crews weighed, photographed, PIT-tagged the kittens and . took hair samples from the kittens for genetic work in an attempt to confirm paternity. Kittens were processed as quickly as possible (11-32 minutes) to minimize the time the kittens were without their mother. While working with the kittens the females remained nearby, often making themselves visible to the field crews. The females generally continued a low growling vocalization the entire time personnel were at the den. In all cases, the female returned to the den site once field crews left the area.

Four of the 6 females that we know had kittens in summer 2003 were still with kittens at the end of April 2004. Two of those females still had 2 kittens with them at that time. Visual observations in February 2004 of one female with 2 kittens indicated all 3 were in good body condition. The mortality of female YK00F16 and her 1 kitten in October 2003 from plague was not due to poor habitat or prey conditions, and thus we might assume she would have raised the 1 kitten to this stage as well. Three probable kitten deaths from female YK00F19 were from 1 litter that most likely failed very early. Through snow-tracking in winter 2003-04 an unknown female (no radio frequency heard in the area of the tracks) we also documented 1-2 additional kittens born spring 2003 and still alive in winter 2004.

Of the 16 kittens we found in summer 2003, we documented the following by April 2004: 6 confirmed alive, 7 confirmed dead, and 3 some evidence dead. Although we tried, we were not able to capture any of the 6 surviving kittens to fit them with radio-collars.

2004.-- In Spring 2004, 26 females from the releases in 1999, 2000 and 2003 had active radio-collars. Of these, we documented 18 possible mating pairs of lynx during breeding season. All 4 of the females that had kittens with them through winter 2003-04 bred again spring 2004, 2 with the same male they successfully bred with spring 2003. During May-June 2004 we found 11 dens and a total of 30 kittens (Table 6). At all dens the females appeared in excellent condition, as did the kittens. The kittens weighed from 250-770 grams. Three of the 11 females with kittens were from the 2003 releases (Table 6). Three additional litters were documented after denning season through either observation of a female lynx with kittens or snow-tracking females with kittens that were not one of the 11 females found on dens. From the size of the kittens they would have been born during the normal denning season in May or June. Nine additional kittens were observed from these litters for a total of 39 known kittens born in 2004. Two of these additional litters were documented from direct follow-ups to sighting made by the public and reported to CDOW.

Two females that had kittens in 2003 and reared at least part of their litters through March 2004, bred and had kittens again in 2004. Two of the litters documented by direct observation or snow-tracking are from females whose collars no longer work. Seven kittens born in 2004 were captured at 10-months of age and fitted with dual satellite/VHF collars. All 7 are alive and currently being monitored.

2005.-- In spring 2005 we had 34 females from the releases in 1999, 2000, 2003 and 2004 that had active radio-collars. We documented 23 possible mating pairs of lynx during breeding season. During May-June 2005 we visited 16 dens and found a total of 46 kittens (Table 7). At all dens the females appeared in excellent condition, as did the kittens. An additional female had a den we were not able to get to during May or June due to high water. Female BC03F03 was hit and killed on I70 on 5/19/2005. She had 2 fetuses in her uterus, so would have contributed to reproduction this year had she lived.

We weighed, photographed, PIT-tagged the kittens and recorded sex. We also took blood samples from the kittens for genetic work in an attempt to confirm paternity. While we were working with the kittens the females remained nearby, often remaining visible to us. The females generally continued a low growling vocalization the entire time we were at the den. In all cases, the female returned to the den site once we left the area.

All of the 2005 dens were scattered throughout the high elevation areas of Colorado, south of Interstate 70. Most of the dens were in Engelmann spruce/subalpine fir forests in areas of extensive downfall. Elevations ranged from 3117-3586 m. We weighed, photographed, and PIT-tagged the kittens, recorded sex and took hair samples from the kittens for genetic work in an attempt to confirm paternity. Four of the females would not leave the den until we reached out to pick up a kitten. While we were working with the kittens the females remained nearby, often remaining visible to us. The females generally continued a low growling vocalization the entire time we were at the den. In all cases, the female returned to the den site once we left the area.

One female, YK00F10 has had litters 3 years in a row. In 2003 she had 4 kittens and raised 2 through the winter. In 2004 she had 2 kittens and raised both through the winter, this year she had 4 kittens again. She has had all 3 litters in the same general area and has had the same mate for 3 years. Eight additional females had a second litter in Colorado this year. Three females from the 2004 releases had litters in 2005. This is the second year in a row we had females released the prior spring, find a territory and a mate within a year and produced live young. In reproduction season 2004 we had 3 females released in spring 2003 that did the same thing. Of those 3, 2 successfully raised at least part of their litters through winter 2005.

Den Sites.--A total of 33 dens have been found. All of the dens except one have been scattered throughout the high elevation areas of Colorado, south of I-70. One den was found in southeastern Wyoming, near the Colorado border. Dens were located on steep ($\bar{x}_{slope} = 29^o$), north-facing, high elevation ($\bar{x}$ = 3347 m) slopes (Figure 2). The dens were typically in Engelmann spruce/subalpine fir forests in areas of extensive downfall (Figures 3, 4, 5).

