LA-13536-MS

Approved for public release;
distribution is unlimited.

*Resource Use, Activity Patterns, and
Disease Analysis of Rocky Mountain Elk
(Cervus elaphus nelsoni) at the
Los Alamos National Laboratory*

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

*Edited by Amy Foulton-Stout, Hector Hinojosa, and
Louisa Lujan-Pacheco, Group CIC-1*

*Photocomposition by Kathy E. Valdez, Group CIC-1 and
Belinda Gutierrez, Group ESH-20*

Cover photo by Rhonda Robinson, ESH-20

An Affirmative Action/Equal Opportunity Employer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither The Regents of the University of California, the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by The Regents of the University of California, the United States Government, or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of The Regents of the University of California, the United States Government, or any agency thereof. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

*Resource Use, Activity Patterns, and
Disease Analysis of Rocky Mountain Elk
(Cervus elaphus nelsoni) at the
Los Alamos National Laboratory*

*James R. Biggs
Kathryn D. Bennett
Phillip R. Fresquez*

ABSTRACT	1
INTRODUCTION	1
Study Area	2
Data Collection	4
Trapping	4
GPS Collar Programming and Reception Rates	5
HABITAT USE	7
Land Cover Type Use and Availability	8
Seasonal LCT Use and Availability	8
Aspect Use and Availability	11
Seasonal Aspect Use and Availability	12
Slope Use and Availability	12
Seasonal Slope Use and Availability	12
WATER SOURCE/GPS LOCATIONAL POSITIONS	18
MOVEMENT PATTERNS	18
Movement Patterns at LANL	20
Seasonal Movement (Migratory) Patterns	20
DAILY ACTIVITY PATTERNS	21
Land Cover Type by Hourly Subperiod	22
Land Cover Type Use by Hourly Subperiod and Season	23
Slope Class by Hourly Subperiod	29
Slope Use by Hourly Subperiod and Season	29
HOME RANGE CHARACTERISTICS	35
Home Range Polygons and Size Estimations	35
Home Range Land Cover Type Composition	37
DISEASE ANALYSIS	40
ACKNOWLEDGEMENTS	42
REFERENCES	42

LIST OF TABLES

1. Elk Captured and Radio Collared with Global Positioning System Units during 1996–98 Study Period, Los Alamos National Laboratory	6
2. Overall GPS Observation Rates for Elk Captured and Collared between 1996–98, Los Alamos National Laboratory	7
3. Mean Home Range Estimates by Season and Year, 1996–98, Los Alamos National Laboratory	37
4. Results of Disease Testing on Blood Samples Drawn from Collared Elk, 1996–98, Los Alamos National Laboratory	41

LIST OF FIGURES

1. Regional location of Los Alamos National Laboratory	3
2. Location of elk trapping sites at the Los Alamos National Laboratory, 1996–98	5
3. Land cover type use and availability for elk, 1996–98, Los Alamos National Laboratory	8
4. Seasonal land cover type use and availability for elk, 1996–98, Los Alamos National Laboratory	9
5. Aspect use and availability for elk, 1996–98, Los Alamos National Laboratory	12
6. Seasonal aspect use and availability for elk, 1996–98, Los Alamos National Laboratory	13
7. Slope use and availability for elk, 1996–98, Los Alamos National Laboratory	15

8. Seasonal slope use and availability for elk, 1996–98, Los Alamos National Laboratory	16
9. Percentage of GPS locations within various distances of two major water sources at Los Alamos National Laboratory	19
10. Areas of concentrated elk use, 1996–98, Los Alamos National Laboratory Boundary	21
11. Primary travel corridors of collared elk use, 1996–98, Los Alamos National Laboratory	22
12. Migratory routes for collared elk, Los Alamos National Laboratory—East Jemez Mountains	23
13. Percent relative use by elk of land cover types within twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory	24
14. Percent relative elk use of land cover types throughout twenty-four hour period, 1996–98, Los Alamos National Laboratory	26
15. Seasonal percent relative elk use of land cover types during twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory	27
16. Percent relative elk use of land cover types throughout twenty-four hour period, 1996–98	30
17. Percent relative elk use of land cover types throughout twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory	32
18. Seasonal percent relative elk use of slope classes by twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory	33
19. Mean home range estimates by season, 1996–98, Los Alamos National Laboratory	36
20. Percent relative home range cover type composition by season, 1996–98, Los Alamos National Laboratory	38

APPENDICES

A Locational Positions of Individually Collared Elk	A-1
B Table of Activity Patterns of Individually Collared Elk by Slope and Land Cover Type	B-1
C Home Range Estimates, Land Cover Type Composition, and Home Range Polygons of Individually Collared Elk	C-1

RESOURCE USE, ACTIVITY PATTERNS, AND DISEASE ANALYSIS OF ROCKY MOUNTAIN ELK
(*CERVUS ELAPHUS NELSONI*) AT THE LOS ALAMOS NATIONAL LABORATORY

by

James R. Biggs, Kathryn D. Bennett, and Phillip R. Fresquez

ABSTRACT

To form the basis for the development of management strategies for elk and other large herbivores, it is necessary to understand how, when, where, and why animals move with respect to the landscape and availability of essential habitats (i.e., foraging, watering). From 1996 to 1998, we evaluated daily/seasonal movements, habitat use, and activity patterns of elk on and near Los Alamos National Laboratory (LANL) property through the use of global positioning system collars and the geographic information system. We have identified primary travel corridors on and immediately adjacent to LANL property and identified travel routes for collared animals moving west off LANL property in the vicinity of Pajarito Mountain. Daily use of different land cover types and terrain was evaluated seasonally by comparing six four-hour periods to one another: 0000–0400, 0400–0800, 0800–1200, 1200–1600, 1600–2000, and 2000–2400. There were significantly more locational fixes of elk in piñon/juniper (Pearson's χ^2 test, $p < 0.05$) compared to all other cover types between the hours of 0400–1200 and significantly more than all other cover types, except ponderosa pine, through the 2000 hour period. In general, use of piñon/juniper increased during daylight hours and decreased during evening hours. Use of grasslands decreased during day hours while increasing during evening hours. Generally, northeast slopes were used greater than expected and west and northwest slopes less than expected. There were significantly greater fixes on 0°–5° slopes compared to all other slope classes between the evening and early morning hours of 1600–0400 and significantly greater than slopes above 10° for all hourly subperiods except 0800–1200. During spring, use of 0°–5° slopes decreased during midday hours while increasing during evening and early morning hours, and animals tended to increase their proportion of use on steeper slopes during most subperiods during summer. We also examined diseases of animals by analyzing blood samples drawn from all collared elk. Vesicular stomatitis was the most commonly observed disease among tested elk. By understanding movement and activity patterns of elk on LANL property, management strategies can be developed and applied to reduce adverse impacts (i.e., automobile accidents, overuse of sensitive habitats) associated with this species.

INTRODUCTION

It is estimated that at least 1800 elk inhabit the Pajarito Plateau, primarily on Bandelier National Monument (BNM) and Los Alamos National Laboratory (LANL) lands. From 1978 to 1980, an extensive study was conducted to investigate movement patterns and population characteristics of elk inhabiting the Pajarito Plateau and portions of the east Jemez Mountains (White 1981). Since that time, no additional detailed studies have been conducted to obtain information on activity patterns of elk in this region and, based on less intensive studies, it appears elk populations are increasing at a high rate on the Pajarito Plateau (Allen 1996). More importantly, several issues of concern have developed since that study. These

include radionuclide uptake and off-site transport by elk (refer to Fresquez et al., 1998), animal/automobile accidents (see Gonzales et al., 1995), overuse of sensitive habitats (i.e., wetlands), issues of game species management with respect to the New Mexico Department of Game and Fish, BNM, US Forest Service land, and Native American Pueblo lands, and adverse impacts to natural and cultural resources (i.e., loss of vegetation, soil loss/erosion).

In 1996, we initiated a preliminary study to evaluate resource use and movement patterns of elk on LANL property as part of an effort that included assessing elk movements in relation to potential contaminant release sites at LANL (refer to Biggs et al., 1997, Fresquez et al., 1998). We refer to this study as preliminary since the only previous study of elk at the Laboratory was conducted in the late 1970s (White 1981), and elk use of Laboratory property has drastically changed during the interim. Consequently, we needed to establish new baseline data and to test the efficiency of a new technology, global positioning system (GPS) radio collars, to this type of study. To form the basis for the development of management strategies for elk and other large herbivores, it is necessary to understand how, when, where, and why animals move with respect to available habitat. Therefore, we evaluated resource use and movements of elk on and near LANL property. In this report, we discuss elk habitat use versus habitat availability, water use, daily and seasonal movement patterns, daily activity patterns, home ranges, and the results of disease testing performed on blood samples drawn from collared elk. We also provide a limited amount of movement data collected in 1995 on four elk collared with very high frequency (VHF) units as part of a small-scale study to identify elk migratory patterns.

