Post- Release Monitoring of Lynx Reintroduced to Colorado

Annual Progress Report for the U. S. Fish and Wildlife Service
December 2001

Interim Report - Preliminary Results

This work continues, and precise analysis of data has yet to be accomplished. Manipulation or interpretation of these data beyond that contained in this report should be labeled as such, and is discouraged.

Tanya M. Shenk
Mammals Research
Colorado Division of Wildlife

Abstract

In an effort to establish a viable population of lynx (*Lynx canadensis*) in Colorado 96 lynx were reintroduced into southwestern Colorado in 1999 and 2000. Release protocols were evaluated by monitoring released individuals through radiotelemetry. Numbers of mortalities and causes of death were documented and this information used to modify subsequent release protocols in an effort to attain the highest probability of survival for released lynx. In general, release protocols were modified by increasing length of time lynx were kept at the Colorado holding facility, delaying time of release to spring, and releasing non-pregnant females. Mortality due to starvation decreased as earlier protocols were modified. A suite of hypotheses was developed to model early survival and factors that may have influenced survival, including sex, age on capture, pregnancy, time spent in the Colorado holding facility, and release time. Models were evaluated using AICc model selection and model averaging used to estimate survival rates. There have been 39 confirmed deaths. Human-caused mortality factors such as gunshot and vehicle collision are the highest cause of death for lynx > 8 months post-release. Locations of each lynx were collected through aerial- or satellite-tracking to document movement patterns. Initial dispersal movement patterns and distances traveled by lynx released in 1999 were highly variable and more extreme than movements of lynx released in 2000. Movement patterns suggest lynx are pairing in March, but successful reproduction has not been documented to date. Snow-tracking results indicate the primary winter prey are snowshoe hare (*Lepus americanus*) and red squirrel (*Tamiasciurus hudsonicus*), with waterfowl and 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. There is a seasonal trend in use of willows (*Salix* spp.) with use peaking in November and being at its lowest in May and June.

Introduction

In an effort to establish a viable population of lynx (*Lynx canadensis*) in Colorado (Seidel et al. 1998), 41 lynx were reintroduced into southwestern Colorado in the winter and spring of 1999 and an additional 55 lynx were released in April and May of 2000. Post-release monitoring of these lynx is crucial to evaluating the progress of this reintroduction effort. The monitoring program also provides information and data critical for improving release techniques to ensure the highest probability of survival for each individual lynx released in the Colorado effort, and perhaps in other reintroduction efforts.

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 habitats used. The second primary goal of the monitoring program is to estimate survival of the reintroduced lynx and, where possible, determine cause of mortality of reintroduced lynx. Such information will help in assessing and modifying release protocols and management of lynx once they have been released.

Additional goals of the post-release monitoring program for lynx reintroduced to the southern Rocky Mountains include refining descriptions of habitat use and movement patterns, determining hunting habits, and obtaining information on reproduction. When the lynx establish home ranges that encompass their preferred habitat, more emphasis will be placed on refining descriptions of movement patterns and habitat use.

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). As a listed species, information specific to the ecology of the lynx in its southern range such as habitats used, movement patterns, mortality factors, survival, and reproduction in Colorado will be needed to develop recovery goals and conservation strategies for this species specific to its southern Rocky Mountain range. Thus, an additional objective of the post-release monitoring program is to develop conservation strategies relevant to lynx in Colorado

Objectives

The initial post-release monitoring of reintroduced lynx will emphasize five primary objectives:

1. Assess and modify release protocols to enure 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.

Study Area

Five areas throughout Colorado were evaluated as potential lynx habitat (Byrne 1998). Criteria investigated in these 5 areas for comparison were (1) relative snowshoe hare densities (Reed at al., unpublished data), (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 release area for reintroducing lynx. Ten release sites within the San Juan Mountains were selected based on land ownership and accessability during time of release for the 41 animals released in 1999. Of the 55 lynx released in spring 2000, 45 were released at Rio Grande Reservoir and 10 lynx were released at 3 sites west of the Continental Divide. Based on current locations of the majority of the released lynx, the core research area remains in the southern San Juan Mountains.

Methods

Reintroduction Effort

A total of 96 lynx were released at selected areas in the San Juan Mountains of southwestern Colorado (Table 1). Estimated age, sex and body condition were ascertained and recorded for each lynx prior to release (see Wild 1999). Specific release sites were selected based on land ownership and accessibility during times of release. Lynx were transported from the holding facility to the release site in cages (usually1, occasionally 2 lynx per cage). Release site location was recorded in Universal Transverse Mercator (UTM) coordinates and identification of all other 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.

Table 1. Colorado lynx reintroduction effort.

Year	Females	Males	TOTAL
1999	22	19	41
2000	35	20	55
TOTAL	57	39	96

Assessment of Release Protocols

In 1999, lynx were released under 5 different release protocols (Table 2). Protocol 1 called for the immediate release of females once they passed veterinary inspection in Colorado. Males were to be held for a period of weeks until females established a territory, and then males were to be released near female territories. Four lynx were released under this protocol with poor survival. Protocol 2 was developed whereby lynx were held at the Colorado holding facility for a minimum of 3 weeks and fed high quality diets to encourage weight gain. Nine lynx were released under Protocol 2.

After a starvation death under Protocol 2, Protocol 3 was developed, requiring the 3-week minimum holding time and high-quality feeding of Protocol 2 plus a release date no earlier than May 1. A spring release would assure that lynx were released when prey was most abundant (i.e., young of the year would be most abundant and hibernating and migratory prey would be available). Twenty lynx were released under Protocol 3. Additionally, 6 females were released under Protocol 3 that were known to be pregnant (Protocol 3P) and 2 that were possibly pregnant (Protocol 3P?).

An assessment of the fates of each lynx under all 5 release protocols used in 1999 led to release protocols for lynx released in 2000. Release protocols 2 and 3 resulted in the fewest post-release (up to 8 months after release date) starvation mortalities. The common element in both protocols was increased captivity time in the Colorado holding facility. The single starvation mortality for lynx released under Protocol 2 in 1999 was also the only juvenile released under that protocol and the only animal released in February (the other 8 Protocol 2 lynx were released in March 1999). Thus, all lynx released in 2000 were released under either Protocol 2 or 3 but not before April 1. Because of the high percentage of starvation mortalities in females pregnant on release, we also attempted to avoid reintroducing lynx that were known to be pregnant. This was best accomplished by trying to have animals captured for the reintroduction effort in Canada prior to their breeding season.

Table 2. Release protocols for lynx released in southwestern Colorado in 1999 and 2000.

Protocol	Description
1	Release females as soon as they pass veterinary inspection in Colorado. Release males once females appear to have settled into an area.
2	Release males or females after they have been held in Colorado holding facility for a minimum of 3 weeks and fed a high quality diet.
3	Release males or females after they have been held in Colorado holding facility for a minimum of 3 weeks, fed a high quality diet, and released no earlier than May 1.
3P	Pregnant females released under Protocol 3.
3P?	Possibly pregnant females released under Protocol 3.

To evaluate the efficacy of the changes in release protocols we developed a series of *a priori* hypotheses concerning factors that affected lynx survival up to 8 months post-release. These factors included (1) the timing of release (winter vs spring), (2) age of lynx released (adults vs. kittens), (3) sex of lynx released, (4) whether or not females were released while pregnant and the interaction of pregnancy and age of the female (adult vs. kitten), and (5) the duration of holding time in the Colorado facility. A series of 11 models were developed using various combinations of these factors. We used AICc (Burnham and Anderson 1998) as the model selection criterion to select the model that best explained the data.

Movement Patterns

To determine general movement patterns and habitats used by reintroduced lynx, regular locations of released lynx were collected through a combination of aerial, satellite and ground radio-tracking. Locations and general habitat descriptions at each location were recorded and mapped. Frequent flights (at least 2 times per week) were critical during the initial post-release periods because of the greater likelihood of dispersal and mortality in reintroduced carnivores during this period. Every effort was made to locate every lynx each flight during this period.

All 41 of the lynx released in the winter and spring of 1999 were fitted with Telonics™ VHF radio-collars, equipped with a mortality switch that activates if the collar remains motionless for 4 hours or more. Fifty-one of the 55 lynx released in the spring 2000 were fitted with Sirtrack™ dual satellite/VHF radio-collars (the other 4 lynx were fitted with Telonics™ VHF collars). These collars also had 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 were staggered throughout the week, with approximately 7 collars being active each day of 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.

Survival and Mortality Factors

When a mortality signal (75 ppm vs. 50 ppm 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, 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 immediately to the Colorado State University Veterinary Hospital 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 Colorado Division of Wildlife 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.). 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.

Survival rates of lynx reintroduced to Colorado were estimated using the Kaplan-Meier method with staggered entries (Pollock et al. 1989) in Program MARK (White and Burnham 1999).

Recaptures

Recaptures were attempted on lynx that were either in poor body condition or need to have their radio collars replaced. Methods of recapture included trapping using a Tomahawk™ live trap baited with a rabbit, and darting lynx with Telazol (3 mg/kg) using a Dan-Inject CO_2

pistol (modified from Poole et al. 1993 as recommended by M.Wild, DVM). Hounds trained to pursue felids were also used to tree lynx for capture. Treed lynx were immobilized with Telazol or medetomidine (0.09mg/kg) and ketamine (3 mg/kg) administered intramuscularly (IM) with either an extendible pole-syringe or a pressurized syringe-dart fired from a Dan-Inject air pistol.

Immobilized lynx were monitored continuously for decreased respiration or hypothermia. If 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 drug, the antagonist Antisedan was administered. Hypothermic (body temperature < 95° F) animals were warmed with hand warmers and blankets.

While immobilized, the lynx were fitted with a replacement VHF/satellite collar and blood and hair samples were collected. Once the animal was processed recovery was expedited by injecting the antagonist Antisedan IM if medetomodine/ketemine was used for immobilization. The lynx was monitored until it was sufficiently recovered to move safely on its own. No antagonist is available for Telezol so lynx anesthetized with this drug were monitored until the animal recovered on its own. If captured and in poor body condition the lynx was anesthetized with Telezol (2 mg/kg) and returned to the Colorado holding facility for rehabilitation.

Reproduction

Reproductive status of all female lynx was determined prior to release through radiographs. Pregnancy was confirmed through radiographs if the bones of the fetuses had begun to ossify. All females known to be pregnant or thought to possibly be pregnant on release were monitored closely from their release through the following August to determine reproductive success. Females remaining within a limited area immediately after release through August were located and observed to look for accompanying kittens or a den site. Females that had been released in 1999 and were alive in spring 2000 were monitored for proximity to males during breeding season and for site fidelity to a given area during the denning period of May and June 2000. Each female lynx from the 1999 releases was directly observed in summer 2000 over 3-5 different visits to look for accompanying kittens or evidence of denning. Each female alive in May 2001 that exhibited stationary movement patterns in June 2001 was observed in summer or fall 2001 to look for accompanying kittens. Females were also snow-tracked in winter months to look for accompanying kitten tracks.

