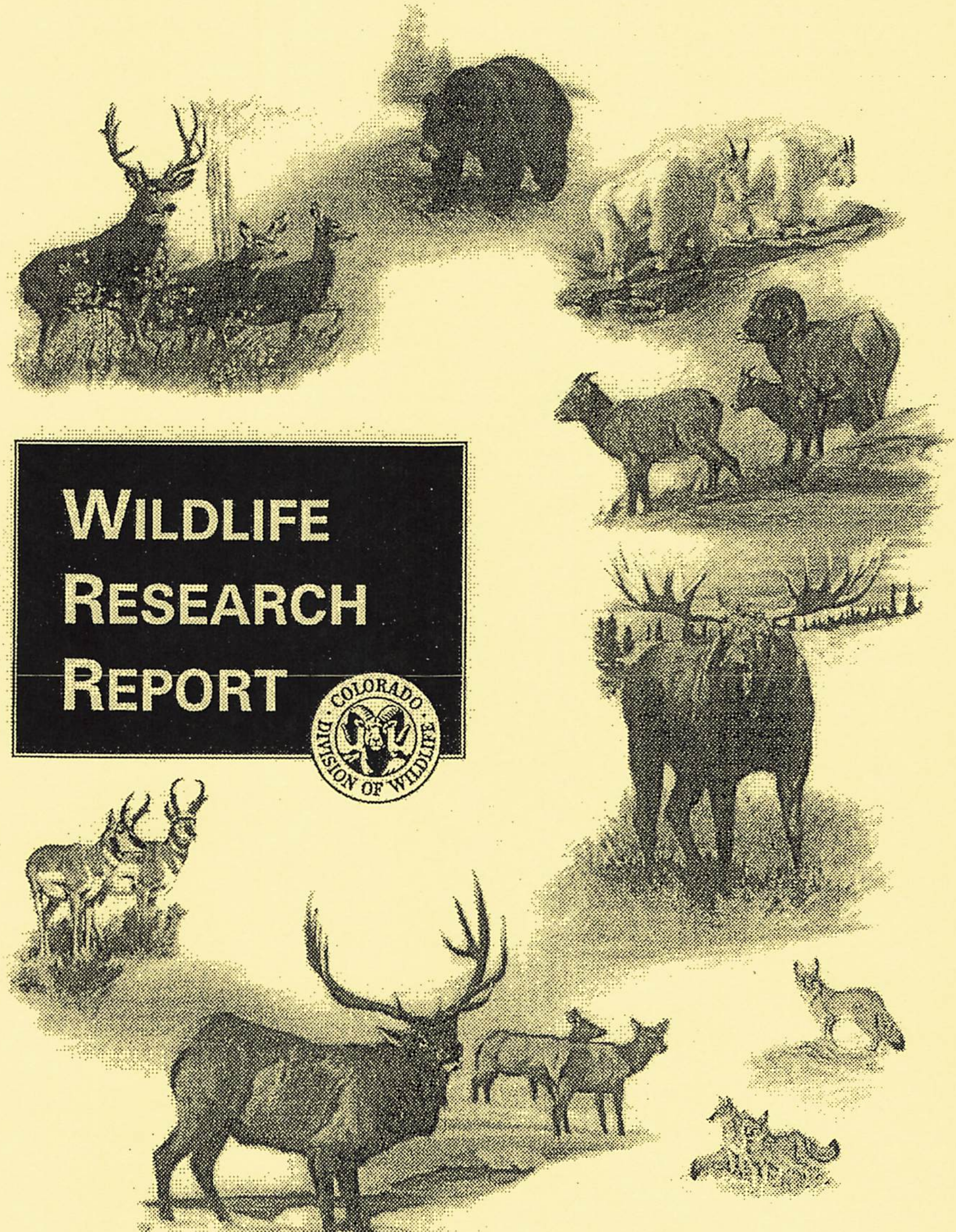
MAMMALS - JULY 2003



WILDLIFE RESEARCH REPORT

COLORADO DIVISION OF WILDLIFE

WILDLIFE RESEARCH REPORT

JULY 2003

MAMMALS RESEARCH PROGRAM

COLORADO DIVISION OF WILDLIFE
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Colorado Division of Wildlife
Wildlife Research Report
July 2003

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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 0662 : Preble's Meadow Jumping Mouse Conservation

Task No. 2 : Effects of Resource Addition on Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) Movement Patterns

Period Covered: July 1, 2002 - June 30, 2003

Author: Anne M. Trainor.

Personnel: T. M. Shenk, K. Wilson, G. C. White

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.

ABSTRACT

The Preble's meadow jumping mouse (*Zapus hudsonius preblei*; PMJM) is a federally threatened species. Improving our understanding of PMJM habitat is essential for the development of effective management strategies for conservation of the species. Thus, the objectives of our research were to compare microhabitat characteristics among low and high use areas within PMJM habitat and to determine how the addition of artificial resources influence the movement patterns of PMJM. A comparison of microhabitat characteristics from a random sample of "high-use" and "no-use" areas indicated a greater ($P < 0.0001$) shrub canopy cover in "high-use" areas verses "no-use" areas (47.7% ± 29.8%, 12.6% ± 14.11%, respectively). Further, "high-use" areas had greater basal cover ($P = 0.013$) and bare ground ($P = 0.0459$) and "no-use" areas contained a greater ($P = 0.0331$) abundance of forb canopy cover. We conducted a manipulation experiment where we constructed patches of artificial resources (food and cover) in areas without previous PMJM activity. PMJM were radio collared and located hourly before and after the addition of food and cover. The majority of PMJM movements were not influenced by the addition of resources in 2002. These results may be due to site fidelity or lack of exploratory movement to locate the additional resources

Effects of Resource Addition on Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) Movement Patterns

Anne M. Trainor
Colorado State University

INTRODUCTION

The U.S. Fish and Wildlife Service (USFWS) listed the Preble's meadow jumping mouse (*Zapus hudsonius preblei*; PMJM) as a threatened species in 1998 under the Endangered Species Act (USFWS 1999). Upon listing, little was known about the biology and habitat requirements of this subspecies within its range along the Front Range of Colorado and southeastern Wyoming. Since listing, a number of projects (e.g., long-term monitoring, surveying, and movement studies) have collected valuable information throughout Colorado (Schorr 2001, Meaney 2000, Shenk and Sivert 1999). However, information on specific habitat requirements and their relationship to the distribution, density, survival and reproduction of PMJM is still lacking.

The threatened status of PMJM requires management decisions be made despite our limited knowledge. In particular, the species and its habitat are subject to habitat conservation plans (HCPs). HCPs are written for endangered and threatened species to compensate for authorized "take" through mitigation practices (Bingham and Noon 1998). HCPs require the use of the "best available" science to determine the biological needs of target species (Harding et al. 2001). Collection of reliable information for the species will improve the mitigation practices developed for HCPs. Well-designed habitat manipulation experiments provide the strongest inference to determine cause and effect relationships. Understanding of the species habitat requirements will enable the development of effective mitigation strategies.

A manipulation experiment was conducted in Douglas County, Colorado (Columbine Open Space) during 2002 and 2003 to advance our understanding of PMJM habitat requirements. We manipulated sections of the riparian habitat and adjacent grassland within the 100-year flood plain. The site was manipulated by adding patches (3 m x 2.43 m) of artificial resources (food and cover). Time limitations of only a 2-year study were inadequate for vegetation to establish and limited funding (cost of planting and sustaining vegetation) restricted this manipulation experiment to simulating habitat with temporary structures and food supplementation. The treatments were placed in areas of low use based on past monitoring studies conducted by the Colorado Division of Wildlife (CDOW) during 1998-2000. PMJM were radio tracked before and after the manipulation to determine if PMJM movements were altered through the addition of resources.

We propose two primary objectives: 1) determine how the presence of resource additions influences the distribution of individual PMJM within a population, and 2) to quantify habitat characteristics of PMJM on a microhabitat scale. We want to examine if the distribution of individual PMJM can be altered in response to the addition of resources (food and cover) and to quantify relevant microhabitat characteristics where PMJM have been detected.

STUDY AREA

The study was conducted within the riparian habitat within Columbine Open Space, owned by Douglas County Open Space managed by the CDOW and the adjacent grassland. Columbine Open Space was selected because PMJM were monitored for 3 years by the CDOW (1998-2000), providing site-specific information on PMJM locations before this manipulation experiment.

METHODS

PMJM were trapped using non-folding Sherman live traps (7.6 cm x 8.9 cm x 22.9 cm) placed 5m apart along approximately 0.5 km transects adjacent to both sides of East Plum Creek for a minimum of 5 consecutive nights. Trapping procedures were in accordance with the guidelines published by the USFWS (1999). Species other than PMJM were recorded by trap location and immediately released. The following information was recorded for captured PMJM: unique identification, trap location, weight, sex, age, and reproductive condition. PMJM were scanned for a passive integrated transponder (PIT) tag. Newly captured individuals were marked by inserting a unique PIT-tag. Individuals $\geq$18 grams were anesthetized with isoflurane and fitted with a 1-g radio transmitter (Holohil Systems Ltd Ontario, Canada). All methods were approved by the Animal Care and Use Committee of Colorado State University (Authorization Number A3572-01).

Radio telemetry was used to monitor locations of individuals for a 21-day period, the battery life of the radio transmitters. Observers attempted to stay approximately 3 m from the radio-tagged individual to avoid influencing PMJM movement. Observations taken 3 m or greater from PMJM did not influence movement (T. Shenk, CDOW personal. comm.). The following information was recorded at each relocation: individual identification, time, weather, and surrounding vegetation. All data were combined into a geographical information system (GIS) database using ArcView®3.2 (Environmental Systems Research Institute, Redlands, California, U.S.A.).

The manipulation experiment consisted of 5 phases: 1) selection of areas of little or no previous use by PMJM based on CDOW location data (1998-2000) collected at Columbine Open Space, 2) recording of pre-treatment location data of radio-tagged individuals for 6 nights, 3) selection of treatment plot location based on pre-treatment and CDOW location data, 4) addition of resources to treatment plots, and 5) recording of post-treatment location of radio-tagged individuals. Two sessions (June and July) of the manipulation experiment were conducted each year.

A digital map with a grid cell size of 9 m x 9 m was constructed for the entire study site with ArcView®3.2 (Environmental Systems Research Institute, Redlands, California, U.S.A.) software. CDOW location data was pooled into a single coverage over the grid to establish areas $\geq$ 1,000 m^2 containing only low use cells (<2 locations/cell based on CDOW location data) within the 100-year flood plain. Location of treatment plots was selected with a stratified random design from a set of candidate cells meeting criteria developed to describe poor PMJM habitat (sparse vegetation and little food) within 60 m of East Plum Creek, and low historical use.

The artificial cover, simulating vertical complexity, was constructed with wheat straw and tree branches distributed in a patch (3 m x 2.43 m). Burlap cloth was suspended 30 cm over the tree branches and straw. Food supplements composed of an equal mixture of whole wheat, dehydrated alfalfa pellets and sweet feed were placed on cardboard trays (0.16 m x 0.3 m) within the straw and branches as an attractant and a source of high protein. The dimensions of the treatments were selected to balance the manageability of construction and decrease the chance of inter and intra-species domination within a treatment.

Quantification of microhabitat variables in areas of high use were examined by comparing a random sample of cells (9 m x 9 m) containing $\geq$ 99 % of PMJM locations for each session to a random sample of cells where no PMJM locations detected. Two line transects were randomly placed in each selected cell with 6 quadrat frames (50 cm x 20 cm) evenly distributed per line transect (Daubenmire 1959). The variables measured in each cell included percent bare ground, shrub, grass, and forb cover and vegetation composition. The location data were analyzed using linear regression. The response variable was the number of locations detected in a cell. A suite of candidate models was developed as predictors of the response variable. Akaike's information criterion (AIC) was applied to select the best "approximating" model (Burnham and Anderson 2002). The independent habitat variables of interest for the models included distance from the center of the cell to the nearest water, area and juxtaposition of nearest shrub, and presence of wetland grasses in the cell. Additional variables -included in the models were period (pre- or post-treatment), sex, session, and year.

The microhabitat data collected from the Daubenmire plots were analyzed with Proc GLM (SAS 2002) to test for differences in means among areas of high use and no use by PMJM.

PRELIMINARY RESULTS

A comparison of microhabitat characteristics from a random sample of "high-use" and "no-use" areas indicated a greater ($P < 0.0001$) shrub canopy cover in "high-use" areas verses "no-use" areas (47.7% ± 29.8%, 12.6% ± 14.11%, respectively). Further, "high-use" areas had greater basal cover ($P = 0.013$) and bare ground ($P = 0.0459$) and "no-use" areas contained a greater ($P = 0.0331$) abundance of forb canopy cover. We conducted a manipulation experiment where we constructed patches of artificial resources (food and cover) in areas without previous PMJM activity. PMJM were radio collared and located hourly before and after the addition of food and cover. The majority of PMJM movements were not influenced by the addition of resources in 2002. These results may be due to site fidelity or lack of exploratory movement to locate the additional resources

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JOB PROGRESS REPORT

State of Colorado	:	Division of Wildlife – Mammals Research
Work Package No. 0670	:	Lynx Conservation
Task No. 2	:	Ecology of Snowshoe Hares (*Lepus americanus*) in Colorado

Period Covered: July 1, 2002 – June 30, 2003

Author: Steven W. Buskirk and Jennifer L. Zahratka

Personnel: T. M. Shenk

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.

ABSTRACT

How the densities of woody stems of different sizes, tree dominants, and successional stage affect densities of snowshoe hares is key to effective management of snowshoe hare habitats in the southern Rocky Mountains. Therefore, we investigated two conceptual issues relating to snowshoe hare habitat in late winter. First, how do site conditions produce woody stems of suitable diameters and heights above the snow surface for food and how do site conditions provide suitable protective cover for hares? Second, do snowshoe hares in fact attain their highest densities in these presumptive high-quality habitats? The results in this progress report are preliminary and subject to revision based upon continuing analyses of data. Still, some patterns in the data are apparent. Temperature appeared to have an effect on capture success whereas moon phase, although it has been reported to have an effect, did not. Our preliminary analysis of vegetation data suggests that canopy cover and distance to the nearest 1-7 cm stem also affect capture success. A resource selection model will be generated in the next phase to determine habitat predictors of capture success. Our comparison of diameters of fecal pellets of snowshoe hares and mountain cottontails suggests a difference in size of pellets between the two sympatric lagomorphs that should be useful for identification of pellets to species in the field.

Ecology of Snowshoe Hares (*Lepus americanus*) in Colorado

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INTRODUCTION

The snowshoe hare (*Lepus americanus*) is a widely distributed and well-studied leporid of North American boreal forests. Scientists have long been interested in the snowshoe hare, its cyclic population fluctuations at high latitudes, and its ecological relationship with the Canada lynx (*Lynx canadensis*). The snowshoe hare is the obligate primary prey item of the lynx, which was listed as threatened under the Endangered Species Act in 2000 (U.S Fish and Wildlife Service 2000). Data dealing with the ecology, particularly the habitat ecology, of southern snowshoe hare populations are lacking, especially in the southern Rocky Mountains. Indeed, only a single study (Dolbeer and Clark 1975) described the habitat associations of hares in the southern Rocky Mountains, but only in the most cursory fashion. The reintroduction of Canada lynx to the southern Rocky Mountains in 1999-2003 has stimulated the need for understanding the habitat requirements of snowshoe hare populations. Data from the southern Rocky Mountains are critical for managing habitats to conserve lynx and other boreal forest predators at their southernmost limits in the southern Rocky Mountains.

The abundance and fitness of snowshoe hares depend on the protection afforded by plants as well as their suitability as food for hares. Although food is an obvious requirement for snowshoe hare survival, snowshoe hares rarely starve to death. Instead, predation is the overwhelming proximate cause of death for snowshoe hares (Hodges 2000*a*) and food shortage only predisposes them to predation. Large-diameter woody structure provides horizontal and vertical protection from predators (Wolff 1980). Also, small-diameter (< 5-mm) (Grigal and Moody 1980) woody stems < 45 cm from the snow surface (Bider 1961) are an important food source (Hodges 2000*b*). Whereas large-diameter woody stems presumably provide protection from predation, small-diameter woody stems are believed to provide nutrition, particularly in winter. Therefore, we assume that woody structure in two different size classes meets two distinct habitat needs of snowshoe hares. Winter is a critical time of year for snowshoe hare survival because fewer woody stems, large or small, are available than in other seasons, and herbaceous plants are not available.

How the densities of woody stems of different sizes, tree dominants, and successional stage affect densities of snowshoe hares is key to effective management of snowshoe hare habitats in the southern Rocky Mountains. Therefore, we investigated two conceptual issues relating to snowshoe hare habitat in late winter. First, how do site conditions produce woody stems of suitable diameters and heights above the snow surface for food and how do site conditions provide suitable protective cover for hares? Second, do snowshoe hares in fact attain their highest densities in these presumptive high-quality habitats? These general questions subsumed more specific ones.

1. In order to understand the links between diet and habitat use in winter, and because diets of snowshoe hares have not been studied in the southern Rocky Mountains, we studied diets of snowshoes hares.
2. Captures of snowshoe hares and non-target leporid species allowed us to collect fecal pellets of known species origin. Because the size of leporid pellets has been used to identify their source to species in the southern Rocky Mountains (Dolbeer and Clark 1975, Bartmann and Byrne 2001) where leporid species are sympatric, we characterized the sizes of fecal pellets of sympatric leporid species, specifically of snowshoe hares and mountain cottontails (*Sylvilagus nuttallii*).
3. Because various abiotic factors (e.g. air temperature, moon phase) have been reported in the literature (Gilbert and Boutin 1991) or anecdotally to affect capture success of snowshoe hares, we

tested for these influences in our data, and accounted for them in our analyses of major treatment effects (e.g. stand type).

STUDY AREA

Location

The study area was a broad area of southwestern Colorado on the Gunnison and Rio Grande National Forests, which we studied during January – April 2002 and January – March 2003. Within our study area, we established two study sites: one was a 1963-km^2 area centered over Taylor Park Reservoir on the Gunnison National Forest (39° 50' N, 106° 34' W); the second was the Divide District (4,089 km^2) of the Rio Grande National Forest (37° 40' N, 106° 40' W) centered directly north of South Fork, Colorado (Figure 1).

Spruce-fir is an important habitat for snowshoe hares throughout its temperate range (Hodges 2000*a*) and it is the most widely distributed stand type in coniferous forests of Colorado. Approximately 48% of the coniferous forests of Colorado are dominated by spruce-fir (Buttery and Gillam 1987). In Colorado, lodgepole pine accounts for 16% of the coniferous forests (Buttery and Gillam 1987); our Gunnison study area represents the southernmost natural extent of this species. Lodgepole pine is an important habitat type for snowshoe hares in other coniferous forests of the Rocky Mountains (Koehler 1990*a*, *b*) and reintroduced lynx have been documented in the Gunnison study area. Therefore, lodgepole pine was included in our study. The Rio Grande study area, although lower in elevation, contains ponderosa pine, also widely distributed in Colorado. About 24% of coniferous forests in Colorado are dominated by ponderosa pine (Buttery and Gillam 1987). Bartmann and Byrne (2001) reported some of their highest densities of lagomorph pellets in ponderosa pine stands. Therefore, it was important for our study to examine the suitability of ponderosa pine stands for snowshoe hares.

Topography

Southwestern Colorado is characterized by wide plateaus, river valleys, and rugged mountains that reach elevations over 4200 m. Elevations of our Gunnison study site ranged from 2850 m to 3480 m. The Rio Grande study site ranged in elevation from 2460 m to 2580 m. Our spruce-fir sites occurred at elevations of 3210 – 3480 m, our lodgepole pine sites occurred at 2850 – 3100 m, and our ponderosa pine sites occurred at 2460 – 2680 m. The overall aspect of each trapping grid varied (Table 1).

Climate

Southwestern Colorado exhibits an arid and temperate climate; strong local variation reflects elevation and aspect. The mean temperature in Gunnison, Colorado from January - April 2002 was -7°C and in South Fork, Colorado the corresponding mean was 0°C. In 2003 the corresponding mean in Gunnison, Colorado was -5°C and in South Fork was -1°C (Weather Channel web site, unpublished data).

Unlike northern Colorado, where more precipitation falls as winter snow than as summer rain, the monsoon season in southwestern Colorado brings most yearly precipitation in late summer. The mean monthly precipitation in Gunnison, Colorado for January – April 2002 was 1.6 cm, whereas in the monsoon months of July and August 2002 the mean was 3.8 cm. In South Fork, Colorado the corresponding means were 1.5 cm and 4.5 cm.

METHODS

Trapping Grid Selection

Our study area comprised the Gunnison and Rio Grande National Forests, within which trapping grids were chosen using a GIS database of national forest lands with Common Vegetation Unit (CVU) coverage using the Integrated Resource Inventory protocol (IRI) made available by each of the forests. Two sets of criteria, applied sequentially, were used to select the site of the trapping grids. The first set of criteria was based upon the CVU coverages using GIS:

1. Stand types included were Engelmann spruce-subalpine fir, lodgepole pine, ponderosa pine and riparian (*Salix* spp.).
2. Structural stage was mature with canopy cover ≥ 40% (SS 4b, 4c) (Buttery and Gillam 1987).
3. Vegetation polygons were considered if ≥ 30 m, but ≤ 1 km from a mapped road, i.e. a highway, paved, graded or gravel road, or a 4-wheel drive road.
4. Vegetation polygons were considered if ≥ 25 ha.
5. Vegetation polygons were considered if shaped so as to admit a 330 m x 550 m (16.5-ha) trapping grid with a 50-m buffer between the edge of the trapping grid and the nearest edge of the polygon.
6. Fifteen of the candidate polygons were selected randomly. Within each of these random polygons a 330-m x 550-m rectangle was placed at a randomly generated orientation (0 - 180°).

All potential ponderosa pine sites on the Gunnison National Forest were excluded using these criteria. All potential riparian sites on the Rio Grande were excluded using these criteria and no lodgepole pine sites were available on the Rio Grande to evaluate by CVU layers. Potential sites were visited in random order, at which time we applied the second set of criteria:

1. Forested sites were excluded if ≥ 40% of the trapping grid was dominated by a cover type other than the nominal species dominant.
2. Candidate sites were excluded if inaccessible by snowmobile and snowshoes.
3. Candidate sites were excluded if they held any unmapped roads.
4. Candidate sites were excluded if logging or thinning had occurred within them.
5. Candidate sites were excluded if avalanche danger was present.
6. Candidate sites were excluded if trapping grids were < 500 m from a grid that had already been included.

The first three sites from the list of candidates for each stand type to meet these criteria were included as trapping grids. Because of the availability of suitable sites, and for logistical reasons, all spruce-fir trapping grids, all lodgepole pine trapping grids and all riparian trapping grids were evaluated on the Gunnison National Forest. Only the ponderosa pine trapping grids were evaluated on the Rio Grande National Forest.

After visiting 14 sites mapped as lodgepole pine on the Gunnison National Forest, three were found that met our criteria. Fifteen sites mapped as spruce-fir on the Gunnison National Forest were evaluated before three were found that met our criteria. Ten sites tentatively mapped as riparian on the Gunnison were visited, but none were found that met our criteria. Fifteen sites mapped as ponderosa pine on the Rio Grande National Forest were visited before three were found that met our criteria.

Trapping and Handling

All methods related to trapping and handling of animals were approved by the University of Wyoming Animal Care and Use Committee and by the Colorado Division of Wildlife Animal Care and Use Committee. Snowshoe hares were trapped using Tomahawk Model 204 live traps (18 cm x 18 cm x 51 cm) placed on trapping grids of 84 traps (7 lines of 12 traps each), with 50-m spacing for a trapping grid size of 16.5 ha (Figure 2). Three replicates for each stand type were sampled for 6 trap nights, which we assumed to be a closed population for the purposes of mark-recapture models. No reproduction occurred during our winter field season. The trapping grid size and method were developed by Scott Mills and Paul Griffin, University of Montana; we used these methods to maximize comparability between our study and theirs. Upon visiting a suitable site, the trapping grid was flagged and numbered using the UTM coordinates generated by a GPS receiver and a compass bearing (Figure 2). Traps were placed in suitable habitat within 2 m of the flagging and if necessary, covered with tree branches to provide cover for captured hares. Traps were baited with a mixture of pellets of Timothy grain, alfalfa, corn, and oats (TACO), alfalfa pellets and apples (P. Griffin, pers. commun.). Traps were checked as early as possible each morning and re-baited as needed.

Once a snowshoe hare was captured, a pillowcase with a drawstring was placed over the front door of the trap. The hare was moved into the bag by gently tipping the trap, blowing on the hare, or making noise. Once the hare was in the bag it was immediately weighed using a 2500-g Pesola spring scale. The hare was then placed between the legs of a kneeling handler with the head facing towards the handler. The second handler marked the hare using a sterile passive-integrated transponder (PIT) tag. One tag was injected subcutaneously with a sterile needle between the shoulder blades. Both ears of the snowshoe hare were also marked using a permanent black marker for short-term identification. After the first day of any trapping session (i.e. on traps days 2-6) every snowshoe hare was scanned with a 125-kHz Mini-portable reader to determine whether the hare was a recapture or a new capture. In the event the snowshoe hare was preyed upon and partially ingested, the earmarks were checked. Each snowshoe hare was sexed by turning the hare on its dorsal side and protruding the genitalia. The forefinger and middle finger were used to apply slight pressure to the vent area just above the anus. Snowshoe hares were then released away from handlers.

Snowshoe hares that suffered severe trap or predation injuries were euthanized with a 1-ml intrathoracic injection of sodium pentobarbital. Each carcass was necropsied and the liver and kidneys preserved for analysis of metals concentrations. After necropsy and tissue collection, euthanized animals were disposed of by cremation or deposited in a landfill. Any non-target species caught in traps were immediately released; whole specimens from any mortality of non-target species were donated to the Denver Museum of Nature and Science.

Diet

In 2003, fecal pellets were collected from the inside of each live-trap where a snowshoe hare was captured and allowed to air dry in kraft brown-paper bags. Fecal pellet samples were randomly selected for diet analyses from 24 individual snowshoe hares: four from each of the three spruce-fir grids and four from each of the three lodgepole pine grids. To reduce the possibility of finding TACO and alfalfa in the diet analyses, only first captures of snowshoe hares were used. Where < 4 snowshoe hares were captured on a trapping grid (e.g. SF 1, LP 2), fecal pellets were collected from fresh snowshoe hare tracks two days after snowfall. Fifteen fecal pellets were required for diet analyses (Bruce Davitt, Washington State University, pers. comm.). If < 15 fecal pellets were collected, a new random sample was chosen. For this reason, one sample (LP 1) was taken from a recaptured snowshoe hare three nights after the initial capture. Fifteen fecal pellets were arbitrarily chosen from each paper bag and transferred to a labeled envelope. Samples were submitted to the Wildlife Habitat and Nutrition Laboratory at Washington State University, Pullman, WA for analysis of diet.

Size of Fecal Pellets

We measured snowshoe hare fecal pellets collected in 2002 to 0.1 mm using SPI dial calipers. Fecal pellets were also collected from every mountain cottontail incidentally captured in 2002 and 2003 and measured in the same way. Partial or damaged fecal pellets were eliminated from measurement. We measured the longest diameter for any non-spherical pellets. For snowshoe hares, 32 samples from 23 animals (n = 2374 fecal pellets) were measured. Ten samples from 10 mountain cottontails (n = 655 pellets) were measured.

Vegetation

Habitat attributes were estimated at two levels: at each trap site and for each trapping grid (Table 2). Within each trapping grid, vegetation was sampled from 15 trap sites, similar to the design of Scott Mills (Figure 2). Methods developed by Tanya Shenk (Colorado Division of Wildlife) to monitor habitat use by reintroduced lynx to Colorado were followed with modification (Figure 3). Accordingly, a 12-m x 12-m square of 25 points was placed in 5 rows of 5 (3 m apart), centered over the trap location (Figure 3). The measurements taken at each of the 25 points included:

1. Snow depth (cm), as measured by a calibrated avalanche probe, from the center of each trap location.
2. Understory "hits" measured in a column of 3-cm radius around an avalanche probe.
   a. All live or dead stems and coarse woody debris (CWD) that fall within the 3-cm radius column using the standardized four-letter genus-species code at 3 height categories (0-0.5 m, 0.51-1.0 m, 1.01 – 1.5 m) above the snow surface.
   b. Each of the above stems classified in 3 different diameter categories (< 5 mm, 5.1 – 10 mm, 10.1 – 15 mm) measured at the point where the stem hit the avalanche probe
3. Overstory was measured using a densitometer attached to the avalanche probe.
   a. Species that hit the crosshairs inside the sighting tube were recorded. Multiple hits by the same species were only recorded once.
4. Every shrub within the plot along with its species and diameter at breast height was recorded (dbh).
5. Every tree within the plot along with its species and dbh was recorded.
6. Every snag within the plot along with its dbh was recorded.
7. Every sapling within the plot along with its species was counted.
8. All coarse woody debris (CWD) deemed usable by snowshoe hare for cover or food (i.e. available above the snow) was recorded along with its diameter.

At all of the 84 trap sites within the trapping grid, including the 15 trap sites sampled as described above, the following data were measured:

1. Snow depth (cm), as measured by a calibrated avalanche probe.
2. Species of, dbh of, and distance to the closest woody stem in two categories: ≥ 1.0 cm – 7.0 and ≥ 7.1 cm at the snow surface.
3. Canopy cover for the center of the trap site, as estimated by the use of a spherical densiometer, in the four cardinal quadrants (NW, NE, SE, SW).

The following rules were used for unusual events:

1. If a point in a vegetation plot lay within a tree bole, the tree species and the dbh was written on the data form.

2. A snag was defined as any dead tree bole >45° from the horizontal. Dead boles <45° vertical angle were considered CWD.

3. The mid-point diameter was measured of exposed CWD partially covered by snow.

4. If a leaning tree fell partially outside the 12 m x 12 m sampling plot it was included if >50% of the tree lay within the sampling plot.

Temperature and Moon Phase

We used daily minimum temperatures recorded by the National Weather Service in Gunnison, Colorado in 2002 and 2003 for each night of trapping. This temperature was intended to represent general weather in the region rather than exact conditions at each trapping grid. We estimated the amount of moonlight for each night of trapping as the percentage of the moon's surface illuminated (Astronomical Applications Department, U.S. Naval Observatory, unpublished data).

STATISTICAL ANALYSIS AND PRELIMINARY RESULTS

We initially examined our preliminary data for distributional properties and homoscedasticity using SPSS 11.0. These properties are not important in predictors used in binary logistic regression, but are important in comparisons of means. Where we found substantive violations of assumptions regarding distributional properties, we used the appropriate non-parametric test. Our basic study design involved three stand types as represented by tree species dominants (spruce-fir, lodgepole pine, ponderosa pine). Other predictor variables (e.g. elevation, air temperature, habitat attributes) were highly co-linear with tree stand type and each other (Table 1). Trapping grids in spruce-fir tended to be at higher elevations, and have deeper snow and lower air temperatures (Table 1). Because air temperature (Paul Griffin, University of Montana, pers. comm.) and moon phase (Gilbert and Boutin 1991) have been reported to affect captures of snowshoe hares, we also explored these possible relationships and their relationship to other predictors.

We first used binary logistic regression to identify factors measured at the scale of the trapping grid (grid-night = unit of replication) that predict capture success. We included stand type (to include the covariates, elevation and snow depth), percent moon phase, temperature and year as candidate predictors of capture success. In this preliminary analysis stand type and temperature were significant in predicting capture success (Table 3).

We then tested how air temperature in Gunnison was related with capture success in spruce-fir and lodgepole pine stands. Although there was no confounding variation with air temperature and stand type (ANOVA $F = 98.8$, $d.f. = 2$, $P = 0.19$; spruce-fir $\bar{x}$ = -14°C, lodgepole pine $\bar{x}$ = -13°C, ponderosa pine $\bar{x}$ = -11°C) we chose to exclude ponderosa pine from this analysis because no hares were captured on the ponderosa pine trapping grids. The relationship between air temperature and captures was significant ($t = -3.9$, $d.f. = 45$, $P < 0.001$), with grid-nights for which captures were recorded having mean minimum temperatures of -11°C, and those for which no captures were recorded having temperatures of -18°C.

We also examined patterns of captures of snowshoe hares within trapping grids using the response variable of whether a trap location recorded a snowshoe hare capture during either 2002 or 2003. We examined patterns of independence of trap locations within a trapping grid by examining the distribution of trap locations where snowshoe hares were captured, versus those where they were not (Figure 4). We observed no obvious pattern of clumping of successful trap locations, and therefore assumed independence of individual traps as sampling units. When we used the grid-night as the unit of replication ($n = 108$), and included ponderosa pine trapping grids, trapping success did not differ between years ($t = -1.57$, $d.f. = 106$, $P = 0.12$). However, when trap-night was used as the unit of replication ($n = 1512$), trapping success did differ between years ($t = -3.14$, $d.f. = 1395$, $P = 0.002$), with more captures in 2003 than 2002.

We used binary logistic regression to identify vegetation attributes that predicted capture success for snowshoe hares in an individual trap (trap-night = unit of replication). In this preliminary analysis we found that canopy cover was a significant predictor of capture success at trap locations (Table 5) with successful trap locations ($\bar{x}$ = 84% cover) having canopy cover 40% greater than that for unsuccessful trap locations ($\bar{x}$ = 60%, Mann-Whitney U = 14086, $P < 0.001$). The other significant predictor was distance to the nearest woody stem 1-7 cm in diameter, with successful trap locations ($\bar{x}$ = 2.0 m) having nearest stems only 56% as far away as unsuccessful trap locations ($\bar{x}$ = 3.6 m, M-W U = 21897, $P <$ 0.001).

We measured the mean sizes of fecal pellets of snowshoe hares ($\bar{x}$ = 8.4 mm) and mountain cottontails ($\bar{x}$ = 7.2 mm) from known species origin and found the means differed (Mann-Whitney U = 26.5, P = 0.001) and 95% confidence intervals did not overlap (Figure 5).

DISCUSSION

The results in this progress report are preliminary and subject to revision based upon continuing analyses of data. Still, some patterns in the data are apparent. Temperature appeared to have an effect on capture success whereas moon phase, although it has been reported to have an effect, did not. Our preliminary analysis of vegetation data suggests that canopy cover and distance to the nearest 1-7 cm stem also affect capture success. A resource selection model will be generated in the next phase to determine habitat predictors of capture success. Our comparison of diameters of fecal pellets of snowshoe hares and mountain cottontails suggests a difference in size of pellets between the two sympatric lagomorphs that should be useful for identification of pellets to species in the field.

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Table 1. Abiotic characteristics of nine trapping grids in three stand types, southwestern Colorado, late winter 2002 and 2003. Snow depth (cm) is the mean (SE) measured at 84 trap locations at each trapping grid. Temperature (°C) (SE) is the mean low temperature recorded in Gunnison for each grid-night. The aspect of each trapping grid is shown in degrees in their respective order.

Trapping grids	Stand Type	Snow depth	Elevation	Temperature	Aspect
PP 1, PP 2, PP 3	*Pinus ponderosa*	2 (0.4)	2600	-11 (1)	50°, 130°, 130°
LP 1, LP 2, LP 3	*Pinus contorta*	45 (1)	3000	-13 (1)	230°, 90°, 130°
SF 1, SF 2, SF 3	*Picea engelmanii, Abies lasiocarpa*	74 (1)	3400	-14 (1)	310°, 150°, 110°

Table 2. Vegetation characteristics for nine trapping grids (see Table 1) in three stand types (n = 3 each), southwestern Colorado. Mean tree density, mean sapling density, and mean snag density (number ha^{-1}) (SE) were counted at 15 trap locations on each grid, late winter 2002. Mean canopy cover (%) (SE) was measured at 84 trap locations on each grid using a densiometer , late winter 2002. The median horizontal cover (%) was measured at 15 trap locations on each grid using a horizontal profile board, late winter 2003.

Stand Type	Tree density	Sapling density	Snag density	Canopy cover	Horizontal cover
Pinus ponderosa	187 (29)	301 (81)	273 (65)	36 (2)	0
Pinus contorta	1268 (138)	554 (109)	443 (67)	73 (1)	10
Picea engelmanii, Abies lasiocarpa	1418 (116)	642 (107)	287 (44)	79 (1)	65

Table 3. Preliminary results of binary logistic regression using stand type (excluding ponderosa pine) and abiotic factors as variables to predict capture success (n = 72). Variables are described fully in the methods section.

						95% C.I.	
Variable	Coefficient	*Z*	*d.f.*	*P*	Odds Ratio	Lower	Upper
Temperature	0.169	3.3	1	0.001	1.184	1.071	1.309
Stand type	1.794	2.7	1	0.006	6.012	NA	
Year	-0.210	-0.3	1	0.771	0.811	NA	
Moonlight	-0.003	-0.2	1	0.808	0.997	0.808	0.997
Constant	-1.146	-0.6	1	0.541	0.318	NA	

Table 4. Preliminary results of binary logistic regression using vegetation characteristics to predict capture success at trapping locations within trapping grids (n=108). Variables are described fully in the methods section.

						95% C.I.	
Variable	Coefficient	*Z*	*d.f.*	*P*	Odds Ratio	Lower	Upper
Canopy cover	0.061	6.10	1	< 0.001	1.063	1.043	1.084
Diameter 1-7 cm	-0.005	0.08	1	0.942	0.995	0.880	1.126
Distance 1-7 cm	-0.002	-2.00	1	0.002	0.998	0.997	0.999
Diameter >7 cm	-0.014	-1.17	1	0.235	0.986	0.963	1.009
Distance >7 cm	0.001	1.00	1	0.148	1.001	0.999	1.003
Constant	-6.058	-6.44	1	< 0.001	0.002	NA	

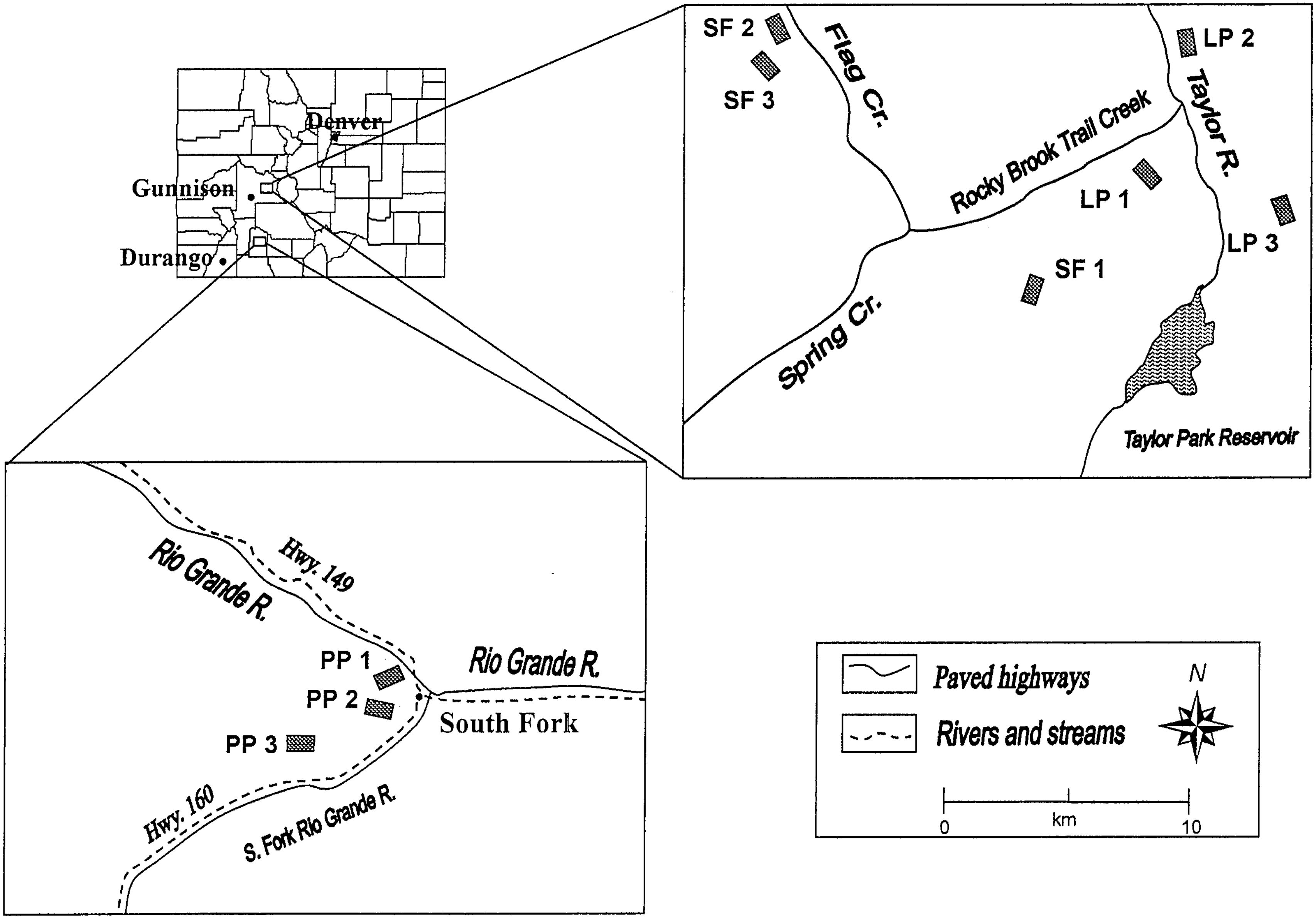

Figure 1. Location of nine trapping grids ( ), southwestern Colorado, 2002 - 2003. SF is spruce-fir, LP is lodgepole pine, and PP is ponderosa pine. Trapping grids are not to scale.

1#	2#	3#	4#	5#	6#	7#
8#	9*	10#	11*	12#	13*	14#
15#	16#	17#	18#	19#	20#	21#
22#	23*	24#	25*	26#	27*	28#
29#	30#	31#	32#	33#	34#	35#
36#	37*	38#	39*	40#	41*	42#
43#	44#	45#	46#	47#	48#	49#
50#	51*	52#	53*	54#	55*	56#
57#	58#	59#	60#	61#	62#	63#
64#	65*	66#	67*	68#	69*	70#
71#	72#	73#	74#	75#	76#	77#
78#	79#	80#	81#	82#	83#	84#

Figure 2. Schematic of 300 m x 550 m trapping grid for estimating population density of snowshoe hares in southern Colorado. Asterisks (*) indicate the location of the 15 vegetation plots centered on trapping points. Pound signs (#) indicate where the point-quarter method will be used on all other trap locations.

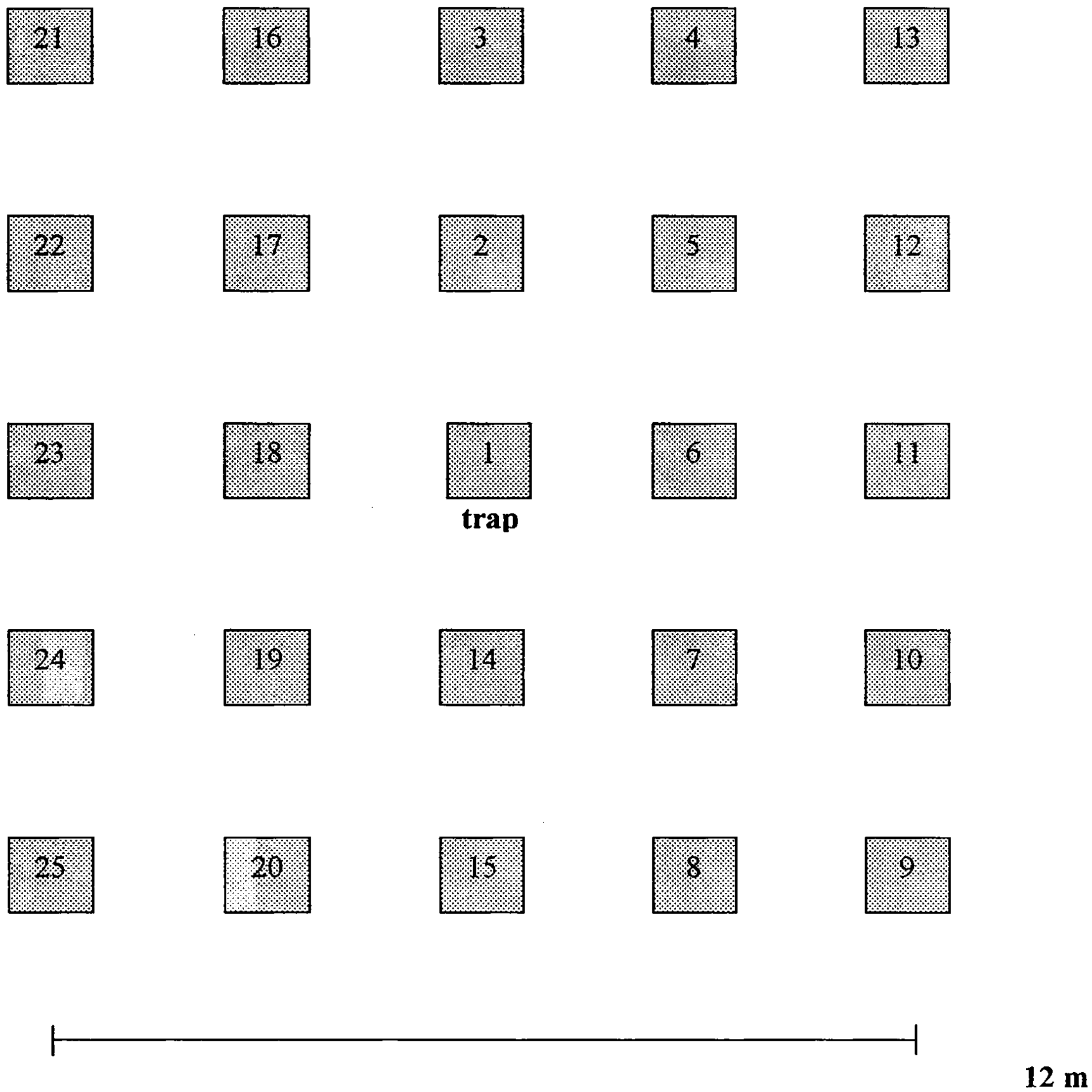

Figure 3. Schematic of 12 m x 12 m vegetation plot centered on each of the 15 trap sites (Figure 2) used in measuring habitat variables for snowshoe hares in southwestern Colorado, late winter 2002. The trap location is at the center of the vegetation plot.

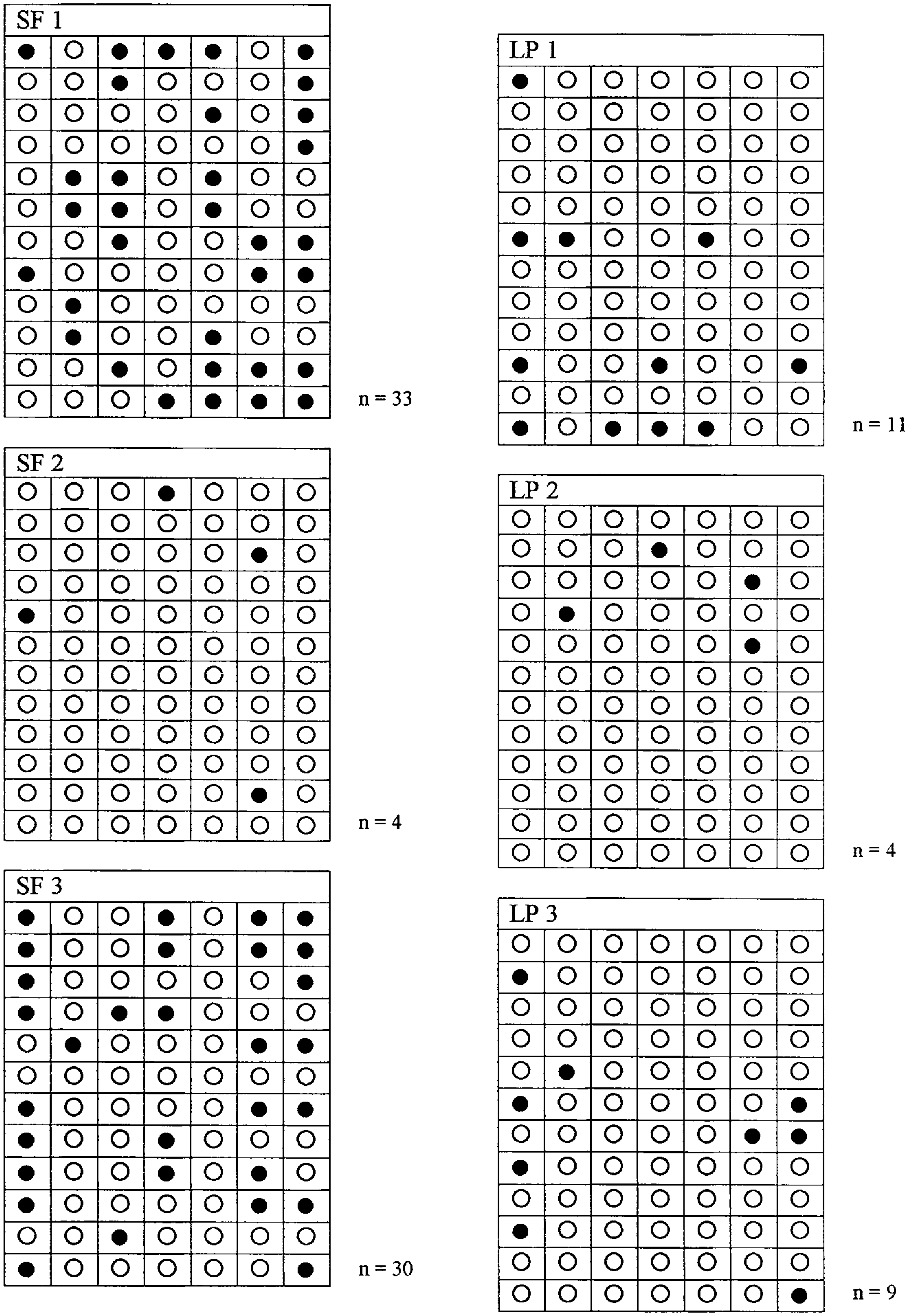

Figure 4. 12 x 7 trapping grid schematic representing snowshoe hare trap successes (●) for 6 trapping grids in two stand types, spruce-fir and lodgepole pine (snowshoe hares were absent from all pondersosa pine trapping grids), southwestern Colorado, late winter 2002 and 2003.

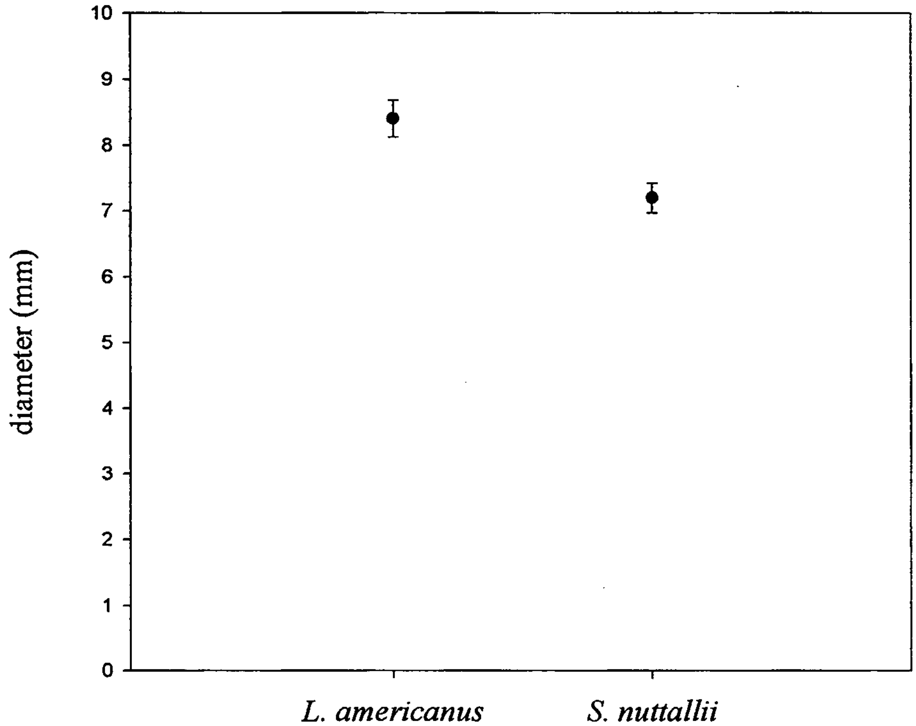

Figure 5. Mean diameters of fecal pellets of *Lepus americanus* (n = 23 animals) and *Sylvilagus nuttallii* (n = 10 animals). Error bars indicate 95% confidence interval.

JOB PROGRESS REPORT

State of Colorado	:	Division of Wildlife - Mammals Research
Work Package No. 0670	:	Lynx Conservation
Task No. 1	:	Post-Release Monitoring of Lynx Reintroduced to Colorado

Period Covered: July 1, 2002 - June 30, 2003

Author: Tanya M. Shenk

Personnel: R. Dickman, R. Kahn, A. Keith, G. Miller, C. Wagner, S. Wait, D. Younkin

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

ABSTRACT

Reproduction is critical to the success of any reintroduction effort if a self-sustaining, viable population is the ultimate goal of the conservation effort. As of winter 2002-2003, no reproduction had been documented from lynx reintroduced to Colorado beginning in winter 1999. However, the low density of lynx present in Colorado by winter 2002-2003 limited the ability to answer the question of whether Colorado is suitable to sustain a viable lynx population because either insufficient habitat or lynx at too low a density to achieve reproductive success could have resulted in the lack of reproduction. Following an analysis of possible management options, it was decided that an augmentation of this reintroduction effort was necessary to eliminate an ambiguous result if successful reproduction had not occurred under densities such as exist in winter 2002-03. The reintroduction effort was augmented with 33 additional animals, released within the Core Area in April 2003, to increase lynx density so that the question of whether lynx can sustain viable populations in Colorado could be more definitively addressed. Based on dispersal patterns of lynx released in 2000, the second cohort, it was hypothesized that lynx released in the Core Area would show the necessary site fidelity to increase lynx densities to enhance the probability of successful reproduction. The first lynx kittens documented to be born to lynx reintroduced to Colorado were found on May 21, 2003. A total of 6 dens and 16 kittens were found in 2003. 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 had 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 Colorado conditions 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.

Post-Release Monitoring of Lynx (*Lynx canadensis*) Reintroduced to Colorado

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INTRODUCTION

The Canada lynx (*Lynx canadensis*) 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. Given the isolation of Colorado to the nearest northern populations, the Colorado Division of Wildlife (CDOW) considered reintroduction as the only option to attempt to reestablish the species in the state.

A key question to be asked when considering the re-establishment of any species is, "What is different now from when they disappeared?" For lynx, the causative factor(s) of their extirpation may never be known. Many of the hypothesized factors, however, have changed substantially since the early and mid-1900's. For example, widespread predator poisoning no longer occurs; conservation of wildlife habitat is now given much stronger consideration in public land management decisions; trapping and hunting are more strictly regulated and regulations enforced; and in some areas, at least, the passage of time has allowed the landscape to recover from abuses of the past, perhaps to a state that is more conducive to lynx survival. It must be acknowledged, however, that there may be other detrimental factors operating now that did not exist previously. In particular, increased human density and development have occurred in some areas and exotic diseases such as plague have been introduced in Colorado.

The uncertainty surrounding the cause of the extirpation of lynx and the effects of current conditions in Colorado on lynx makes it impossible to predict with confidence whether Colorado has sufficient habitat to sustain viable population(s) of lynx. In order to perform the best test of this question the CDOW led a cooperative effort to reintroduce wild-trapped lynx from Canada and Alaska into southwestern Colorado beginning in 1999. It was hoped the effort would clarify whether or not Colorado is or is not suitable for sustaining viable lynx populations, provided the fate of the released animals could be determined.

The goal of the Colorado lynx reintroduction program is to establish a 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 seven 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.

Prior to the reintroduction, it was hypothesized that a minimum of 100 animals would need to be released for a fair evaluation of the suitable/unsuitable question. In 1999 and 2000, 96 lynx (57 females, 39 males) were released into the San Juan Mountains of southwestern Colorado. The 1999 cohort of 41 individuals scattered widely, and suffered a first year mortality of 17 (41%) lynx (Shenk 2001). The 2000 cohort of 55 animals, being released into areas already occupied (although sparsely) by the previous year's animals, were more sedentary, and experienced a first year mortality of 10 (18%) lynx. 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 all the reintroduced lynx (31%). Mortalities due to starvation (23%) were minimized with the improved release protocols. To date, only 2 of the 55 lynx released in 2000 died of starvation. However, the improved survival of reintroduced lynx provided only partial evidence that Colorado could sustain a viable population of the species. As of winter 2003, no successful reproduction had been documented. This lack of reproduction resulted in an increased emphasis on the question of whether or not Colorado could provide sufficient habitat to sustain a self-sustaining population of lynx.

Two options existed to address the problem of answering the suitable/unsuitable question. The first was to continue to monitor the existing animals for recruitment, with the understanding that the probability of detection would decrease rapidly as radio-collars failed, and the probability of successful pairing might further decrease with lowered densities due to natural mortality. Possible outcomes include 1) the animals currently out there would eventually reproduce with sufficient success to establish a viable population of lynx, 2) the animals currently out there would reproduce although not in sufficient numbers to offset mortality or 3) the animals currently out there would fail to reproduce. The primary reasons for outcomes 2 and 3 are either that Colorado does not have sufficient habitat to support viable populations of lynx or there were too few lynx released to achieve sufficient successful reproduction. Thus, the question of whether or not Colorado can support viable population(s) of lynx would remain arguable.

A second option would be to supplement the existing lynx by re-introducing additional lynx over multiple years into the Core Area to attain a density approaching that of established populations of lynx. The possible outcomes could be any of those listed for the first option. The difference, however, would be that the low-density explanation for failure to establish a viable population would be difficult to support. Thus, CDOW could more definitively address the question of the suitability of Colorado for lynx populations.

An analysis of these two options was conducted to determine the best management strategy to pursue to enhance the ability to assess the outcome. An update of the post-release monitoring program was also conducted.

OBJECTIVES

The initial post-release monitoring of reintroduced lynx will emphasize 5 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. Lastly, an analysis was conducted to evaluate tow management options for assessing Colorado's suitability for sustaining a viable lynx population.

METHODS

Augmentation

An analysis of two management options was conducted to determine the best management strategy to pursue to enhance the ability to assess whether Colorado provided suitable habiat for a viable, self-sustaining population of lynx.

In response to the completed analysis, the current reintroduction effort was augmented with additional animals, released within the Core Area, to increase lynx density so that the question of whether lynx can sustain viable populations in Colorado could be more definitively addressed. These new releases were conducted under the protocols found to maximize survival (see Shenk 1999). Based on dispersal patterns of lynx released in 2000, the second cohort, it was hypothesized that lynx released in the Core Area would show the necessary site fidelity to increase lynx densities to enhance the probability of successful reproduction.

Movement Patterns

To determine general movement patterns and habitat 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 all lynx each flight during this period.

All 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). All 33 lynx released in 2003 were fitted with Sirtrack™ dual satellite/VHF radio-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 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.). 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.

Reproduction

Females 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. Each female that exhibited stationary movement patterns in May or June 2003 was observed to look for accompanying kittens.

If kittens were found at a den site they 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 recorded.

Den site location was recorded as Universal Transmercator (UTM) Coordinates. Other data to be recorded include general vegetation characteristics, elevation, weather, field personnel, time at the den, and behavioral responses of the kittens and female.

RESULTS

Rationale for Augmentation

Thirty-six reintroduced lynx were known to be in the Core Area in winter 2002-2003, which is approximately 10,000 mi^2. Thus, the lowest possible density of lynx in the Core Area was approximately 2 lynx / 500 mi^2, an area slightly larger than Rocky Mountain National Park. The highest density of reintroduced lynx in the Core Area was approximately 3 lynx / 500 mi^2, if all the missing lynx at that time were currently there but not being detected due to faulty radio collars. If additional naturally occurring lynx were in the area these densities could have been even higher. Lynx densities reported for natural populations occurring in northern habitats range from < 13 lynx / 500 mi^2 during snowshoe hare lows to 104-259 lynx / 500 mi^2 in years of peak hare densities in mature forests.

The densities of lynx reported for populations in the north during the low in the hare cycle may not represent the lowest densities at which lynx could exist and maintain viable populations. At these lows, northern lynx still reproduce although at a much lower rate then when the hare density is higher. This low reproductive rate could be related to poor body condition, low lynx densities, or a combination of both. What can be assumed is that lynx occurring at these low densities are able to rebound and achieve higher densities. Given that reintroduced lynx in Colorado are in good body condition, CDOW may only need to increase densities to achieve reproductive rates that would sustain a viable population of lynx.

Densities of lynx reported for their northern range reflect densities where lynx habitat is more uniform and consistent than in Colorado. In Colorado, although the Core Area is described as 10,000 mi^2, lynx are not using the Core Area uniformly but rather are dispersed in patches throughout the Core Area. Therefore the densities calculated for lynx in Colorado are not directly comparable to those estimated from the north. It is difficult, however, to estimate an appropriate correction factor for Colorado densities to make them comparable to those reported for northern populations. Therefore, the number of lynx needed to augment the current population to achieve a density of 13 lynx/ 500 mi^2 under several combinations of current density and percent of the Core Area that has suitable habitat was estimated (Table 1).

Although this analysis required numerous assumptions, an augmentation effort of at least 150 animals (no more than 50 per year) is a minimum target for achieving densities of lynx conducive to successful reproduction and recruitment. Once minimum densities have been achieved, additional releases should continue over four to five years to maintain the minimum densities considered necessary for successful reproduction. Monitoring of the lynx population throughout the augmentation will be critical and should be conducted rigorously. The target density of 13 lynx / 500 mi^2 is based on the lowest densities documented for northern populations. However, lynx may be able to rebound from lower densities. Thus, through monitoring CDOW should estimate at what densities reproduction occurs, and at what densities successful recruitment of animals occurs. This may happen at densities lower than low lynx densities estimated for the north.

Table 1. Estimates of current densities of reintroduced lynx in the Core Area under various combinations of number of lynx and percent suitable habitat. Calculations of how many lynx would be needed under these conditions to achieve densities similar to the lowest densities reported for northern populations are presented and the number of additional lynx needed to achieve this density.

Density Assumptions		Density lynx/ 500 mi^2	Lynx needed to achieve 13 lynx/ 500 mi^2	Minimum additional lynx needed[1]
No.of lynx	% Area suitable			
minimum	100%	1.8	260	224
maximum	100%	2.6	260	208
minimum	75%	2.4	195	159
maximum	75%	3.5	195	143
minimum	50%	3.6	130	94
maximum	50%	5.2	130	78

[1]Assumes no mortality.

Augmentation

Based on the adoption of the augmentation management strategy, 33 lynx were released in April 2003, bringing the total number of lynx reintroduced to Colorado to 129 (Table 2). The 33 lynx reintroduced in 2003 had been captured in Quebec, Manitoba and British Columbia. These new releases were conducted under the protocols found to maximize survival (see Shenk 2001). All 33 lynx were released in the Core Area of southwestern Colorado. Each lynx was released with a dual VHF/satellite radio collar so that the lynx can be monitor for movement and mortality. 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 (usually 1, 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 2. Colorado lynx reintroduction effort as of June 30, 2004.

Year	Females	Males	TOTAL
1999	22	19	41
2000	35	20	55
2003	17	16	33
TOTAL	74	55	129

Reproduction

Nine pairs of lynx were documented during the 2003 breeding season (March and April). In May and June 2003, 6 dens and a total of 16 kittens were found in the lynx core research area in southwestern Colorado (Table 3). 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. 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.

Table 3. Reproduction information for summer 2003.

		Date Den	Kittens		
Female	Release Year	Found	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

The dens were scattered throughout the Core 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 (10,630 - 11,670 feet). Field crews weighed, photographed, and PIT-tagged the kittens. Field crews also 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 us. 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.

Locations

The 2003 releases have remained in the Core Area with the exception of 2 lynx that went briefly to New Mexico but subsequently returned to Colorado. Most lynx continue to use terrain within the Core Area: New Mexico north to Gunnison, west as far as Taylor Mesa and east to Monarch Pass. There are some lynx north of Gunnison up to the I70 corridor and in the Taylor Park area. No lynx are known to be north of I70 at this time.

Mortalities

Of the total 129 lynx released in 1999, 2000 and 2003 there are 46 known mortalities. Of these 46 mortalities, 25 are from the 1999 releases, 20 are from the 2000 releases, and 1 is from the 2003 releases. Causes of death are listed in Table 4.

Table 4. Causes of death for lynx released into southwestern Colorado in 1999, 2000 and 2003.

Cause of Death	1999 Male	1999 Female	2000 Male	2000 Female	2000 Unk	2003 Male	2003 Female	Total
Starvation	1	6	1	1				9
Hit by Vehicle		2		3	1			6
Shot	3	1	1	1				6
Probable Predation		1						1
Plague				3				3
Unknown: Human Caused								
Probable Shot	1	2	1					4
Probable Hit by Vehicle		2						2
Unknown: Not Starvation	1	2		1				4
Unknown	2	1	4	3		1		11
Total Mortalities	8	17	7	12	1	1		46

Current Status

At this time, CDOW is tracking 61 of the 83 lynx still possibly alive. A lynx is listed as missing if a signal has not been heard from the animal for at least 1 year. There are 21 lynx that CDOW has not heard signals on since at least June 30, 2002 (Table 5). One of these missing lynx cannot be identified but was hit by a truck in New Mexico, thus only 20 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. Expanded flights outside the research area during the summer and fall months may yield locating these missing lynx. Two of the lynx released in 2000 have probably slipped their collars. Thus, CDOW has tracked 61 individual lynx since at least June 30, 2002.

Table 5. Status of lynx reintroduced to Colorado as of June 30, 2003.

	Females	Males	Unknown	TOTALS
Released	74	55		129
Known Dead	29	16	1	46
Possible Alive	45	39		83
Missing	7	14		21 (1 is unknown mortality)
Slipped Collar	1	1?		1-2
Tracking	37	24		61

DISCUSSION

The low density of lynx present in Colorado in winter 2002-2003 limited the ability to answer to the question of whether Colorado has sufficient suitable habitat to sustain a viable lynx population. At that time, the lack of successful reproduction may have reflected either insufficient habitat or lynx at too low a density to achieve reproductive success. It was decided that an augmentation of this reintroduction effort was necessary to eliminate an ambiguous result if successful reproduction had not occurred under densities existing in winter 2002-03. In order to maintain densities equal to those in areas that have maintained breeding populations the CDOW would need to reintroduce 50 lynx per year for the next three years and augment the population with an additional 10-12 lynx for years 4 through 6.

The reintroduction effort was augmented with 33 additional animals, released within the Core Area in April 2003, to increase lynx density so that the question of whether lynx can sustain viable populations in Colorado could be more definitively addressed. Based on dispersal patterns of lynx released in 2000, the second cohort, it was assumed lynx released in the Core Area would show the necessary site fidelity to increase lynx densities to enhance the probability of successful reproduction.