Before initiating this study, the most common form of collecting activity data on wild animals was through the use of tracking via VHF radio collars, which requires obtaining three locational fixes on the ground or by air by the researcher. Although this is still the most widely used technique, new methods are in the testing phase. These include the use of GPS technology which does not require personnel in the field to obtain locations of animals. We elected to use GPS collars due to the inherent problems with conducting a study of this magnitude using VHF units. Among these problems were inaccessibility of secured areas and inaccessibility of other areas due to terrain, land ownership, and political boundaries. A complete description of the application of GPS collars with respect to this study is given in Fresquez et al. (1996), Biggs et al. (1997), and Bennett et al. (1997).

Study Area

LANL is located in north-central New Mexico on the Pajarito Plateau, approximately 120 km (80 mi) north of Albuquerque and 40 km (25 mi) west of Santa Fe (Figure 1). The Laboratory is bounded to the east by the Pueblo of San Ildefonso, U.S. Forest Service property to the west and north, and BNM to the south. Within BNM is the 1977 La Mesa Fire burn area. The Plateau is an apron of volcanic rock stretching 33 to 40 km (20 to 25 mi) in a north-south direction and 8 to 16 km (5 to 10 mi) from east to west. The average elevation of the Plateau is 2286 m (7500 ft). It slopes gradually eastward from the edge of the Jemez Mountains, a complex pile of volcanic rock situated along the northwest margin of the Rio Grande rift. From an elevation of approximately 1890 m (6200 ft) at White Rock, N.M., the Plateau scarp drops to 1646 m (5400 ft) at the Rio Grande. Intermittent streams flowing southeastward have dissected the Plateau into a number of finger-like, narrow mesas separated by deep, narrow canyons.

North-central New Mexico consists of a variety of vegetative complexes that are dictated by a wide range of elevational zones. Two climatic zones consisting of three plant communities are found in the upland (nonriparian) mountainous areas and include the Rocky Mountain Subalpine Conifer Forest and Woodland, the Rocky Mountain Montane Conifer Forest, and the Great Basin Conifer Woodland (Brown 1980). There are also two grassland climatic zones that contain at least three different upland communities found at the lower elevations of the region. These include the Plains Grassland, the Great Basin Shrub Grassland, and the Rocky Mountain Montane Grassland.

Figure 1. Regional location of Los Alamos National Laboratory.

In addition to the upland communities, there are numerous wetland (riparian) plant communities that occur in association with most of the previously mentioned uplands. These wetland communities are located within five different climatic zones and include the Cold Temperate Swamp and Riparian Forest, the Arctic-Boreal Swamp-Scrub, the Arctic-Boreal Marshland, the Arctic-Boreal Strand (streams, lakes), and the Cold Temperate Strand (streams, lakes).

The Rio Grande floodplain contains the lowest elevations in or near Los Alamos County and is characterized by a Plains and Great Basin Riparian-Deciduous Forest with cottonwood (*Populus spp.*) and willow (*Salix spp.*) within its boundaries. Juniper (*Juniperus monosperma*) becomes a typical upland overstory species at elevations ranging from about 1680 to 1860 m (5600 to 6200 ft), intermixed with lesser amounts of piñon pine (*Pinus edulis*), both species typical of the Great Basin Conifer Woodland. Piñon pine and juniper are common at higher elevations (1860 to 2070 m or 6200 to 6900 ft) and occur on much of the mesatops. Ponderosa pine (*Pinus ponderosa*) is a common species at about 2070 to 2250 m (6900 to 7500 ft) on the higher mesatops and along many of the north-facing canyon slopes. Species of fir (*Pseudotsuga* and *Abies*) can be found along the higher north-facing slopes intermixing with ponderosa pine, which is often referred to as a mixed-conifer community. Species of the Rocky Mountain Subalpine Conifer Forest and Woodland occur along the extreme western edge of the county and are more prevalent at the higher elevations of the nearby Jemez Mountains.

Most of the canyon stream channels in and adjacent to Los Alamos County are ephemeral (flowing during periods of precipitation), and are therefore not considered wetlands. However, permanent flow from springs and laboratory facilities result in a small number of permanent or near-permanent streams along or within short stretches of certain canyons. Many of these streams and other wetlands are characterized by vegetation of the Rocky Mountain Riparian Deciduous Forest and the Plains Interior Marshland.

DATA COLLECTION

Trapping

Five sites at LANL (Figure 2) were selected for trapping elk based on the following criteria:

- previous movement information of elk on the Pajarito Plateau (includes BNM and LANL) (White 1981, Biggs et al., 1996); we attempted to collar animals of different herds at different locations on LANL property to maximize representation of elk populations in this area,
  - known areas of high elk activity; due to labor, time, and budget constraints, we had to maximize our probability of capturing animals within a given time period, and
  - proximity of trapping to areas of current LANL operations/resource conflict issues; although not reported in this paper, a secondary objective of this study was to identify potential pathways of contaminant transport off LANL property (Fresquez et al., 1998); therefore, trapping locations were located near a radioactive-waste burial site and outfall effluent sources (artificial water sources).
- Trapping also took place in areas of high automobile collisions with elk (Gonzales et al., 1995).

We collected data on physical measurements (weight and length), blood diseases, and age of each animal. Trapping took place from January through April. This time period maximized the chances for capture because natural food sources were less available due to snow cover and it was before the beginning of seasonal migration. Animals were captured with collapsible clover traps baited with apples and alfalfa. Animals were pulled down with ropes within the clover trap. Once the animal was restrained, trained personnel entered the trap and placed a hood over the head of the animal. Animals were then fitted with the radio collar. The weight of each animal was estimated using an equine weight tape, and the age of each animal was estimated by checking tooth wear. Blood draws were performed via the jugular vein by a certified animal technician.

We captured six elk (five cows and one bull) during March and April 1996. All six animals were harvested by hunters or died as a result of collisions with automobiles. Collars from four of these animals were refurbished by the manufacturer and, with the addition of two new collars, deployed on different animals (five cows and one bull) in 1997 and 1998, resulting in a total of twelve collared animals (Table 1).

Figure 2. Location of elk trapping sites at the Los Alamos National Laboratory, 1996–98.

Estimated age of cow elk ranged from 1 to 7 years. Of the six animals collared in 1996, four were captured in shallow canyons dominated by piñon/juniper. The other two elk were captured on a mesatop dominated by ponderosa pine. The bull was harvested by a hunter on September 13, 1996, and one of the cows was taken by a hunter in mid-December within two miles northeast of LANL property. Of the six animals collared in 1997 and 1998, all five cows were captured on mesatops dominated by ponderosa pine, and the bull was captured on a mesatop dominated by piñon/juniper. Two collars malfunctioned within two weeks of deployment, and two collared animals were killed by vehicle collisions within six weeks of deployment.

GPS Collar Programming and Reception Rates

We used a Telonics model ST14GPS receiver with a VHF beacon transmitter with an estimated battery life of 12 to 14 months. The on-board microchips stored longitude, latitude, Greenwich Mean Time, Julian day, hour of the day, minute of the hour, and an error detection code. The collar was programmed to acquire a GPS locational fix every 23 hours and to uplink to Argos satellites every 3 to 4 days. Data retrieved from Argos, Inc., were stored on a laptop computer for post-processing, which was required to format the data into a form that could be translated into longitude and latitude. Data required for differential correction (the process of correcting GPS data collected at an unknown location with data collected simultaneously at a known location) of collar data were not collected in the current version of the Telonics collar. Therefore, we could not differentially correct collar data. However, locational error rates were calculated using a “test collar” of the same model collar placed on elk. The test collar was placed in

Table 1. Elk Captured and Radio Collared with Global Positioning System Units during 1996-98 Study Period, Los Alamos National Laboratory