Hunting Behavior

Snow-tracking of released lynx provided preliminary information on hunting behavior by documenting location of kills, food caches, chases, and diet composition estimated through scat analysis. Snow-tracking was conducted during February-May 1999 (Year 1), November 1999 – May 2000 (Year 2), and November 2000 - April 2001 (Year 3). Prey 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, the remainder was left where found so as not to interfere with the possibility that the scat was being used by the animal as a territory mark.

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 snow-tracking and site-scale habitat data collection. Specific objectives for the site-scale habitat data collection included:

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).
3. Compare site-scale habitat use between sexes.
4. Compare habitat use over years.
5. Develop methodology that will result in data that will be comparable to data collected in studies investigating the ecology of snowshoe hare in Colorado.

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 Year 1 and Year 2 to track each lynx. In Year 3 we attempted to track all lynx within the Core Release 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 direction that most closely defined the cardinal points (e.g., N, NW, etc.). Slope was defined as the dihedral angle between the horizontal and the plane of the ground surface (e.g., 45°).

There were 4 levels of intensity of human activity recorded. They included:

1. None: track was not found off an existing snowmobile, ski, or snow shoe track. Distance to nearest human track is greater than 1.0 km
2. Low: track was found near low human activity (e.g., existing snowmobile or ski track)
3. Medium: track found near medium human activity (detected the presence of other people

in the area during tracking effort).

4. High: track found near high human activity (e.g., detected presence of many people nearby, near major road, near housing).

There were 2 categories for recording detection of tracks of other species. They included "M" for tracks from multiple animals of the same species and "T" for detection of tracks of only a single animal of the species.

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 sites that occurred too frequently to measure each in detail. Site II areas were places where lynx may have selected habitat features. At each of the 2 types of sites the date, lynx tracked, slope, aspect, forest structure class, UTM coordinates, and elevation was recorded. Forest structure classes included grass/forb, shrub/seedling, sapling/pole, mature, and old growth as defined in Table 3. 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. 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.

Table 3. 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.

The Site II areas included areas that might reflect specific habitat features lynx selected for. These sites required habitat sampling (see below) 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), travel (if no other sites sampled in last hour), and road crossing (both sides of road).

Description of the Habitat Plot

A habitat sampling plot was completed wherever a Site II was encountered. 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.

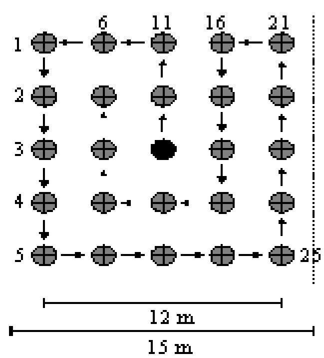

Figure 1. Design of site-scale habitat sampling plot. Each point was 3 m apart. The object that triggered the habitat sampling (e.g., a kill) was located at the center point.

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.

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 = 0-15 cm, B = 15.1-30 cm, C = 30.1-45 cm, D = 45.1-60 cm, E = ≫60 cm). 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).

Results

Assessment of Release Protocols

A total of 41 lynx were released in Colorado in 1999 under 5 different release protocols (Table 2). Release protocols were modified as new information became available from monitoring the released lynx through radio-telemetry and snow-tracking. Each modification of the release protocols decreased the percent of animals dying from starvation.

Three of the 4 animals released under Protocol 1 died of starvation within 6 weeks of their release and the fourth was recaptured and returned to the holding facility where she recovered and was later re-released. Reevaluation of the condition of animals released under the Protocol 1 suggested that these animals might not have been in optimal physical condition when released. Therefore, Protocol 2 was initiated. Most lynx gained considerable body weight while in captivity (Wild 1999). Nine lynx were released under this second protocol. Of these, 1 juvenile female died of starvation 7 weeks after release.

After the starvation death under Protocol 2, Protocol 3 was developed (3-week minimum holding time, high quality diet, no release prior to May 1). Twenty lynx were released under Protocol 3 with no starvation deaths of these animals occurring within 6 months post-release. Six females were released under Protocol 3P (known to be pregnant) and 2 under Protocol 3P? (possibly pregnant). Two of the 6 pregnant lynx released died of starvation within 6 months post-release.

An assessment of the fates of each lynx under all 5 release protocols used in 1999 led to release protocols for lynx released in 2000. Release Protocols 2 and 3 resulted in the fewest starvation mortalities up to 8 months after release date. The common element in both protocols 2 and 3 was increased captivity time in the Colorado holding facility. The single starvation mortality for lynx released under Protocol 2 in 1999 was also the only juvenile released under that protocol and the only animal released in February (the other 8 Protocol 2 lynx were released in March 1999). Thus, all lynx released in 2000 were released under either Protocol 2 or 3 but not before April 1. Because of the high percentage of starvation mortalities in females pregnant on release, we also attempted to avoid reintroducing lynx that were known to be pregnant. This was best accomplished by trying to have animals captured for the reintroduction effort in Canada prior to their breeding season.

Table 4. Starvation mortalities and recaptures of poor body condition lynx reintroduced to Colorado under the 5 release protocols over 2 years.

Release Protocol	Year	Total Number Released	Number of. Starvation Mortalities [a]	% Mortality	Number of Recaptures in Poor Body Condition [a]	% Failure of Release Protocol
1	1999	4	3[b]	75	1	100
2	1999	9	1[c]	11	0	11
2	2000	41	1[c]	2	0	2
3	1999	20	0	0	0	0
3	2000	10	0	0	0	0
3P?	1999	2	0	0	0	0
3P?	2000	3	0	0	0	0
3P	1999	6	2[d]	33	0	33
3P	2000	1	0	0	0	0

[a] within 8 months of release.
[b] 1 juvenile, 2 adults.
[c] juvenile.
[d] adults.

A series of 11 models (Table 5) were developed using various combinations of the hypothesized factors that may have affected survival up to 8 months post-release: (1) whether the release was in winter or spring (Rel), (2) whether the released lynx was an adult or kitten (age), (3) sex of lynx released (sex), (4) whether or not females were released while pregnant (preg) and the interaction of pregnancy and age of the female (adult vs. kitten), and (5) the duration of holding time in the Colorado facility (DCF). Survival time and DCF were modeled with and without a log transformation (Ln) because of possible threshold effects over time. We used AICc as the model selection criterion to select the model that best explains the data (Table 5). The model that best fit the data was {S(age+preg+Rel+LnT+LnDCF}, which suggested pregnancy had a deleterious effect on survival of females, with the effect being stronger on kittens than adults (Figure 2). This model also indicated that winter releases led to higher mortality than spring releases for both non-pregnant kittens (Figure 3) and non-pregnant adults (Figure 4), with no sex effects on either age class. Lastly, long stays in the Colorado holding facility increased survival if the duration was at least 21 days with no significant decrease or increase in survival for stays longer than 21 days (Figures 2, 3, 4).

Table 5. Model selection results of the *a priori* models concerning the effects of age, sex, pregnancy, season of release, and amount of time spent in the Colorado holding facility on survival of lynx 8 months post-release. Ranking based on AICc values.

Model	AICc	ΔAICc	AICc Weight	# Pars.	Deviance
{S(age+preg+Rel+LnT+LnDCF}	200.120	0	0.28305	6	188.036
{S(age*preg+Rel+LnT+LnDCF}	201.027	1.91	0.10908	7	187.914
{S(age+preg+Rel+T+LnDCF}	202.702	2.58	0.07784	6	190.618
{S(age+preg+Rel+T+T2+LnDCF}	203.225	3.10	0.05993	7	189.113
{S(age+Rel+preg+LnDCF}	203.266	3.15	0.05871	5	193.206
{S(age+preg+Rel+T'+T2'+LnDCF}	204.069	3.95	0.03930	7	189.957
{S(age+preg+Rel+T"+T2"+LnDCF}	204.936	4.82	0.02547	7	190.824
{S(age*preg +Rel+LnDCF}	205.265	5.14	0.02161	6	193.181
{S(age*Rel+preg+LnDCF}	205.289	5.17	0.02135	6	193.205
{S(age+Rel+preg+DCF}	205.609	5.49	0.01819	5	195.549
{S(age+Rel+preg+DCF+DCF2}	205.760	5.64	0.01687	6	193.676

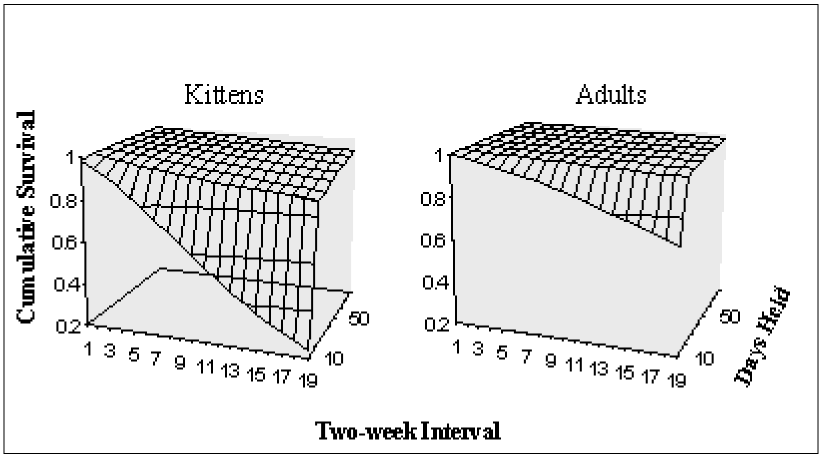

Figure 2. Effects of pregnancy and time spent in the Colorado holding facility on survival of pregnant kittens and adult females.

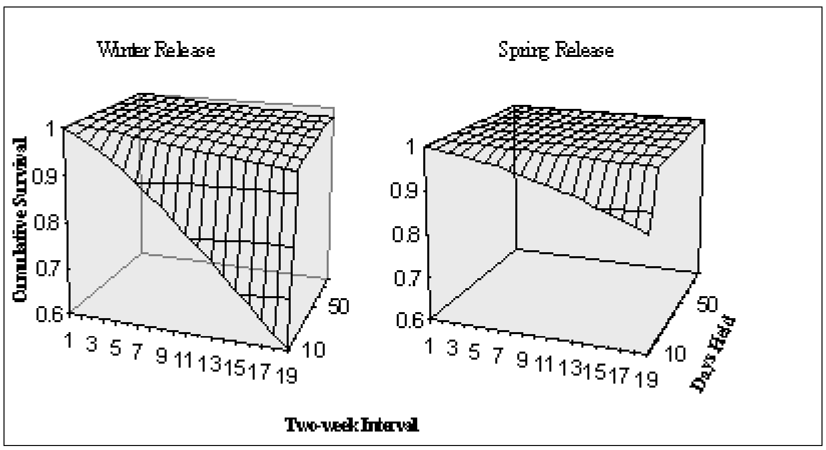

Figure 3. Effects of release season and time spent in the Colorado holding facility on survival of non-pregnant kittens.