The first lynx kittens documented to be born to lynx reintroduced to Colorado were found on May 21, 2003. A total of 6 dens and 16 kittens were found in 2003. While this is a milestone CDOW has been hoping to achieve, live births are the first step towards recruitment. Recruitment into a population would require these kittens to survive through their first year of life and 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 add more so that the population can grow. Although den sites will not be visited again until fall 2003, so as not to disturb the female and kittens further, the female's movement patterns will be monitored through aerial telemetry. During fall 2003, demales with kittens will be observed through walk-ins to try to count the number of kittens still with her. Alternatively, the females will be snow-tracked once there is sufficient snowfall on the ground to document the presence and number of kittens. Kittens typically stay with their mothers until they are 10 months old.

The Colorado lynx reintroduction effort has overcome most obstacles encountered so far. From results to date it can be concluded that the CDOW has developed release protocols that ensure high initial post-release survival (Shenk 2001), and on an individual level lynx have demonstrated they can survive long-term in areas of Colorado. It had 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 Colorado conditions can support the recruitment necessary to more-than-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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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 0880 : Black-footed Ferret Conservation

Task 1 : Disease Monitoring & Management

Period Covered: July 1 2002 through June 30, 2003

Author: L. L. Wolfe and L. A. Baeten

Personnel: D. Finley, P. Schnurr, K. Cramer, H. Edwards, E. Knox, C. T. Larsen, N. Mier, M. W. Miller, K. Taurman, E. S. Williams

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.

ABSTRACT

We continued monitoring carnivores at proposed black-footed ferret reintroduction sites for serological evidence of select disease epidemics. Sampling at the Wolf Creek Management Area (WCMA) in August 2003 revealed little evidence of ongoing epidemics that could impede black-footed ferret restoration efforts. Serology data from culled coyotes showed no evidence of active canine distemper or plague epidemics in the WCMA vicinity. In contrast, serologic evidence of exposure to tularemia was relatively high (~30%), consistent with previous observations in this and other monitored areas. We will continue this work as part of the ongoing Colorado–Utah black-footed ferret reintroduction protocol.

INTRODUCTION

As part of the Colorado–Utah black-footed ferret reintroduction protocol, we continued monitoring carnivores at proposed ferret reintroduction sites for serological evidence of select disease epidemics. Originally, we monitored coyote (*Canis latrans*) populations at two Colorado sites: the Little Snake Management Area (LSMA) and the Wolf Creek Management Area (WCMA), Colorado. Under this program, >200 coyotes have been collected for post-mortem examination and samples collected as described in established protocols since March 1997. Monitoring has been accomplished via cooperative efforts of Colorado Division of Wildlife, USDA Wildlife Services, and Bureau of Land Management (BLM) personnel.

To date, no lesions indicative of active infections with any of the select pathogens (*Francisellia tularensis*, *Yersinia pestis*, canine distemper virus [CDV]) have been noted on gross examinations of carcasses. However, relatively high proportions (31-89%) of the coyotes collected from the LSMA had positive titers to plague between March 1997 and July 1999. Although the proportion of plague-positive coyotes declined during the sampling period, evidence of continued exposure and perhaps declining prairie dog abundance led to abandonment of surveillance at LSMA after 1999. Monitoring at the WCMA has continued, and black-footed ferrets were reintroduced at this site in 2001.

METHODS

Coyotes were collected using a combination of calling and aerial gunning (USDA-APHIS-Wildlife Services). In light of ambiguity in results from mid-winter sampling attributable to the inability to accurately estimate ages of coyotes in the field, we began focusing on late summer sampling to monitor epidemic trends. Postmortem examination, sampling, and serological methods were as described previously (Colorado Division of Wildlife, Disease Survey of Carnivores in the Little Snake Area, ACUC 1997-3).

RESULTS AND DISCUSSION

Initial sampling (February 2000) at WCMA indicated substantially lower exposure rates to select pathogens than observed at LSMA. Data from 2001 surveys indicated a relatively high proportion of adult coyotes exposed to canine distemper virus (CDV)(Figure 1): in February 2001, about 79% of the coyotes sampled had serum neutralizing titers ≥1:16. Recent sampling revealed lower proportions of CDV-positive coyotes, similar to the initial sampling periods. In contrast to canine distemper, exposure to plague appears relatively rare among coyotes sampled from WCMA (Figure 1). As tularemia is commonly found in rodents in Colorado, a seroprevalence of 20–40% is not surprising in WCMA

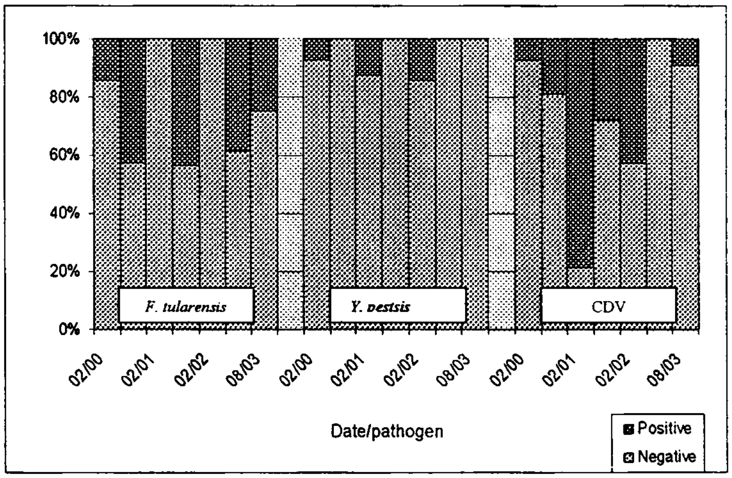

Figure 1. Seroprevalence of presumed tularemia, plague, and canine distemper exposure among coyotes sampled from the Wolf Creek Management Area, Colorado, during February 2000 to August 2003.

JOB PROGRESS REPORT

State of Colorado	:	Division of Wildlife – Mammals Research
Work Package No. 3001	:	Deer Conservation
Task No. 4	:	Effect of Nutrition and Habitat Enhancements on Mule Deer Recruitment and Survival Rates
Federal Aid Project W-185-R	:	

Period Covered: July 1, 2002 - June 30, 2003

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ABSTRACT

To further understand the factors that caused deer numbers to decline in western Colorado during the 1990s, we designed and initiated a field experiment to measure deer population parameters in response to a nutrition enhancement treatment. During November 2000 – June 2003, we captured and radio-collared 533 individual mule deer evenly distributed among treatment and control units on the Uncompahgre Plateau in southwest Colorado. This included 216 adult females, 94 of which received vaginal implant transmitters (VITs), 160 6-month old fawns, and 157 newborn fawns born from either treatment or control adult does. We enhanced the nutrition of deer in the treatment unit by providing a safe, pelleted supplemental feed on a daily basis from December through April each winter. Early winter fawn:doe ratios were measured using helicopter and ground classification surveys the year following treatment delivery to determine whether fawn production and survival increased as a result of enhanced nutrition of adult females. We also measured overwinter fawn survival rates in response to the treatment. In 2002 and 2003, we measured pregnancy rates, fetus rates, and body condition of treatment and control adult does during late winter using ultrasonography. We also directly measured fetus survival and neonate survival by using VITs to help locate and radio-collar newborn fawns born from treatment and control does. Estimated percent body fat of adult does during late February and early March of 2002 and 2003 was significantly higher ($F_{1,90} = 108.21, P < 0.001$) for treatment deer (10.4%, SE = 0.48, $n = 48$) than control deer (4.0%, SE = 0.36, $n = 46$). Serum thyroid hormone concentrations (measured only in 2003) were higher in treatment does than control does as well ($F_{4,52} = 32.59, P < 0.001$). Pregnancy and fetus rates were similar among treatment and control does. The pregnancy rate of adult does was 0.95 (SE = 0.036, $n = 38$) and the fetus rate was 1.80 fetuses/doe (SE = 0.10, $n = 36$) during 2002. Rates were similar in 2003, where we measured a pregnancy rate of 0.92 (SE = 0.034, $n = 63$) and a fetus rate of 1.74 fetuses/doe (SE = 0.069, $n = 50$) which included 5 yearlings (the fetus rate excluding yearlings was 1.82 fetuses/doe, SE = 0.066, $n = 45$). The fetus survival rate with treatment and control fetuses combined was 0.86 (SE = 0.073) during 2002 and 0.97 (SE = 0.024) during 2003. Based on multiple early winter age classification surveys, we concluded that the winter nutrition enhancement treatment did not cause an increase in neonatal production and survival during 2001. Neonate survival data coupled with early

winter age classification surveys indicated a marginal treatment effect during 2002. However, fawn production and summer-fall survival was relatively good during 2001 and 2002 for the overall population, and not representative of most years during the past decade when the population declined. During 2003, as of late September, survival of newborn treatment fawns was 0.745 (SE = 0.059) and control fawn survival was 0.614 (SE = 0.073). During 2001-02, the overwinter survival rate of fawns was significantly greater ($\chi^2_1 = 13.216$, $P < 0.001$) in the treatment unit ($S(t) = 0.865$, SE = 0.056) than in the control unit ($S(t) = 0.510$, SE = 0.080). Again in 2002-03, the overwinter survival rate of fawns was significantly greater ($\chi^2_1 = 5.734$, $P = 0.017$) in the treatment unit ($S(t) = 0.900$, SE = 0.047) than in the control unit ($S(t) = 0.691$, SE = 0.074). Because of a cross-over over experimental design, the treatment unit during winter 2001-02 became the control unit during winter 2002-03, and vice versa. Thus, the overwinter survival treatment effect was replicated across each experimental unit. Combining both years of data, the best model of overwinter fawn survival (AICc = 148.63) included the treatment effect ($\chi^2_1 = 14.71$, $P < 0.001$), early winter fawn mass ($\chi^2_1 = 16.80$, $P < 0.001$), year ($\chi^2_1 = 3.53$, $P = 0.060$), and sex ($\chi^2_1 = 1.99$, $P = 0.158$). The AIC model selection analysis emphasized the importance of both the treatment effect as well as early winter mass of fawns, because any models without treatment or fawn mass were very poor. Early winter mass was not different among experimental units ($F_1 = 0.35$, $P = 0.558$), thus the effect of the treatment was not confounded with fawn mass. We will continue this research for 1.5 more years. The results reported here are preliminary and should be treated as such.

EFFECT OF NUTRITION AND HABITAT ENHANCEMENTS ON MULE DEER RECRUITMENT AND SURVIVAL RATES

C. J. Bishop, G. C. White, D. J. Freddy, and B. E. Watkins

P. N. OBJECTIVES

1. To determine experimentally whether enhancing mule deer nutrition during winter and early spring by supplemental feeding increases fetus survival, neonate survival, early winter fawn:doe ratios or overwinter fawn survival.

2. To determine experimentally to what extent habitat treatments replicate the effect of enhanced nutrition from supplemental feeding.

SEGMENT OBJECTIVES

1. Capture and radio-collar a target sample of adult female mule deer and 6 month-old fawns during late November through mid-December in a treatment unit and a control unit.

2. Capture a target sample of adult female mule deer in the treatment unit and the control unit to measure pregnancy rates, fetal rates, and body condition during late February to early March, and fit each adult female deer with a radio collar and vaginal implant transmitter.

3. Deliver the nutrition enhancement treatment to all deer occupying the treatment unit from early December through the end of April.

4. Capture and radio-collar a target sample of newborn fawns from treatment and control radio-collared does during June using the vaginal implant transmitters as a technique to determine the timing and location of birth.

5. Measure fetus survival, neonate survival, early winter fawn:doe ratios, overwinter fawn survival, and annual adult female survival based on radio-collared deer from the treatment and control units.

INTRODUCTION

Mule deer (*Odocoileus hemionus*) numbers apparently declined during the 1990's throughout much of the West, and have clearly decreased since the peak population levels documented in the 1940's-60's (Gill et al. 1999, Unsworth et al. 1999). Biologists and sportsmen alike have concerns as to what factors may be responsible for declining population trends. Although previous and current research indicates that multiple interacting factors are responsible, habitat and predation have received the focus of attention. A number of studies have evaluated whether predator control increases deer survival, yet results are highly variable (Connolly 1981, Ballard et al. 2001). Together, predator control studies with adequate rigor indicate that predation effects on mule deer are variable as a result of time-specific and site-specific factors. Studies which have demonstrated deer population responses to predator control treatments have failed to determine whether predation is ultimately more limiting than habitat. Numerous research studies have evaluated mule deer habitat quality, but virtually no studies have documented population responses to habitat improvements. In many areas where declining deer numbers are of concern, predation is common yet habitat quality appears to have declined. The question remains as to whether predation, habitat, or some other factor is more limiting to mule deer in these situations, and whether habitat quality can be improved for the benefit of deer. It may also be that no single factor is any more or less important than another, and that a more comprehensive understanding of multi-factor interactions is paramount.

We designed a field experiment to measure deer population responses to nutrition enhancement treatments, to further understand the causative factors underlying observed deer population dynamics. We are conducting the study on the Uncompahgre Plateau in southwest Colorado, where several predator species are present in abundant numbers: coyotes (*Canis latrans*), mountain lions (*Felis concolor*), and bears (*Ursus americanus*). In addition to predation, myriad diseases in combination proximately affect survival of the Uncompahgre deer population (Pojar 2000, B.E. Watkins, unpublished data). Predator numbers have not and will not be manipulated in any manner during the course of the study. All factors have been left constant with the exception of deer nutrition. Deer nutrition is being enhanced by providing supplemental feed to deer occupying a treatment area during the winter. If December fawn recruitment and/or overwinter fawn survival improve as a direct result of the nutrition enhancement treatment, then we can presume that deer nutrition is ultimately more limiting than predation or disease. The second phase of the field experiment, which has not yet been initiated, will incorporate habitat manipulation treatments. The treatments will consist of prescribed fire or mechanical techniques to set back succession of pinyon-juniper (*Pinus edulis-Juniperus osteosperma*) habitat in an effort to improve the vigor and quality of winter habitat for mule deer. Deer population responses will be measured in relation to the habitat manipulations in the same manner as the supplemental feed. Thus, the experiment allows us to determine whether nutritional quality of winter range habitat is ultimately more limiting than other factors in a late-seral pinyon-juniper/sagebrush (*Artemisia* spp.) landscape, and if so, whether habitat can be effectively improved for mule deer. The results will also advance our current understanding of multi-factor interactions, with direct implications for mule deer management.

MATERIALS AND METHODS

Experimental Approach

Experimental Design and Study Area

We non-randomly selected two areas within mule deer winter range on the Uncompahgre Plateau to create 2 experimental units (A-B) (Fig. 1). The following criteria were used to select experimental units:

1.) Deer densities (~50-80 deer/mi^2): areas were selected where deer densities were sufficient to meet sample size requirements within the experimental unit, while simultaneously selecting areas that would require feeding less than ~500-600 animals during a normal winter
2.) Buffer zones: areas were selected such that experimental units would be separated by several miles of non-treatment area (buffers) to prevent deer from occupying more than one experimental unit
3.) Similarity: areas were selected that comprise relatively similar habitat complexes and deer densities that are representative of the overall area
4.) Elk populations: areas were selected to minimize the number of elk present during normal winters

Units A and B are receiving the nutrition enhancement treatment in a cross-over experimental design, and are being used to address P.N. Objective 1. Unit A served as the treatment unit, while Unit B served as the control, for the first 2 winters of research (2000 – 2002). Beginning November 2002, Unit B received the treatment while Unit A served as the control. Upon completion of P.N. Objective 1, two additional winter range experimental units will be used to conduct phase 2 of the research, or P.N. Objective 2. Habitat in one unit will be manipulated to set back plant succession (treatment), while habitat in the other unit will remain unchanged (control) throughout the experiment.

Year	Unit A	Unit B
2000-01	Treatment	Control
2001-02	Treatment	Control
2002-03	Control	Treatment
2003-04	Control	Treatment

Figure 1. Schematic representation of experimental units and nutrition enhancement treatment allocation. Units A and B are located in winter range habitat on the Uncompahgre Plateau in southwest Colorado. The nutrition enhancement cross-over design will encompass 4 years.

The 2 experimental units (A and B) receiving the nutrition enhancement treatment are (Figs. 2 and 3):

(1) Experimental unit A includes the Colona Tract of the Billy Creek State Wildlife Area and adjacent land, located approximately 13 km south of Montrose, CO adjacent to U.S. Hwy 550 South. The experimental unit is located within the Colona USGS 7.5 Minute Quadrangle, and roughly includes the polygon defined by the following Zone 13 UTM coordinates: (1) 254000 E, 4250200 N; (2) 252700 E, 4249400 N; (3) 254700 E, 4245600 N; and (4) 256200 E, 4246600 N.

(2) Experimental unit B includes Shavano Valley and adjacent land extending west to the Dry Creek Rim. Shavano Valley is located approximately 13 km west of Montrose, CO. The experimental unit is located within the Dry Creek Basin and Montrose West Quadrangles (USGS 7.5 Minute), and roughly includes the polygon defined by the following Zone 13 UTM coordinates: (1) 238400 E, 4262600 N; (2) 232400 E, 4256700 N; (3) 235000 E, 4253600 N; and (4) 239500 E, 4258200 N.

In late April and May, prior to fawning, deer from the winter range experimental units migrate to summer range. The summer range study area is defined by movements of the radio-collared deer, which encompass >1000 mi^2 covering the southern portion of the Uncompahgre Plateau and adjacent San Juan Mountains to the south and east (Fig. 2). The summer range study area extends north to the Dry Creek river drainage on the Uncompaghre Plateau, south to Mineral Creek near Silverton, CO, east to the Big Blue river drainage, and west to the San Miguel River canyon. However, a majority of the radio-collared deer summer on the Uncompahgre Plateau between Dry Creek to the north and Horsefly Peak to the south.

Winter range elevations range from 1830 m (6000 ft) in Shavano Valley to 2318 m (7600 ft) adjacent to the Dry Creek Rim above Shavano Valley. Winter range habitat is dominated by pinyon-juniper with interspersed sagebrush adjacent to agricultural fields in the Shavano and Uncompahgre Valleys. Summer range elevations occupied by deer range from 1891 m (6200 ft) in the Uncompahgre Valley to 3538 m (11,600 ft) in Imogene Basin southwest of Ouray, CO. Summer range habitats are dominated by spruce-fir (*Picea* spp.-*Abies* spp.), aspen (*Populus tremuloides*), ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*), and to a lesser extent, sagebrush and pinyon-juniper at lower elevations.

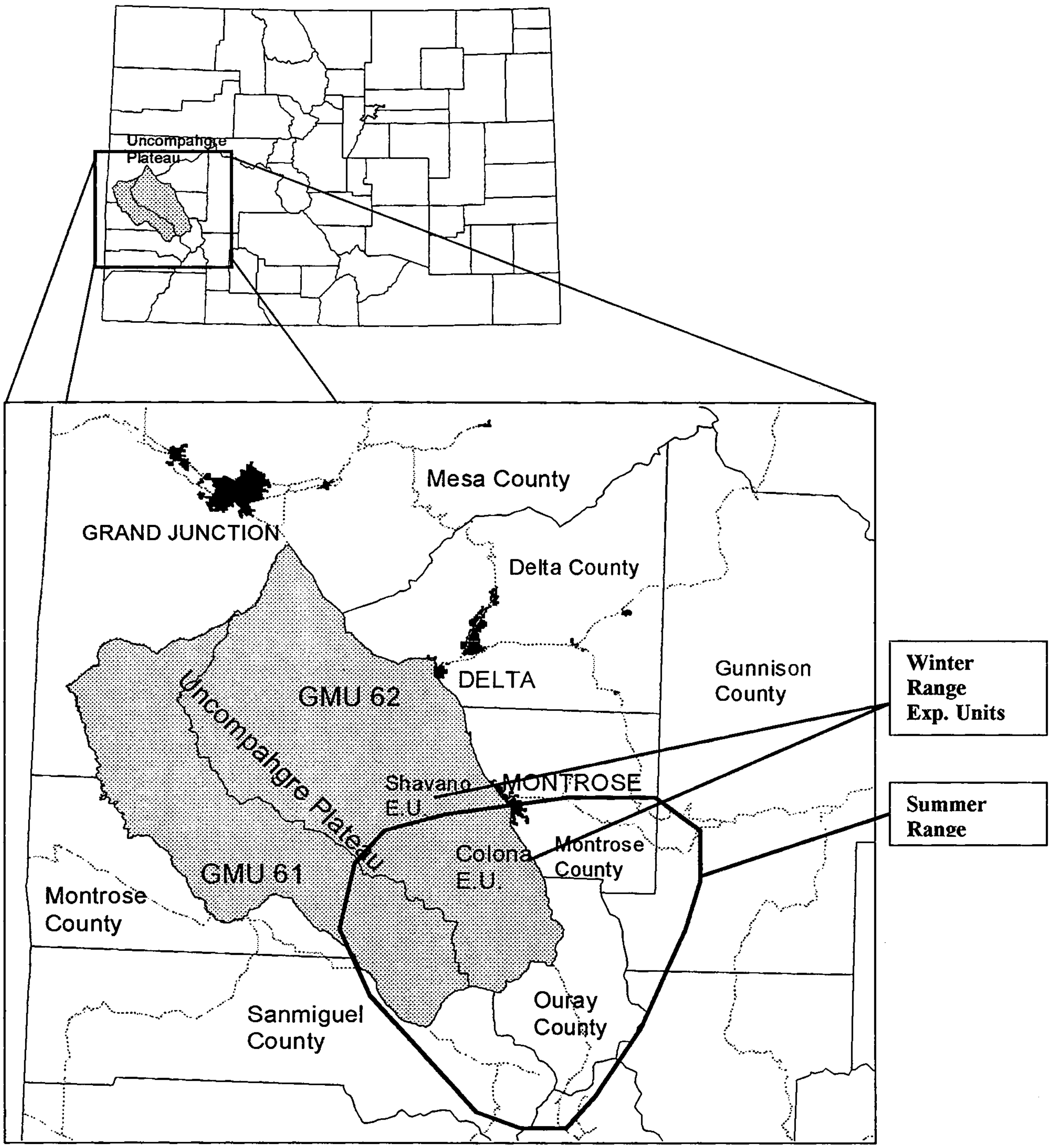

Figure 2. Location of Colona and Shavano (Units A and B) experimental units in Game Management Unit 62 on the Uncompahgre Plateau, southwest Colorado; and location of the summer range study area throughout the southern Uncompahgre Plateau and adjacent San Juan Mountains

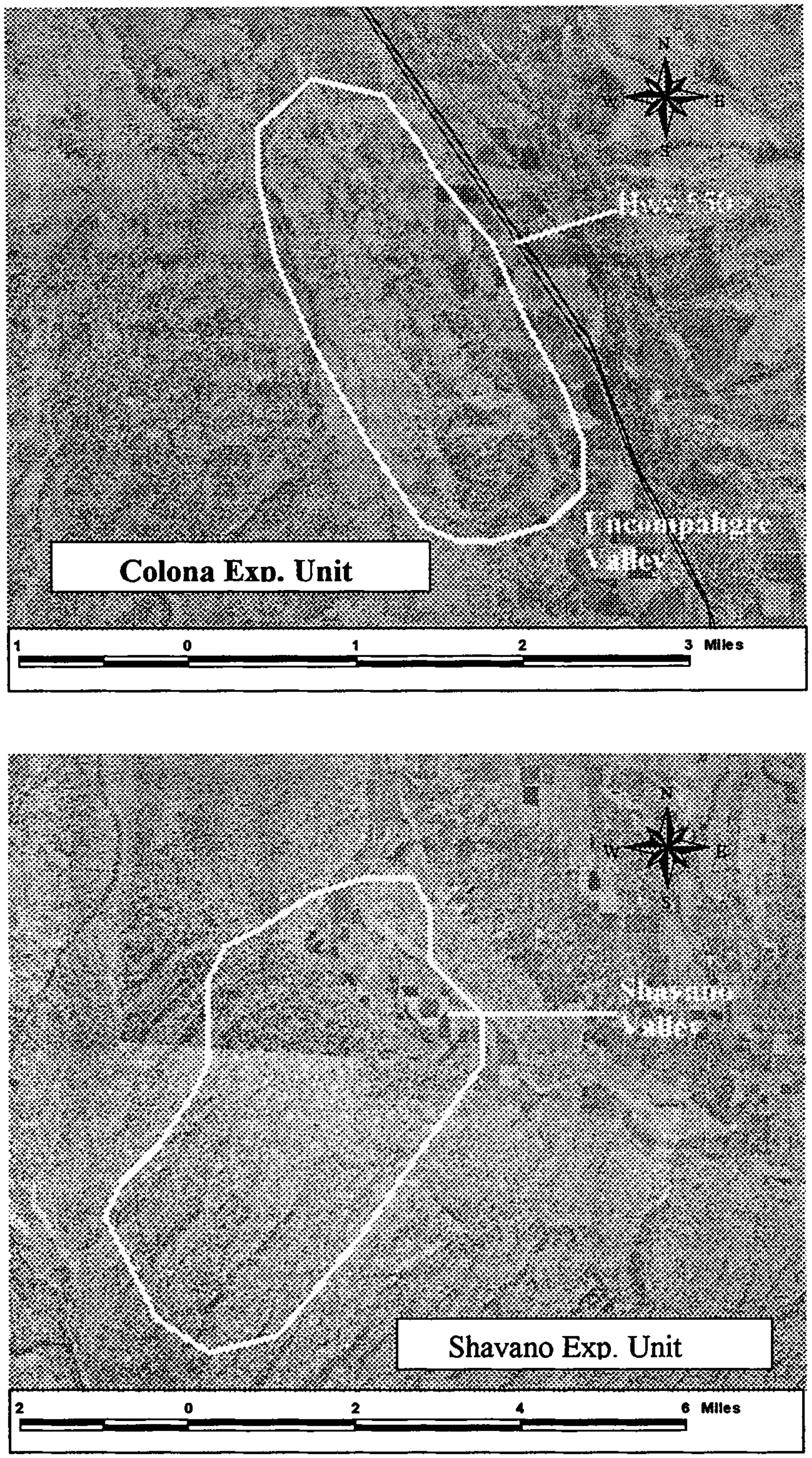

Figure 3. Colona and Shavano experimental units (Units A and B), located in Game Management Unit 62 on the Uncompahgre Plateau, southwest Colorado. Polygons represent the nucleus of each experimental unit, which is where animals have been collared and the nutrition enhancement treatment delivered.

Response Variables

The response variables are fetal and neonatal survival rates, early winter fawn:doe ratios, and overwinter fawn survival rates. The nutrition enhancement treatment is delivered to deer from December through April, fetus survival is assessed during June, neonate survival is measured from June to December, and fawn:doe ratios are measured during the following December and January (1 year after the treatment was initiated). Overwinter fawn survival is measured from December to June as a direct result of the current winter's treatment. We are measuring these response variables in each experimental unit (treatment and control) to determine whether enhanced winter nutrition of adult does increases subsequent newborn fawn production and survival, and whether enhanced winter nutrition of 6-mo. old fawns directly increases overwinter fawn survival. Ultimately, these measurements provide an assessment of the effect of winter range habitat quality on yearling recruitment, and thus population productivity. We are also measuring overwinter and annual survival of adult does as a function of enhanced winter nutrition.

Sample Size

Fetus/Neonate Survival: We were primarily interested in survival of newborn fawns from radio-collared does that occupy the 2 winter range experimental units. Fetus survival is also important, but difficult to measure. Fetus rates from a sample of radio-collared does can be measured in winter, but the fate of *all* fetuses cannot be determined the following June because of logistical constraints. Fetus survival rates can only be measured from some unpredictable fraction of the radio-collared doe sample, making sample size calculations of limited use. Thus, our sample size calculations were based on quantifying neonate survival, not fetus survival. For neonate survival, a sample size of 40 neonates per experimental unit per year provides power of 0.81 to detect a difference of 0.15 in survival between 2 experimental units if survival among control fawns is 0.40. We assumed a control survival rate of 0.40 based on neonate survival rates measured recently for the Uncompahgre deer population (Pojar 2000) in combination with December fawn:doe ratios measured during the late 1980's and 1990's, when the Uncompahgre population declined (B. E. Watkins, unpublished data). Based on Bishop et al. (2002), we determined that 60 radio-collared does (30 treatment and 30 control) equipped with vaginal implant transmitters (VITs) would be necessary to capture a minimum of 80 newborn fawns. We also assumed that some fawns would be captured from other treatment and control radio-collared does not equipped with VITs. The 60 radio-collared does with VITs are also being used to evaluate fetus survival; however, logistical constraints limit the power of fetus survival comparisons among experimental units.

Early winter fawn:doe ratios: We desired to detect an effect size, i.e., an increase in fawn:doe ratios in response to the treatments, in the range of 15 to 20 fawns per 100 does. These values were based on simple population models with overwinter fawn survival of 0.444, adult female survival of 0.853, and December fawn:doe ratios of 66 fawns per 100 does to obtain a stationary population (Unsworth et al. 1999). Based on surveys of the Uncompahgre deer population during the 1990's, the standard deviation of the fawn:doe ratio for groups with at least one adult female was 57, with a mean of 41. Using an expected standard deviation of 57, the standard error of the mean fawn:doe ratio for 40 radio-collared does is $57/(40^{1/2}) = 9.0$, which is the expected standard deviation of measured fawn:doe ratios on each experimental unit. We assessed power using a two-sample *t*-test with a sample size of 4, representing the 4 years of the study where fawn:doe ratios are being measured in response to enhanced nutrition. Our power to detect an increase of 20 fawns per 100 does based on classification of 40 radio-collared doe groups in each experimental unit is about 0.87.

A sample size of 40 fawns per experimental unit per year provides a power of 0.81 to detect a difference of 0.15 in survival between 2 experimental units if survival on the control unit is 0.40. We expected to see an increase in fawn survival (effect size) of approximately 0.15, because this was the difference measured in the density reduction experiment conducted by White and Bartmann (1998).

Adult and 6-month Old Fawn Capture

During November and December, adult does and 6-month old fawns were captured using baited drop nets (Ramsey 1968, Schmidt et al. 1978) and helicopter net guns (Barrett et al. 1982, van Reenen 1982). Drop nets were baited with certified weed-free alfalfa hay and apple pulp. Drop nets were used as the principle capture technique for a 3-4 week capture period; helicopter net-gunning was then used at the end of the drop-net capture to secure the remainder of deer needed to meet our target sample sizes. All deer were hobbled and blind-folded after being captured. Deer captured via drop nets were carried away from the net to an adjacent handling site using stretchers. Deer were fitted with leather radio collars equipped with mortality sensors, which cause an increase in pulse rate after remaining motionless for 4 hours. Permanent collars were placed on adult females, while temporary collars were placed on fawns. To make collars temporary, one end of the collar was cut in half and reattached using rubber surgical tubing; fawns shed the collars ≥6 months post-capture. A rectangular piece of flexible plastic (Ritchey® neck band material) engraved with a unique identifier was stitched to the side of each collar. The unique identifier consisted of 2 symbols for adult females, and 1 symbol on 2 different colors of plastic for fawns. The identifiers were necessary to visually identify deer from the ground. This allowed us to effectively document use of the treatment, measure fawn:doe ratios from the ground, and assess experimental unit population size via mark-resight estimators. We recorded the weight, hind foot length and chest girth of each deer, and collected blood samples to evaluate disease prevalence.

During late February and early March, an additional 30 adult female deer were captured in each experimental unit by net-gunning. Captured deer were ferried by the helicopter to a central processing location, where deer were carried by stretchers to a tent for handling. For each captured deer, we used ultrasonography to measure pregnancy status, fetal rate, and body condition. Only pregnant does were retained and radio-collared. We then inserted a vaginal implant transmitter (VIT) in each doe as a technique for locating the timing and location of her birth site the following June. We also recorded the weight, hind foot length and chest girth of each deer, and collected blood samples to evaluate disease prevalence.

Body Condition and Reproductive Status

We estimated body fat of treatment and control adult does during mid-late winter using an Aloka 210 (Aloka, Inc., Wallinford, Conn.) portable ultrasound unit with a 5 MHz linear transducer. We measured maximum subcutaneous fat thickness on the rump (MAXFAT) following the methodology of Stephenson et al. (1998, 2002). We also measured thickness of the longissimus dorsi muscle via ultrasound (Cook et al. 2001, Stephenson et al. 2002). A small area of hair was shaved to ensure contact between the transducer and the skin. Vegetable oil was applied to the shaved area for conduction purposes and fat/muscle thickness was measured using electronic calipers. We coupled the ultrasound measurements with body condition scores (BCS) obtained from palpation of the ribs, withers, and rump (Cook 2000). MAXFAT and rump BCS measurements were combined into a condition index used to estimate percent body fat (Cook and Cook 2002): $\% \text{Fat} = -6.6387617 + 7.4271417x - 1.11579443x^2 + 0.07733803x^3$ where $x = \text{rLIVINDEX} = (\text{MAXFAT} - 0.15) + \text{rump BCS}$ (if $\text{MAXFAT} < 0.15$, then $\text{rLIVINDEX} = \text{rump BCS}$). The rLIVINDEX and body fat regression was initially developed and validated for elk by Cook et al. (2001), and then modified by incorporating a validation of MAXFAT for mule deer performed by Stephenson et al. (2002).

During mid-late winter 2003, we also evaluated differences in serum thyroid hormone concentrations between treatment and control adult does. Specifically, we measured total thyroxine (T4), free T4 (FT4), total tri-iodothyronine (T3), and free T3 (FT3) following the methodologies of Watkins et al. (1983, 1991). Blood samples were collected at the time of capture, and serum hormone analyses were performed by the Michigan State University Animal Health Diagnostic Laboratory (East Lansing, Michigan). We compared serum thyroid hormone concentrations between treatment and control adult does, and also compared hormone levels to body fat estimates derived from the ultrasonography.

We quantified reproductive status (Stephenson et al. 1995, Pojar 2000) with ultrasound via transabdominal scanning using a 3 MHz linear transducer. We searched for fetuses by scanning a portion of the abdomen that was shaved caudal to the last rib and left of the midline. We systematically searched each uterine horn to identify fetal numbers ranging from 0 to 3. Whenever possible, we measured eye diameter of each fetus to approximately estimate fetal age and parturition date.

Vaginal Implant Transmitters (VITs)

We used VITs manufactured by Advanced Telemetry Systems, Inc. (Isanti, MN). The VIT was 76 mm long, excluding antenna length, and had 2 plastic wings with a width of 57 mm when fully spread apart. The plastic wings were used to retain the transmitter in the vagina until parturition. The VIT weighed 15 grams and contained a 10-28 lithium battery programmed to a 12-hour on/off cycle. The diameter of the transmitter/battery was 14 mm, and was encased in an impermeable, water-proof, electrical resin. The transmitter contained an embedded heat-sensor which dictated the frequency pulse rate. When the heat sensor dropped below 90°F, synonymous with transmitter expulsion from the deer, the pulse rate changed from 40 PPM to 80 PPM. VIT batteries were programmed to be active from 0430 to 1630 hrs prior to daylight savings, and thus were active from 0530 to 1730 hrs after daylight savings and during the fawning period. The VIT was inserted into deer using a vaginoscope (Jorgensen Laboratories, Inc., Loveland, CO) and alligator forceps. The vaginoscope was 6" long with a 5/8" internal diameter and had a machined end (smooth surface) to minimize trauma when inserted into the vagina. A discreet mark was placed on the applicator showing the appropriate distance it should be inserted into the deer. The length of a typical mule deer vaginal tract was obtained by taking measurements from road-killed deer and/or other fresh deer carcasses obtained in the study area.

Prior to use in the field, VITs were sterilized using a Chlorhexidine solution, air-dried, and sealed in a 3" x 8" sterilization pouch. Sterilization containers with Chlorhexidine solution were used on site during capture to sterilize the vaginoscope and alligator forceps between each use. A new pair of nitrile surgical gloves was used to handle the vaginoscope and VIT for each deer. To insert a VIT, the plastic wings were folded together and placed into the end of the vaginoscope. We then liberally applied sterile KY Jelly to the scope and inserted it into the deer's vagina to the point where the mark on the applicator was reached. The alligator forceps, which extended through the vaginoscope to hold the VIT, was held firmly in place while the scope was pulled out from the vagina. This procedure pushed the VIT out of the scope into the vagina, and the plastic wings spread apart to hold the transmitter in place. The transmitter antenna was typically flush with the vulva, but on occasion extended up to 1 cm beyond the vulva. The tip of the antenna was encapsulated in a wax bead to protect the deer.

Neonate Fawn Capture

During June we relocated each of the radio-collared does having a VIT each morning using aerial and ground telemetry. Flights began at 0530 hr and were usually completed by 1000 – 1100 hrs. The early flights were crucial for detecting fast signals because shed VITs could exceed 90 °F by mid-day if shed in the open, which caused them to switch back to a slow ("pre-birth") pulse. When a fast ("postpartum") pulse rate was detected, we located the VIT from the ground to determine whether it was shed at the birth site. If the transmitter was located at the birth site, we identified whether any fawn(s) were stillborn. If the fawn(s) were no longer present at the birth site, or could not be found in the vicinity of the birth site, we located the radio-collared doe and searched for fawns at her location. All personnel involved wore surgical gloves to help minimize human scent when handling fawns. For each doe, we attempted to locate each of her fawns and document whether any fawns were stillborn. We attempted to account for each doe's fetuses in order to quantify *in utero* fetal survival from February to birth. We placed a drop-off radio-collar on each live fawn; radio collars were constructed with elastic neck-band material to facilitate expansion. Hole-punched, leather tabs extended from the end of the elastic and from the transmitter for attachment purposes. Collars were made temporary by cutting the leather tab extending from the elastic and reattaching the leather with latex tubing, which caused the collars to shed from the animal >6 months post-capture. For each fawn, mass and hind foot length were recorded, and a nasal swab sample was collected to screen for Bovine Viral Diarrhea. We then recorded basic vegetation characteristics of the birth site and promptly exited the site.

We also routinely located treatment and control radio-collared does not having VITs and attempted to capture their fawns to help achieve our targeted sample size. Each of these does had been previously captured during the research, and were present on either the treatment or control experimental unit during winter.

Measurement of Survival Rates and Fawn:Doe Ratios

We measured survival rates by radio-monitoring collared deer from the ground and air to determine fate (live/mortality). We also attempted to determine the cause of each mortality, with a primary goal of distinguishing between predation and non-predation mortality causes. Deer were radio-monitored from the ground on a daily basis throughout the year and from the air on approximately a biweekly basis. We were able to detect signals from nearly all radio-collared deer each day during winter, which typically allowed us to arrive at mortality sites within 24 hours of the mortality event. During summer and migration periods, deer were distributed widely and thus were more difficult to radio-monitor. All radio-collared neonates were checked daily throughout the summer and fall, whereas some adult and yearling deer could not be ground-monitored on a routine basis. In result, we typically located neonate mortalities within 24 hours of death, but some adult deer mortalities were not detected for several days, or on rare occasion, for one or more weeks. Fresh, intact neonate carcasses were collected and submitted to the Colorado Division of Wildlife's Wildlife Health Laboratory or the Colorado State University Diagnostic Laboratory for necropsy and tissue analyses. Fresh, intact adult and 6-month old fawn carcasses were also submitted for laboratory necropsy when feasible. Field necropsies were performed on all other deer mortalities, and when appropriate, tissue samples were collected and submitted for analysis.

Each winter we used the radio-collared does to measure fawn:doe ratios in each experimental unit. The resulting fawn:doe ratio is a measurement of the previous year's treatment effect. We measured fawn:doe ratios using 2 techniques: (1) We located the sample of radio-collared does in each experimental unit from a fixed-wing airplane, and used the set of locations to define boundaries for the experimental unit. Shortly after (i.e. 1-2 days), we used a helicopter to systematically fly the defined unit and classify all deer groups encountered. For each group, we documented whether a radio-collared doe was present. (2) We located each radio-collared doe by radio telemetry from the ground. The group of deer with the collared doe was counted and classified by age and sex. Both methods were employed to gather as much information as possible to determine whether there was a treatment effect. The "true" value cannot be measured perfectly because of the inherent biases and potential sources of error associated with each technique. Thus, by employing both techniques, we had a greater chance of fully understanding whether the treatment caused an effect.

Treatment Delivery

Deer nutrition was enhanced in the treatment area by providing a safe, pelleted supplemental feed. The supplemental feed was developed through extensive testing with both captive and wild deer (Baker and Hobbs 1985, Baker et al. 1998), and has been safely used in both applied research and management projects. Pellets were distributed daily using 4wd pickup trucks and ATVs on primitive roads throughout the experimental unit to provide a food source for the entire deer population in the treatment unit. Each 50lb. bag of pellets was carried ≤200m from the truck/ATV and distributed by hand in approximately 20-30 small piles of feed in a linear fashion. Numerous bags were distributed in successive order allowing us to create linear lines of feed that spanned most of the treatment area, which prevented animals from concentrating in any single location. This feeding technique also prevented dominant animals from restricting access to the food supply because of the large area over which pellets were distributed. We supplied pellets ad libitum such that a small residual remained when the next day's ration was provided. Collared deer were closely monitored to ensure that treatment deer remained in the experimental unit and actually consumed the feed, and to make sure that non-treatment deer remained in the control unit, which they did. The few treatment adult does that moved away from the treatment unit were withdrawn from the sample for purposes of measuring treatment effects. However, to avoid any biases, all 6-month old fawns captured in the treatment unit were included in survival analyses regardless of whether they accessed the supplement or not. This was because some fawns died shortly after capture (e.g. 2-3 weeks), before we could document whether they had access to the feed. Also, very few fawns that survived more than 2-3 weeks moved away from the treatment unit.

The pelleted ration was commercially produced in the form of $2 \times 1 \times 0.5$-cm wafers (Baker and Hobbs 1985). Feed constituents (i.e. digestibility, protein, gross energy etc.) vastly exceeded those of typical winter range deer diets; exact constituent values are provided by Baker et al. (1998). When provided ad libitum, the feed should have allowed deer to meet or exceed nutritional requirements for growth and maintenance (Ullrey et al. 1967, Verme and Ullrey 1972, Thompson et al. 1973, Smith et al. 1975, Baker et al. 1979, Holter et al. 1979). The basis for feeding such high quality pellets was to ensure that the treatment (enhanced nutrition) was effectively delivered to the deer. Our intent was not to determine the exact level of nutrition necessary to increase fawn recruitment, but rather to determine if nutrition is a limiting factor to recruitment. If nutrition is in fact limiting, we will rely on habitat manipulation treatments to evaluate what exactly can be done via management to increase fawn survival and recruitment.

Statistical Methods

A preliminary fawn:doe ratio analysis was completed using PROC MIXED in SAS (SAS Institute 1997). We used a reduced model with experimental unit as the independent variable; we considered experimental unit as a fixed effect and radio-collared does within an experimental unit as random effects. Survival rates were calculated using a Kaplan-Meier survival analysis (Kaplan and Meier 1958, Pollock et al. 1989), and contrasted among experimental units and sexes using a chi-square analysis. For neonate survival analyses, we used a common entry date because a staggered entry would have biased survival rates low due to early mortalities that occurred before most of the sample was captured. We modeled overwinter fawn survival with a logistic regression model using PROC LOGISTIC in SAS (SAS Institute 1989*a*); model selection was performed using Akaike's Information Criterion (AIC) (Burnham and Anderson 1998). Survival was modeled as a function of the nutrition enhancement treatment, sex, year, and capture mass. We used a general linear model in PROC GLM in SAS (SAS Institute 1989*b*) to test for differences in estimated percent body fat between treatment and control adult does and a multivariate model to test for differences in T4, FT4, T3, and FT3 thryoid hormones between treatment and control does. We then used PROG REG (SAS Institute 1989*b*) to evaluate the relationship between estimated percent body fat and serum thyroid hormone concentrations. We analyzed fetus survival directly with a binomial survival rate for the subset of fetuses with known fates. We also indirectly analyzed fetus survival by comparing the February fetus rate with the number of live newborn fawns/doe observed in June using a change-in-ratio estimator (White et al. 1996). Other results in this report are presented as data summaries incorporating means and standard errors, or in some cases, raw data values. These results are incomplete and preliminary in nature, and should be treated as such.

RESULTS AND DISCUSSION

Deer Capture

During November and December 2000-2002, we captured and radio-collared 122 adult female mule deer evenly distributed among the treatment and control units. We also captured and radio-collared 160 6-month old fawns during November and December 2001-2002 (40 fawns/unit/year). Due to budgeting constraints, we were unable to radio-collar 6-month old fawns during 2000. We captured an additional 94 adult females during late February and early March 2002-2003 and equipped them with radio collars and VITs. During June 2002-2003, we captured and radio-collared 157 newborn fawns from radio-collared adult females. Thus, the following results are based upon radio-monitoring of 533 individual mule deer evenly distributed among treatment and control units during November 2000-June 2003.

Treatment Delivery

2000-01

From December 15, 2000, through April 19, 2001, we distributed 88 tons of the pelleted ration. For most of the winter and spring, on average, we distributed 0.85 tons of feed each day throughout 22 feeding sites across the 2.3 mi^2 treatment unit. Deer were fed ad libitum because there was always residual feed remaining the next day during the feeding routine. Each sack was distributed in approximately 20-30 distinct, small piles, resulting in >1000 small piles of feed throughout the treatment unit. This effort allowed deer to effectively access the feed in small groups, and no aggression was ever observed among deer seeking access to the feed. By distributing the feed in this manner, we were able to avoid the negative aspects associated with large-scale feeding operations. Deer adapted to the pelleted supplement right away and utilized it extensively throughout the winter. We continually monitored deer use of the feed from ground observation points, where we obtained 440 visual observations of radio-collared does consuming the feed. These observations, coupled with daily radio-monitoring and periodic aerial relocations, indicate 32 of the 37 radio-collared treatment does spent the entire winter and spring within the boundaries of the treatment unit and received the supplement on a daily basis.

Mark-resight population estimates from March helicopter (489 deer, SE = 62) and ground (494 deer, SE = 81) surveys, coupled with feed consumption, indicate we fed roughly 450 to 500 deer during most of the winter and spring. Feed consumption declined coincident with spring green-up, although deer continued to use the feed through mid-late April, at which point they began migrating to summer range. We also fed approximately 25 to 30 elk, but the elk did not affect deer access to the feed. Deer in the control experimental unit did not receive feed or any other treatment. Based on helicopter mark-resight surveys, the deer density in the treatment unit in December was 120 deer/mi^2 (SE = 9), but increased shortly after and was 213 deer/mi^2 (SE = 27) in March. Deer densities in the control unit changed little from 83 deer/mi^2 (SE = 12) in December to 101 deer/mi^2 (SE = 14) in March.

2001-02

From December 15, 2001, through April 25, 2002, we distributed 194 tons of the supplement throughout the treatment unit. For most of the winter and spring, we distributed 2.0-2.1 tons of feed each day. The dramatic increase in supplement distribution from the previous year occurred because a large number of elk descended into the Uncompahgre Valley during mid-late fall/early winter. Elk arrived in unusually large numbers throughout much of the valley prior to the onset of treatment delivery. Once feeding was initiated, approximately 300-500 elk adapted to the feed and remained in or around the 2.3 mi^2 treatment unit throughout most of the winter.

Given myriad logistical and budgetary constraints, 2.1 tons was the maximum amount of feed we could routinely deliver on a daily basis. Feed was not delivered ad libitum to all deer and elk in the treatment unit throughout the winter because residual feed was rarely observed during the next day's distribution. However, daily field observations indicated most deer approached ad libitum consumption of the supplement. In contrast to the previous winter, deer were waiting for the daily supplement to arrive each morning. Deer then consumed the supplement immediately after it was distributed. Elk were rarely observed utilizing the feed until late morning or afternoon, and elk continued to forage in fields below the treatment unit, whereas deer did not. We observed numerous radio-collared deer consuming the pelleted supplement each day; not all of these observations were recorded because of time constraints with distributing the feed. Given this time limitation, we still recorded 818 observations of radio-collared deer consuming the supplemental feed (497 collared doe observations and 321 collared fawn observations). Most days, >100 and sometimes 200-300 deer were observed utilizing the pellets during the course of distributing the supplement. These observations rarely included elk; thus, deer-elk competition was minimized because of temporal differences in feeding, and deer clearly had first access to the feed.

2002-03

Beginning December 2002, we switched the treatment and control units consistent with the cross-over experimental design. From December 15, 2002, through April 30, 2003, we distributed 97 tons of the supplement throughout the new treatment unit, which had served as the control unit the previous 2 years. The supplement was distributed daily throughout 29 sites over a larger area (~7 mi^2) than the first 2 years of research because of the greater size of the experimental unit and broader distribution of radio-collared deer. Residual feed was always present throughout the winter, thus deer were fed ad libitum. Only small groups of elk periodically accessed the supplement, and did not affect deer access. We obtained 286 observations of radio-collared deer consuming the supplement, which were difficult to obtain because the supplement was spread out over a large area and only a single feed site could be observed at any given moment. We also used daily ground radio-monitoring and periodic aerial relocations to document deer access to the supplement.

Body Condition

Estimated percent body fat of adult does during late February and early March of 2002 and 2003 was significantly higher for treatment deer than control deer ($F_{1,90} = 108.21$, $P < 0.001$). Over both years combined, mean predicted body fat was 10.4% (SE = 0.48) for treatment adult does and 4.0% (SE = 0.36) for control does. The interaction of experimental unit × year for predicted body fat was also significant ($F_{1,90} = 21.79$, $P < 0.001$). This interaction occurred because the difference in body fat between treatment and control deer was greater during 2003 than during 2002. During 2002, mean predicted body fat was 8.2% (SE = 0.92) for treatment adult does and 5.0% (SE = 0.71) for control does, whereas during 2003, mean predicted body fat was 11.7% (SE = 0.35) for treatment does and 3.4% (SE = 0.35) for control does. The body fat estimates reported here should accurately reflect deer, but may be further refined in the future as additional research provides more data on the relationship between body condition indices and estimated percent body fat.

In 2003, serum thyroid hormone concentrations were higher in treatment does than control does ($F_{4, 52}$ = 32.59, $P < 0.001$). T4 was the most important thyroid hormone in describing the single canonical variable (1.78*T4 - 0.04*T3 + 0.20*FT4 – 0.27*FT3). Not surprisingly, there was a high partial correlation between T4 and FT4 ($r = 0.77$, $P < 0.001$) and between T3 and FT3 ($r = 0.73$, $P < 0.001$), which has been documented previously (Watkins et al. 1983). When treated as 4 separate ANOVAs, T4 ($F_{1, 55}$ = 127.45, $P < 0.001$), FT4 ($F_{1, 55}$ = 81.72, $P < 0.001$), and T3 ($F_{1, 55}$= 5.39, $P = 0.024$) were significantly higher in treatment does than control does, whereas FT3 levels were less different among treatment and control deer ($F_{1, 55}$ = 2.59, $P = 0.113$). Given these results, we evaluated the relationship between T4 concentrations and estimated percent body fat (derived form ultrasound and BCS indices) using a simple linear regression model (% Fat = -5.114 + 0.106*T4, $r^2 = 0.59$, $P < 0.001$). Similar correlations between T4 and actual percent body fat during mid-late winter have been previously documented for white-tailed deer and elk (Watkins et al. 1991, Cook et al. 2001).

Fetus Survival and Pregnancy/Fetus Rates

We began measuring fetus survival in 2002 as part of our effort to capture and radio-collar newborn fawns born from radio-collared does. Similar numbers of stillborns were observed between treatment and control does during both 2002 and 2003, so all fetus survival analyses reported here represent pooled estimates. In February-March 2002, 36 of 38 adult does captured were pregnant, thus the pregnancy rate was 0.95 (SE = 0.036). We measured an average of 1.80 fetuses/doe (SE = 0.10, $n = 36$), which included 1.77 fetuses/doe (SE = 0.14, $n = 18$) in the treatment unit and 1.83 fetuses/doe (SE = 0.15, $n = 18$) in the control unit. During June 2002, we determined the fate of all fetuses (live or stillborn) from only 14 of the 36 VIT does, largely because of a high VIT battery failure rate. The survival rate of fetuses ($n = 22$) from these 14 does was 0.86 (SE = 0.073). We also assessed fetus survival using a change-in-ratio estimator between the fetal rate measured in February-March and the observed number of live fawns/doe postpartum in June. In June 2002, considering all does ($n = 43$) that we located any fawn from, whether live or stillborn, we observed 1.42 (SE = 0.11) live fawns/doe postpartum. This rate should represent a conservative estimate of live fawns/doe postpartum because we inevitably failed to locate all live fawns from each doe. In other words, this estimate would treat any unaccounted fetuses (from the February measurement) as if they were stillborns. For radio-collared does that did not have VITs, and thus we did not have a winter fetus rate measurement, singletons would infer that either the deer only had 1 fetus, or that the other fetus died. It is likely that some of these singletons had a twin that we did not locate. This equates to a conservative fetus survival rate estimate of 0.79 (SE = 0.18).

In February-March 2003, 58 of 63 adult does captured were pregnant, resulting in a pregnancy rate of 0.92 (SE = 0.034). Critical personnel and equipment for measuring fetus rates were not continuously available due to capture delays associated with helicopter mechanical problems. Some of the deer fetus counts were performed by inexperienced observers without optimum ultrasound equipment. VITs worked very well, though, allowing us to determine fetus numbers at parturition for many of the deer. Thus, we determined winter fetus rates by using the greatest fetus count for each individual deer, whether obtained using ultrasound during February-March or by locating newborn fawns and stillborns at birthsites during June. We were unable to determine a fetus count for 8 treatment deer because only pregnancy was established with ultrasound and no birthsite assessments were possible in June. These 8 deer were removed from the fetus rate estimates. Of the 50 deer where a fetus count was obtained, 5 were yearlings (2 treatment yearlings, 3 control yearlings). We measured 1.74 fetuses/doe (SE = 0.069, $n = 50$) overall including yearlings, and 1.82 fetuses/doe (SE = 0.066, $n = 45$) excluding yearlings. Fetus rates with yearlings included were 1.77 fetuses/doe (SE = 0.091, $n = 22$) in the treatment unit and 1.70

fetuses/doe (SE = 0.10, $n = 28$) in the control unit. During June 2003, we determined the fate of all fetuses (live or stillborn) from 33 of the 58 VIT does; the good success was based on VITs commonly being shed at birthsites. The survival rate of fetuses ($n = 58$) from these 33 does was 0.97 (SE = 0.024). In June 2003, incorporating all does ($n = 71$) that we located any fawn from, whether live or stillborn, we observed 1.49 (SE = 0.072) live fawns/doe postpartum. Using the change-in-ratio estimator described above, this results in an overall conservative fetus survival rate estimate of 0.86 (SE = 0.15).

Neonatal Survival/Fawn: Doe Ratios

2001

In December 2000, at the beginning of the study and prior to the first year's treatment delivery, fawn:doe ratios were similar in the 2 experimental units. Pre-treatment fawn:doe ratios were 52.6 fawns:100 does (SE = 5.3) in the treatment unit, and 51.6 fawns:100 does (SE = 5.0) in the control unit. In late December 2001 and early January 2002, following the first year's treatment, we conducted 2 age classification helicopter surveys in the treatment and control units. On 12/23/01, we observed 52.8 fawns:100 does (SE = 6.7) in the treatment unit, and 36.7 fawns:100 does (SE = 3.8) in the control unit. On 1/8/02, we observed 54.7 fawns:100 does (SE = 6.6) in the treatment unit, and 50.5 fawns:100 does (SE = 6.0) in the control unit. During December 2001 – February 2002, we obtained fawn:doe ratio estimates from ground observations of radio-collared deer groups for both treatment and control deer. This survey resulted in 61.2 fawns:100 does (SE = 7.8) in the treatment unit, and 74.5 fawns:100 does (SE = 8.5) in the control unit, although the result was not statistically significant ($t_{74} = 1.16$, $P = 0.249$).

The fawn:doe ratio results are conflicting, and clearly do not provide evidence that there was any treatment effect. In short, we concluded that the nutrition enhancement treatment did not cause an increase in neonatal production and survival during 2001. However, our results, in conjunction with a December estimate of 64 fawns:100 does for the entire Uncompahgre deer population (B.E. Watkins, unpublished), indicate fawn production and survival was good during 2001. The observed fawn:doe ratios coupled with overwinter fawn survival and annual adult survival rates indicate the deer population was increasing. Considering the past 1-2 decades, this was an atypically good year for the Uncompahgre deer population. It would appear that whatever set of environmental conditions have led to a declining deer population were not present during 2001 in the same manner as in the past. Our main interest lies in observing the effect of the treatment on the deer population in a year where fawn:doe ratios are lower for the population as a whole, similar to what they have been much of the past 15 years.

2002

During June – December 2002, following the second year's treatment, we measured neonate survival directly using radio-collared fawns; however, sample sizes were based on a technique assessment of VITs and were relatively small for contrasting treatment and control survival of neonates (Bishop et al. 2002). Treatment fawn survival was 0.613 (SE = 0.115, $n = 29$) and control fawn survival was 0.511 (SE = 0.108, $n = 25$). In late December 2002 and early January 2003, we once again conducted 2 age classification helicopter surveys in the treatment and control units. On 12/31/02, we observed 91.9 fawns:100 does (SE = 8.4) in the treatment unit, and 52.2 fawns:100 does (SE = 6.9) in the control unit. On 1/21/03, we observed 52.6 fawns:100 does (SE = 6.4) in the treatment unit, and 36.8 fawns:100 does (SE = 3.9) in the control unit. The combined helicopter survey data indicated 68.1 fawns:100 does (SE = 5.6) in the treatment unit and 42.8 fawns:100 does (SE = 3.5) in the control unit. Oppositely, fawn:doe ratio estimates from ground classifications of doe groups during December 2002 – February 2003 were 47.7 fawns:100 does (SE = 6.3) in the treatment unit, and 63.4 fawns:100 does (SE = 7.5) in the control unit ($t_{108} = 1.61$, $P = 0.110$). As in 2001, fawn:doe ratio results were conflicting. Helicopter survey data varied between 2 different flights, but consistently indicated a treatment effect. Ground classification data did not indicate a treatment effect. Also, survival data combined with age ratio data indicate neonate production and survival was reasonably favorable during 2002, and not indicative of the low fawn recruitment observed during the late 1980's and 1990's.

Our results from 2001 and 2002 point out the inherent difficulties and biases associated with precisely measuring fawn:doe ratios, particularly in this research study. Ratios obtained from helicopter surveys were based on 2 short-duration flights/unit/year over spatially small units. Helicopter surveys were complicated by high deer densities in heavy cover, making both deer detection and fawn:doe classifications a considerable challenge. There is a variety of potential biases that may have affected the helicopter surveys, including differential sightability of does and fawns, double classification of some deer, and incorrectly classifying yearling bucks with small antlers. Ground fawn:doe ratio observations of radio-collared doe groups were made using spotting scopes and field glasses, where we commonly studied the deer for some time. Incorrect classifications during these surveys were likely minimal. For example, small-antlered yearling bucks (e.g. 3 – 6" spikes) were detected from the ground, whereas they were undoubtedly missed on occasion during helicopter surveys. We also obtained repeated observations for some of the radio-collared doe groups from the ground. The main potential bias affecting ground fawn:doe classifications was how observations were made. Many of the ground classifications in the Shavano Valley experimental unit were made by radio-tracking does during the day. On the other hand, a majority of ground classifications in the Colona experimental unit were based on observing deer groups as they entered openings to feed during the late afternoon.

Given the inherent difficulties of measuring fawn:doe ratios in the 2 experimental units, and the lack of a clear indication as to the effectiveness of the treatment, we intensified efforts in 2003 to directly measure survival of neonate fawns born from treatment and control radio-collared does. At the completion of the research, we will test whether enhanced winter nutrition of adult does improved newborn fawn survival based on a three-year model of radio-collared neonate survival data. We will continue to measure early winter fawn:doe ratios, but the data will be used cautiously to make inferences regarding treatment effects.

2003

During June 2003, we captured and radio-collared 103 newborn fawns born from treatment and control radio-collared does (55 treatment fawns, 48 control fawns). The VITs worked well; we captured fawns from 41 of the 54 does fitted with VITs. As of late September 2003, treatment fawn survival was 0.745 (SE = 0.059) and control fawn survival was 0.614 (SE = 0.073).

Neonate Mortality Causes

During 2002, 11 of the 29 treatment fawns died from the following causes: 3 – coyote predation, 2 – bear predation, 1 – felid predation, 1 – predation where the predator was undetermined, 1 – disease/ malnutrition, 1 – abandonment, 1 – road-kill, and 1 – trauma/injury. Twelve of the 25 control fawns died: 6 – malnutrition/disease, 3 – coyote predation, 1 – felid predation, 1 – bear predation, and 1 predation mortality where the predator was undetermined. Thus, 13% of all radio-collared fawns died from malnutrition, 11% from coyote predation, 6% from bear predation, 4% from felid predation, 4% from predation (unknown predator), and 6% from miscellaneous causes. Currently (June – September 2003), 14 of the 55 treatment fawns have died from the following causes: 6 – disease/malnutrition/starvation, 4 – coyote predation, 3 – predation (unknown predator), and 1 – felid predation. Over the same time period, 18 of the 48 control fawns have died: 8 – coyote predation, 4 – disease/malnutrition/starvation, 3 – felid predation, 1 – bear predation, and 2 – unknown. Thus, as of the end of September during 2003, 12%

of all radio-collared fawns have died from coyote predation, 10% from disease/malnutrition/starvation, 4% from felid predation, 3% from predation (unknown predator), 1% from bear predation, and 2% from unknown causes.

Overwinter Fawn Survival and Mortality Causes

During winter 2001-02 (Dec 1, 2001 – May 31, 2002), the survival rate of fawns was significantly greater (χ^2_1 = 13.216, P < 0.001) in the treatment unit (S(t) = 0.865, SE = 0.056) than in the control unit (S(t) = 0.510, SE = 0.080). Again in 2002-03 (Dec 1, 2002 – May 31, 2003), the overwinter survival rate of fawns was significantly greater (χ^2_1 = 5.734, P = 0.017) in the treatment unit (S(t) = 0.900, SE = 0.047) than in the control unit (S(t) = 0.691, SE = 0.074) (Fig. 4). The treatment unit during winter 2001-02 became the control unit during winter 2002-03, and vice versa. Thus, the overwinter survival treatment effect was replicated across each experimental unit. Combining both years of data, the best model of overwinter fawn survival (AICc = 148.63) included treatment (χ^2_1 = 14.71, P < 0.001), early winter fawn mass (χ^2_1 = 16.80, P < 0.001), year (χ^2_1 = 3.53, P = 0.060), and sex (χ^2_1 = 1.99, P = 0.158). The AIC model selection analysis emphasizes the importance of both the treatment effect as well as early winter mass of fawns, because any models without treatment or fawn mass were very poor (Table 1). Survival of fawns receiving the nutrition enhancement treatment was 0.31 higher than survival of control fawns during two mild to average winters, and surviving fawns averaged 2.9 kg heavier than fawns that died. Early winter mass was not different among experimental units (F_1 = 0.35, P = 0.558), thus the effect of the treatment was not confounded with fawn mass. Fawn mass was similar between winters as well (F_1 = 0.45, P = 0.502). The importance of early winter fawn mass as a predictor of overwinter survival has been documented previously (White et al. 1987, Bishop 1998, White and Bartmann 1998, Unsworth et al. 1999). In summary, the nutrition enhancement treatment improved overwinter fawn survival and thus yearling recruitment, and heavier fawns in each experimental unit had higher survival probabilities.

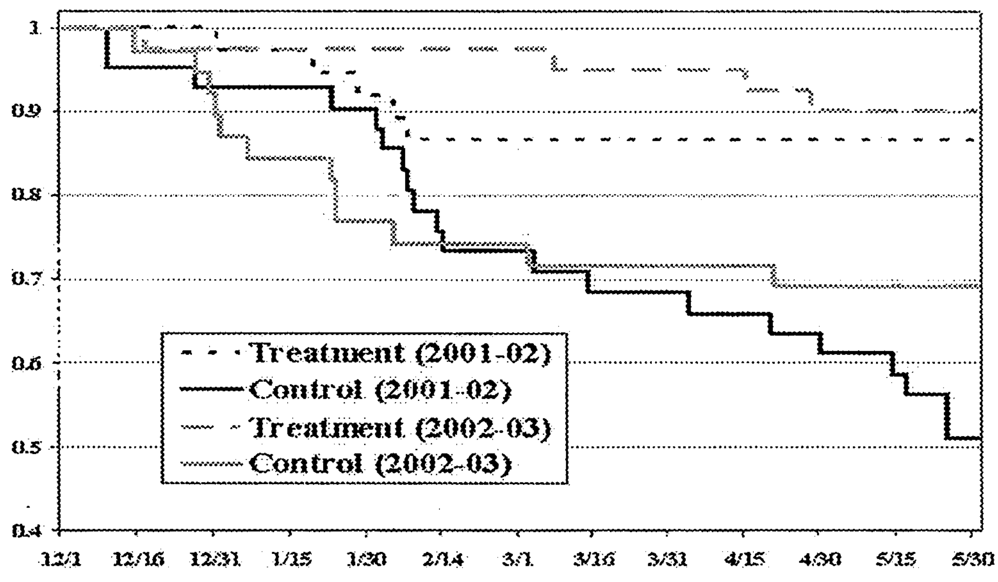

Figure 4. Overwinter fawn survival (Dec 1 – May 31) in a nutrition enhancement treatment unit (S(t) = 0.865, SE = 0.056, 2001-02; S(t) = 0.900, SE = 0.047, 2002-03) and a control unit (S(t) = 0.510, SE = 0.080, 2001-02; S(t) = 0.691, SE = 0.074, 2002-03), Uncompahgre Plateau, southwest Colorado.

Model Name	-2 Log Likelihood	# Parameters (K)	AIC	AICc	Δ AICc
Treatment + Sex + Year + Mass	**143.231**	**5**	**153.231**	**148.626**	**0**
Treatment + Year + Mass	**145.286**	**4**	**153.286**	**149.548**	**0.92**
Treatment + Sex + Year + Trt*Year + Mass	**143.059**	**6**	**155.059**	**149.615**	**0.99**
Treatment + Sex + Mass	**146.898**	**4**	**154.898**	**151.159**	**2.53**
Treatment + Mass	**148.957**	**3**	**154.957**	**152.113**	**3.49**
Sex + Year + Mass	**160.345**	**4**	**168.345**	**164.606**	**15.98**
Treatment	**165.845**	**2**	**169.845**	**167.922**	**19.30**
Sex + Year	**178.195**	**3**	**184.195**	**181.351**	**32.73**

Table 1. Model selection results for a logistic regression analysis of overwinter mule deer fawn survival in southwest Colorado. Enhanced nutrition (Treatment) and early winter fawn mass were the critical predictors of survival. Model selection was performed using Akaike's Information Criterion (AIC).

During winter 2001-02, five fawns in the treatment unit died: 2 from malnutrition/sickness and 3 from disease. Of the 2 fawn mortalities caused by malnutrition/sickness, 1 was a result of basic malnutrition and occurred on December 31, 2001, shortly after the treatment was initiated. The other fawn died early as well and had a combination of heavy parasite loads, scours, and general poor condition. Each of the 3 fawns that died from disease had adequate fat stores. At least one of these fawns died as a result of pneumonia. In the control unit, 19 fawns died during the winter: 5 from malnutrition, 6 from mountain lion/bobcat predation, 4 from coyote/canine predation, 3 unknown predation mortalities, and 1 unknown. A majority of the fawns killed by predators had virtually no femur marrow fat remaining, indicating the predation was likely compensatory in nature. During winter 2002-03, where the initial control unit became the treatment following the cross-over, four fawns died in the treatment unit: 3 from coyote predation and 1 unknown mortality. In the control unit, 12 fawns died during the winter: 4 from coyote predation, 2 from malnutrition, 1 from mountain lion predation, 1 was road-killed, and 4 causes were unknown. As in the previous winter, these fawns had virtually no femur marrow fat remaining, indicating very poor condition.