ID Number	Date of Capture	Location of Capture	Sex	Estimated Age	Estimated Weight	Remarks
1603301	April 3, 1996	Southwest LANL	Cow	~ 2 to 3 yr	545 lb	Harvested by NMDGF* 11/25/97 southwest LANL
1603401	March 19, 1996	Northeast LANL	Cow	4 to 5 yr	617 lb	Harvested by NMDGF 11/19/97 southwest LANL
1603501	March 26, 1996	Northeast LANL	Cow	undetermined	525 lb	Harvested on 12/20/96 within 1 mile northeast of LANL, San Ildefonso.
1603601	March 15, 1996	Northeast LANL	Cow	~ 2 yr	545 lb	Hit by car 2/97, found in Canada del Buey
1603701	March 12, 1996	Northeast LANL	Cow	~ 4 to 5 yr	650 lb	Harvested 10/97 by hunter within 1 mile west of LANL
1603801	April 23, 1996	Southwest LANL	Bull	~ 2 yr	659 lb	Harvested 9/13/96 0.5 to 1 mile NW of LANL
3002	January 6, 1998	Southwest LANL DARHT**	Cow	~ 7 yr	807 lb	Collar malfunctional
3003	January 15, 1998	Central LANL TA-36	Bull	~ 2 - 3 yr	545 lb	Collar malfunctional
1603302	March 10, 1998	Central LANL TA-40 meadow	Cow	~ 2 - 3 yr	639 lb	Road kill 4/25/98, east Jemez Rd. near firing site; carried calf to term
1603402	March 11, 1998	Central LANL TA-40, near cement pond	Cow	Unknown	585 lb	In field
1603502	February 26, 1998	Central LANL TA-40 meadow	Cow	~ 4 - 5 yr	673 lb	Road kill 4/8/98, Pajarito Rd. ~200 yds past TA-55 entrance; carried calf to term
1603802	March 14, 1997	Southwest LANL DARHT	Cow	Yearling	515 lb	In field

* NMDGF = New Mexico Department of Game and Fish

** DARHT = Dual Axis Radiographic Hydrotest facility

varying habitats and terrain throughout LANL property (Bennett et al., 1997). No significant differences were found in the mean locational error between mesatops and canyons, and approximately 79% of the locational fixes were estimated to be within 120 m (396 ft) of the actual location. There were no significant differences ($\alpha = 0.05$) in locational error with respect to vegetation cover type and topography, therefore, we are assuming a similar error rate for collars deployed on elk. Telonics programmed the rate of position acquisition and uplink to Argos satellites for downloading collar data.

Approximately 1800 fixes were obtained between March 1996 and June 1998 for all 10 elk combined (Table 2). We calculated an approximately 64% reception success rate (number of actual fixes/total number of potential fixes) for all animals combined with a range of 54% to 96% for individual animals (Table 2). The lowest reception rates were observed in elk that spent the majority of their time in more steep mountainous terrain within ponderosa pine and mixed conifer habitats (see Biggs et al., 1998). These areas may limit the reception and transmission success rate of the GPS collar. Bennett et al. (1997) did not test these areas to determine locational error and reception rates for a GPS collar. Reception rates of about 86% were also reported by Bennett et al. In this study, we report an overall mean reception rate of 64%. The difference between rates may be a result of several factors. If animals are moving while a

Table 2. Overall GPS Observation Rates for Elk Captured and Collared between 1996–98, Los Alamos National Laboratory

ID			Total Number	Observation	
Number	Date of Capture	Sex	of Locational Fixes	Rate	Remarks
1603301	April 3, 1996	Cow	290	60.7%	Harvested 11/25/97
1603401	March 19, 1996	Cow	337	68.2%	Harvested 11/19/97
1603501	March 26, 1996	Cow	125	54.1%	Harvested 12/20/96
1603601	March 15, 1996	Cow	166	68.6%	Road kill 02/97
1603701	March 12, 1996	Cow	321	56.8%	Harvested 10/97
1603801	April 23, 1996	Bull	70	54.3%	Harvested 9/13/96
1603302	March 10, 1998	Cow	50	96.2%	Road kill 4/25/98
1603402	March 11, 1998	Cow	105	86.1%	In field
1603502	February 26, 1998	Cow	30	73.2%	Road kill 4/8/98
1603802	March 14, 1997	Cow	357	69.6%	In field

locational fix is being attempted, error readings may occur and a fix may not be obtained within the allotted receiving time. We experienced this phenomena during use of the GPS test collar. Or, the test collar was placed on an elevated stand simulating the height of an adult elk with the collar situated in a normal position (dorsal antenna, ventral transmitter). If interference of the antenna is occurring during either locational fixing or while data are uplinking due to animal behavior, or if the antenna has shifted on the animal's neck, locational fix errors may result. Some of these types of interferences may occur with VHF units but could be compounded with a GPS unit due to two separate data linkages occurring—receiving of the satellite locational fix and transmission of those fixes to the Argos satellite. In addition, analysis of the test collar data only tested one type of reception error, that of a locational fix. Since a hand-held uplink receiver was used in the testing of the collar, error associated with satellite uplink was untested. For additional information and data analysis on observations rates of GPS collars deployed on elk, see Biggs et al. (1998).

HABITAT USE

Overall and seasonal land cover type (LCT) and terrain use and availability was evaluated by overlaying individual elk locational positions onto land cover type (dominant overstory vegetation) and topographical (slope and aspect) maps (Koch et al., 1996). Of important note: although error rates were estimated at approximately 120 m, this was not applied to locational fixes as part of the analysis for this report since not all cover types presented in this report were evaluated with respect to GPS collar observation and error rate. Additional studies are planned to more accurately define these error rates for application to resource use studies. Furthermore, missing GPS collar observation rates are not accounted for in all cover and slope types. As a result, land cover types and terrain that inhibit satellite acquisition by the collar may be underestimated in the habitat analysis. Extensive future studies are proposed to identify biases associated with varying habitat characteristics. Once this has been performed, the development and application of correction factors will be conducted.

Analysis of LCT characteristics for individual animal home ranges is provided in the "Home Range Analysis" section of this report. Where animals survived for more than one year, seasonal results are provided separately (i.e., spring 1997, spring 1998). Ground truthing of LANDSAT thematic mapper images that detect reflected radiation from the earth's surface (infrared wavelengths) were classified into eight land cover types used for analyzing habitat use by elk:

Cover Type	
Developed land	Aspen forest
Mixed-conifer forest	Ponderosa pine forest
Piñon-juniper woodland	Grassland
Bare ground	Juniper woodland

Land Cover Type Use and Availability

By taking into account the amount of a particular cover type that is available to the amount that has animal locational fixes, we attempted to identify if specific cover types were being utilized more or less than expected throughout the year.

We compared the percent relative occurrence of locational fixes for all elk combined (chi-squared test [χ^2], $\alpha = 0.05$, $n = 2009$) by each LCT to the amount of the LCT that is available (Figure 3). We conducted this by combining locational data of cows and bulls from March 1996 through July 1998. Differences between observed use versus expected use are described as either "greater/less than" which indicates a 25%–50% difference between expected and observed values or "much greater/less than" indicating a >50% difference between expected and observed values. For a detailed description of LCT composition within individual animal home ranges, refer to the section titled "Home Range Analysis" of this report. We observed significant differences ($\chi^2 = 513$, $DF = 7$, $n = 2009$, $p < 0.001$) between the amount of LCT available and the amount used throughout the year. Elk used juniper woodland at a rate much less than expected (>50% difference between expected and observed locational fixes) and developed areas at a rate less than expected (25%–50% difference between observed and expected values). However, this is likely due to the cover type defined as 'developed' including not only parking lots and roads but also impenetrable structures. Elk used grasslands at a rate much greater than expected (>50% difference between observed and expected) and aspen forests at a rate greater than expected (25%–50% difference between observed and expected values). All other LCTs were used relatively consistent with the amount available (<25% difference between observed and expected values).

Seasonal LCT Use and Availability

We compared seasonal use by elk of each LCT by the total amount of each LCT available. Significant differences ($\alpha = 0.05$) in LCT use and availability were observed for all seasons examined (Figure 4).

Figure 3. Land cover type use and availability for elk, 1996–98, Los Alamos National Laboratory.

(a)

(b)

Figure 4. Seasonal land cover type use and availability for elk, 1996-98, Los Alamos National Laboratory.

(c)

(d)

Figure 4. Seasonal land cover type use and availability for elk, 1996–98, Los Alamos National Laboratory (Cont.).

(c)

Figure 4. Seasonal land cover type use and availability for elk, 1996–98, Los Alamos National Laboratory (Cont.).

During calving, summer, and fall, elk used aspen forests at a rate much greater than expected and used this LCT much less than expected in spring and winter. The lack of use in spring and winter may coincide with greater snowfall in the higher elevations during that period where aspen forests are most common. In summer, elk tended to use forested cover types (ponderosa pine, aspen, mixed conifer) at a rate greater than expected and during the winter used these cover types at a rate less than expected. During all seasons except fall, elk used grasslands much greater than expected. In fall they used grasslands at a rate greater than expected. Also during all seasons, juniper woodlands were used much less than expected which may be partially due to the fact that juniper woodlands are found in some of the steeper, and less used, terrain of LANL. Areas of bare ground were also used much less than expected during all seasons.