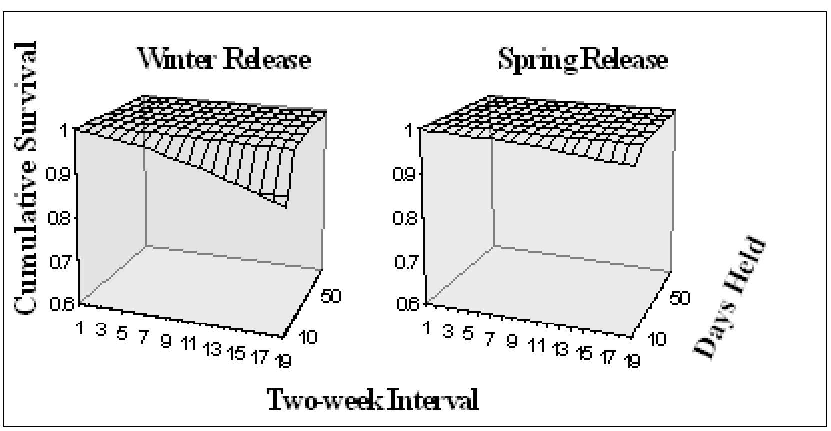

Figure 4. Effects of release season and time spent in the Colorado holding facility on survival of non-pregnant adults.

Movement Patterns

A total of 2,158 aerial VHF locations for all 96 reintroduced lynx have been collected to date (Figure 5, Figure 6). An additional 4,020 satellite locations (1,375 satellite locations if multiple locations for a single night were averaged and counted as only 1 location) for 49 of the 51 lynx fitted with dual collars have been collected. Two satellite collars never worked after the lynx were released.

The majority of movements in 1999 away from the an area encompassed by a100-km radius area centered on the release sites (Core Release Area) were to the north (Figure 5), although some movements occurred to the south into New Mexico and west into Utah as well. A single male from the 1999 releases traveled to Nebraska where he was shot in violation of Nebraska regulations. Initial dispersal habitats used by lynx released in 1999 were highly variable, from high elevation Engelmann spruce/subalpine fir to Nebraska agricultural lands.

Dispersal movement directions for lynx released in 2000 were similar to those of lynx released in 1999 (Figure 6). Most movements away from the Core Release Area were to the north. However, more animals remained within the Core Release Area. Numerous travel corridors have been used repeatedly by more than one lynx, possibly suggesting route selection based on olfactory cues. 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).

Most lynx currently being tracked are within the Core Release Area (Figure 7). Mortalities occurred throughout the areas through which lynx moved. However, mortalities occurred in New Mexico in higher proportion to all lynx locations in that area than elsewhere (Figure 8).

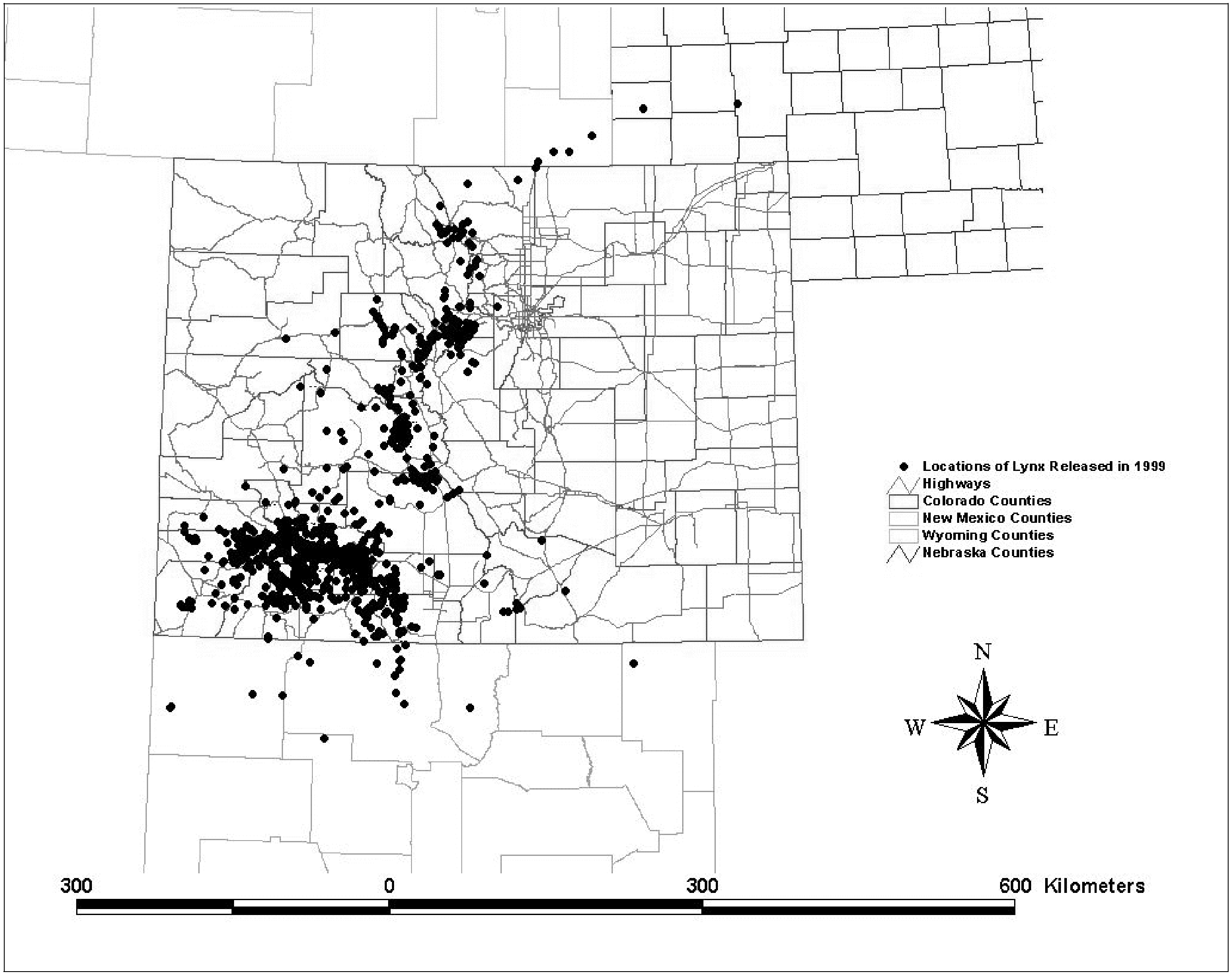

Figure 4. Locations of lynx released in 1999, obtained through aerial telemetry.

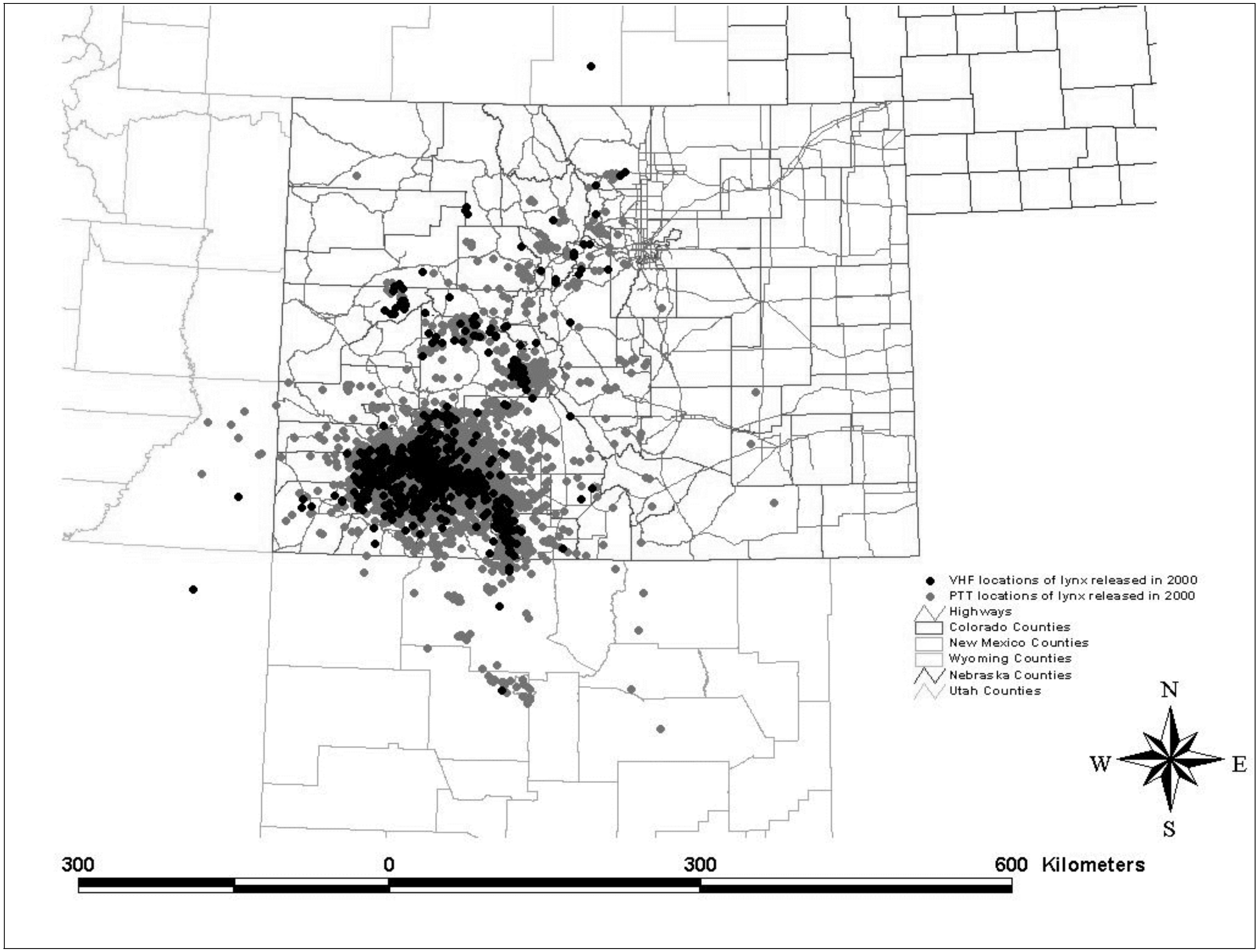

Figure 5. Locations of lynx released in 2000. Gray circles indicate locations obtained from satellite collars. Black circles are locations obtained through aerial telemetry.