Recaptures

Two adult lynx were captured in 2001 for collar replacement. One lynx was captured in a tomahawk live-trap, the other was treed by hounds and then anesthetized using a jab pole. Five adult lynx were captured in 2002; 3 were treed by hounds and 2 were captured in padded leghold traps. In 2004, 1 lynx was captured with a Belisle snare and 6 other adult lynx were captured in box-traps. Trapping effort was substantially increased in winter and spring 2005 and 12 adult lynx were captured and re-collared. In addition, 7 kittens born in Colorado in 2004 were also captured and collared. All lynx captured in 2005 were caught in box-traps. All captured lynx were fitted with new Sirtrack ^{TM} dual VHF/satellite collars.

Six adult lynx were captured from March 1999-June 30, 2005 because they were in poor body condition. Five of these lynx were successfully treated at the Frisco Creek Rehabilitation Center and re-released in the Core Research Area. One lynx, BC00F7, died from starvation and hypothermia. Two lynx were captured because they were in atypical habitat outside the state of Colorado. They were held at Frisco Creek Rehabilitation Center for a minimum of 3 weeks and re-released in the Core Research Area in Colorado. Prior to release these lynx were fitted with new Sirtrack ^{TM} dual VHF/satellite collars.

HABITAT USE

Landscape-scale daytime habitat use was documented from 7421 aerial locations of lynx collected from February 1999-June 30, 2005. Throughout the year Engelmann spruce / subalpine fir was the dominant cover used by lynx. A mix of Engelmann spruce, subalpine fir and aspen (*Populus tremuloides*) was the second most common cover type used throughout the year. Various riparian and riparian-mix areas were the third most common cover type where lynx were found during the daytime flights. Use of Engelmann spruce-subalpine fir forests and Engelmann spruce-subalpine fir-aspen forests was similar throughout the year. There was a trend in increased use of riparian areas beginning in July, peaking in November, and dropping off December through June.

Site-scale habitat data collected from snow-tracking efforts indicate Engelmann spruce and subalpine fir were also the most common forest stands used by lynx for all activities during winter in southwestern Colorado. Comparisons were made among sites used for long beds, dens, travel and where they made kills. Little difference in aspect, mean slope and mean elevation were detected for 3 of the 4 site types including long beds, travel and kills where lynx typically use gentler slopes ($\bar{x} = 15.7^o$) at an mean elevation of 3173 m, and varying aspects with a slight preference for north-facing slopes (Figure 2). Den sites however, were located at higher elevations ($\bar{x}$ = 3347 m), steeper slopes ($\bar{x} = 29^o$) and more commonly on north-facing slopes (Figure 2).

Mean percent total overstory was higher for long bed and kill sites than travel or den sites (Figure 3). Engelmann spruce provided a mean of 35.87% overstory for kills and long beds, with travel sites averaging 28% and den sites having the lowest mean percent overstory of 23% (Figure 3). Mean percent subalpine fir or aspen overstory did not vary across use sites (Figure 3). Willow overstory was highly variable and no dens were located in willow overstory.

A total of 1841 site-scale habitat plots were completed in winter from December 2002 through April 2005. The most common understory species at all 3 height categories above the snow (low = 0-0.5m, medium = 0.51 - 1.0 m, high = 1.1 - 1.5 m) was Engelmann spruce, subalpine fir, willow (*Salix* spp.)

and aspen (Figure 4). Various other species such as Ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), cottonwood (*Populus sargentii*), birch (*Betula* spp.) and others were also found in less than 5% of the habitat plots. If present, willow provided the greatest percent cover within a plot followed by Engelmann spruce, subalpine fir, aspen and coarse woody debris for long beds, kills and travel sites. Areas documented in willow used by lynx are typically on the edge of willow thickets as tracks are quickly lost within the thicket. Den sites had significantly higher percent understory cover for all three height categories. Understory at den sites was primarily made up of coarse woody debris (Figure 3).

The most common tree species documented in the site-scale habitat plots was Engelmann spruce Figure 5). Subalpine fir and aspen were also present in >35% of the plots. Most habitat plots were vegetated with trees of DBH < 6" (Figure 5). As DBH increased, percent occurrence decreased within the plot. Although decreasing in abundance as size increased, most lynx use sites had trees in each of the DBH categories, indicating mature forest stands except for dens. Den sites had a broad spectrum of Engelmann spruce tree sizes, including > 18" but no large subalpine fir or aspen trees. While Engelmann spruce and subalpine fir occurred in similar densities for kills, long beds and travel sites, den sites had twice the density of subalpine firs found at all other sites (Figure 5).

DIET AND HUNTING BEHAVIOR

Winter diet of lynx was documented through detection of kills found through snow-tracking. Prey species from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed. A total of 400 kills were located from February 1999-April 2005. We collected 671 scat samples from February 1999-April 2004 that will be analyzed for content. In each winter, the most common prey item was snowshoe hare, followed by red squirrel (Table 8).