Our data showed a strong preference for grasslands at LANL by elk during all seasons. This is consistent with what has been found in other habitat use studies (Irwin and Peek 1983; Frank and McNaughton 1992). In contrast, White (1981) found limited use of open grass/shrublands outside of the winter period and greater use of the taller forested stands. This difference in results between studies may be related to more elk residing year-round on the Pajarito Plateau in recent years than in the 1970s, when White conducted his study. Also, grasslands are more prevalent along the Pajarito Plateau than in the adjoining higher mountainous terrain where forests predominate.

Aspect Use and Availability

Using methodology similar to evaluating elk use of LCTs, we examined elk use of slope aspect.

When pooling all data, we observed a significant difference ($\chi^2 = 138$, $n = 1926$, $p < 0.001$) between the relative occurrence of elk on slope aspect and the amount available (Figure 5). Elk used northeast slopes greater than expected and west slopes less than expected (25%–50% difference between expected and observed values) and used northwest slopes much less than expected (>50% difference between expected and observed values).

Figure 5. Aspect use and availability for elk, 1996–1998, Los Alamos National Laboratory.

Seasonal Aspect Use and Availability

Significant differences in use versus availability were observed in all seasonal periods (Figure 6). During spring, east slopes were used greater than expected and southwest slopes were used less than expected. West and northwest slopes were used much less than expected. During calving, west and northwest slopes were used less than expected. In summer, northeast slopes were used greater than expected and west slopes were used much less than expected. In fall, north slopes were used much less than expected and east, northeast, and south slopes were used greater than expected. West and northwest slopes were used much less than expected. During winter, northeast slopes were used greater than expected, southeast slopes less than expected, and west and northwest slopes much less than expected.

Slope Use and Availability

Slope use versus availability was also analyzed similar to land cover type use/availability (Figure 7). when pooling all slope use data, 0°–5° slopes were used greater than expected and 20°–25° slopes were used less than expected. All slopes classes greater than 25° were used much less than expected.

Seasonal Slope Use and Availability

Slope classes greater than 40° were omitted from further analysis. During spring, 0°–5° slopes were used greater than expected and 15°–20° slopes were used less than expected (Figure 8). All other slope classes greater than 20° were used much less than expected. During calving, 20°–25° slopes were used less than expected, and all slope classes above 25° were used much less than expected. In summer, 25°–35° slopes were used much less than expected and 35°–40° slopes were used less than expected. In fall 0°–5° slopes were used greater than expected and 25°–30° slopes were used less than expected. Slope classes above 30° were used much less than expected. During winter, 0°–5° slopes were used greater than expected and 20°–25° slopes were used less than expected. Slope classes greater than 25° were used much less than expected.

(a)

(b)

Figure 6. Seasonal aspect use and availability for elk, 1996–1998, Los Alamos National Laboratory.

(c)

(d)

Figure 6. Seasonal aspect use and availability for elk, 1996–1998, Los Alamos National Laboratory (Cont.).

(e)

Figure 6. Seasonal aspect use and availability for elk, 1996–1998, Los Alamos National Laboratory (Cont.).

Figure 7. Slope use and availability for elk, 1996–1998, Los Alamos National Laboratory.

(b)

Figure 8. Seasonal slope use and availability for elk, 1996–1998, Los Alamos National Laboratory.

(c)

(d)

Figure 8. Seasonal slope use and availability for elk, 1996–1998, Los Alamos National Laboratory (Cont.).

(e)

Figure 8. Seasonal slope use and availability for elk, 1996–1998, Los Alamos National Laboratory (Cont.)

WATER SOURCE/GPS LOCATIONAL POSITIONS

We evaluated relative percent seasonal and yearly water source use by overlaying permanent water sources on to the geographic information system (GIS) and calculating the number of locational fixes within a set of five distances from those sources: 0.25 mi, 0.50 mi, 0.75 mi, 1.0 mi, and 2.0 mi (Figure 9). Cumulated percent use was 15%, 34%, 46%, 56%, and 85%, respectively. When eliminating inaccessible areas (based on terrain, fences, buildings), there are about 3 to 4 water sources available to elk on a year-round basis, most of which are located in the southwest portion of LANL. We elected to analyze locational data around two of the primary water sources. The intent of this analysis was to examine use at two of the most accessible water sources at LANL property. Additional water sources are available to elk on at least a seasonal basis.

MOVEMENT PATTERNS

We examined the movement patterns of collared animals by plotting all locational fixes onto GIS overlay coverages of topography and physical structures (i.e., security fences, roads, buildings). By overlaying these coverages, we were better able to define travel routes used by elk on and near LANL property and routes used on a seasonal basis for elk moving off LANL property by eliminating nonusable areas such as buildings and vertical cliffs. We were also able to eliminate inaccessible areas such as those surrounded by security fences. Two maps of the primary travel routes on and near LANL property are provided. The maps depict travel routes based on collared animals only and should not be interpreted to indicate all travel routes of elk on or near LANL. It is unknown if the number of animals collared are fully representative of all herds occurring on LANL property as the intent of the telemetry work to date is to obtain preliminary data to assess resource use, rather than to obtain data on population size and herd structure. Furthermore, the population dynamics of elk on the Pajarito Plateau appears to be changing relatively rapidly with respect to range expansion (northerly and easterly expansion) and seasonal use (i.e., calving on LANL property). However, all of the collared cow elk have been observed with other elk in herds

Figure 9. Percent of GPS locations within various distances of two major water sources at Los Alamos National Laboratory. Percentages of locations were based on the total number of locations within two miles of LANL boundary.

ranging in size from approximately 5 to as high as 100, depending on the time of year (larger herds are observed during the rutting/breeding season of September and October). A complete map of all locational fixes and individual maps of each collared animal's locational fixes recorded during the length of the study is provided in Appendix A. As discussed below, we have observed similarities in movement patterns from year to year by different collared animals. As part of the seasonal movement patterns discussed below, we have also included maps depicting movements of VHF collared animals from 1995 (Appendix A). Four animals were collared on LANL property with VHF units in 1995 and depict travel routes different from those of the animals captured in 1996–98.

Movement Patterns at LANL

Based on the locational fixes of all collared animals, we have identified areas of concentrated use on LANL property (Figure 10). We have identified approximately 6 to 8 primary travel corridors with several branches on LANL property in relation to these areas of concentrated use (Figure 11). These travel corridors occur in the west-central, central, and east-central portion of the Laboratory. All collared animals were captured in these areas and, as such, animals collared in other portions of LANL may reveal additional travel corridors. The VHF-collared animals captured in the southern portion of LANL did reveal different movement patterns (described below). Travel routes in the east portion of LANL appear to be dictated by security fences and other structures. There are two areas where routes cross between LANL property and Pueblo of San Ildefonso property, both crossing Pajarito Road. A permanent water source occurs where routes interconnect along lower Pajarito Road.

Travel routes in the west portion of LANL tend to circulate around Technical Area (TA)16 with routes extending into TAs 6, 8, 9, and 15. Water sources have typically been present in TA-16 during the course of this study. As previously mentioned, identification of travel routes is based on data collected from collared animals only and therefore other heavily traveled routes may not appear on these figures. For instance, we know from previous studies that elk frequently travel into and out of TA-40; however, we did not identify travel routes in that area.

Seasonal Movement (Migratory) Patterns

Three of the elk collared from 1996–98 migrated or traveled west off LANL property towards or near the Valle Grande during some period of the study. These movements generally took place in the fall and spring during the typical seasonal migration period. The primary travel route for these animals occurred in the vicinity of Pajarito Mountain with essentially one route extending off LANL property near TAs 8 and 58 (Figure 12). However, we observed a different route of travel for the four elk collared in 1995 with VHF units. Three of these animals were captured and collared in the southern portion of LANL and the fourth was captured and collared next to lower Pajarito Road in the east-central portion of LANL. These animals, including the one captured along Pajarito Road, moved along the southwest and southern border of LANL through the American Springs/Dome Mountain area (refer to Appendix A). Locations of VHF collared animals were obtained less frequently than the GPS collared animals (approximately once/week); therefore, the routes are considered as only “possible” travel routes. All four animals migrated off LANL property. Because no animals were captured in this area between 1996 and 1998, we are unable to assess if recent changes in movement patterns have occurred in these portions of LANL.