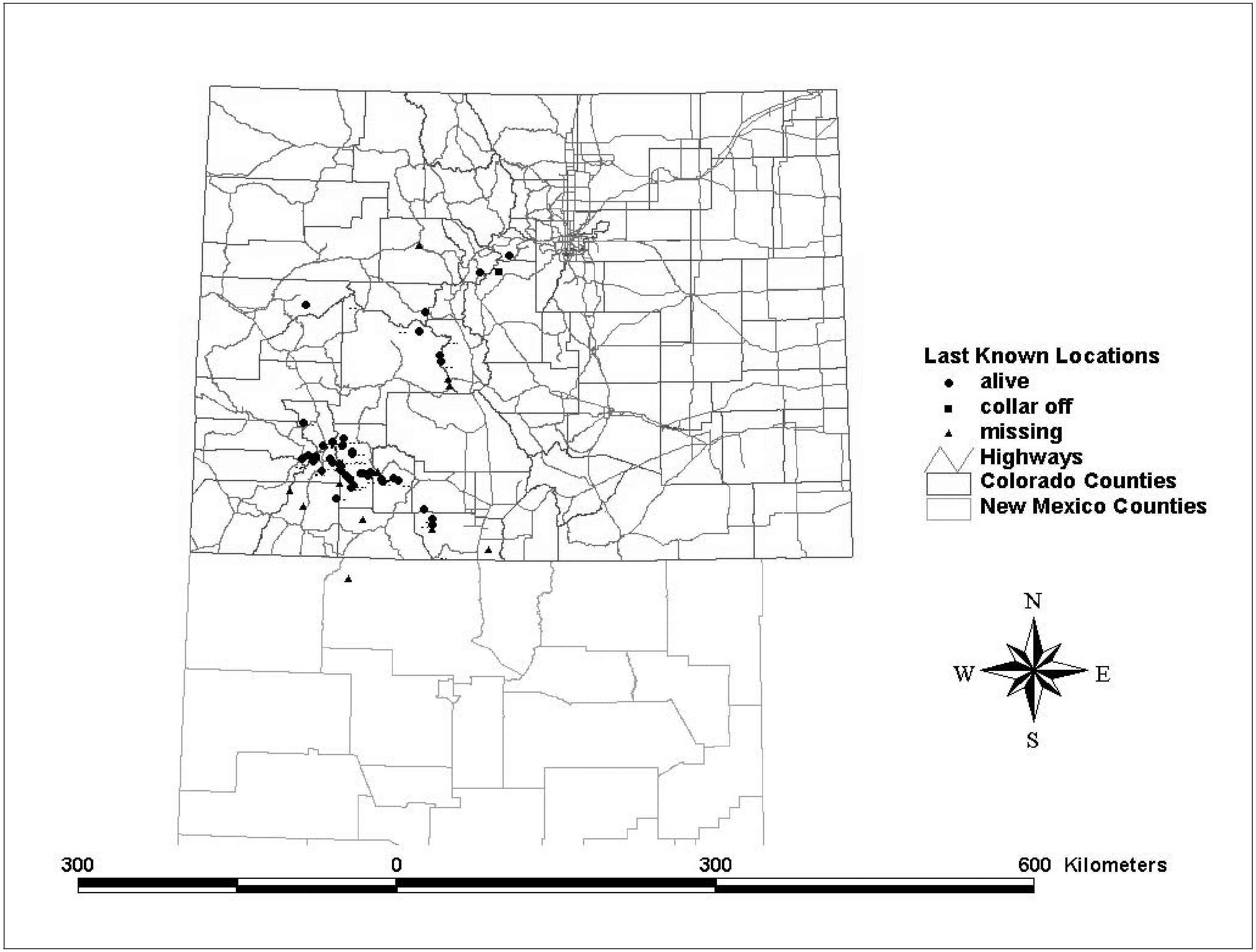

Figure 6. Last known locations of lynx. Circles depict locations of lynx currently being tracked. Triangles are last known locations of missing lynx.

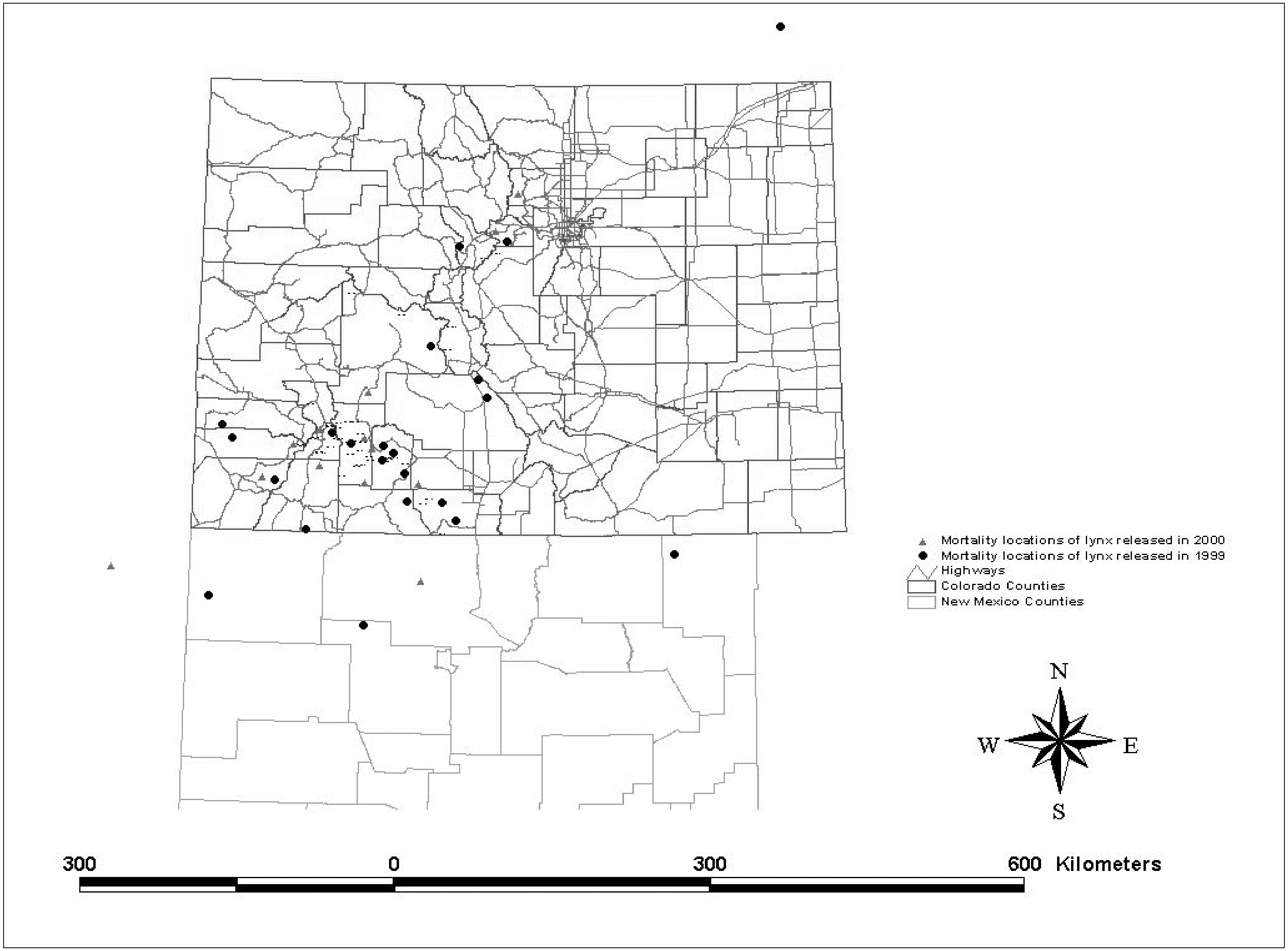

Figure 7. Locations of lynx mortalities. Circles depict mortalities of lynx released in 1999, triangles depict mortalities from lynx released in 2000.

Survival and Mortality Factors

Of the 96 lynx released, 39 mortalities have been recorded to date. From the 1999 releases (41 animals) we have had 24 known mortalities (Table 6). From the 2000 releases (55 animals) we have 15 known mortalities (Table 6). Of the total 9 confirmed starvation deaths, 3 were associated with animals released in less than ideal body condition (released under Protocol 1) and 2 were lynx less than1-year old (Table 4). Fourteen of the mortalities died of unknown causes. In 4 of these cases starvation could be ruled out as cause of death by evidence of good body condition through examination of bone marrow. Pneumonic plague could be ruled out in all 14 cases. Delayed retrieval of carcasses resulted in advanced deterioration of the body, making determination of cause of death impossible.

Necropsy results for 3 female lynx released in 2000, indicate they died from pneumonic plague. Two of these lynx were in good condition, with abdominal fat, no muscle wasting, and fat in the bone marrow. The only gross lesions were an acute fibrinous pneumonia (i.e., lung infection of short duration). These lynx had probably only been sick a few days before they died. A third female was in poorer body condition when found. Plague was diagnosed by flourescent antibody tests and isolation of *Yersinia pestis* from lung and spleen samples. A fourth lynx was also diagnosed with plague after she was hit by a car. A male lynx, recaptured near Laramie, Wyoming, tested positive for plague titers but did not have active plague. Thus, he had been exposed to plague but either did not contract the disease or recovered from the disease.

Table 6. Causes of death for lynx released into southwestern Colorado in 1999 and 2000.

Cause	1999 Male	1999 Female	2000 Male	2000 Female	2000 Unknown	Total
Starvation	1	6	1	1		9
Road-kill		2		2	1	5
Shot	2	1	1	1		5
Human-caused [a]	1	1				2
Trauma - unknown cause		1				1
Possible predation		1				1
Plague				3		3
Unknown	2	3	2	2		9
Unknown – not starvation [b]	1	2		1		4
Total Mortalities	7	17	4	10	1	39

[a] Cut collar found, no carcass.

[b] Starvation ruled out by condition of bone marrow.