A comparison of percent overstory for successful and unsuccessful snowshoe hare chases indicated lynx were more successful at sites with slightly higher percent overstory, if the overstory species were Englemann spruce, subalpine fir or willow. Lynx were slightly less successful in areas of greater aspen overstory (Figure 6). This trend was repeated for percent understory at all 3 height categories (Figure 7) except that higher aspen understory improved hunting success. Higher density of Engelmann spruce and subalpine fir increased hunting success while increased aspen density decreased hunting success (Figure 8).

DISCUSSION

In an effort to establish a viable population of lynx in Colorado, CDOW initiated a reintroduction effort in 1997 with the first lynx released in winter 1999. From 1999 through spring 2004, 166 lynx were released in the Core Research Area. The reintroduction effort was augmented with the release of 37 additional animals in April 2005 and 1 in June 2005, bringing the total to 204 lynx reintroduced to southwestern Colorado.

Locations of each lynx were collected through aerial- or satellite-tracking to document movement patterns and to detect mortalities. Most lynx remain in the southwestern quarter of Colorado. Dispersal movement patterns for lynx released in 2000 and subsequent years were similar to those of lynx released in 1999. However, more animals released in 2000 and subsequent years remained within the Core Research Area than those released in 1999. This increased site fidelity may have been due to the presence of con-specifics in the area on release. Numerous travel corridors have been used repeatedly by more than 1 lynx. These travel corridors include the Cochetopa Hills area for northerly movements, the Rio Grande Reservoir-Silverton-Lizardhead Pass for movements to the west, and southerly movements down the east side of Wolf Creek Pass to the southeast to the Conejos River Valley. Lynx appear to remain faithful to an area during winter months, and exhibit more extensive movements away from these areas in the summer. Most lynx currently being tracked are within the Core Research Area. During the summer months, lynx were documented to make extensive movements away from their winter use areas. Extensive summer movements away from areas used throughout the rest of the year have been documented in native lynx in Wyoming and Montana (Squires and Laurion 1999). Human-caused mortality factors such as gunshot and vehicle collision are currently the highest causes of death.

Reproduction is critical to achieving a self-sustaining viable population of lynx in Colorado. Reproduction was first documented from the 2003 reproduction season and again in 2004 and 2005. Additional reproduction is likely to have occurred in females we are no longer tracking, and from Colorado born lynx that have not been collared. The dens we find are more representative of the minimum number of litters and kittens in a reproduction season. Live-births and over-winter survival of kittens are the first steps towards recruitment into the breeding population defined as when these Colorado-born lynx will produce offspring of their own. To achieve a viable population of lynx, enough kittens need to be recruited into the population to offset the mortality that occurs in that year and hopefully even exceed the mortality rate for an increasing population.

Mowat et al. (1999) suggest lynx and snowshoe hare select similar habitats except that hares select more dense stands than lynx. Very dense understory limits hunting success of the lynx and provides refugia for hares. Given the high proportion of snowshoe hare in the lynx diet in Colorado, we might then assume the habitats used by reintroduced lynx also depict areas where snowshoes hare are abundant and available for capture by lynx in Colorado. From both aerial locations taken throughout the year and from the site-scale habitat data collected in winter, the most common areas used by lynx are in stands of Engelmann spruce and subalpine fir. This is in contrast to adjacent areas of Ponderosa pine, pinyon juniper, aspen and oakbrush. The lack of lodgepole pine in the areas used by the lynx may be more reflective of the limited amount of lodgepole pine in southwestern Colorado, the Core Research Area, rather than avoidance of this tree species.

Hodges (1999) summarized habitats used by snowshoe hare from 15 studies as areas of dense understory cover from shrubs, stands that are densely stocked, and stands at ages where branches have more lateral cover. Species composition and stand age appears to be less correlated with hare habitat use than is understory structure (Hodges 1999). The stands need to be old enough to provide dense cover and browse for the hares and cover for the lynx. In winter, the cover/browse needs to be tall enough to still provide browse and cover in average snow depths. Hares also use riparian areas and mature forests with understory. Site-scale habitat use documented for lynx in Colorado indicate lynx are most commonly using areas with Engelmann spruce understory present from the snow line to at least 1.5 m above the snow. The mean percent understory cover within the habitat plots is typically less than 15% regardless of understory species. However, if the understory species is willow, percent understory cover is typically double that, with mean number of shrubs per plot approximately 80, far greater than for any other understory species.

In winter, hares browse on small diameter woody stems (<0.25"), bark and needles. In summer, hares shift their diet to include forbs, grasses, and other succulents as well as continuing to browse on woody stems. This shift in diet may express itself in seasonal shifts in habitat use, using more or denser coniferous cover in winter than in summer. The increased use of riparian areas by lynx in Colorado from July to November may reflect a seasonal shift in hare habitat use in Colorado. Major (1989) suggested lynx hunted the edge of dense riparian willow stands. The use of these edge habitats may allow lynx to hunt hares that live in habitats normally too dense to hunt effectively. The use of riparian areas and riparian-Engelmann spruce-subalpine fir and riparian-aspen mixes documented in Colorado may stem from a similar hunting strategy. However, too little is known about habitat use by hares in Colorado to test this hypothesis at this time.