Adult Female Survival and Causes of Mortality

During winter 2000-01 (Dec 1, 2000 – May 31, 2001), the adult doe survival rate in the treatment unit ($S(t) = 0.968$, SE = 0.032) was greater ($\chi^2_1 = 2.649$, $P = 0.104$) than the survival rate in the control unit ($S(t) = 0.861$, SE = 0.058). However, annual adult doe survival rates (Dec 1, 2000 – Nov 30, 2001) were similar among the treatment and control deer (Trt: $S(t) = 0.839$, SE = 0.066; Control: $S(t) = 0.833$, SE = 0.062; $\chi^2_1 = 0.004$, $P = 0.947$). We observed a similar result the following year. The 2001-02 overwinter adult doe survival rate in the treatment unit ($S(t) = 0.942$, SE = 0.030) was greater ($\chi^2_1 = 3.116$, $P = 0.078$) than survival in the control unit ($S(t) = 0.848$, SE = 0.044), yet annual adult doe survival was similar among treatment and control deer (Trt: $S(t) = 0.824$, SE = 0.049; Control: $S(t) = 0.818$, SE = 0.047; $\chi^2_1 = 0.090$, $P = 0.764$). Thus, mortalities of control deer occurred primarily during the winter months, while treatment does died primarily during the summer and fall months.

During winter 2002-03, following the treatment cross-over, overwinter adult doe survival rates were similar among treatment and control deer (Trt: S(t) = 0.945, SE = 0.024; Control: S(t) = 0.924, SE = 0.028; $\chi^2_1 = 0.360$, $P = 0.549$). The main difference from the previous 2 years was that overwinter survival of adult does in the Shavano experimental unit increased in 2002-03 upon receiving the treatment. Current annual adult doe survival rates (Dec 1, 2002 – Oct 7, 2003) are 0.888 (SE = 0.034) for treatment does and 0.835 (SE = 0.039) for control does. The treatment has apparently had a minimal impact on annual adult doe survival, and annual survival rates measured thus far align with expected survival based on other studies (Unsworth et al. 1999, B.E. Watkins, unpublished).

During 2000-02, when the Colona experimental unit received the treatment and the Shavano experimental unit was the control, 16 treatment and 16 control does died. The 16 treatment does died from the following categories: 4 – road-killed, 3 – while giving birth, 3 – predation (undetermined predator), 2 – non-predation unknown (intact carcasses with no evidence of predation or scavenging), 1 – disease (chronic arthritis), 1 – mountain lion predation, and 2 – unknown. Predation was not a major mortality factor for treatment does, and a majority of mortalities were independent of nutrition (does were in good condition). The 16 control doe mortalities included the following causes: 5 – mountain lion predation, 3 – malnutrition, 2 – non-predation unknown, 1 – road-killed, 1 – bear predation, 1 – injury (fence), 1 – legal harvest, and 2 – unknown. Predation and malnutrition were the major mortality causes of control deer. Interestingly, during this 2-year period, we did not document any coyote predation on adult does.

Thus far during 2003, with Shavano as the treatment and Colona as the control, there have been 9 treatment doe mortalities: 3 – coyote predation, 3 – disease/infection, 1 – road-killed, and 2 unknown. Two of the coyote mortalities, 2 of the disease mortalities, and the road-kill occurred on adult does in good condition. There have been 14 control doe mortalities thus far in 2003: 3 – coyote predation, 3 – malnutrition/disease, 3 – non-predation unknown, 1 – mountain lion predation, 1 – road-kill, and 3 – unknown. As we saw during 2000 – 2002, malnutrition and predation were the major mortality factors of control does.

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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 3001 : Deer Conservation

Task 1 : Mule Deer Life Cycle – Neonatal Fawn Survival

Federal Aid Project W-185-R :

Period Covered: July 1 2002 through June 30, 2003

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The following is the abstract of the manuscript submitted to the Journal of Wildlife Management describing the neonatal fawn survival study on the Uncompahgre Plateau. Because of requests by reviewers or editors some aspects of the presentation and analysis may be modified. Manipulation or interpretation of these data beyond that contained in this report should be labeled as such, and is discouraged.

NEONATAL MULE DEER FAWN SURVIVAL IN WEST-CENTRAL COLORADO

ABSTRACT

Declining mule deer (*Odocoileus hemionus*) populations resulting from apparent low recruitment brought management and political focus on neonatal fawn survival. We captured mule deer fawns on the Uncompahgre Plateau (5,957 km^2) in west-central Colorado, USA, at a mean age of 3 days (range from newborn to 6 days), and we radiomarked them with mortality-sensing drop-off radiocollars. Two hundred thirty fawns were radiomarked with samples of 50 in 1999, 88 in 2000, and 92 in 2001. Designated neonate survival period was from capture to 14 December. Survival was different among years (X_2^2 = 6.160, $P = 0.046$) with 3-year mean survival of 0.501. Cause-specific mortality ordered from highest to lowest was sick/starve, coyote, unknown, trauma, bear, and feline. Neither all predation combined (coyote, bear, and feline; $P = 0.379$) nor coyote predation alone ($P > 0.989$) differed among years. By 31 July, 74% of the sick/starve mortality and 75% of the predation mortality had taken place with 76% of mortality from all sources occurring by this date. Mean fawn weights at capture were different among years ($P = 0.044$). We also found a difference in hind foot length among years ($P = 0.002$). Weight and hind foot means were different between 2000 and 2001 ($P > 0.017$) with 1999 not different from either 2000 or 2001 ($P < 0.017$). Mean capture date was 19 June (SD = 4.83 days) and median capture date was 19 June (range = 9 Jun to 6 Jul) with 94.78% of all captures occurring between 13 and 30 June. This implies that most does were bred during their first estrous cycle. Neonatal survival through 14 December did not completely account for observed low f:d ratios. We hypothesized fetus mortality during late pregnancy or mortality of fawns at birth (before they could be detected for capture) as potential causes of poor recruitment.

JOB PROGRESS REPORT

State of Colorado : Division of Wildlife - Mammals Research

Work Package No. 3002 : Elk Conservation

Task No. RMNP : Technical Support for Elk and Vegetation Management Environmental Impact Statement for Rocky Mountain National Park

Federal Aid Project W-153-R :

Period Covered: July 1, 2002 - June 30, 2003

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ABSTRACT

Overabundant wild ungulate populations have become a significant concern for natural resource managers in many parts of North America. Wild ungulates can do serious and lasting harm to many plant communities, and preventing such damage requires controlling the growth of their populations. In protected areas such as national parks, traditional methods of population control may not be feasible or publically acceptable. In these situations, alternative methods of population control are needed. One alternative is controlling the fertility of females. In this study, we evaluated the feasibility of using gonadotropin releasing hormone (GnRH) analog to control reproduction in free-ranging female elk in Rocky Mountain National Park. During fall of 2002, we captured, radio-collared and treated 34 adult elk. Seventeen elk were treated subcutaneously with a controlled release bio-implant containing 32.5 mg of leuprolide and seventeen elk were treated with the same formulation without leuprolide. We evaluated the effects of leuprolide treatments on reproductive rates, body condition, behavior, and daily activity patterns of female elk during September 2002 to April 2003. Leuprolide administered as a sustained release formulation was 100% effective in preventing pregnancy in female elk. Body condition of all experimental elk declined from fall 2002 to spring 2003. Changes in loin depth and body condition score were similar (P 0.254) for both treated and control elk, whereas overwinter loss in mean percent rump fat was greater (P 0.057) for treated elk compared to controls. There were no differences ($P = 0.36$) in reproductive behavior rates during the breeding season between treated and control elk.

TECHNICAL SUPPORT FOR ELK AND VEGETATION MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT FOR ROCKY MOUNTAIN NATIONAL PARK

D. L. Baker, M. A. Wild, and M. M. Conner

P. N. OBJECTIVE

Conduct experiments with captive and free-ranging elk to evaluate fertility control as an management alternative for controlling elk populations in Rocky Mountain National Park (RMNP), Colorado.

SEGMENT OBJECTIVES

1. Capture, radio-collar, and apply fertility control treatments to a target sample of free-ranging adult female elk in RMNP during September 2002.

2. Evaluate the effects of fertility control on reproductive rates of treated and non- treated adult female elk and the reversibility of these effects if they occur.

3. Evaluate the effects of fertility control on body condition of treated and non-treated adult female elk.

4. Evaluate the effects of fertility control on reproductive behavior and daily activity patterns of treated and non-treated adult female elk.

INTRODUCTION

Overabundant wild ungulate populations have become a significant problem for natural resource managers in North America. Unregulated populations can cause adverse effects that are ecological, economic, or political in scope and resolving these issues often requires controlling animal abundance (Jewell and Holt 1981, Garrott et al. 1993, McCullough et al.1997, Smith 2001).

In Rocky Mountain National Park (RMNP), Colorado, the impact of herbivory by elk has emerged as a fundamentally important problem for those who manage the Park and its wildlife (Hess 1993, Zeignefuss et al. 1996). In 1968, RMNP adopted a natural-regulation policy for management of ungulates (Cole 1971, Houston 1971) with the objective of allowing density dependent processes to regulate elk numbers within park boundaries and use sport hunting to harvest as many animals as possible in areas surrounding the Park.
Recently, however, Park managers have become concerned that possible unnatural concentrations of elk may be altering natural plant communities and ecosystem sustainability. Soil conditions and the status of willow and aspen plant communities have declined. Wet meadow, dry grasssland, and alpine and subalpine sites show evidence of deterioration from overgrazing by elk (Singer et al. 1998, White et al. 1998). As a result of the decline in these vegetation types and the diversity of the animal species that are associated with them, the Park and other natural resource agencies are evaluating alternative management strategies for reducing elk densities within RMNP and the surrounding Estes Valley.

One alternative being considered is controlling the fertility of female elk. Fertility control has been widely advocated as an alternative to lethal methods of population control for wildlife and considerable research has been directed toward development of different contraceptive agents (see reviews by Kirkpatrick and Turner 1985, Fagerstone et al. 2001). Field and laboratory studies have evaluated the efficacy of delivery of contraceptives to ungulates (Jacobsen et al. 1995, DeNicola et al. 1997, Kirkpatrick et al. 1997) and models have been developed to represent effects of fertility control on the population dynamics of individual species and populations (Garrott and Siniff 1992, Seagle and Close 1996, Hobbs et al. 2000). To date, most contraceptive research for wild ungulates has focused on the development of immunocontraceptive vaccines and steroidal hormonal agents. However, after more than 40 years of research, the success of these approaches have been primarily limited to captive wildlife and small localized urban populations of wild ungulates. To meet this challenge, new technologies and approaches are needed if fertility control is to become practical and acceptable management tool for controlling overabundant wildlife species.

A promising new non-steroidal, non-immunological approach to contraception involves potent analogs of gonadotropin-releasing hormone (GnRH). GnRH is a molecule produced in the hypothalamus of the brain. It directs specific cells in the pituitary gland to synthesize and secrete two important reproductive hormones; follicle stimulating hormone (FSH) and luteinizing hormone (LH). These latter two hormones, known as gonadotropes, control the proper functioning of the ovaries in the female and testes in the male. Chronic treatment with continuous, high doses of GnRH agonists results in temporary suppression of pituitary responsiveness and gonadotropin secretion. Resulting decreases in plasma LH and FSH in females leads to suppression of ovulation, estrous cyclicity, and gonadal steroidogenesis (Belchetz et al.1978, Evans and Rawlings 1994). Once GnRH agonist treatments are terminated, normal pituitary function is gradually restored (Bergfeld et al. 1996).

GnRH agonists have been shown to inhibit ovulation in several domestic ungulate species including sheep (McNeilly and Fraser 1987), cattle (D'Occhio et al. 1996; D'Occhio and Aspden 1999), and horses (Montovan et al. 1990). However, studies on wild ungulates are limited (Becker and Katz 1995; Brown et al. 1999) and to our knowledge, and only one study has demonstrated their effectiveness as a contraceptive agent (Baker et al. 2002). GnRH agonists provide a potential biotechnology for achieving a controlled, reversible suppression of fertility in both captive and free-ranging female wild ungulates. However, their practicality as a contraceptive agent is dependent on effective inhibition of reproduction without negative behavioral or physiological side-effects, and efficacious application in free-ranging elk.

In previous experiments, we determined the effectiveness of GnRH agonist (leuprolide) for controlling fertility in captive female elk and assessed the physiological and behavioral side-effects of treatment (Baker et al. 2002). Leuprolide administered as a subcutaneous, controlled release formulation was 100 % effective in preventing reproduction in elk for one breeding season. Serum LH and progesterone (P_4) concentrations were reduced to baseline levels by day 30 and remained at those levels for 190-252 days posttreatment, with a return to normal fertility the following breeding season. In addition, there were no adverse physiological side-effects and behavioral effects were minimal. However, these results were obtained under controlled conditions with captive animals of known fertility and in excellent body condition. While these results provide strong inference on the potential utility of leuprolide as a contraceptive agent, studies with wild elk are needed to evaluate whether the technique is truly feasible and practical. Thus, the goal of this study was to conduct a field experiment to examine the efficacy of leuprolide as a contraceptive agent and to contribute further understanding of its effects on reproduction and behavior in free-ranging female elk. Our specific objectives were to determine in elk : 1) the effectiveness of leuprolide in preventing pregnancy, 2) the effects of leuprolide on reproductive behavior, 3) the effects of leuprolide on body condition, and 4) the reversibility of leuprolide treatments.

MATERIALS AND METHODS

Study Area

Investigations were conducted in Rocky Mountain National Park and adjacent Estes Valley on the east slope of the Continental Divide between 2000 and 2800 m elevation. Experimental elk were selected from one of two subpopulations that historically wintered in Moraine Park/Beaver Meadows or Horseshoe Park (Bear 1989).

Experimental Procedures

During late summer and early fall of 2002, 34 adult female elk were immobilized by darting, from the ground, with 3.0 mg of carfentanil citrate (Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) and 10-20 mg xylazine hydrochloride (Rompun; Bayer AG, Leverkusen, Germany). In order to insure that reproductive failure, if it occurred, was due to contraceptive effects rather than the effects of age or diminished body condition, we attempted to select only adult females of prime reproductive age and in moderate to excellent body condition. We hoped to accomplished this in 2 ways: 1) before immobilization, we made a visual assessment of the target animal using age (calf, yearling, adult) and relative fatness and body musculature (condition). Animal condition was classified as good, medium or poor (Riney 1960) and only medium or good condition females were selected, and 2) once the animal was immobilized we estimated age using tooth wear and replacement (Quimby and Gaab 1957), lactational status, and body condition using ultrasonography (Cook et al. 2001).

Captured elk were fitted with frequency-specific transmitters on neck collars containing a plastic identification sleeve marked with a unique alpha-numeric code of 76 mm-high black characters on a colored background (white for controls; yellow for treatment)(Freddy 1993). To meet U.S. Food and Drug Administration regulations, all immobilized animals were marked to prevent human consumption. Radio collars were marked with "Do Not Consume".

Once sedated, female elk received a subcutaneous, sustained release leuprolide formulation (32.5 mg) using the ATRIGEL ® drug delivery system (Atrix Laboratories, Inc., Ft. Collins, CO, USA) (Dunn et al. 1994). We reversed the effects of the immobilizing drug with 300 mg of naltrexone HcL (Wildlife Pharmaceuticals, Fort Collins, Colorado, USA). To minimize any possibility of infection from immobilization, each darted elk also received a subcutaneous injection of long-lasting penicillin. We collected blood (20 ml) from each elk as baseline information for health parameters. Blood was archived by veterinarians with the National Park Service (NPS).

Measurements

Reproductive rates:

We assessed the effects of leuprolide treatments on reproduction in elk using 4 methods: pregnancy-specific protein B (PSPB) (Noyes et al. 1997), serum progesterone (P_4) (Willard et al. 1994), rectal palpation (Greer and Hawkins 1967) and fecal progesterone metabolites (FPM) (Garrott et al. 1998). We determined pregnancy status of all treated and untreated elk during late gestation (March- April) by relocating animals using radiotelemetry and recapturing them following the immobilization procedures previously described. Once immobilized, a trained wildlife veterinarian, rectally palpated each female and determined the presence or absence of a gravid uterus. A single blood sample (10 ml) was collected via jugular venipuncture from each animal for PSPB(BioTracking, Moscow, Idaho, USA) and P_4 (Niswender 1973) analysis. At the same time, a single fecal sample was collected for fecal P_4 determination.

Females having fecal P_4 levels < 0.9 □g/gm were considered nonpregnant and those. 1.0 □g/gm pregnant. Discrimination for samples with concentrations between 0.90-0.99 □g/gm was regarded as inconclusive. We will evaluate the reversibility of leuprolide treatments during March - April 2004 by using the reproductive measurements described above.

Reproductive behavior:

We examined the effects of leuprolide on reproductive interactions of male and female elk during 2 time periods; breeding season (defined as the period 15 September to 15 November) and postbreeding season (defined as the period 15 January to 15 March). We used focal animal sampling procedures to sample reproductive behaviors of all experimental elk (Lehner 1996). Behavioral measurements were be made by locating a breeding group containing radio collared/marked elk. Depending on the environmental conditions, topography, available cover, and elk viewing restrictions in RMNP, the observer attempted to approach the group undetected to within 150-500 m. Observations were made with the aid of binoculars and 15-60X spotting scope during morning (0500-0800) and late day (1400-1700). Time-of-day sampling periods were randomly assigned each week using a randomized block design. Each sampling period consisted of at least 2 hours of continuous observations. We combined individual behaviors into 4 general categories: male copulatory, male precopulatory, female precopulatory, and general breeding (Table 1). Our experimental unit for analyses was the individually marked female in each breeding group. Because sexual interactions were generally short duration (< 30 sec) relative to sampling interval, we recorded the number of occurrences of each event rather than length of time and calculated sexual interaction rates as behaviors per animal per hour.

Body condition:

Recent research has correlated measures of body condition, using ultrasonography of body fat deposits, to reproductive success in elk (Cook et al. 2001). Using these predictive models, we estimated the body condition of all female elk using body condition scoring and ultrasonography of fat and lean body mass. We classified each female as either excellent, very good, moderate, low, or very low reproductive candidates. We selected only those females that were judged to be, at least, in the moderate (10-15 % body fat; > 90% pregnancy rate) category. Elk that met this criteria were randomly assigned to either treatment or control groups; elk that did not, were rejected from the experiment. Additionally, we measured change in rump fat and lean body of females between fall capture and spring re-capture to evaluate the effects of leuprolide treatments on body condition.

Statistical analysis:

Reproductive rates. In previous experiments, a sample size of 5 treated and 5 control elk was sufficient to detect significant differences (*P.* 0.05) in pregnancy rates of captive animals (Baker et al. 2002). However, free-ranging elk are more elusive than their captive counterparts and treatment application and measurements of response variables less certain. Uncontrolled variables such as natural mortality, hunting mortality, low pregnancy rates, relocation success, and transmitter failure increase the need for larger sample sizes.

We performed a sample size analysis with Fisher's Exact Test, using a software program (NCSS PASS 2000) to estimate the number of treated and control animals needed to detect treatment differences for PSPB, fecal progesterone metabolites, and calving rates (Table 2). For PSPB and fecal progesterone metabolites, we assumed the lowest reported pregnancy rate (63 %) for elk in RMNP (Johnson and Monello, unpublished data), 90 % recapture of radio collared females, and 100% accuracy of PSPB for pregnancy determination in elk greater than 100 days of gestation (Huang et al. 2000). For estimating sample sizes for calving rates, we assumed 63 % pregnancy rates and an 85 % success in confirming presence or absence of a calf. Results of these analyses indicated that a sample size as low as 10 treated and 10 control females would be sufficient to detect a significant treatment effect using PSPB, and serum and fecal P_4 values.

Reproductive behavior:

We tested specific reproductive behavior hypotheses that mean behavior rate was not different between treatment and control groups for both breeding and postbreeding seasons using an ANOV model with repeated measures structure. Time was treated as a within subject effect using a multivariate approach to repeated measures (Morrison 1976). To test for treatment effects, we accounted for time-of- day effects, date effects, and their interactions. PROC GENMOD (SAS Institute 1993) was used to estimate and test for differences in mean behavior rate by treatment, time- of- day, and date. Means and standard errors were estimated using least squares, and hypothesis tests were be based on type III generalized estimating equations that accounted for correlation in repeated measures.

Table 1. Description of elk reproductive behaviors and associated behavior categories.

Behavior category	Reproductive behavior
Reproductive:	
General Breeding	Male directed behavior related to establishing, maintaining, and defending a group or harem of female wapiti
Male pre-copulatory	Male courtship behavior directed toward an individual female to induce or detect oestrus or ovulation (e.g. urine testing, flehmen, tongue flick, lick , smell, or rub female's body, chivy)
Female pre-copulatory	Female courtship behavior directed toward dominant male to arouse copulatory behavior (e.g. lick and rub male, mount, lordosis, twitch hocks)
Copulatory	Male behavior directed toward a receptive female in oestrus (e.g. precopulatory mounts, intromission, pelvic thrust)
Non-Reproductive:	
Feeding	Head down in vegetation
Idling	Bedded or standing upright and not feeding
Moving	Ambulating

Table 2. Sample size estimates and power of the test for measurements of reproductive rates in female elk in RMNP.

Measurement	Treatment (n)	Control (n)	α	1-β
PSPB/Fecal P				
1.	10	10	0.05	0.9386
2.	10	20	0.05	0.9890
3.	10	120	0.05	0.9996
Calving rates				
1.	10	20	0.05	0.8613
2.	20	20	0.05	0.9685
3.	20	25	0.05	0.9829
4.	20	30	0.05	0.9865

RESULTS AND DISCUSSION

Fall: 2002

We captured, sampled, and radio collared 34 female elk in RMNP during 24 August - 7 September, 2002. Elk were captured from 5 general locations in the RMNP : Kawuneeche Valley (7), alpine tundra areas near Trail Ridge Road (4), Hidden Valley (3), Beaver Meadows (9), and Moraine Park (11). Seventeen females were given a subcutaneous formulation containing 32.5 mg of leuprolide and seventeen a placebo formulation without leuprolide. No capture-related mortalities were observed. Estimated ages of leuprolide-treated females ranged from 1-12 years of age (= 6.9, SE = 0.82) and 1-10 years of age (= 6.3, SE = 0.72) for untreated elk. Two yearling females were included in both groups. Yearling females were included as experimental animals because they met *a priori* body composition criteria. and because we wanted additional information on the effects of leuprolide in this age group. Seventy percent of treated females were determined to be lactating when captured compared to 61 % of control females. Fall body condition of leuprolide-treated and control females were similar for rump fat depth ($P = 0.56$), loin depth ($P = 0.91$), and body condition score (BCS) ($P = 0.38$) (Table 3). Rump fat percent of leuprolide-treated females ranged from 8.8 - 16.3 % (= 13.1 %, SE = 0.40) and from 10.6 - 15.9 % (= 12.7 %, SE = 0.38) for control elk. With the exception of one animal, all females in the experiment had a rump fat percentage of greater than10 % (> 90 % pregnancy rate).

Table 3. Mean fat depth, percent rump fat, body condition score, and loin depth of leuprolide-treated and control female elk sampled during Aug-Sept, 2002 and Mar-Apr, 2003, in Rocky Mountain National Park, Colorado.

	Leuprolide		Control	
Measurements	Mean	SE	Mean	SE
Fall (Aug-Sept 2002):				
Rump fat depth (cm)	2.13	0.18	2.00	0.11
Loin depth (cm)	5.43	0.12	5.41	0.10
Body condition score	3.53	0.12	3.38	0.11
Rump fat (%)	13.10	0.40	12.73	0.38
Spring (Mar-Apr 2003):				
Rump fat depth (cm)	0.37	0.04	0.72	0.12
Loin depth (cm)	4.84	0.08	5.00	0.11
Body condition score	2.36	0.12	2.48	0.13
Rump fat (%)	6.90	0.04	8.20	0.49
Fall - Spring				
Δ Rump fat depth (cm)	- 1.76		- 1.28	
Δ Loin depth (cm)	- 0.59		- 0.41	
Δ Body condition score	- 1.17		- 0.90	
Δ Rump fat (%)	- 6.20		- 4.50	

We observed reproductive behaviors of treated and control elk in RMNP and Estes Valley during 11 September to 27 November, 2002. We recorded a total of 144, one hour observations for 16 different radio collared female elk (8 treated; 8 control). No copulatory behaviors were observed during this period, thus there was no analysis for this category. There were no differences in reproductive behavior rates (number of behaviors/hour) for general breeding ($P = 0.36$), female precopulatory ($P = 0.13$), or male precopulatory ($P = 0.70$) behaviors (Fig.1). In general, control females showed somewhat higher rates of general breeding (25 % higher than treated females) and male precopulatory (9 % higher than treated females) behaviors, but none of these differences were statistically significant. In addition to reproductive behaviors, we evaluated the effects of leuprolide on the daily activity patterns of treated and control female elk. These data are currently being analyzed.

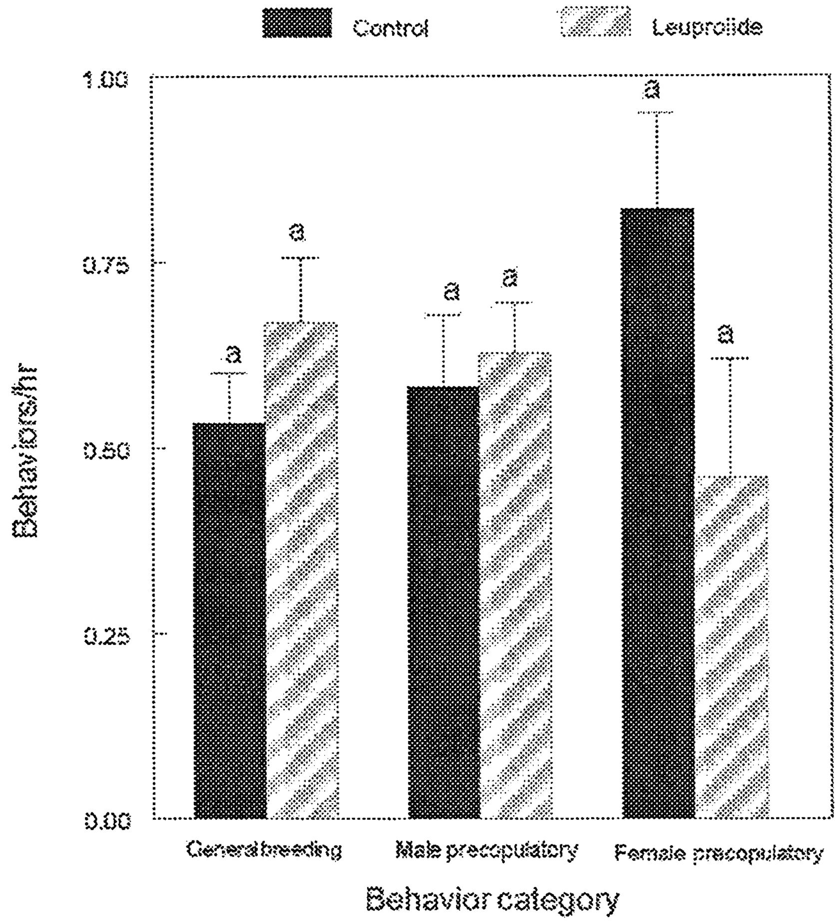

Figure 1. Mean (± SE) reproductive behavior rates during the breeding season for control female elk (n = 8) and females treated with a sustained release implant containing 32.5 mg leuprolide formulation (n = 8), in Rocky Mountain National Park, Colorado. Columns with different lower case letters indicate significant differences between means (*P* 0.05).

Spring 2003

During 24 March to 30 April, 2003, we evaluated the effects of leuprolide on pregnancy rates, body condition, and reproductive behavior of treated and control female elk. Using the capture methods previously described, we recaptured 15 out of 17 treated elk and 17 out of 17 control elk. Elk were recaptured in 3 general locations: RMNP (13), Estes Park, Colorado area (16), and Loveland, Colorado area (3).

Leuprolide, administered as a sustained release formulation, prior to the breeding season, effectively prevented pregnancy in all female elk for one year. Pregnancy rates of untreated females ranged from

64.7 - 78.5 %, depending on the method of determination. Fecal P_4 analyses for pregnancy determination have not been completed.

Body condition of experimental elk declined for all measures of body composition during fall 2003 and spring 2004 (Table 3). Changes in mean loin depth (*P* 0.25) and body condition score (*P* 0.08) were similar for both treated and control female elk, whereas, overwinter loss in mean percent rump fat was greater (*P* 0.057) for elk treated with leuprolide. Post-breeding season reproductive behaviors and daily activity patterns of control and leuprolide-treated females are currently being analyzed.

SUMMARY

To date, we have completed or are in the process of completing 3 out of the 4 objectives originally stated for this investigation. First, we have evaluated the effects of leuprolide on pregnancy rates of female elk using rectal palpation, PSPB, and P_4 analysis and all methods support the conclusion that leuprolide is 100% effective in preventing pregnancy for at least one breeding season. The only remaining analysis for pregnancy determination is fecal P_4, which will be completed during winter 2004. Second, we have evaluated the effects of leuprolide on breeding and post-breeding reproductive behavior of elk. Although neither of these data sets have been completely analyzed, leuprolide does not appear to have deleterious effects on elk reproductive behavior or daily activity patterns. Third, we assessed the effects of leuprolide on body condition dynamics of elk. We observed only minor differences in overwinter body composition changes between treated and control elk. The only objective yet to be completed is to confirm the reversibility of leuprolide treatments. This will be accomplished during March-April 2004 by comparing pregnancy rates of treated and control female elk.

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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package 3002 : Elk Conservation

Task No. 3 : Estimating Calf and Adult Survival Rates and Pregnancy Rates of Gunnison Basin Elk

Federal Aid Project. W-153-R-16 :

Period Covered: July 1, 2002- June 30, 2003

Author: D. J. Freddy

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ABSTRACT

We used aerial and ground surveys to estimate survival rates and assess sources of mortality for radio-collared adult elk (*Cervus elaphpus nelsonii*) in the Gunnison Basin of Colorado. Between 15 December 2000 and 14 June 2003, hunting accounted for 94% and 79% of the adult, age $\geq$12 months, female and male deaths, respectively, while natural causes were attributed to 6% and 21% of the adult female and male deaths, respectively. During 3 winter-spring intervals, 15 December - 14 June, natural survival rates for adult females, age $\geq$18 months, were $\geq$ 0.98 (n = 39-86 elk, 148-168 elk-winters). During 2 summer-fall intervals, 15 June - 14 December, natural survival rates for adult females, age $\geq$12 months, were $\geq$0.97 (n = 37-86 elk, 98-157 elk-summers). Including hunting mortalities reduced summer-fall female survival to 0.91 $\pm$ 0.07 in 2001 (n = 77) and 0.77 $\pm$ 0.08 in 2002 (n = 112). During 2 annual intervals, 15 December to next 14 December, natural survival rates for adult females, age $\geq$ 18 months, were $\geq$0.97 (n = 33-61). Including hunting mortalities reduced annual female survival to 0.92 $\pm$ 0.08 in 2001 (n = 39) and 0.74 $\pm$ 0.09 in 2002 (n = 82). Natural survival rates for 2 cohorts of yearlings, age 12-23 months, were 1.00 for females (n = 59) and 0.93 $\pm$ 0.08 (n = 43) for males. Including hunting mortalities reduced cohort survival to 0.87 $\pm$ 0.08 (n = 68) for females and 0.82 $\pm$ 0.11 (n = 49) for males. During summer-fall, natural survival rate for male elk, age 24-29 months, was 1.00 (n = 14) which was reduced to 0.74 $\pm$ 0.22 (n = 19) by including hunting mortalities. During winter-spring, natural survival rate for male elk, age 30-35 months, was 1.00 (n = 13). Predation by mountain lions or black bears was suspected in 4 of the 5 adult elk natural deaths. Hunting removal rates for adult females, age $\geq$12 months, were 0.08 $\pm$ 0.06 (n = 76) in 2001 and lower than the 0.23 $\pm$ 0.08 (n = 112) in 2002 (P = 0.006). Removal rates for yearling females, age 12-17 months, averaged 0.13 $\pm$ 0.08 (n = 68). Removal rate for yearling males averaged 0.13 $\pm$ 0.10 (n = 48) and for legal branch-antlered males was 0.26 $\pm$ 0.22 (n = 19). Wounding loss as a percent of legal harvest was 44 for all adult females and 0 for branch-antlered males. All hunting deaths of yearling males were illegal harvest/wounding loss while removal rate for branch-antlered males was unexpectedly low, likely representing a year effect on elk vulnerability. Apparent differences in survival of adult females between DAUs ($P \leq$ 0.063) likely reflected geographic differences in vulnerability of elk to hunting while differences in male survival between DAUs (P = 0.046) reflected impacts of illegal harvest/wounding loss on removal of yearling males. Adult female elk body condition suggested marginally deficient levels of seasonal nutrition in 2002.

Distribution and movements of radio-collared elk during 3 years of monitoring revealed that elk had a relatively high fidelity to the Gunnison Basin as defined by current DAU boundaries but elk also commonly ventured into adjoining GMUs outside the Gunnison Basin. Distribution patterns revealed minimal interchange of elk between areas north and south of U.S. Highway 50 which bisected the Gunnison Basin from east to west. Movements by adult females, young females, and young males (n = 35, 48, and 76) suggested DAU elk population management boundaries might be altered to better represent elk population units. Young male and female elk tended to move greater distances and exhibit higher rates of venturing into adjoining GMUs than adult females. Patterns of dispersion suggested movement corridors that allowed for genetic linkage between Gunnison Basin and other elk populations.

All information in this report is preliminary and subject to further evaluation.

JOB PROGRESS REPORT
ESTIMATING CALF AND ADULT SURVIVAL AND PREGNANCY RATES OF GUNNISON BASIN ELK POPULATIONS

DAVID J. FREDDY

P.N. OBJECTIVE

Estimate survival rates of calf, adult female, and adult male elk and estimate pregnancy rates of adult female elk in Gunnison Basin elk populations for 3 years. *NOTE:* Prioritization of available research funding resulted in discontinuing efforts to estimate calf survival, pregnancy rates, and body condition during 2002-03 but allowed for monitoring adult elk survival through June 2003.

SEGMENT OBJECTIVES

1. Estimate calf, adult female and adult male survival rates during winter, December-June.
2. Estimate adult male and female survival rates during summer-fall, June-November.
3. Estimate harvest removal rates for yearling and adult males and females.
4. Estimate pregnancy rates, fetal rates, conception dates, and body condition of female elk collected in December.
5. Summarize data in Research Progress reports and prepare peer-reviewed publications.

INTRODUCTION

The elk resource has many benefits but frequent social, political, and economic conflicts suggest elk can reach "social" if not "biological" carrying capacities (Freddy et al. 1993). Recent controversy surrounding elk in the Gunnison Basin (Basin) of Colorado (Roath et al. 1999) exemplifies conflicting social and biological agendas regarding appropriate numbers of elk.

The core of conflict in elk management often centers on establishing management objectives for numbers of elk that are agreeable to competing interests and then monitoring elk populations to demonstrate that objectives are achieved. This type of conflict is paramount in Colorado Division of Wildlife (CDOW) elk population Data Analysis Units (DAUs) E-25, E-41, and E-43 in the Gunnison Basin where a combination of resource carrying capacity objectives for elk on winter ranges and difficulties associated with knowingly achieving those objectives has fostered argumentative distrust among public groups and management agencies. Accomplishing management by population objective can depend on reliably estimating elk population size which is expensive and intensive (Samuel et al. 1987, Bear et al. 1989, Unsworth et al. 1990, Anderson et al. 1998, Cogan and Diefenbach 1998, Eberhardt et al. 1998, Freddy 1998).

Alternatively, population size and trend can be estimated using computer models that incorporate harvest, age and sex ratios, and survival rates (White 1991, Bartholow 1999). Model outputs are extremely sensitive to estimates of survival rates such that, reliable measurements of survival can greatly enhance the quality of models (Nelson and Peek 1982).

We chose to estimate survival rates of calf and adult elk during winter and adults year-around to aid in developing improved population models for elk in the Basin. The Basin in south-central Colorado encompasses the entire headwaters of the main Gunnison River and the centrally located town of Gunnison. Between 12-16,000 elk and 8-10,000 mule deer (*Odocoileus hemionus*) are thought to exist within the Basin. Elk are managed as 3 populations representing DAUs E-25 (Game Management Units [GMU] 66, 67), E-41 (GMU 54), and E-43(GMUs 55, 551). The 3 DAUs encompass about 9,291 km^2 of which 3,648 km^2 are considered potential winter range for elk (CDOW unpublished WRIS database). DAUs are contiguous with few major geographic barriers separating DAUs that would absolutely prevent interchange of elk among DAUs (Freddy 2002).

The Basin represents a high altitude, cold winter range for both elk and mule deer which is similar to ecosystems in North Park, Middle Park, and the San Luis Valley, Colorado. The sagebrush (*Artemisia tridentata*) steppe winter ranges (2,250-2,700 m elevation) can receive both extreme snow depths and cold temperatures that cause severe mortality among ungulates (Carpenter et al. 1984) while the conifer meadow and alpine summer ranges (3,000-4,200 m elevation) can be lush sources of forage subjected to periodic drought. Overall, these ranges collectively are thought to be less productive and nutritious for elk than the milder climate oakbrush-pinyon-juniper winter ranges and aspen and subalpine summer ranges of the Grand Mesa, Colorado where elk survival was measured from 1993-2000 (Freddy 2000).

METHODS

Capture

Adult female (age ≥30 months) and calf (age 6 months) male and female elk were captured and radio-collared using helicopter net-gunning from 16-22 December, 2000 and 16-20 December 2001 (Table 1, and Freddy 2002). All radio-collars were 172-176 MHz and contained 4-6 hour mortality sensors (Lotek®, Inc.). Calf collars were expandable allowing collars to remain on elk as they matured to adults (Freddy 2002). All capture protocols were approved by the CDOW Animal Care and Use Committee.

Our desired yearly sample sizes for radio-collared calves (n = 78) and adult females (n = 39, Freddy 2002) were based on detecting yearly differences of ±15% in calf survival rates and ±10% in adult female survival rates for elk throughout the entire Basin. Our statistical power was thus premised on treating elk in all 3 elk management DAUs within the Basin as 1 population of elk. If calves and adult females were captured and radioed for 3 years in each DAU, we would be able to detect differences in survival rates among DAUs by pooling survival data within each DAU over 3 years (Freddy 2002).

We chose to radio-collar equal numbers of calves (26) and adult females (13) yearly among DAUs knowing that counts of elk were similar but not equal among DAUs (Freddy 2002). Prior to capturing elk, the 3 DAUs demarcating the Basin were divided into 10 geographic trap-zones (Figure 1, A-J). Within each DAU, we distributed numbers of calves and adult females captured according to observed relative proportions of elk counted in each trap-zone within each DAU resulting in radio-collared elk being distributed across the landscape relative to numbers of elk counted during early winter. Counts of elk occurred during sex and age composition surveys conducted with a helicopter during December-January post-harvest 1995-96, 1997-98, and 1999-2000 prior to initiating this study (Freddy 2002).

Telemetry Monitoring

During this yearly segment, we monitored life or death status of radio-collared elk at 2-4 week intervals from July 2002 through June 2003 using a Cessna 185 or 182 equipped with strut mounted 'H' antennas. Additionally, as in previous years, the Cessna 185 was equipped with a rotational belly mounted 'H' antenna to provide more directional accuracy in interpreting telemetry signals. We used a

Lotek® SRX400 receiver-scanner for monitoring telemetry signals. Elk survival data were compiled using the RADIOS module of the CDOW program DEAMAN® (White 1991).

Mortality Assessments

All suspected mortalities based on telemetry mortality signals were confirmed using ground searches. Once carcasses were located, criteria for assigning probable cause of death followed standardized written procedures that included assessment of body position and body condition, presence of bite or claw marks and sub-dermal hemorrhaging or gunshot wounds, presence of tracks or drag marks, and collection of organ, muscle, and femur marrow samples for laboratory analyses, if available (Wade and Browns 1982, Freddy 1998). Multiple photographs were taken of the carcass along with any potential evidence for assessing cause of death and when appropriate, an outside expert (T. D. I. Beck, CDOW retired) was consulted to assess evidence.

Field necropsies were performed to the extent possible depending on completeness of carcass. We routinely collected muscle samples from large muscle groups in the hind- and forequarters of carcasses when available during the first winter post-capture to assess for evidence of capture myopathy (Lewis et al. 1977, Spraker 1982, Haigh and Hudson 1993). Histopathology assessments of organ and muscle samples were completed by the Colorado State University Veterinary Diagnostic Laboratory and analyses of percent femur marrow fat (FMF) on a dry-matter basis were conducted by the CDOW research laboratory.

Field technicians provided a standardized written summary for each death. The principal investigator made the final assessment for probable cause of death based upon field summaries, photographs, and laboratory analyses. Potential causes of death included malnutrition, predation by black bears (*Ursus americanus*), mountain lions, (*Felis concolor*), coyotes (*Canis latrans*), and domestic dogs (*Canis familiaris*), legal and illegal hunter harvest, accidental trauma, plant poisoning, capture-induced, and unknown (Freddy 1997). Causes of death were broadly summarized as malnutrition, predation, suspected malnutrition, suspected predation, accident, unknown, hunter harvest, and capture-induced. Mortalities classed as malnutrition were usually nearly intact carcasses with little or no evidence of predator presence whereas mortalities classed as predation usually had evidence of bite wounds and sub-dermal hemorrhaging indicating bites were inflicted on a live animal. In those cases classed as suspected malnutrition or suspected predation a preponderance of collected evidence was used to assign cause of death to the most likely class. Telemetry collars that prematurely slipped-off elk causing a mortality signal to be emitted were confirmed by locating and retrieving the collar.

Elk were subjected to multiple hunting seasons during fall 2002. These seasons were: archery, 31 August-29 September; muzzleloading, 14-22 September; elk-only, rifle, 12-16 October; deer-elk first combined, rifle, 19-25 October; deer-elk second combined, rifle, 2-8 November; deer-elk third combined, rifle, 9-13 November, and late antlerless elk only, 23 November - 15 December in all Basin DAUs, E-25, E-41, and E-43. Harvest of males was restricted to branch-antlered males with spike-antlered males (yearlings) not legal quarry. Hunters harvesting radioed elk were asked to complete a mail-in questionnaire to provide information on radio-collars and general health condition of elk (Appendix D).

Survival Rates

Survival rates of radio-collared elk were calculated for this report using the binomial estimator and in final analyses will be calculated using a Kaplan-Meier estimator (White and Garrott 1990). Binomial estimates of survival rates were calculated as mean survival ($\hat{s}$) = [Alive / Alive+Dead collared elk], with a variance of [VAR ($\hat{s}$) = ($\hat{s}$) × (1-$\hat{s}$) / *n* collars], and 95% confidence intervals of ($\hat{s}$) $\pm$ [t $_{\alpha=0.05,\, n-}$

$_{1\,df} \times \sqrt{}$ (VAR ($\hat{s}$))]. Survival rates were estimated for time intervals of winter-spring (15 December - 14 June), summer-fall (15 June - 14 December), and yearly (15 December - 14 December) which coincided with capturing and radio-collaring elk and thus represented a biological year. Survival rates for these seasonal intervals corresponded to time periods used for input of survival rates into standard population models constructed by CDOW. By definition, calf elk became 12-month old yearlings on 15 June and calves surviving to this date were considered to be recruited into the population.

For adult elk during time intervals that included hunting seasons, we calculated survival rates inclusive of natural and hunting related mortalities, exclusive of hunting mortalities, and exclusive of natural mortalities. Excluding, or censoring hunting mortalities, provided estimates of natural survival rates, while censoring natural mortalities but including hunting mortalities provided estimates of hunting removal rates calculated as (r) = (1 – $\hat{s}$), with ($\hat{s}$) being survival rate with natural mortalities censored. Survival rates representing estimates averaged across multiple years or time intervals may have involved individual radioed elk that were common to multiple intervals. In these cases, years or time intervals were considered independent events, and sample sizes were expressed as elk-years or elk-winters reflecting that individual radioed elk contributed to estimates over multiple intervals.

Chi-square contingency tests (χ^2) were used in this segment for initially comparing adult elk survival (alive or dead categories) among sexes, years, cohorts, and DAUs (White and Garrott 1990, SAS 1988 PROC FREQ). Parameter estimates were expressed as means $\pm$95% confidence limits unless otherwise noted.

Elk dying of suspected captured-induced trauma were censored from survival estimates. Deaths of calves or adults occurring within 1-week of capture were likely to be classed as capture-induced deaths unless field evidence strongly suggested a natural cause of death independent of capture. Capture-induced trauma could affect animals for up to 2-4 weeks post-capture so we routinely attempted to assess whether deaths were potentially capture-induced. We also censored elk having telemetry collars that electronically failed or slipped-off the elk (White and Garrott 1990). Elk with failed or slipped collars were censored for an entire seasonal time interval for binomial survival estimates and will be censored on the date they were last known alive based on telemetry signals in Kaplan-Meier estimates of survival. Elk whose telemetry signals disappeared during hunting seasons continued to be monitored for several subsequent months over large geographic areas until such time these elk were judged to have likely been removed during hunting seasons. Radioed elk that disappeared during hunting seasons were assumed to have been legally harvested.

Elk Distribution and Movements

During aerial flights to monitor survival status of elk (Table 8), we interpreted telemetry signal strength and direction to judge general locations of each elk. Locations were collected at a level of accuracy deemed sufficient to assess movements of elk among DAUs and GMUs and assess general areas used by elk seasonally. However, we documented locations of elk that made large or unique movements, such as across main highways or DAU boundaries, by obtaining more precise fixes on telemetry signals such that location errors were likely of radius <500 m; elk mortalities were more precisely located to aid recovery of collars from ground surveys. Our data is limited to inferences regarding distribution of elk during daylight hours as flights were conducted between 7 AM and 7 PM Mountain Standard or Daylight Savings time. ***NOTE***: Primary data collection was completed in June 2003 but we were able to incorporate locations of hunter harvested elk during fall 2003 and locations of live elk from December 2003 into this report.

We collected written descriptive generalized locations of each radio-collared elk during aerial surveys; i.e, lower Beaver Creek, upper Big Blue Creek, Home Gulch, etc., and stored information in sequentially dated archived files of the RADIOS module of the DEAMAN database (White 1991) that were later compiled for each elk. We did not routinely collect refined aerial telemetry locations (Carrel et al. 1997) because of limited available aircraft-hours and desire to avoid risks of low-level flying in mountainous terrain.

To describe macro-spatial distribution of elk, we summarized information for 3 general classes of elk: males radio-collared as calves (MCA) having location observations from age 6-months to maximum age of 42 months (the only males radio-collared were calves, Tables 1, 9); adult females (AF) captured as adults (age ≥30 months, Tables 1, 10) and located as adults; and, those females radioed as 6-month calves (FCA) that survived until age ≥12 months (Tables 4, 5, 11) and located to maximum age of 42 months. The span of months an elk survived determined number of locations per elk. Descriptions of estimated elk locations were manually input into ArcGIS8® to create a point-coverage shape-file with each point identified by elk radio-collar frequency, sex, age, date, season, and attributed with existing ArcGIS coverages for UTMx and UTMy coordinates (NAD 27), trap-zone, GMU, and DAU.

We used locations from 100% of the males to maximize sample size because males had higher mortality rates than females primarily due to higher removal rates during hunting seasons and censoring due to slipped collars. In part to economize data input, we used locations from a random sample of adult females and those female calves surviving to adults (Tables 9, 10). We used restricted random sampling to select AF and FCA with stipulations that within each trap-zone, ≈65% of the AF and FCA would be selected with a minimum sample size of 3 AF and FCA per trap-zone and that each trap-site within a trap-zone was represented by at least 1 AF and FCA provided there was a surviving elk from a trap-site. These stipulations assured that estimated distributions of elk reflected a geographically proportioned sample of radioed females among and within DAUs (Tables 9, 10). These 3 sets of elk locations were used for all spatial summaries except for elk mortalities which were based on 100% of the elk mortalities (Freddy 2002). We presumed that AF would represent the most stable or habitual patterns of spatial use while MCA and FCA maturing to young adults would represent more variable patterns of dispersing individuals or individuals establishing their home ranges.

We defined seasons as: Winter - 1 December-31 March when snow on the ground was common at all elevations and forage was most restricted in availability and quality; Spring - 1 April-30 May when snow cover was receding from lower to higher elevations and herbaceous forage was progressing from cured to growing status; Summer - 1 June-30 August when forage was green and growing at all elevations; Fall - 1 September-30 November when herbaceous forage was changing from growing to cured status, snow was progressively accumulating from higher to lower elevations, and all regular hunting seasons were ongoing. We summarized locations in June for adult females (AF plus FCA of age ≥ 12 months) to identify areas that could be associated with birthing and rearing of young elk calves with most of the June locations obtained during the first and third weeks of June.

We recognized the importance of obtaining a random sample of radio-collared elk to reduce bias in assessing spatial use by elk in the Basin (Erickson et al. 2001, Manly et al. 2002). We consider our radio-collared elk to be a sufficiently unbiased random sample of elk in the Basin. First, elk were originally captured using a systematic system stratified to geographic trap-zones and trap-sites with numbers of elk captured in each trap-zone determined *apriori* to capture and proportionate to documented elk densities and, additionally, efforts were made to avoid capturing multiple elk from any single group of elk (Garton et al. 2001). Second, for female elk captured and radio-collared as calves or adults, we randomly selected a sub-sample of these females again proportioned by trap-zone strata to represent the distribution of female elk in the Basin. For males, we used 100% of the radio-collared elk and therefore relied only on our capture sampling protocols to achieve a random sample. Third, our aerial flights were sufficiently spaced in time to minimize effects of temporal correlation on locations of individual elk (Otis and White 1999) and we obtained locations for nearly all elk during all flights so that each elk provided data.

Arguments have been presented regarding individual elk versus elk locations as the appropriate sampling unit (Otis and White 1999, Erickson et al. 2001). To describe spatial distribution of elk, we created maps in ArcGIS8 that pooled elk locations across radio-collared elk and therefore assumed each location was an independent sample unit with inferences limited to the distribution of the population of radio-collared elk in the Basin. We estimated maximum distances and directions elk moved from their original trap-sites and their home ranges during their monitored life-span to represent patterns of spatial use based on individual elk as independent sample units, thereby representing the entire elk population in the Gunnison Basin. We used Spatial Analyst® of ArcGIS8 to calculate maximum movement vectors (MMV) and minimum convex polygon (MCP) year-around home ranges recognizing that MCP were sensitive to location outliers (Kernohan et al. 2001) . Vectors and MCP were calculated only for those elk having $\geq$8 locations who generally had attained an age $\geq$12 months. We pooled data among years and therefore presumed no year effects.

We caution that location data should not be used to assign importance to elk of micro-habitat types or micro-scale geographic areas. Importantly, areas estimated to have low levels of use by elk based on spatial plots of locations should not necessarily be deemed unimportant but rather may reflect our coarseness of estimated locations. Plots of spatial locations are weighted towards areas used by elk during winter because of the relative seasonal concentration of animals, length of defined winter relative to other seasons, and number of aerial flights conducted (Table 8).

RESULTS AND DISCUSSION

Sampling Distribution of Captured Radio-collared Elk

Proportions of total elk captured and radio-collared within each trap-zone in December 2000 and 2001 generally reflected the proportions of elk counted in each trap-zone within each DAU (Table 2). Large differences in numbers of elk counted among trap-zones within a DAU were adequately reflected by proportions of elk captured in those trap-zones especially in DAUs E-43 and E-41. Limitations on capture imposed by local weather, time, logistics, and daily elk distribution prevented capturing elk in exact proportions to relative estimated numbers of elk. Requiring equal numbers of calves and adult females to be radio-collared for each DAU to meet sample size requirements did not unduly distort the distribution of radio-collared elk relative to numbers of elk counted among DAUs (Table 2).

Weather

Precipitation in the Basin during summer-fall 2002 was well below average while winter-spring snow depths during 2002-03 approached average for some areas at elevations >3,000 m. Although official NOAA weather data has not been summarized, severe drought conditions generally existed for the Basin and most of southwestern Colorado during 2002 and recent previous years. Large forest fires were common in many parts of Colorado during summer 2002.

Based on observations made during summer-fall aerial flights, winter ranges in the Basin were parched during summer and fall 2002 due to lack of rainfall. Extremely dry summer conditions were also evident for alpine ranges where vegetation also looked parched, many high elevation snow-fields became almost non-existent, and in some cases, small alpine lakes were devoid of water. Casual ground surveys at all elevations reinforced the poor production of annual vegetation and the limited sources of water in creeks, lakes, and ponds. In general, the Basin appeared driest in the southeast and east and less dry in the southwest and north-central portions. Subjectively, the summer drought in sub-alpine and alpine ranges surrounding the Basin was worst to least worst in: the La Garita Mountains, Collegiate Peaks, San Juan Mountains, West Elk Mountains, Ragged-Ruby Mountains, and Maroon Bells-Elk Mountains. Some moderation in the drought cycle occurred with rain and snow received in mid-September that may have promoted some vegetation regrowth at mid-elevations. In early November, 20-30 cm of snow was received on winter ranges and more at higher elevations, but this snow slowly dissipated from lower elevation open sites as fall progressed into winter.

During winter 2002-03, snow depths were generally shallow and seldom exceeded 30 cm on most segments of winter range in the Basin based on observations during aerial survey flights. From December through February, many south- and west-facing slopes within sagebrush winter ranges were devoid of snow. Snow had melted from primary winter ranges by late-March to early April. Snow depths by 26 March at elevations >3,050 m, appeared lowest to highest in: the La Garita Mountains, Collegiate Mountains, San Juan Mountains, West Elk Mountains, and Ragged-Ruby-Maroon Bells-Elk Mountains. By 26 April, the snow-line varied between 2,900 and 3,300 m through out the Basin. Winter temperatures were again generally mild for the Basin with daily minimums seldom below -26 C and generally >-18 C and daily maximums often >-6 C.

Collar Failures

Two radio-collars were censored between 15 June 2002 and 14 June 2003. One female age 13 months (173.681/01), slipped her collar between 17 July and 22 August 2002 apparently because latex snubbers prematurely broke allowing the calf collar to expand and slip over the yearling female's head (see Freddy 2002). The collar on male 175.250/01was plagued by white-noise frequencies that interfered with detecting the pulse signal from the first day the collar was deployed on 19 December 2001 until 7 February 2003 when the collar was last heard. This collar was considered to have failed electronically.

Adult Elk Survival

Deaths from hunting were the primary cause of mortalities in adult (age ≥12 months) male and female radio-collared elk. Between 15 December 2000 and 14 June 2003, 34 adult females died with 32 (94%) deaths attributed to hunting and 2 deaths (6%) from natural causes and, for adult males, 14 died with 11 (79%) deaths due to hunting and 3 (21%) from natural causes (Appendix C). Hunting also accounted for >90% of the deaths of adult radio-collared elk on the Grand Mesa (Freddy 1998).

Adult Female Survival.--During winter-spring intervals, natural survival rates for adult females age ≥30 months were ≥0.98 ± 0.03 as no mortalities occurred during 2000-01(n = 39) and 2001-02 (n = 48), and 1 mountain lion predation mortality occurred in May 2002-03 (n = 61). For all winter-spring intervals, survival rate was 0.99 ± 0.02 (n = 148 elk-winters). Similarly, natural survival rates for all adult females age ≥18 months during 2 winter-spring intervals were ≥0.99 ± 0.03 (n = 82, 2001-02, = 86, 2002-03) and 0.99 ± 0.01 for both winter-spring intervals (n = 168 elk-winters) (Table 3).

During summer-fall intervals, natural survival rates for adult females age ≥24 months were ≥0.97 ± 0.05 in 2001 (n = 37) and 2002 (n = 61), and 0.99 ± 0.02 for both summer-fall intervals (n = 98 elk-summers, hunting mortalities censored). The 1 natural death involved a female age 19 years and occurred about 1 July 2001 from unknown causes. Survival rates during summer-fall inclusive of hunting and natural mortalities were 0.92 ± 0.08 and 0.74 ± 0.09 in 2001 (n = 39) and 2002 (n = 82), respectively (Table 3). Similarly, for all adult females age ≥12 months, natural survival rates were ≥0.99 ± 0.03 in

2001 ($n = 71$) and 2002 ($n = 86$), and 0.99 ± 0.02 for both summer-fall intervals ($n = 157$ elk-summers, hunting mortalities censored). Survival rates during summer-fall for all adult females age ≥12 months inclusive of hunting and natural deaths were 0.91 ± 0.07 in 2001 ($n = 77$) and 0.77 ± 0.08 in 2002 ($n = 112$) (Table 3). Survival rates during summer-fall, inclusive of hunting mortalities, were lower in 2002 than 2001 for adult females age ≥24 months ($\chi^2 = 5.336$, df = 1, $P = 0.021$) and age ≥12 months ($\chi^2 = 6.316$, df = 1, $P = 0.012$).

Annual natural survival rates for adult females age ≥30 months were ≥0.97 ± 0.05 in 2000-01 ($n = 37$) and 2001-02 (n = 33) while survival rates including hunting and natural mortalities were 0.92 ± 0.08 ($n = 39$) in 2001 and 0.69 ± 0.14 ($n = 48$) in 2002. For adult females age ≥18 months, annual natural survival rates were ≥0.97 ± 0.05 in 2000-01 ($n = 37$) and 2001-02 (n = 61) while survival rates including hunting and natural deaths were 0.92 ± 0.08 ($n = 39$) in 2001 and 0.74 ± 0.09 ($n = 82$) in 2002 (Table 3). Annual survival rates, inclusive of hunting mortalities, were lower in 2002 than 2001 for adult females age ≥30 months ($\chi^2 = 7.277$, df = 1, $P = 0.007$) and age ≥18 months ($\chi^2 = 5.336$, df = 1, $P = 0.021$).

Yearling Female Survival.--During summer-fall intervals, natural survival rates for female elk, age 12-17 months, were 1.00 in 2001 ($n = 34$), 2002 ($n = 25$), and for both summer-fall intervals ($n = 59$) as no natural mortalities occurred. Survival rates including hunting mortalities were 0.89 ± 0.10 ($n = 38$) in 2001, 0.83 ± 0.14 ($n = 30$) in 2002, and 0.87 ± 0.08 ($n = 68$) for both years as rates were similar between years ($\chi^2 = 0.550$, df = 1, $P = 0.458$). During winter-spring intervals, natural survival rates for female elk, age 18-23 months, were 1.00 in 2001 ($n = 34$), 2002 ($n = 25$), and for both winter-spring intervals ($n = 59$) as no natural mortalities occurred (Tables 4, 5).

Over their first year as a young adult, natural survival rates for yearling females, age 12 to 23 months, were 1.00 ($n = 59$) as no natural deaths occurred. Survival rates including hunting mortalities were 0.89 ± 0.10 ($n = 38$) in 2001, 0.83 ± 0.14 ($n = 30$) in 2002, and 0.87 ± 0.08 ($n = 68$) for both years as rates were similar between years ($\chi^2 = 0.550$, df = 1, $P = 0.458$) (Tables 4, 5).

Yearling Male Survival.--During summer-fall intervals, natural survival rates for male elk, age 12-17 months, were 0.90 ± 0.13 in 2001 ($n = 21$), 1.00 in 2002 ($n = 23$), and 0.95 ± 0.06 for both years ($n = 44$) as rates were similar between years ($\chi^2 = 2.295$, df = 1, $P = 0.130$). The two mortalities in July 2001 were from suspected black bear and mountain lion predation. Survival rates including hunting mortalities were 0.86 ± 0.15 ($n = 22$) in 2001, 0.82 ± 0.15 ($n = 28$) in 2002, and 0.87 ± 0.09 ($n = 60$) for both years as rates were similar between years ($\chi^2 = 0.163$, df = 1, $P = 0.686$). During winter-spring intervals, natural survival rates for male elk, age 18-23 months, were 1.00 in 2001 ($n = 19$), 0.95 ± 0.09 in 2002 ($n = 22$), and 0.98 ± 0.05 ($n = 41$) for both years as rates were similar between years ($\chi^2 = 0.885$, df = 1, $P = 0.347$). The 1 mortality in April 2002 was from suspected mountain lion predation (Tables 4, 5).

Over their first year as a young adult, natural survival rates for yearling males, age 12 to 23 months, were 0.90 ± 0.13 ($n = 21$) in 2001, 0.95 ± 0.09 ($n = 22$) in 2002, and 0.93 ± 0.08 ($n = 43$) for both years as rates were similar between years ($\chi^2 = 0.410$, df = 1, $P = 0.522$). Survival rates including hunting mortalities were 0.86 ± 0.15 ($n = 22$) in 2001, 0.78 ± 0.17 ($n = 27$), and 0.82 ± 0.11 ($n = 49$) for both years as rates were similar between years ($\chi^2 = 0.596$, df = 1, $P = 0.440$)(Tables 4, 5).

Adult Male Survival.--During summer-fall, natural survival rate for male elk, age 24-29 months, was 1.00 ($n = 14$) and including hunting mortalities, was 0.74 ± 0.22 ($n = 19$) in 2002. During winter-spring, natural survival rate for male elk, age 30-35 months, was 1.00 in 2003 ($n = 14$) (Table 4).

Adult Elk Harvest Removal

Male Removal.-- Removal rate (*r*) for adult males, age 24-29 months and assumed to be legal branch-antlered males, was 0.26 $\pm$ 0.22, or 26%, as 5 of 19 were harvested during fall 2002 (Table 4). Wounding loss was 0% of the legal harvest and 80% of the harvest occurred in the third rifle combined season. On the Grand Mesa, removal rate, inclusive of elk wounded, averaged 76% during 1995-99 with a range of 64-92% under similar harvest regulations for branch-antlered males (Freddy 2000).

Removal rates for yearling males were 0.05 $\pm$ 0.10 in 2001 (n = 20, 1 killed), 0.18 $\pm$ 0.15 in 2002 (n = 28, 5 killed), and 0.13 $\pm$ 0.10 for both years (n = 48) as rates were similar between years (χ^2 = 1.763, df = 1, P = 0.184) (Tables 4, 5). Five deaths were considered wounding/illegal loss and 1 was an illegal harvest because only the radio-collar was found under the ice in a main stream along a road indicating the hunter took possession of the yearling bull. In 2002, all deaths occurred during the third rifle combined season. Five of the yearling bulls had spike antlers with 4 sets of antlers still covered by velvet. On the Grand Mesa, wounding/illegal removal rates of yearling bulls averaged 11% and ranged from 3 to 17% during 1994-97 (Freddy 1997, 1998).

Female Removal.-- Removal rates for adult females, age $\geq$24 months, were 0.05 $\pm$ 0.08 (n = 38) in 2001 and 0.26 $\pm$ 0.10 (n = 82) in 2002 with rate being higher in 2002 (χ^2 = 6.939, df = 1, P = 0.008). For adult females, age $\geq$12 months, removal rates were 0.08 $\pm$ 0.06 (n = 76) in 2001 and 0.23 $\pm$ 0.08 (n = 112) in 2002 with rate being higher in 2002 (χ^2 = 7.523, df = 1, P = 0.006). Removal rates for yearling females, age 12-17 months, were 0.11 $\pm$ 0.11 (n = 38) in 2001, 0.17 $\pm$ 0.14 (n = 30) in 2002, and 0.13 $\pm$ 0.08 (n = 68) for both years as rates were similar between years (χ^2 = 0.550, df = 1, P = 0.458)(Tables 3, 4, 5).

Wounding loss on adult females, age $\geq$12 months, was 100% of the legal harvest in 2001 (3 harvested, 3 wounded) and 44% of the legal harvest in 2002 (18 harvested, 8 wounded). In 2002, 42% of the adult female hunting mortality occurred during the late season and 27% during the third rifle combined season. Wounding losses in 2002 that occurred during all regular hunting seasons represented 36% of the legal harvest during those seasons and, similarly, losses in the late season represented 57% of the legal late season harvest. However, frequency of wounding loss was not different between regular and late seasons (χ^2 = 0.280, df = 1, P = 0.597). Wounding loss for adult females on Grand Mesa averaged between 25 and 30% over 6 years (Freddy 1998, 2000).

Of the 26 adult females killed in 2002, 13 or 50%, were killed in GMU 55 and the northwestern portion of GMU 551, representing a core area of DAU E-43 (Fig. 1). This distribution of harvest likely resulted from a combination of major movements by elk coupled with timely snowfall that was advantageous to hunters. By the 31 October aerial flight (Table 8), nearly all radio-collared elk that had previously been in the upper portions of the Taylor River system (northeastern portion of GMU 55) had moved into South Lottis, Crystal, and East Beaver creeks in the southwestern portion of GMU 55. This mass movement of radio-collared elk to a relatively small area was not duplicated during October by radio-collared elk in other portions of the Basin. This concentration of elk then became static and vulnerable to hunters when the large snowfall occurred on 9 November and snow depths persisted well into the late rifle season.

Adult Elk Survival By DAU

Comparisons in survival rates for adult females between DAUs suggested survival was highest in E-41 and lowest in E-43 for either females age $\geq$12 months or $\geq$30 months(Table 6). During the multi-year interval 15 December 2000 through 14 June 2003, survival in E-43 was lower than E-41 for both age groupings of adult females ($\chi^2 = 3.793$, df = 1, $P = 0.052$, age $\geq$12 months; $\chi^2 = 3.463$, df = 1, $P = 0.063$, age $\geq$30 months). Differences in survival between E-25 and E-43 and E-25 and E-41 were not significant for either age grouping of adult females ($P \geq 0.138$). Differences in survival reflect the comparative impacts or relative success of hunting antlerless elk in these DAUs as there were only 2 natural mortalities of adult females among all DAUs resulting in natural survival rates of 0.92 to 1.00 (Table 6).

Comparisons in survival rates for adult males between DAUs suggested there were marginal differences in survival, in part due to the insensitivity associated with small sample of radio-collared males (Table 7). During the multi-year interval 15 June 2001 through 14 June 2003, survival of males, age 12-35 months, was not different between all paired combinations of DAUs E-25, E-43, and E-41 ($\chi^2 \leq 2.488$, df = 1, $P \geq 0.115$). For males age 12-23 months, differences in survival occurred only between E-43 and E-41 ($\chi^2 = 3.980$, df = 1, $P = 0.046$). Differences between these 2 DAUs occurred primarily because all natural deaths of yearling males and nearly all illegal wounding loss of yearling males occurred in E-43 (Table 7).