Previous studies have shown that in this region elk migrate from the summer ranges of the higher Jemez Mountains to the lower Pajarito Plateau and adjacent areas during the winter months (White 1981; Allen 1996). White (1981) trapped and radio-collared 39 elk in 1978–79 to study movement patterns in the vicinity of LANL. Most of the elk he tracked wintered on the east slope of the Jemez Mountains just west of LANL and on the La Mesa Fire burn south of LANL; these animals migrated to the Valle Grande during calving and summer months. He also reported that the cow elk preferred the eastern slopes of the Jemez Mountains as a wintering area and the northern Valle Grande as a calving/nursing area. None of the elk White (1981) collared were considered resident animals on the Pajarito Plateau. In contrast, only three of the 10 GPS-collared elk in our study exhibited migratory behavior: two cows and a bull. This is the first documented evidence that individual elk are remaining on LANL property and thus, the Pajarito Plateau, on a year-round basis.

During 1996, the bulk of our study period, this region experienced an abnormally dry winter, spring, and summer which may have affected typical movement patterns of migratory animals in this area. During moist years, herbaceous forage plants on the drier lower-elevation sites do not desiccate and lose nutritional value as early as they do during dry years and, as a result, elk have less incentive to move to higher elevations and remain more widely dispersed (Marcum and Scott 1985). During dry years, plants desiccate quicker at lower elevations; therefore, elk typically concentrate on higher-elevation areas where forage is still succulent. Despite the lack of moisture, four of the six GPS-collared elk in 1996 remained on the lower-elevation Pajarito Plateau throughout the dry period. The fact that we are now finding

Figure 10. Areas of concentrated elk use, 1996–1998, Los Alamos National Laboratory.

resident animals on the lower-elevation LANL property, even during periods of drought, is likely related to the protective status of LANL and adjacent BNM. This same scenario has been reported elsewhere (McQuorkdale et al., 1986). The increased use and distribution expansion on the Plateau is also a result of the 1977 La Mesa Fire which created a large amount of foraging habitat south of LANL.

DAILY ACTIVITY PATTERNS

Daily use by season of different land cover types and terrain was evaluated by comparing six four-hour periods to one another: 0000–0400, 0400–0800, 0800–1200, 1200–1600, 1600–2000, and 2000–2400. GPS locational fixes within differing land cover types (i.e., ponderosa pine, open/grass) and slope classes were compared among the various hourly periods. Aspect use was not analyzed due to low sample size following subdivision by hourly subperiod (8 aspect classes by 6 hourly subperiods.) Slope use was analyzed by classes as follows: 0°–5°, 10°–15°, 15°–20°, 20°–25°, 25°–30°, 30°–35°, 35°–40°, and >40°.

Figure 11. Primary travel corridors of collared elk, 1996–1998, Los Alamos National Laboratory.

However, because of low sample sizes in slope classes above 20°, only data from slopes less than 20° were used in the analysis. Only the most commonly used land cover types and slope classes were statistically analyzed. Data from all land cover types and slope classes can be found in Appendix B, Table 1.

Land Cover Type by Hourly Subperiod

Based on all data collected and pooled and when comparing LCTs use by hourly subperiods, elk utilized piñon/juniper significantly greater (Pearson's χ^2 test, 20°–25°, $\alpha = p > 0.05$) than all other cover types between the hours of 0400–1200 and significantly greater than all other cover types except ponderosa pine through the 2000-hour period (Figure 13). In general, use of piñon/juniper increased during daylight hours

Figure 12. Migratory routes for collared elk, Los Alamos National Laboratory–East Jemez Mountains.

and decreased during evening hours. Use of grasslands decreased during day hours while increasing during evening hours. We found no significant differences in use of individual cover types between hourly subperiods (Figure 14).

Land Cover Type Use by Hourly Subperiod and Season

Due to insufficient sample sizes, statistical analyses on use of LCTs or slopes by season and hourly subperiods were not performed. However, based on the available data, several trends in daily use of cover types were observed. During spring, use of piñon/juniper woodlands tended to increase during midday hours while use of grasslands decreased (Figure 15), as was seen for all data combined and discussed

Figure 13. Percent relative use by elk of land cover types within twenty-four hour subperiods*, 1996-98, Los Alamos National Laboratory.

*Vertical box denotes 95%CI, horizontal bar denotes mean.

Figure 13. Percent relative use by elk of land cover types within twenty-four hour subperiods*, 1996-98, Los Alamos National Laboratory (Cont.).

*Vertical box denotes 95%CI, horizontal bar denotes mean.

Figure 14. Percent relative elk use of land cover types throughout twenty-four hour period*, 1996-98.

*Vertical box denotes 95%CI, horizontal bar denotes mean.

Figure 15. Seasonal percent relative elk use of land cover types during twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory.

Summer

Fall

Figure 15. Seasonal percent relative elk use of land cover types during twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory (Cont.).

Figure 15. Seasonal percent relative elk use of land cover types during twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory (Cont.).

above. Use of ponderosa pine forests generally followed that of piñon/juniper woodlands. Use of mixed conifer and ponderosa pine forests increased during calving. Use of forests and woodlands were relatively similar during summer months with somewhat of an increase during early morning and midday hours. In fall, there was a marked increase in use of piñon/juniper woodlands during early- and mid- morning hours (0400–1200). Finally, in winter there appeared to be a particularly strong shift in use to piñon/juniper woodlands between 0400–1200. Much of the shift in patterns of elk use within the different cover types between seasons can be attributed to thermoregulatory responses. For instance, during warmer seasons animals may increase their use of more shaded forested habitats compared to open grasslands. Conversely, during daylight hours, elk may increase their use of open habitats in winter months.

Slope Class by Hourly Subperiod

Use of 0°–5° slopes was significantly greater than all other slope classes between the evening and early morning hours of 1600–0400 and significantly greater than slopes above 10° for all hourly subperiods except 0800–1200 (Figure 16). As slope steepness increased, use generally decreased. Although not statistically significant, use of 0°–5° slopes tended to decrease during midday hours while use of steeper slopes slightly increased (Figure 17).

Slope Use by Hourly Subperiod and Season

During spring, use of 0°–5° slopes decreased during midday hours while increasing during evening and early morning hours (Figure 18). In calving, slope use remained relatively consistent throughout the 24-hour period. Animals tended to increase their proportion of use on steeper slopes during most subperiods during summer. Elk appeared to use slopes less than 10° greater during midday hours in fall and winter.

Figure 16. Percent relative elk use of land cover types throughout twenty-four hour period*, 1996-98.

*Vertical box denotes 95%CI, horizontal bar denotes mean.

Figure 16. Percent relative elk use of land cover types throughout twenty-four hour period*, 1996-98 (Cont.).

*Vertical box denotes 95%CI, horizontal bar denotes mean.

Figure 17. Percent relative elk use of land cover types throughout twenty-four hour subperiods*, 1996–98, Los Alamos National Laboratory.

*Vertical box denotes 95% CI, horizontal bar denotes mean.

(a)

(b)

Figure 18. Seasonal percent relative elk use of slope classes by twenty-four hour subperiods, 1996–98, Los Alamos National Laboratory.

Figure 18. Seasonal percent relative elk use of slope classes by twenty-four hour subperiods, 1996-98, Los Alamos National Laboratory (Cont.).

Figure 18. Seasonal percent relative elk use of slope classes by twenty-four hour subperiods, 1996-98, Los Alamos National Laboratory (Cont.).

HOME RANGE CHARACTERISTICS

Habitat characterizations (vegetation types) within the home-range polygons were evaluated by overlaying the home-range polygons on to a vegetation land cover map delineating dominant overstory vegetation (Koch et al., 1996). Land cover types used in this analysis were the same as those used in the "Habitat Use" section of this report. All analysis were performed on a seasonal basis. The adaptive kernel method of Program CALHOME (Kie et al., 1994) was used to estimate the home range size (hectares) at the 95% utilization distribution of each animal collared between 1996 and 1998. Field units were calculated at 1-m units, and grid cell size was automatically determined by the program. Core activity areas were estimated at the 50% utilization distribution. Home ranges and core activity areas were estimated by season and delineated as follows: calving (May-June), summer (July-August), fall (September-October), winter (November-February), and spring (March-April). Once home range polygons were calculated by Program CALHOME, the output dataset consisting of X,Y UTM coordinates was imported to the GIS. The home range polygons were treated as separate coverages and then overlaid on to topographical and land cover maps.

Home Range Polygons and Size Estimations

A breakdown of individual animal home range estimates by year and season, including core activity areas, is given in Appendix C, Table 1 for animals surviving at least one defined season (2 to 4 months). In some cases, data was collected on animals greater than one year and more than one seasonal estimation may be present. Home range polygons, including core areas, for each animal is given in Appendix C.