Lynx also require sufficient denning habitat. Denning habitat has been described by Koehler (1990) and Mowat et al. (1999) as areas having dense downed trees, roots, or dense live vegetation. We found this to be in true in Colorado as well. In addition, the dens used by reintroduced lynx were at high elevation, steep north-facing slopes. All females that were documented with kittens denned in areas within their winter-use area.

Snow-tracking of released lynx provided information on hunting behavior and diet through documentation of kills, food caches, chases, and diet composition estimated through prey remains. Snow-tracking results indicate the primary winter prey species are snowshoe hare and red squirrel, with other mammals and birds forming a minor part of the winter diet. In winter, lynx reintroduced to Colorado appear to be feeding on their preferred prey species, snowshoe hare and red squirrel in similar proportions as those reported for northern lynx during lows in the snowshoe hare cycle (Aubry et al., 1999). Caution must be used in interpreting the proportion of identified kills. Such a proportion ignores other food items that are consumed in their entirety and thus are biased towards larger prey and may not accurately represent the proportion of smaller prey items, such as microtines, in lynx winter diet. Through snow-tracking we have evidence that lynx are mousing and several of the fresh carcasses have yielded small mammals in the gut on necropsy. The summer diet of lynx has been documented to include less snowshoe hare and more alternative prey than in winter (Mowat et al., 1999). All evidence suggests reintroduced lynx are finding adequate food resources.

SUMMARY

From results to date it can be concluded that CDOW has developed release protocols that ensure high initial post-release survival, and on an individual level lynx have demonstrated they can survive long-term in areas of Colorado. It has also been documented that reintroduced lynx could exhibit site fidelity, engage in breeding behavior and produce kittens. What is yet to be demonstrated is whether current conditions in Colorado can support the recruitment necessary to offset annual mortality for a population to sustain itself. Monitoring of reintroduced lynx will continue in an effort to document such viability.

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Table 1. Definitions of forest structure classes used to describe habitat sites (Thomas 1979).

Forest Structure	Class Definition
Grass/forb	The grass/forb stage is created naturally by a catastrophic event, such as wildfire, and is typified by the near complete absence of snags, litter or down material in the aspen and ponderosa pine types, or vice versa in the lodgepole or subalpine forest types.
Shrub/seedling	The shrub/seedling stage occurs when tree seedlings or shrubs grow up to 2.5 cm at diameter breast height (DBH), either naturally or artificially through planting.
Sapling/pole	The sapling/pole stage is a young stage where tree DBH's range from 2.5-17.5 cm with tree heights ranging 1.8-13.5 m. These trees are 5-100 years of age, depending on species and site condition.
Mature	The mature stage occurs when tree diameters reach a relatively large size (25-50 cm) and the trees are usually 90 or more years old. Forest stands begin to experience accelerated mortality from disease and insects.
Old-growth	The old-growth stage occurs when a mature stand is at advanced age (100 years for aspen or 200 years for spruce), is very slow growing, and has advanced degrees of disease, insects, snags, and down, dead material. An exception to this occurs in ponderosa pine and aspen types where these old-growth stands typically experience low densities of down dead material or snags.

Table 2. Lynx released in Colorado from February 1999 through June 30, 2005.

Year	Females	Males	TOTAL
1999	22	19	41
2000	35	20	55
2003	17	16	33
2004	17	20	37
2005	18	20	38
TOTAL	109	95	204

Table 3. Causes of death for adult lynx released into southwestern Colorado in 1999-2005 as of June30, 2005.

Cause of Death	Number of Mortalities
Unknown	22
Starvation	9
Hit by Vehicle	9
Shot	8
Probable Shot	6
Plague	4
Probable Predation	2
Probable Hit by Vehicle	2
Other Human Caused	2
Illness	1
Territorial Dispute	1
Total Mortalities	66

Table 4. Status of adult lynx reintroduced to Colorado as of June 30, 2005.

	Females	Males	Unknown	TOTALS
Released	109	95		204
Known Dead	40	25	1	66
Possible Alive	69	70		138
Missing	16	13		28[a]
Tracking	53	57		110

[a] 1 is unknown mortality

Table 5. Lynx reproduction documented in 2003.

Female	Release Year	Date Den Found	Number of Kittens		
			Females	Males	Total
BC00F8	2000	5/21/03	?	?	2
BC00F19	2000	5/26/03	1	1	2
YK00F16	2000	6/19/03	1	1	2
YK99F1	1999	6/10/03	2	1	3
YK00F19	2000	6/11/03	1	2	3
YK00F10	2000	5/31/03	2	2	4
		TOTAL	7	7	16

Table 6. Lynx reproduction documented in 2004.