Calf Cohort to Adult Survival

Survival by female and male calves to age 23 months for the year 2000 calf cohort favored females over males by 1.3x (0.87 vs 0.66, $\chi^2 = 4.540$, df = 1, $P = 0.033$), primarily because of high female calf survival (0.97) compared to males (0.78) (Table 4) whereas survival to age 23 months was nearly equal for both sexes (0.64M, 0.68F) for the 2001 calf cohort as both sexes had similar survival rates as calves (0.84M, 0.82F) and harvest removal rates as yearlings (0.18M and 0.17F) (Table 5). For the 2000 cohort, survival to age 35 months was higher for females (0.72) than males (0.48) ($\chi^2 = 4.416$, df = 1, $P = 0.036$). A higher survival for females would be expected because of the potentially high hunting removal rate on males at age 24-29 months when males first become branch-antlered and legal quarry. In 2002, 2-year old males were removed at an unexpectedly low rate of 0.26 which likely reduced the differential survival between sexes in this cohort.

Adult Elk Body Condition

Insight into elk nutritional status during fall was obtained from estimates of FMF for recovered wounding losses of adult elk during hunting seasons. For adult females that died during October or November, FMF averaged 97.3% ($n = 7$) and ranged from 95.9 - 99.0%. These females were 2 -17 years old with 6 collected in 2002 and 1 in 2001. Yearling females age 16-17 months ($n = 2$) had average FMF of 92.6% which ranged from 85.2-95.2% with both samples from October-November 2001. Yearling males age 17-18 months ($n = 4$) had average FMF of 89.5% which ranged from 86.3-92.2%. Male samples were collected in November ($n = 3$, 2002) and December ($n = 1$, 2001) (Appendix C). These FMF values suggested elk were replenishing femur marrow fat and achieving minimally adequate body condition status (Mech and DelGiudice 1985) before entering winter.

Additionally, hunters who harvested radioed elk provided further insight into elk nutritional status. Hunters ($n = 16$, fall 2002 only) who harvested radioed elk judged the general health condition of their elk as excellent (56%), good (38%), and fair (6%). Rump fat for adult females ($n = 12$) was judged plentiful in 25%, fair in 58%, and poor in 17% while adult males, age 24-29 months ($n = 2$), had poor rump fat (100%). Internal and mesentery fat was judged plentiful in 25%, fair in 33%, and poor in 42% of the adult females ($n = 12$) and considered poor in 100% of the adult males ($n = 2$). These judgments followed the summer of 2002 which was extremely dry when production of forage was relatively poor. As expected, adult males were lean on fat following the rut. The judged fat condition of adult females was highly variable but 75% were rated in fair or poor fat condition. In comparison, for adult females harvested by hunters in December 2000 and 2001 following comparatively more productive forage summers, measurements of kidney fat and subsequent estimates of total body fat for adult females indicated 65% were in moderate and 30% in low body condition status, with 0% rated in very good or excellent condition (Freddy 2002).

Collectively, these assessments of body condition suggest that elk in the Basin were subject to marginally deficient levels of seasonal nutrition. Although FMF values were high during fall, the subcutaneous rump and internal and mesentery fat deposits are the fat stores most sensitive in reflecting nutritional condition and are the most important fat stores available to mitigate impacts of nutritional stress during winter and late stages of fetal development (Riney 1955, Kistner et al. 1980, Harder and Kirkpatrick 1994, Cook et al. 2001).

Few assessments of adult elk body condition during winter and spring were available because few radio-collared elk died. Femur marrow fat was 73.5% in a 22-month old male in April 2003 and 8.6% in a 4-year old female in May 2003. Both deaths likely involved predation by mountain lions (Appendix C).

Elk Distribution and Movements

Distribution.--Examining macro-movements of elk revealed few instances of elk moving north or south across U.S. Highway 50 (Hwy 50) which bisects the Basin from east to west. We therefore divided distribution maps into Gunnison-North, representing elk captured in trap-zones F-J, and Gunnison-South, representing elk captured in trap-zones A-E (see Fig. 1). Importantly, Hwy 50 divided DAU E-43 into segments north and south of this highway. Distribution and movement patterns of elk were based on 16-27 elk per class of elk (MCA, AF, FCA) per Gunnison-North or Gunnison-South areas and an average of 26-32 locations per elk for each class of elk representing >3,700 total locations (Table 12).

Based on locations, all classes of elk (MCA, AF, FCA) showed relatively high fidelity to areas in the Basin as defined by the collective boundaries of DAUs E-25, E-41, and E-43 (Figs. 2-4). Exceptions were seen with some elk using areas primarily during spring, summer, and fall in adjacent GMUs 65, 63, 53, and 521 to the west and north, 48, 481, 68, and 681 to the east, and 76 and 79 to the south. Deepest penetration into adjoining GMUs occurred in GMUs 65, 63, 53, 76, and 79. A few AF, FCA, and MCA did move and use areas outside the Basin during winter in GMUs 65, 63, 521, 68, 681, 76 and 79 (Figs. 2-4).

We realize the following descriptive narratives of areas used by elk cannot be referenced in detail on the maps provided (Figs. 2-27) because providing geographic names on maps was space limited. As such, the narratives will be most useful when maps with geographic references are used in conjunction with the narrative. Maps provide a UTM reference grid which should allow for specific areas of interest to be spatially referenced.

Gunnison Elk-North.-- AF, FCA, and MCA remained almost exclusively north of Hwy 50 during all seasons. AF leaving the Basin most commonly ventured into GMU 63 and 53 to the west (Fig. 5). FCA followed similar patterns with elk venturing into GMUs 63, 53, and GMU 521 to the west and north and additionally, to the east into 481 (Fig. 6). MCA followed similar patterns but with apparently much of the dispersed activity focused into GMUs 53 and 521 to the northwest with a few elk venturing into GMUs 63 and 411 to the west, 43, 471, and 48 to the north, and 76 and 79 to the south (Fig. 7).

Areas used during winter by elk within each trap-zone were: *trap-zone F*, Dawson Ridge-Horn Gulch, Tomichi Dome, Greathouse Gulch-Yellowpine Ridge, Wood Gulch, lower Hot Springs Creek; *trap-zone G*, lower Gold to lower Alder creeks, Roundup Basin, Cabin and East Cabin creeks and Sheep Gulch, Lost Canyon, Fisher, and Tepee gulches, Beaver-East Beaver creeks, Almont Triangle, Roaring Judy Creek-Round Mountain, lower Cement Creek; *trap-zone H*, areas surrounding Flattop Mountain to lower Carbon Creek; *trap-zone I*, lower West Antelope and Antelope creeks, Steers Gulch, lower Beaver, Steuben, and Dry creeks; *trap-zone J*, lower East Elk Creek, Dry Gulch, Tenderfoot Mesa, lower Red, West Elk , Coal, and Soap creeks (Figs. 5-7).

Areas used during spring by elk within each trap-zone were: *trap-zone F*, Tomichi Dome-Waunita Park with suspected movement corridors to summer ranges associated with Waunita Pass-Little Baldy Mountain and Triano-Canyon creeks to upper Quartz creeks; *trap-zone G*, Beaver-East Beaver, Threemile, and Fivemile creeks, east of Taylor Reservoir from Willow to Illinois creek, Almont Triangle-Roaring Judy Creek, lower Cement and Brush creeks, with suspected movement corridors to summer areas lying between Spring and Summerville creeks along the Taylor River canyon for elk moving north or northeast from winter ranges and a corridor passing through Crystal, South Lottis, and Lottis creeks for elk moving northeast and east; *trap-zone H*, western portions of Red Mountain from Willow Creek to Carbon Peak in lower Carbon Creek with a diffuse movement corridor through branches of Carbon Creek to Gibson Ridge and Mt. Axtell; *trap-zone I*, upper West Antelope Creek, middle elevations of Squirrel, Castle, Pass, Beaver, Steuben, and Willow creeks with a movement corridor from upper West Antelope through lower Castle Creek to Pass Creek; *trap-zone J*, middle elevations of Dry Creek to Red Creek, pronounced use of areas near Little and Big Soap parks in Soap Creek, and in adjoining Coal Basin in GMU 53, with a suspected movement corridor from lower West Elk and Soap creeks through Soap parks to upper West and main Soap creeks to Coal Basin and Soap Basin (Figs. 5-7).

Areas used during summer by elk within each trap-zone were: *trap-zone F*, upper Dawson Ridge to Triano Creek, upper South and Middle Quartz creeks, Granite Mountain, Tomichi Pass, upper Chalk Creek, Waunita Pass-Little Baldy Mountain; *trap-zone G*, upper East Beaver and Crystal creeks, Union Park-Lottis Creek, areas east and northeast of Taylor Park Reservoir through Willow, Texas, Illinois, Pieplant, Red Mountain, Tellurium, and Pine creeks, upper Sayres Gulch of Lake Creek, Trail, South Italian, and Italian creeks and headwaters of Taylor River, upper Cement and Brush creeks, Dry Basin, Copper Creek, upper Slate River, and Oh-Be-Joyful Creek; *trap-zone H*, Red Mountain, upper Carbon Creek, Whetstone Mountain, Gibson Ridge, Mt. Axtell; *trap-zone I*, upper Pass, Castle, and branches of Beaver creeks; *trap-zone J*, West and upper Soap creeks and Soap Basin, with adjoining areas in Coal Basin, and Coal, Robinson, and Cliff creeks in GMU 53, and upper Curecanti, Crystal, and Dyer creeks in GMU63 (Figs. 5-7).

Areas receiving use by female elk in June may be of importance to successful rearing of calves and these areas should receive further surveillance as to their importance to elk reproduction (Fig. 11). Areas of interest within each trap-zone were: *trap-zone F*, Waunita Park, upper South Quartz and upper Tomichi creeks; *trap-zone G*, upper East Beaver Creek, Union Park, east of Taylor River from Texas Creek north to Pine Creek, upper East Brush Creek; *trap-zone H*, western slopes of Red Mountain, Carbon Creek and Carbon Mountain; *trap-zone I*, confluence of North and South Castle creeks, upper Pass Creek; *trap-zone J*, upper East Soap and West Elk creeks, Big Soap Park, and Coal Creek to Spruce Draw within Coal Basin in adjacent GMU 53.

Areas receiving focused use by elk during fall were difficult to identify because elk movements were diffuse and likely heavily affected by hunting seasons from September to December. However, some elk in trap-zones F and G appeared more prone to move to areas near winter ranges than did elk in trap-zones H-J, especially to areas near Tomichi Dome (trap-zone F) and East Beaver Creek (trap-zone G) (Figs. 5-7).

Maximum movement vectors (MMV) and year-around home ranges (MCP) revealed general patterns of movement for the elk population north of Hwy 50. Directions moved by AF and FCA for each trap-zone were (Figs. 13, 14, 19, 20): *trap-zone F*, elk moved northeast to summer ranges generally within the confines of GMU 551 north of Hwy 50; *trap-zone G*, elk from southern trap-sites moved relatively long distances north-northeast into the upper Taylor River and Collegiate Peaks areas, while elk from the northern Almont trap-sites moved north-northwest with elk from both areas generally remaining within GMU 55 with the exception of an elk moving southwest across Hwy 50 into GMU 67; *trap-zone H*, elk moved north, west, and southwest frequenting both DAUs E-41 and E-43; *trap-zone I*, elk moved northwest to northeast frequenting both DAUs E-41 and E-43 and leaving the Basin into GMU 53 and 521 with the exception of an elk moving southeast across Hwy 50 into GMU 551; *trap-zone J*, elk moved from north to west commonly leaving the Basin into GMUs 53 and 63. Directions moved by MCA were similar to AF and FCA for each trap-zone but MCA often traveled further outside the Basin into adjoining GMUs including one long-distance movement south across Hwy 50 into GMUs 76 and 79 (Figs. 15, 21).

From 37% to 55% of elk in each class ventured into GMUs outside the Gunnison-North area during their seasonal movements with estimated rates of dispersion similar for MMV and MCP metrics (Table 13). However, MCP documented elk moving into GMUs not detected by MMV probably because MMV were limited to one data point per elk whereas MCP incorporated multiple data points per elk. Estimated rates of movement to outside GMUs were highest for MCA and FCA. Movements were most frequent to the west and northwest into GMU 53 by AF, FCA, and MCA primarily by elk from trap-zones I and J (Figs. 13-15). MCA demonstrated a greater tendency to venture into more outside GMUs than did AF or FCA (Table 13). One elk from each of the AF, FCA, and MCA classes moved south and crossed Hwy 50 between Gunnison and Sargents, Colorado indicating up to 5% of the Gunnison-North elk may move south across Hwy 50 (Table 13). For MCA, 38% of the legal hunting harvest (6 of 16) occurred in outside GMUs, primarily in 63, 53, and 521 (Fig. 27).

Maximum distances (MMV) moved were similar among elk classes ($F = 1.08_{2, 83}$, $P = 0.342$) and averaged 32.3 km for AF, 37.6 km for FCA, and 38.5 km for MCA (Table 14). Extreme distances moved were 111 km by MCA and 65 km for FCA. Young male and female elk, as expected, were responsible for longest movements likely reflecting aspects of dispersal or exploratory behavior and therefore, most likely to promote genetic interchange with other elk populations. Maximum distances (MMV) moved by all classes of elk occurred primarily during summer (67-70%) and fall (12-21%) and probably reflected migrations to summer ranges and possibly, responses to hunting seasons during fall. Maximum movements that occurred during winter for FCA and MCA (6-7%) usually indicated elk moved to winter ranges distant from the original trap-site winter range which occurred more rarely for adult females (Table 15).

Overall, MMV and MCP of all elk revealed a progressive interaction among spatially adjoining segments of the elk population from east to west but with little interchange between extreme eastern and western segments of elk inhabiting areas north of Hwy 50 (Figs. 13-15, 19-21). Somewhat discrete movement patterns suggested that segments of the elk population could be specifically targeted for harvest in specific geographic areas either during regular or late hunting seasons. Also, elk movements indicated corridors of interaction between Basin elk and elk populations to the east, north, and west. Notably, comparable studies of elk movements on the Grand Mesa (Freddy 1997, 1998) and Gunnison Basin (this project) have documented interchange between these large elk populations involving both male and female elk that moved between populations via corridors in GMUs 53 and 521 that would allow for genetic linkage of elk in GMUs 54 and 55 (Gunnison Basin) with elk in GMU 42 (Grand Mesa) south of Rifle, Colorado.

Comparisons with Previous Studies.-- From 1978 through 1981, distribution and movements of elk in the north-central portion of the Gunnison Basin were documented by 2 graduate student projects (Young 1982, Wright 1983). These graduate projects were prompted by proposals to construct a large molybdenum mine complex north of Gunnison (not constructed as of 2003) and focused on elk inhabiting areas north of U.S. Highway 50 between Quartz Creek on the east and Soap Creek on the west, which equated to portions of Gunnison Elk-North or trap-zones G-J (Fig. 1) in the current elk project. Both of these projects obtained spatially precise aerial relocations of radio-collared elk which provided detailed summaries of areas and movement corridors used by elk. Information from these projects plus the current project documented patterns in elk movements that apparently have persisted for at least 20 years. Here, I briefly summarize these patterns. For reference, I summarized results of these graduate projects according to the definitions of seasons used in the current elk project: Winter - 1 December-31March;

Spring - 1 April-30 May; Summer - 1 June-30 August; Fall - 1 September-30 November; and, June was considered to be inclusive of calf birthing and rearing.

Gunnison Elk-North 1978-1981.-- During winters 1978-79 and 1979-80, snow depths approaching 1 m on some winter ranges along with cold temperatures prompted emergency feeding of mule deer and elk and these conditions constrained areas used by elk (Young 1982) much more so than during 2000-2003. In spite of these harsh winter conditions, areas used by elk as outlined by Young (1982:44, 45) were remarkably similar to areas used by elk in winters 2000-2003, allowing for elk to be at slightly higher elevations because of comparably reduced snow depths during winters 2000-2003 (Figs. 5-7). Areas used during winter by elk as noted by Young (1982:39-42, 44-45) within trap-zones of the current project were: *trap-zone G*, lower Cabin Creek and Sewell Gulch, and the Almont Triangle; *trap-zone H*, areas west and southwest of Flattop Mountain; *trap-zone I*, lower Steuben and Beaver creeks; and *trap-zone J*, lower Red Creek and Dillon Mesa.

During spring 1979 and 1980, above average snow depths likely retarded or hindered movements of elk from winter areas to areas used during spring. However, descriptions of areas used in spring 1979 and 1980 were similar to observations in 2000-2003 (Young 1982:39-42, 51-52) (Figs. 5-7). Areas used during spring (Young 1982) within the current trap-zones were: *trap-zone G*, upper Cabin creeks and Lost Canyon Gulch and from the Almont Triangle to Round Mountain; *trap-zone H*, west and north of Flattop Mountain along with the western slopes of Red Mountain; *trap-zone I*, from Beaver Creek northeast through Antelope and Mill creeks; *trap-zone J*; areas near Red Creek. During April and May, Young (1982:32-35) found elk to make noticeable movements upward in elevation as was also observed during 2000-2003 (Freddy 2002:205). Corridors used by elk during these movements in spring towards summer areas as described by Young (1982:46-50) were similar to general movements observed during the current project. Spring movement corridors according to Young (1982) within current trap-zones were: *trap-zone G*, from Cabin creeks and Lost Canyon Gulch into Beaver-East Beaver creeks, from Beaver-East Beaver creeks north into upper Spring Creek, Matchless Mountain, Italian creeks, and upper Taylor River, and to areas east and northeast in Union Park and Taylor Park, and then also from Almont Triangle north to Brush Creek; *trap-zone H*, from Flattop Mountain north to Red Mountain and onto Mt. Axtell, Gibson Ridge and Whetstone Peak with some elk moving towards Kebler Pass; *trap-zone I*, from Beaver Creek north to Mill, Castle, and Pass creeks; *trap-zone J*, from Red Creek west and north into Soap Creek.

During summer, areas used by elk as documented by Young (1982:39-42) and Wright (1983:39, 41) were similar to areas used during summers 2000-2003 (Figs. 5-7). Areas used according to Young (1982) and Wright (1983) within current trap-zones were: *trap-zone G*, an extensive area from Fossil Ridge to Taylor Park, to upper Taylor River and Italian creeks, and to Brush creeks near the town of Gothic; *trap-zone H*, from Red Mountain to Mt Axtell and Whetstone Peak and near Ohio and Kebler passes; *trap-zone I*, areas in upper Beaver, Mill, Castle, and Pass creeks and upper Anthracite Creek; *trap-zone J*, upper Soap and West Elk creeks and north into Robinson, Kaufman, and Cliff (GMU 53) creeks. Most drainages on the eastern and western flanks of the West Elk Mountains were used by elk in summer according to Young (1982) and Wright (1983). Both Young (1982:30-35) and Wright (1983:31-37) documented elk at highest elevations in sub-alpine and alpine areas from late June to early August which was similar to observations in 2000-2003 (Freddy 2002:205).

Areas used and associated with calving during June as noted by Young (1982:39-42) and outlined by Wright (1983:25, 30) were similar to distribution of elk in June 2000-2003 (Fig. 11). Areas used by elk (Young 1982, Wright 1983) within current trap-zones were: *trap-zone G*, a large diffuse area inclusive of Beaver-East Beaver creeks, Fossil Ridge, Union Park, Taylor Park, Italian creeks, Brush creeks, and Spring Creek with observations in 1979 and 1980 (Young 1982) suggesting elk calved in areas near Round Mountain near Almont, Rosebud Gulch of Spring Creek, and areas near Matchless mountains possibly because melting of the snow-pack was delayed by cooler temperatures and overall greater snow-depths resulting in elk moving shorter distances in these years than in 1981 (Wright 1983) or 2000-2003 (Fig. 11); *trap-zone H,* Red Mountain, especially the western slopes, and Mt. Axtell north to Coal Creek; *trap-zone I*, from upper Antelope creeks, through Mill, Castle, and Pass creeks to Swampy Pass; *trap-zone J*, upper West Elk Creek, areas near Big Soap Park and Soap Basin in upper Soap Creek, and north into Kaufman and Robinson creeks (GMU 53).

During fall, Wright (1983) focused attention on distribution and movements of elk in relation to timing of hunting seasons. During fall 1980 and 1981(Wright 1983:124-137), distribution of elk encompassed an extensive area including portions of summer, spring, and upper winter ranges similar to observations in 2000-2003 (Figs. 5-7). Straight-line distances traveled by elk and downward shifts in elevations used by elk were most pronounced during and following the first rifle elk season (≈ 10-20 October, Wright 1983:142-147). In response to rifle seasons, areas that elk moved into (Wright 1983) within current trap-zones were: *trap-zone G*, from upper Taylor River and Italian creeks south into Spring Creek, Matchless mountains, and Beaver-East Beaver creek, and from Taylor and Union parks southwest into Beaver-East Beaver creeks; *trap-zone H*, from Mt. Axtell and Whetstone Peak south to Red and Flattop mountains; *trap-zone I*, from Pass and Castle creeks south into Mill, West Antelope, and Beaver creeks; *trap-zone J*, from Kaufman Ridge and Cliff Creek (GMU 53) south into Cow and Coal creeks of lower Soap Creek and West Elk Creek. The tendency for elk in trap-zone G to make long movements during rifle seasons to areas associated with Beaver-East Beaver creeks (Wright 1983) remained apparent in 2000-2003 (Figs. 5-7).

Movement corridors used during spring and fall by elk as illustrated by Wright (1983:56, 59) and noted by Young (1982) agreed with observations in 2000-2003. Within the current *trap-zone G*, Wright (1983:59) noted multiple movement corridors for fall movements. Elk from upper Taylor River, Italian creeks, upper East River and Brush creeks moved south via portions of Spring and Roaring Judy creeks to the Almont Triangle and Beaver-East Beaver creeks while elk from northeast and southeast of Taylor Park Reservoir moved through Matchless mountains or Lottis creeks into Crystal Creek and eventually to Beaver-East Beaver creeks and on south into Cabin creeks. Both of these corridors required elk to cross the Taylor River canyon and highway between Almont Triangle and Crystal Creek. In *trap-zone H*, Wright (1983:56) showed elk moving relatively short distances from Mt. Axtell, Gibson Ridge, and Whetstone Peak south to areas around Flattop Mountain which was also documented by Young (1982). In *trap-zone I*, elk moved from Swampy Pass and Pass Creek of upper Ohio Creek south through Castle, Mill, and Antelope creeks to reach winter ranges in lower Antelope and Beaver creeks. In *trap-zone J*, elk moved from Robinson and Cliff creeks (GMU 53) south through upper Soap Creek and down Soap and West Elk creeks to winter ranges associated with lower Soap, Red, and West Elk creeks. Young (1982:87) described similar corridors for both spring and fall movements of elk in trap-zones I and J as areas flanking the west and east sides of the West Elk Mountains that were often associated with aspen vegetation.

Differences among Projects 1978-1981 and 2000-2003.-- Distribution and movements of elk documented by Young (1982) and Wright (1983) were primarily based on movements of adult female elk. The current study (Freddy 2002) benefited from capturing elk over a broader range of trap-sites the within Gunnison Elk-North area that were located from Tomichi Dome on the east to Soap Creek on the west (Fig. 1) and from radio-collaring 6-month old male and female calves in addition to radio-collaring adult female elk. These calves, as they became 12-18 months of age, were responsible for many of the wide-ranging movements that indicated Gunnison Elk-North interacted with elk in areas to the east, north, and west of the main Gunnison Basin (GMUs 56, 481, 48, 471, 43, 521, 53, 63, Table 13, Figs. 13-15, 19-21). This interchange was likely also occurring, at least to some degree, from 1978 to 1981, but Young (1982) and Wright (1983) may have been less able to document such movements because adult female elk were less likely to disperse to out-lying areas. However, as was observed in 2000-2003, Wright (1983:23) documented interchange in the upper Taylor River with elk to the north in GMUs 43 or 471 and noted movements of elk north during summer into GMU 53 (Kaufman Ridge) while Young (1982:61) noted elk moving into upper Anthracite creek (GMU 521). Neither author documented movement of elk to the west into GMU 63 as was observed in 2000-2003.

Gunnison Elk-South.-- AF, FCA, and MCA remained exclusively south of Hwy 50 during all seasons. We did not detect movement to the north across Hwy 50 by elk from trap-zones A through E. AF and FCA leaving the Basin were detected in GMU 65 to the west, GMU 76 to the south, and GMUs 68 and 681 to the east (Figs. 8, 9). MCA generally stayed within the Basin except for some movement into adjoining GMUs 68 and 681 to the east and 76 to the south (Fig. 10).

Areas used during winter by elk within each trap-zone were: *trap-zone A*, areas west and adjacent to the Lake Fork of the Gunnison River including Willow Mesa to upper Willow and Little Willow creeks and Round Mountain, Campbell to Narrow Grade and Elk creeks, Well Gulch to Bill Hare Gulch, with some female elk using areas in adjoining GMU 65 in the lower Cimarron River associated with the Cimarron State Wildlife Area and in Cow and Owl creeks east of Ridgway; *trap-zone B*, Carpenter Ridge to Kezar Basin and lower Wolf Creek with adjoining areas in lower Cebolla Creek, areas east and adjacent to the Lake Fork of the Gunnison River including Lake Gulch, Red Bridge to Dutch Gulch, and adjoining lower elevations of Indian Creek, Yeager Gulch, Trout, Skunk, Fourth of July, and Devils creeks, Sparling Gulch near Lake City, Colorado, lower Powderhorn Creek, and Calf and Rough creeks of upper Cebolla creek with disjunct activity in Shallow and Fir creeks near Creede, Colorado to the south in adjoining GMU 76; *trap-zone C*, mid-lower elevations from South Beaver Creek west through Pole, Sugar, Camp, and Willow creeks, and Huntsman Mesa and Willow Creek south into the Road Beaver creeks; *trap-zone D*, lower and upper Long Gulch including Dutch Gulch and Green Mountain, lower Bead Creek to Rock Creek, Alkali Creek to Homestead Gulch, Poison Ridge to Cold Spring and Burro parks, and Cochetopa Dome with some elk venturing east into lower Sheep, Fourmile, and branches of Luders creeks in adjoining GMUs 68 and 681; *trap-zone E*, areas surrounding Table Top Mountain, Camp Kettle Gulch, lower elevations of Razor Creek and adjoining northwest, west, and southwest portions of Razor Dome, and lower elevation branches of Home, Myers, Wolverine and Stag gulches (Figs. 8-10).

Areas used during spring by elk within each trap-zone were: *trap-zone A*, areas west of the Lake Fork of the Gunnison River in upper Little Willow and Willow creeks and from Dwyer Gulch to Elk Creek, areas adjacent to Blue Mesa and lower Little Blue creeks along with lower Pine Creek, and areas near the Cimarron State Wildlife Area to the west in GMU 65 with suspected movement corridors from Elk Creek into Big Blue Creek and from Willow Mesa west towards Blue Mesa and then south towards the Alpine Plateau; *trap-zone B*, east of the Lake Fork of the Gunnison River from lower Indian Creek to Yeager Gulch and Trout Creek, Big Buck Creek to Fourth of July and Devils creeks, and lower Calf Creek and Fish Canyon Ridge in upper Cebolla Creek with suspected movement corridors from Fourth of July Creek to Waterdog Lake and then east to Calf Creek Plateau or south into Rambouillet Park; *trap-zone C*, upper Sugar Creek to lower Camp Creek, Willow Creek from Soderquist Reservoir to Rock Creek Park, and Rock Creek and Summit parks; *trap-zone D*, Alkali Creek to Homestead Gulch, areas adjacent to Sorro and Elk Parks, Cochetopa Dome and Park; *trap-zone E*, areas south of Razor Dome and into Home Gulch, Razor Creek lower to upper parks, branches of Barret and Needle creeks, lower Dutchman and Hicks creeks with a suspected movement corridor from Razor Creek to Long Branch Creek (Figs. 8-10).

Areas used during summer by elk within each trap-zone were: *trap-zone A*, Blue Mesa along with segments of lower Pine, Little Blue, and Middle Blue creeks, upper Willow, Pine, and Little and Middle Blue creeks along the Alpine Plateau, alpine and sub-alpine areas of upper Big Blue and Fall creeks, upper El Paso and Nellie creeks and Sunshine and Gravel mountains in Henson Creek, and High Mesa and Firebox Creek areas of the Little Cimarron River in adjoining GMU 65 used by some female elk; *trap-zone B*, upper Fourth of July and Devils creeks, upper Trout Creek, Waterdog Lake area, Cannibal Plateau, Calf Creek Plateau, Calf, Brush, and Deer creeks, and in adjoining GMU 76 in upper West Willow and Rat creeks north of Creede, Colorado, Rito Hondo and Big Buck creeks and Pole Creek Mountain in the upper northwestern portions of the Rio Grande River; *trap-zone C*, upper East Beaver, Deer Beaver, Monument, and South Beaver creeks, and upper Rock and Monument Rock creeks; *trap-*

zone D, Pauline Creek west through Elk and Blue parks to Los Pinos Pass and upper branches of Los Pinos Creek with some elk moving east into upper Luders and East Pass creeks in adjoining in GMU 68; *trap-zone E*, upper Home Gulch-Green Mountain, areas adjacent to lower and upper Razor Creek parks, branches of upper Needle Creek, lower to upper Long Branch creek, and upper Indian and Marshall creeks (Figs. 8-10).

Areas receiving use by female elk in June (Fig. 12) that should receive further surveillance as to their importance to elk reproduction were: *trap-zone A*, Blue Mesa and lower Big, Middle, and Little Blue creeks and adjoining Pine Creek, subalpine in upper Big Blue Creek; *trap-zone B*, Waterdog Lake area, mid- to upper elevations of Calf and Brush Creeks and Calf Creek Plateau; *trap-zone C*, upper portions of Monument, Rock, and Monument Rock creeks; *trap-zone D*, Sorro to Blue parks in Pauline Creek; *trap-zone D*, areas near lower and upper Razor Creek parks.

Distribution of elk in the fall was diffuse, again likely because of hunting seasons, but there were some areas of focused use: *trap-zone A*, lower Pine and Little Blue creeks near Blue Mesa, and upper Big Blue and Fall creeks; *trap-zone B*, Trout Creek and Yeager Gulch; *trap-zone C*, East Beaver Creek; *trap-zone D*, Elk Park to Los Pinos Pass, upper Alkali Creek and Homestead Gulch; *trap-zone E*, Long Branch Creek, Razor Creek parks, and upper Home Gulch to Green Mountain with some indication that elk in this trap-zone were prone to move sooner to areas near winter ranges (Figs. 8-10).

Maximum movement vectors (MMV) and MCP revealed patterns of movement for the elk population south of Hwy 50. Directions moved by AF and FCA for each trap-zone were (Figs. 16, 17, 22, 23): *trap-zone A*, elk moved west, southwest, and east with some activity outside the Basin in adjoining GMU 65 ; *trap-zone B*, elk moved primarily south to west with activity into adjoining GMUs 65 and 76; *trap-zone C*, elk moved southeast to southwest with movements outside the Basin into adjoining GMUs 65 and 76; *trap-zone D*, elk moved southeast to southwest with movement into adjoining GMUs 68 and 76; *trap-zone E*, elk moved from east to southwest with some activity into GMUs 681 and 68. Directions moved by MCA were similar to AF and FCA for each trap-zone with MCA in trap-zone C exhibiting the widest array of directions moved (Figs. 18, 24). Travel by MCA outside the Basin was east into adjoining GMUs 681 and 68 and south into GMU 76.

From 25% to 62% of the elk ventured into GMUs outside of the Gunnison-South area during their seasonal movements with estimated rates of dispersion higher for MCP than MMV (Table 13). Movements to the east and west by AF, FCA, and MCA into GMUs 68 and 681, and 65, respectively, were most frequent and associated with elk from all trap-zones A-E (Figs. 16-18). MCA and FCA demonstrated a greater tendency than AF to venture into outside GMUs (Table 13). No elk were detected north of Hwy 50 indicating that ≈0% of the Gunnison-South elk move north across Hwy 50 (Table 13).

Maximum distances (MMV) moved were similar among elk classes ($F = 0.052_{2, 46}$, $P = 0.949$) and averaged 34.8 km for AF, 33.4 km for FCA, and 34.8 km for MCA (Table 14). Extreme distances moved were 62.5 km by MCA and 78.5 km for FCA. Young male and female elk were again responsible for longest movements. Maximum distances (MMV) moved by all classes of elk occurred primarily during summer (42-57%) and fall (8-25%), again reflecting migrations to summer ranges and potential responses to hunting seasons during fall. Maximum movements that occurred during winter for FCA and MCA (19-33%) usually indicated elk moved to winter ranges distant from the original trap-site winter range (Table 15).

Observed elk movements indicated a mixing and continuous flow of elk from east to west among adjoining segments of the elk population within GMUs 67 and 66 (DAU E-25) and some interaction among elk in GMU 67 with elk to the east in the adjoining southern half of GMU 551 (DAU E-43) and among elk in GMU 67 with elk to the west in GMU 65 (Figs. 16-18, 22-24). Elk trapped in GMU 551 south of Hwy 50 remained within the southern portion of GMU 551 or associated with elk in GMUs 681, 68, and 67 rather than interacting with elk north of Hwy 50. Movements indicated interaction among elk in the Basin south of Hwy 50 with elk in GMUs 681, 68, 76, and 65.

Elk Distribution and DAU Boundaries.-- Distribution and movements of Gunnison Basin elk provide a basis for assessing the adequacy of current DAU boundaries. DAU boundaries reflect attempts to compartmentalize elk into populations that can be managed as relatively closed demographic units based on patterns of elk distribution and harvest while GMU boundaries serve primarily to distribute hunter numbers and hunting effort among segments of elk populations.

Dividing the Basin into DAUs north and south of Hwy 50 could be considered as interchange of elk across this highway was low. Merging DAU E-43 with DAU E-41 north of Hwy 50 could be considered as there was a continuous mixing of elk from east to west across this geographic area. Additionally, the interaction with elk in GMUs 53 and 63 suggest these areas to the northwest and west of the Gunnison Basin could be incorporated into one large DAU that would merge elk in the North Fork of the Gunnison River with elk in the Gunnison Basin.

Historically, Young (1982:65) and Wright (1983:23) concluded there were 3 sub-populations of elk (noted as EA, DA, WA) in the area of their studies within the Gunnison Elk-North area. These sub-populations, defined from east to west, were bounded by: from Quartz Creek west to the East and Gunnison rivers (EA) which corresponded to current trap-zone G; from the East and Gunnison rivers west to Ohio Creek (DA), which corresponded to current trap-zone H; and, from Ohio Creek west to Soap Creek (WA), which corresponded to current trap-zones I and J (see Fig. 1). Interchange of marked elk among these 3 sub-populations was low and the interchange that did occur was primarily during hunting seasons when elk were disturbed by human activity (Young 1982, Wright 1983). Wright (1983:179) recommended creating a separate GMU for the DA area (trap-zone H) to allow for more specific population management. Movements and distribution of elk during 2000-2003 tended to reinforce this general pattern of interchange among sub-population areas except that the current study documented more interchange on summer ranges in the north-central portion of the Gunnison Basin (Crested Butte to Kebler Pass) between elk trapped in trap-zone H with elk trapped in either trap-zones G or I (Figs. 13-15, 19-21). Young (1982:60) also showed some overlap during summer in the Kebler Pass area between current trap-zone H and I elk. Although some spatial separation does continue to exist among these 3 sub-populations of elk, current distribution and movements of elk north of Hwy 50 would suggest that all 3 sub-populations should be in the same meta-DAU population (Figs. 19-21).

Current DAU boundaries for elk south of Hwy 50 could be modified to add GMU 551 south of Hwy 50 to E-25. Consideration should be given to adding GMU 65 or the Cimarron River portion of this unit to DAU E-25.

Distribution of Elk Mortalities.--Mortalities of calves ($n = 21$) were scattered throughout the Basin (Fig. 25, Appendices A, B, Freddy 2002). Incidents of predation or suspected predation were often associated with mountain lions and frequently occurred within spatial proximity of each other within trap-zones A, B, C, and J. Incidents of malnutrition were detected in trap-zones A, F, I, and J. Clustering of 4 mortalities in lower Soap-Coal creeks (trap-zone J) was associated with mountain lion activity.

Mortalities of adult females ($n = 40$) were almost exclusively due to hunting (95%) and were scattered throughout the Basin (Fig. 26, Appendix C). Relative clustering of hunting mortalities occurred in southwestern portion of trap-zone G involving Cabin, East Beaver, Lost Canyon creeks, and in trap-zone F from Yellow Pine ridge to Lookout Mountain. Notable outlier deaths occurred in GMU 681 to the southeast, GMU 76 to the south, and GMU 63 to the west. The 1 incident of predation was attributed to mountain lion which occurred in proximity to lion predation on a calf (trap-zone E, Figs. 25, 26).

Mortalities of adult males ($n = 26$) were primarily due to hunting (88%) and occurred mainly in trap-zones G through J and north of Hwy 50 (Fig. 27, Appendix C). Adult males were harvested outside the Basin in adjacent northern GMUs 63, 53, and 521. Notable outlier deaths occurred in GMU 48 to the northeast, GMU 681 to the southeast, and GMU 411 to the northwest. Clustering of hunting mortalities occurred in areas near East Beaver-Cabin creeks in trap-zone G. Four of five illegal hunting incidents involving yearling male elk occurred in trap-zone G and all deaths involving suspected predation by bears or mountain lions (n = 3) occurred in trap-zone G (Fig. 27).

SUMMARY

Natural survival rates for adult elk in the Gunnison Basin were ≥97% for females and ≥90% for males for all elk ages and seasonal intervals examined between December 2000 and June 2003 with results mimicking natural survival rates estimated for elk on Grand Mesa during 7 consecutive years from 1993 to 2000. Hunting removal rates on adult females increased in 2002 over 2001 reflecting attempts to liberalize the harvest of antlerless elk. In 2002, the adult female removal rate of 23% likely stabilized or reduced population growth for one year. The illegal harvest/wounding loss rate of 13% on yearling spike-antlered elk was similar to the 11% rate documented for yearling male elk on Grand Mesa. Wounding loss on adult females was 44% and commensurate with the high rate of 25-30% documented on Grand Mesa. Assessments of adult female elk body condition suggested marginally deficient levels of nutrition during 2002. Distribution and movements of radio-collared elk suggested DAU population boundaries might be altered. Patterns of dispersion suggested movement corridors that would allow for genetic linkage between Gunnison Basin and other elk populations.

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Table 1. Number of male (M) and female (F) calf and adult female elk radio-collared in each DAU and trap-zone in the Gunnison Basin, December 2000 and 2001.

		Calf Elk Collared									Adult Female Elk			Total Elk	
		2000			2001			2000-01			Collared			Collared	
DAU-(GMUs)	Trapzone	M	F	Total	M	F	Total	M	F	Total	2000	2001	2000-01	2000	2001
E-25 (66, 67)	A - Lake Fork	4	7	11	2	4	6	6	11	17	5	1	6	16	7
	B - Cebolla	3	4	7	2	0	2	5	4	9	3	2	5	10	4
	C - Huntsman	4	1	5	6	6	12	10	7	17	3	2	5	8	14
	D - Sawtooth	2	1	3	2	4	6	4	5	9	2	1	3	5	7
subtotals E-25		13	13	26	12	14	26	25	27	52	13	6	19	39	32
E-43 (55, 551)	E - Razor	1	2	3	1	5[a]	6	2	7	9	2	1	3	5	7
	F - Tomichi	4	1	5	3	3	6	7	4	11	3	0	3	8	6
	G - Almont	7	11	18	11	5	16	18	16	34	8	2	10	26	18
subtotals E-43		12	14	26	15	13	28	27	27	54	13	3	16	39	31
E-41 (54)	H - Flat Top	2	4	6	3	3	6	5	7	12	4	1	5	10	7
	I - Beaver	4	6	10	3	4	7	7	10	17	4	0	4	14	7
	J - West Elk	7	3	10	7	6	13	14	9	23	5	2	7	15	15
subtotals E-41		13	13	26	13	13	26	26	26	52	13	3	16	39	29
Totals	All Subtotals	38	40	78	40	40	80	78	80	158	39	12	51	117	92

[a] Includes 2 female calves that died of capture-induced causes within 24 hours of capture for which 2 additional female calves were captured from the same area and radio-collared prior to completing capture of all elk. The net beginning sample size was therefore11 female calves for estimating survival rates in DAU E-43 in 2001.

Table 2. Numbers and proportions (%) of adult female and calf elk counted within geographic trap-zones (TZ) in relation to numbers and proportions (%) of radio-collared adult female and calf elk captured within trap-zones in elk DAUs E-25, E-43, and E-41 and DAUs combined in the Gunnison Basin. Counts of elk represent total adult females and total calves counted during elk sex and age classification helicopter flights conducted post-harvest during December-January for years 1995-96, 1997-98, and 1999-2000 combined. Elk captured in December 2000 and 2001.

	DAU E-25				
Elk Class	TZ - A	TZ - B	TZ - C	TZ - D	DAU-Total
Adult Females-Counted	1,553 (34)	1,113 (24)	1,366 (30)	569 (12)	4,601 (100)
Adult Females-Captured	6 (32)	5 (26)	5 (26)	3 (16)	19 (100)
Calves-Counted	660 (33)	504 (25)	647 (32)	180 (9)	1,991 (100)
Calves-Captured	17 (33)	9 (17)	17 (33)	9 (17)	52 (100)

	DAU E-43			
Elk Class	TZ - E	TZ - F	TZ - G	DAU-Total
Adult Females-Counted	634 (11)	1,133 (20)	3,860 (68)	5,627 (100)
Adult Females-Captured	3 (19)	3 (19)	10 (62)	16 (100)
Calves-Counted	302 (11)	633 (23)	1,847 (66)	2,782 (100)
Calves-Captured	9 (17)	11 (20)	34 (63)	54 (100)

	DAU E-41			
Elk Class	TZ - H	TZ - I	TZ - J	DAU-Total
Adult Females-Counted	1,120 (21)	2,134 (40)	2,039 (39)	5,293 (100)
Adult Females-Captured	5 (31)	4 (25)	7 (44)	16 (100)
Calves-Counted	535 (23)	939 (40)	903 (38)	2,377 (100)
Calves-Captured	12 (23)	17 (33)	23 (44)	52 (100)

	DAUs			
Elk Class	DAU E-25	DAU E-43	DAU E-41	DAUs-Total
Adult Females-Counted	4,601 (30)	5,267 (35)	5,293 (35)	15,161 (100)
Adult Females-Captured	19 (37)	16 (31)	16 (31)	51 (100)
Calves-Counted	1,991 (28)	2,782 (39)	2,377 (33)	7,150 (100)
Calves-Captured	52 (33)	54 (34)	52 (33)	158 (100)

Table 3. Survival rates during winter-spring (WS), summer-fall (SF), and annual (Ann) seasonal intervals from 15 December 2000 to 14 June 2003 for adult female elk age ≥24 months (mos.) and ≥12 months that were radio-collared in December 2000 and 2001 in the Gunnison Basin, Colorado. Survival rates include all sources of mortality. Survival rates and confidence limits calculated using binomial estimator based on *n*-collars that excluded censored elk. All radioed elk combined among DAUs E-25, E-41, and E-43.

	Seasonal Survival Intervals and Dates						
	WS	SF	Ann	WS	SF	Ann	WS
	12/15/00 - 06/14/01	06/15/01- 12/14/01	12/15/00- 12/14/01	12/15/01- 06/14/02	06/15/02- 12/14/02	12/15/01- 12/14/02	12/15/02- 06/14/03
FEMALES (age ≥ 24 mos.)							
Survival Rate	1.00	0.92	0.92	1.00	0.74	0.69	0.98
Lower 95% CL		0.84	0.84		0.65	0.55	0.95
Upper 95% CL		1.00	1.00		0.84	0.82	1.00
n Collars	39[a]	39[a]	39[a]	48[b]	82[c]	48[b]	61[d]
Collars Deployed	39	39	39	48	82	48	61
Collars Censored	0	0	0	0	0	0	0
Died	0	3[e]	3[e]	0	21[f]	15[f]	1[g]
Non-hunting Deaths	0	1	1	0	0	0	1
Hunting Deaths	0	2	2	0	21	15	0
FEMALES (age ≥ 12 mos.)							
Survival Rate	1.00	0.91	0.92	1.00	0.77	0.74	0.99
Lower 95% CL		0.84	0.84		0.69	0.65	0.96
Upper 95% CL		0.97	1.00		0.85	0.84	1.00
n Collars	39[a]	77[h]	39[a]	82[i]	112[j]	82[k]	86[l]
Collars Deployed	39	77	39	82	113	82	86
Collars Censored	0	0	0	0	1[n]	0	0
Died	0	7[m]	3[e]	0	26[f]	21[f]	1[g]
Non-hunting Deaths	0	1	1	0	0	0	1
Hunting Deaths	0	6	2	0	26	21	0

[a] Includes only adult females age ≥ 30 months radio-collared 16-22 December 2000 as there were no females age 18 months radio-collared at time of initial capture and radio-collaring.

[b] Includes 12 additional adult females age ≥ 30 months radio-collared 16-20 December 2001.

[c] Includes 34 females age 24-29 months recruited from surviving radioed calves and 48 females age ≥36 months.

[d] Includes 28 females age 30-35 months recruited from surviving radioed calves and 33 females ≥42 months.

[e] Adult female deaths: 172.758/00 in early July of unknown causes, 172.030/00 archery/muzzleloading wounding loss, and 174.478/00 harvested first rifle season.

[f] See Appendix C for listing of hunting and non-hunting mortalities for adult radio-collared elk.

[g] Female 174.629/01 died early May from mountain lion predation.

[h] Includes 38 females age 12-17 months recruited from surviving radioed calves and to 39 females age ≥36 months.

[i] Includes 34 females age 18-23 months recruited from surviving radioed calves and 48 females age ≥ 30 months.

[j] Includes 31 females age 12-17 months and 34 females age 24-29 months recruited from surviving radioed calves and 48 females age ≥36 months.

[k] Includes 34 females age 18-29 months recruited from surviving radioed calves and 48 females ≥30 months.

[l] Includes 25 females age 18-23 months and 28 females age 30-35 months recruited from surviving radioed calves, and 33 females age ≥42 months.

[m] Adult female deaths:172.758/00 in early July of unknown causes, 172.030/00 archery/muzzleloading wounding loss, 174.478/00 harvested first rifle season, 172.619/00 and 174.360/00 wounding loss first and fourth rifle seasons, respectively, and 173.589/00 and 174.560/00 disappeared late and third rifle seasons, respectively.

[n] Censored elk 173.681/01 mid-July for slipped collar.

Table 4. Survival rates during winter-spring (WS) and summer-fall (SF) seasonal intervals from 15 December 2000 to 14 June 2003 for the cohort of 6-month old elk calves radio-collared in December 2000 in the Gunnison Basin, Colorado. Survival rates include all sources of mortality. Survival rates and confidence limits calculated using binomial estimator based on *n*-collars that excluded censored elk. All radioed elk combined among DAUs E-25, E-41, and E-43.

	Elk Age In Months (mos.) and Seasonal Intervals and Dates						
	6-11 mos.	12-17 mos.	18-23 mos.	6-23 mos.	24-29 mos.	30-35 mos.	6-35 mos.
	WS	SF	WS	All Intervals	SF	WS	All Intervals
MALES	12/15/00 - 06/14/01	06/15/01- 12/14/01	12/15/01- 06/14/02	12/15/00- 06/14/02	06/15/02- 12/14/02	12/15/02- 06/14/03	12/15/00- 06/14/03
Survival Rate	0.78	0.86	1.00	0.66	0.74	1.00	0.48
Lower 95% CL	0.63	0.71		0.48	0.52		0.29
Upper 95% CL	0.93	1.00		0.84	0.95		0.67
n Collars	32	22	19	29	19	14	29
Collars Deployed	38	25	19	38	19	14	38
Collars Censored	6[a]	3[b]	0	9	0	0	9
Died	7	3	0	10	5	0	15
Non-hunting Deaths	7[c]	2[d]	0	9	0	0	9
Hunting Deaths	0	1[e]	0	1	5[f]	0	6
FEMALES							
Survival Rate	0.97	0.89	1.00	0.87	0.82	1.00	0.72
Lower 95% CL	0.92	0.79		0.76	0.69		0.57
Upper 95% CL	1.00	0.99		0.98	0.96		0.86
n Collars	39	38	34	39	34	28	39
Collars Deployed	40	38	34	40	34	28	40
Collars Censored	1[g]	0	0	1	0	0	1
Died	1	4	0	5	6	0	11
Non-hunting Deaths	1[c]	0	0	1	0	0	1
Hunting Deaths	0	4[h]	0	4	6[i]	0	10

[a] Male calves censored: for post-capture induced mortality 173.082/00 on 12/29/00; for slipped collars 173.269/00 on 4/30/01, 173/170/00 on 5/7/01, 173.250/00 on 5/25/01, 173.151/00 and 173.220/00 on 6/7/01.

[b] Yearling males censored: slipped collars, 173.091/00, 173.391/00, and 173.510/00 between 6/22/01 and 7/20/01.

[c] See Appendix A for timing and estimated causes of calf deaths.

[d] Males 173.330/00 and 173.340/00 died during early July of suspected mountain lion and black bear predation.

[e] Yearling male 174.140/00 illegally wounded and died about 12/10/01 during late-season for antlerless elk.

[f] Harvested as branch-antlered males: 172.890/00 in first rifle season, 173.358/00, 174.200/00, 174.729/00, 174.800/00 in third rifle season.

[g] Female calf censored: for post-capture induced mortality 172.379/00 on 12/26/00.

[h] Yearling females 172.619/00 and 174.360/00 wounded during first and fourth rifle seasons, respectively and 174.560/00 and 173.589/00 disappeared during third rifle and late rifle seasons respectively, and assumed legally harvested.

[i] Females harvested: 172.230/00 first rifle season, 172.450/00 third rifle season, 172.529/00 and 174.520/00 wounding losses third rifle season, 174.910/00 and 172.540/00 disappeared in third rifle and late rifle seasons, respectively, and assumed legally harvested.

Table 5. Survival rates during winter-spring (WS) and summer-fall (SF) seasonal intervals from 15 December 2001 to 14 June 2003 for the cohort of 6-month old elk calves radio-collared in December 2001 in the Gunnison Basin, Colorado. Survival rates include all sources of mortality. Survival rates and confidence limits calculated using binomial estimator based on *n*-collars that excluded censored elk. All radioed elk combined among DAUs E-25, E-41, and E-43.

	Elk Age In Months (mos.) and Seasonal Intervals and Dates			
	6-11 mos.	12-17 mos.	18-23 mos.	6-23 mos.
	WS	SF	WS	All Intervals
MALES	12/15/01 - 06/14/02	06/15/02- 12/14/02	12/15/02- 06/14/03	12/15/01- 06/14/03
Survival Rate	0.84	0.82	0.95	0.64
Lower 95% CL	0.71	0.67	0.86	0.47
Upper 95% CL	0.96	0.97	1.00	0.81
n Collars	37	28	22	33
Collars Deployed	40	31	23	40
Collars Censored	3[a]	3[b]	1[c]	7
Died	6	5	1	12
Non-hunting Deaths	6[d]	0	1[e]	7
Hunting Deaths	0	5[f]	0	5
FEMALES				
Survival Rate	0.82	0.83	1.00	0.68
Lower 95% CL	0.69	0.69		0.52
Upper 95% CL	0.94	0.97		0.83
n Collars	38	30	25	37
Collars Deployed	40	31	25	40
Collars Censored	2[g]	1[h]	0	3
Died	7	5	0	12
Non-hunting Deaths	7[d]	0	0	7
Hunting Deaths	0	5[i]	0	5

[a] Male calves censored: for post-capture induced mortality 174.720/01 on 12/19/01; for slipped-collars, 174.099/01 on 5/20/02 and 175.221/01 on 6/3/02.
[b] Male yearlings censored: 173.170/01, 174.580/01, 174.690/01 for slipped-collars between 6/18 and 7/17/02.
[c] Male censored: 175.250/01 on 2/7/03 possible collar failure.
[d] See Appendix B for timing and estimated causes of calf deaths.
[e] Male died 173.949/01 early April suspected mountain lion predation.
[f] Male yearlings died: 173.041/01, 173.082/01, 173.091/01, 173.340/01, 174.380/01; all illegal harvests during Fall hunting seasons 2002.
[g] Female calves censored: for post-capture induced mortality 173.429/01 on 12/16/01 and 173.740/01 on 12/16/01.
[h] Female yearling censored: 173.681/01 for slipped-collar between 7/17 and 8/21/02.
[i] Female yearlings died: 172.519/01, 172.741/01, 173.210/01, 173.999/01, 174.019/01; all died during Fall 2002 hunting seasons as legal harvest.

Table 6. Survival rates for adult female elk age ≥30 months (mos.) and ≥12 months by DAU from 15 December 2000 to 14 June 2003. Elk assigned to a DAU based on being trapped within that DAU. Elk were radio-collared in December 2000 and 2001 in the Gunnison Basin, Colorado. Females age ≥30 months include only females originally radioed at that age and do not include recruitment of radioed calves surviving to older age classes. Females age ≥12 months include females originally radioed at age ≥30 months and recruitment of radioed calves surviving to age ≥12 months. Survival rates include all sources of mortality. Survival rates and confidence limits calculated using binomial estimator based on *n*-collars that excluded censored elk.

	Survival Rates by DAU for Multi-year Interval Dates						
	DAU E-25	DAU E-43	DAU E-41		DAU E-25	DAU E-43	DAU E-41
	12/15/00 - 06/14/03	12/15/00 - 06/14/03	12/15/00 - 06/14/03		12/15/00 - 06/14/03	12/15/00 - 06/14/03	12/15/00 - 06/14/03
FEMALES (age ≥ 30 mos.)				FEMALES (age ≥ 12 mos.)			
Survival Rate	0.58	0.50	0.81	Survival Rate	0.74	0.60	0.81
Lower 95% CL	0.34	0.234	0.61	Lower 95% CL	0.61	0.44	0.67
Upper 95% CL	0.82	0.766	1.00	Upper 95% CL	0.88	0.76	0.94
n Collars	19	16	16	*n* Collars	43	40	36
Collars Deployed	19	16	16	Collars Deployed	44	40	36
Collars Censored	0	0	0	Collars Censored	1	0	0
Died	8	8	3	Died	11	16	7
Non-hunting Deaths	1	0	1	Non-hunting Deaths	1	0	1
Hunting Deaths	7	8	2	Hunting Deaths	10	16	6

Table 7. Survival rates for adult male elk age 12-35 months (mos.) and age 12-23 months by DAU for intervals between 15 June 2001and 14 June 2003. Elk assigned to a DAU based on being trapped within that DAU. Elk were radio-collared as calves in December 2000 and 2001 in the Gunnison Basin, Colorado. Survival rates for age 12-35 months represent elk combined from 2 cohorts of yearlings of which 1 cohort advanced to age 24+ months and was subject to 1 hunting season as legal branch-antlered males. Survival rates for age 12-23 months represent elk combined from 2 cohorts of yearlings neither of were subject to hunting season as legal branch-antlered males during the time intervals summarized. Survival rates include all sources of mortality. Survival rates and confidence limits calculated using binomial estimator based on *n*-collars that excluded censored elk.

	Survival Rates by DAU for Multi-year Interval Dates						
	DAU E-25	DAU E-43	DAU E-41		DAU E-25	DAU E-43	DAU E-41
	6/15/01 - 6/14/03	6/15/01 - 6/14/03	6/15/01 - 6/14/03		6/15/01&02- 6/14/02&03	6/15/01&02- 6/14/02&03	6/15/01&02- 6/14/02&03
Males (age 12-35 mos.)				Males (age 12-23 mos.)			
Survival Rate	0.88	0.57	0.77	Survival Rate	0.88	0.70	0.94
Lower 95% CL	0.60	0.35	0.55	Lower 95% CL	0.60	0.50	0.83
Upper 95% CL	1.00	0.78	0.98	Upper 95% CL	1.00	0.90	1.00
n Collars	8	23	17	*n* Collars	8	23	18
Collars Deployed	12	24	20	Collars Deployed	12	24	20
Collars Censored	4	1	3	Collars Censored	4	1	2
Died	1	10	4	Died	1	7	1
Non-hunting Deaths	0	3	0	Non-hunting Deaths	0	3	0
Hunting Deaths	1	7	4	Hunting Deaths	1	4	1

Table 8. Dates of aerial surveys to determine survival status and general locations of radio-collared elk in the Gunnison Basin, January 2001 - December 2003. Seasons defined as: Winter - December-March; Spring - April-May; Summer - June-August; Fall - September-November.

Year	Total Flights	Season	Flight Dates (mm/dd)
2001	9	Winter	01/04, 01/24, 02/02, 02/16, 03/02, 03/19, 12/05, 12/27, 12/28
	5	Spring	04/13, 04/27, 05/10, 05/18, 05/25
	6	Summer	06/01, 06/07, 06/22, 07/13, 07,20, 08/21
	6	Fall	09/08, 09/25, 10/18, 10/30, 11/08, 11/16
	26	All	
2002	8	Winter	01/03, 01/09, 01/24, 02/07, 02/21, 03/06, 03/20, 12/19
	7	Spring	04/04, 04/19, 04/30, 05/10, 05/15, 05/20, 05/28
	6	Summer	06/03, 06/18, 06/19, 07/17, 08/08, 08/21
	3	Fall	10/01, 10/31, 11/19
	24	All	
2003	4	Winter	01/07, 02/07, 03/26, 12/19
	2	Spring	04/25, 05/21
	2	Summer	06/25, 06/26
	0	Fall	
	8	All	

Table 9. Male elk calves radio-collared in December 2000 and 2001 within each trap-zone whose estimated seasonal geographic locations were used to illustrate spatial distribution of young male elk in the Gunnison Basin, December 2000 - December 2003. Within each trap-zone, 100% of the calves were used to illustrate distribution. Maximum age of these elk in December 2003 was 42 months. Number of calves radioed does not include calves dying from capture-induced deaths.

Trap-zone	Male Calves Radioed	Elk Selected To Illustrate Spatial Distribution	Representing Elk in DAU	
A	6	6	E-25	
B	3	3	E-25	
C	10	10	E-25	
D	4	4	E-25	E-25 Total = 23
E	2	2	E-43	
F	7	7	E-43	
G	18	18	E-43	E-43 Total = 27
H	5	5	E-41	
I	7	7	E-41	
J	14	14	E-41	E-41 Total = 26
All	76	76		

Table 10. Adult female elk within each trap-zone whose estimated seasonal geographic locations were used to illustrate spatial distribution of adult female elk in the Gunnison Basin, December 2000 - December 2003. Within each trap-zone, ≈65% of the females captured as adults (age ≥30 months) were selected at random to illustrate elk distribution.

Trap-zone	Adult Females Radioed	Elk Selected To Illustrate Spatial Distribution	Representing Elk in DAU	
A	6	4	E-25	
B	5	3	E-25	
C	5	3	E-25	
D	3	3	E-25	E-25 Total = 13
E	3	3	E-43	
F	3	3	E-43	
G	10	6	E-43	E-43 Total = 12
H	5	3	E-41	
I	4	3	E-41	
J	7	4	E-41	E-41 Total = 10
All	51	35		

Table 11. Female elk calves radio-collared in December 2000 and 2001 within each trap-zone that survived to age ≥12 months whose estimated seasonal geographic locations were used to illustrate spatial distribution of young female elk in the Gunnison Basin, December 2000 - December 2003. Within each trap-zone, ≈65% of surviving calves were selected at random to illustrate elk distribution. Maximum age of these elk in December 2003 was 42 months. Number of calves radioed does not include calves dying from capture-induced deaths.

Trap-zone	Female Calves Radioed	Female Calves Surviving To Age ≥ 12 Months	Elk Selected To Illustrate Spatial Distribution	Representing Elk in DAU	
A	11	10	7	E-25	
B	4	4	3	E-25	
C	7	6	4	E-25	
D	5	5	4	E-25	E-25 Total = 18
E	7	5	3	E-43	
F	4	4	3	E-43	
G	16	15	10	E-43	E-43 Total = 16
H	7	4	3	E-41	
I	10	9	6	E-41	
J	9	7	5	E-41	E-41 Total = 14
All	80	69	48		

Table 12. Sample sizes for estimating seasonal distribution and movements of adult female (AF), female calf to adult (FCA) and male calf to adult (MCA) elk in the north and south portions of the Gunnison Basin based on elk locations, maximum movement vectors (MMV), and minimum convex polygon home ranges (MCP) from December 2000 through December 2003. The north Basin represented elk captured in trap-zones F-J and the south Basin represented elk captured in trap-zones A-E (see Fig. 1).

Gunnison Basin North or South Elk Group Class	Elk Sampled Per Data Type			Locations Per Elk			
	Locations	MMV	MCP	Avg.	Min	Max	Total Locations
North AF	19	19	19	30	8	43	578
South AF	16	16	16	26	13	39	420
North FCA	27	27	27	32	15	44	874
South FCA	21	21	21	29	12	43	608
North MCA	51	40	40	20	2	40	1,016
South MCA	25	12	12	11	3	39	264

Table 13. Number and percentages (%) of radio-collared elk venturing into Game Management Units (GMUs) outside the Gunnison Basin North or South from December 2000 through December 2003 for adult females (AF), female calves to adults (FCA), and male calves to adults (MCA) based on maximum movement vectors (MMV) and home ranges (MCP). Percentages based on elk sampled for MMV and MCP (see Table 12).

Gunnison Basin North or South Elk Group Class	GMUs with Number and (%) of Elk Venturing Into Each GMU													
	48 & 481	56	68 & 681	76 & 79	65	64	63	53	521	43 & 471	411	67	551	All Out[a]
North AF – MMV	1 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (26)	0 (0)	0 (0)	0 (0)	1[b] (5)	0 (0)	7 (37)
MCP	1 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (5)	5 (26)	0 (0)	0 (0)	0 (0)	1[b] (5)	0 (0)	7 (37)
North FCA – MMV	2 (7)	1 (4)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	3 (11)	2 (7)	0 (0)	0 (0)	0 (0)	1[b] (4)	10 (37)
MCP	2 (7)	1 (4)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	6 (22)	2 (7)	0 (0)	0 (0)	0 (0)	1[b] (4)	11 (41)
North MCA – MMV	3 (3)	1 (3)	0 (0)	1[b] (3)	0 (0)	0 (0)	0 (0)	11 (28)	2 (5)	2 (5)	1 (3)	0 (0)	0 (0)	21 (53)
MCP	4 (10)	1 (3)	1 (3)	1[b] (3)	0 (0)	0 (0)	4 (10)	14 (35)	2 (5)	2 (6)	1 (3)	0 (0)	0 (0)	22 (55)
South AF – MMV	0 (0)	0 (0)	3 (19)	0 (0)	1 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (25)
MCP	0 (0)	0 (0)	4 (25)	0 (0)	3 (19)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (44)
South FCA – MMV	0 (0)	0 (0)	1 (5)	4 (19)	2 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (33)
MCP	0 (0)	0 (0)	2 (10)	4 (19)	4 (19)	3 (14)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	13 (62)
South MCA – MMV	0 (0)	0 (0)	4 (33)	2 (17)	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (58)
MCP	0 (0)	0 (0)	4 (33)	2 (17)	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (58)

[a] Sum and percent of individual elk that moved to outside GMUs, does not double-count elk that ventured to >1 outside GMU based on MCP.

[b] Moved south across U. S. Highway 50.

Table 14. Maximum movement vector (MMV) distances (km) and confidence limits (CL) for classes of elk in the Gunnison Basin North, South, and All areas from December 2000 to December 2003.

Maximum Vector Statistics	Movement Vectors (MMV) for Elk Classes in Gunnison Basin Areas								
	Adult Females North	Adult Females South	Calf To Adult Females North	Calf To Adult Females South	Calf To Adult Males North	Calf To Adult Males South	All Adult Females	All Calf To Adult Females	All Calf To Adult Males
Mean (km)	32.3	34.8	37.6	33.4	38.5	34.8	33.4	35.8	37.7
Minimum	15.0	15.4	11.9	15.3	13.4	6.4	15.0	11.9	6.4
Maximum	56.4	57.2	65.0	78.5	111.0	62.5	57.2	78.5	111.0
Variance	105.9	125.5	175.9	218.1	350.4	343.9	112.7	175.9	344.7
SE of Mean	2.4	2.8	2.6	3.2	3.0	5.4	1.8	2.0	2.6
95% Lower CL	27.3	28.8	32.4	26.7	32.5	23.0	29.8	31.7	32.5
95% Upper CL	37.2	40.8	42.9	40.1	44.5	46.6	37.1	39.8	42.8
n = elk	19	16	27	21	40	12	35	48	52

Table 15. Number and percentages (%) of maximum movement vectors (MMV) by season of occurrence for elk classes in the Gunnison Basin North, South, and All areas from December 2000 to December 2003.

Seasons For Maximum Vectors	Number and (%) Movement Vectors (MMV) for Elk Classes in Gunnison Basin Areas								
	Adult Females North	Adult Females South	Calf To Adult Females North	Calf To Adult Females South	Calf To Adult Males North	Calf To Adult Males South	All Adult Females	All Calf To Adult Females	All Calf To Adult Males
Winter	0 (0)	1 (6)	2 (7)	4 (19)	2 (6)	4 (33)	1 (3)	6 (12)	6 (11)
Spring	2 (11)	2 (13)	3 (11)	3 (14)	5 (12)	2 (17)	4 (11)	6 (12)	7 (13)
Summer	13 (68)	9 (56)	18 (67)	12 (57)	28 (70)	5 (42)	22 (63)	30 (64)	33 (65)
Fall	4 (21)	4 (25)	4 (15)	2 (10)	5 (12)	1 (8)	8 (23)	6 (12)	6 (11)
n = elk	19 (100)	16 (100)	27 (100)	21(100)	40 (100)	12 (100)	35 (100)	48 (100)	52 (100)

Appendix A. Radio-collared calf elk mortalities in the Gunnison Basin, 15 December to 14 June, 2000-01.

No	Elk ID	Sex	Mass	Trap-zone	Death Date	Recovered	Femur Marrow Fat	Tissue Samples	Parasites	Carcass Status	Death Cause	Death Location		
												UTMx	UTMy	Drainage
1	173.082/00	M	92	B	12/29/00-1/4/01	5-Jan-01	White Creamy 38.7%	Yes CM	n/a	Nearly Complete	Capture Related / Lion	303163	4253981	Lake Gulch
2	172.379/00	F	127	H	12/19-26/00	3-Jan-01	White Firm 94.7%	n/a	n/a	Scavenged	Capture Related	335406	4282773	Flat Top
3	173.640/00	F	82	A	2/1-7/01	7-Feb-01	Red Jelly 15.8%	No CM	Moderate sarcocysts	Partially Scavenged	Lion Predation	304608	4243376	Lake Fork
4	172.959/00	M	125	J	2/15/01	15-Feb-01	Watery Pink 48.7%	No CM	Moderate sarcocysts	Carcass Complete	Unk.-Suspect Starvation	304753	4261110	Red Ck.
5	173.351/00	M	52	F	3/21/01	24-Mar-01	Red Jelly 27.5%	No CM	Normal sarcocysts	Scavenged	Unk.-Suspect Starvation	360867	4262422	Yellow Pine
6	173.160/00	M	94	A	3/25/01	26-Mar-01	Red Jelly 42.8%	No CM	Moderate sarcocysts/NI	Carcass Complete	Starvation	298132	4230866	Dwyer Gulch
7	173.300/00	M	112	I	3/31/01	1-Apr-01	Red Jelly 0.0%	No CM	Severe sarcocysts/NI	Carcass Complete	Unk.-Suspect Starvation	308379	4263917	Dry Gulch
8	173.041/00	M	97	I	4/13-14/01	15-Apr-01	Red Jelly 77.66%	No CM	Severe sarcocysts/NI	Nearly Complete	Unk.-Suspect Starvation	320104	4270341	Beavear Ck.
9	173.949/00	M	107	A	4/20/01	26-Apr-01	Red Creamy 45.27%	No CM	Normal sarcocysts	Scavenged	Lion Predation	311827	4245467	Cebolla Ck.
10	173.011/00	M	113	J	4/28-5/10/01	23-May-01	Red Jelly 13.15%	n/a	n/a	Scavenged	Bear Predation	300715	4268428	E. Coal Ck.
Mass = Weight of calf (kg) at capture; CM = capture myopathy; NI = no evidence of inflamation around sarcocysts; n/a = samples not available; Unk.=unknown.														