Mean estimates for each season for all years combined is shown in Figure 19, and mean estimates for each season and year are shown in Table 3. It should be noted that in many instances the sample size (n) provided in the figure includes more than one year of seasonal data for the same animal. Mean home range size was largest during fall (mean = 5736 ha) and smallest in spring (mean = 2270 ha) with calving,

(a)

Note: vertical box denotes range of values, horizontal bar denotes mean

(b)

Note: vertical box denotes range of values, horizontal bar denotes mean

Figure 19. Mean home range estimates for elk by season, 1996–98, Los Alamos National Laboratory.

Table 3. Mean Home Range Estimates by Season and Year, 1996–98, Los Alamos National Laboratory.

Season	Home Range Estimate			Core Area Estimate		
	Year			Year		
Spring	1996	1997	1998	1996	1997	1998
Mean	2800.8	1538.8	2335	317.2	433.3	274.5
SE	899.9	510.2	764.1	89.6	203.4	154.7
Calving						
Mean	4830	3720	4647.5	705.5	841.1	844
SE	1600.2	1431.5	914.5	322.3	316	105.2
Summer						
Mean	2478	2167		345.8	375.9	
SE	280.3	258.0		77.9	128.6	
Fall						
Mean	6750.2			903.9		
SE	1890.4			417.7		
Winter						
Mean	2858.3			458.1		
SE	07.2			131.3		

SE = Standard error.

winter, and summer being relatively similar. The large home range size in fall is likely due to animals migrating off LANL property during that period and thus expanding their home range sizes whereas during the spring period, animals most likely migrated before our collaring effort (refer to figures of home range polygons provided in Appendix C). The home range core area sizes ranged from 340 ha in spring to 787 ha in fall, following a relatively similar pattern in size to the overall home range polygons. Seasonal home range core activity areas (50%) were generally less than 500 ha during spring, summer, and winter, and greater than 500 ha during calving and fall.

Multi-year data is available only for spring (3 years), calving (3 years), and summer (2 years) seasons. Mean home range size varied from 1540 ha in 1997 to 2800 in 1996. Home range size variation from year to year was proportionately similar during calving ranging from a low of 3720 ha in 1997 to a high of 4830 ha in 1996. During summer, the home range was considerably greater in 1996 (4890 ha) compared to 1997 (2167 ha). No data were available for summer 1998.

Home Range Land Cover Type Composition

Home range and cover type data were pooled and analyzed on all GPS collared animals between 1996 and 1998. The majority of the animals home ranges occurred on LANL property and Pueblo of San Ildefonso property but in a few cases extended on to adjacent US Forest Service property west of LANL. The relative percent composition of each cover type classified for LANL and surrounding areas (Koch et al., 1996) was calculated for seasonal home ranges, including core areas (50% utilization contours) of all animals combined. The mean relative percent cover type composition, by season, is shown in Figure 20, and a breakdown of seasonal home range cover type composition by individual animal is given in Appendix C, Table 2.

As would be expected, based on percent availability of cover types, ponderosa pine forest and piñon/juniper woodland cover types made up the majority of cover type composition within all seasonal home ranges (Figure 20). However, there were some differences in cover type composition between seasons. Home ranges consisted of much less mixed conifer in spring and winter compared to all other seasons. This is likely due to the greater amount of accessibility to mixed conifer during warmer months when snow is absent. There is a greater amount of mixed conifer occurring on summer ranges compared to winter ranges for those animals that migrate west off LANL property. Relative percent composition of grassland within home ranges tended to be lowest in winter, but composition of piñon/juniper woodland was highest compared to all other seasons. Much of the cover type composition of seasonal home ranges

Figure 20. Percent relative home range cover type composition by season, 1996–98, Los Alamos National Laboratory.

Figure 20. Percent relative home range cover type composition by season, 1996–98, Los Alamos National Laboratory (Cont.).

Figure 20. Percent relative home range cover type composition by season, 1996-98, Los Alamos National Laboratory (Cont.).

is a direct reflection of accessibility to foraging areas as dictated by snow cover and thermoregulatory responses of individual animals to weather conditions. In general, the home ranges tended to include a greater amount of open woodlands during the cooler seasons and forested habitats during the warmer months.

DISEASE ANALYSIS

We had 14 to 16 serologic tests run on blood samples drawn from the twelve elk, including one animal that was not radio-tagged (Table 4). The diseases selected for testing are similar to those most frequently tested for by the NMDGF. Tests were performed at the Texas Veterinary Medical Diagnostic Laboratory in Amarillo, Texas, and at the New Mexico Department of Agriculture Veterinary Diagnostic Services in Albuquerque, New Mexico. Descriptions of diseases are taken from Fraser (1986).

Vesicular stomatitis is a viral disease that is spread by insects and movements of animals and can be widespread in cattle, horses, and pigs, which are most susceptible. However, the disease has a variety of hosts including deer and elk. A common symptom of vesicular stomatitis is lesions of the mouth and tongue. Typically there are no significant effects to infected animals. Two different viruses of vesicular stomatitis exist, the Indiana and New Jersey viruses. Five of the seven elk sampled in 1996 tested positive for exposure to the New Jersey strain of vesicular stomatitis, which may have been a reflection of the outbreak that took place in New Mexico in 1995. Three of the four animals sampled in 1998 tested positive for the New Jersey and/or Indiana strains.

Q-fever is a rickettsial infection of mammals and is found in most areas where livestock occur. Q-fever can cause abortion in some types of cattle. Ticks act as the primary reservoir agent in wild animals, and the infection can spread via airborne transmission or through direct contact and ingestion of reproductive discharges. Three animals tested positive for Q-fever.

Table 4. Results of Disease Testing¹ on Blood Samples Drawn from Collared Elk, 1996–98, Los Alamos National Laboratory.

ID Number	Blue Tongue	Q-Fever	Chlamydia	Brucellosis	Leptospirosis	Johne's	BVD
1	–	–	–	–	–	Low	Low
1603301	–	–	–	–	–	Low-Mod	–
1603401	–	–	–	–	–	–	–
1603501	–	–	–	–	–	Low	–
1603601	–	–	–	–	–	Mod	–
1603701	–	–	–	–	–	–	–
1603801	–	–	–	–	–	–	–
3002	–	–	–	–	–	–	–
3003	–	N/A	–	–	–	–	–
1603302	–	+	+	–	–	–	–
1603402							
1603502	–	+	+	–	–	–	–
1603802	–	Low +	Low +	–	–	–	–

ID Number	IBR	Plague	Tularemia	Ana- plasmosis	BRSV	Pasteurellosis	Toxo- plasmosis	Vesicular stomatitis
1	–	–	–	–	–	–	–	– IN/ mod + NJ
1603301	–	–	–	–	–	–	–	– IN/ mod + NJ
1603401–		–	–	–	–	–	–	– IN/ strong + NJ
1603501	–	–	–	–	–	–	+	– IN/ low + NJ
1603601	–	–	–	–	–	–	–	– IN/ mod + NJ
1603701	–	–	–	–	–	–	–	– IN/– NJ
1603801	–	–	–	–	–	–	–	– IN/– NJ
3002	–	–	–	–	–	–	–	low + IN/ low + NJ
3003	–	–	–	–	–	Possible	–	–
1603302	+	–	–	–	–	–	–	– IN/ low + NJ
1603402								
1603502 low + NJ	Possible	–	–	–	–	–	Possible ²	low + IN/
1603802	–	–	–	–	–	–	–	– IN/– NJ

¹ testing methods: IBR, BVD, BRSV, VS-Indiana (IN) and VS-New Jersey (NJ) - viral neutralization; Q-fever, chlamydia, and anaplasmosis - complement fixation; bluetongue - AGID; Johne's disease - complement fixation and AGID; toxoplasmosis - indirect hemagglutination; leptospirosis - microscopic agglutination test; plague - passive hemagglutination; tularemia - rapid slide agglutination test; brucellosis - standard plate test; pasteurellosis - bacteriological test.

² active infection or possible indication of early infection.

Johne's disease, also known as paratuberculosis, is a chronic, contagious disease that results in eventual death of the animal. Because this is a chronic disease and the initial signs of infection are often vague, animals testing negative may in fact be positive. Four of seven animals sampled in 1996 tested positive for Johne's disease; no other animals sampled in subsequent years tested positive.

Chlamydia was found in three of the animals tested. Chlamydia is an infectious disease that causes abortion in animals. Animals may become infected during birth or shortly thereafter through ingestion of infectious materials.