Recaptures

Seven lynx have been recaptured and 6 subsequently re-released since their initial release. Lynx BC99F6 was released in 1999 under Protocol 1. Her behavior and incidental sightings by the public suggested the lynx was in poor condition. We trapped her using a Tomahawk™ live trap baited with rabbit. She was recaptured the first night (March 25, 1999) we set the trap. On capture, we found she was severely emaciated. We anesthetized her with Telezol (2 mg/kg) and returned her to the Colorado holding facility. She was rehabilitated through diet. The lynx gained weight steadily and was re-released on May 28, 1999. She was hit by a car on Interstate 70 on July 19, 1999. Necropsy results indicated she was in excellent body condition at her time of death.

Lynx AK99M9 was released on May 12, 1999 and recaptured on March 24, 2000. Field observations by the lynx monitoring crew suggested that the lynx was severely emaciated. Live-trapping the lynx failed, so the lynx was darted with Telazol (3 mg/kg) using a Dan-Inject CO_2 pistol. Physical examination revealed severe emaciation (6 kg). The lynx was returned to the Colorado holding facility and rehabilitated through diet. The lynx gained weight steadily and was re-released on May 3, 2000 but has not been located since and is listed as missing.

Lynx AK99F2 was released on May 7, 1999 and recaptured on April 18, 2000. Field observations by the lynx monitoring crew suggested that the lynx was emaciated. She was live-trapped with a Tomohawk™ live trap with one night's effort. On capture, we found she was emaciated. We anesthetized her with Telezol (2 mg/kg) and returned her to the Colorado holding facility. She was rehabilitated through diet. The lynx gained weight steadily and was re-released on May 22, 2000. This lynx is currently in the Core Release Area.

Lynx BC00F7 was released on April 2, 2000 and recaptured on February 11, 2001. She was severely emaciated and was captured by anesthetizing her with Telazol delivered IM by a jab-pole. She was returned to the Frisco Creek Wildlife Rehabilitation Center but died that night from emaciation and hypothermia.

Lynx BC00M13 was released on April 2, 2000 and recaptured on March 21, 2001 near Laramie, Wyoming. He had been observed by a homeowner on his porch. We recaptured the lynx because this type of behavior was not considered normal. On examination he was in good body condition. After a period of observation this lynx was re-released at the Rio Grande Reservoir on April 24, 2001. This lynx had previously been listed as one of our 15 missing lynx as he had not been located since Sept 2000. This lynx is currently in the Core Release Area

Lynx YK99F5 was recaptured on April19, 2001 to have her radio collar changed. She was captured in a live trap baited with one of her own kills. She was in very good body condition. We anesthetized her with Telazol (3mg/kg), processed and released her on the same site where she was captured. Only her cut collar was found on October 17, 2001, cause of death is assumed human-caused.

Lynx AK99F5 was treed by hounds and anesthetized with Telazol (3 mg/kg) on September 2, 2001. Her collar was exchanged, hair and blood samples were collected. She was in very good body condition and showed no evidence of lactation. She was re-released on the site she was recaptured once she recovered from the Telazol. This lynx remains in the same area as her recapture, within the Core Release Area.

Reproduction

Six lynx released in 1999 were known to be pregnant (Table 2, Release Protocol 3P), and 2 other females released may have been pregnant (Table 2, Release Protocol 3P?). Three of the 6 lynx known to have been pregnant on release in 1999 died within 2 months after release: 2 starved and 1 was killed on the road. Long-distance movements and lack of stationary movement patterns of the other 3 lynx known to have been pregnant on release in 1999 suggests these females did not have young with them by July 1999. Of the 2 females that might have been pregnant, movement patterns were not suggestive of a female rearing young. It is not known if any other females bred and/or had young once released, however no females snow-tracked in Year 2 had young with them.

Beginning in March 2000 both male and female lynx began to exhibit extensive movements

(>100 km) away from areas they had used throughout the winter. For example, 1 male moved from the area near Frisco he used in the winter to the area west of Lizardhead Pass, a straight line distance of approximately 270 km (Figure 8). Such movements by both females and males put them in close (< 5 km) proximity to a lynx of the opposite sex. These extreme movements may have been related to breeding behavior. All 7 females alive in spring 2000 were documented in close (< 5 km) proximity to a male during the breeding season and could have bred. Two isolated males did not move during March or April and thus were not in close proximity to a known female during the breeding season. This was a male that had used the area in and adjacent to the northwest corner of Rocky Mountain National Park and a male that used the area around Cuchara, Colorado throughout the winter.

The 7 females in the wild during breeding season 2000 were monitored for site fidelity to a given area during the denning period of May and June. Each of these 7 females was directly observed in summer 2000 over 3-5 different visits to look for accompanying kittens. No kittens were found. The question of whether they successfully bred or had kittens at some point in 2000 is unknown. However, no kittens were found during the following winter through snow-tracking.

From radiographs taken of the 35 females released in 2000, after breeding season,1 female was known to be pregnant and 3 were possibly pregnant. Movement patterns suggested none of these 4 females had kittens with them by July 2000.

Of the 49 lynx being tracked on a regular basis during the March 2001 breeding season, there were 29 females and 20 males. We documented movements that may have been related to breeding. The largest movement observed was a male that moved to Laramie, Wyoming and was subsequently recaptured, rehabilitated and re-released in the Core Release Area in Colorado after the breeding season. Other movements were of a much smaller scale, 10-30 km. These movements were primarily movements of males towards a female. We documented 10 potential 'pairs' where a pair was defined as a male and female within 5 km of each other and in the same drainage. More pairs could have occurred which we did not document from aerial- or ground-tracking because of the time delays between lynx locations. To date, no reproduction has been documented in 2001 from direct observations of females. Snow-tracking efforts this winter will focus initially on females in an attempt to document possible kittens through tracks.

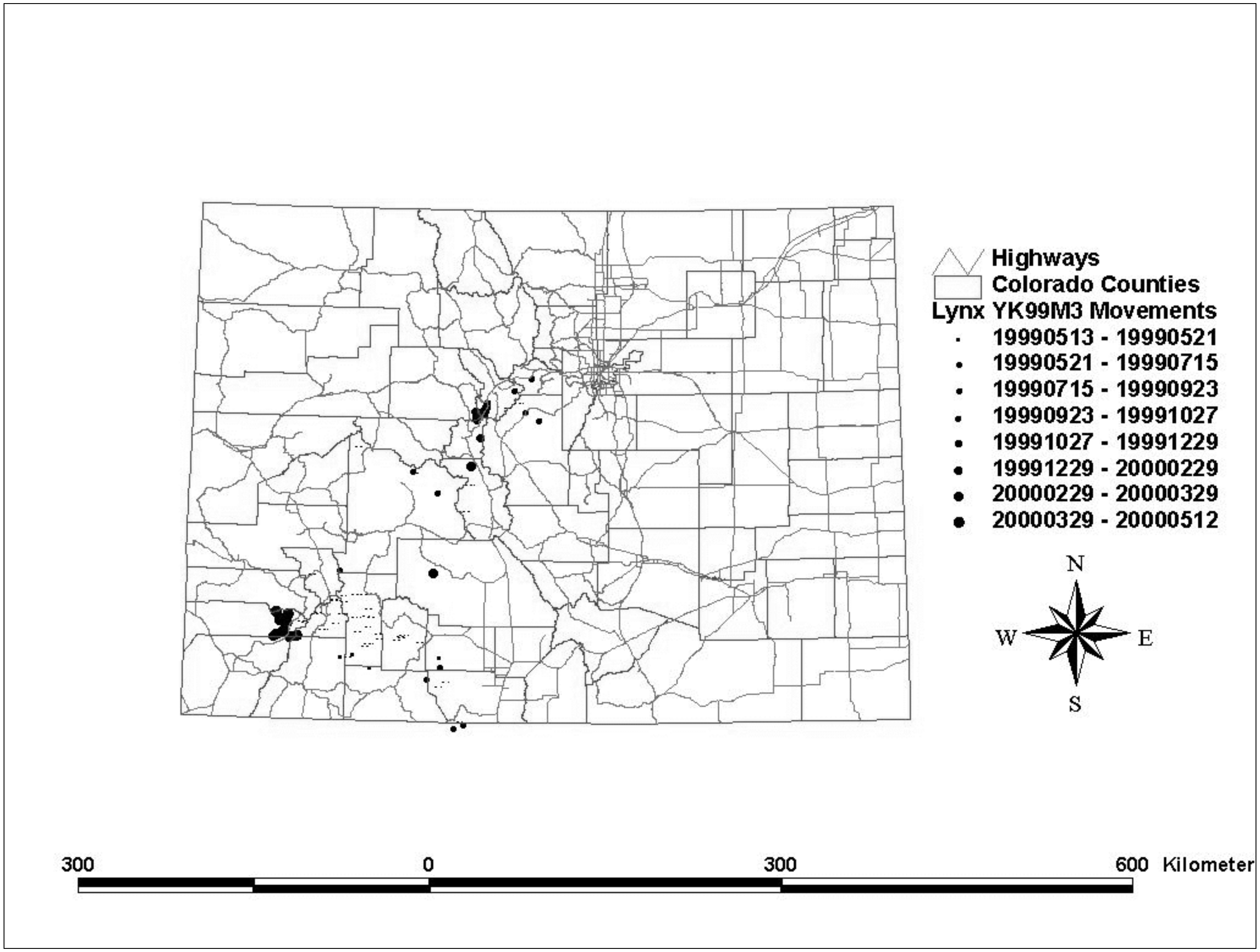

Figure 9. Movements of a male lynx in breeding season 2000. Straight-line distance from winter use area to the area used during breeding season in approximately 270 km. The larger the circle the more recent the date, up to May 2000

Current Status

Of the total 96 lynx released we have 39 known mortalities (Table 7). We currently are listing 16 lynx as missing - 11 males, 5 females. We have not heard signals on 13 (11 males, 2 females) of these lynx since at least December 2000. The remaining 3 missing lynx are females that have been lost for less than 1 year. 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). We continue to search for all missing lynx during both aerial and ground searches. There have been 4 incidents where lynx missing for over a year have returned to the Core Release Area and are now once again being monitored on a regular basis. Thus, it is premature to consider missing lynx as lost to the Colorado lynx program. However, of the 16 missing lynx, 3 have collars whose battery life expired spring 2001 and will probably never be located through telemetry. At least 1 of the missing lynx is a mortality where we know a collar was found on a road kill but the collar was not returned to the CDOW for identification. One female is known to have slipped her collar. Thus, we are currently tracking 41 lynx.

Table 7. Current status of lynx reintroduced to Colorado.

	Females	Males	Unknown	TOTAL
Released	57	39		96
Known Dead	27	11	1	39
Missing	5	11		16[a]
Slipped Collar	1			1
Tracking	24	17		41

[a] 1 is unknown mortality.