Appendix B. Radio-collared calf elk mortalities in the Gunnison Basin, 15 December to 14 June, 2001-02.

No	Elk ID	Sex	Mass	Trap-Zone	Death Date	Recovered	Femur Marrow Fat	Tissue Samples	Parasites	Carcass Status	Death Cause	Death Location		
												UTMx	UTMy	Drainage
1	173.429/01	F	100	E	12/18/2001	20-Dec-01	Firm core,pink;87.45%	No CM	unremarkable	Carcass Complete	Capture Related Fence Kill	351433	4245033	Prosser Ck
2	173.740/01	F	101	E	12/21/2001	21-Dec-01	Firm core, pink;66.5%	Mild CM	n/a	Carcass Complete	Capture Related euthanized	353050	4250600	E. Table Top Mt
3	174.720/01	M	101	B	12/21-23/2001	26-Dec-01	Soft core, pink;88.87%	No CM	Low Sarcosysts	Partially Scavenged	Capture Related / Lion	302744	4230958	Skunk Ck.
4	173.269/01	M	98	J	01/2-12/2002	14-Jan-02	n/a	n/a	n/a	Totally Scavenged	Unk.-suspect lion predation	300102	4267074	Pearson Pt.
5	172.350/01	F	86	H	01/3-7/2002	8-Jan-02	Firm core,pink;78.50%	No CM	unremarkable	Partially Scavenged	Bear Predation	334033	4282350	Flat Top Mtn
6	173.852/01	F	101	I	1/4-9/2002	10-Jan-02	Firm core, pink;90.71%	No CM	Low Sarcosysts	Partially Scavenged	Lion predation	321888	4275810	W. Antelope Ck
7	175.181/01	M	91	A	1/15-2/5/2002	6-Feb-02	Firm, red; 68.56%	n/a	n/a	Scavenged heavily	Unk.-suspect coyote predation	297064	4231180	Dwyer Gulch
8	172.170/01	F	58	H	01/20-21/2002	23-Jan-02	Jelly, red: 1.57%	No CM	broncho-pneumonia	Carcass Complete	Accident-Haystack collapse	330243	4280937	Redden's
9	173.861/01	F	102	J	1/25-28/2002	29-Jan-02	Firm core, pink: 94.36%	No CM	Moderate sarcocysts	Partially Scavenged	Lion predation	299250	4267725	Pearson Pt.
10	174.770/01	M	92	A	2/21-28/2002	4-Mar-02	Soft core, red; 5.27%	No CM	Moderate sarcocysts	Carcass Complete	Accident-fell, trapped	294622	4227200	Elk Ck.
11	172.379/01	F	81	G	2/25-3/6/2002	7-Mar-02	n/a	n/a	n/a	Totally Scavenged	Unknown	342715	4288645	Almont Triangle
12	173.300/01	M	none	J	2/27-3/6/2002	9-Mar-02	n/a	n/a	n/a	Not Found-Snow	Unknown	299323	4268454	N. Pearson Pt.
13	173.632/01	F	96	C	3/20-25/2002	26-Mar-02	Firm core, pink: 83.60%	No CM	Moderate sarcocysts	Partially Scavenged	Lion predation	322925	4232867	Road Beaver Ck.
14	173.780/01	F	108	J	4/25-4/30/2002	1-May-02	Firm core, pink; 27.08%	n/a	n/a	Totally Scavenged	Unknown	306109	4267739	Red Ck.
15	175.240/01	M	100	C	5/15-5/20/2002	21-May-02	Red, firm core; 60.02%	n/a	n/a	Totally Scavenged	Unk.-suspect lion predation	325443	4235881	N. Road Beaver Ck.
16	174.180/01	M	95	E	5/15-5/20/2002	22-May-02	Firm core, pink;75.63%	n/a	n/a	Totally Scavenged	Unk.-suspect lion predation	351363	4240438	Home Gulch
Mass = Weight of calf (kg) at capture; CM = capture myopathy; n/a = samples not available; Unk.=unknown														

Appendix C. Radio-collared adult elk mortalities in the Gunnison Basin 15 December 2000 to 14 June 2003.

No	Elk ID	Age @ Death	Sex	Trap-zone	Death Date	Recovered	Femur Marrow Fat	Tissue Samples	Parasites	Carcass Status	Death Cause	Death Location		
												UTMx	UTMy	Drainage
1	172.758/00	19 yrs	F	H	>06/22 <7/21/01	21-Jul-01	n/a	n/a	n/a	Decomposed	Unknown Mortality	321262	4294461	S. Carbon Mtn.
2	173.330/00	12 mos	M	G	>06/22 <7/24/01	24-Jul-01	77.46%	n/a	n/a	Scavenged	Unknown-Suspect Predation	354289	4290527	Summerville Ck.
3	173.340/00	12 mos	M	G	>6/22 <7/20/01	16-Aug-01	n/a	n/a	n/a	Heavily Scavenged	Unknown-Suspect Predation	384766	4303460	N. Cottonwood Ck.
4	172.030/00	6 yrs	F	C	>9/25 <10/18/01	19-Oct-01	white, solid 97.31%	n/a	n/a	Heavily Scavenged	Archery/Muzzle wounding loss	322980	4227638	Swinehart Gulch
5	172.619/00	16 mos	F	J	>10/13 <10/18/01	20-Oct-01	pink, crumbles 85.18%	n/a	n/a	Complete	Rifle 1st season wounding loss	299161	4275164	Cow Ck.
6	174.478/00	5-9 yrs	F	G	10/13/2001	17-Oct-01	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 1st season Legal	341000	4242650	Rock Ck.
7	174.360/00	17 mos	F	G	>11/8 <11/16/01	17-Nov-01	white/gray solid 95.18%	n/a	n/a	Complete	Rifle 4th season wounding loss	346979	4279939	E. Beaver Ck.
8	174.140/00	18 mos	M	C	>12/5 <12/28/01	29-Dec-01	white/pink, firm 86.27%	n/a	n/a	Scavenged	Rifle Late season wounding/illegal	308573	4242145	Lake City Cut-Off
9	173.589/00	18 mos	F	B	>12/28/01 <1/3/02	n/a	n/a	n/a	n/a	n/a	Disappear Late Rifle season Legal	n/a	n/a	Low Cebolla Ck.
10	174.560/00	17 mos	F	J	>10/30/01 <12/31/01	n/a	n/a	n/a	n/a	n/a	Disappear 3rd rifle season Legal	n/a	n/a	West Elk Ck.
11	172.039/00	5-9 yrs	F	D	11/27/2002	27-Nov-02	n/a	n/a	n/a	Plentiful Fat-HQ	Rifle Late season Legal	351800	4238200	Home Gulch
12	172.101/00	5-9 yrs	F	C	11/23/2002	24-Nov-02	n/a	n/a	n/a	Low Fat-HQ	Rifle Late season Legal	317200	4353200	Wolf Ck.Cebolla Ck.
13	172.201/00	4 yrs	F	B	>11/1 <11/19/2002	10-Dec-02	white, firm 96.13%	n/a	n/a	Totally Scavenged	Rifle 4th season Wounding Loss	296298	4220588	Bill Hare Gulch
14	172.230/00	28 mos	F	A	10/14/2002	15-Oct-02	n/a	n/a	n/a	Plentiful Fat-HQ	Rifle 1st season Legal	301800	4220500	Nourse Ck.
15	172.411/00	5-9 yrs	F	G	>11/1 <11/13/2002	26-Mar-03	n/a	n/a	n/a	Emaciated	Rifle 4th season Wounding Loss	350800	4263100	NE Parlin Town
16	172.450/00	29 mos	F	G	11/6/2002	6-Nov-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 3rd season Legal	340300	4283300	SW Almont Triangle
17	172.519/01	15 mos	F	I	9/21/2002	22-Sep-02	n/a	n/a	n/a	Moderate Fat-HQ	Muzzleloading season Legal	323000	4279100	Clay Gulch
18	172.529/00	29 mos	F	G	>11/1 <11/19/2002	21-Nov-02	white, firm 95.90%	n/a	n/a	Partially Scavenged	Rifle 3rd season wounding loss	341303	4270882	Sheep Gulch
19	172.549/00	5 yrs	F	G	>11/19 <12/19/02	19-Dec-02	n/a inadequate sample	n/a	n/a	Complete	Rifle Late season wounding loss	347668	4275522	Lost Canyon Gulch
20	172.581/00	5-9 yrs	F	G	12/6/2002	13-Dec-02	n/a	n/a	n/a	n/a	Rifle Late season Legal	346300	4274200	Cabin Ck.
21	172.639/00	5-9 yrs	F	G	11/10/2002	12-Nov-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 4th season Legal	340600	4278350	Leaps Fisher Gulch
22	172.670/00	5-9 yrs	F	G	11/30/2002	2-Dec-02	n/a	n/a	n/a	n/a	Rifle Late season Legal	346500	4273800	Lost Canyon Gulch
23	172.741/01	17 mos	F	G	11/2/2002	9-Nov-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 3rd season Legal	361500	4270200	McIntyre Gulch
24	173.041/01	17 mos	M	G	>11/1 <11/19/2002	21-Nov-02	white, firm 91.34%	n/a	n/a	Complete	Rifle 3rd season wounding/Illegal loss	349206	4273981	Cabin Ck. Tents Ck.
25	173.082/01	17 mos	M	G	>11/1 <11/19/2002	22-Nov-02	white, firm 88.11%	n/a	n/a	Complete	Rifle 3rd season wounding/Illegal loss	342844	4286400	Almont Triangle
26	173.091/01	17 mos	M	G	>11/1 <11/19/2002	21-Nov-02	white, firm 92.19%	n/a	n/a	Complete	Rifle 3rd season wounding/Illegal loss	347101	4279609	East Beaver Ck.
27	173.262/01	7 yrs	F	A	>11/19 <12/19/2002	20-Dec-02	white, firm 99.01%	n/a	n/a	Heavily Scavenged	Rifle Late season wounding loss	299643	4248782	Willow Mesa
28	173.340/01	17 mos	M	G	11/2/2002	4-Nov-02	n/a	n/a	n/a	Complete	Rifle 3rd season wounding/Illegal loss	349149	4274727	Cabin Ck. Tents Ck.
29	173.358/00	29 mos	M	G	11/6/2002	8-Nov-02	n/a	n/a	n/a	n/a	Rifle 3rd season Legal	349000	4283500	East Beaver Ck.
30	173.999/01	16 mos	F	E	10/20/2002	21-Oct-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 2nd season Legal	372700	4248200	Templeton Gulch
31	174.019/01	17 mos	F	A	11/4/2002	5-Nov-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle 3rd season Legal	294300	4248400	Pine Ck. Ridge
32	174.129/01	7 yrs	F	H	10/19/2002	20-Oct-02	n/a	n/a	n/a	n/a	Rifle 1st season Legal	326100	4292600	Owens Ck. Ohio Ck.
33	174.200/00	29 mos	M	G	11/2/2002	4-Nov-02	n/a	n/a	n/a	Low Fat-HQ	Rifle 3rd season Legal	353600	4272100	Alder Ck.
34	174.260/00	2-4 yrs	F	J	12/8/2002	9-Dec-02	n/a	n/a	n/a	Plentiful Fat-HQ	Rifle Late season Legal	307800	4270600	W. Fork Red Ck.
35	174.380/01	17 mos	M	H	>11/1 <11/19/2002	22-Nov-02	n/a	n/a	n/a	Collar Under Ice	Rifle 3rd season illegal loss	322526	4290153	Ohio Ck. Road
36	174.420/00	5-9 yrs	F	F	11/12/2002	12-Nov-02	n/a	n/a	n/a	Low Fat-HQ	Rifle 4th season Legal	364250	4263650	Greathouse Gulch
37	174.520/00	29 mos	F	F	>11/1 <11/19/2002	21-Nov-02	white, firm 97.18%	n/a	n/a	Heavily Scavenged	Rifle 3rd season wounding loss	364938	4268448	Lookout Mtn.
38	174.729/00	29 mos	M	G	11/3/2002	8-Nov-02	n/a	n/a	n/a	Low Fat-HQ	Rifle 3rd season Legal	350000	4276300	East Beaver Ck.
39	174.800/00	29 mos	M	J	11/3/2002	3-Nov-02	n/a	n/a	n/a	n/a	Rifle 3rd season Legal	282200	4291000	Smith Fk . Ck.
40	174.870/01	13 yrs	F	B	>11/19 <12/19/2002	20-Dec-02	white, firm 97.57%	n/a	n/a	Heavily Scavenged	Rifle Late season wounding loss	306192	4237853	Indian Ck.
41	174.880/01	5-9 yrs	F	G	12/10/2002	12-Dec-02	n/a	n/a	n/a	Moderate Fat-HQ	Rifle-Late season Legal	346000	4274500	Lost Canyon Gulch
42	174.959/00	17 yrs	F	D	>11/19 <12/19/2002	20-Dec-02	white, firm 98.31%	n/a	n/a	Heavily Scavenged	Rifle Late season wounding loss	339255	4241223	Rock Ck.
43	172.890/00	28 mos	M	J	>10/1 <10/16/02	n/a	n/a	n/a	n/a	n/a	Disappear Rifle 1st season Legal	n/a	n/a	West Elk Ck.
44	172.540/00	18 mos	F	G	>11/19 <12/15/02	n/a	n/a	n/a	n/a	n/a	Disappear Rifle Late season Legal	n/a	n/a	Cabin Ck.
45	174.910/00	29 mos	F	J	>11/1 <11/13/02	n/a	n/a	n/a	n/a	n/a	Disappear Rifle 3rd season Legal	n/a	n/a	Soap Ck.
46	173.210/01	17 mos	F	F	>11/1 <11/13/02	n/a	n/a	n/a	n/a	n/a	Disappear Rifle 3rd season Legal	n/a	n/a	Yellow Pine Ridge
47	173.949/01	22 mos	M	G	>4/10 <4/25/03	30-Apr-03	dry, low volume 73.54%	n/a	n/a	Heavily Scavenged	Unknown-Suspect Predation	350545	4280587	East Beaver Ck.
48	174.629/01	4 yrs	F	D	>5/7 <5/21/03	22-May-03	dry, low volume 8.64%	n/a	n/a	Totally Scavenged	Lion predation	348869	4242544	W. Razor Dome

n/a = samples not available; Unk.=unknown; HQ= relative elk fat status from hunter questionnaire information

Appendix D. Follow-up questionnaire mailed to hunters who harvested a radio-collared elk in the Gunnison Basin during 2002 hunting seasons.

Hunter Questionnaire, Gunnison Elk, Hunting Seasons

Please take just a minute to complete this questionnaire and RETURN IN THE ENCLOSED SELF-ADDRESSED AND STAMPED ENVELOPE.

HUNTER NAME:

JUST **CIRCLE** THE MOST APPROPRIATE ANSWER:

1. Did you see the radio-collar on the elk before you decided to shoot at the elk.

Yes No

2. If you saw the radio-collar before shooting, did you hesitate to shoot the elk because the elk was radio-collared?
Yes No

3. Had the radio-collar caused noticeable damage to the neck hair and/or caused any sores or wounds on the neck?
Hair Damage: Yes No Sores: Yes No

4. In your opinion, how was the radio-collar fitting around the elk's neck:

Tightly Just about Right Loosely

5. In your opinion, do you think the general health condition of the elk was:

Excellent Good Fair Poor Don't Know

6. When you skinned the elk, do you recall whether the rump fat was:

Plentiful Fair Amount Present Not Much At All Don't Know

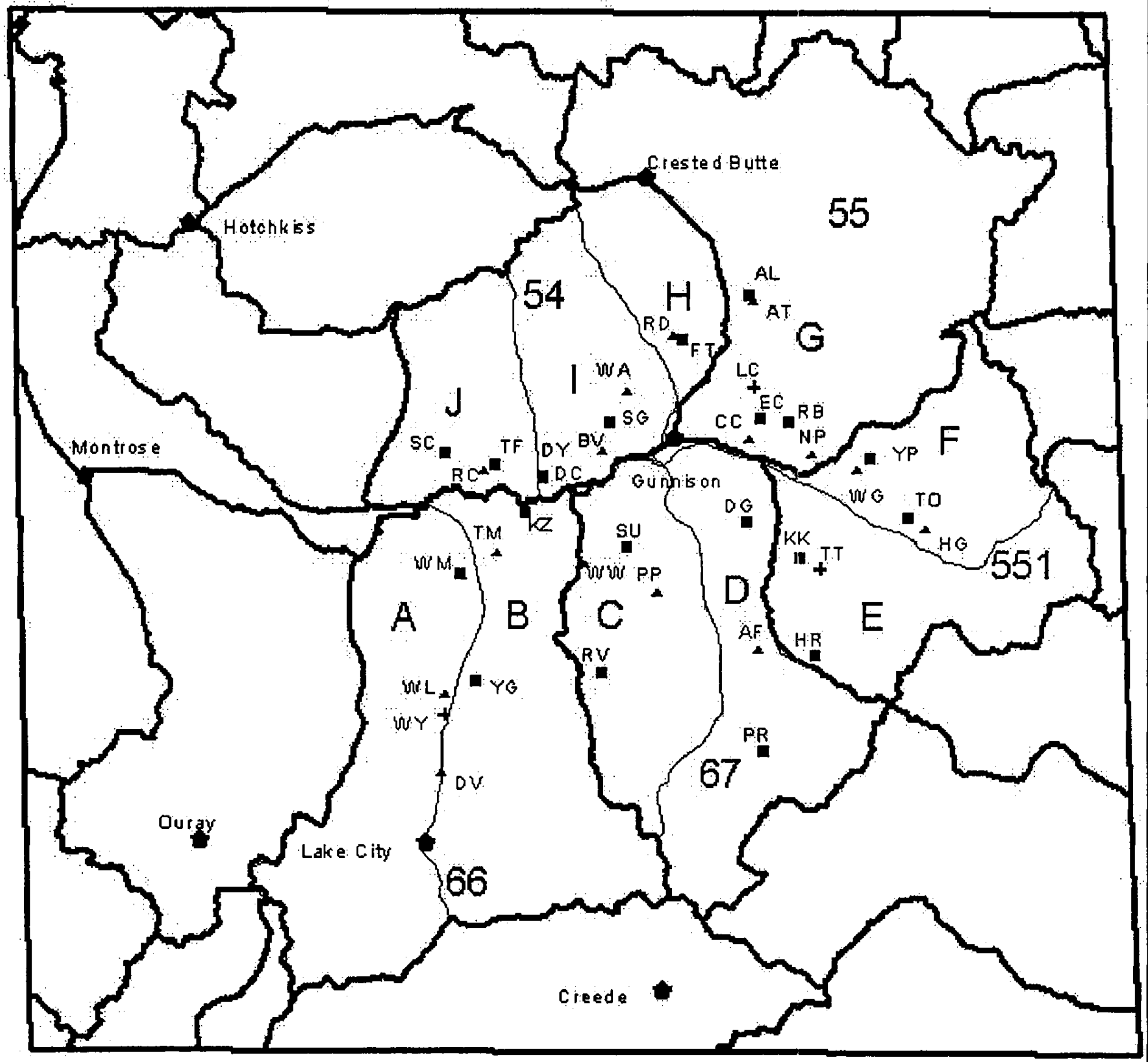
7. When you eviscerated the elk, do you recall whether internal fat amongst the organs was:

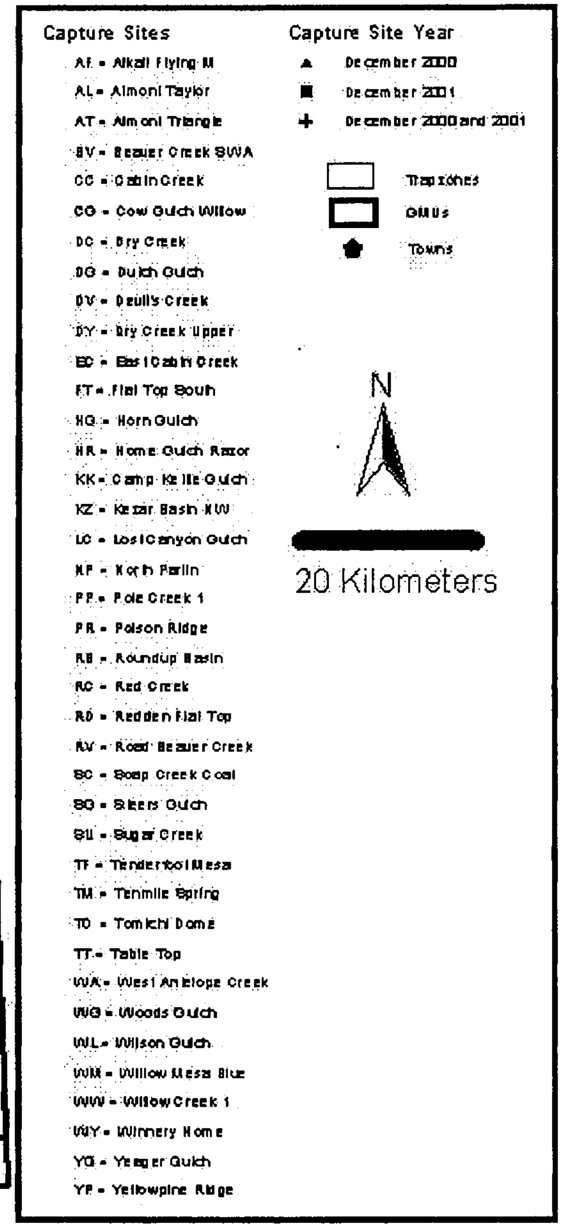
Plentiful Fair Amount Present Not Much At All Don't Know

8. Comments You Would Like to Make:

THANK YOU:
DAVE FREDDY
WILDLIFE RESEARCHER
COLORADO DIVISION OF WILDLIFE
317 WEST PROSPECT ROAD
FORT COLLINS, CO 80526

Fig. 1. Game Management Units (54-551), trapzones (A-J), and elk capture sites in the Gunnison Basin in 2000 and 2001.





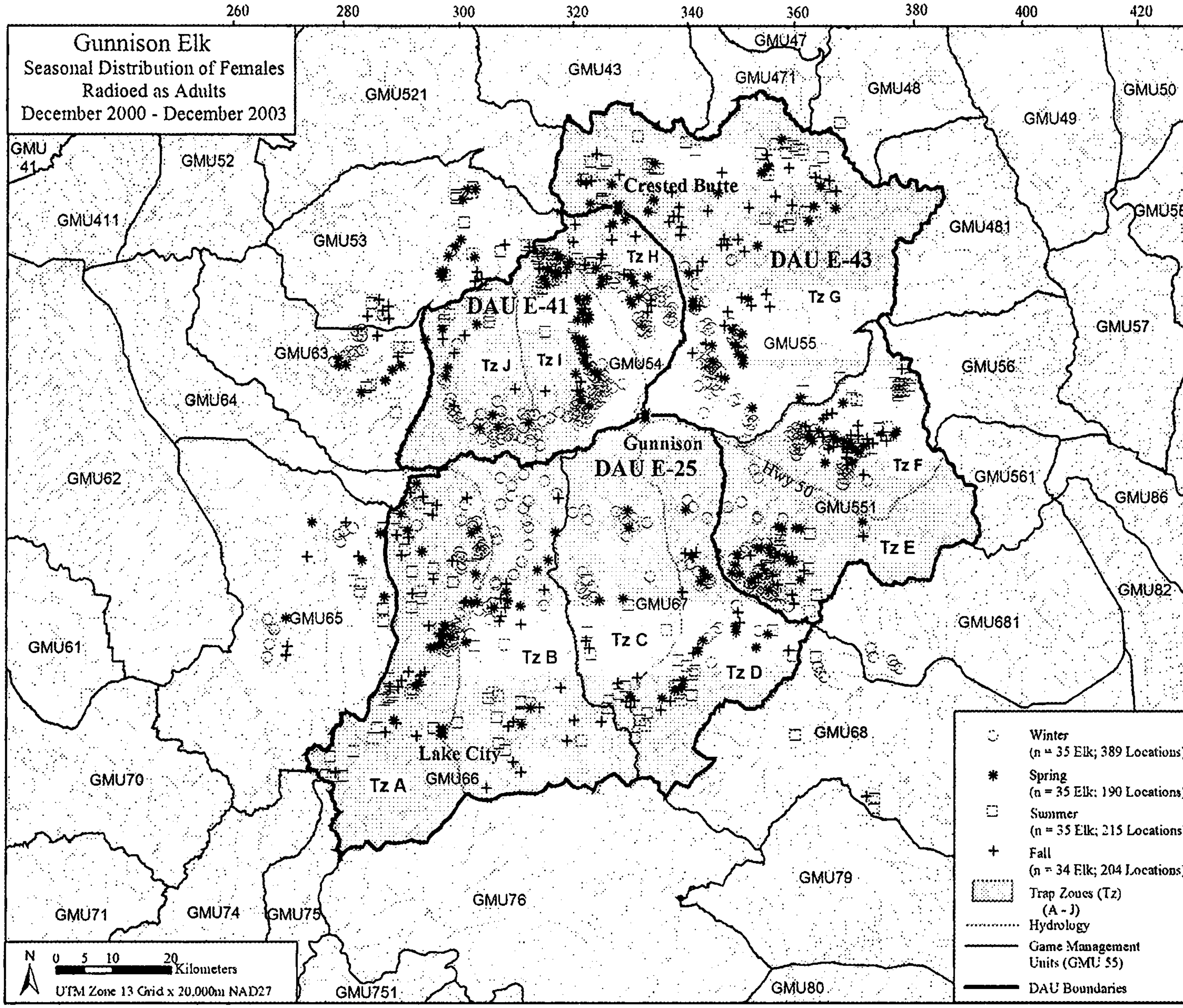


Figure 2. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as adults at age ≥30-months and captured throughout the Gunnison Basin in trap-zones A-J. Distribution includes locations of elk captures and deaths and was based on random selection of n = 35 from N = 51 adult females. See Methods for sampling protocols and definitions of seasons.

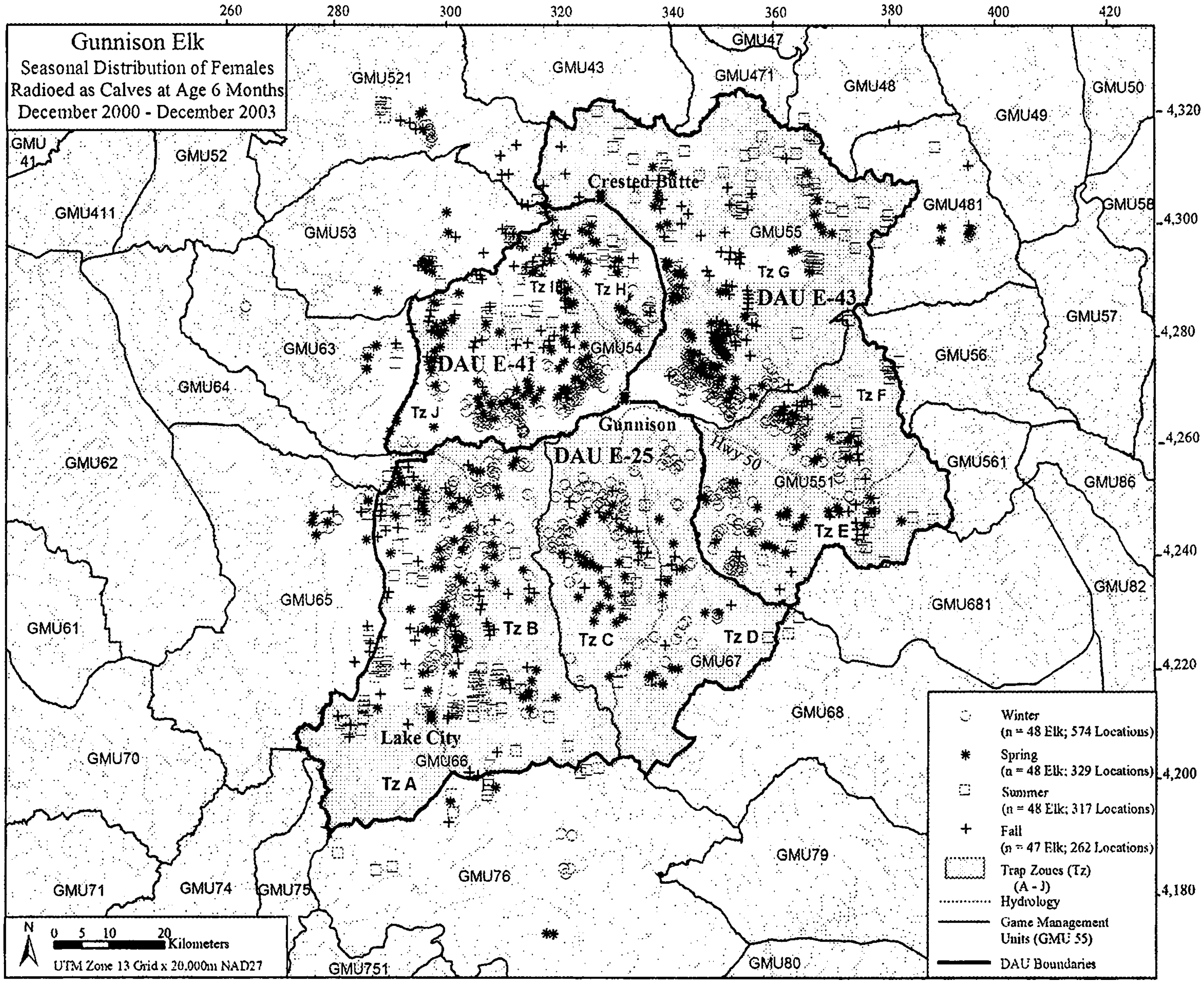


Figure 3. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as calves at age 6-months that survived to age ≥12-months and captured throughout the Gunnison Basin in trap-zones A-J. Distribution includes locations of elk captures and deaths and was based on random selection of n = 48 from N = 69 female calves. See Methods for sampling protocols and definitions of seasons.

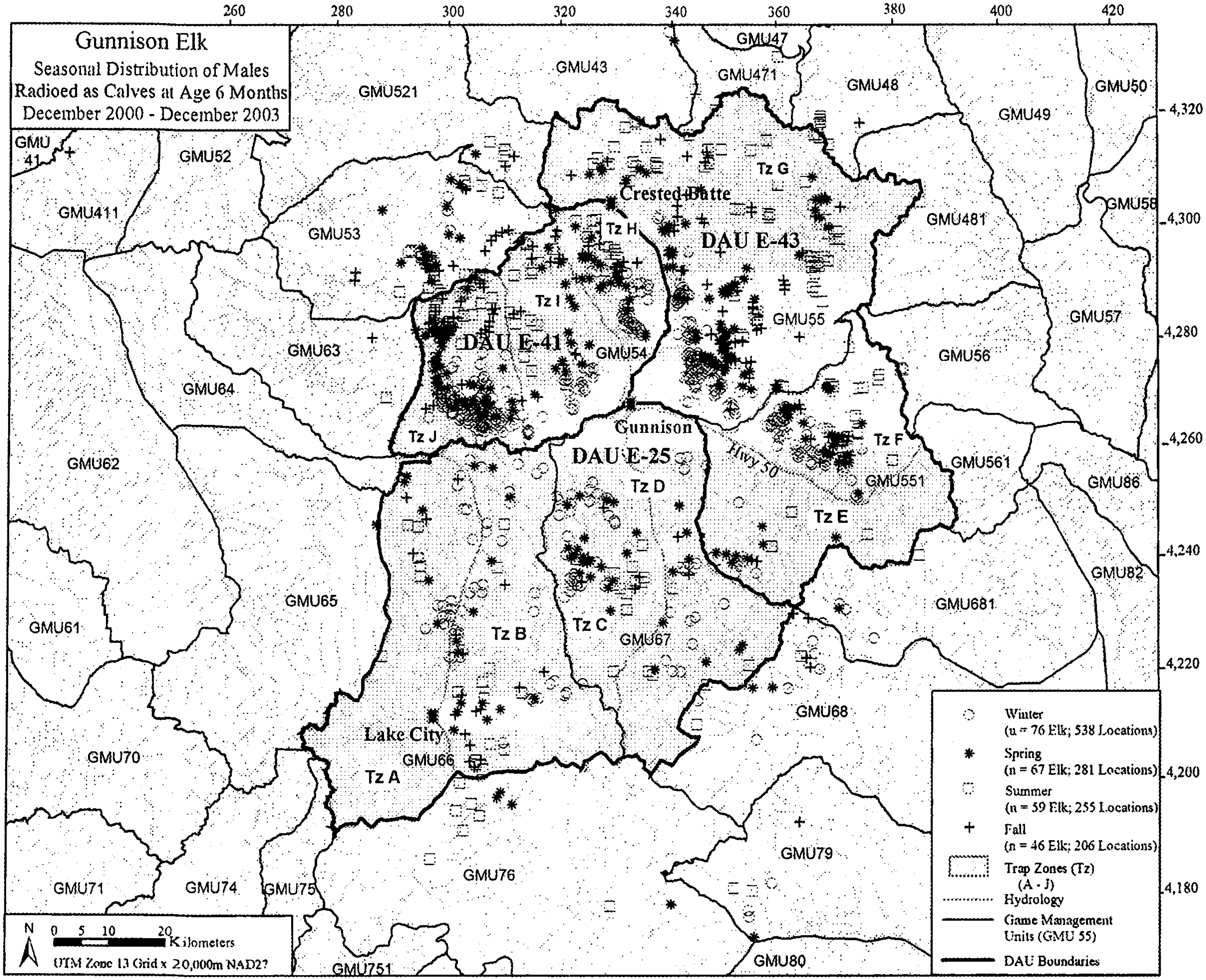


Figure 4. Seasonal distribution from December 2000 through December 2003 of male elk radio-collared as calves at age 6-months and captured throughout the Gunnison Basin in trap-zones A-J. Distribution includes locations of elk captures and deaths and was based on all calves $N = 76$. See Methods for sampling protocols and definitions of seasons.

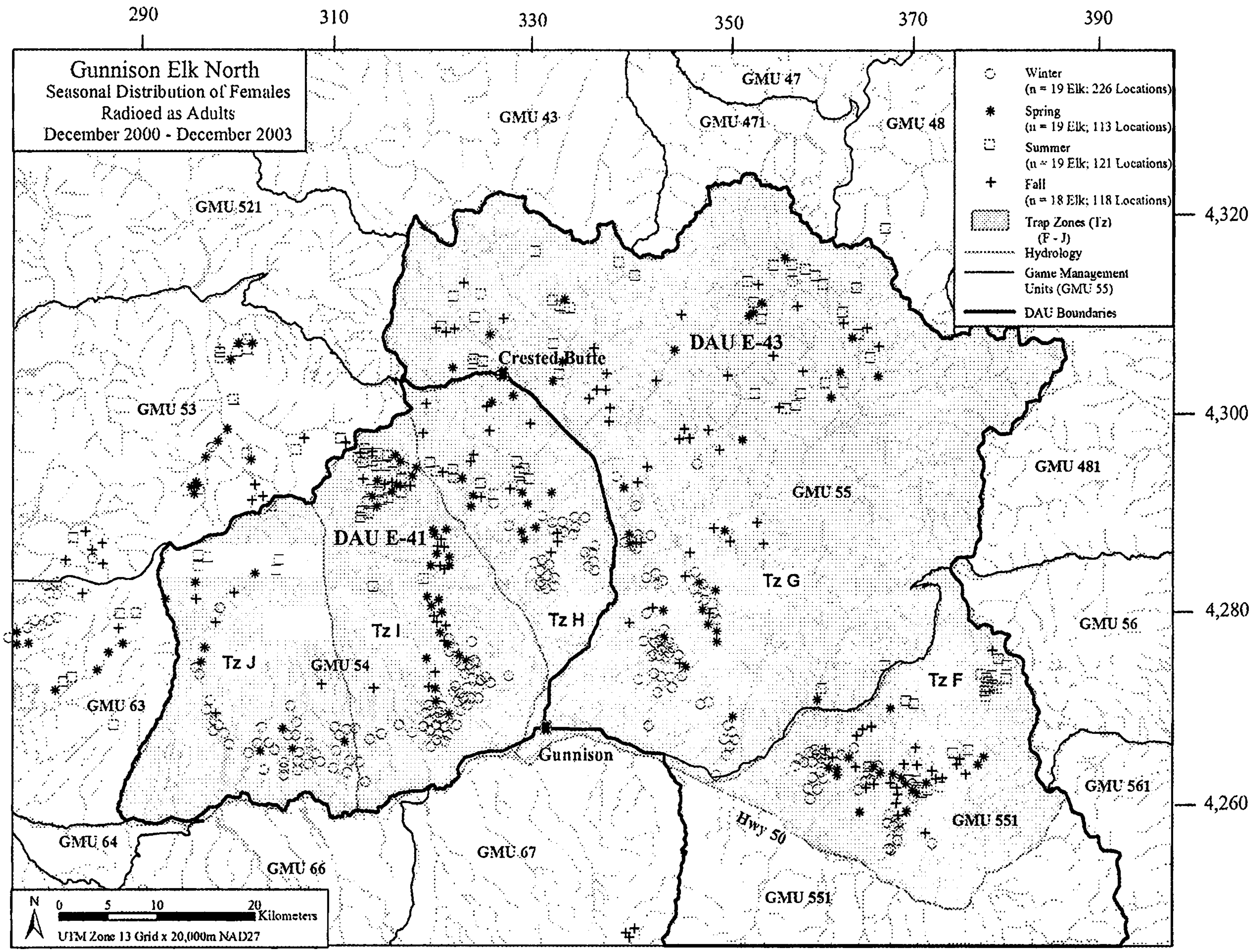


Figure 5. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as adults at age ≥30-months that were captured north of U.S. Highway 50 in trap-zones F, G, H, I, and J of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on random selection of n = 19 from N = 29 adult females. See Methods for sampling protocols and definitions of seasons

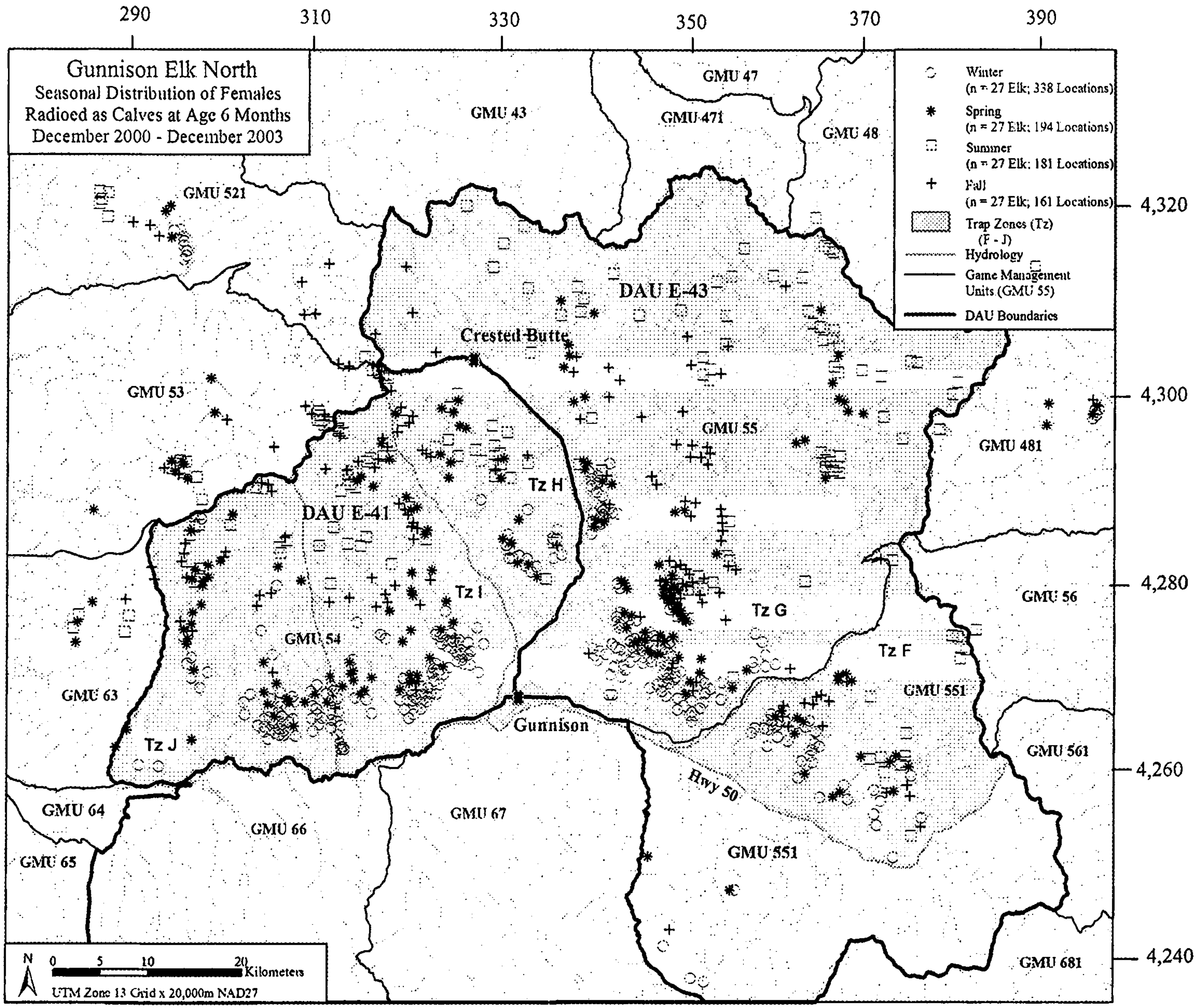


Figure 6. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as calves at age 6-months that survived to age ≥12-months that were captured north of U.S. Highway 50 in trap-zones F, G, H, I, and J of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on random selection of n = 27 from N = 39 female calves. See Methods for sampling protocols and definitions of seasons.

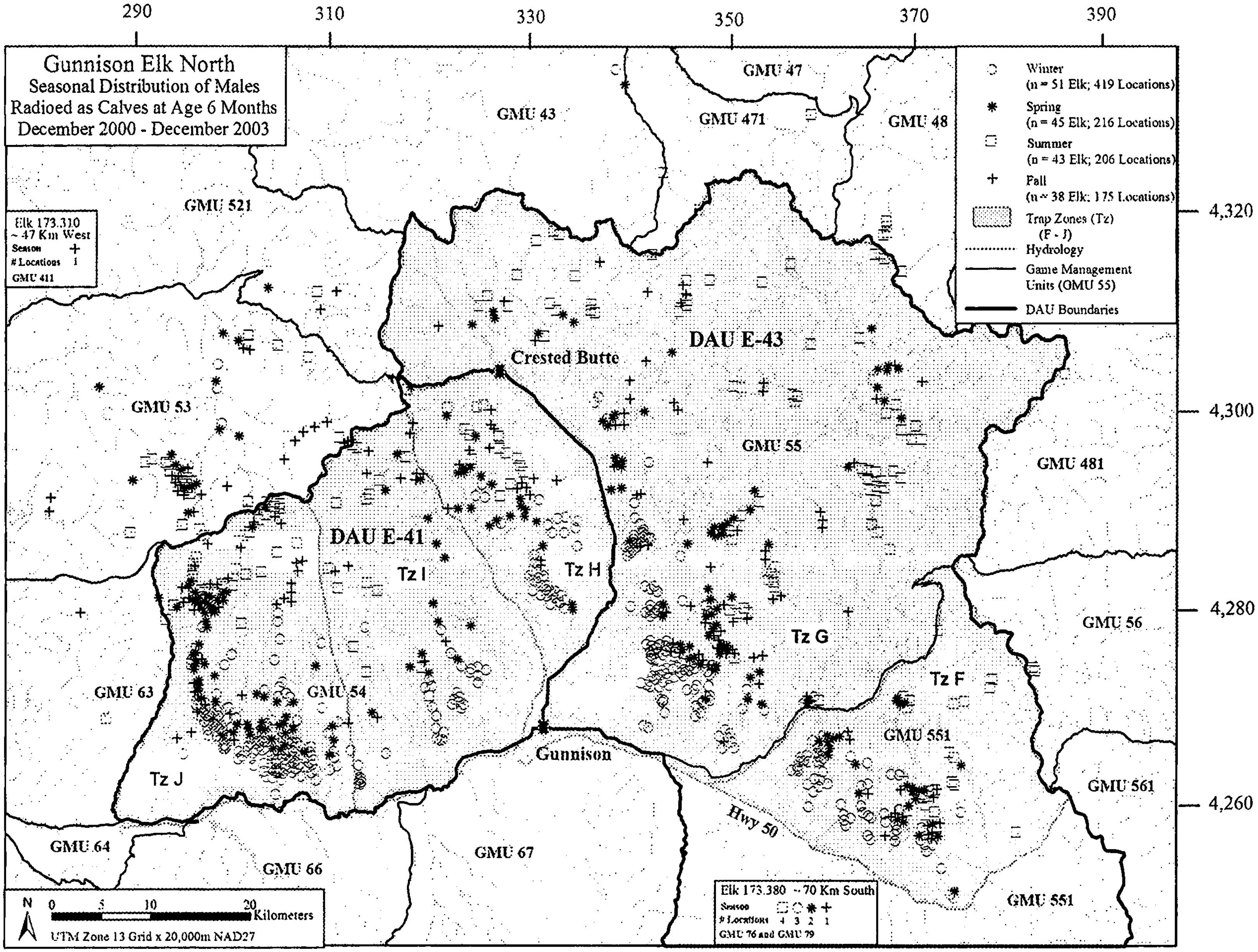


Figure 7. Seasonal distribution from December 2000 through December 2003 of male elk radio-collared as calves at age 6-months that were captured north of U.S. Highway 50 in trap-zones F, G, H, I, and J of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on all calves $N = 51$. See Methods for sampling protocols and definitions of seasons

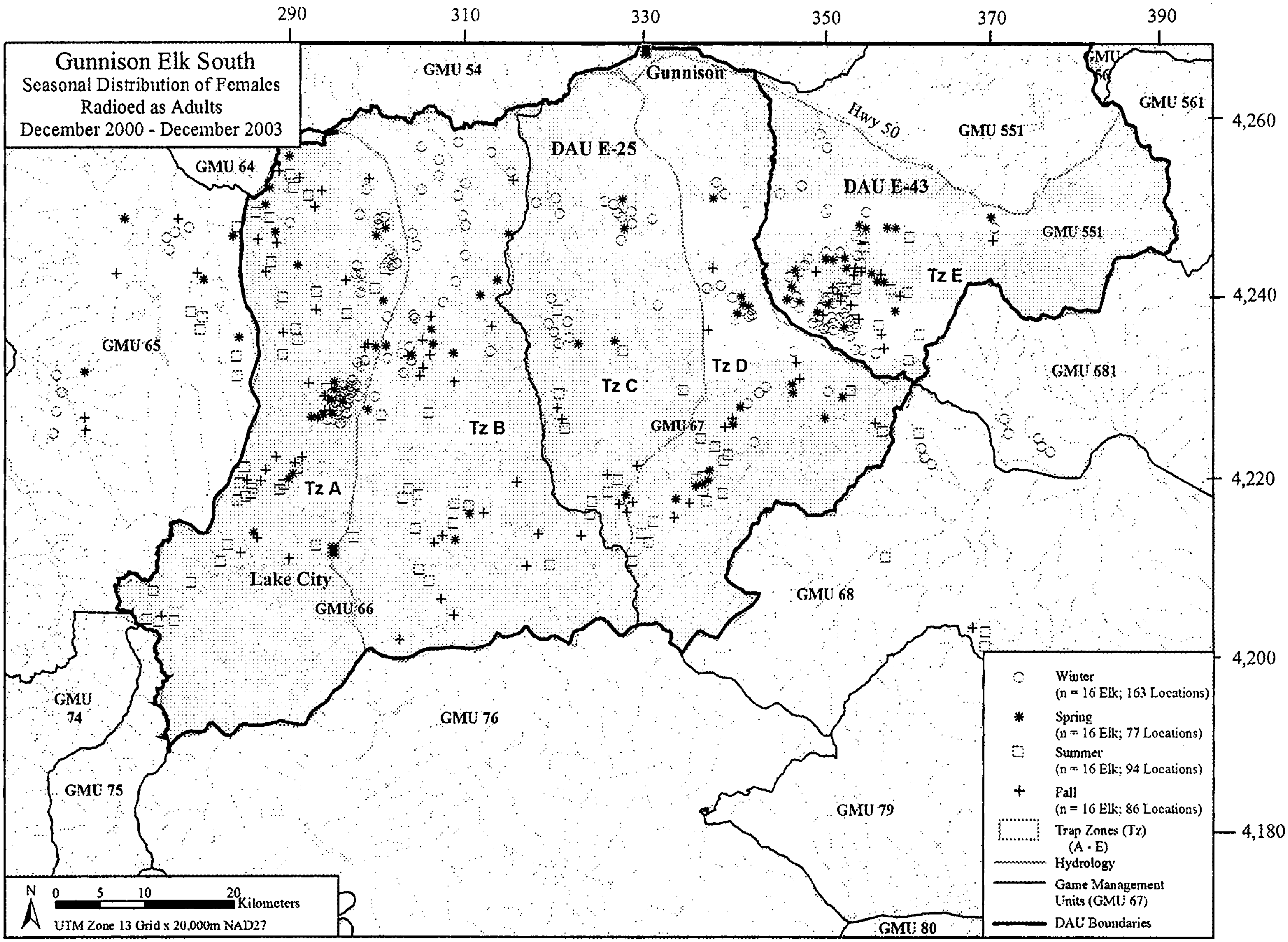


Figure 8. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as adults at age ≥30-months that were captured south of U.S. Highway 50 in trap-zones A, B, C, D, and E of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on random selection of n = 16 from N = 22 adult females. See Methods for sampling protocols and definitions of seasons.

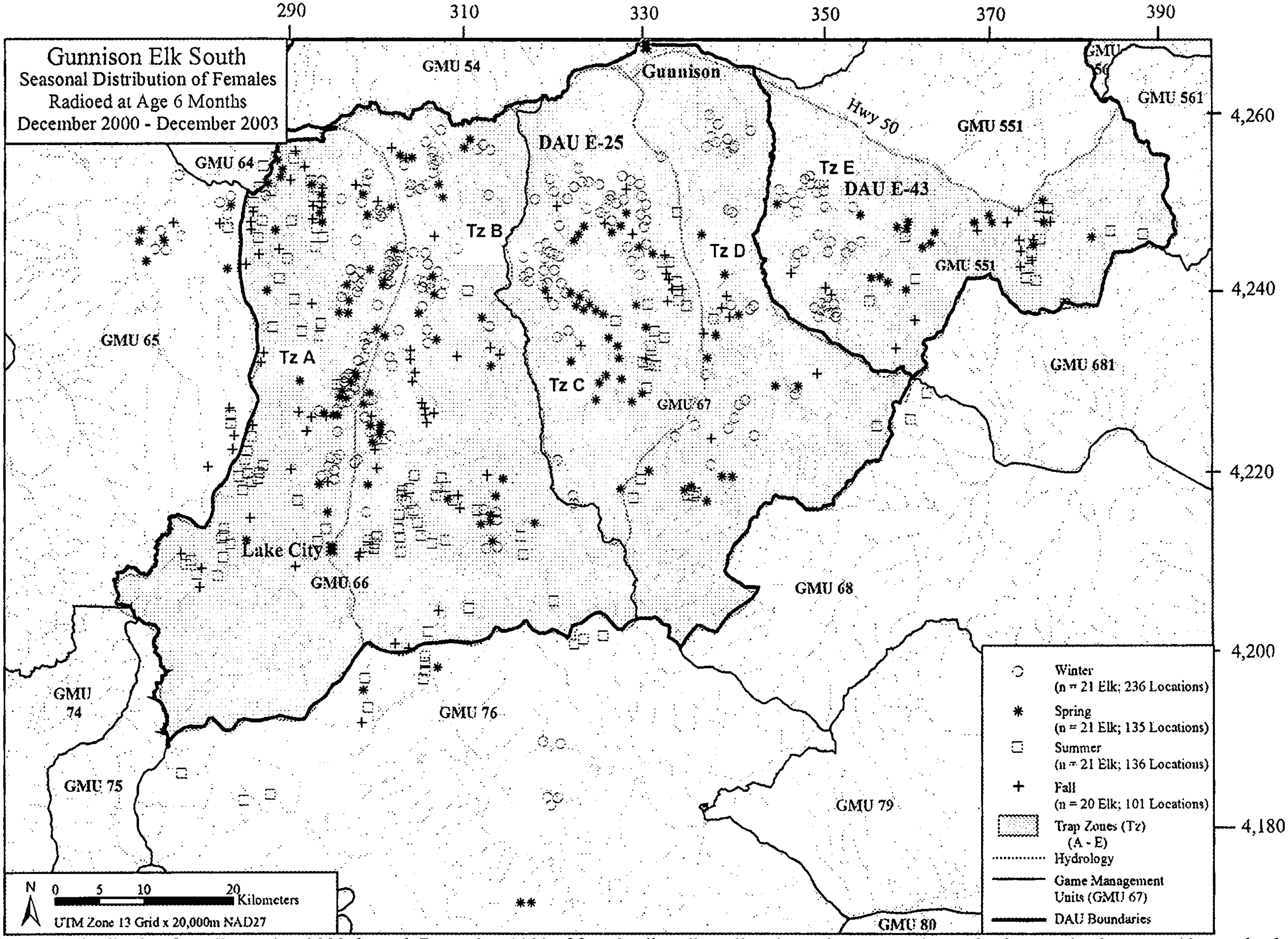


Figure 9. Seasonal distribution from December 2000 through December 2003 of female elk radio-collared as calves at age 6-months that survived to age ≥12-months that were captured south of U.S. Highway 50 in trap-zones A, B, C, D, and E of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on random selection of n = 21 from N = 30 female calves. See Methods for sampling protocols and definitions of seasons.

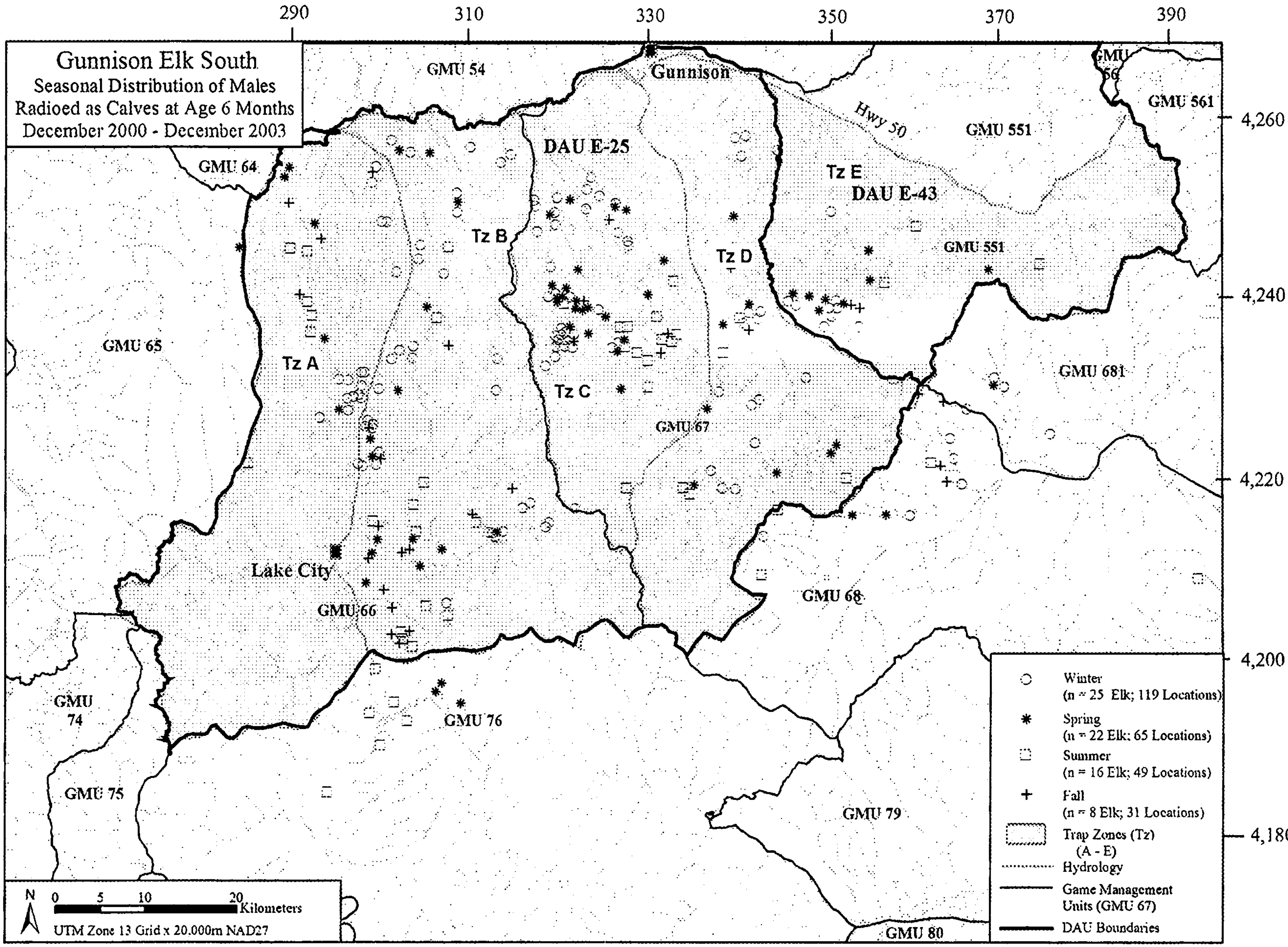


Figure 10. Seasonal distribution from December 2000 through December 2003 of male elk radio-collared as calves at age 6-months that were captured south of U.S. Highway 50 in trap-zones A, B, C, D, and E of the Gunnison Basin. Distribution includes locations of elk captures and deaths and was based on all calves $N = 25$. See Methods for sampling protocols and definitions of seasons.

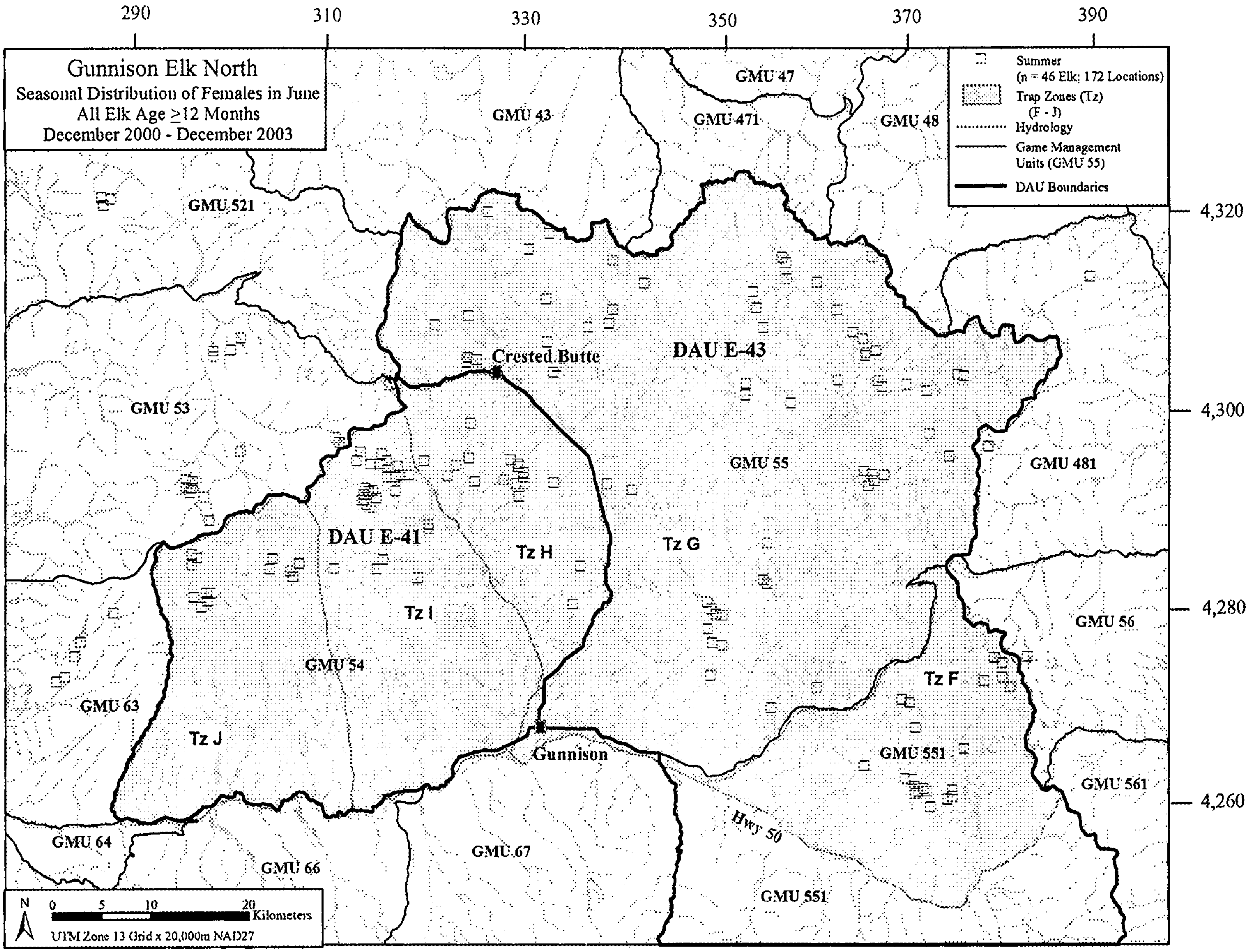


Figure 11. Distribution during June 2001-2003 of radio-collared female elk whose age was ≥12-months when locations were acquired. Elk were captured north of U.S. Highway 50 in trap-zones F, G, H, I, and J of the Gunnison Basin and locations were based on the same females randomly selected as adults or calves that were used to describe composite seasonal distributions of elk where n = 46 from N = 68 females.

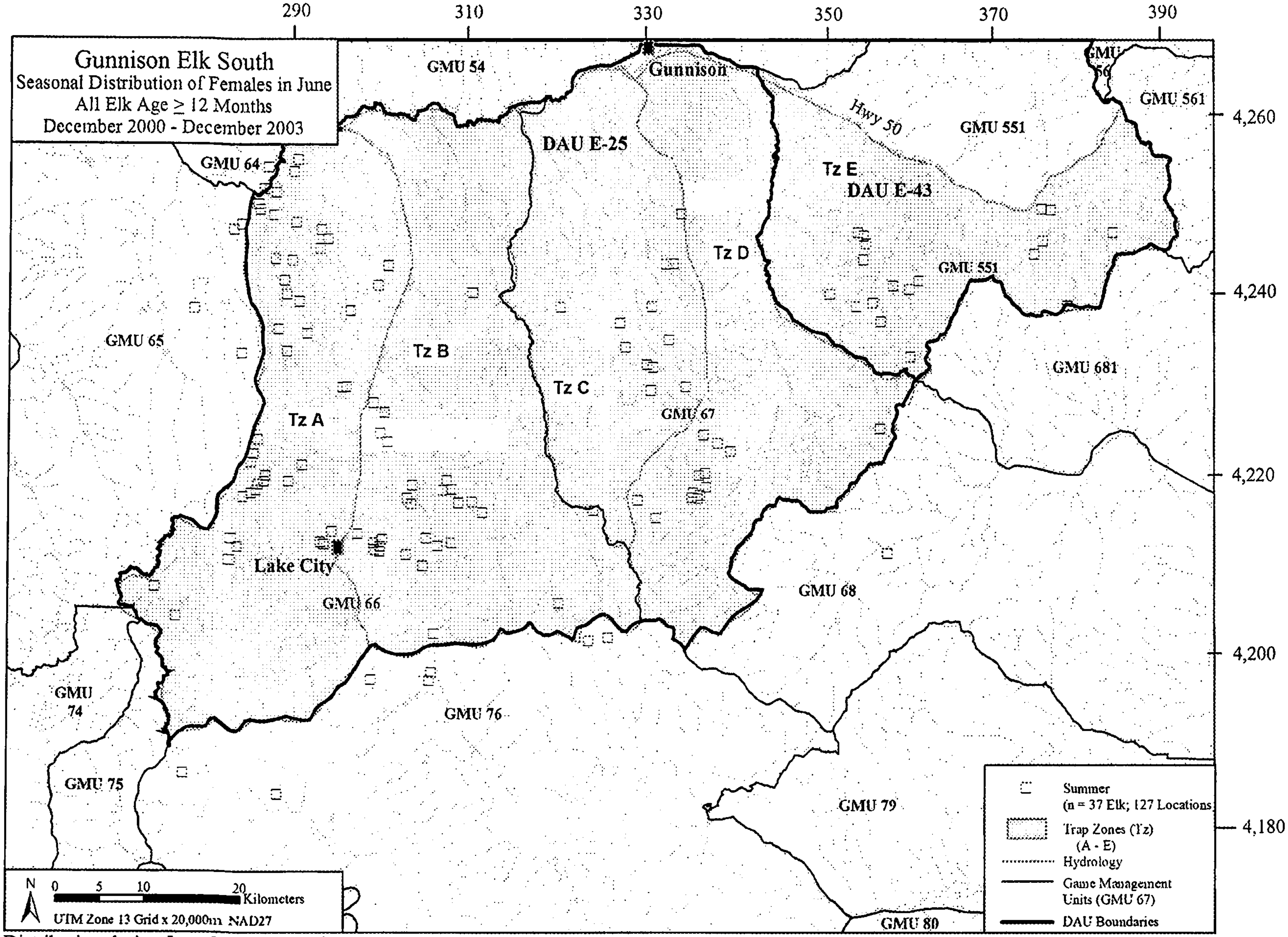


Figure 12. Distribution during June 2001-2003 of radio-collared female elk whose age was ≥12-months when locations were acquired. Elk were captured south of U.S. Highway 50 in trap-zones A, B, C, D, and E of the Gunnison Basin and locations were based on the same females randomly selected as adults or calves that were used to describe composite seasonal distributions of elk where $n = 37$ from $N = 52$ females.