Female ID	Release Year	Previous Litter	Date Den Found	Date Kittens Found	Number of Kittens		
					Females	Males	Total
YK00F2	2000		5/28/2004		3	1	4
AK00F2	2000		5/31/2004		2	1	3
YK00F1	2000		6/1/2004		3		3
YK00F15	2000		6/4/2004		1	2	3
BC00F14	2000		6/7/2004		1	2	3
BC00F18	2000		6/10/2004		4		4
YK00F10	2000		6/17/2004		1	1	2
BC03F02	2003		6/25/2004			2	2
BC03F10	2003		6/26/2004		2		2
BC03F09	2003		6/29/2004		1	1	2
YK00F7	2000		6/30/2004		1	1	2
YK99F1	1999			Dec 2004			2
Unknown				Sept 2004			4
Unknown				Feb 2005			3
TOTAL					19	11	39

Table 7. Lynx reproduction documented in 2005.

Female ID	Release year	Previous Litters	Date Den Found	Number of Kittens		
				Total	Males	Females
AK00F02	2000	2004	5/21/2005	3	2	1
YK00F15	2000	2004	5/28/2005	2	1	1
YK00F10	2000	2003, 2004	6/1/2005	4	2	2
YK00F11	2000		6/9/2005	2		2
YK00F01	2000	2004	6/10/2005	3	2	1
YK00F07	2000	2004	6/14/2005	3	1	2
BC00F18	2000	2004	6/24/2005	2	1	1
BC03F02	2003	2004	5/25/2005	2	1	1
BC03F01	2003		5/27/2005	4	2	2
QU03F06	2003		6/5/2005	3	3	
QU03F04	2003		6/14/2005	3	1	2
QU03F07	2003		6/16/2005	4	3	1
BC03F09	2003	2004	6/27/2005	2	1	1
BC03F10	2003	2004	-	?		
BC04F01	2004		6/11/2005	3	2	1
BC04F03	2004		6/19/2005	3		3
BC04F05	2004		6/23/2005	3	3	
TOTAL				46	25	21

Table 8. Number of kills found each winter field season through snow-tracking of lynx and percent composition of kills of the three primary prey species.

Field Season	n	Prey (%)			
		Snowshoe Hare	Red Squirrel	Cottontail	Other
1999	9	55.56	22.22	0	22.22
1999-2000	83	67.47	19.28	1.20	12.05
2000-2001	89	67.42	19.10	8.99	4.49
2001-2002	54	90.74	5.56	0	3.70
2002-2003	65	90.77	6.15	0	3.08
2003-2004	37	67.57	27.03	2.70	2.70
2004-2005	78	83.33	10.26	0	6.41

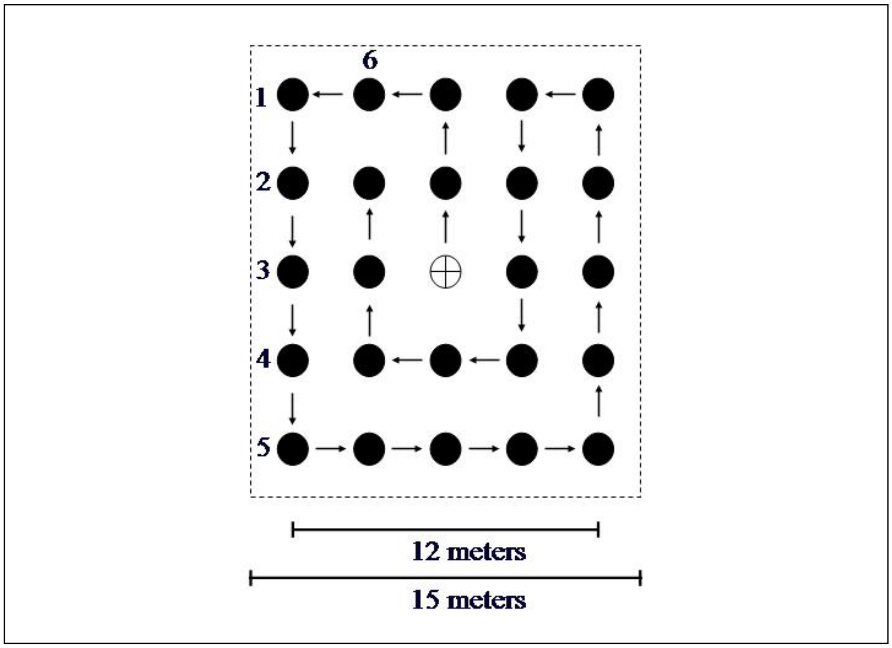

Figure 1. Design of site-scale habitat plot sampling plot. Each of the 25 points are 3 meters apart (the first 6 points are labeled 1-6). The object that triggered a habitat plot (e.g., kill) is the center point, depicted by the hollow circle. The actual pints encompass a 12 m x 12 m square but the understory and overstory data collected are influenced by vegetation occurring within a 15 m x 15 m square.