Hunting Behavior

Snow-tracking of released lynx provided preliminary information on hunting behavior by documenting location of kills, food caches, chases, and through scat analysis. Prey from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed.

During Year 1 a total of 10 kills were located. All the snow-tracking effort was conducted on 9 lynx released under Protocols 1 and 2. Any lynx released under Protocol 3 were released too late to track. In Year 2, ground crews tracked 13 of the lynx released in 1999. Two other lynx were being located during this time but were not in areas covered by snow. We found 64 kills and collected 109 scat samples that will be analyzed for content. Lynx released in 2000 were released too late to snow track in Year 2. In Year 3, field crews snow-tracked 48 lynx, documented 86 kills and collected 189 scat samples.

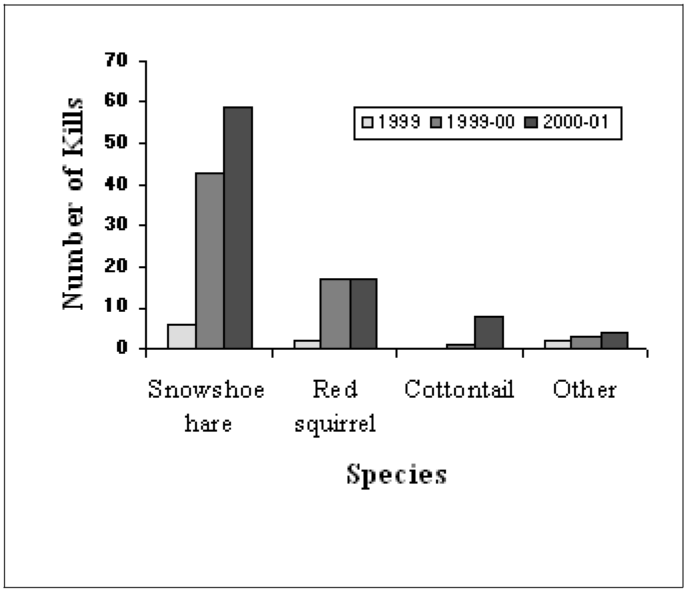

Figure 10. Winter diet of reintroduced lynx estimated from snow-tracking data.

Data collected on kills (Figure 10) suggests the reintroduced lynx are feeding on their preferred prey species, snowshoe hare (*Lepus americanus*) and pine (red) squirrel (*Tamiasciurus hudsonicus*) 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. For example, through snow-tracking we have some evidence that lynx are mousing and several of the fresh carcasses have yielded small mammals in the gut on necropsy.

However, the extent of small mammals in the diet are not accurately portrayed by information collected based on prey remains in snow. Nearly all the scat samples collected have been found through snow-tracking efforts and thus will be representative of winter diet only. The summer diet of lynx elsewhere has been documented to include less snowshoe hare and more alternative prey than in winter (Mowat et al. 1999).

Habitat Use

Gross habitat use was documented from 2441 aerial locations of lynx collected from February 1999 through December 2001. Throughout the year Engelmann spruce (*Picea engelmannii*) / subalpine fir (*Abies lasiocarpa*) (S/F) was the dominant cover used by lynx (Figure 11). A mix of Engelmann spruce, subalpine fir and aspen (*Populus tremuloides*) (S/F/A) was the second most common cover type used throughout the year. Various riparian and riparian mix areas was the third most common cover type where lynx were

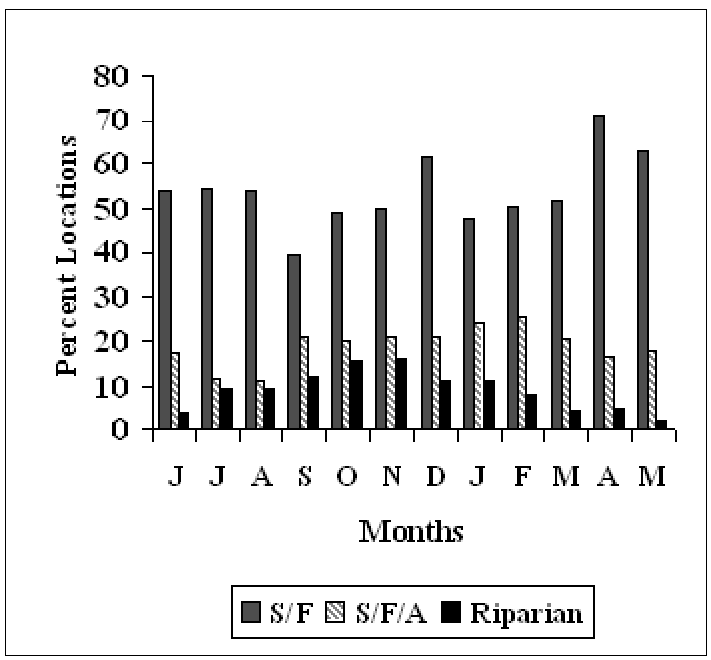

Figure 11. Percent aerial locations in Engelmann spruce - subalpine fir forests (S/F), Engelmann spruce- subalpine fir-aspen forests (S/F/A), and riparian areas by month.

found during the daytime flights. Use of S/F and S/F/A 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.

A total of 473 site-scale habitat plots were completed in Year 3. The majority understory species at all 3 heights was Engelmann spruce, followed by subalpine fir, willow (*Salix* spp.) and aspen (Figure 12). 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. Coarse woody debris was also present in 10-35% of plots. If present, willow provided the greatest percent cover within a plot (Figure 13) followed by Engelmann spruce, subalpine fir, aspen and coarse woody debris.

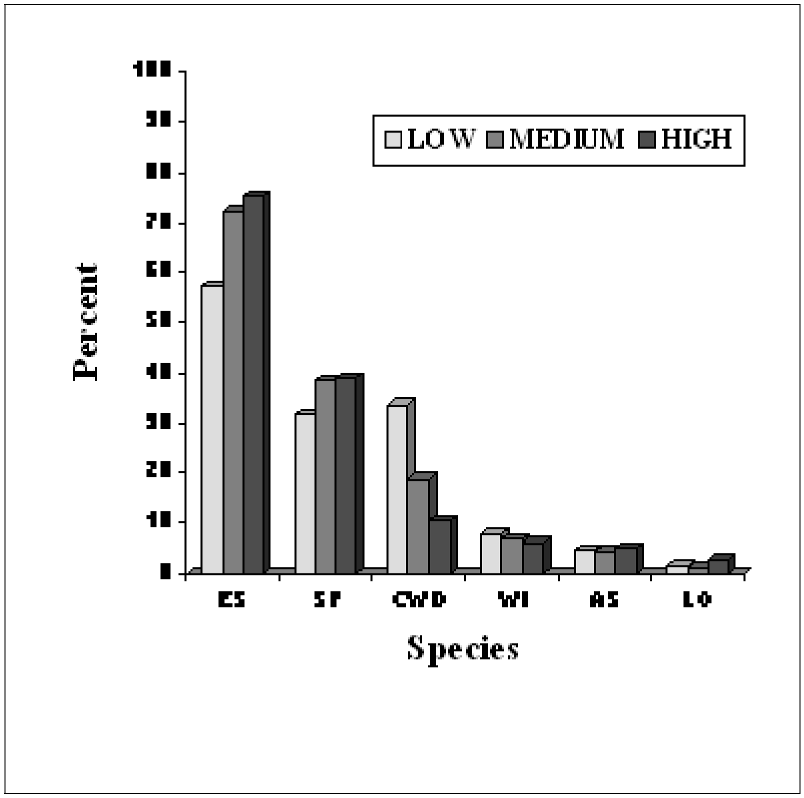

Figure 12. Mean percent cover of habitat plot by understory tree/shrub species Engelmann spruce (ES), subalpine fir (SF), willow (WI), aspen (AS), lodgepole pine (LO), and coarse woody debris (CWD) if species is present. Mean percent cover is estimated for 3 height levels above the snow (low = 0-0.5m, medium = 0.51 - 1.0 m, high = 1.1 - 1.5 m).

Engelmann spruce provided a mean of 35.87 % overstory within 86.68% of the plots (Figure 14). Subalpine fir and aspen provided overstory for < 50% of the plots, but when present provided approximately the same mean percent cover as Engelmann spruce (Figure 14). Willow and lodgepole pine provided fewer than 10% of the plots with cover, but when present provided nearly the same percent cover as the other tree species (Figure 14).

The most common tree species in the habitat plots was Engelmann spruce (Figure 15). Subalpine fir and aspen were also present in > 35% of the plots. Most habitat plots were vegetated with trees of DBH < 6" (Figure 15). As DBH increased, percent occurrence decreased within the plot. The larger DBH trees (>18") within the plots were generally Engelmann spruce with fewer subalpine firs of that DBH class present in the habitat plots. No willow or aspen of DBH > 18" were present in any of the plots. Of the 5 most common tree species in the habitat plots, mean number of trees for each DBH size class ranged from 0.18 to 10.82 except for willow which averaged 74.83 plants per plot (Figure 16). Areas of willow used by lynx are typically dense willow thickets.

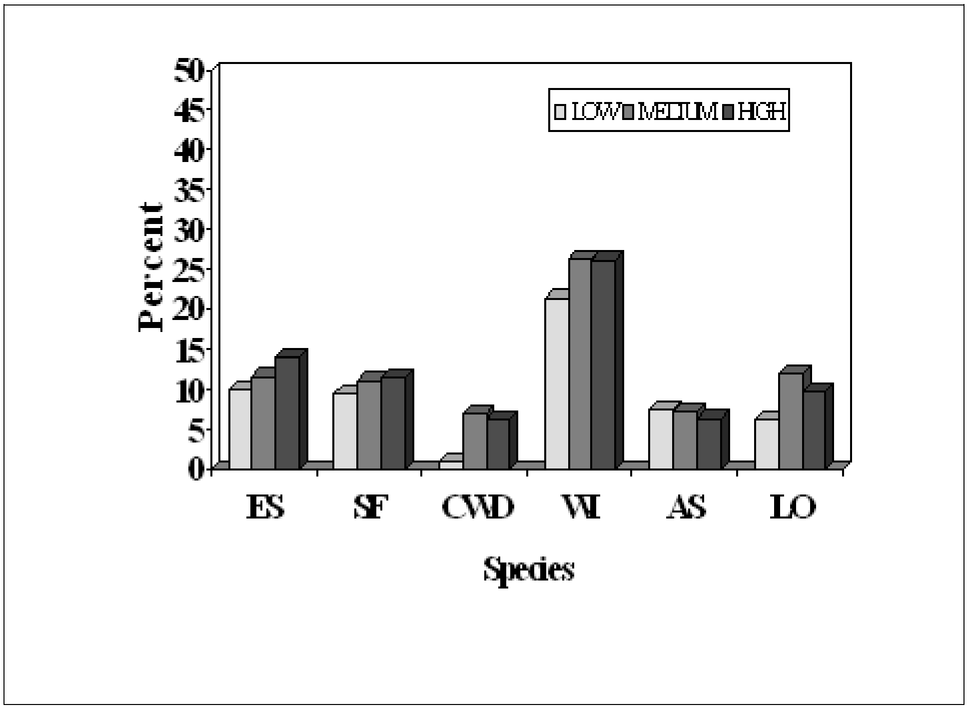

Figure 13. Mean percent cover of habitat plots by understory tree or shrub species Engelmann spruce (ES), subalpine fir (SF), willow (WI), aspen (AS), lodgepole pine (LO), and coarse woody debris (CWD) if species is present.