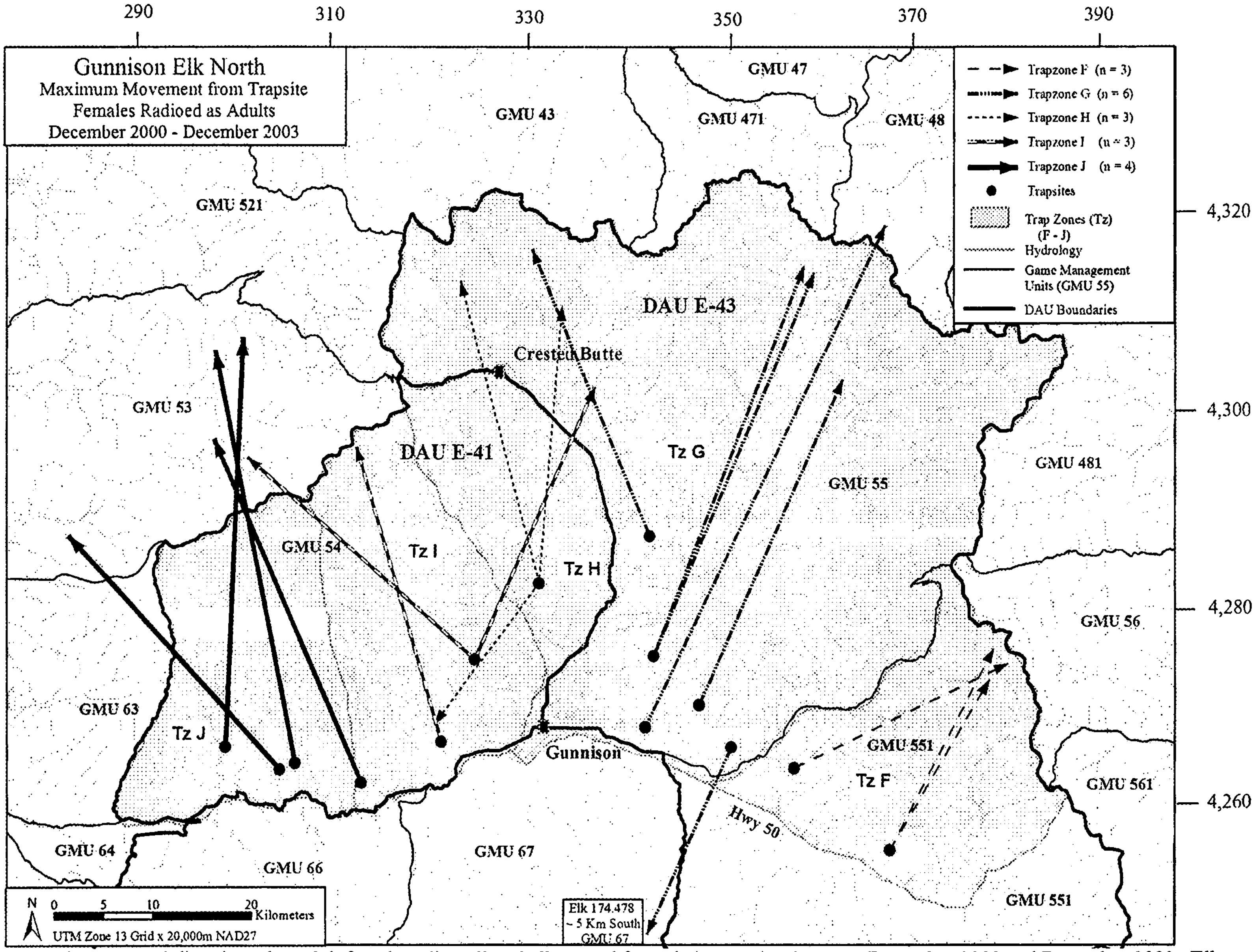


Figure 13. Maximum distances and directions that adult female radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as adults at age ≥30-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. Movement vectors based on the same adult female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations (n = 19).

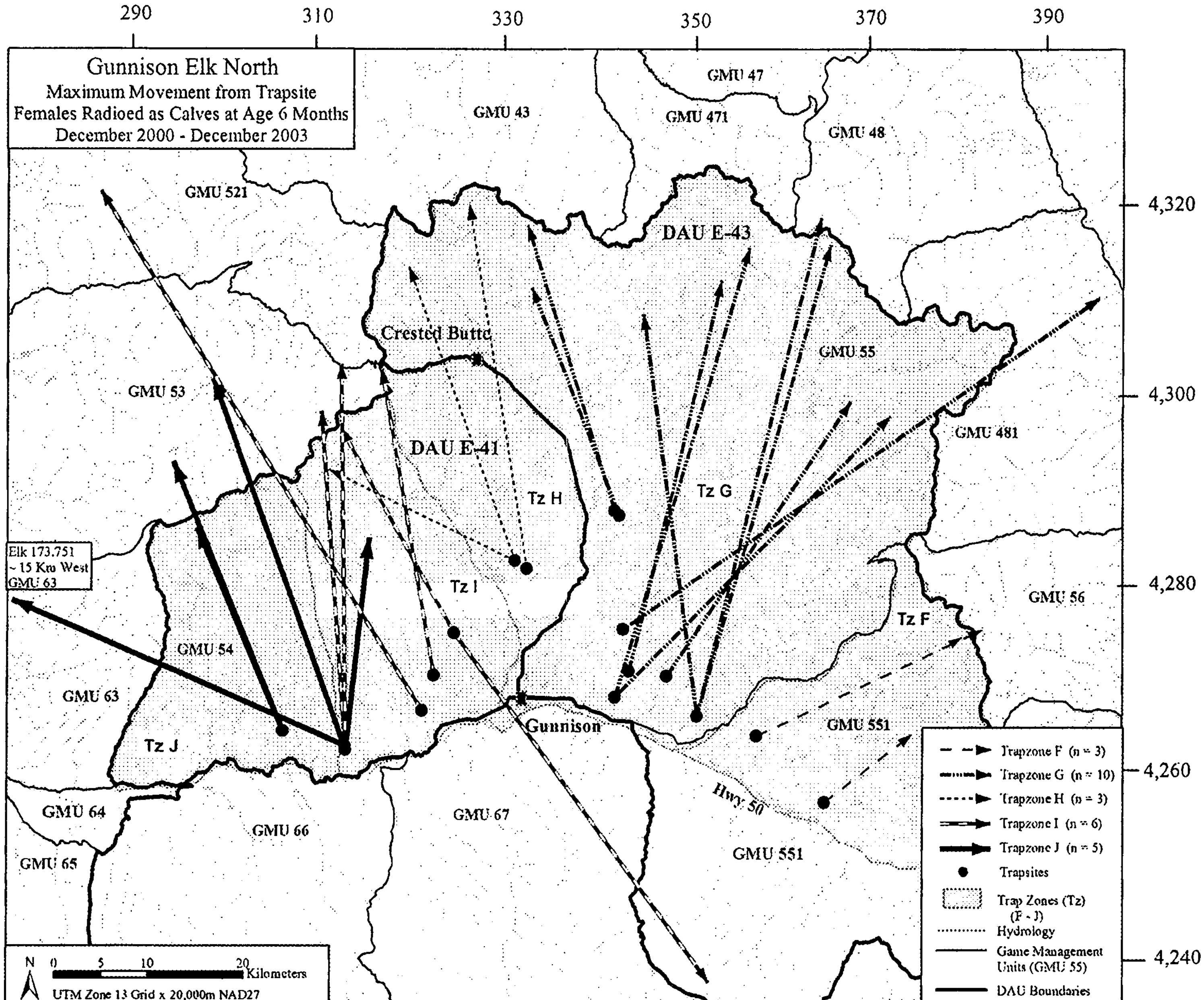


Figure 14. Maximum distances and directions that young female radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as calves at age 6-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. Movement vectors based on the same calf female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 27).

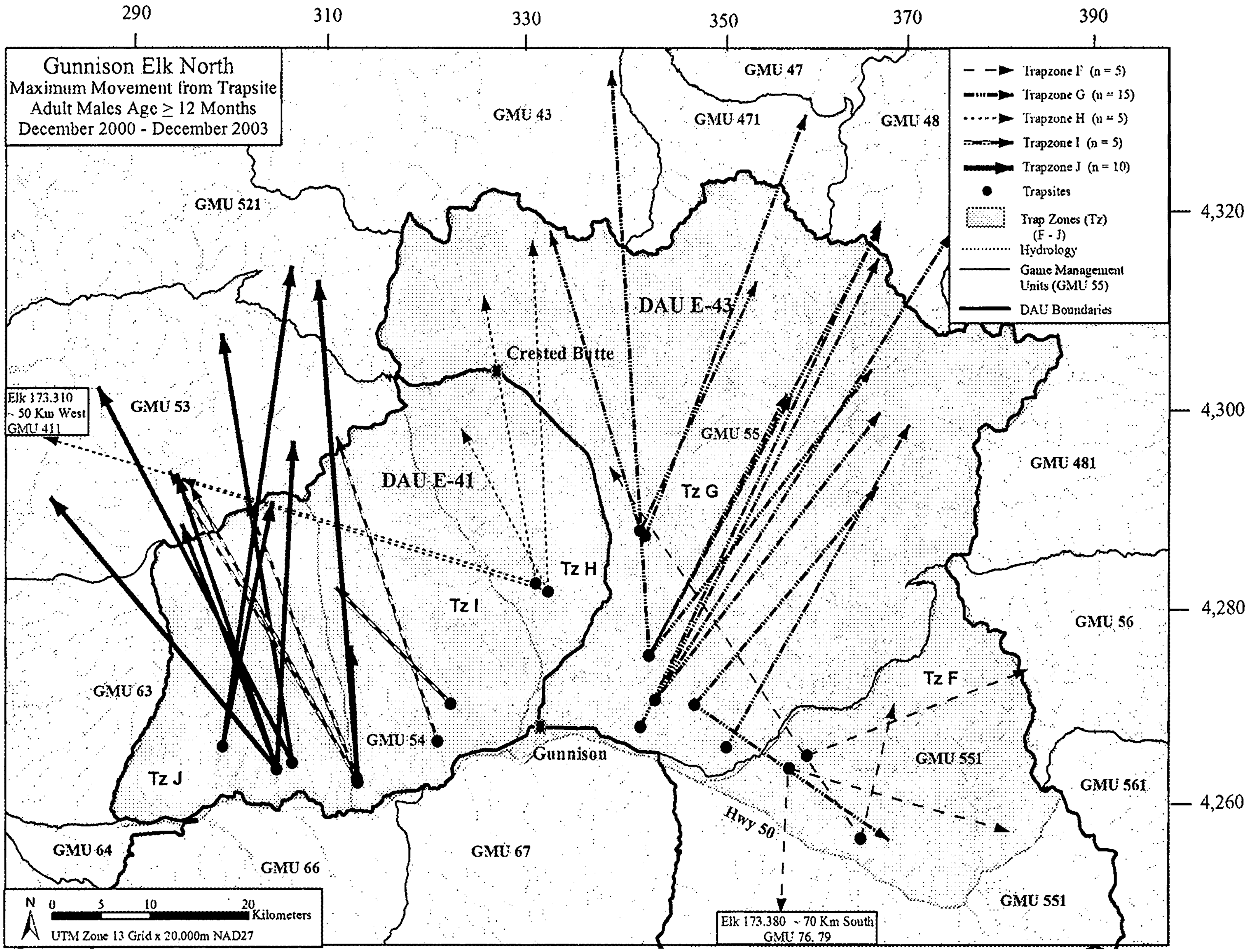


Figure 15. Maximum distances and directions that young male radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as calves at age 6-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. Movement vectors based on the same male elk used to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 40).

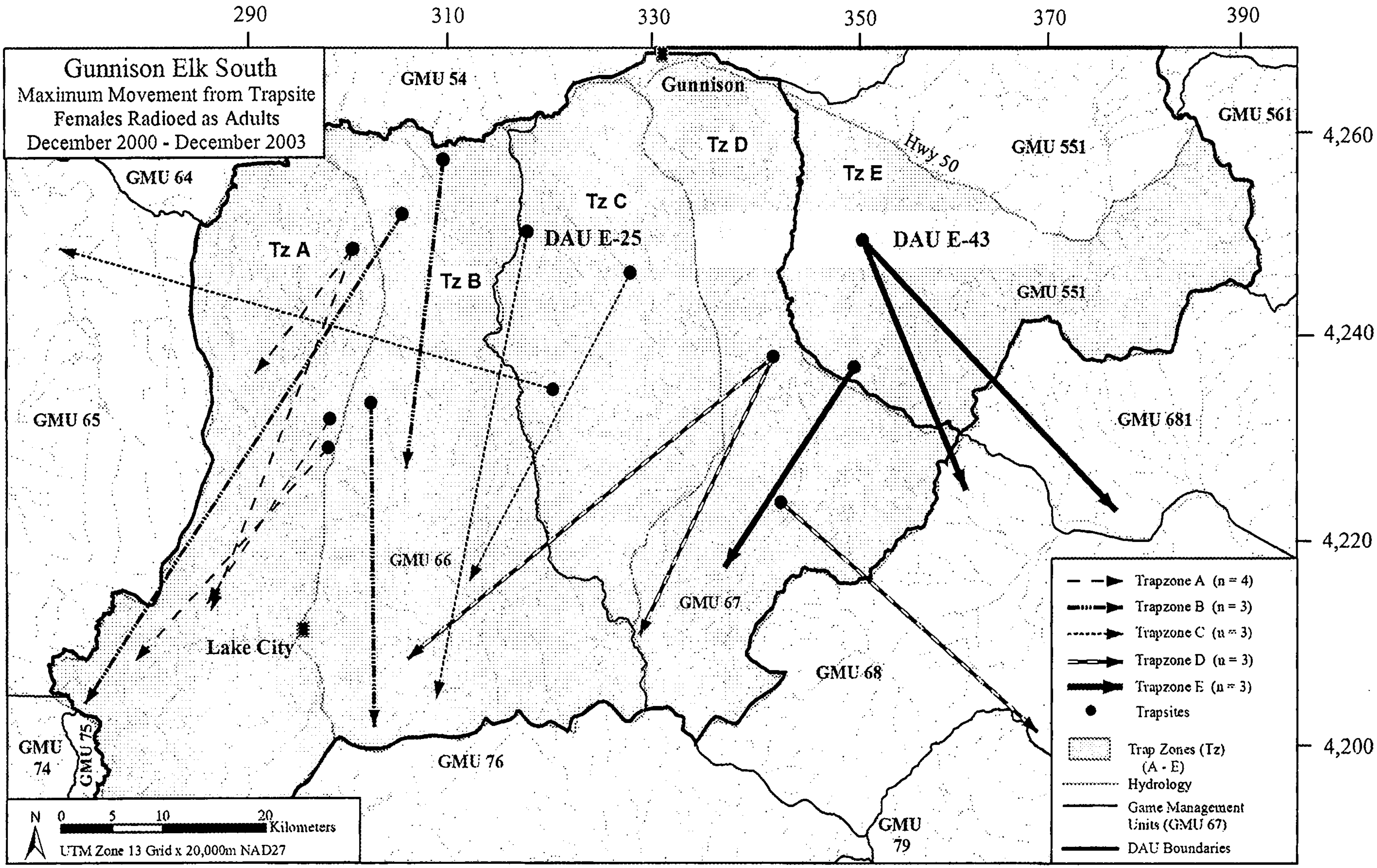


Figure 16. Maximum distances and directions that adult female radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as adults at age ≥30-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. Movement vectors based on the same adult female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations (n = 16).

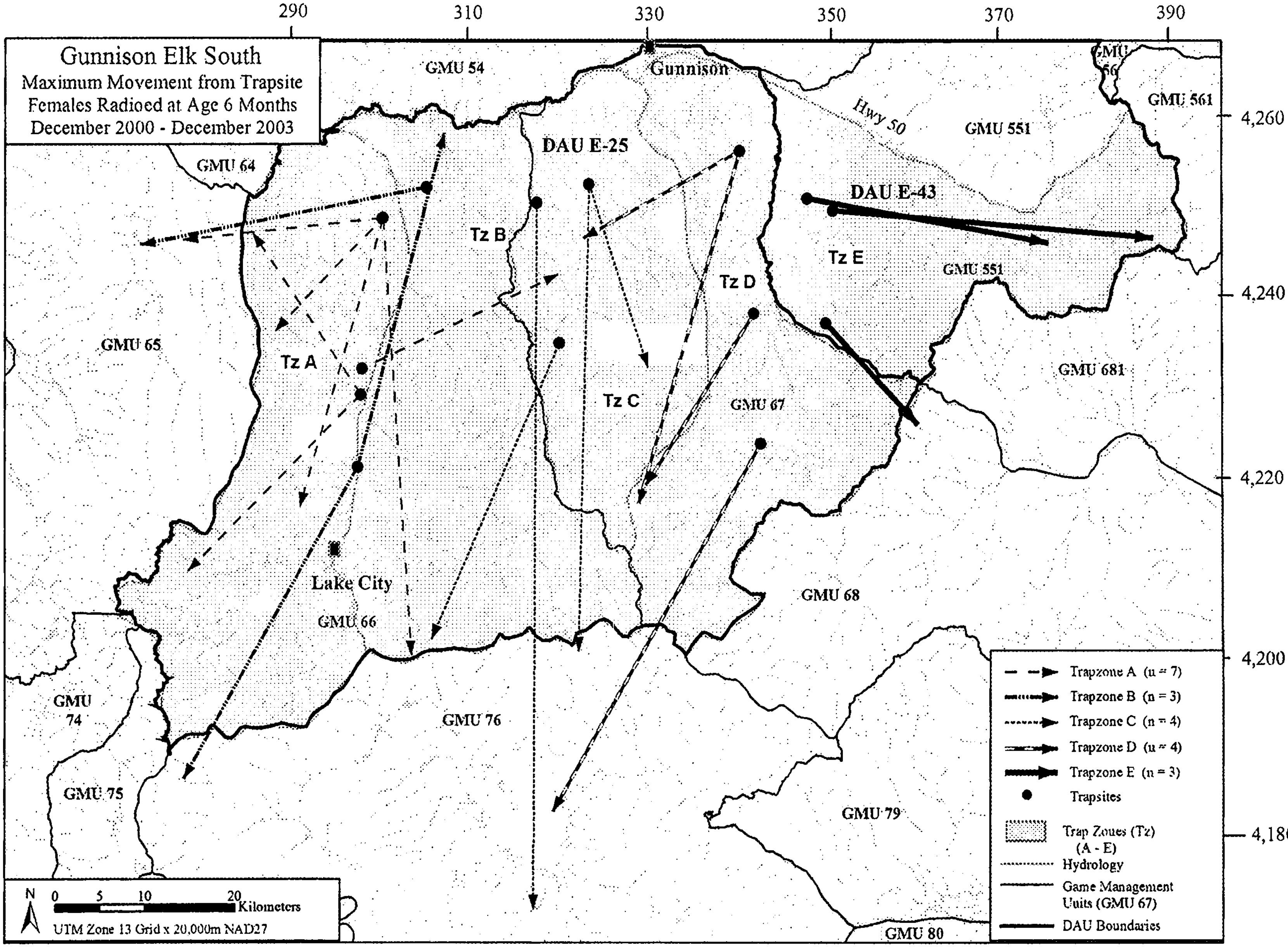


Figure 17. Maximum distances and directions that young female radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as calves at age 6-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. Movement vectors based on the same calf female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 21).

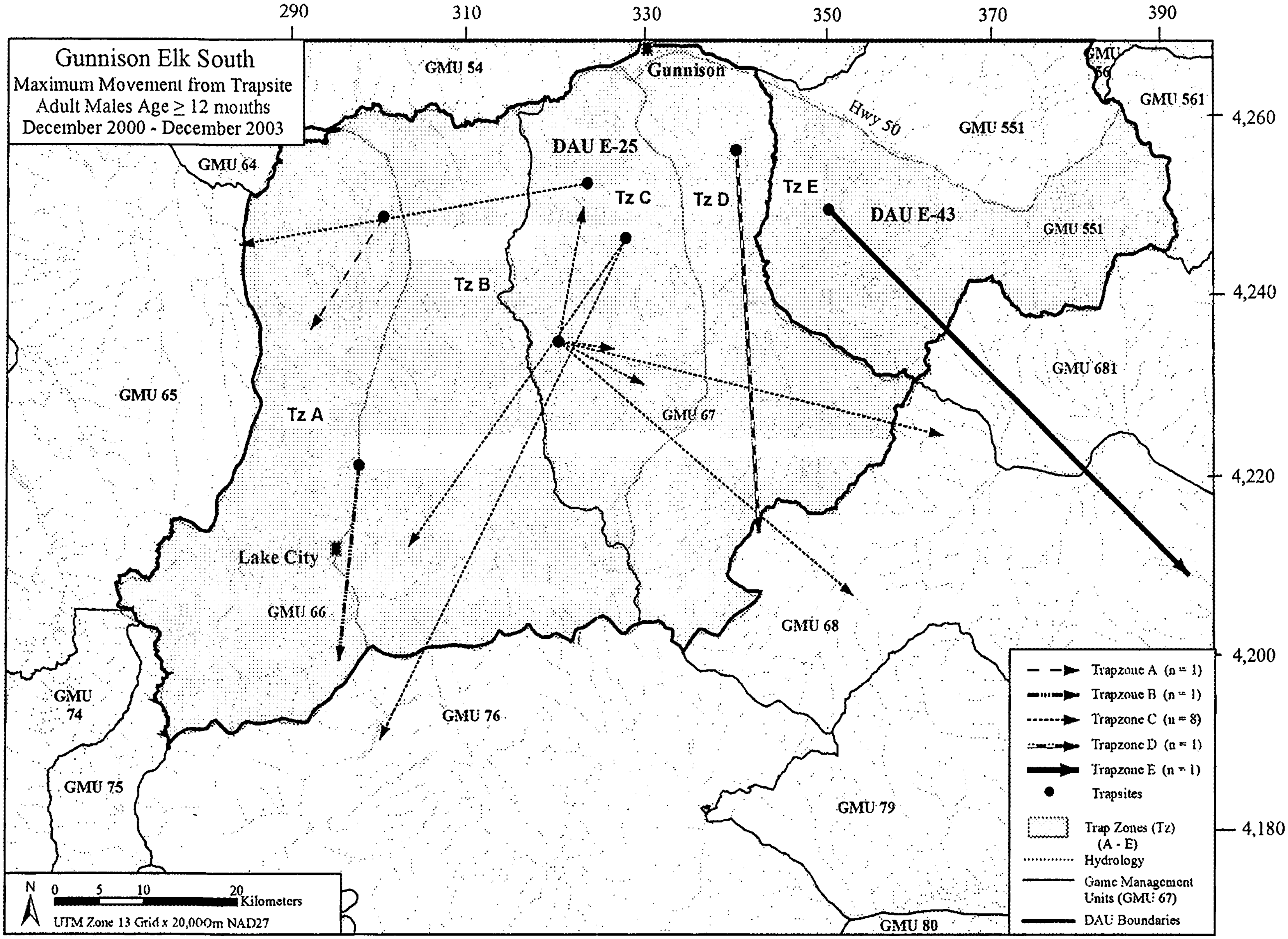


Figure 18. Maximum distances and directions that young male radio-collared elk moved from their trap-sites between December 2000 and December 2003. Elk captured as calves at age 6-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. Movement vectors based on the same male elk used to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 12).

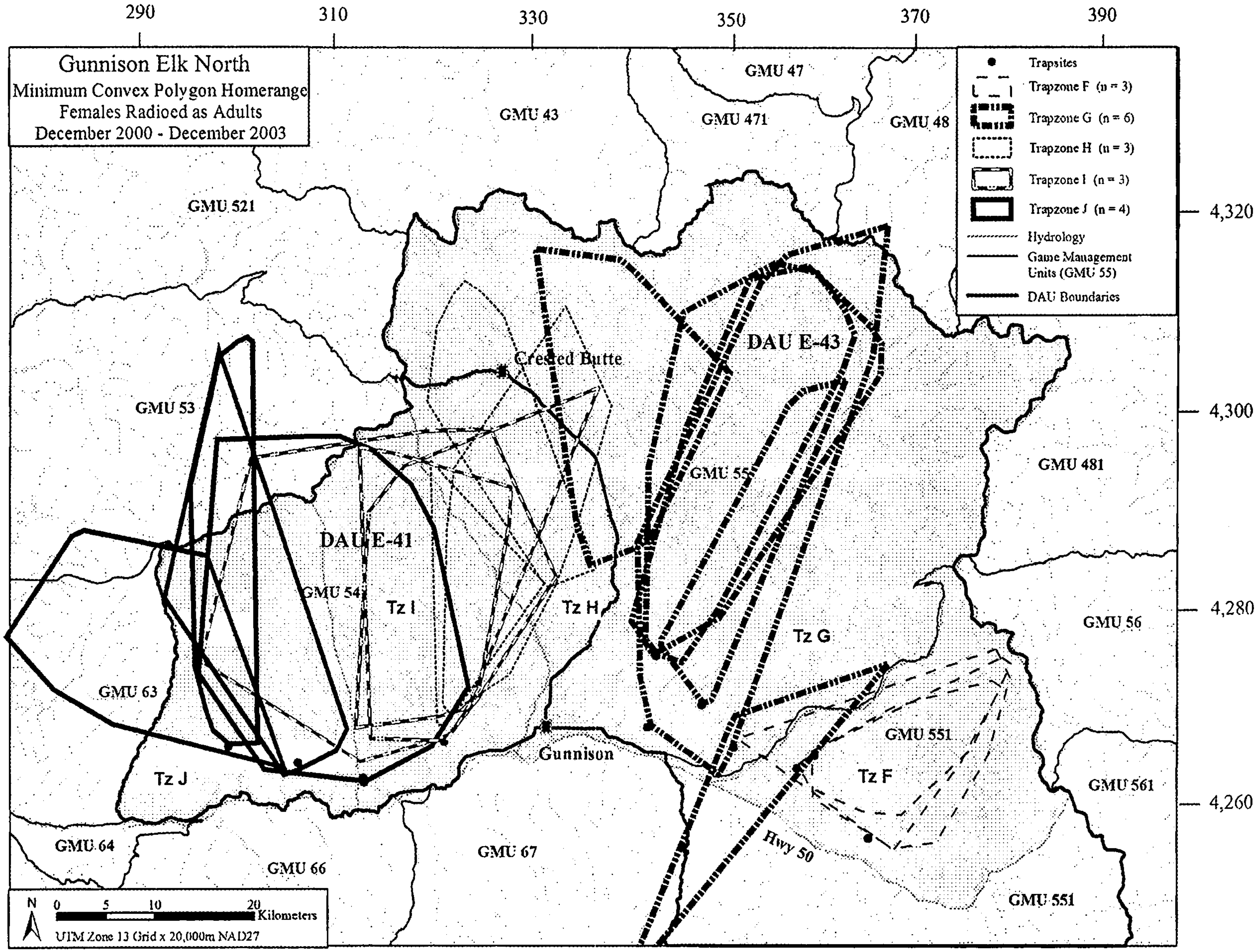


Figure 19. Minimum convex polygon (MCP) home ranges for adult female radio-collared elk between December 2000 and December 2003. Elk captured as adults at age ≥30-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. MCP based on the same adult female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations (n = 19).

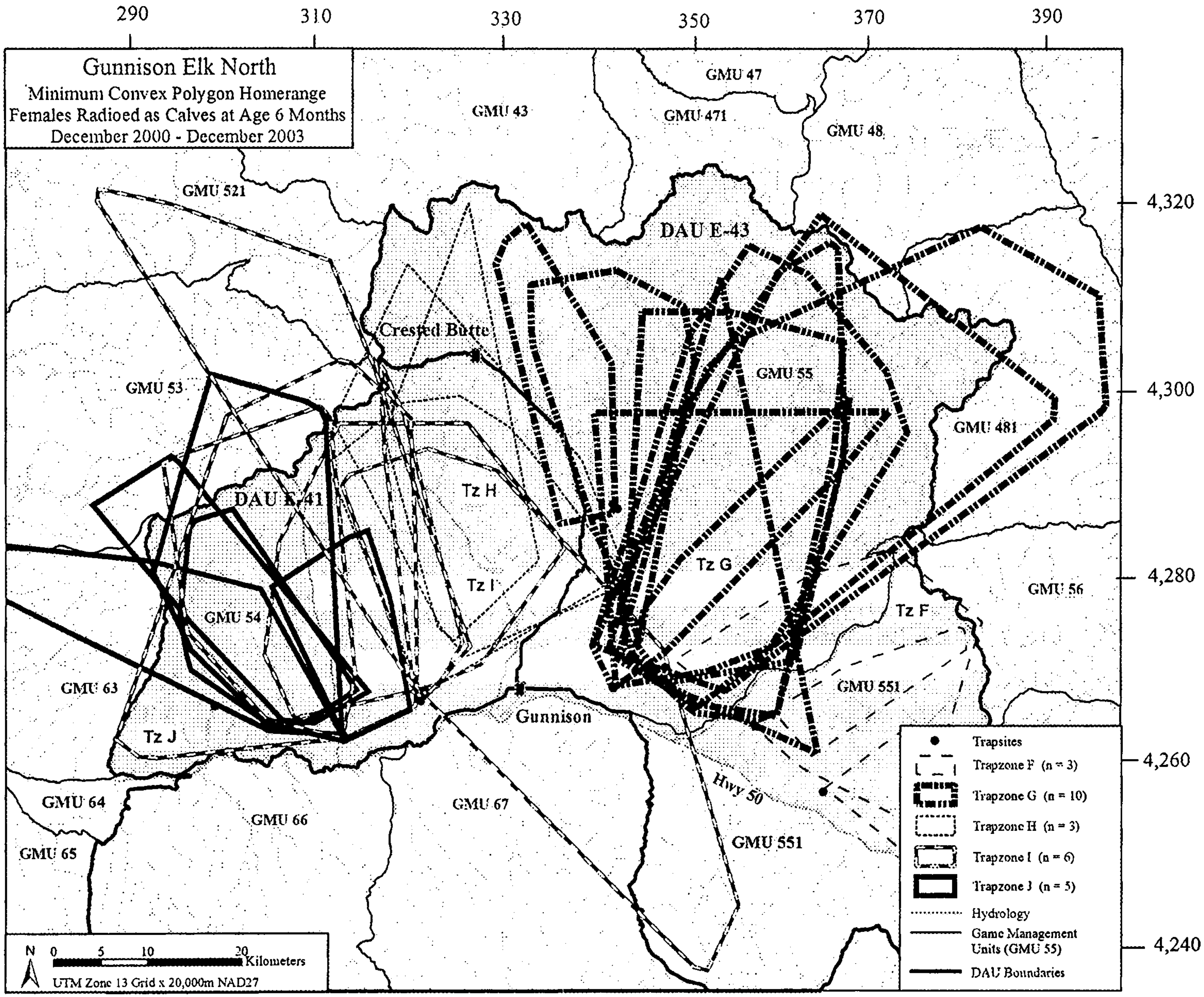


Figure 20. Minimum convex polygon (MCP) home ranges for young female radio-collared elk between December 2000 and December 2003. Elk captured as calves at age 6-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. MCP based on the same calf female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 27).

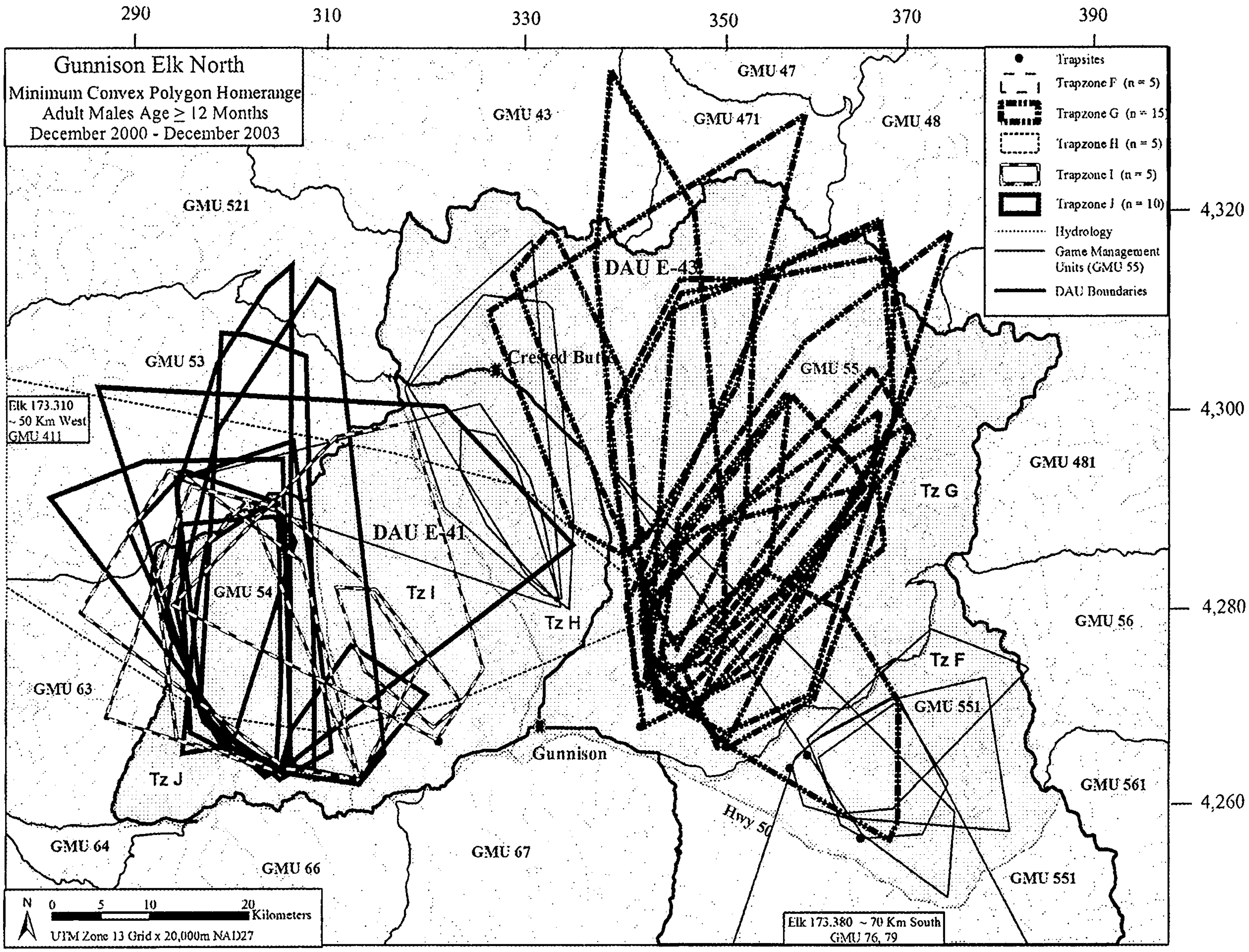


Figure 21. Minimum convex polygon (MCP) home ranges for young male radio-collared elk between December 2000 and December 2003. Elk captured as calves at age 6-months north of U.S. Highway 50 in trap-zones F-J of the Gunnison Basin. MCP based on the same male elk used to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 40).

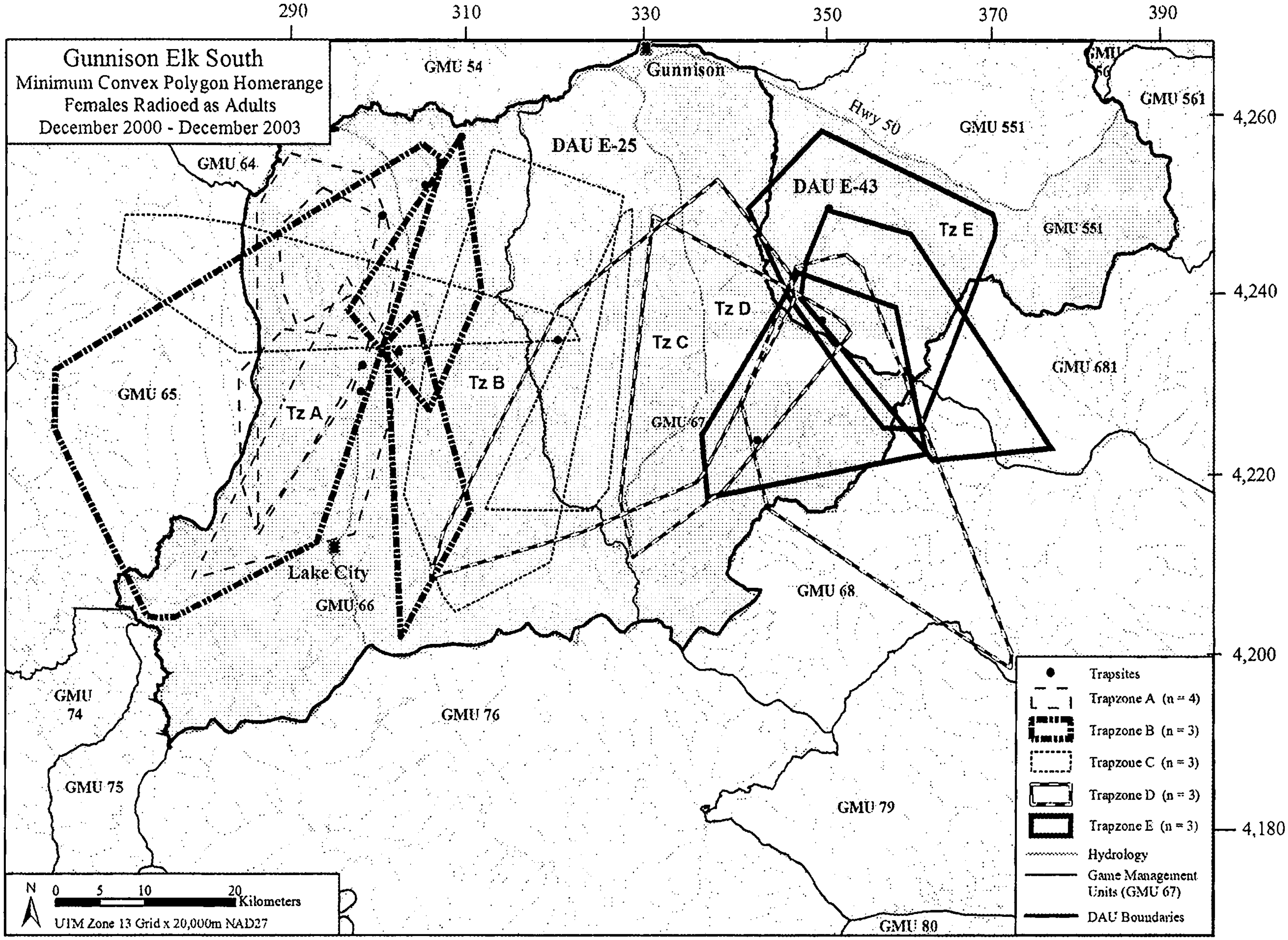


Figure 22. Minimum convex polygon (MCP) home ranges for adult female radio-collared elk between December 2000 and December 2003. Elk captured as adults at age ≥30-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. MCP based on the same adult female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations (n = 16).

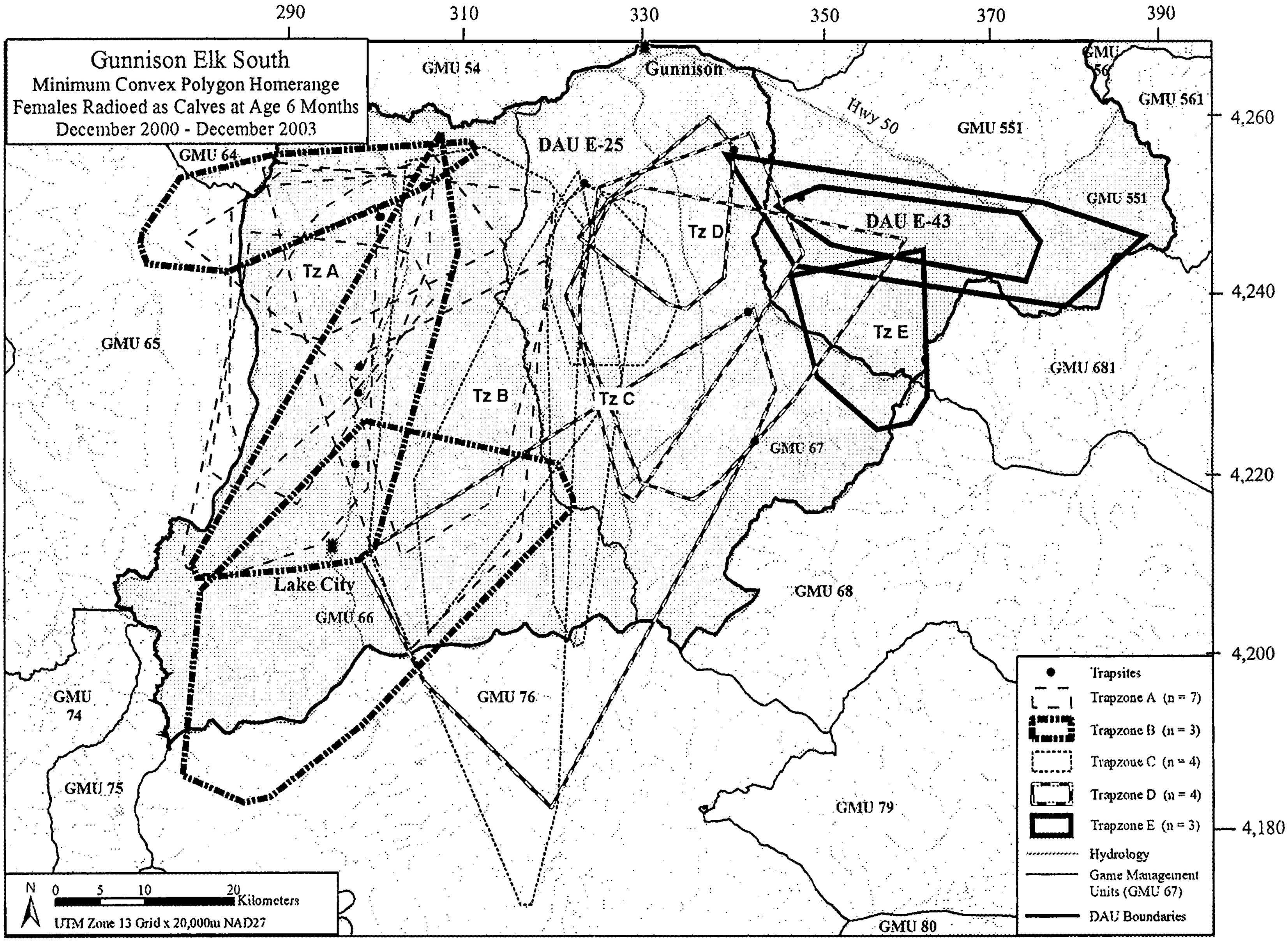


Figure 23. Minimum convex polygon (MCP) home ranges for young female radio-collared elk between December 2000 and December 2003. Elk captured as calves at age 6-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. MCP based on the same calf female elk randomly selected to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 21).

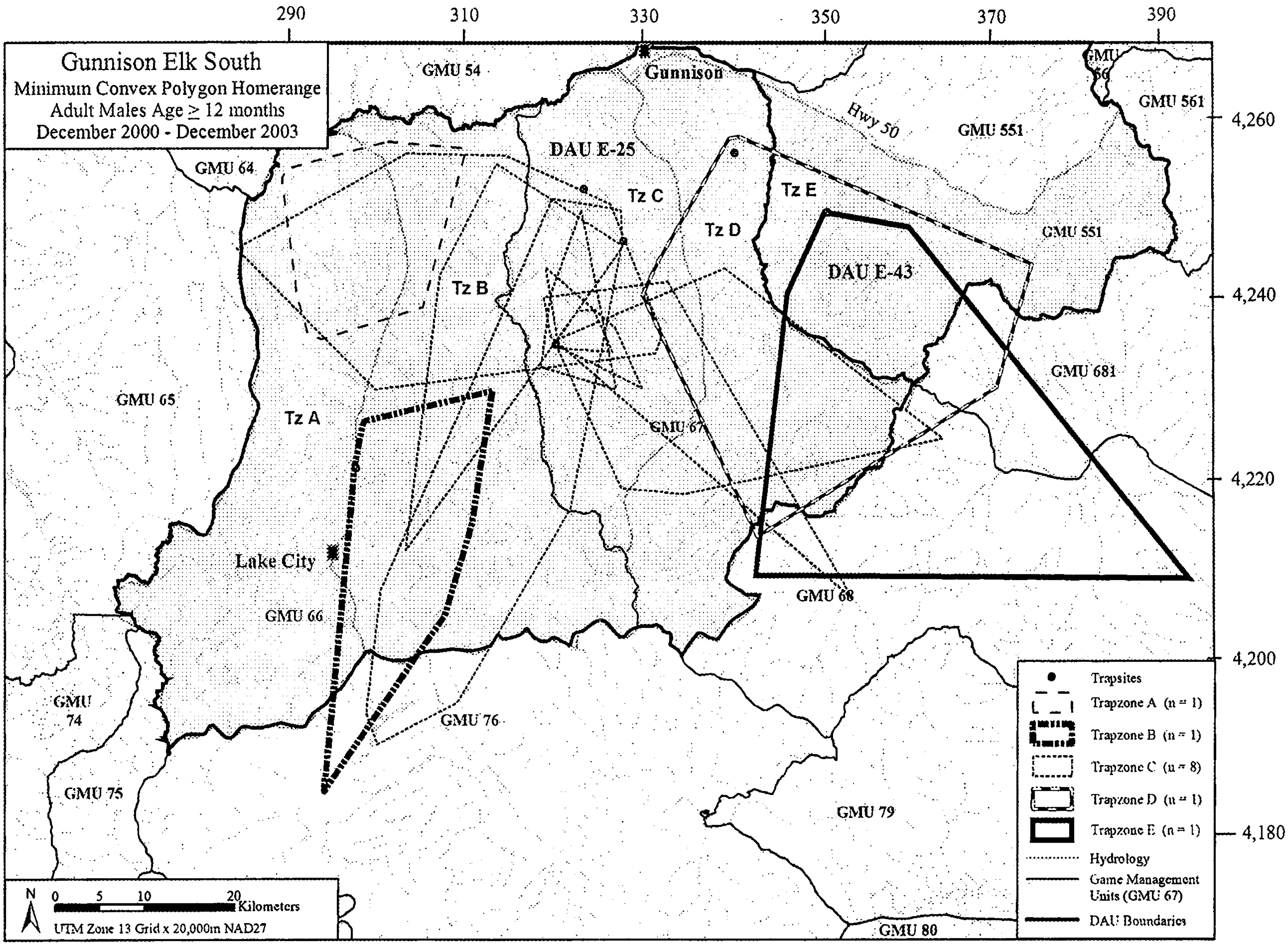


Figure 24. Minimum convex polygon (MCP) home ranges for young male radio-collared elk between December 2000 and December 2003. Elk captured as calves at age 6-months south of U.S. Highway 50 in trap-zones A-E of the Gunnison Basin. MCP based on the same male elk used to describe composite seasonal distributions of elk which had ≥8 locations and generally attained an age ≥12-months (n = 12).

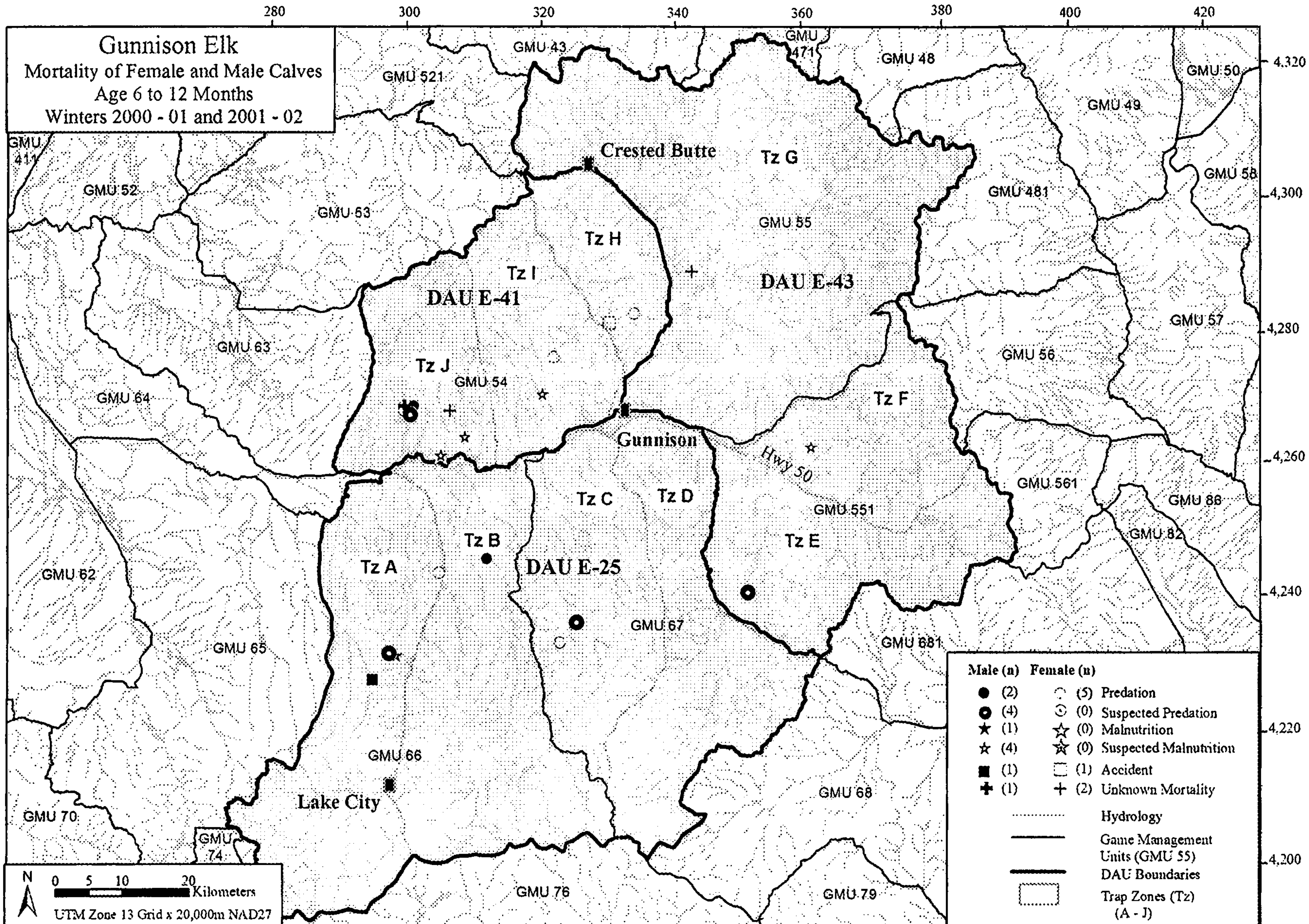


Figure 25. Locations of mortalities for female (n = 8) and male (n = 13) radio-collared calf elk during winter between 15 December and 15 June, 2000-01 and 2001-02. Elk were captured throughout the Gunnison Basin in trap-zones A-J and were age 6 to 12 months at time of death.

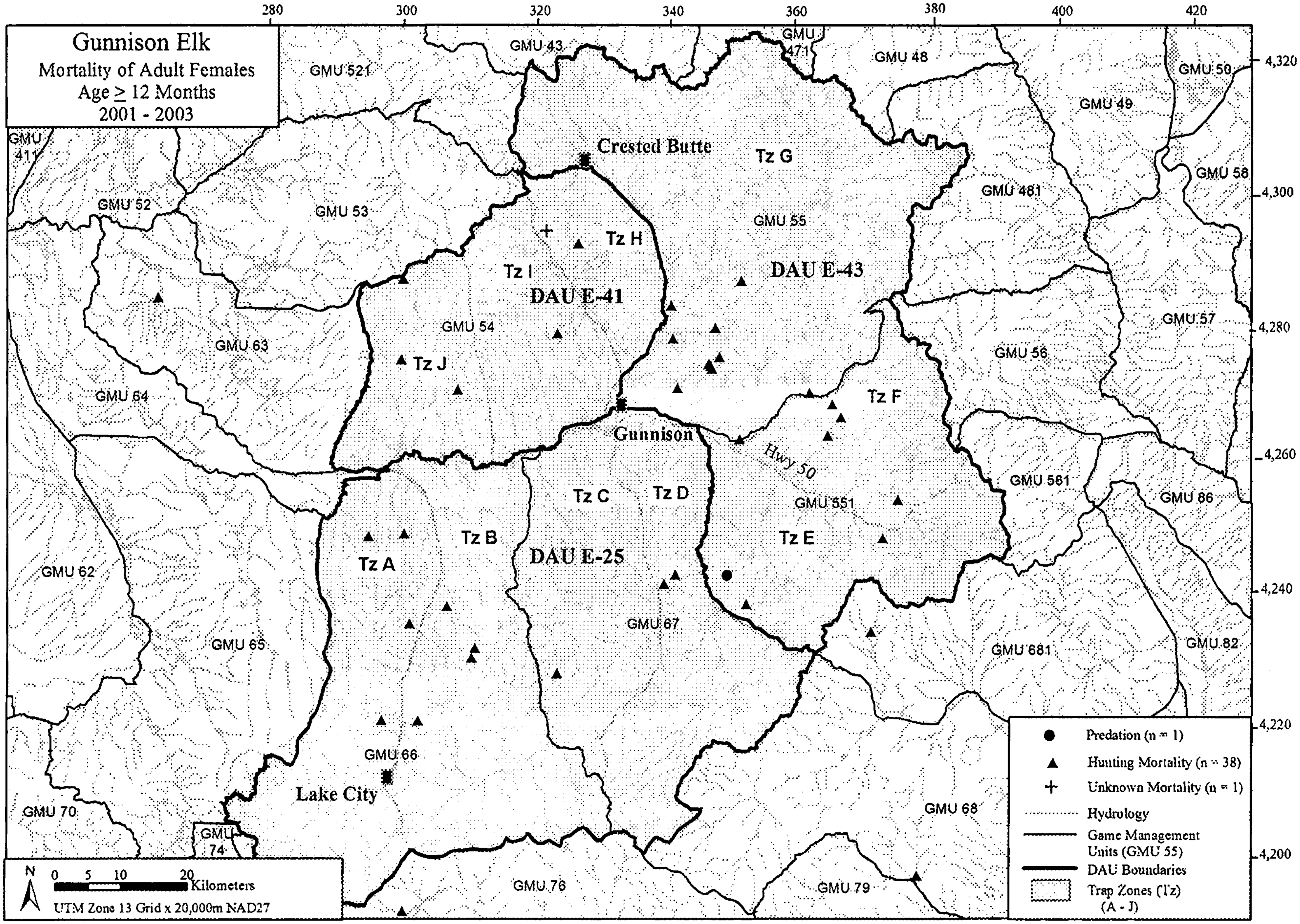


Figure 26. Locations of mortalities (n = 40) for adult female radio-collared elk between January 2001 and December 2003. Elk were captured throughout the Gunnison Basin in trap-zones A-J and were age ≥12 months at time of death.

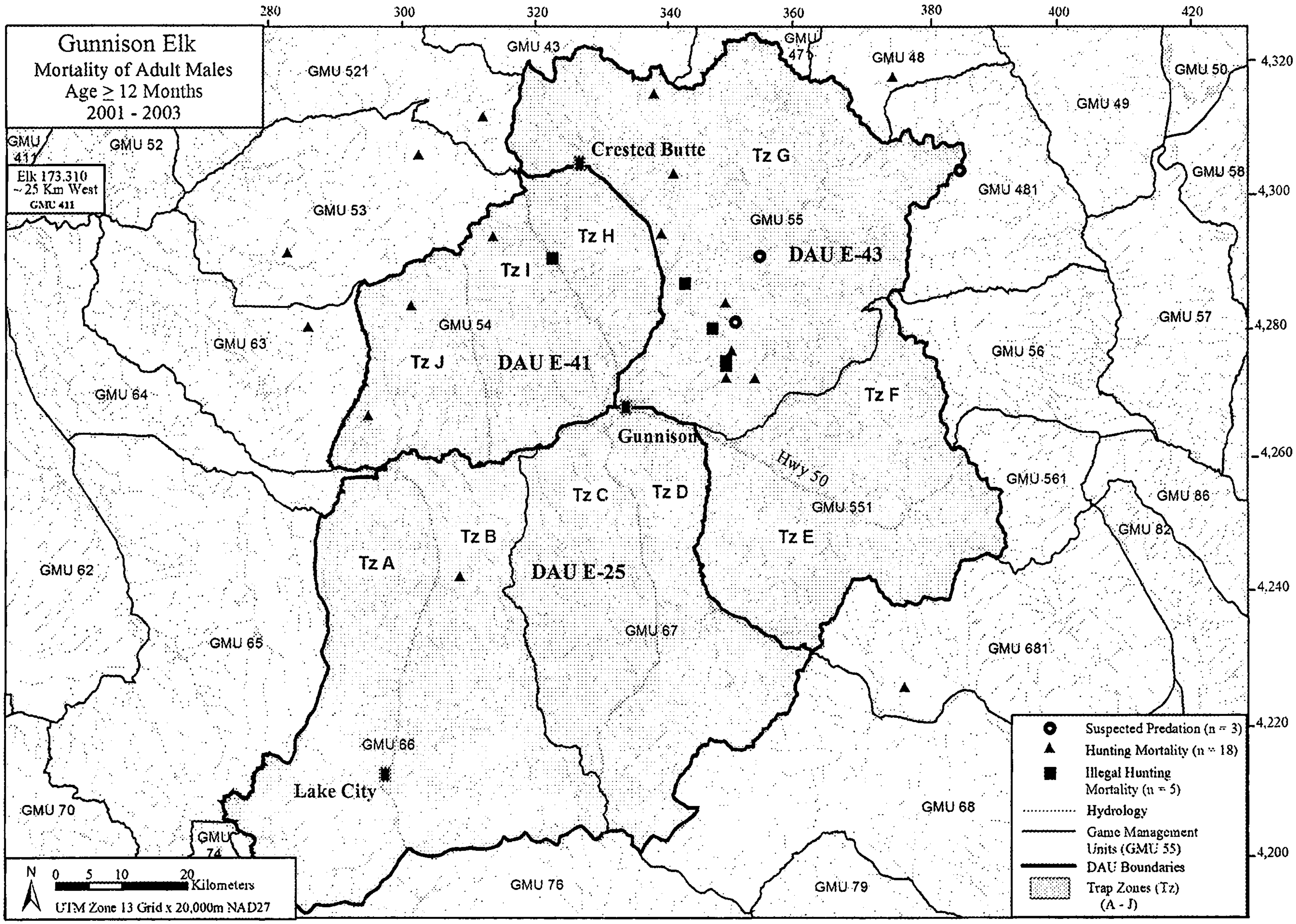


Figure 27. Locations of mortalities (n = 26) for adult male radio-collared elk that occurred between July 2001 and December 2003. Elk were captured throughout the Gunnison Basin in trap-zones A-J and were age ≥12 months at time of death.

JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 3740 : Chronic Wasting Disease and Other Wildlife Disease Management

Task 1 : Chronic Wasting Disease in Mule Deer Monitoring & Management

Period Covered: July 1 2002 through June 30, 2003

Author: Michael W. Miller and L. L. Wolfe

Personnel: L. A. Baeten, T. H. Baker, M. M. Conner, K. Cramer, T. R. Davis, V. Dreitz, C. P. Hibler, N. T. Hobbs, E. Hoover, D. O. Hunter, E. Knox, C. E. Krumm, C. T. Larsen, N. Mier, B. E. Powers, J. Rhyan, C. J. Sigurdson, T. R. Spraker, K. Taurman, E. S. Williams, D. Wroe

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.

ABSTRACT

We continued conducting research on various aspects of chronic wasting disease (CWD) epidemiology and management. Here, we report progress in ongoing and recently-completed work. Studies focused on improving and expanding surveillance in free-ranging populations, understanding and modeling transmission mechanisms, identifying ecological and anthropogenic factors that may influence epidemic dynamics, and evaluating and applying alternative diagnostic and control strategies. In addition to preliminary findings reported here, eight original studies, as well as one review article, were published publication during this segment; citations are appended to the report.

INTRODUCTION

We continued conducting research on various aspects of chronic wasting disease (CWD) epidemiology and management. Some parts of this work were conducted in collaboration with investigators at Colorado State University, the University of Wyoming, and elsewhere. Specific projects were supported with various combinations of funds from the Colorado Division of Wildlife (CDOW), Federal Aid in Wildlife Restoration Project W-153-R, the U.S. Department of Agriculture, and National Science Foundation/National Institutes of Health Grant DEB-0091961.

METHODS

Our work on CWD is both multidisciplinary and multifaceted, but broadly falls under the topics of "epidemiology and management" or "pathogenesis and diagnosis". For simplicity, we describe progress under those headings below.

STUDIES OF CWD EPIDEMIOLOGY & MANAGEMENT

We continued or initiated studies related to surveillance, transmission mechanisms, epidemic trend forecasting, potential host range and strain variation, risk factors, and management tools and feasibility as aids to understanding and controlling CWD in free-ranging deer and elk in Colorado.

Statewide surveillance: The discovery of CWD in northwestern Colorado in January 2002 created a sudden demand for both more widespread surveillance and more rapid turnaround on laboratory results. Consequently, the CDOW's CWD surveillance program was overhauled and its capacity greatly expanded over the summer of 2002 in order to meet anticipated demands for surveillance data, as well as to meet policy-based decisions to provide carcass quality assurance information for individual hunters. The most notable changes were the addition of three regional submission laboratories, streamlining of tissue sampling methods, and incorporation of a rapid screening test for CWD diagnosis. Details of overall programmatic features and changes were described on a new CWD-oriented CDOW web page (http://wildlife.state.co.us/CWD/index.asp); details of the evaluation of modified sampling and testing procedures are described below.

Transmission mechanisms: We summarized findings on empirical evidence of animal–animal transmission of CWD and the relative importance of this mechanism in epidemic dynamics.

We also completed an experiment comparing the relative contributions of live animals, contaminated environments, and infected carcasses to CWD transmission. In this study, 34 free-ranging mule deer from two sources distant to known endemic foci of chronic wasting disease (Rocky Mountain Arsenal National Wildlife Refuge, US Air Force Academy) were captured for use as experimental subjects during March-May 2002. We transported these deer to the Colorado Division of Wildlife's Foothills Wildlife Research Facility (FWRF), where they were placed in paddocks (n = 3 replicates/exposure route; n = 3 deer/paddock). Exposure treatments were: confinement in paddocks housing naturally-infected deer (1 infected deer/paddock), confinement in paddocks where infected deer previously resided, and confinement in paddocks where carcasses from CWD-infected deer have decomposed *in situ* (1 carcass/paddock); unexposed control paddocks are also being maintained. Entire paddock groups will be sacrificed and examined at the first sign of CWD in any subject deer within a paddock. We compared infection rates within and among treatments to examine which of these may contribute to perpetuation of CWD epidemics.

Modeling epidemic dynamics in captive mule deer: Developing detailed, temporally dynamic models of CWD in wild populations is a pressing management need, but available field data are presently insufficient to clearly reveal natural trends in ongoing epidemic dynamics. Moreover, there are several plausible ways to model CWD transmission mechanisms, yet field data will likely not provide sufficient resolution for discerning the most appropriate representation. To begin understanding how to best model CWD transmission, we have undertaken a model selection exercise using a time series of data on prevalence on CWD in captive mule deer. We assembled 26 years of data (1974–2000) from CDOW's Foothills Wildlife Research Facility. These data are being used to evaluate strength of evidence for a set of candidate models involving indirect and direct transmission, as well as with and without latency periods. Estimates of transmission rates derived from these models will provide an upper bound on what could be expected in wild populations and will guide construction of candidate sets for modeling those populations.

Host range and strain variation: We continued a series of experimental studies in cattle, fallow deer, and mountain lions to explore potential host range of CWD after intense but natural exposure; these experiments compliment ongoing surveillance for evidence of infection in species not known to be natural hosts of CWD, including moose, mountain lions, and cattle. We also continued work looking for evidence of strain variation in CWD agent from various deer sources using domestic ferrets as a laboratory model.

Effects of land use on prevalence: Because land-use changes are likely to shape the spatial and temporal dynamics of CWD, as well as options for its management, we have been working to understand the effect of land use on patterns of CWD prevalence in free-ranging mule deer. We conducted a study to determine whether CWD prevalence in urban areas is higher than prevalence in non-urban areas. We categorized two land use types: urban areas contained $\geq$ 1 housing unit/10 acres and non-urban areas (e.g., ranch, state, and federal lands) contained < 1 housing unit/10 acres. We compared CWD prevalence between land use types in 3 study areas in northern Colorado (Glacier View Meadows [GVM], Horsetooth [HT], Estes Park [EP]) in which urban and non-urban areas were juxtaposed. In each study area, we delineated urban areas surrounded by a 1-2 km buffer and non-urban areas concentric to the buffer. Deer were sampled in approximately equal numbers from the two land use categories.

We used a combination of data collected from mule deer sampled via postmortem (Miller et al., 2000, J. Wildl. Dis. 36:676–690; Miller & Williams, 2002, Vet. Rec. 151:610–612) and antemortem (Wolfe et al., 2002, J. Wildl. Manage. 66:564–573) methods described previously; our target was 210 samples for each land-use category, which provided the ability to detect 10% differences in prevalence between categories with 90% probability at the 0.05 confidence level. We assumed sampling was normally distributed and tried to balance sampling equally among study areas.

Selective predation upon infected mule deer: To test for evidence of selective predation, we began a study to compare prevalence of CWD among puma-killed mule deer to prevalence among mule deer harvested or randomly culled by humans within home ranges of collared mountain lions. Sample size calculations were based on the number of deer samples needed to detect two-fold differences in CWD prevalence: we assume that if the mountain lions are showing selectivity for deer with CWD, then the prevalence in the deer killed by mountain lions will be at least twice the prevalence of CWD in the local deer population. Telemetry-marked mountain lions are being monitored and, when available, brainstem (medulla oblongata at the level of the obex), retropharyngeal lymph nodes, and tonsils are collected from puma-killed mule deer carcasses; where none of these tissues are available, we will try to locate and sample other lymphoid tissues (e.g., submandibular or mesenteric lymph nodes, Peyers patches, etc.). Representative subsamples of collected tissues will be fixed in 10% neutral buffered formalin, and the remainder stored frozen. Tissues will be evaluated for presence of PrP^{CWD} accumulations using established immunohistochemistry (IHC) techniques; IHC-positive cases will be further evaluated with hematoxylin and eosin staining to stage the duration of CWD infection. We will compare CWD prevalence among puma-killed deer to prevalence among deer harvested by hunters in the same area. Using cumulative location data from each collared puma, home range will be estimated. Data from mule deer harvested and sampled within each home range will be extracted from our harvest survey database, preferentially using data collected during the period of predation sampling where sufficient harvest data are available for that time period. To assess differences between predation- and harvest-associated prevalence, we will calculate the CI on the difference as described above; if the CI does not include 0, then we will conclude that these rates differ.

Influence of trace minerals on susceptibility: To investigate the potential influence of trace minerals on CWD susceptibility, we began two independent studies. In a retrospective study, we will use archived tissues to compare tissue levels of copper (Cu), molybdenum (Mo), and manganese (Mn) in mule deer infected with CWD to levels in apparently uninfected deer from the same geographic area. We also started an experiment to examine the effect of Cu supplementation on CWD susceptibility in white-tailed deer, wherein we will compare the natural infection rate and course of CWD in captive deer receiving a sustained-release oral Cu supplement to the rate and course in unsupplemented controls residing in the same paddock.