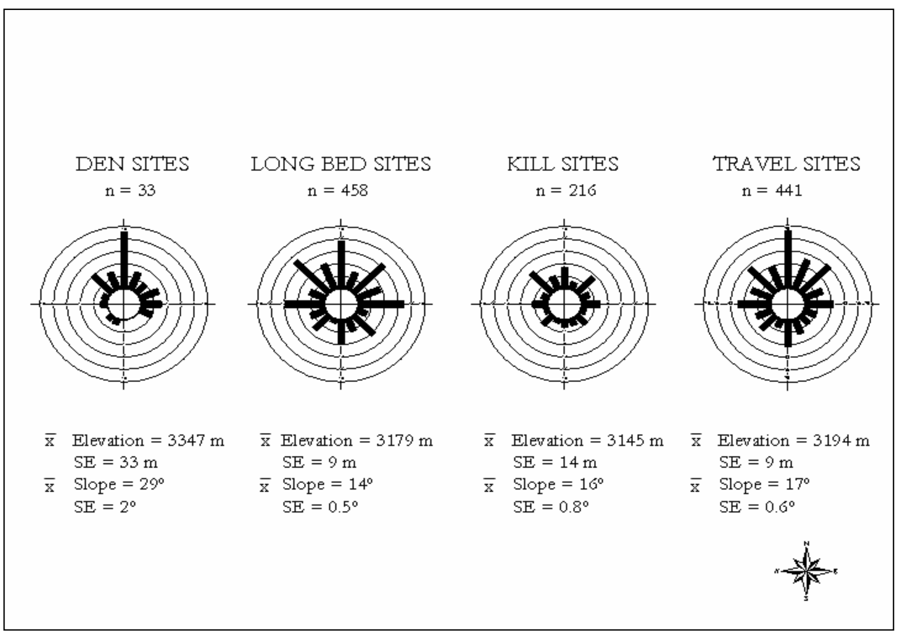

Figure 2. Frequency of aspect, mean elevation and SE and mean slope and SE for 4 lynx use sites; dens, long beds, kills and travel.

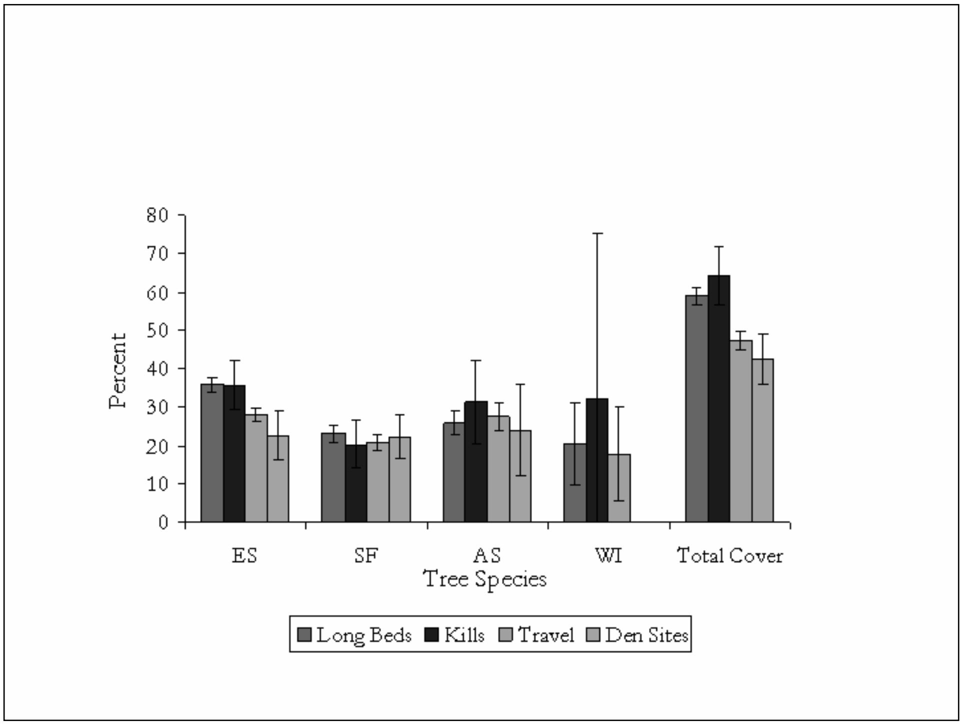

Figure 3. Mean percent overstory by tree species Engelmann spruce (ES), subalpine fir (SF), aspen (AS), willow (WI) and total cover for 4 different lynx use sites: long beds, kill sites, travel and den sites. Confidence intervals (95%) are depicted by error bars.