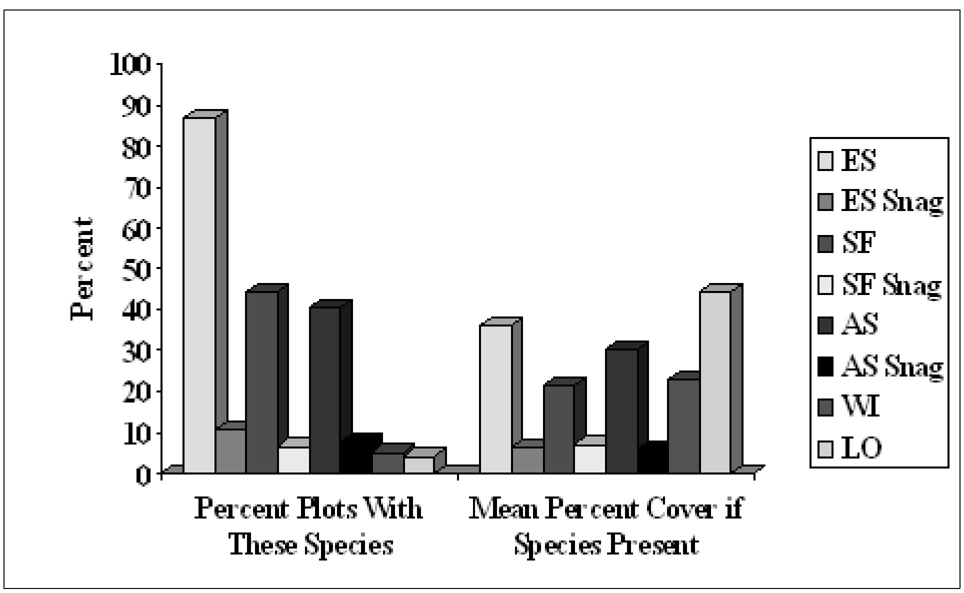

Figure 14. Percent plots with overstory tree species Engelmann spruce (ES), subalpine fir (SF), willow (WI), aspen (AS), lodgepole pine (LO), and coarse woody debris (CWD). Mean percent overstory cover if tree species present.

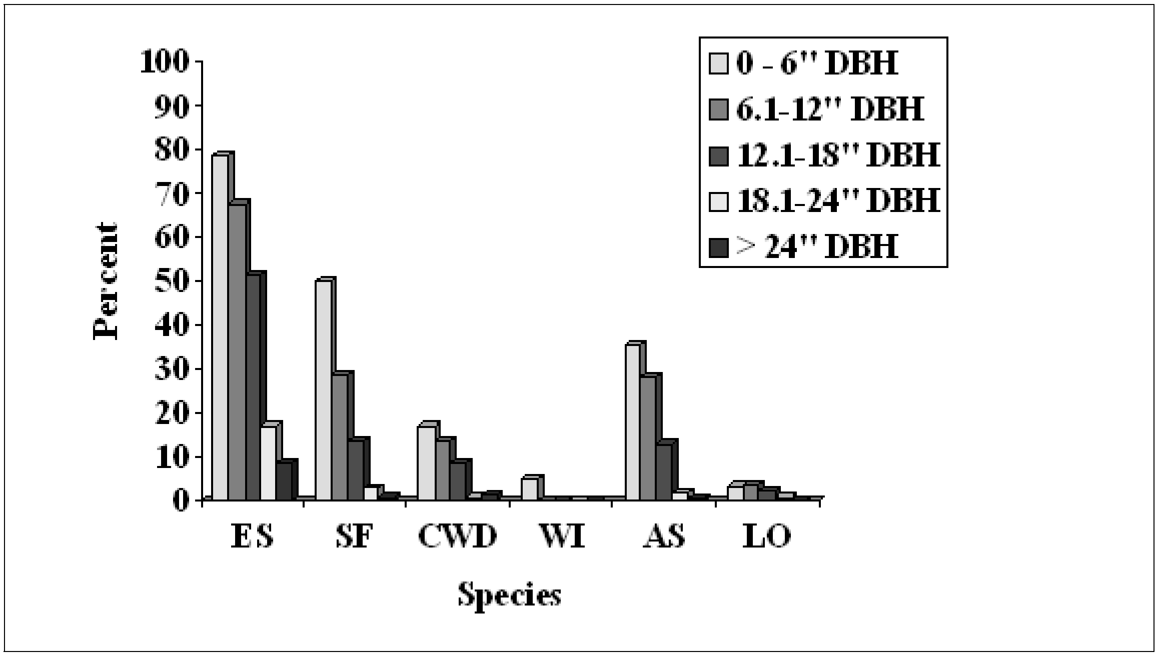

Figure 15. Percent of habitat plots with tree species Engelmann spruce (ES), subalpine fire (SF), willow (WI), aspen (AS), lodgepole pine (LO), and coarse woody debris (CWD) by diameter at breast height (DBH) size class.

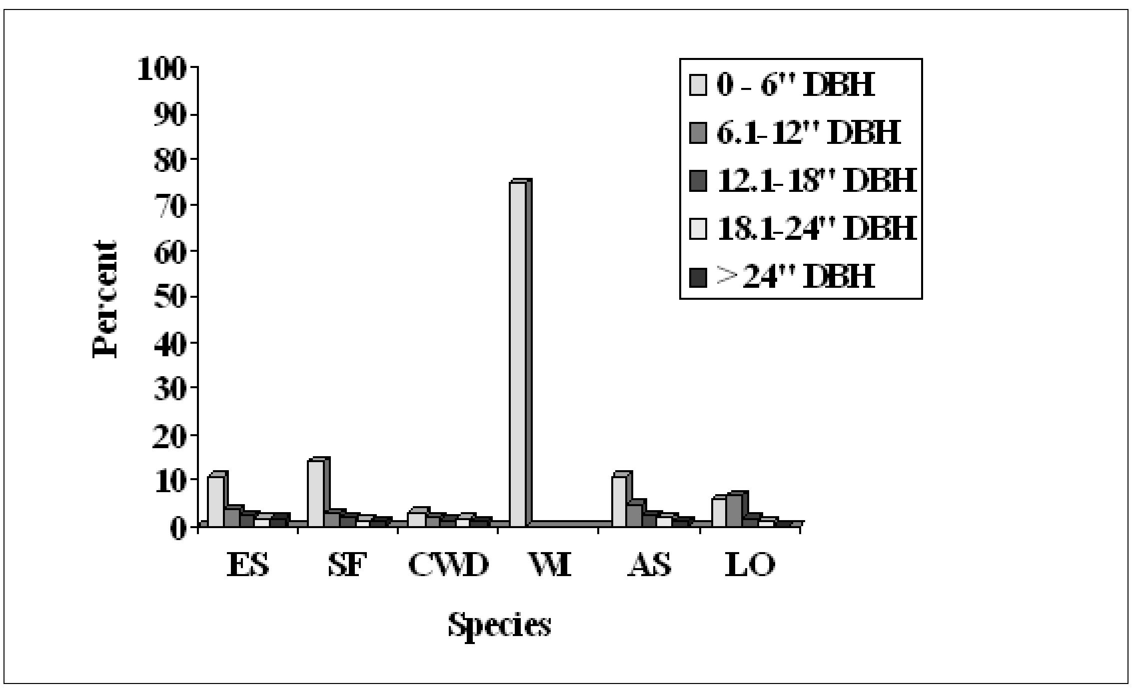

Figure 16. Mean number of trees or shrubs in habitat plots with tree species Engelmann spruce (ES), subalpine fire (SF), willow (WI), aspen (AS), lodgepole pine (LO), and coarse woody debris (CWD) by diameter at breast height (DBH) size class.

Discussion

Of the 96 lynx released in Colorado in 1999 and 2000 we are currently monitoring 41 lynx on a regular basis and an additional 16 lynx may still be alive, although not being monitored. We have 39 confirmed mortalities. Survival of lynx released in the second year has been higher than lynx released in the first year. Human-caused mortalities due to vehicle collision, gunshot, and the mortalities where only a cut collar was found comprise the greatest known cause of mortality for the reintroduced lynx (31%). Mortalities due to starvation (23%) were minimized with improved release protocols. Only 2 of the 55 lynx released in 2000 died of starvation and 1 of those died 8.5 months post-release. Three lynx died of plague, 1 road kill tested positive for plague, and 1 lynx had plague positive titers while healthy. Carnivores are most often exposed to plague by eating infected rodents or by being bitten by rodent fleas (Biggens and Kosoy 2001). Although it is known that felids are highly susceptible to plague (Aiello 1998), the 5 cases of plague in lynx reintroduced to Colorado are the first documented for this species.

Dispersal movement patterns for lynx released in 2000 were similar to those of lynx released in 1999. However, more animals remained within the Core Release Area. This increased site fidelity may be due to the presence of con-specifics in the area on release. Numerous travel corridors have been used repeatedly by more than 1 lynx, possibly suggesting route selection based on olfactory cues. 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 Release Area. During the summer of 2000 and 2001, several lynx that had been faithful to a given area during the winter months made large 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).

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. Nearly all the scat samples collected have been found through snow-tracking efforts and thus are representative of winter diet only. However, the summer diet of lynx has been documented to include less snowshoe hare and more alternative prey than in winter (Mowat et al., 1999).

Reproduction is critical to achieving a self-sustaining viable population of lynx in Colorado. Although females have been monitored and observed during each denning season, no kittens have been found to date. Snow-tracking has also not provided evidence that any of the females tracked had kittens with them. However, the question of whether they successfully bred or had kittens at some point is unknown. With only 7 females from the 1999 releases in the wild in spring 2000 it was expected that there might not be successful reproduction in 2000. However, the extreme movements observed by both females and males in March and April 2000 may have been related to breeding behavior. March and April are the natural breeding periods for northern lynx (Tumlison 1987). From observations of the 29 females alive in summer 2001, we have not yet documented kittens. We may still find evidence of kittens through snow-tracking efforts in winter 2001-02.