Bovine viral diarrhea (BVD) is an infectious disease, usually of young animals, that results in fever, hemorrhages of the alimentary tract, diarrhea, and dehydration. It may cause embryonic death or abortion in pregnant cows or result in poorly viable calves which, if persistent, may eventually die. The virus is generally transmitted by direct contact with infected animals or by indirect contact with contaminated forage or other materials. Only one of the animals sampled tested positive for BVD.

Two animals (one positive, one possible) tested positive for infectious bovine rhinotracheitis (IBR), a respiratory disease of ruminants. In addition, it can result in abortions, encephalitis, conjunctivitis, and genital infection of animals. The respiratory form is common where large herds may be present and occur in crowded conditions. Infection is more severe in calves and can often result in death to the infected animal.

Toxoplasmosis is a significant disease in that it can cause death or disability to newborn humans. The disease is best known for its transmission via infected domestic cats, but the disease also occurs in large herbivores and can cause death to an animal fetus as well. Humans can also acquire the disease via consuming uncooked infected meat (i.e., game or domestic animals). Two of the animals sampled (one positive, one possible) tested positive for toxoplasmosis.

Pasteurellosis, also known as shipping fever, can result in acute respiratory disease and ultimately pneumonia in animals. The onset of this disease may be due to environmental stress on the animals or via viral infection. Samples from one of the animals tested indicated possible infection of pasteurellosis.

ACKNOWLEDGEMENTS

This study was funded by the Environment, Safety, and Health Division of Los Alamos National Laboratory, Los Alamos, New Mexico. We thank Rhonda Robinson and Mary Salisbury for field crew support and data processing and Stan Tomkiewicz for GPS collar technical support. We also thank Tim Haarmann, David Keller, Leonard Sandoval, Louie Naranjo and other members of ESH-20 for field crew support and Louisa Lujan Pacheco, Amy Foulton-Stout, Hector Hinojosa, Kathy Valdez, and Belinda Gutierrez for report editing and production. Special thanks go to Mary Mullen for statistical advice and analysis. Finally, we would like to thank members of Bandelier National Monument, the Bureau of Indian Affairs, and the New Mexico Department of Game and Fish for their assistance in this project and members of the public who returned GPS collars from harvested and road killed animals.

REFERENCES

- Allen, C. D., "Elk Response to the La Mesa Fire and Current Status in the Jemez Mountains," in: Fire effects in Southwestern Forests: Proceedings of the Second La Mesa Fire Symposium; 1994 March 29-31; Los Alamos, New Mexico. Allen, Craig D., Ed., Gen. Tech. Rep. RM-GTR-286. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station (1996).
- Bennett, K. D., J. R. Biggs, and P. R. Fresquez, "Determination of Locational Error Associated with GPS Radio Collars in Relation to Vegetation Canopy and Topographical Influences of North-central New Mexico," Los Alamos National Laboratory report LA-UR-96-4921 (1997).
- Biggs, J. R., K. D. Bennett, P. R. Fresquez, and R. Robinson, "Movements, Disease Analysis, and Tritium Concentrations of Rocky Mountain Elk of the Pajarito Plateau," pp. 9, In: Proceedings of A Symposium of Biological Research in the Jemez Mountains, New Mexico (Santa Fe, NM, October 25) (1996).

- Biggs, J. R., K. D. Bennett, and P. R. Fresquez, "Evaluation of Habitat Use by Rocky Mountain Elk (*Cervus elaphus nelsoni*) in North Central New Mexico using Global Positioning System (GPS) Radio Collars," Los Alamos National Laboratory report LA-13279-MS (1997).
- Biggs, J. R., K. D. Bennett, and P. R. Fresquez, "Estimation of Observation Rates of Global Positioning Collars Deployed on Elk," Los Alamos National Laboratory report LA-UR-98-1080 (1998).
- Brown, D. E., "Biotic Communities of the American Southwest, United States, and Mexico," in: Desert Plants (Boyce Thompson Arboretum, AZ), Vol. 4 (1980).
- Frank, D. A., and S. J. McNaughton, "The Ecology of Plants, Large Mammalian Herbivores, and Drought in Yellowstone National Park," *Ecology* 73(6):2043-2058 (1992).
- Fraser, C. M. (ed.), "The Merck Veterinary Manual, A Handbook of Diagnosis, Therapy, and Disease Prevention and Control for the Veterinarian," Merck and Co. (6th edition) Rahway, N.J.
- Fresquez, P. R., J. R. Biggs, and K. D. Bennett, "Seasonal Movements, Activity Patterns, and Radionuclide Concentrations of Rocky Mountain Elk (*Cervus elaphus nelsoni*) and Male Deer (*Odocoileus hemionus*) Inhabiting the Pajarito Plateau," (1996) in: "Technology Development, Evaluation, and Application (TDEA) FY 1996 Progress Report," R. Barks, ed., Los Alamos National Laboratory report LA-13264-MS (1997).
- Fresquez, P. R., J. R. Biggs, K. D. Bennett, D. Kraig, M. A. Mullen, and J. Ferenbaugh, "Radionuclide Concentrations in Deer and Elk at Los Alamos National Laboratory: 1991 - 1998," Los Alamos National Laboratory report (*in preparation*) (1998).
- Gonzalez, T. C., T. S. Foxx, and J. R. Biggs, "Analysis of Animal-Related Accidents in Los Alamos County," Los Alamos National Laboratory report LA-UR-95-3950 (1995).
- Irwin, L. L., and J. M. Peek, "Elk Habitat Use Relative to Forest Succession in Idaho," *J. Wildl. Manage.* 47(3):664-672 (1983).
- Kie, J. G., J. A. Baldwin, and C. J. Evans, "CALHOME Home Range Analysis Program, Electronic User's Manual," U.S. Forest Service, Pacific Southwest Research Station, Fresno, CA (July 1994).
- Koch, S. W., T. K. Budge, S. G. Ferran, L. F. Sandoval, M. A. Mullen, K. D. Bennett, and R. G. Balice, "Preliminary Land Cover Map for Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-96-3362 (1996).
- Marcum, C. L., and M. D. Scott, "Influences of Weather on Elk Use of Spring-Summer Habitat," *J. Wildl. Manage.* 49(1):73-76 (1985).
- McCorquodale, S. M., K. J. Raedeke, and R. D. Taber, "Elk Habitat Use Patterns in the Shrub Steppe of Washington," *J. Wildl. Manage.* 50(4):664-669 (1986).
- White, G. C., "Biotelemetry Studies on Elk," Los Alamos Scientific Laboratory report LA-8529-NERP (1981).

APPENDIX A

LOCATIONAL POSITIONS OF INDIVIDUALLY COLLARED ELK

5 0 5 10 Miles

Figure A-1. All elk locational positions, 1996–98.

Figure A-2. Locational positions of elk 1603301, 1996–97.

4 0 4 8 12 Miles

Figure A-3. Locational positions of elk 1603401, 1996–97.

Figure A-4. Locational positions of elk 1603501, 1996.

Figure A-5. Locational positions of elk 1603601, 1996–97.

Figure A-6. Locational positions of elk 1603701, 1996–97.

4 0 4 8 12 Miles

Figure A-7. Locational positions of elk 1603801, 1996.

Figure A-8. Locational positions of elk 1603302, 1998.

Figure A-9. Locational positions of elk 1603402, 1998.

Figure A-10. Locational positions of elk 1603502, 1998.

Figure A-11. Locational positions of elk 1603802, 1997–98.

Figure A-12. Elk #11 locations and movements collected during 1995 using VHF collars.

Figure A-13. Elk #12 locations and movements collected during 1995 using VHF collars.

Figure A-14. Elk #14 locations and movements collected during 1995 using VHF collars.

Figure A-15. Elk #16 locations and movements collected during 1995 using VHF collars.