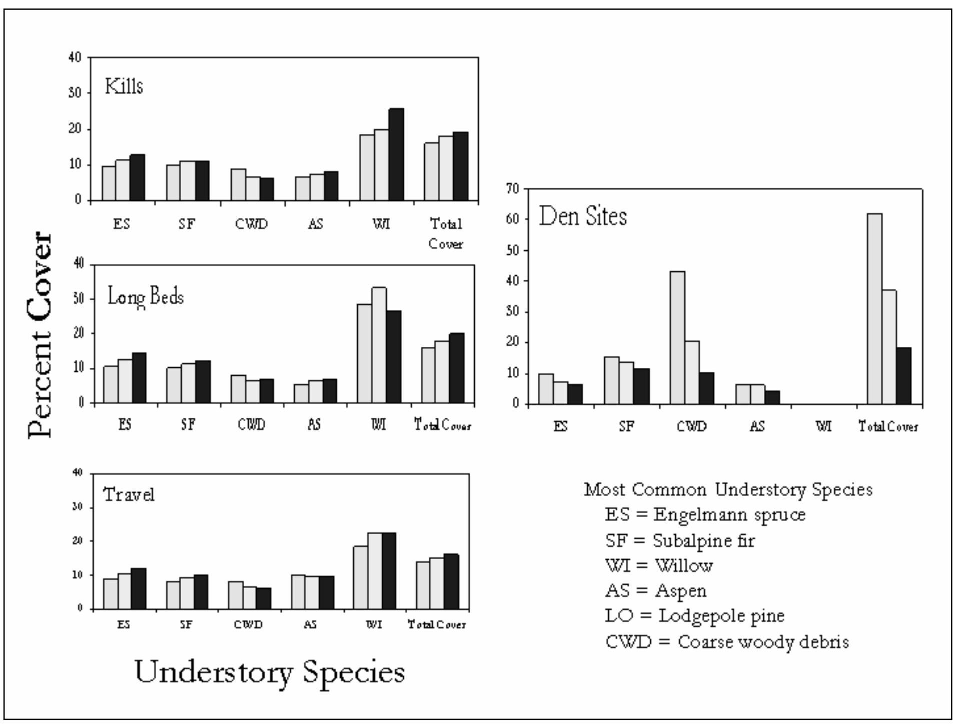

Figure 4. Mean percent understory by tree species Engelmann spruce (ES), subalpine fir (SF), coarse woody debris (CWD), aspen (AS), willow (WI) and total cover for 4 different lynx use sites: long beds, kill sites, travel and den sites.

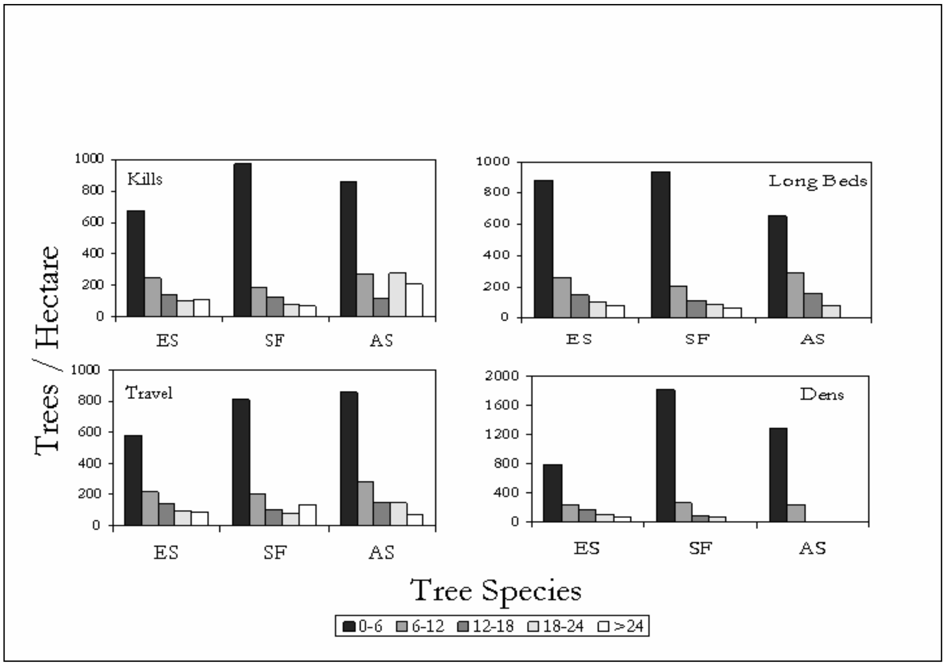

Figure 5. Mean tree density by species Engelmann spruce (ES), subalpine fir (SF) and aspen (AS) and dbh size class for 4 different lynx use sites.