Vaccination as a preventive tool: We collaborated with investigators from Colorado State University to conduct a pilot study evaluating safety and serologic responses of mule deer to an anti-PrP vaccine. Four captive deer (2 vaccinates and 2 controls) were monitored and sampled over a 4-month period for evidence of vaccine effects on health and serum antibody levels.

Evaluation of an urban CWD management strategy: Recognizing the need for alternatives to traditional strategies for controlling CWD, we initiated a pilot study to evaluate "test and cull" as an approach for managing CWD in urban habitats. Previously, models exploring probable consequences of various management strategies identified selective removal of infected individuals as a potentially effective method for reducing CWD prevalence in mule deer populations, provided that infected deer were detected early and a large (>50%) proportion of the population could be sampled annually (Gross and Miller, 2001, J. Wildl. Manage. 65:205-215). During November-December 2002, 113 free-ranging mule deer were captured, tested, and marked with timed-release radiocollars in urban areas throughout Estes Park to assess the feasibility of such a management approach. This sampling effort represented testing of about 25% of the adult mule deer residing Estes Park. In January 2003, biopsy-positive deer were culled. Dropped radiocollars were recovered in March-April 2003 for reuse in a second round of sampling planned for April-May 2003. In addition to the primary goal of assessing feasibility, data gathered in the course of this study will also be useful in improving our understanding and modeling of the influences of urban landscapes on CWD epidemiology.

STUDIES OF CWD PATHOGENESIS & DIAGNOSIS

We continued or initiated studies related to rapid screening test evaluation, pathogenesis in natural hosts, and live-animal diagnostic test refinement and evaluation as aids to improving approaches for CWD surveillance and diagnosis in free-ranging deer and elk in Colorado.

Evaluation of a rapid screening test: In conjunction with expanded CWD surveillance in Colorado during Sep–Dec 2002, tissue samples (n = 25,050 total) from 23,256 mule deer, white-tailed deer, and Rocky Mountain elk collected statewide were examined using an ELISA developed by Bio-Rad Laboratories, Inc. (brELISA) in a two-phase study. In the validation phase of this study, a total of 4,175 retropharyngeal lymph node (RLN) or obex (OB) tissue samples were examined independently by brELISA and immunohistochemistry (IHC). There were 137 IHC positive samples and 4,038 IHC negative samples. Optical density (OD) values from brELISA were classified as "not detected" or "suspect" based on recommended cut-off values during the validation phase. Based on the validation phase data, only RLN samples were collected for the field application phase of this study and only samples with brELISA OD values > 0.1 were examined by IHC. We estimated assay performance parameters (sensitivity, specificity, agreement) for brELISA to determine the utility of this rapid screening assay in CWD surveillance programs.

Pathogenesis in natural host species: We continued our work studying the pathogenesis of CWD in white-tailed deer after oral inoculation with infectious, conspecific brain tissue. This study will complement studies documenting CWD pathogenesis in mule deer and elk that already have been completed.

Evaluation of antemortem diagnostic techniques: In order to better study and manage CWD across landscapes where hunting and culling are not feasible sources of diagnostic samples, we continued working to refine and evaluate techniques for sampling live animals. Previously, we conducted a field study to evaluate tonsil biopsy immunohistochemistry (IHC) as a tool for diagnosing CWD in live, free-ranging mule deer and estimating prevalence. Based on our initial success, we have applied these techniques to gather data for new studies related to effects of land use patterns on CWD prevalence and its management, as described elsewhere in this report.

We also initiated a study to evaluate a prospective rapid blood test for diagnosing CWD in live deer. A total of 37 samples from 21 different captive mule deer, some infected with CWD, were submitted to a private testing laboratory (GeneThera, Denver, CO) for evaluation using collection materials and instructions provided by the laboratory. In order to objectively assess reliability and repeatability of the candidate assay, the testing laboratory was blinded to the infection status and animal identification for individual samples that we submitted.

RESULTS AND DISCUSSION

STUDIES OF CWD EPIDEMIOLOGY & MANAGEMENT

Statewide CWD surveillance: The CDOW sampled over 26,000 deer and elk harvested or culled in northeastern Colorado and other select locations. Survey results were posted on the Division's CWD web page. Prevalence data also will be used to augment an existing database that is the foundation for ongoing analyses and modeling of temporal and spatial aspects of CWD epidemiology, as well as for evaluating responses to management. This year's data will be particularly useful in further exploring local patterns of disease prevalence related to deer movement, density, and land use patterns. Moreover, the surveillance strategy and methods first devised and implemented in Colorado recently served as a model for developing national recommendations on CWD surveillance in free-ranging populations.

Transmission mechanisms: A manuscript describing our findings on the relative importance of animal–animal transmission of CWD, as compared to maternal transmission, was accepted for publication and should appear this fall.

Our experiment comparing the relative contributions of live animals, contaminated environments, and infected carcasses to CWD transmission revealed that CWD can be transmitted indirectly, from environments contaminated by excreta or decomposed carcasses to susceptible animals. Under experimental conditions, mule deer became infected in 2 of 3 paddocks containing naturally infected deer, in 2 of 3 paddocks where infected deer carcasses had decomposed *in situ* ~1.8 years earlier, and in 1 of 3 paddocks where infected deer had last resided 2.2 years earlier. Our data suggest that indirect transmission and environmental persistence of infectious prions will complicate efforts to control CWD, and perhaps other animal prion diseases.

Modeling epidemic dynamics in captive mule deer: Preliminary analyses suggest that indirect transmission models best represent epidemic data; moreover, our model selection results align well with independent empirical findings on CWD transmission mechanisms. We will continue refining candidate models before making final comparisons and parameter estimations. Findings should be of use in refining epidemic models of CWD in free-ranging mule deer populations.

Host range and strain variation: Cattle (n = 11) living in paddocks with naturally-infected mule deer remained healthy through 6 years of exposure; in contrast, only 1 of 12 mule deer introduced into these same paddocks in 1997 is still alive. Our results are consistent with data from cell-free conversion (Raymond et al., 2000, EMBO 19:4425-4430) and intracerebral (IC) challenge (Hamir et al., 2001, J. Vet. Diag. Invest. 13:91–96) studies that suggest the probability of natural susceptibility to CWD in cattle is extremely low. Similarly, neither signs nor postmortem evidence of infection have been observed in fallow deer (n = 24) exposed to infected mule deer for ≤2.5 years, and mountain lions (n = 3) consuming carcasses of CWD-infected deer and elk for >1 year also have remained healthy. No evidence of infection has been observed in moose, mountain lions, or cattle examined via ongoing surveillance.

Clinical signs and postmortem findings consistent with CWD in ferrets were observed in four of five IC-inoculated with tissue from infected deer, but have not been observed in the free-ranging white-tailed deer or control groups. Incidence and incubation periods were consistent among affected groups. Preliminary assessment of Western blots (WB) revealed no apparent differences in glycosylation patterns among WB-positive ferrets. In the absence of changes in status in the unaffected groups, we will terminate this study in the next 6 months and summarize our findings.

Effects of land use on prevalence: Preliminary analyses revealed that CWD prevalence was higher among deer sampled from urban areas (12.5%, CI=8.4–16.8%, n=243) than among deer from juxtaposed non-urban areas (7.3%, CI=4.3–10.3%, n=288) (Fisher's exact test, P=0.04). The magnitude of difference between CWD prevalence rates associated with urban and non-urban land use (5.3%, CI=2.4–8.2%) further emphasized the apparent effect of urban land use on CWD prevalence. Although CWD prevalence varied somewhat among study sites, it did not differ (Fisher's exact test, P=0.088). Area-specific differences may reflect greater risk or exposure among subpopulations. However, the trend of higher CWD prevalence in areas of urban land use was consistent across all three sites.

Our findings suggest that urbanization is playing an undesirable role in CWD epidemic dynamics in northcentral Colorado's mule deer populations. The underlying cause of this influence on CWD prevalence remains unclear. Urban landscapes may attract or artificially congregate wild cervids. Supplemental feeding, although illegal in Colorado, occurred throughout urban areas in all 3 of our study sites. Urban areas also may provide refuge from predation. Mountain lions are likely the main predator of deer in this area, but they are reclusive and seldom hunt in urban lands. Deer may become more sedentary in urban areas – in extreme cases, urban development may even promote elimination or modification of seasonal migration patterns made by resident deer. Regardless of the reason(s), urban landscapes clearly cannot be ignored in attempts to manage CWD and perhaps other important wildlife disease problems.
Selective predation upon infected mule deer: Our work continues from a pilot study conducted to evaluate available global positioning system (GPS)-based telemetry collars for use in this sampling application. We are now sampling mule deer carcasses to test for evidence of CWD infection by monitoring collared mountain lions 1–3 times/week and locating prospective kill sites using a remotely downloadable GPS telemetry system (Lotek, Inc.; model GPS4000). We will continue refining our monitoring approach to ensure that we find kill sites quickly enough to retrieve a suitable tissue sample to test for CWD. Whether target sample sizes can be attained in the time planned for this work remains to be determined.

Influence of trace minerals on susceptibility: Both studies are underway.

Vaccination as a preventive tool: We observed no adverse effects of vaccination on captive mule deer; serology results are pending.

Evaluation of an urban CWD management strategy: Data from our December pilot trial indicate that testing and culling mule deer appears to be a viable approach for managing CWD in Estes Park. Based on the success of the first round of pilot testing, the CDOW has committed to a 5-year management experiment to evaluate the efficacy of test and cull in lowering CWD prevalence in an urban mule deer population. A manuscript describing the results of our feasibility study is in preparation.

STUDIES OF CWD PATHOGENESIS & DIAGNOSIS

Evaluation of a rapid screening test: In the validation phase, using IHC-positive cases as known CWD-infected individuals and assuming IHC-negative cases were uninfected, the relative sensitivity of brELISA depending on species ranged from 98.3–100% for RLN samples and 92.1–93.3% for OB samples; the relative specificity of brELISA depending on species ranged from 99.9–100% for RLN samples and was 100% for OB samples. Overall agreement between brELISA and IHC was ≥97.6% in RLN samples and ≥95.7% in OB samples of all species where values could be calculated; moreover, mean brELISA OD values were ≥46× higher in IHC-positive samples than in IHC–negative samples. Discrepancies were observed only in early-stage cases of CWD. Among 20,875 RLN samples screened with brELISA during the field application phase, 155 of 8,877 mule deer, 33 of 11,731 elk, and 9 of 267 white-tailed deer samples (197 total) had OD values > 0.1 and were further evaluated by IHC to confirm evidence of CWD infection. Of cases flagged for IHC follow-up, 143 of 155 mule deer, 29 of 33 elk, and all 9 white-tailed deer were confirmed positive. Mean (± SE) OD values for IHC-positive cases detected during the field application phase were comparable to those measured in RLN tissues during the validation phase. Based on these data, brELISA was determined to be an excellent rapid test for screening large numbers of samples in surveys designed to detect CWD infections in deer and elk populations.

Pathogenesis in natural host species: Although our study of CWD pathogenesis in white-tailed deer is ongoing, some white-tailed deer inoculated orally with about 2.5 g of brain tissue homogenate (containing about 15 μg PrP^{CWD}) already developed clinical CWD and were euthanized in end-stage disease 16–30 mo postinoculation (PI). The clinical course in inoculated white-tailed deer was similar to that previously observed in mule deer inoculated with about 15 μg PrP^{CWD} from infected mule deer. Laboratory evaluations of tissues from both our white-tailed deer and mule deer pathogenesis studies are pending.

Evaluation of antemortem diagnostic techniques: Tonsil biopsy is a useful tool for estimating CWD prevalence in nonhunted mule deer populations. In addition to applications in the two field studies described here, the techniques we developed are being used in at least four other field studies of CWD epidemiology (WY, NM, WI, SD).

Thus far, we have been unable to assess the reliability or repeatability of the "GeneThera test". Over 6 mo have passed since blind samples were submitted, but we have been unable to obtain any test results despite repeated attempts to contact the laboratory. Until such evaluations can be completed, we cannot recommend incorporation of this candidate test into any of our ongoing CWD research or management programs.

APPENDIX

Publications arising from ongoing CWD work:

Gould, D. H., J. L. Voss, M. W. Miller, A. M. Bachand, B. A. Cummings, and A. A. Frank. 2003. Survey of cattle in northeast Colorado for evidence of chronic wasting disease: Geographical and high risk targeted sample. Journal of Veterinary Diagnostic Investigation 15: 274–277.

Hibler, C. P., K. L. Wilson, T. R. Spraker, M. W. Miller, R. R. Zink, L. L. DeBuse, E. Andersen, D. Schweitzer, J. A. Kennedy, L. A. Baeten, J. F. Smeltzer, M. D. Salman, and B. E. Powers. 2003. Field validation and assessment of an enzyme-linked immunosorbent assay for detecting chronic wasting disease in mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and Rocky Mountain elk (*Cervus elaphus nelsoni*). Journal of Veterinary Diagnostic Investigation 15: 311–319.

Race, R. E., A. Raines, T. G. M. Baron, M. W. Miller, A. Jenny, and E. S. Williams. 2002. Comparison of abnormal prion protein glycoform patterns from transmissible spongiform encephalopathy agent-infected deer, elk, sheep, and cattle. Journal of Virology 76(23): 12365–12368.

Samuel, M. D., D. O. Joly, M. A. Wild, S. D. Wright, D. L. Otis, R. W. Werge, and M. W. Miller. 2003. Surveillance strategies for detecting chronic wasting disease in free-ranging deer and elk. Results of a CWD surveillance workshop. USGS, BRD, National Wildlife Health Center, Madison, Wisconsin.

Sigurdson, C. J., C. Barillas-Mury, M. W. Miller, B. Oesch, L. J. van Keulen, J. P. Langeveld, and E. A. Hoover. 2002. PrP(CWD) lymphoid cell targets in early and advanced chronic wasting disease of mule deer. Journal of General Virology 83: 2617–2628.

Spraker, T. R., K. I. O'Rourke, A. Balachandran, R. R. Zink, B. A. Cummings, M. W. Miller, and B. E. Powers. 2002*a*. Validation of monoclonal antibody F99/97.6.1 for immunohistochemical staining of brain and tonsil in mule deer (*Odocoileus hemionus*) with chronic wasting disease. Journal of Veterinary Diagnostic Investigation 14:3–7.

Spraker, T. R., R. R. Zink, B. A. Cummings, M. A. Wild, M. W. Miller, and K. I. O'Rourke. 2002*b*. Comparison of histological lesions and immunohistochemical staining of proteinase resistant prion protein in a naturally-occurring spongiform encephalopathy of free-ranging mule deer (*Odocoileus hemionus*) with those of chronic wasting disease of captive mule deer. Veterinary Pathology 39:110–119.

Wild, M. A., T. R. Spraker, C. J. Sigurdson, K. I. O'Rourke, and M. W. Miller. 2002. Preclinical diagnosis of chronic wasting disease in captive mule deer (Odocoileus hemionus) and white-tailed deer (*Odocoileus virginianus*) using tonsillar biopsy. Journal of General Virology 83: 2629–2634.

Williams, E. S., and M. W. Miller. 2003. Transmissible spongiform encephalopathies in non-domestic animals: origin, transmission, and risk factors. *In* Risk analysis of prion diseases in animals. C. I. Lasmézas and D. B. Adams, (eds.). Revue scientifique et technique Office international des Epizooties 22: 145-156.

JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 3740 : Chronic Wasting Disease and Other Wildlife Disease Management

Task 2 : Chronic Wasting Disease Surveillance and Laboratory Support

Period Covered: July 1 2002 through June 30, 2003

Author: L. A. Baeten

Personnel: K. Cramer, K. Green, E. Knox, C. T. Larsen, N. Mier, M. W. Miller, K. Taurman, and L. L. Wolfe

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.

ABSTRACT

We established and staffed a Wildlife Health Laboratory (WHL) to facilitate expanded needs for chronic wasting disease (CWD) surveillance throughout Colorado. WHL activities supported CWD epidemiology and management work, as well as various new and ongoing CWD research projects.

INTRODUCTION

We established and staffed a Wildlife Health Laboratory (WHL) to facilitate expanded needs for chronic wasting disease (CWD) surveillance throughout Colorado. WHL activities supported CWD epidemiology and management work, as well as various new and ongoing CWD research projects. Key contributions are described herein.

METHODS

Statewide CWD surveillance: The discovery of CWD in northwestern Colorado in January 2002 created a sudden demand for both more widespread surveillance and more rapid turnaround on laboratory results. Consequently, the CDOW's CWD surveillance program was overhauled and its capacity greatly expanded over the summer of 2002 in order to meet anticipated demands for surveillance data, as well as to meet policy-based decisions to provide carcass quality assurance information for individual hunters. The most notable changes were the addition of three regional submission laboratories, streamlining of tissue sampling methods, and incorporation of a rapid screening test for CWD diagnosis. Details of overall programmatic features and changes were described on a new CWD-oriented CDOW web page (http://wildlife.state.co.us/CWD/index.asp); details of the evaluation of modified sampling and testing procedures are described below.

Evaluation of a rapid screening test: In conjunction with expanded CWD surveillance in Colorado during Sep–Dec 2002, tissue samples (n = 25,050 total) from 23,256 mule deer, white-tailed deer, and Rocky Mountain elk collected statewide were examined using an ELISA developed by Bio-Rad Laboratories, Inc. (brELISA) in a two-phase study. In the validation phase of this study, a total of 4,175 retropharyngeal lymph node (RLN) or obex (OB) tissue samples were examined independently by brELISA and immunohistochemistry (IHC). There were 137 IHC positive samples and 4,038 IHC negative samples. Optical density (OD) values from brELISA were classified as "not detected" or "suspect" based on recommended cut-off values during the validation phase. Based on the validation phase data, only RLN samples were collected for the field application phase of this study and only samples with brELISA OD values > 0.1 were examined by IHC. We estimated assay performance parameters (sensitivity, specificity, agreement) for brELISA to determine the utility of this rapid screening assay in CWD surveillance programs.

RESULTS AND DISCUSSION

Statewide CWD surveillance: The CDOW sampled over 26,000 deer and elk harvested or culled in northeastern Colorado and other select locations. Survey results were posted on the Division's CWD web page. Prevalence data also will be used to augment an existing database that is the foundation for ongoing analyses and modeling of temporal and spatial aspects of CWD epidemiology, as well as for evaluating responses to management. This year's data will be particularly useful in further exploring local patterns of disease prevalence related to deer movement, density, and land use patterns. Moreover, the surveillance strategy and methods first devised and implemented in Colorado recently served as a model for developing national recommendations on CWD surveillance in free-ranging populations.

Evaluation of a rapid screening test: In the validation phase, using IHC-positive cases as known CWD-infected individuals and assuming IHC-negative cases were uninfected, the relative sensitivity of brELISA depending on species ranged from 98.3–100% for RLN samples and 92.1–93.3% for OB samples; the relative specificity of brELISA depending on species ranged from 99.9–100% for RLN samples and was 100% for OB samples. Overall agreement between brELISA and IHC was ≥97.6% in RLN samples and ≥95.7% in OB samples of all species where values could be calculated; moreover, mean brELISA OD values were ≥46× higher in IHC-positive samples than in IHC–negative samples. Discrepancies were observed only in early-stage cases of CWD. Among 20,875 RLN samples screened with brELISA during the field application phase, 155 of 8,877 mule deer, 33 of 11,731 elk, and 9 of 267 white-tailed deer samples (197 total) had OD values > 0.1 and were further evaluated by IHC to confirm evidence of CWD infection. Of cases flagged for IHC follow-up, 143 of 155 mule deer, 29 of 33 elk, and all 9 white-tailed deer were confirmed positive. Mean (± SE) OD values for IHC-positive cases detected during the field application phase were comparable to those measured in RLN tissues during the validation phase. Based on these data, brELISA was determined to be an excellent rapid test for screening large numbers of samples in surveys designed to detect CWD infections in deer and elk populations.

Publications:

Hibler, CP, Wilson, KL, Spraker, TR, Miller, MW, Zink, RR, DeBuse, LL, Andersen, E, Shcweitzer, D, Kennedy, JA, Baeten, LA, Smeltzer, JF, Salman, MD, Powers, BE **Field Validation and assessment of an enzyme-linked immunosorbent assay for detecting chronic wasting disease in mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and Rocky Mountain elk (*Cervus elaphus nelsoni*).** 2003 J. Vet Diagn Invest 15:311-319.

APPENDIX

Publications arising from WHL contributions to ongoing CWD work:

Hibler, C. P., K. L. Wilson, T. R. Spraker, M. W. Miller, R. R. Zink, L. L. DeBuse, E. Andersen, D. Schweitzer, J. A. Kennedy, L. A. Baeten, J. F. Smeltzer, M. D. Salman, and B. E. Powers. 2003. Field validation and assessment of an enzyme-linked immunosorbent assay for detecting chronic wasting disease in mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and Rocky Mountain elk (*Cervus elaphus nelsoni*). Journal of Veterinary Diagnostic Investigation 15: 311–319.

Samuel, M. D., D. O. Joly, M. A. Wild, S. D. Wright, D. L. Otis, R. W. Werge, and M. W. Miller. 2003. Surveillance strategies for detecting chronic wasting disease in free-ranging deer and elk. Results of a CWD surveillance workshop. USGS, BRD, National Wildlife Health Center, Madison, Wisconsin.

JOB PROGRESS REPORT

State of Colorado :	Division of Wildlife – Mammals Research
Work Package No. 8160, 3740 :	Chronic Wasting Disease and other Willife Disease Management
Task No. 3 :	Animal and Pen Support Facilities

Period Covered: January 1, 2001 - June 30, 2003.

Author: T.R. Davis

Personnel: 2001: H. Barr, C. Budler, N. Dryer, D. Finley, J. Foster, M. Foster, J. Habel, M. Hanusack, L. Ho, B. Hotchmuth, E. Jones, S. Liss, M. Lowe, M. Miers, A. Mitchell, , T. Petersburg, T. Terrell, C. Weagley,

2001/2002: B. Bates, D. Biggins, E. Berrill, K. Downing, D. Finely, J. Foster, M. Foster, J. Grigg, J. Habel, M. Hanusack, J. Hatch, C. Hernandez, L. Ho, E. Jones, M. Lowe, A. Mitchell, N. Miers, A. Ray, L. Reimer, R. Rhyan, K. Sparks, T. Stout, T. Terrell, R. Thompson, M. Thonhoff, C. Weagley, D. Weaver, B. Williams, T. Zeaman,

2002/2003: M. Anderson, B. Bates, K. Beamer, L. Dahl, J. Fenwick, D. Fox, K. Fox, J. Habel, J. Hatch, T. Halasinski, M. Hanusack, G. Harvey, L. Ho, E. Jones, G. Kyriacou, M. Lowe, N. Miers, A. Mitchell, A. Northrup, R. Rutledge, K. Steffen, T. Stout, D. Thompson, R. Thompson, D. Weaver,

ABSTRACT

The Colorado Division of Wildlife's Foothills Wildlife Research Facility (FWRF) maintained captive animals (2000/2001 annual total: 262, 2001/2002 annual total: 320, 2002/2003 annual total: 312) and facilities in support of twenty-one captive wildlife research projects. Chronic wasting disease (CWD) pathology, and etiology, in deer and potential transmission to other species was the primary focus of research during this period, however FWRF supported a number of other significant research projects including contraception and reproductive effects, pathogen immunization, foraging behavior, drug delivery systems, and evaluation of wildlife capture pharmaceuticals. Three new species; fallow deer, domestic ferrets, and mountain lions were added to support CWD research as well as additional numbers of mule deer and white-tailed deer. Chronic wasting disease was again a significant source of mortality in mule deer and white-tailed deer and is reflected by the number of CWD research projects conducted at FWRF during this period. The CWD Management Protocol was updated to incorporate new information and early detection techniques, while maintaining the philosophy of managing the disease for research purposes under heightened bio-safety guidelines and intensive herd management. Additionally, a number of other protocols were revised, and new SOP's developed to accommodate the new species, facility improvements, and expanded research. An expanded database, a 5 year facility capitol construction plan, and a draft facility fee schedule were also implemented. The quality of animal care and facility maintenance provided by temporary, work-study, personal service, intern and volunteer employees is in part reflected by the finding of compliance under the Animal Welfare Act during the annual USDA APHIS inspections of FWRF. In addition to routine maintenance, the FWRF team made significant facility improvements including new facilities to accommodate expanded CWD mule deer research,

partial completion of a mountain lion holding facility, and support for construction of the new Wildlife Health Lab now located within the FWRF perimeter.

Animal Maintenance:

Routine animal husbandry including feeding, health observations, training, weighing, and clean-up, was performed primarily by well trained temporary employees, work-study students, and volunteers. FWRF was inspected by USDA APHIS for compliance with federal animal welfare regulations on March 8 2001, April 12 2002, and April 30 2003.

Table 1 summarizes the species totals reported to USDA animal welfare and includes all neonates born at the facility, transfers into and out of the facility, and all animals that died or were humanely euthanised during the respective fiscal year. Ungulate herd levels at any one time averaged approximately 70 percent of the ungulate total and 60-65 percent of the total number of animals housed at the facility.

Table 1. Species reported to USDA Animal Welfare

Species	2000/2001 Total	2001/2002 Total	2002/2003 Total
Bighorn Sheep	57	52	28
Elk	26	22	25
Fallow Deer	25	25	36
Mule Deer	74	126	139
Pronghorn Antelope	21	20	21
White-tailed Deer	24	40	39
Ungulate Total	227	285	288
Ungulate Mean	159	200	202
Cattle	11	11	11
Domestic Ferrets	21	21	10
Mountain Lions	3	3	3
Facility Total	262	320	312

Herd Management:

Three new species; domestic ferrets, fallow deer, and mountain lions were added to the facility in FY 2000/2001 and mule deer and white-tailed deer herd levels were expanded in FY 01/02, and 02/03 through herd management practices and incoming transfers. Additional adult animals were brought in to support expanding CWD, fertility control, and brucellosis vaccine research and consisted primarily of free ranging and habituated mule deer obtained from various locations around the state. Captive mule deer, white-tailed deer, and pronghorn antelope were also brought in from out of state to supplement FWRF herds. The bighorn sheep herd was reduced in FY 2001/2002 and FY 2002/2003 through natural mortality and an out-going transfer of excess animals. The Fallow deer herd was allowed to expand naturally as per the study protocol in FY 2001/2002, while the cattle elk, and pronghorn herd levels remained relatively constant for the period.

Commission approval was granted in 2001 to transfer excess FWRF captive wildlife, and/or orphaned neonates out of state to support collaborative and non-agency wildlife research projects. In 2001 the excess bighorn sheep were transferred to a research facility in Idaho, and in 2001, 2002, and 2003 orphaned mule deer neonates were transferred to a captive facility in Wyoming. It is important to note that the 2002 and 2003 out of state transfers were not of FWRF origin, but habituated orphaned fawns not suitable for release. Other facility transfers include several excess bighorn weanlings that went to a zoo for display, several pronghorn bucks that were borrowed from (and returned to), another captive wildlife research facility, and several free ranging bull elk brought in for breeding purposes.

Breeding was planned annually to maintain optimal population sizes of the various species required to support current and future research projects. Depending on research objectives, some of the offspring from FWRF animals were hand-raised, and various species of wild orphaned neonates were accepted for hand rearing. Habituated weanlings and adult animals were also accepted whenever herd levels would allow. Hand rearing protocols for mule deer are described by Parker and Wong (1987), and by Wild and Miller (1991) for bighorn sheep, elk, pronghorn antelope, and white-tailed deer. The male cattle, domestic ferrets and mountain lions were castrated at an early age, and the male fallow deer were vasectomized in the summer of 02/03 to prevent further breeding. Table 3 summarizes the breeding and rearing practices of ungulate species for the period:

Table 3. Ungulate breeding and rearing practices

Species 2000/2001	FWRF Breeding 2000	FWRF Neonate Rearing 2001	Orphans 2001
Bighorn Sheep	Bred	Dam raised	0
Elk	Bred 5 Cows	Hand raised 2, dam raised 2, 1 stillborn	1 weanling
Fallow Deer	Yearlings, did not breed	No offspring	0
Mule Deer	Bred	Hand raised 4, dam raised others	0
Pronghorn Antelope	Bred	Hand raised 4 , 2 still born, others Euthanized as per study protocol	0
White-tailed Deer	Bred 3 yearlings	Dam raised	13 orphans

2001/2002	FWRF Breeding 2001	FWRF Neonate Rearing 2002	Orphans 2002
Bighorn sheep	Bred	Hand raised 5, dam raised others	1 orphan
Elk	Did not breed	No offspring	1 weanling
Fallow Deer	Bred	Dam raised	0
Mule Deer	Bred	Hand raised 20, dam raised others	3 orphans, 9 weanlings
Pronghorn Antelope	Bred	Euthanized as per study protocol	1 weanling
White-tailed Deer	Bred	Dam raised	11 orphans, 2 weanlings

2002/2003	FWRF Breeding 2002	FWRF Neonate Rearing 2003	Orphans 2003
Bighorn Sheep	Not bred	No offspring	0
Elk	Bred 3 cows	1 hand raised, 2 dam raised	0
Fallow Deer	Not bred	No offspring	0
Mule Deer	Bred	Dam raised	5 weanlings,
Pronghorn Antelope	Bred	Hand raised	1 orphan
White-tailed Deer	Bred	Dam raised	0

Nutritional Maintenance:

Feeding protocols for ungulates previously housed at the facility were reviewed by Wild (1997). The fallow deer were maintained on a high quality grass alfalfa mix hay and Regular Ranch-way deer and elk ration. The domestic ferrets were maintained on a commercial ferret chow, and the mountain lion kittens were initially maintained on Kitten Milk Replacer, Nurtural, and commercial kitten chow. The kittens were switched to a ground commercial feline diet at weaning, and were introduced to chunk deer and elk meat for training purposes at four months of age. A commercial carnivore supplement was added to the training meat to enhance dietary levels of calcium, and vitamins A and E, and was offered several times weekly. At five months of age, the kittens were gradually introduced to whole deer and elk carcasses and carcass portions with the GI tract removed, and are currently maintained on carcass portions, and training meat with supplement.

Individuals of all species maintained reasonable body condition on available diets with the exception of some mule deer fawns, and CWD infected animals at the clinical stage of the disease. Fawn mortalities may have been associated with general poor body condition of does infected with chronic wasting disease, the presence of other etiological agents, and/or interspecies competition for space and cover in paddocks housing cattle and fallow deer.

Pen Enrichment:

In an effort to provide cover and subsequently reduce stress, the mule deer in the cattle pens were provided with a refuge area not accessible to the cattle, and artificial refuge areas were constructed in all paddocks housing semi-wild deer and dam raised neonates. Single piece and "L" shaped hide-outs, were constructed on site, and vegetation ex-closures were added in early spring and removed later to provide seasonal natural cover. Additionally, the Fort Collins Water Treatment Plant donated rock, labor and the use of equipment to construct two rock mountains in the bighorn sheep pens to enhance the natural structure in these areas.

In addition to pen structure, behavioral enrichment was offered through training. The mountain lions were trained using operant conditioning; a form of training based on a reward system, and used widely in wildlife display facilities. Using this system, the lion kittens were taught to sit, platform, kennel, and stretch up on the fence for physical exams. Hand raised ungulate neonates were treat trained using the same philosophy, and were taught to follow their human trainers and stand on the scale for physical exams and weighing. Passive training was also used to habituate animals to the scale and alley-way by feeding the animals supplement in these areas, and allowing free exploration without human interference.

Health Maintenance:

Animal health care was provided as required and as mandated by the preventive medicine program (Wild 1995) and chronic wasting disease protocols. Overall, captive wildlife maintained at FWRF remained healthy throughout the period. Chronic wasting disease (CWD) continues to be a significant source of mortality in captive mule deer and white-tailed deer and is reflected by the number of animals dedicated to CWD research projects throughout this period. Dystocia was a significant source of mortality in adult pronghorn does, and was associated with a failure of the cervix to dilate at the time of parturition. The underlying cause of the pronghorn dystocia is still unknown, and the collaborative USDA RB51 brucellosis vaccine project was put on hold in FY 2002/2003 due to the resulting reduced number of adult females available. Other significant etiological agents included Epizootic hemorrhagic disease (EHD), bluetongue virus (BTV), and clostridium perfringens.

Standard Operating Procedures:

Chronic wasting disease

The CWD management protocol was again revised in FY 2002/2003 (Attachment 1). Generally, CWD continues to be managed as described by Wild (1997): to maintain CWD and maximize potential exposure for specific research objectives. The revised protocol was prepared to incorporate new information resulting from recent research findings: increasing bio-security, incorporating early detection techniques, and intensive herd management of CWD infected animals (Wild et. al 2002, Wolfe et. al 2002). All animals at FWRF were monitored closely for clinical signs of CWD, and tissues from all mortalities occurring at FWRF were examined for evidence of infection with CWD.

Systems development

In addition to the CWD protocol, all animal husbandry, facility security, FWRF management protocols, and veterinary supply inventories were reviewed and updated. Protocols were developed to manage the new species, and an Access database was developed to track additional information such as projects and veterinary treatments. The old paradox database and hard copies of vital records, necropsy, clinical pathology, and transfer information was integrated into the new database. Facility and animal maintenance costs were analyzed and incorporated into a draft fee schedule for use of research animals and FWRF facilities by professional collaborators, and a draft 5 year facility capitol construction plan was developed to address long term planning needs.

Educational Contributions

FWRF functions primarily to support wildlife research, however when possible and relevant, facility tours were provided to school, university, and professional groups. We emphasized the importance of maintaining captive wildlife to perform controlled experiments, and the contributions made by current and historic research projects conducted at FWRF. FWRF animals and facilities were also used occasionally for hands-on training of CDOW employees, collaborators, and other professional groups in sampling techniques and chemical immobilization.

Research Projects:

Facility operations offered support for research projects conducted by CDOW personnel and other collaborators that were initiated, conducted, or continued using FWRF animals and facilities. A total of twenty one research projects were supported by FWRF for the period:

- *Cattle susceptibility to chronic wasting disease.*
- *Mechanisms of CWD transmission in mule deer.*
- *Evaluation of prospective preventative therapies for chronic wasting disease in mule deer.*
- *Validation of a potential blood test for chronic wasting disease (GeneThera test).*
- *Prion peptide immunization and challenge.*
- *Molecular epidemiology of strain variations in chronic wasting disease.*
- *Susceptibility of Mountain Lions to chronic wasting disease.*
- *Susceptibility of fallow deer to chronic wasting disease.*
- *Pathogenesis of chronic wasting disease in white-tailed deer.*
- *Effects of GnRH-PAP on reproduction and behavior in female mule deer.*
- *Evaluation of GnRH agonist (leuprolide) as a reversible contraceptive in mule deer.*

- *Evaluation of GnRH agonist (Lupron) as a potential contraceptive in rocky mountain elk: Effects on pregnancy.*
- *Development of a remote delivery system for GnRH agonist (leuprolide) in female elk.*
- *Paradoxical immunosuppression in bighorn lambs as a mechanism for depressed recruitment following pastuerellosis epidemics.*
- *Biosafety and reproductive effects of RB51(brucellosis) vaccine in pronghorn.*
- *Evaluation of drug delivery and dart trauma using collared and un-collared pneudart and daninject darts.*
- *Evaluation of A3080 (thiafentanil oxalate) and naltrexone HCL for the immobilization and reversal of mule deer.*
- *Evaluation of A3080 (thiafentanil oxalate) and naltrexone HCL for the immobilization and reversal of pronghorn antelope.*
- *Effects of 2% DRC-1339 treated brown rice on non-target species.*
- *Testing alternative models of herbivore foraging in heterogeneous environments.*
- *Field Immobilization Training.*

Facility Improvement Projects:

A variety of scheduled and unscheduled maintenance and repair activities were necessary to support facility operation and ongoing research programs. Highlights include construction of the new Wildlife Health Lab (WHL) housing a laboratory, office space, a necropsy lab, and walk in freezer/cooler space, now located within the FWRF perimeter. This project was designed, constructed, and funded by the CDOW engineering and capitol construction team, while FWRF personnel provided support services.

Additional facility modifications include twelve new paddocks, associated buildings, alleys and an access road to support the CWD transmission study, and an automatic water system for all paddocks on the east side of the facility. Other improvements included five new isolation pens, perimeter fence and gate upgrades, and construction of compost bins to hold animal waste material generated from CWD research paddocks. A new mountain lion facility including a concrete block building containing 4 indoor dens and a work space, a 50 x 60 foot outdoor pen, and shift containment system is currently under construction. A 2000 gallon vault was installed on the east side, a new pasture was also constructed on the west side, and the old house trailer was demolished. Additionally, the Soldier Canyon Filter Plant donated several culverts and constructed a detention pond on the west side of the facility to better manage natural water run-off and scheduled water releases from the plant.

Facility maintenance and construction projects were prioritized based on animal welfare concerns and anticipated research needs. Table 3 summarizes the completed, current, and on-going facility construction maintenance projects for the period.

Table 3. Facility Improvement Projects

Project	Status	Details and Information	Completion Year
1. Improvements to west rearing area	Completed	Replace roofs on existing pens, and add 5 additional pens with shelters	2001/2002
2. East lab improvements	Completed	Remove garage door, replace with permanent wall, add window	2001/2002
3. Add 13 automatic waters, 4 shut off valves to east side	Completed	Automatic waters installed in all existing pens and new paddocks for transmission study. CSU provided the electric contractor, FWRF contracted out plumbing	2001/2002
4. Add pellet feed storage shed, and feed-shed to east side	Completed	Purchase Tough Sheds, level sites, pour concrete pads for Transmission study, purchased 1 shed, other was supplied by WHL	2001/2002
5. Construct 12 new pens on east side	Completed	Construct 9 new pens, and split 2 pens into 4 for Transmission study, CSU provided contractor for installation	2001/2002
6. Construct 2 additional feed storage sheds on east side	Completed	Construct Feed-sheds for north and south transmission study pens	2001/2002
7. Construct 13 feed shelters on east side	Completed	Construct feed shelters for transmission study pens	2001/2002
8.Construct alley system and gates for new pens on east side	Completed	Construct 400 feet of alley, 16 walk-thru gates for transmission study	2001/2002
9. Construct access road to new alley system on east side	Completed	Construct road, culvert donated by Fort Collins Water Treatment Plant	2001/2002
10. Replace all wooden drive through gates with 7 foot metal tubing gates, add gate to south side of D3	Completed	Purchased all gates <14 foot long, 14'gates donated by CDOW game damage, installed gates, added horse fence, add gate opening in D3 – contracted out electric fence modifications	2001/2002
11. Construct new pasture on west side (D1)	Completed	Construction of D1 pasture contracted out by NWRC	2001/2002
12. Plumbing upgrades to west hub area	Completed	Install automatic water in D1, and a water shut off valve in the west hub, contracted out plumbing and excavation	2001/2002
13. Construct 2	Completed	Construct 1 feed shelter, and 1	2001/2002

shelters in D1		animal shelter	
14.East fawn rearing area improvements	Completed	Reconstruct roof structures, repair shelters, double fencing on N. side, add 1 alley gate	2001/2002
15. House trailer demolition, and FWRF site clean-up	Completed	Demo old trailer, clean up, organize FWRF construction materials and supplies, remove waste	2001/2002
16. Construct ram pen exclosure around feed area in E3	Completed	Purchased range panels, installed panels, added horse fence	2002/2003
17. Reconstruct shed on west side of west scale-room, modify scale	Completed	Reconstruct shed, modify scale to accommodate access from west side	2002/2003
18. Water damage repair to E1/E2 feed-shed	Completed	Remove soil on west side, reconstruct wall, re-grade soil	2002/2003
19. Perimeter Fence upgrades	Completed	Replace rotten posts, add V-mesh to lower 4 feet of perimeter fence, contracted out labor on V-mesh	2002/2003
20. Upgrade 2 perimeter and main east and west gates	Completed	Replace 4 old drive thru gates with 8 foot chain link gates	2002/2003
21. Add Secondary perimeter gate and 8 foot fence on south side of facility	Completed	Close off FWRF access road between the Ft. Collins Water Treatment Plant and Soldier Canyon Filter Plant, contracted out time and materials	2002/2003
22. Compost animal waste from CWD paddocks	Initial start-up is completed, composting is on-going	Construct compost bins, purchase bacteria, train personnel to mix and monitor, Contracted out initial bin construction, and start-up	2002/2003
23. Replace east side septic tank	Completed	Replaced rusted metal 1000 gallon tank with a 2000 gallon concrete vault, Contracted out time and materials	2002/2003
24. Rock mountains constructed in upper sheep pens	Completed	Rocks, equipt, and time to construct the mountains donated by the Ft. Collins Water Treatment Plant	2002/2003
25. Construct west deten- tion pond	Completed	Construct pond to maintain drainage water inside our perimeter fence, time and equipt. to construct pond was donated by the Soldier Canyon Filter Plant	2002/2003
26. Construct mountain lion holding facility	Current project: planning, utilities, and building construction completed. finish:	Utilities, concrete block building, 50 x 60 foot outdoor pen, shift containment system, and 4 indoor dens, building slab, and alley concrete, concrete block building,	Project began 2001/2002, scheduled for completion 2004/2005

	outdoor pen, shift containment, indoor dens	plumbing, electrical, and engineering contracted out	
27. Reconstruct west isolation pens	Current project: 5 completed, finish: 7	Demolish old pens and shelters, reconstruct with upgraded design and materials	Project began 2001/2002, scheduled for completion 2004/2005
28. New roofs/repair structure on old feed-sheds and animal shelters.	On-going project	Approx. ¼ of the old structures and roofs on the facility have been replaced in the last 2 years using treated lumber and long lasting roofing materials	Began 2000/2001, as needed
29. Add additional animal shelters	On-going project	Construct additional shelters in pens with heavy stocking rates. (36 ungulate pens on the facility)	Began 2001/2002, as needed
30. Road Maintenance	On-going project	Road grading and upkeep	As needed
31. Paint old building exteriors	On-going project	Now using CCA treated lumber, or metal siding for repairs & building replacements to reduce the amount of painting necessary in the future.	Old structures are on a painting schedule every 3-5 years
32. Repair/replace latches, and broken or water damaged alley-way boards	On-going project	Now using CCA treated lumber for all repairs	As needed
33. Replace walk thru alley gates	On-going project	Replace old gates as necessary	As needed
34. Replace old visual barrier fencing and utility wire on metal gates	On-going project: most of the old material has been replaced, but this project is on-going due to animal and environmental damage	Old snow fence and construction fence replaced and moved to the outside of the paddock fence (except interior fences), utility wire is systematically being replaced with horse-fence	Began 2001/2002, as needed
35. Animal holding fence upgrades, and repairs	On-going project: rotten posts have been replaced all over the facility, and many double fences have been constructed to comply with CWD protocols	Replace old range fence and V-mesh, as well as electric fencing in pens that house deer, Construct double fences as required by CWD protocols	Began 2002/2003, as needed
36. Construct artificial refuge areas inside pens for neonates and adults	On-going project: completed for all new east side paddocks, maintain existing, construct	Construct single and L-shaped, refuge areas to provide refuge and shade, construct hog panel seasonal exclosures to promote vegetation growth in the spring	Began 2002/2003, as needed

	new		
37. Add windscreen to west and south facing fence-lines	On-going project	Provide additional shaded areas for animals, and maintain existing	Began 2002/2003, as needed
38. Mowing and weed control	On-going project	Seasonal mowing and manual, chemical noxious weed control	As needed
39.WHL maintenance	On-going project	Provide maintenance assistance to WHL, and support for initial lab construction	Began 2002/2003, as needed
40. Unscheduled miscellaneous emergency facility repairs	On-going project	Emergency repairs to structures, animal holding facilities, perimeter fence, automatic waters, utilities, etc…	As Needed

Addendum 1.

PROTOCOL FOR MANAGING CHRONIC WASTING DISEASE AT FOOTHILLS WILDLIFE RESEARCH FACILITY

Draft Rev. 2003

HISTORY

Chronic wasting disease (CWD) is a transmissible spongiform encephalopathy (TSE) or prion disease of cervids (deer and elk). Other TSE's include scrapie of sheep, bovine spongiform encephalopathy (BSE), and Crutzfeld-Jacob disease of humans. The disease causes behavioral changes and loss of body condition and is invariably fatal to infected deer and elk.

Despite a comprehensive program initiated in 1985 to eradicate CWD from cervids and the environment at Foothills Wildlife Research Facility (FWRF), CWD remains endemic at the facility. After the 1985 clean-up, CWD was first diagnosed in elk in 1989 and in mule deer in 1994. Natural transmission is now common in mule deer at FWRF and sporadic cases continue to occur in elk. Additionally, natural transmission rates are markedly higher and self-sustaining in paddocks housing infected animals being used in ongoing CWD research studies compared to paddock areas housing animals for other research studies.

Based on these observations, guidelines established in 1985 (and revised in 1993 and again in 1997) for maintaining a CWD-free facility are largely obsolete. Here, we provide additional revisions to those guidelines that are directed at maintaining the disease for research purposes in captive deer and elk while minimizing the risk to personnel and the potential spread of CWD outside the facility.

OBJECTIVES

1. Prevent transmission or exposure of CWD from FWRF to animals or facilities outside FWRF.
2. Minimize potential for exposing FWRF personnel and visitors to pathogens or potential pathogens including CWD.
3. Maintain endemic CWD in deer at FWRF; however, animals showing end stage clinical signs of CWD will be euthanized to avoid undue suffering, unless directed otherwise by research protocol.
4. Minimize potential spread of CWD among species of captive wildlife (deer, elk and noncervid research animals).
5. Minimize cross contamination between CWD infected and non-targeted research animals.
6. Prevent cross contamination between CWD research treatment groups.

ASSUMPTIONS

1. CWD is an infectious disease of deer and elk caused by an abnormally shaped protein prion. CWD is not widespread in free-ranging cervids. Where it occurs, the prevalence of disease varies greatly.
2. Mode of transmission for CWD is not known, and may be direct, via animal/animal contact, or indirect, through contact with excreta (saliva, urine, feces); animate and inanimate objects may serve as fomites (vehicles) in transmitting CWD.
3. Non-cervid wildlife and domestic species are not naturally susceptible to CWD. It is possible that non-cervids could be inapparent carriers of CWD; however, no data have been produced to support this possiblity.
4. Based on patterns seen in other TSE's, it seems likely that if CWD is transmitted to a new host species, then the likelihood of further transmission to others within that species is increased.

5. There is no evidence that CWD is transmissible to humans; however, it is prudent to minimize human exposure to CWD as well as animal pathogens known to be transmissible to humans (e.g. *Salmonella spp., E. Coli*, etc.).

APPROACH

Overview:

1. Follow established guidelines that prevent contact of captive research animals with animals outside FWRF (wild and domestic).
2. Minimize potential spread of infectious material outside FWRF perimeter.
3. Minimize potential transmission of CWD between species of captive animals, between CWD and non-CWD research animals, between research projects, and between experimental treatment groups where necessary. This includes transmission from mule deer/cattle pens, mule deer/fallow deer pens, therapy mule deer pens, white-tailed deer, and mountain lion pens via contaminated materials or potentially contaminated, equipment, or clothing.
4. Maintain each species of animal in isolation from others, unless directed by research protocol (e.g., mule deer with cattle, mule deer with fallow deer).
5. Educate animal caretakers about CWD (hazards, protocols, and clinical signs exhibited by affected animals). Perform daily animal observations and maintain detailed records of animal health as a portion of the FWRF CWD surveillance program.

Animals:

1. Exclude wild or captive cervids from CWD established areas from entering the captive herd, unless directed by a research protocol. Established areas will now include: northeastern, northcentral, and northwestern Colorado, Park, Albany, and surrounding counties in Wyoming, and the Denver Zoo. However established areas are dynamic and may change as surveillance for CWD increases. Therefore, please consult the latest CWD update for guidance.
2. Depending on intended use, orphans, and neonates raised outside FWRF, may be accepted from areas that are CWD established, as well as areas that are not CWD established. These animals will be maintained separately to minimize potential CWD transmission to uninfected neonates that come from sources outside the established area.
3. Raise and maintain each animal species in isolation from others, unless directed by a research protocol.
4. To prevent transmission of CWD from FWRF to facilities where CWD is not established, non-cervid species from FWRF will be transferred or donated to other facilities only if the following criteria are met: 1) the transfer location is within the CWD established area, 2) animals are scheduled for a specific research project, 3) the destination is a closed facility (no egress of live animals), 4) animals will not be used in "tame animal trials" in non-confined environments. 5) transfer is approved by the mammal's research leader, 6) recipients will be notified of CWD risks associated with accepting animals from FWRF.
5. Transfers of live cervids from FWRF are prohibited.

Animal Maintenance:

1. House and maintain each species in isolation from other species, unless directed by a research protocol.
2. House and maintain CWD research animals separate from non-CWD research animals.
3. Maintain accurate records for all animals. This information includes (but is not limited to): birth date, origin, body weights on tractable animals, vaccinations, health problems and treatments, research projects, and movements (intra and inter facility). Additionally,
   a. Tag all animals for easy individual identification.

b. Train FWRF personnel to recognize clinical signs of CWD. FWRF personnel will maintain daily animal observation records describing animal status and will report abnormal observations to the facility manager.

4. Where feasible, weigh and/or briefly examine every animal at least once monthly. Wild research animals usually cannot be handled for weighing; these will be visually examined and immobilized via a dart injection for closer examination if necessary.
5. Follow a preventative medicine program that includes routine vaccination, anthelmintic treatment, hoof trimming, nutritional evaluation, and other measures to optimize overall health of research animals.
6. Initiate early detection measures by conducting annual tonsil biopsies on all deer (WTD, MD) housed within the facility. CWD positive animals will be removed at the discretion of the lead project researcher from non-CWD research paddocks and 1) added to the CWD research herd, 2) held in isolation, or 3)humanely euthanized.

Use of Research Animals Outside FWRF:

1. The transport of non-cervid species from FWRF to facilities or locations, outside the CWD established area is prohibited.
2. The transport of non-cervid species to facilities or locations outside FWRF but within areas where CWD occurs is prohibited unless expressly approved by the mammal's research leader.
3. The transport of cervids outside FWRF is prohibited.
4. Procedures for isolating cervids at other CDOW facilities will be the same as those at FWRF.
5. Animals of any species maintained at FWRF will not be released into the wild.
6. The FWRF Manager is responsible for maintaining accurate records of animals transferred into and out of FWRF.

General Facilities and Equipment:

1. Exclude free-ranging wildlife and livestock from the facility or from contact with captive animals using interior and perimeter fencing. A minimum 4 foot corridor must be maintained between interior pasture fencing and the 8 foot tall perimeter fence surrounding FWRF. The perimeter gates will remain closed at all times, the perimeter fence is inspected monthly, and necessary repairs are made top priority for facility maintenance.
2. Maintain each species of animal separately and allow no direct or fence-line contact unless directed by a research protocol.
3. Minimize runoff between pens housing different species through appropriate pen assignment and drainage control, unless directed by a research protocol.
4. Use drainage control to minimize runoff outside the facility in areas where natural and/or man made drainages occur inside CWD paddocks.
5. Minimize common use of equipment between pens housing different species, between CWD and non-CWD paddock areas, and between CWD treatment groups. When it is necessary to use the same equipment (vehicles) a 20 % chlorine, or 5 % LPH solution can be used to disinfect equipment immediately following the use of equipment inside CWD infected paddock areas.
6. All equipment, materials, organic, inorganic, materials that have been exposed to CWD pathogens must either remain on site or follow EPA treatment guidelines prior to leaving FWRF.
7. Feed and handle animals or clean pens using the following traffic pattern: Clean CWD controls (MD,WTD), non-cervids, elk, non-CWD research mule deer, CWD research mule deer, CWD infected white-tailed deer, mule deer with cattle/fallow deer. Additionally, follow specific protocols for traffic patterns between various CWD research treatment groups.
8. Clean animal pens (especially feed areas and waters) weekly. Dispose of waste from pens housing non-CWD research animals, and clean controls in the main dumpster. Waste from all

CWD infected paddocks must never leave the facility.

9. Fecal material and non-palatable feed from CWD research paddocks will be reduced through on-site composting and palatable feed will be recycled to the cattle.
10. Isolation pens, digestion cages, and other areas where animals are held for extended periods, will be cleaned of organic matter and disinfected with a 20% chlorine solution, or 5% LPH solution after use. The researcher last using the area will be responsible for cleanup. Cooperative compliance will be made a condition of all study plans using FWRF ungulates and facilities.
11. Different species may be held concurrently in isolation pens if a buffer zone (empty pen) is used.

Feed:

1. Hay will not be accepted from areas where domestic sheep have grazed on cultivated pastures.

Personnel:

1. Wash hands before and after handling each species of animal, before and after handling non-CWD and CWD research animals.
2. No eating or drinking allowed in animal areas.
3. Dedicate one pair of shoes/boots to FWRF. Change into/out of this pair of shoes when you arrive at work/when you leave. Alternately, shoes can be sprayed liberally, and/or washed thoroughly in 20% chlorine or 5% LPH solution.
4. Coveralls, boots, and gloves, are required when handling animals showing clinical signs of CWD; and face masks and eye protection are available for use if desired.
5. Coveralls and/or boots are a protocol requirement for CWD infected areas, and CWD control groups. Additionally, each set of treatment groups within a research project may require a separate set of boots and/or coveralls depending on research objectives. Please do not enter a paddock unless you know the protocol.
6. Unsupervised access to FWRF will be limited to authorized personnel. Unauthorized persons will not enter animal pens or be permitted direct contact with research animals. The facility will be locked except when attended during normal business hours.
7. Visitors will be informed that FWRF houses CWD infected animals and is within the CWD established area, and will be given the option of wearing rubber overshoes which will remain on site.
8. All researchers and collaborators and their subordinates will comply with this protocol. All personnel working at FWRF will be required to read this protocol and other appropriate literature and to sign the attached sheet of informed consent.

Additional Requirements for CWD research Pens:

1. Protective clothing such as designated boots/shoe covers and/or coveralls and must be worn when entering all pens housing CWD infected animals (currently these are: mule deer/cattle pens, mule deer/fallow deer pens, mule deer therapy pens, infected WTD pens, and mountain lion pens), as well as all CWD control pens.
2. Place waste feed and manure from infected mule deer and white tailed deer pens in the storage compost pile at FWRF (NOT in the dumpster, or working compost piles). Compost will be mixed appropriately and put into composting bins by assigned personnel. Finished compost will be incinerated, or used for topsoil in CWD infected paddocks as needed.
3. Waste feed from the mountain lion pens is disposed of through incineration or sent to CSU for chemical digestion. Fecal material from the lion pens is composted along with other CWD pen waste material.
4. Dedicated (separate) equipment (wheelbarrows, rakes, shovels, water brushes, bucket scrapers, etc.) must be used for cleaning CWD infected vs. CWD control and non-CWD research

paddocks. Additionally, separate cleaning equipment may be required for each treatment group within specific research projects. Please ask the facility manager if you are not sure of the cleaning protocol.

5. Vehicles must be cleaned after use in all CWD paddocks. Wash organic material from tires, remove all organic material from the truck bed and disinfect with a 20 % chlorine, or 5% LPH solution.
6. Clean-up procedures following depopulation of a CWD infected paddock: disinfect feed bunks and feed pans in 5% LPH solution and rinse thoroughly, disinfect water receptacle with a 20% bleach solution and rinse thoroughly, rake out all fecal material, spray feed shelter and soil under and around shelter with a 50% bleach solution. Allow all to dry thoroughly before re-population of paddock. Additional clean-up procedures may be required such as removing the top 6 inches soil around a feed area, soaking with bleach solution, and adding road-base. This will depend on the specific research project.
7. Keep gates to pens, hub/working area, and main east and west gates closed at all times except when passing through.
8. Animal carcasses must be enclosed with a protective cover to contain potentially infectious materials during transportation to the Wildlife Health Lab (WHL) on site, or off site to the CSU Vet Teaching Hospital (VTH) or the Wyoming State Veterinary Lab (WSVL). Alternatively, the truck/equipment could be cleaned with a 20% chlorine solution after use if transported to the necropsy lab on site.
9. Cattle will not leave the facility alive unless transferred to a biosecurity level 2 or greater facility and this requirement is part of a written change to the established research protocol.
10. Report any abnormalities or accidents immediately to facility supervisor.

CWD SURVEILLANCE PROGRAM

1. Euthanize any animal showing clinical signs of CWD and examine tissues grossly and histologically.
2. Perform complete postmortem examination and histologically examine brain tissue of any animal that dies at FWRF.
3. Carcass disposition will be by incineration (required for cattle), chemical digestion, or appropriate burial at the Larimer County Landfill.
4. If CWD is diagnosed in any noncervid species at FWRF, this protocol will be immediately revised and biosecurity at FWRF further increased.
5. The attending veterinarian, facility manager, and Research Facility Animal Care Committee (RFAC) will evaluate and amend this program as necessary.

The FWRF CWD PROTOCOL WAS FIRST ESTABLISHED IN 1985
AND REVISED: 1993
1997
2003

INFORMED CONSENT

I, ________________________, have read the Foothills Wildlife Research Facility (FWRF) protocol concerning chronic wasting disease (CWD) and agree to follow the protocol. Although there is no evidence that CWD is transmissible to humans, I realize that I will be working with research animals and in an environment potentially infected with CWD. I understand that this protocol reflects current knowledge on measures for minimizing exposure to and spread of CWD and other potential pathogens at FWRF.

________________________________ ______________

Signature Date

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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. : Multispecies Investigations

Task No. : Prairie Dog Research and Wildlife Extension

Period Covered: July 1, 2002 - June 30, 2003

Author: W. F. Andelt, Colorado State University, Dept. Fishery and Wildlife Biology

Personnel: M. Christopher, J. Dennis, L. Gepfert, E. Hollowed, BLM, S. M. Quinlivan, P. M. Schnurr, A. Seglund, Utah Division of Wildlife Resources, G. C. White, D. Younkin

PRAIRIE DOG AND PREDATOR-GROUSE RESEARCH, AND WILDLIFE EXTENSION

W. F. Andelt

OBJECTIVES

1. Objectively assess and document the current scientific knowledge base about Gunnison's prairie dogs by 1 September 2002 via a technical review draft publication, submitted to the CDOW research peer review process.

2. Conduct on-the-ground surveys, and collect measurements of key elements of Gunnison's prairie dog colonies at 50 sites in western Colorado by September 30, 2002, and provide a report, including data summaries, by October 30, 2002, to CDOW's project leader. By October 30, 2002, provide a data set that can be used by other investigators to develop a defensible, quantified Gunnison's prairie dog inventory technique.

3. Provide information specifically directed toward chronic wasting disease from DOW/DNR to the public through CSU's Extension network of 57 county Extension offices and provide intensive training to at least 4 offices and 100 employees/volunteers in key western slope counties by April 30, 2003.

4. Provide general wildlife information and information regarding human-wildlife conflicts from DOW/DNR to the public through the CSU's Extension network of 57 county Extension offices and provide intensive training to at least 4 offices and 100 employees/volunteers by April 30, 2003.

5. Provide analyses of data on the possible role of predators in the sage grouse decline in northwest Colorado.

STATUS OF GUNNISON'S PRAIRIE DOGS IN COLORADO

W. F. Andelt

The Gunnison's prairie dog (*Cynomys gunnisoni*) occurs in Colorado, Arizona, New Mexico, and Utah. Their geographical range probably has not changed much during the past century (Knowles 2002). However, acreage of Gunnison's prairie dogs within their range likely has contracted during the past century. The extent of decline is unknown because there were no accurate accounts of the abundance of prairie dogs prior to settlement (Clark 1973, Anderson et al. 1986, Knowles 2002), and the abundance of Gunnison's prairie dogs today also is not well known. Approximately 22% of the range of Gunnison's prairie dog occurs in Colorado (Knowles 2002), where it is distributed primarily across the southwestern quarter of the state at elevations of 6,000 to 12,000 feet (Fitzgerald et al. 1994). The Gunnison's prairie dog consists of 2 subspecies (*C. g. gunnisoni* and *C. g. zuniensis*). In Colorado *C. g. gunnisoni* occurs in the Gunnison River drainage, the upper Arkansas and South Platte drainages, and in the San Luis Valley (Fitzgerald et al. 1994). In Colorado, *C. g. zuniensis* occurs at lower elevations in Montezuma, La Plata, Dolores, San Miguel, and Montrose counties (Fitzgerald et al. 1994). Densities of Gunnison's prairie dogs range from 5 to 10 per acre (Knowles 2002).

The primary threat to Gunnison's prairie dogs is plague (*Yersinia pestis*), whereas poisoning, recreational shooting, agricultural land conversion, and urbanization are of secondary importance (Knowles 2002). Plague became apparent in Gunnison's prairie dog colonies during the late 1940s (Lechleitner et al. 1968, Cully 1993). Plague often kills >99% of Gunnison's prairie dogs (Lechleitner et al. 1968). South Park, Colorado apparently contained 913,000 acres of Gunnison's prairie dogs in 1941, but an epizootic of sylvatic plague entered this area in 1947, and by 1949 plague reduced the acreage of prairie dogs by 95% (Ecke and Johnson 1952, Fitzgerald 1969, Armstrong 1972). Plague has continued in this area during the 1950s and 1960s (Lechleitner et al. 1962, Fitzgerald and Lechleitner 1974). During the first half of the 20th century, Gunnison's prairie dogs were mostly eliminated from the major valleys in Colorado (Burnett and McCampbell 1926, Longhurst 1944) due to plague or poisoning (Knowles 2002). Recently, most wildlife biologists interviewed by Knowles (2002) felt that plague was the dominant controlling factor of prairie dogs. Recover of Gunnison's prairie dogs from plague appears to range from no recovery to a pattern where colonies are regularly lost, but new colonies appear and grow in other areas (Knowles 2002).

Gunnison's prairie dogs were subject to poisoning in the higher valleys of Colorado during the 1950s (Lechleitner et al. 1968). Control of Gunnison's prairie dog continues on private land, but control of prairie dogs on Federal lands currently does not appear to be a conservation issue (Knowles 2002).

The current abundance of Gunnison's prairie dog in Colorado is not well known. Some biologists (Fitzgerald 1991), environmental proponents, and other individuals have expressed concern that populations of Gunnison's prairie dogs have been reduced by epizootics of plague (Lechleitner et al. 1962, 1968; Fitzgerald 1969, 1978, 1993; Rayor 1985), and control of prairie dogs (Fitzgerald 1991) in Colorado. Speculation exists that the Gunnison's prairie dog might be petitioned for listing as threatened or endangered. Decisions to list the Gunnison's prairie dog should be based upon the most accurate and most current data. In this report, I summarize information from various sources about the status of Gunnison's prairie dog in Colorado.

Colorado Agricultural Statistics Service (1990) Survey

Colorado Agricultural Statistics Service (1990) surveyed 9,046 farmers and ranchers and obtained nearly 3,000 surveys to estimate that 1,553,000 acres were occupied by prairie dogs in Colorado during 1989. This survey estimated acres occupied by prairie dogs in each county, but it did not differentiate between acres occupied by Gunnison's prairie dogs, black-tailed prairie dogs (*Cynomys ludovicianus*), and white-tailed prairie dogs (*Cynomys leucurus*). Thus, I used distribution maps in Fitzgerald et al. (1994) to ascertain which counties were occupied by the 3 species of prairie dogs. In counties where Gunnison's prairie dogs overlapped with 1 of the other species of prairie dogs, I estimated the relative proportion of the county that was occupied by Gunnison's prairie dogs. I multiplied that proportion by the acreage reported occupied by all prairie dogs in a county to obtain an estimate of the acreage occupied by Gunnison's prairie dogs for that county. I summed the acres of reported Gunnison's prairie dogs in each county and obtained an estimated 445,500 acres of reported Gunnison's prairie dogs in Colorado during 1989 (Table 1).

Jim Fitzgerald (1991) letter to Galen Buterbaugh, U.S. Fish and Wildlife Service

Fitzgerald (1991) expressed concern about the status of the *gunnisoni* subspecies of the Gunnison's prairie dog. He indicated that plague and poisoning have eliminated almost all populations in South Park. He also indicated populations appear to be in poor condition in the San Luis Valley, they appear to be gone from the extreme upper Arkansas River valley, and populations appear to be small and patchy in other parts of its historic range in Colorado. He believed Gunnison's prairie dogs are gone from Jefferson, Douglas, and Lake Counties in Colorado. He noted that a large complex exists on the Curecante National Recreation Area west of Gunnison, Colorado. Fitzgerald (1991) sent inquiries to all Colorado Division of Wildlife District Wildlife Managers and Wildlife Biologists and reported that a disappointing number of colonies were identified. He indicated that the low number of reports of colonies sent to him by the Colorado Division of Wildlife and his low estimates are in direct contrast to acreage of Gunnison's prairie dogs reported by Colorado Agricultural Statistics Service (1990).

Robert Finley (1991) Survey of Distribution and Status of Gunnison's Prairie Dogs in Colorado

Finley (1991) conducted a broad reconnaissance survey of the distribution of Gunnison's prairie dogs by driving some highways and roads and recording observations of prairie dogs. He observed 74 Gunnison's prairie dog colonies, of which 42 were active. He recorded colonies in 10 counties. He reported the largest active colonies were in the Gunnison drainage. He reported that South Park was almost devoid of prairie dogs, but he found a medium sized colony near Hartsel and a few on the periphery. He indicated that some mammalogists suspect that the spread of Wyoming ground squirrels southward through Colorado, after prairie dogs die out from plague, may be preventing prairie dogs from repopulating their former towns east of the Continental Divide and north of the Arkansas River. Finley (1991) concluded that populations of Gunnison's prairie dogs "seem to be far below those reported in the years prior to plague epizootics", "but I do not feel that the present situation is serious enough to warrant protection by Threatened status."

Mike Threlkeld, Chief of Rodent Control, Colorado Department of Agriculture (Personal Communication, 11 June 2002)

Mike Threlkeld indicated that there are large acreages of Gunnison's prairie dogs around Cortez (perhaps 7,000 acres), Dolores, Montrose (perhaps 7,000 acres), Blue Mesa Reservoir, between Dove Creek and Nucla/Naturita, west of Canyon City, north of Salida, and on the Ute Mountain Indian Reservation (perhaps over 7,000 acres).

Colorado Division of Wildlife (2002) Report on Acreage of Gunnison's Prairie dogs

Field personnel from the Colorado Division of Wildlife, Forest Service, and the Bureau of Land Management placed Gunnison's prairie dog colonies on 1:50,000 US Geological Survey County sheets during July and August, 2002 (Colorado Division of Wildlife 2002). The colonies were assigned as active (prairie dogs know to be present in the last 3 years) or unknown status (prairie dogs have been active but current presence in the area is unknown and requires field verification). From this exercise, the Colorado Division of Wildlife (2002) reported 85,795 acres of active and 194,777 of unknown acres of Gunnison's prairie dogs in Colorado (Table 1). In addition, 53,832 acres of active prairie dogs were identified in Delta County, where it was not know if these acres represented Gunnison's or white-tailed prairie dogs. These acreages are considered preliminary minimum estimates of the number of acres occupied by Gunnsion's prairie dogs.