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 shifts 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 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. No den sites have been located as yet in Colorado for comparison.

Through extensive monitoring of released animals we were able to continuously evaluate and modify release protocols to improve survival of released lynx. The primary element in later, more successful release protocols was increased time in captivity at the Colorado holding facility.

Increasing the amount of time lynx were held in the Colorado holding facility provided each lynx with an opportunity to increase body weight and acclimate to the climate, elevation, and local conditions of the environment they would be released into. Although most lynx were housed in individual pens, with a few sharing a pen with one other lynx, the holding facility also allowed the lynx to hear and smell each other throughout this acclimation period. Such contact may have provided time for social interactions to occur. Such social interactions may improve the likelihood these animals could form a breeding population.

If additional lynx are released in Colorado the following guidelines are recommended in establishing release protocols. Translocated animals should be adults and females should not be pregnant on release. Once lynx are moved from their place of origin they should be held a minimum of 3 weeks in a local holding facility to provide a high quality diet for gaining optimal body condition prior to release in the new area, acclimation time to adjust to local conditions, and possible social interactions. Animals should be released in the spring to ensure the highest prey abundance in the release area. These release protocol guidelines may also prove useful if other states attempt lynx reintroductions or augmentations.

Future Research

Future research will include the continued monitoring of lynx released in Colorado that have remained in the Core Release Area. Such monitoring will include continued data collection and analysis on survival and mortality factors, reproduction, habitat use, winter and summer diet, and movement patterns. If additional funding becomes available, reintroduced lynx that have moved beyond the Core Release Area should also be monitored, particularly those lynx using areas near the Interstate Highway 70 corridor. We will continue to attempt to recapture lynx to replace radio collars that are either malfunctioning or scheduled to stop functioning. Any Colorado born lynx will be radio collared once they reach a minimum of 10 months of age.

Studies have been initiated to refine mark-recapture techniques to estimate abundance of lynx from hair-snag data. Such an approach would provide a non-invasive technique for estimating abundance.

A snowshoe hare ecology study was initiated in 2001 to describe density of hares in various forest stands and which habitats and topographic features are most important to hare density and survival. From this research, management prescriptions may be designed to better manage forests for optimal hare populations. Maintaining abundant and widespread snowshoe hare populations is essential to establishing lynx in Colorado.

Through funding provided by Colorado Department of Transportation (CDOT) a detailed analysis of lynx movement patterns as they relate to highways has been initiated.

The feasibility of augmenting this reintroduction effort by releasing additional animals from Canada and Alaska is being considered by CDOW to improve the likelihood of establishing a viable population of lynx in Colorado.

Funding is being sought to develop protocols for collecting data on lynx summer diet by using dogs trained to locate lynx scat

If viable, self-sustaining populations of lynx are established in Colorado, habitat manipulation studies will be needed to more fully understand how lynx respond to their habitat and how best to alter habitats to maintain and enhance lynx populations.

Acknowledgments

The lynx reintroduction program involved the efforts of literally hundreds of people across North America, in Canada and the U. S. Any attempt to properly acknowledge all the people who played a role in this effort is at risk of missing many people. The following list should be considered to be incomplete.

CDOW CLAWS Team (1998-2001): Bill Andree, Tom Beck, Gene Byrne, Bruce Gill, Mike Grode, Rick Kahn (Program Leader), Dave Kenvin, Todd Malmsbury, Jim Olterman, Dale Reed, John Seidel, Scott Wait, Margaret Wild. *CDOW*: John Mumma (Director 1996-2000), Conrad Albert, Jerry Apker, Cary Carron, Don Crane, Larry DeClaire, Phil Ehrlich, Lee Flores, Delana Friedrich, Dave Gallegos, Juanita Garcia, Drayton Harrison, Jon Kindler, Ann Mangusso, Jerrie McKee, Melody Miller, Mike Miller, Kirk Navo, Robin Olterman, Jerry Pacheo, Mike Reid, Ellen Salem, Eric Schaller, Mike Sherman, Jennie Slater, Steve Steinert, Kip Stransky, Suzanne Tracey, Anne Trainor, Brad Weinmeister, Nancy Wild, Perry Will, Brent Woodward, Kelly Woods, Kevin Wright. *Lynx Advisory Team* (1998-2001): Steve Buskirk, Jeff Copeland, Dave Kenny, John Krebs, Brian Miller (Co-leader), Mike Phillips, Kim Poole, Rich Reading (Co-leader), Rob Ramey, John Weaver. *U. S. Forest Service:* Kit Buell, Joan Friedlander, Jerry Mastel, John Squires, Fred Wahl. *U. S. Fish And Wildlife Service:* Lee Carlson, Gary Patton (1998-2000), Kurt Broderdorp. *State Agencies*: Gary Koehler (Washington). *National Park Service:* Steve King. *Colorado State University*: Alan B. Franklin, Gary C. White. *Colorado Natural Heritage Program:* Rob Schorr, Mike Wunder. *Alaska:* ADF&G: Cathie Harms, Mark Mcnay, Dan Reed (Regional Manager), Wayne Reglin (Director), Ken Taylor (Assist. Director), Ken Whitten, Randy Zarnke, Other:Ron Perkins (trapper), Dr. Cort Zachel (veterinarian). *British Columbia*: Dr. Gary Armstrong (veterinarian), Mike Badry (government), Paul Blackwell (trapper coordinator), Trappers: Dennis Brown, Ken Graham, Tom Sbo, Terry Stocks, Ron Teppema, Matt Ounpuu. *Yukon*: Government: Arthur Hoole (Director), Harvey Jessup, Brian Pelchat, Helen Slama, Trappers:Roger Alfred, Ron Chamber, Raymond Craft, Lance Goodwin, Jerry Kruse, Elizabeth Hofer, Jurg Hofer, Guenther Mueller (YK Trapper's Association), Ken Reeder, Rene Rivard (Trapper coordinator), Russ Rose, Gilbert Tulk, Dave Young. *Alberta*: Al Cook. *Northwest Territories:* Albert Bourque, Robert Mulders (Furbearer Biologist), Doug Steward (Director NWT Renewable Res.), Fort Providence Native People. *Colorado Holding Facility*: Herman and Susan Dieterich. *Pilots*: Dell Dhabolt, Larry Gepfert, Al Keith, Jim Olterman, Matt Secor, Whitey Wannamaker, Dave Younkin. *Field Crews*: Bryce Bateman, Bob Dickman, Denny Morris, Gene Orth, Chris Parmater, Jake Powell, Jeremy Rockweit, Jennifer Zahratka. *Photographs*: Tom Beck, Bruce Gill, Mary Lloyd, Rich Reading, Rick Thompson. *Funding*: CDOW, GOCO, Turner Foundation, U.S. Forest Service, Vail Associates.

Literature Cited

Aiello, S. E., editor 1998. The Merck Veterinary Manual. Eighth Edition. Merck & Co., Inc. Whitehorse Station, New Jersey.

Aubry, K. B., G. M. Koehler, J. R. Squires. 1999. Ecology of Canada lynx in southern boreal forests. Pages 373-396 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S McKelvey, and J. R. Squires, editors. Ecology and Conservation of Lynx in the United States. General Technical Report for U. S. D. A. Rocky Mountain Research Station. University of Colorado Press, Boulder, Colorado.

Biggins, D. E. and M. Y. Kosoy. 2001. Influences of introduced plague in North American mammals: implications from ecology of plague in Asia. Journal of Mammalogy 82: 906-916.

Burnham, K. P. and D. R. Anderson. 1998. Model Selection and Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York, New York.

Byrne, G. 1998. Core area release site selection and considerations for a Canada lynx reintroduction in Colorado. Report for the Colorado Division of Wildlife.

Curtis, J. T. 1959. The vegetation of Wisconsin. University of Wisconsin Pres, Madison.

Ganey, J. L. and W. M. Block. A comparison of two techniques for measuring canopy closure. Western Journal of Applied Forestry 9:1: 21-23.

Hodges, K. E. 1999. Ecology of snowshoe hares in southern boreal and montane forests. Pages 163-206 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S McKelvey, and J. R. Squires editors. Ecology and Conservation of Lynx in the United States. General Technical Report for U. S. D. A. Rocky Mountain Research Station. University of Colorado Press, Boulder, Colorado.

Koehler, G. M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology 68:845-851.

Laymon, S. A. 1988. The ecology of the spotted owl in the central Sierra Nevada, California. PhD Dissertation University of California, Berkeley, California.

Major, A. R. 1989. Lynx, *Lynx canadensis canadensis* (Kerr) predation patterns and habitat use in the Yukon Territory, Canada. M. S. Thesis, State University of New York, Syracuse.

Mowat, G., K. G. Poole, and M. O'Donoghue. 1999. Ecology of lynx in northern Canada and Alaska. Pages 265-306 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S McKelvey, and J. R. Squires, editors. Ecology and Conservation of Lynx in the United States. General Technical Report for U. S. D. A. Rocky Mountain Research Station. University of Colorado Press, Boulder, Colorado.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7-15.

Poole, K. G., G. Mowat, and B. G. Slough. 1993. Chemical immobilization of lynx. Wildlife Society Bulletin 21:136-140.

Seidel, J., B. Andree, S. Berlinger, K. Buell, G. Byrne, B. Gill, D. Kenvin, and D. Reed. 1998. Draft strategy for the conservation and reestablishment of lynx and wolverine in the southern Rocky Mountains. Report for the Colorado Division of Wildlife.

Shenk, T. M. 1999. Program narrative: Post-release monitoring of reintroduced lynx (*Lynx canadensis*) to Colorado. Report for the Colorado Division of Wildlife.

Squires, J. R. and T. Laurion. 1999. Lynx home range and movements in Montana and Wyoming: preliminary results. Pages 337-349 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S McKelvey, and J. R. Squires, editors. Ecology and Conservation of Lynx in the United States. General Technical Report for U. S. D. A. Rocky Mountain Research Station. University Press of Colorado, Boulder, Colorado.

Thomas, J. W. Ed. 1979. Wildlife habitats in managed forests - the Blue Mountains of Oregon and Washington. USDA Agricultural Handbook No. 553. U. S. Government Printing Office. Washington, D. C.

Tumlison, R. 1987. Mammalian Species: *Felis lynx*. American Society of Mammalogists.

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.

White, G. C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 (suppl):120-138.

Wild, M. A. 1999. Lynx veterinary services and diagnostics. Job Progress Report for the Colorado Division of Wildlife. Fort Collins, Colorado.