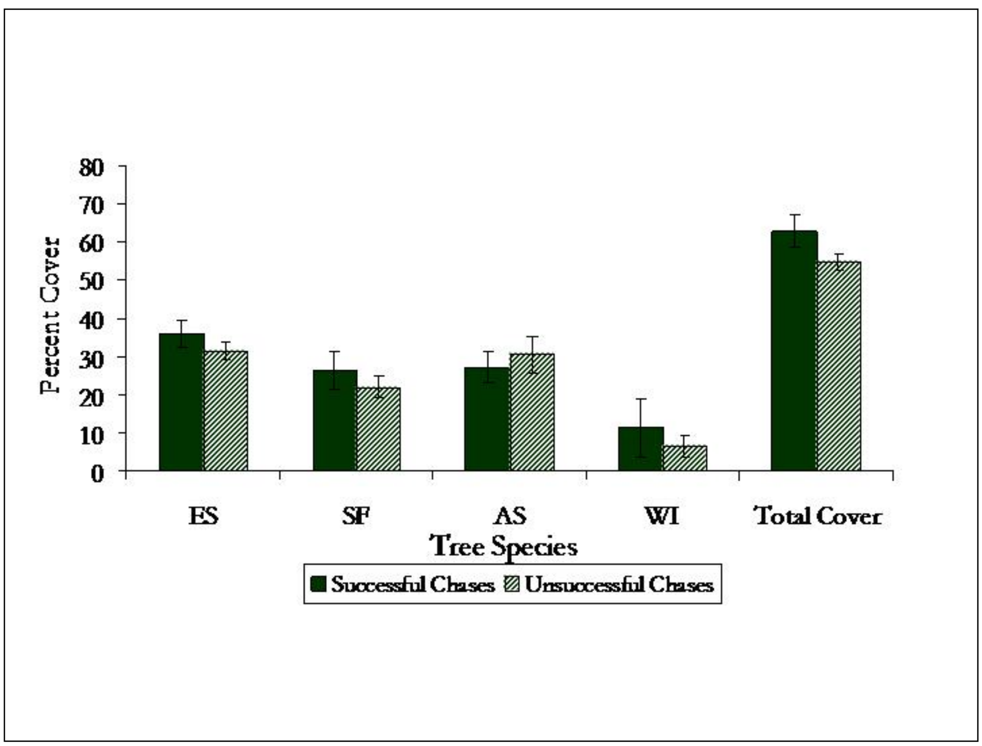

Figure 6. Mean percent overstory by tree species Engelmann spruce (ES), subalpine fir (SF), aspen (AS), willow (WI) and total cover for successful and unsuccessful snowshoe hare chases. Confidence intervals (95%) are depicted by error bars.

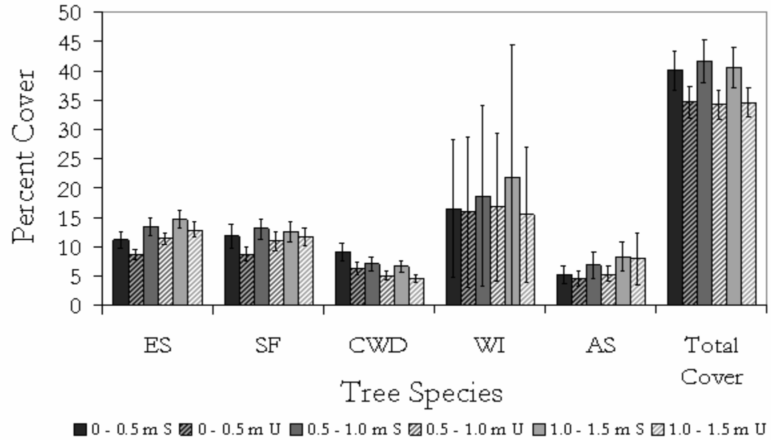

Figure 7. Mean percent understory by tree species Engelmann spruce (ES), subalpine fir (SF), aspen (AS), willow (WI) and total cover for 3 different understory height categories for successful and unsuccessful snowshoe hare chases. Confidence intervals (95%) are depicted by error bars.

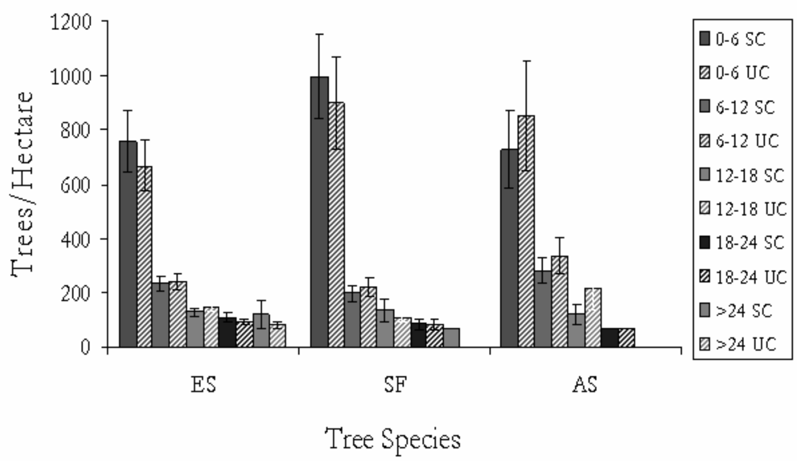

Figure 8. Mean tree density by species Engelmann spruce (ES), subalpine fir (SF) and aspen (AS) and 5 DBH size classes for successful chases (SC) and unsuccessful chases (UC) of snowshoe hare.