Craig Knowles (2002) Report on Status of White-tailed and Gunnison's Prairie Dogs

Knowles (2002) primarily summarized Colorado Division of Wildlife (2002) for his assessment of the current status of Gunnison's prairie dogs in Colorado. He criticized the Colorado Agricultural Statistics Service (1990) report of acreage of prairie dogs in Colorado by stating "...these estimates clearly greatly inflate the acreage at least in some counties." However, it is worth noting that Knowles (1998) reported that there was only 44,000 acres of black-tailed prairie dogs in Colorado during 1998, whereas the Colorado Agricultural Statistics Service (1990) estimated about 930,000 (calculated from their report). Recent aerial surveys by the Colorado Division of Wildlife (following Sidle et al. 2001) indicate that there are about 631,000 acres occupied by black-tailed prairie dogs in Colorado (F. Pusaterie, personal communication). Thus, the estimates provided by Colorado Agricultural Statistics Service (1990) were much closer than Knowles (1998) to the acreage reported by the Colorado Division of Wildlife. Knowles (2002) indicated that Gunnison's prairie dog populations in Colorado were greatly reduced by plague and poisoning during the 1900s and this decline may be continuing, or at best, the populations may be stable.

Synthesis of Reports on Abundance of Gunnison's Prairie Dogs in Colorado

Abundance of Gunnison's prairie dogs likely has declined in Colorado, particularly starting during the 1940s when plague became endemic. Our best estimates of the acreage of Gunnison's prairie dogs in Colorado seem to be provided by Colorado Division of Wildlife (2002) and Colorado Agricultural Statistics Service (1990). The Colorado Division of Wildlife (2002) reports a preliminary minimum of 85,700 acres of active Gunnison's prairie dogs, another 194,800 acres of Gunnison's prairie dogs where their status is unknown, and another 53,800 acres of prairie dogs in Delta County which are either Gunnison's or white-tailed prairie dogs. The Colorado Agricultural Statistics Service (1990) survey of acreage of prairie dogs in Colorado during 1989, from which I derived 445,500 acres of reported Gunnison's prairie dogs, has been criticized as biased by Knowles (1998, 2002). However, Colorado Agricultural Statistics Service (1990) and Colorado Division of Wildlife (2002) seem to concur at least to some extent. The Colorado Division of Wildlife is assessing the feasibility of aerial surveys for estimating acreage of Gunnison's prairie dogs in Colorado. Pending feasibility, these surveys are needed to provide better estimates of the acreage of Gunnison's prairie dogs in Colorado.

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Table 1. Acres of Gunnison's prairie dogs reported and estimated from the Colorado Agricultural Statistics Service (1990) survey during 1989 and estimated by Colorado Division of Wildlife (2002) during 2002 in Colorado.

	Colorado Agricultural Statistics Service survey			Colorado Division of Wildlife	
County	Acres of all prairie dogs	Proportion acres[a] occupied by Gunnison's p.dogs	Acres of Gunnison's prairie dogs	Active acres	Unknown acres
Alamosa	6,200	1.0	6,200	2	12,220
Archuleta	48,900	1.0	48,900	15,978	18,226
Chaffee	3,200	1.0	3,200	2,467	0
Conejos	20,500	1.0	20,500	4,707	67,218
Costilla	1,600	1.0	1,600	14,948	25,439
Custer	5,900	1.0	5,900		
Delta	52,500	0.12	6,300		
Dolores	56,000	1.0	56,000	3,363	2,549
Douglas	12,600	0.25	3,150	58	0
El Paso	16,700	0.05	835		
Fremont	15,300	1.0	15,300		
Gunnison	5,800	1.0	5,800	611	221
Hinsdale	300	1.0	300		
Huerfano	6,400	0.63	4,032		
Jefferson	1,700	0.31	527		
Lake	900	1.0	900		
La Plata	80,000	1.0	80,000	6,816	619
Las Animas	18,500	0.2	3,700		
Mineral	200	1.0	200	449	1,221
Montezuma	92,000	1.0	92,000	12,223	0
Montrose	52,100	0.73	38,033	6,482	0
Ouray	7,400	0.5	3,700	647	0
Park	5,100	1.0	5,100	42	3,150
Rio Grande	14,300	1.0	14,300	12,263	2,094
Saguache	13,200	1.0	13,200	2,659	58,891
San Juan		1.0			
San Miguel	13,400	1.0	13,400	2,017	2,927
Teller	5,200	1.0	5,200	63	0
TOTAL:	555,900		448,277	85,795	194,777

[a]Obtained by estimating the proportion of a county (from Fitzgerald et al. 1994) that was occupied by Gunnison's prairie dogs, white-tailed prairie dogs, and black-tailed prairie dogs, and then dividing the proportion for Gunnison's prairie dogs by the sum of proportions for all 3 species.

EVALUATION OF AERIAL SURVEYS FOR ESTIMATING ACREAGE OF GUNNISON'S AND WHITE-TAILED PRAIRIE DOGS IN COLORADO AND UTAH

W. F. Andelt, P. M. Schnurr, and A. Seglund

During November 2002, we (Andelt and Schnurr 2002) reported our assessment of 3 survey techniques, including ground surveys, interpretation of satellite imagery (Sidle et al. 2002), and aerial surveys (Sidle et al. 2001), for obtaining a valid estimate of the distribution and acreage of Gunnison's prairie dogs (*Cynomys gunnisoni*) in Colorado. We concluded that ground surveys likely would be very difficult, if not impossible to implement for obtaining a valid scientific estimate of acreage of Gunnison's prairie dogs in Colorado. However, we recognized that ground surveys could be used to provide an estimate of the minimum acreage of Gunnison's prairie dogs in Colorado. We concluded that satellite imagery is very expensive ($2,000 per 36 mi^2 or $2,880 per 100 mi^2 of digital imagery [John Norman, Natural Resources Ecology Lab, CSU; personal communication]), the imagery would need to be interpreted and verified, activity of prairie dog towns would need to be ascertained on the ground, and it is unknown if the technology would be suitable in rolling terrain. Aerial surveys, using line intercept methodology, have been used to estimate area occupied by black-tailed prairie dogs (*Cynomys ludovicianus*) (Sidle et al. 2001, J. Dennis and F. Pusaterie, Colorado Division of Wildlife; personal communication). We concluded that the technique held promise for estimating acreage of Gunnison's prairie dogs in Colorado. In this paper, we report on our current progress in evaluating aerial surveys for estimating acreage of Gunnison's and white-tailed prairie dogs (*Cynomys leucurus*) in Colorado and Utah.

Initially, on 13 June 2002, William Andelt accompanied Jim Dennis and Dave Younkin on an aerial survey of black-tailed prairie dogs to gain additional familiarity with the technique. On 24 June 2002, William Andelt and Larry Gepfert, CDOW, flew over the 32 active Gunnison's prairie dog colonies reported by Joe Cappodice. With the aid of a GPS unit, all colonies were located, although some of the smaller colonies were somewhat difficult to observe. We ascertained that aerial surveys appear to have potential for establishing distribution of Gunnison's prairie dogs and that further investigation of the technique was merited. However, because of some difficulty in observing some colonies, we, in collaboration with Gary White, decided that future test flights should also obtain photos of prairie dog colonies; classify colonies as being located in grassland, short shrubs, tall shrubs, or agriculture; rank the colonies as barely detectable, detectable, or highly detectible; and classify colonies as active, inactive, or unknown. Our plans were to use these data to estimate detection probabilities for the various categories of colonies. We then planned to use the detection probabilities to correct acreages of prairie dog colonies observed from the air (White 2002).

Subsequently, during summer 2002, Pam Schnurr and Gary White met with Amy Seglund and Bill Bates, biologists with the Utah Division of Wildlife Resources (UDWR). Both states agreed to coordinate and cooperate to further ascertain the feasibility of aerial surveys to estimate acreage of Gunnison's and white-tailed prairie dogs, and to develop detection probabilities for both species.

METHODS

We entered the boundaries of known Gunnison's and white-tailed prairie dog colonies in both Colorado and Utah into GIS Arc/Info. We established 31, 17, 19, and 11 transects across these Gunnison's and white-tailed prairie dog colonies in Colorado and Utah, respectively. These transects were established across known colonies in both states along with a number of control transects (i.e. transects over areas without colonies). Beginning and ending UTM coordinates were ascertained for each transect and placed in a spreadsheet. We hired and trained a ground crew that verified the distribution of all white-tailed prairie dog colonies on the transects in Colorado.

Jim Dennis and Dave Younkin, CDOW, and Brad Crompton and Craig Hunt, from the Utah Division of Wildlife Resources flew all 4 sets of transects and obtained GPS coordinates for the beginning and end of prairie dog colonies on the transects. The crew from Colorado had extensive experience surveying black-tailed prairie dogs, whereas the crew from Utah had extensive experience with aerial surveys of wildlife, other than prairie dogs. The Utah and Colorado survey teams flew the transects in opposite directions.

We plotted the endpoints of the prairie dog colonies that were ascertained by both aerial crews on all transects in GIS Arc/Info. We used Arc/Info to determine the lengths of each colony on each transect and then entered these data in a spreadsheet. We summed the lengths of colonies ascertained on the ground and from the air on each transect. We analyzed these data in SAS using Proc GLM to determine the effect of aerial team, rating of colony visibility, and rating of habitat type on the proportion of colonies observed on aerial versus ground surveys. We censored transects without prairie dogs known on ground surveys, and then used Spearman Correlation (Proc CORR) analyses to ascertain correlations for proportion of colonies observed, ratings of visibility, and ratings of habitat types between the 2 aerial crews. We also used Spearman Correlation analyses to ascertain correlations between ratings of visibility of colonies and proportion of colonies detected, and ratings of habitat types and proportion of colonies detected.

RESULTS

The Colorado and Utah teams overestimated lengths of Gunnison's prairie dog colonies on transects in Colorado and Utah (Table 1). Both teams also overestimated lengths of white-tailed prairie dog colonies on the white-tailed site in Utah. In contrast, the Colorado team underestimated lengths of colonies on the white-tailed site in Colorado. Although the Utah team closely estimated the overall average lengths of colonies on this site, we found considerable variation between total lengths of colonies on transects observed by this team versus those known on the ground. The Utah aerial team ($x = 5.3$; S.E. = 1.11), compared to the Colorado team ($x = 2.3$; S.E. = 0.36), observed a greater proportion of lengths of colonies on transects (Tables 1, 2), however both teams significantly overestimated the lengths of colonies compared to the lengths ascertained on the ground. The proportion of length of prairie dog colonies observed from the air compared to the lengths ascertained from the ground were not related to ratings of visibility nor to ratings of habitat types observed from the air (Table 2).

Proportion of lengths of prairie dog colonies detected by aerial crews from Colorado and Utah were weakly correlated (Table 3). However, ratings of visibility of colonies and ratings of type of habitat found on transects of colonies were not correlated between the Colorado and Utah aerial crews. The 2 crews did not consistently report finding prairie dogs in the same areas along the same transect. This may partially explain the differences between the 2 crews in their ratings of visibility of colonies and rating of habitat types on transects.

Proportions of lengths of colonies detected by aerial crews were not correlated with rating of visibility of colonies on transects (Table 4). The greatest proportions of lengths of colonies were detected by aerial crews on transects described as grasslands followed by transects described as short shrubs and then followed by transects described as tall shrubs (Table 4).

The Colorado team rated prairie dogs on 76% of 51 transects as active, 12% as unknown, and 12% as a combination of active and unknown. The Utah team rated prairie dogs on 28% of 63 transects as active, 2% as inactive, 57% as unknown, and 25% as a combination of active, inactive, and unknown.

DISCUSSIONS AND RECOMMENDATIONS

We recognize a number of goals when inventorying prairie dogs. We believe the most important goal is to obtain accurate and repeatable estimates (i.e. low variation within and among survey crews) of the acreage of Gunnison's and white-tailed prairie dogs. Low variation among survey crews is necessary so that differences between estimates of acreage are actually related to increases or decreases in acreage of prairie dogs rather than differences between crews. Another goal for inventorying prairie dogs is to establish minimum acreages of prairie dogs which we can relate to their status and decisions about listing them as threatened or endangered.

Our goal has been to ascertain the feasibility of aerial surveys for estimating acreage of Gunnison's and white-tailed prairie dogs in Colorado and Utah. We envisioned this as a multi-step process. We first flew over known Gunnison's prairie dog colonies and noted that many of the colonies were visible from the air. Next, we arranged aerial surveys by crews from Colorado and Utah to estimate the length of colonies on transects where the distribution of prairie dogs were known to us, but unknown to the crews. Accuracy of aerial surveys was not sufficient to estimate detection probabilities.

We found significant variation between the 2 aerial teams in estimates of lengths of prairie dog colonies on transects, however these estimates were weakly correlated between the 2 teams. Shortly after completing the aerial flights and before data were compiled, Jim Dennis noted that his team likely could have more accurately estimated lengths of prairie dog colonies by conducting some flights followed by ground reconnaissance of the same transects to verify what they were observing from the air (see Appendix 1). We anticipate this training would enhance accuracy of estimates. We recommend that training, or other methods to improve estimates between teams, are needed before broad scale surveys are conducted. The large variation between teams in our study indicate that, without improving accuracy and consistency between teams, it would be difficult to ascertain even moderate changes in acreages of prairie dogs.

The Colorado and Utah teams surveyed the Colorado white-tailed prairie dog site on 20 September and 28 August 2002, respectively. The Colorado team rated 10 of the transects as active and 2 as unknown. The Utah team rated 4 transects as active, 1 as inactive, 5 as unknown, and 4 as active-inactive or active-unknown. We surveyed part of the Colorado white-tailed site from the ground on 23 September 2002 and found very little sign of activity by prairie dogs. Thus, we recommend that ground crews verify ratings of activity on a random sample of future transects. If aerial crews are unable to accurately determine activity, a ground crew will need to verify activity on a random portion of transects on future surveys.

We reviewed potential causes for why estimates of lengths of prairie dog colonies varied between ground surveys and aerial surveys, and between the 2 aerial crews. We closely surveyed the distribution of prairie dogs on the white-tailed sites in Colorado and Utah, but additional verification on the ground is needed for the 2 Gunnison's prairie dog sites to insure that accuracy of ground surveys is not a cause of error.

Coordinates of prairie dog colonies were recorded on the ground and by the Utah team in the NAD27 datum. The Colorado team used the WGS84 datum when they flew the transects. The use of the WGS84 resulted in the Colorado team being 38 to 219 m off the actual transect, depending on the study area and direction of flight (east-west versus north-south). Although we initially suspected that the 38 to 219 m away from transects resulted in some errors, our review of the data suggested that accuracy appeared similar when the airplane was on the transect versus away from the transect. The Utah team strayed over 1,000 m from portions of 4 transects which likely attributed to some errors.

We recognize 2 general approaches (ground vs. aerial surveys) for continuing surveys of Gunnison's and white-tailed prairie dogs. To continue aerial surveys, we recommend that the distribution of prairie dogs is more accurately verified on the ground on the 2 Gunnison's prairie dog sites. If distributions are different than what is currently known, the distribution of prairie dogs on aerial and ground surveys should be compared again. Then, we recommend training aerial crews by conducting flights over short transects over some colonies and then surveying the colonies from the ground so that they can better ascertain what they are observing from the air. After this training, we recommend re-flying the previous transects to ascertain if accuracy can be improved. If accuracy cannot be improved, we recommend discontinuing aerial surveys.

An alternative to surveying prairie dogs from the air would be to continue Pam Schnurr's earlier work of meeting with biologists to plot known distribution of Gunnison's and white-tailed prairie dogs on maps. A ground crew should then verify a random portion of these distributions. Although this alternative likely would cost less than aerial surveys, it likely would underestimate acreage of prairie dogs and would not provide an adequate and repeatable sample for future comparisons. However, this methodology might be sufficient for considerations of listing prairie dogs as threatened or endangered.

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Table 1. Average length (m) of Gunnison's and white-tailed prairie dog colonies, observed from the ground and reported by aerial survey crews from the Colorado Division of Wildlife and the Utah Division of Wildlife Resources, on transects surveyed in Colorado and Utah during August, September, and November 2002.

				Transects		Avg. length of colonies/transect[a]		Proportion of colony length observed[b]		
			Date of		Avg.					
Area	Species	Team	survey	N	length	Ground	Aerial	N	$\bar{X}$	S.E.
Colorado	Gunnison's	Colo	9/19-20	31	8,671	264	723	18	2.6	0.65
Colorado	Gunnison's	Utah	10/1	31	8,671	246	1,511	18	8.4	2.57
Colorado	White-tailed	Colo	9/20	17	5,446	1,955	1,202	14	0.7	0.16
Colorado	White-tailed	Utah	8/28	17	5,446	1,955	1,984	14	1.8	0.80
Utah	Gunnison's	Colo	9/23	19	10,660	424	1,770	11	3.5	0.97
Utah	Gunnison's	Utah	8/28	19	10,660	424	3,406	11	7.5	2.09
Utah	White-tailed	Colo	9/24	11	40,403	2,912	9,714	8	2.7	0.85
Utah	White-tailed	Utah	8/26	11	40,403	2,912	5,418	8	1.7	0.44
			TOTAL:							
		Colo		78	12,928	1,045	2,350	51	2.3	0.36
		Utah		78	12,928	1,045	2,626	51	5.3	1.11

[a]Represents average length of colonies known primarily from ground reconnaissance, and estimated from aerial surveys on transects with and without prairie dog colonies.

[b]Represents proportion of length of prairie dog colonies observed from aerial surveys divided by lengths ascertained from ground reconnaissance on transects with prairie dog colonies.

Table 2. Effects of aerial teams[a], ratings of visibility of colonies[b], and ratings of habitat types[c] on proportions of length of Gunnison's and white-tailed prairie dog colonies observed on aerial transects during August, September, and November 2002.

Independent variable	df	F	P
Aerial teams	1	6.79	0.011
Rating of visibility	4	0.57	0.684
Rating of habitat type	5	0.48	0.793

[a]Aerial team from Colorado Division of Wildlife and from Utah Division of Wildlife Resources.

[b]Barely detectible, barely detectible-detectible, detectible, detectible-highly detectible, highly detectible.

[c]Grassland, grassland-short shrub, short shrub, short shrub-tall shrub, tall shrub, agricultural.

Table 3. Correlations between aerial crews from the Colorado Division of Wildlife and the Utah Division of Wildlife Resources for proportions of lengths of prairie dog colonies detected, ratings of visibility[a], and ratings of habitat types[b] on aerial transects of Gunnison's and white-tailed prairie dogs observed during August, September, and November 2002.

	Colorado team			Utah team				
Variable	N	$\bar{X}$	S.E.	N	$\bar{X}$	S.E.	r_s	P
Proportion of colony length detected	51	2.3	0.36	51	5.3	1.11	0.301	0.032
Rating of visibility of colony	30	2.4	0.11	30	2.5	0.10	-0.020	0.916
Rating of habitat type on colony	22	2.2	0.12	22	1.4	0.08	-0.066	0.769

[a]1 = barely detectible, 1.5 = barely detectible-detectible, 2 = detectible, 2.5 = detectible-highly detectible, 3 = highly detectible.

[b]1 = grassland, 1.5 = grassland-short shrub, 2 = short shrub, 2.5 = short shrub-tall shrub, 3 = tall shrub.

Table 4. Correlations between ratings of visibility[a] and proportions of prairie dog colony lengths detected, and ratings of habitat types[b] and proportions of prairie dog colony lengths detected on transects of Gunnison's and white-tailed prairie dogs combined by aerial crews from the Colorado Division of Wildlife and the Utah Division of Wildlife Resources combined during August, September, and November 2002.

	Visibility/Habitat			Proportion of colony detected				
Variable	N	$\bar{X}$	S.E.	N	$\bar{X}$	S.E.	r_s	P
Visibility versus proportion of colony length detected	77	2.4	0.07	77	4.5	0.76	0.038	0.742
Habitat versus proportion of colony length detected	65	1.7	0.07	65	4.3	0.88	-0.246	0.048

[a]1 = barely detectible, 1.5 = barely detectible-detectible, 2 = detectible, 2.5 = detectible-highly detectible, 3 = highly detectible.

[b]1 = grassland, 1.5 = grassland-short shrub, 2 = short shrub, 2.5 = short shrub-tall shrub, 3 = tall shrub.

Appendix 1. Suggestions for Aerial Surveys (from Andelt and Schnurr 2002).

Based upon our flight with Larry Gepfert and suggestions from Jim Dennis and Dave Younkin we have developed a number of suggestions for aerial surveys of Gunnison's prairie dogs and white-tailed prairie dogs:

- Elevation and overall range distributions (Armstrong 1972, Fitzgerald et al. 1994) should be ascertained before aerial surveys are conducted to minimize the area that needs to be surveyed.

- Flight crews should spend at least 1 day on the ground in Gunnison's prairie dog and white-tailed prairie dog towns to become more familiar with the towns before they fly transects. The crews should also gain experience by flying over known colonies. After flying over known colonies, the crew should spend some time on the ground in a colony to better ascertain what they have seen from the air.

- Transects should be constructed along drainages, instead of across drainages, to minimize changes in elevation while conducting surveys. Further, transects should be flown down the drainage, instead of up drainages, to maximize aircraft maneuverability while minimizing danger.

RECOMMENDED PLANS FOR FUTURE

- Complete ground surveys to establish the remaining "known" boundaries for white-tailed prairie dog colony transects already flown in Colorado. Compare known and aerial estimates of the locations of prairie dog colonies to ascertain accuracy of aerial surveys.

- Ascertain if a correction for detection probabilities will need to be employed. This will be primarily needed if the aerial crews were unable to observe a significant proportion of the "known" colonies.

- Determine strata boundaries utilizing recent WRIS mapped activity areas and elevation limits for prairie dogs to minimize the extent of surveys.

- Establish transect lines along drainages and within strata.

- Determine who will conduct aerial surveys in Colorado. We suspect that we will need to contract with a commercial company.

- Ascertain if prairie dog colony activity can be determined from the air. If colony activity cannot be determined from the air, a subset ground sampling technique will need to be established to determine activity. During September field trips to the white-tailed colony in Colorado, we were unable to ascertain activity of many colonies because many prairie dogs apparently entered hibernation early this year due to the drought (Dean Biggins, personal communication).

PRELIMINARY EVALUATION OF SURVEYS OF PLOTS FOR ESTIMATING OCCURRENCE OF WHITE-TAILED PRAIRIE DOGS IN COLORADO AND UTAH

W. F. Andelt, G. C. White, P. M. Schnurr, and A. Seglund

Our research (see above) indicated that aerial line-intercept surveys likely will not work for reliably estimating acreage of Gunnison's and white-tailed prairie dogs. Thus, during Spring 2003, we established a pilot project and surveyed 19 500 by 500 m plots from the ground and air to ascertain if surveys of plots can be used to ascertain trends in occurrence of white-tailed prairie dogs in Colorado and Utah. We focused on white-tailed prairie dogs because they have been petitioned for listing as a threatened or endangered species, but we also plan to expand this methodology for Gunnison's prairie dogs.

METHODS

We overlaid 7.5 minute topo maps (NAD27 datum) in GIS with 500 by 500 m grid lines on each of 4 study areas (Wolf Creek and Grand Valley, Colorado, Coyote Basin and Cisco, Utah) where locations of prairie dogs were identified. After reviewing the maps and visiting with colleagues familiar with distributions of prairie dogs in each of the 4 study areas, we visited grids (plots) in the field and choose 6 plots in Wolf Creek and 6 plots Coyote Basin such that 2 had low, 2 had medium, and 2 had relatively high abundance of prairie dogs. Also within this classification, 1 of each of the low, medium, and high abundance grids had low visibility and the other high visibility. We also established 4 plots in the Grand Valley, near Grand Junction, and 3 plots near Cisco, Utah in areas with relatively low abundance of white-tailed prairie dogs.

During June 2003, we visited the 4 corners of most study plots 3 times each to establish detection probabilities, with 1 visit during 0700–1100, another visit during 1100–1500, and another visit during 1500–1900 hrs. For each study plot, we recorded the investigator's name, date, time, UTM Zone, GPS coordinates for the lower left (SW) corner of the plot, percent cloud cover, and soil type (from a soil survey map), approximate precipitation during last 24 hours, and approximate precipitation during last 30 minutes. For the 4 corners of each plot, we recorded temperature, wind direction, approximate wind speed, percent of plot that was visible, percent of plot in sunshine, rating of visibility, rating of elevation, number of mounds observed, and groups of prairie dogs observed.

On 12 June, William Andelt flew over each study plot to ascertain if prairie dogs could be reliably detected in plots from aircraft. We also hired a commercial company to photograph, with high resolution, 9 by 9 inch, color infrared film, 21 study plots to ascertain its feasibility for establishing occurrence of prairie dogs in plots.

RESULTS AND DISCUSSION

We are currently analyzing data from our pilot observations of white-tailed prairie dogs within 19 study plots. Initial results indicate that we should be able to reliably monitor occurrence and detect changes in occurrence of white-tailed prairie dogs by visiting plots from the ground. We plan to establish about 300 (based upon computer simulations) random plots within the range of white-tailed prairie dogs in Colorado. We plan to hire a field crew and visit these plots to ascertain occurrence of prairie dogs during spring and summer 2004. Our flight over 21 study plots indicate that an airplane might be used to establish occurrence of prairie dogs in high density plots, especially on warm days with snow cover during spring. We will evaluate aerial photographs after they are developed. We also plan to conduct a pilot study, during spring 2004, of the above methodology for ascertaining occurrence of Gunnison's prairie dogs in Colorado. We are currently writing a proposal which will detail our subsequent work.

CHRONIC WASTING DISEASE

W. F. Andelt

We established links, on my web site (http://www.coopext.colostate.edu/wildlife/ , then, go to Diseases), to 9 sites that contain information on chronic wasting disease. I informed all extension personnel, including all county extension agents, in Colorado about the availability of this information on my web site. I also informed 153 Cooperative Extension volunteers at 3 training sessions in Colorado, that information on chronic wasting disease was available on my web site. My web page on Diseases was accessed 701 times during January-June, 2003.

EXTENSION INFORMATION ON RESOLVING HUMAN-WILDLIFE CONFLICTS

W. F. Andelt

My Cooperative Extension activities included:

Refereed Publications:

Yoder, C. A., W. F. Andelt, L. A. Miller, J. J. Johnston, and M. J. Goodall. 2003. Effectiveness of twenty, twenty-five diazacholesterol, avian gonadotropin releasing hormone, and chicken riboflavin carrier protein for inhibiting reproduction in Coturnix quail. (Submitted to Poultry Science).

Refereed Publications In Preparation:

Schwartz, A. M., and W. F. Andelt. Effects of castration on reproduction and social structure in the black-tailed prairie dog (*Cynomys ludovicianus*). (Manuscript is 95% completed, will be submitted to the Journal of Wildlife Management).

Schwartz, A. M., and W. F. Andelt. Effects of castration on body mass and survival in the black-tailed prairie dog (*Cynomys ludovicianus*). (Manuscript is 95% completed, will be submitted to the Journal of Wildlife Management).

Heffernan, D. J., W. F. Andelt, and J. A. Shivik. Coyote exploratory behavior following removal of novel stimuli. (Manuscript is 95% completed, will be submitted to the Journal of Wildlife Management.

Book Chapters:

Lamb, B. L., R. P. Reading, and W. F. Andelt. 2003. Public attitudes and perceptions toward black-tailed prairie dogs. Pages _ to _ *in* J. L. Hoogland, editor. Conservation and management of prairie dogs. Island Press, Washington, D.C. (Submitted 2nd draft).

Andelt, W. F. 2003. Methods and economics of managing prairie dogs. Pages _ to _ *in* J. L. Hoogland, editor. Conservation and management of prairie dogs. Island Press, Washington, D.C. (Submitted 3rd draft).

Extension Publications:

Andelt, W. F. 2002. Impacts of drought on wildlife. 1pp. (Published at http://drought.colostate.edu/).

Andelt, W. F., S.N. Hopper, and M. Cerato. 2002 (revised). Preventing woodpecker damage. Cooperative Extension Bulletin, Colorado State University, Fort Collins. 5pp. (Published at http://www.ext.colostate.edu/PUBS/NATRES/pubnatr.html).

Andelt, W. F. 2003. Preventing woodpecker damage to trees. The Green Scene (July, In press).

Cerato, M., and W. F. Andelt. 2003 (revised). Coping with skunks. Cooperative Extension Bulletin, Colorado State University, Fort Collins. 5pp. (In press; will be published at http://www.ext.colostate.edu/PUBS/NATRES/pubnatr.html).

Cerato, M., and W. F. Andelt. 2003 (revised). Coping with snakes. Cooperative Extension Bulletin, Colorado State University, Fort Collins. 6pp. (Published at http://www.ext.colostate.edu/PUBS/NATRES/pubnatr.html).

Progress Reports:

Andelt, W. F., and P. Schnurr. 2002. Progress report: inventorying Gunnison's prairie dogs in Colorado. Progress report submitted to Gary Miller, Colorado Division of Wildlife, 7 November 2002. 7pp.

Andelt, W. F. 2003. Status of Gunnison's prairie dogs in Colorado. Progress report submitted to Gary Miller, Colorado Division of Wildlife, 13 January 2003. 10pp.

Andelt, W. F., P. Schnurr, and A. Seglund. 2003. Evaluation of aerial surveys for estimating acreage of Gunnison's and white-tailed prairie dogs in Colorado and Utah. Progress report submitted to Gary Miller, Colorado Division of Wildlife, 24 February 2003. 13pp.

Papers Presentation at National, Regional, and State Meetings:

Andelt, W. F. 2003. Alternatives to toxicants for managing conflicts with black-tailed prairie dogs. Colorado Prairie Dog Technical Conference, Fort Collins, Colorado (Invited paper).

Andelt, W. F. 2003. Behavioral modification of coyotes to reduce predation on livestock. Department of Fisheries and Wildlife, Utah State University (Invited paper).

Andelt, W. F. 2003. Evaluation of aerial surveys for estimating acreage of Gunnison's and white-tailed prairie dogs in Colorado and Utah. Colorado Prairie Dog Technical Conference, Fort Collins, Colorado.

Andelt, W. F. 2003. Incorporating experimental design in education on managing human-wildlife conflicts at Colorado State University. Tenth Wildlife Damage Management Conference, Hots Springs, Arkansas (Invited paper).

Andelt, W. F. 2003. Managing conflicts with coyotes: aversive stimuli, novel stimuli, and livestock guarding dogs. Wyoming Student Chapter of The Wildlife Society, Laramie, Wyoming (Invited paper).

Andelt, W. F. 2003. Non-lethal methods for managing conflicts with prairie dogs. Colorado Prairie Dog Technical Conference, Fort Collins, Colorado (Invited paper).

Jozwiak, E. A., T. N. Bailey, and W. F. Andelt. 2003. Response of wolves to changing harvest levels on the Kenai NWR, Alaska. The World Wolf Congress 2003 – Bridging Science and Community, The Banff Centre, Banff, Canada (submitted).

Analyzed about 200 predator scats to help assess the role of various predators in the decline of sage grouse in northwestern Colorado.

Obtained $1,200 from the Renewable Resources Extension Act to revise Cooperative Extension fact sheets on managing conflicts with wildlife.

Submitted a research proposal to study Ecology of coyotes and coyote predation on bighorn sheep in Rocky Mountain National Park, Colorado. Project was not funded.

Co-coordinator and instructor at 3 2–4 hour workshops for 153 extension volunteers and 3 Colorado Division of Wildlife employees.

Speaker at 3 Cooperative Extension meetings with 80 participants.

Provided training for 55 biologists and other professionals including wildlife commissioners at 1 workshop.

Presented 3 guest lectures to 107 students in Colorado State University courses on managing conflicts with wildlife.

Advised an M.S. candidate that conducted research on resolving conflicts with prairie dogs, and a Ph.D. candidate that was conducted research on coyotes.

Served on 2 M.S. and 1 PhD. Committees.

Evaluated 27 posters for the Cooperative Extension Poster Session at the February 2003 In-Service training.

Served on the Jefferson County Cooperative Extension Natural Resources Agent Search Committee.

Served as a Mentor for Thomas Mason, Jefferson County Cooperative Extension Natural Resources County Agent.

Served on the Colorado Department of Agriculture Pesticide Review Committee. Commented on impacts of pesticides on wildlife.. Provided extensive reviews of the efficacy data for the Rodex 4000 (an explosive device for killing rodents), and efficacy of 2 repellents (Deer Stopper, Deer Stopper Ready to Use) for deterring deer.
Served on the Colorado State University Cooperative Extension, College of Natural Resources, Renewable Resources Extension Act Committee.

Served on the Rodent Program Review Panel for the National Wildlife Research Center.

Updated my web site on Managing Conflicts with Wildlife at (http://www.coopext.colostate.edu/wildlife/). Various pages of the web site have been accessed 227 to 3,381 times each during January-June 2003.

Provided interviews for 5 newspaper reporters at United Press International, Rocky Mountain News, Denver Post, and others.

Provided interviews for 2 radio stations.

Wrote 1 news release for CSU Cooperative Extension Agents.

Reviewed 2 manuscripts for scientific journals and 1 manuscript for a colleague.

Participated in about 75 meetings.

Wrote about 50 e-mail messages about conflicts with wildlife.

Answered about 50 telephone inquiries about managing conflicts with wildlife.

POSSIBLE ROLE OF PREDATORS IN THE SAGE GROUSE DECLINE

W. F. Andelt

Approximately $5,200 was received from the Moffat County Department of Natural Resources to conduct preliminary research on the possible role of predators in the sage grouse (*Centrocercus urophasianus*) decline in Moffat County. Red fox (*Vulpes vulpes*; Flinders [1999]) have been reported as one of the primary mammalian predators of sage grouse, whereas coyotes (*Canis latrans*; Presnall and Wood [1953]), bobcats (*Felis rufus*; Hartzler [1974], mink (*Mustella vison*; Hartzler [1974]), badgers (*Taxidea taxus*; Gill [1965]), and ground squirrels (*Spermophilus* spp.; Schroeder and Baydack [2001]) also prey on adults or nests of sage grouse. Thus, we obtained data on relative abundance of mammalian carnivores on 2 study areas (immediately northwest of Craig ["Craig"] and north of Maybell ("Maybell"). Sage grouse are scarce on the Craig study area which is fragmented habitat (sagebrush-grassland interspersed with CRP, alfalfa, and wheat), whereas they are moderately abundant on the Maybell study area which is primarily contiguous habitat (mostly sagebrush-grassland).

Golden eagles (*Aquila chrysaetos*; Hartzler [1974]) appear to be the primary avian predator of sage grouse, particularly on leks, whereas prairie falcons (*Falco mexicanus;* Hartzler [1974]), red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*B. swainsoni*), ferruginous hawks (*B. regalis*), northern harriers (*Circus cyaneus*; references in Schroeder and Baydack 2001) may occasionally kill some sage grouse. Common ravens (*Corvus corax*; Allred [1942], Autenrieth [1981], Alstatt [1988]) appear to be the primary avian predators of sage grouse nests or simulated nests, whereas black-billed magpies (*Pica pica*; Autenrieth [1981]) may prey on some nests. Consequently, we collected data on relative abundance of avian predators, and collected carnivore scats on the Craig study area, the Maybell study area, and in the Axial basin (Appendix 1), which consists primarily of contiguous habitat (mostly sagebrush-grassland) where sage grouse are moderately abundant. I also provided information to Dr. Tony Apa and colleagues on identifying which predators killed sage grouse or depredated their nests.

Relative Abundance of Mammalian Predators

During 5 to 10 June 2001, we (Dr. Andelt, 1 graduate student, and 1 technician) set 92 scent stations on the Craig study area and 92 scent stations on the Maybell study area to gain an assessment of general abundance of carnivores on the 2 sites. Scent stations are 1-yard diameter circles of sifted earth with an attractant (fatty acid scent, small traffic cone or both) placed in the center. The scent stations were set in groups of 4 with each station 0.2 miles apart. Each group of 4 scent stations were set at least 2 miles apart to minimize visits to different groups of stations by individual carnivores. The locations for stations were mostly randomly selected from BLM maps. The stations were checked 1 day after they were set. A few of the stations were rendered inoperable by light to moderate rain. I used chi-square tests (PROC FREQ, SAS Inst. Inc. 1988) to analyze the data.

Red fox visited more scent stations ($X_1^2 = 5.465$; $P = 0.0194$) and more groups of stations ($X_1^2 = 5.199$; $P = 0.0226$) on the area with few sage grouse compared to the area where grouse were fairly abundant (Table 1). We need to interpret these data with caution. First, we do not know exactly how scent station visitation rates relate to relative abundance of red fox on the 2 sites, but these data do suggest that red fox likely are more abundant on the site where grouse are rare. These data also do not indicate that red fox caused the decline of sage grouse. Surprisingly, we did not positively identify coyote tracks at any of the stations although it is possible that 1 or 2 of the stations could have been visited by coyotes.

Table 1. Visits by red fox to scent stations set in Moffat County, Colorado during 5 to 10 June 2001.

	Few grouse (Craig study area)	Grouse moderately abundant (Maybell study area)
Number scent stations	92	92
Operable stations	78	87
Operable groups of stations	19	21
Stations visited by red fox	12	4
Groups of stations visited by red fox	9	3
Stations visited by coyotes	0	0

Raptor Surveys

We established 10 1-mile long survey routes on roads on the Craig study area, 10 1-mile long survey routes on the Maybell study area, and 10 1-mile long survey routes in the Axial Basin. We counted raptors (hawks, eagles, magpies), at all distances, along these transects once per month from August 2001 through June 2002 to ascertain if the abundance of raptors differs among the 3 areas. I compared abundance of various raptors on transects with ANOVA (PROC GLM, SAS Inst. Inc. 1988).

Abundance of none of the raptors varied among study areas ($F_{2,276} = 0.15–2.82$; $P = 0.865–0.062$, Table 2). In general, black-billed magpies were the most abundant raptor followed by American crows (*Corvus brachyrhynchos*; Table 2).

Table 2. Average number of raptors observed per month[a] on the Craig, Maybell, and Axial Basin study areas in Moffat County, Colorado from August 2001 through June 2002.

	Few grouse	Grouse moderately abundant	
	(Craig study area)	Maybell study area)	Axial Basin
Golden eagle	0.7	2.2	1.6
Common raven	0.6	0.9	0.0
Black-billed magpie	7.8	7.8	6.4
Prairie falcon	0.0	0.0	0.0
Red-tailed hawk	0.3	0.8	0.5
Ferruginous hawk	0.0	0.1	0.0
Northern harrier	0.2	0.0	0.1
Bald eagle (*Haliaeetus leucocephalus*)	0.0	0.2	0.1
American crow	3.7	6.2	9.1
American kestrel (*Falco sparverius*)	0.2	0.1	0.2
Turkey vulture (*Cathartes aura*)	0.8	0.0	0.0
Other (unidentified)	0.2	0.0	0.0

[a]Ten 1-mile long transects were driven once per month and all raptors observed from the vehicle were recorded from August 2001 through June 2002, except observations were not made during January and observations also were not made on the Maybell study area during February due to difficulty traversing roads.

Carnivore Food Habits

We established 10 1-mile long survey routes on roads on the Craig study area, 10 1-mile long survey routes on roads on the Maybell study area, and 10 1-mile long survey routes on roads in Axial Basin (Appendix 1). We collected carnivore (primarily coyote and red fox) scats along these survey routes once per month from August 2001 through June 2002, except for January when travel was hindered by snow. We measured the diameters of scats with calipers and weighed them on an electronic balance. Green and Flinders (1981) reported that only 5% of red fox scats are ≥18 mm in maximum diameter and that only 4% of coyote scats were <16 mm in maximum diameter. I extrapolated data from Weaver and Fritts (1979) and Danner and Dodd (1982) which indicated that only about 8 and 11% of coyote scats are <16 mm in maximum diameter. Thus, I classified scats <16 mm in diameter as red fox and those ≥18 mm in diameter as coyote. Scats that consisted of short segments were classified as bobcat (Murie 1954). We placed these scats in fine-mesh nylon bags and washed and dried them. We visually inspected the scats to determine if they contained sage grouse feathers or egg shells to help ascertain if red fox or coyotes preyed on sage grouse. When feathers were found, we ascertained if they were from sage grouse according to overall size of the feathers, presence and size of quills, presence of aftershafts, and general structure of the feather. Only birds in the order Galliformes, which includes sage grouse, have aftershafts (Elbroch and Marks 2001:235) on their feathers.

A total of 224 scats were collected and analyzed (Table 3). Based upon diameter and segmentation of scats, we ascertained that 26 scats were from red fox, 141 from coyotes, 4 from bobcats, and 53 scats could not be assigned to species. Although we collected scats on 10 miles of roads in each study area, the greatest numbers of scats were found on the Maybell and Axial Basin study areas, whereas the fewest scats were found on the Craig study area. Roads on the Craig study area are traveled more frequently by automobiles and are graded more frequently than roads on the other 2 study areas. These activities obliterate scats, thus relative abundance of scats likely is a poor indicator of relative abundance of carnivores on the 3 study areas. We found feathers in only 5 of 224 scats and none of the feathers appeared to be from sage grouse (Table 3).

Table 3. Number carnivore scats and presence of feathers in scats found on transects on the Craig, Maybell, and Axial Basin study areas in Moffat County, Colorado from August 2001 through June 2002.

	Few grouse	Grouse moderately abundant	
	(Craig study area)	Maybell study area)	Axial Basin
Total scats	18	101	105
Red fox scats	4	13	9
Red fox scats with feathers	1	1	0
Coyote scats	9	66	66
Coyote scats with feathers	0	1	1
Bobcat scats	0	1	3
Bobcat scats with feathers	0	0	0
Unknown scats[a]	5	21	27
Unknown scats with feathers	0	1	0

[a]Based upon diameter and weight, we could not assign these scats to red fox, coyote, or bobcat.

Assistance with Determining which Predators are Responsible for Depredating Sage Grouse and their Nests:

I provided Tony Apa and colleagues with information on how to determine which predators killed grouse or depredated their nests.

SYNTHESIS OF RESULTS AND DISCUSSION

Results of our scent station surveys suggest that red fox are more abundant on the Craig study area, where few sage grouse were present, than on the Maybell study area, where grouse were moderately abundant. The absence of sage grouse feathers in 141 scats, ascertained to be from coyotes, suggests that coyotes perhaps may not be substantial predators of sage grouse. We also did not find grouse feathers in 26 scats ascertained to be from red fox, and 4 scats ascertained to be from bobcats, however these small sample sizes do not allow for strong inferences regarding predation by red fox and bobcats on sage grouse. Even if feathers would have been found in coyote, red fox, or bobcat scats, it would still be difficult to ascertain the impact of either species on sage grouse without knowing densities of these 3 carnivores, densities of sage grouse, carnivore digestion and defecation rates, etc. However, I analyzed carnivore scats in a preliminary attempt to ascertain if either species might be frequently preying on sage grouse.

Prior research has indicated that golden eagles and common ravens are the primary avian predators of sage grouse and their nests, respectively. Our raptor surveys indicated that both species were fairly common on most of our study areas. Initially, we expected that we might find more golden eagles and common ravens on the Craig study area, where sage grouse are scarce, if they are having an impact on sage grouse. However, predators are opportunists which often frequent areas of highest prey abundance. Due to these factors, and due to no significant differences in abundance of golden eagles and common raven among the 3 study areas, it is difficult to draw solid inferences from this study about the impact of these species on sage grouse. Ultimately, the best way to ascertain impacts of various predators on adult sage grouse, sage grouse chicks, and sage grouse nests is to monitor survival and causes of mortality for these life stages of sage grouse.

ACKNOWLEDGMENTS

I thank numerous individuals that assisted with this project. J. Comstock provided continuous encouragement and financial support for the study. G. Miller and the Colorado Division of Wildlife provided financial support while W. Andelt conducted the study. J. Shivik and the National Wildlife Research Center provide salary support for D. Heffernan and D. Martin while they assisted with the study. T. Apa and R. Hoffman provided suggestions for the study. D. Heffernan and D. Martin assisted with scent station surveys. A. Martin and V. Dobrich conducted surveys of raptors and collected carnivore scats. C. Simpson analyzed carnivore scats to determine presence of feathers and egg shells. R. Ryder and R. Hoffman assisted with ascertaining if feathers in carnivore scats were from sage grouse.

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Appendix 1. GPS coordinates for transects where carnivore scats were collected and raptors were observed (datum = WGS 84).

	---Scat---				---Raptor---			
	Start of transect		End of transect		Start of transect		End of transect	
Transect #	X	Y	X	Y	X	Y	X	Y
CRAIG STUDY AREA - FRAGMENTED HABITAT								
1	286321	4495138	286359	4496685	286359	4496685	286417	4498162
2	286993	4504934	287551	4506266	286753	4503651	286993	4504934
3	290602	4498993	289265	4499443	289265	4499443	287842	4499021
4	283274	4497952	282630	4499345	282630	4499345	281182	4499731
5	280846	4499870	279994	4500954	279994	4500954	278429	4500997
6	277689	4503788	276290	4504491	276290	4504491	274892	4505050
7	272894	4505463	271595	4505789	271595	4505789	270687	4504525
8	277304	4496358	278798	4496016	278798	4496016	279930	4495509
9	281065	4493667	281903	4492847	281903	4492847	281766	4491265
10	275680	4490952	274742	4491859	274742	4491859	273755	4492689
MAYBELL AREA - UNFRAGMENTED HABITAT								
11	747333	4497815	748923	4497867	748923	4497867	750446	4498098
12	747215	4502458	745844	4501925	745844	4501925	744495	4501667
13	749179	4508451	750735	4508465	750735	4508465	752004	4509245
14	745930	4508307	744658	4507713	744658	4507713	744178	4508932
15	742374	4510170	742575	4511677	742575	4511677	741688	4511365
16	739699	4510025	738301	4510610	738301	4510610	737962	4511658
17	745369	4514231	746090	4515477	746090	4515477	?	?
18	743327	4521876	744832	4522160	744832	4522160	746305	4521754
19	749357	4520229	750726	4519826	750726	4519826	752031	4519026
20	248318	4517684	249268	4516416	249268	4516416	249486	4514902
AXIAL BASIN								
21	253432	4480100	253671	4478589	253671	4478589	253641	4477122
22	252975	4474342	254317	4474661	254317	4474661	255142	4475609
23	257571	4476843	257398	4475313	257398	4475313	257138	4473907
24	256457	4472106	255153	4471305	255153	4471305	254046	4470304
25	249225	4470006	249317	4471575	249317	4471575	249559	4473119
26	245513	4472271	246720	4473285	246720	4473285	247862	4474390
27	254021	4467748	252917	4466698	252917	4466698	251914	4465499
28	258706	4465355	257542	4464349	259268	4466465	258706	4465355
29	262032	4470302	260734	4470308	260734	4470308	260138	4468956
30	250505	4478294	249580	4477016	249580	4477016	248906	4475569

JOB PROGRESS REPORT

State of Colorado : Mammals Research Program

Work Package No. : Multispecies Investigations

Task No. 5 : Consulting Service for Mark-Recapture Analysis

Federal Aid Project No. W-153-R-2

Period Covered: July 1, 2002 - June 30, 2003

Author: G. C. White

Personnel: C. Bishop, G. Miller, T. E. Remington, D. J. Freddy, T. M. Shenk, L. Stevens, J. Craig, R. Kahn, D. C. Bowden, F. Pusateri, J. Dennis, P. Schnurr, B. Andelt, A. Seglund, D. Finley, A. Linstrom, D. Walsh, K. Strohm.

ABSTRACT

Progress towards the objectives of this job include:

1. Consulting assistance to CDOW on harvest surveys, terrestrial inventory systems, and population modeling procedures was provided. Estimates of spring and fall turkey, spring snow goose, sharp-tailed and sage grouse, chukars, ptarmigan, Abert's squirrels, and general small game harvest were computed from survey data, and programs and harvest estimates provided to CDOW via email and CD ROM. Computer code written in SAS to compute these estimates and display results graphically was also provided. Computer code was also written in SAS to estimate the compliance rate of Colorado small game license holders with the Harvest Information Program.

2. The DEAMAN software package for the storage, summary, and analysis of big game population and harvest data was revised further as a Windows 95/98/NT/2000/ME/XP program. A User's Manual was provided to terrestrial biologists on CD and also distributed via the WWW at http://www.cnr.colostate.edu/~gwhite/deaman.

3. Consultation with CDOW Terrestial Biologists in the use of DEAMAN and population modeling procedures continued. Numerous questions were answered via meetings with biologists, and via email.

4. A paper, coauthored with Marilet Zablan and Clait Braun, was published in the Journal of Wildlife Management on past efforts to estimate survival rates of sage grouse in North Park from CDOW banding records. The full citation is: Zablan, M. A., C. E. Braun, and G. C. White. 2003. Estimation of northern sage-grouse survival in North Park, Colorado. Journal of Wildlife Management 67:144-154.

5. A paper on the estimation of population size from correlated sampling unit estimates of the variable of interest was published in the Journal of Wildlife Management. The methodology developed in this paper is proposed for use in a joint Colorado/Utah survey of the colony area of white-tailed and Gunnison prairie dogs in western Colorado and eastern Utah. The full citation is: Bowden, D. C., G. C. White, A. B. Franklin, and J. L. Ganey. 2003. Estimating population size with correlated sampling unit estimates. Journal of Wildlife Management 67:1-10.

6. A paper on the use of lek counts to index prairie grouse populations was published in the Wildlife Society Bulletin: Walsh, D. P., G. C. White, T. E. Remington, and D. C. Bowden. 2003. Evaluation of Lek Count Index for Prairie Grouse Wildlife Society Bulletin. 32:56-68.

7. A paper on the estimation of sage grouse populations was submitted to the Journal of Wildlife Management: Walsh, D. P., G. C. White, T. E. Remington, and D. C. Bowden. 2003. Population Estimation of Greater Sage-Grouse. Journal of Wildlife Management. Submitted.

8. A paper on the effects of early season hunter numbers on elk movement was published in the Journal of Wildlife Management: Vieira, M. E. P., M. M. Conner, G. C. White, and D. J. Freddy. 2003. Relative effects of early season hunter numbers and opening date on elk movement in northwest Colorado. Journal of Wildlife Management. 67:717-728.

9. A paper on the impact of limited antlered harvest on mule deer sex and age ratios was submitted to the Wildlife Society Bulletin: Bishop, C. J., G. C. White, D. J. Freddy, and B. E. Watkins. 2003. Effect of limited antlered harvest on mule deer sex and age ratios. Wildlife Society Bulletin. Submitted.

10. A paper on the survival and recruitment of peregrine falcons was published in the Journal of Wildlife Management: Craig, G. R., G. C. White, and J. H. Enderson. 2004. Survival, recruitment, and rate of population change of the Colorado peregrine falcon population. Journal of Wildlife Management. In Press.

11. A research study to examine the impact of nutrition on the decline of mule deer fecundity during the last 20 years was continued. I have provided input on estimation of the number of deer on the feed sites, and developed an estimator of fawn survival rates based on radio-collared does and fall and spring fawn:doe ratios.

12. A graduate research project by Dan Walsh to evaluate utility of lek counts of Greater Sage-grouse in Middle Park was completed. Mark-resight methods are being used to estimate lek attendance and population size. The thesis citation is: Walsh, D. P. 2002. Population Estimation Techniques for Greater Sage-grouse. M. S. Thesis, Colorado State University, Fort Collins. USA. 158pp.

13. A graduate research project to develop a sage grouse population model, using North Park sage grouse data to develop parameter estimates, was initiated. The graduate student is Kristen Strohm.

14. An analysis to estimate the estimate the percent of eastern Colorado inhabited by black-tailed prairie dogs was completed and results provided to CDOW personnel involved with the effort. Estimates were computed in an Excel spreadsheet, and also verified through a program written in SAS to be sure that no errors in the calculations would be found when the spreadsheet is distributed to interested stakeholders.

15. Development of the design of a monitoring system for white-tailed prairie dogs in western Colorado and eastern Utah was started. This effort is in cooperation with Pam Schnurr, Bill Andelt, and Amy Seglund.

16. Development of the design of a monitoring system for swift fox in eastern Colorado was started. This effort is in cooperation with Francie Pusatari and Darby Finley.

17. Two new graduate students have been accepted for my supervision in the Department of Fishery and Wildlife Biology at Colorado State University. Chad Bishop will start a Ph.D. program in Fall, 2003, and Aaron Linstrom will start an M.S. program in Fall, 2003.

CONSULTING SERVICES FOR MARK-RECAPTURE ANALYSES

G. C. White

P. N. OBJECTIVES

Assess the status of Colorado swift fox population through an occupancy monitoring approach.

SEGMENT OBJECTIVES

1. Develop a monitoring scheme to estimate the occupancy rate of swift fox in eastern Colorado.

2. Determine necessary sample sizes to obtain adequate statistical power to detect biologically important changes in the occupancy rate.

RESULTS AND DISCUSSION

Estimation of occupancy rate for Swift Foxes (*Vulpes velox*) in eastern Colorado was based on trapping data provided by Finley (1999). The data consist of 72 randomly selected trapping grids 4 miles by 5 miles in area, with 20 traps set at 1 mile intervals.

METHODS

The occupancy model of MacKenzie et al. (2002) was fit to the 72 trapping grids using Program MARK (White and Burnham 1999). The model fit included 8 detection probabilities (p) for the 8 trapping occasions plus the probability of occupancy (ψ). Detection probabilities were predicted with the month that a grid was trapped. Month was modeled with trigometric functions; sin(Monthx2π/12) and cos(Monthx2π/12), and powers of these functions. By using these sin and cosine functions, I can make the capture probability continuous across the December to January interval. Trend models were also used to model capture probabilities across occasions, forcing a linear trend on a logit scale in the capture probabilities.

The percentage of each trapping grid comprised of short grass prairie was used as an additional covariate to predict both detection probability and probability of occupancy on a logit scale.

Model selection was performed with AIC_c (Burnham and Anderson 1999).

RESULTS

Model selection results (Table 1)suggest that month is an important predictor of the probability of detecting foxes on a grid. In addition, the top-ranked AIC_c includes a positive trend effect in the detection probabilities across the occasions, consistent with the results from the population estimation models.

Model selection results also suggest that short grass prairie vegetation affects both the detection probability as well as the probability of occupancy. Detection probability is affected by the density of animals on the grid, and the percentage of short grass prairie on a trapping grid correlates ($r = 0.375$) with estimated population sizes provided in Table 5 of my September 23rd memo.

Table 1. Model selection results from fitting the occupancy estimation model of MacKenzie et al. (2002).

Model	AICc	ΔAICc	AICc Weights	Num Par.	Deviance
{p(T+cosMonth+cosMonth^2) psi(SGPProp)}	318.6146	0.0000	0.31440	6	305.3223
{p(T+cosMonth+cosMonth^2+SGPProp) psi(SGPProp)}	319.0596	0.4450	0.25168	7	303.3096
{p(T+cosMonth+cosMonth^2+SGPProp) psi}	320.1094	1.4948	0.14890	6	306.8171
{p(cosMonth+cosMonth^2) psi(SGPProp)}	321.2674	2.6528	0.08345	5	310.3583
{p(cosMonth+cosMonth^2+SGPProp) psi(SGPProp)}	321.3341	2.7195	0.08071	6	308.0418
{p(T+cosMonth+cosMonth^2) psi}	322.6843	4.0697	0.04109	5	311.7753
{p(cosMonth+cosMonth^2+cosMonth^3) psi}	322.7973	4.1827	0.03884	5	311.8882
{p(cosMonth) psi(SGPProp)}	323.6307	5.0161	0.02560	4	315.0337
{p(cosMonth+cosMonth^2) psi}	325.5083	6.8937	0.01001	4	316.9113
{p(cosMonth) psi}	328.1180	9.5034	0.00272	3	321.7651
{p(cosMonth+sinMonth) psi}	329.1845	10.5699	0.00159	4	320.5875
{p(t+cosMonth+cosMonth^2) psi}	330.1385	11.5239	0.00099	11	303.7385
{p(.) psi}	340.3683	21.7537	0.00001	2	336.1944
{p(sinMonth) psi}	342.5446	23.9300	0	3	336.1917
{p(t) psi}	343.2296	24.6150	0	9	322.3264

Parameter values for the top-ranked AIC_c model (Table 2) demonstrate the increasing detection probability with occasion. In addition, the estimate of ψ of 0.821 suggests that 59.1 of the 72 grids trapped contained foxes, in contrast to the 51 grids that were observed to have foxes.

Table 2. Parameter estimates for the month of March from the top-ranked AIC_c occupancy model {$p(T$ + cos(Month) + $\cos^2$(Month)) psi(SGP Proportion)}, where month was set to March (3), and the short grass prairie habitat proportion for the trapping grid was set to 66.9%, the mean of the grids trapped.

Parameter	Estimate	SE	LCI	UCI
p_1	0.611647	0.083074	0.442448	0.757627
p_2	0.675704	0.066681	0.534363	0.790928
p_3	0.733793	0.060627	0.600043	0.835107
p_4	0.784792	0.061708	0.640538	0.881835
p_5	0.828306	0.064248	0.665567	0.921227
p_6	0.864541	0.065008	0.682552	0.949861
p_7	0.894106	0.063204	0.695294	0.968985
p_8	0.917831	0.059218	0.705628	0.981150
ψ	0.820811	0.065876	0.655653	0.916806

The effect of month in the top-ranked AIC_c model (Figure 1) is significant, and somewhat consistent with the results obtained with the population estimation models that included the variable month (reported in the memo of September 23). That is, the lowest detection probabilities are during summer. However, the occupancy model results suggest that September through March have the highest detection probabilities.

The impact of the percentage of short grass prairie habitat on the estimates of occupancy is strong (Figure 2), with the probability of occupancy estimated at 34% for trapping grids with no short grass prairie habitat up to 93% for grids consisting of 100% short grass prairie.

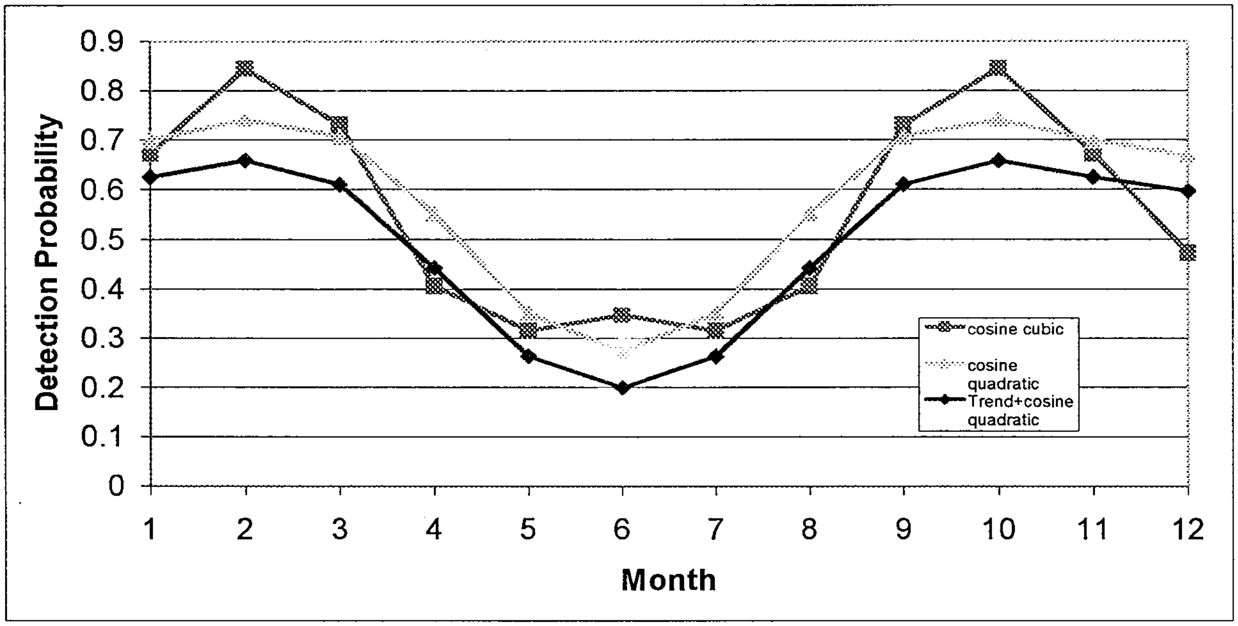

Figure 1. Effect of month in the 3 of the models of occupancy considered for detection probability: {p(cosMonth+cosMonth^2+cosMonth^3) psi}=cosine cubic, {p(cosMonth+cosMonth^2) psi}=cosine quadratic, and {$p(T$ + cos(Month) + $\cos^2$(Month)) psi}=Trend+cosine quadratic. The values shown for {$p(T$ + cos(Month) + $\cos^2$(Month)) psi} are for p_1, so estimates for p_2 through p_8 increase monotonically from this value.

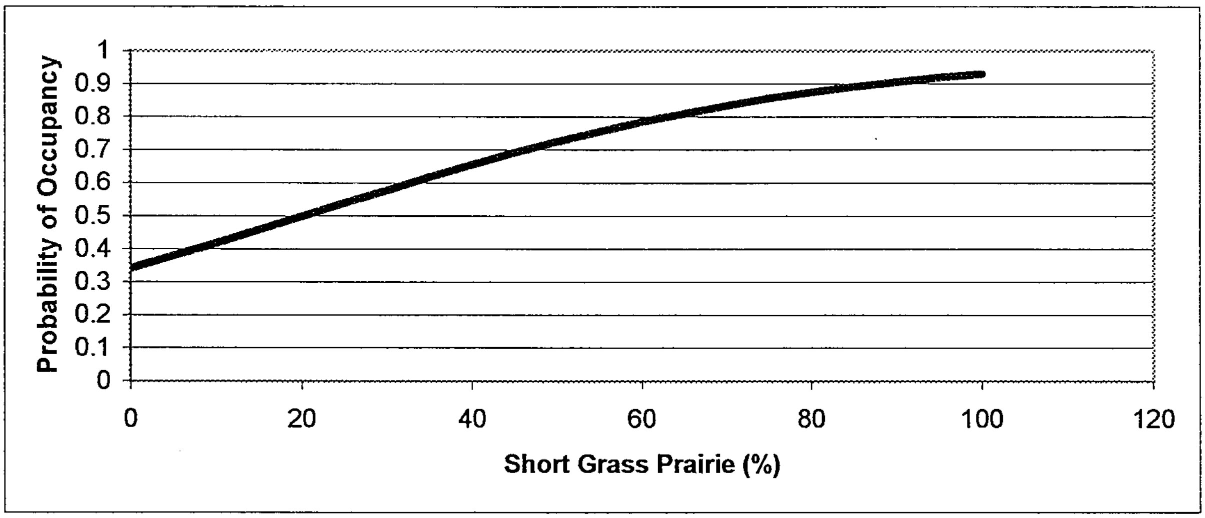

Figure 2. Effect of the percentage of the grid consisting of short grass prairie habitat on the probability of occupancy for the top-ranked AIC_c model {$p(T$ + cos(Month) + $\cos^2$(Month)) psi(SGP Proportion)}.

DISCUSSION

The high detection probabilities during the September through March period suggests that swift fox monitoring should take place during this period. The increasing detection probability with trapping occasion also suggests that increasing the number of occasions will result in higher detection probabilities on each succeeding occasion.

However, this trend effect is relatively minor. That is, the probability of not detecting foxes on a grid with 2 occasions trapped during March with the trend model estimates is (1 - 0.610297)□(1 - 0.6749937) = 0.126656. With the cosine quadratic model that does not include a trend across occasions, the probability of not detecting foxes is 0.085212. With 3 trapping occasions in March, the corresponding probabilities are 0.041164 and 0.024874, respectively.

The strong relationship between the probability of occupancy and the short grass prairie habitat variable suggests that the design of an occupancy monitoring scheme should include this covariate. In particular, a ratio estimator can be developed that predicts the probability of occupancy based on the relationship in Figure 2.

FURTHER WORK

A reasonable estimate of the number of swift foxes in eastern Colorado can be obtained from the grid trapping scheme analyzed here. The population estimate for each trapping grid within a strata can be used to obtain a naive estimate of population density that will be biased high. However, through the use of radio collars, the proportion of time that marked animals spend on the trapping grid where they were initially captured can be used to correct these naive estimates. That is, the naive estimate multiplied by the proportion of radio locations on the trapping grid gives an unbiased estimate of density. Such a procedure has been used by White and Shenk (2001) to estimate population sizes for Preble's Meadow Jumping Mice, and details are provided in that article. Thus, to obtain an unbiased population estimate, radio-collared animals would be required.

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JOB PROGRESS REPORT

State of Colorado : Division of Wildlife – Mammals Research

Work Package No. 7210 : Research support / Administrative Services

Task No. 1 : Customer Services – Library Services

Period Covered: July 1, 2002 – June 30, 2003

Author: Jacqueline A. Boss

Personnel: Jacqueline A. Boss

ABSTRACT

During the Segment, the following were accomplished:

1,024 publications acquired by the Research Center Library for the use of Colorado Div. of Wildlife employees, cooperators, wildlife educators, and the public. These publications include books, interlibrary loan materials, periodicals, and newsletters.

1,941 items of information delivered to Colorado Div. of Wildlife employees, cooperators, wildlife educators, and the public, resulting from requests and literature searches.

585 items of information cataloged into the electronic and card catalogues, which including duplicates and additional volumes, expanded the Research Center Library inventory to 22,995 items.

1,131 items of information entered into the electronic catalogue for the maintenance of the circulation system of the Research Center Library.

1,316 items checked-out by Colorado Div. of Wildlife employees, cooperators, wildlife educators, and the public indicating satisfaction of library services.

1,590 items of information delivered that are produced by the Colorado Div. of Wildlife employees, cooperators, wildlife educators, and the public. These items include: 1) publications - 951 [*from time to time duplicated books donated to our Library are also given to CDOW employees and are included in this number*], 2) research articles by CDOW personnel - 344, and 3) CDOW federal aid reports - 295.

COLORADO DIV. OF WILDLIFE RESEARCH LIBRARY SERVICES

Jacqueline A. Boss

SEGMENT OBJECTIVE

Provide an effective support program of library services at minimal cost through centralization and enhancement of accountability for Colorado Div. of Wildlife employees, cooperators, wildlife educators, and the public.

SUMMARY OF SERVICES

Maintain Electronic and Card Catalogues of all Research Library Holdings

585 is the total number of items cataloged during this period. This includes not only new acquisitions, but also older materials from the Library collection being entered into the electronic catalog for the first time. Among the new acquisitions are Federal Aid : Job Progress Reports and manuscripts written by Colorado Div. of Wildlife Researchers and other employees.

1,131 is the total number of items of information added to the electronic circulation system during this period. This includes not only the above mentioned newly cataloged items, but also newly acquired serials, volumes, additional copies, and other items being assigned scanning numbers for the electronic circulation system for the first time.

$178,625.90 is the "known value" of the 22,995 items in the Research Center Library collection as of June 30, 2003. The project to determine the value of the library collection began in May 2000. As time permits, the value of books already in the collection is determined, and added to the already "known value." Each month's addition of values of older materials, plus the new materials, increases the value of the Library collection. Not included in the "known value" of the Library collection are all of the periodicals, older materials, and government documents, which continue to be a large part of the collection, thus the "known value" of the Library collection continues to grow month by month

Some of the Publications Acquired in the Research Center Library

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