APPENDIX B

**TABLE OF ACTIVITY PATTERNS OF INDIVIDUALLY COLLARED ELK
BY SLOPE AND LAND COVER TYPE**

Table B-1. Relative Percent Use of Land Cover Types by Elk, by Season and Hourly Subperiod

Season	Cover Type	Hourly Subperiod					
		0000-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400
Spring	Bare Ground	1.19	1.06	0	1	0	1.27
	Mixed Conifer	2.38	1.06	5	6	0	1.27
	Aspen	0	0	0	0	1.15	0
	Ponderosa Pine	20.24	38.30	38	36	32.18	31.65
	Piñon-Juniper	41.67	41.49	50	44	40.23	31.65
	Juniper Woodland	0	0	0	0	1.15	0
	Grassland	27.38	17.02	6	11	16.09	27.85
	Developed	7.14	1.06	1	2	9.20	6.33
Sample size (n)		84	94	100	100	87	79
Calving	Bare Ground	2.08	0	1.61	2.67	1.12	1.22
	Mixed Conifer	14.58	24.19	20.97	12	10.11	13.41
	Aspen	1.04	1.61	1.61	4	1.12	4.88
	Ponderosa Pine	33.33	33.87	29.03	26.67	30.34	28.05
	Piñon-Juniper	27.08	20.97	30.65	33.33	32.58	29.27
	Juniper Woodland	1.04	0	0	1.33	0	0
	Grassland	20.83	19.35	14.52	17.33	22.47	23.17
	Developed	0	0	1.61	2.67	2.25	0
Sample size (n)		96	62	62	75	89	82
Summer	Bare Ground	1.67	4.17	1.75	1.67	2.50	0
	Mixed Conifer	23.33	20.83	26.32	23.33	31.25	24.39
	Aspen	1.67	2.08	1.75	6.67	6.25	1.22
	Ponderosa Pine	21.67	20.83	26.32	21.67	15	23.17
	Piñon-Juniper	23.33	41.67	31.58	31.67	22.50	21.95
	Juniper Woodland	0	0	0	0	0	0
	Grassland	26.67	10.42	12.28	13.33	22.50	25.61
	Developed	1.67	0	0	1.67	0	3.66
Sample size (n)		60	48	57	60	80	82
Fall	Bare Ground	22.22	0	0	0	0	0
	Mixed Conifer	0	7.14	15	30.43	6.25	20
	Aspen	0	0	0	4.35	12.50	20
	Ponderosa Pine	33.33	14.29	30	13.04	25	20
	Piñon-Juniper	44.44	71.43	55	34.78	25	10
	Juniper Woodland	0	0	0	0	0	0
	Grassland	0	7.14	0	17.39	31.25	30
	Developed	0	0	0	0	0	0
Sample size (n)		9	14	20	23	16	10
Winter	Bare Ground	3.61	4.60	1.14	3.12	3.33	2.60
	Mixed Conifer	3.61	4.60	1.14	1.04	1.11	1.30
	Aspen	1.20	0	0	0	1.11	0
	Ponderosa Pine	22.89	12.64	18.18	19.79	20	19.48
	Piñon-Juniper	44.58	64.37	72.73	55.21	54.44	45.45
	Juniper Woodland	0	0	0	0	1.11	1.30
	Grassland	19.28	12.64	4.55	17.71	15.56	20.78
	Developed	4.82	1.15	1.14	3.12	3.33	9.09
Sample size (n)		83	87	87	96	90	77

Table B-2. Relative Percent Use of Slope Classes by Elk, by Season and Hourly Subperiod

Season	Cover Type	Hourly Subperiod					
		0000–0400	0400–0800	0800–1200	1200–1600	1600–2000	2000–2400
Spring	0%–5%	64.29	52.13	33	40	57.47	63.29
	5%–10%	17.86	23.40	29	32	18.39	22.78
	10%–15%	8.33	14.89	18	12	11.49	6.33
	15%–20%	5.95	7.45	9	11	6.90	3.80
	20%–25%	3.57	2.13	3	3	5.75	3.80
	25%–30%	0	0	4	2	0	0
	30%–35%	0	0	3	0	0	0
	35%–40%	0	0	1	0	0	0
Sample size (n)		84	94	100	100	87	79
Calving	0%–5%	36.46	33.87	29.03	28	33.71	29.27
	5%–10%	22.92	29.03	29.03	25.33	37.08	39.02
	10%–15%	18.75	19.35	22.58	16	15.73	15.85
	15%–20%	12.50	11.29	12.90	17.33	6.74	9.76
	20%–25%	6.25	3.23	6.45	9.33	3.37	4.88
	25%–30%	2.08	3.23	0	2.67	2.25	0
	30%–35%	0	0	0	1.33	1.12	1.22
	35%–40%	1.04	0	0	0	0	0
Sample size (n)		96	62	62	75	89	82
Summer	0%–5%	40	27.08	26.32	25	38.75	39.02
	5%–10%	21.67	27.08	29.82	26.67	26.25	23.17
	10%–15%	16.67	31.25	15.79	20	22.50	12.20
	15%–20%	3.33	8.33	21.05	15	6.25	12.20
	20%–25%	15	4.17	7.02	6.67	5	6.10
	25%–30%	3.33	2.08	0	5	0	6.10
	30%–35%	0	0	0	0	0	0
	35%–40%	0	0	0	1.67	1.25	1.22
Sample size (n)		63	48	57	60	80	82
Fall	0%–5%	33.33	42.86	30	30.43	43.75	40
	5%–10%	44.44	28.57	20	26.09	18.75	30
	10%–15%	11.11	14.29	20	13.04	12.50	10
	15%–20%	11.11	7.14	15	13.04	12.50	10
	20%–25%	0	0	10	17.39	6.25	10
	25%–30%	0	7.14	5	0	6.25	0
	30%–35%	0	0	0	0	0	0
	35%–40%	0	0	0	0	0	0
Sample size (n)		9	14	20	23	16	1
Winter	0%–5%	46.99	42.53	38.64	41.67	50	51.95
	5%–10%	21.69	20.69	35.23	26.04	18.89	19.48
	10%–15%	13.25	22.99	14.77	16.67	13.33	15.58
	15%–20%	10.84	8.05	4.55	10.42	14.44	7.79
	20%–25%	6.02	3.45	5.68	4.17	3.33	3.90
	25%–30%	1.20	2.30	1.14	1.04	0	1.30
	30%–35%	0	0	0	0	0	0
	35%–40%	0	0	0	0	0	0
Sample size (n)		83	87	88	96	90	77

APPENDIX C

**HOME RANGE ESTIMATES, LAND COVER TYPE COMPOSITION, AND HOME
RANGE POLYGONS FOR INDIVIDUALLY COLLARED ELK**

Table C-1. Home Range Estimations for Elk by Season, LANL, 1996–98

Animal ID	Year	Season	% Contour	Home Range	Core	Number of Locational Fixes
1603301	1996	Spring	95	1269	283.2	11
		Calving	95	1172	221.1	28
		Summer	95	2607	133.8	30
		Fall	95	4361	268.5	36
		Winter	95	4834	584.7	93
1603401	1996	Spring	95	2517	349.6	27
		Calving	99	5642	677.9	48
		Summer	95	3306	592.2	41
		Fall	95	3829	150.4	28
		Winter	95	2634	383.4	108
1603501	1996	Spring	95	1218	141.2	34
		Calving	95	5116	497.1	41
		Summer	95	1588	382.5	21
		Fall	95	3021	484.5	29
		Winter	95	5004	564.5	63
1603601	1996	Spring	95	2843	642.2	41
		Calving	95	2138	258.3	49
		Summer	95	1957	356.5	39
		Fall	95	10160	1213	37
		Winter	95	3062	735.4	87
1603701	1996	Spring	95	6157	169.9	35
		Calving	95	2892	300.3	23
		Summer	95	221	115.9	19
		Fall	95	12380	2403	21
		Winter	95	903	128.9	81
1603801	1996	Calving	95	12020	2278	38
		Summer	95	3199	494.1	32
1603301	1997	Spring	95	2059	989.2	45
		Calving	95	2825	235.5	38
		Summer	95	1651	128.9	23
1603401	1997	Spring	95	2582	437.7	58
		Calving	95	1426	588.1	26
1603701	1997	Spring	95	1278	275.9	55
		Calving	95	7907	1717	43
		Summer	95	2432	561.8	44
1603802	1997	Spring	95	236.1	30.21	46
		Calving	95	2722	823.8	40
		Summer	95	2418	437	52
		Fall	95	669.3	202.5	21
		Winter	99	11980	1591	94
1603302	1998	Spring	95	3306	330.8	50
1603402	1998	Spring	95	3926	689.8	48
		Calving	95	5562	949.1	57
1603502	1998	Spring	95	700.9	23.95	30
1603802	1998	Spring	95	1407	53.34	58
		Calving	95	3733	738.8	42

Table C-2. Percent Relative Land Cover Type Composition of Home Range and Core Areas for Elk, 1996–98

Animal ID	Year	Season	Bare Ground	Mixed Conifer	Aspen	Ponderosa Pine	Piñon-Juniper	Juniper Woodland	Grassland	Developed
1603301	1996	Spring								
home range			1	13	5	53.3	6.3	<1	19.4	2.4
core area			1.5	7.7	1.4	53.5	14.1	<1	13.4	8.1
1603401	1996	Spring								
home range			1.4	1	<1	24.3	65	1	5.3	1.6
core area			1	0	0	17.4	75.9	1.3	1	1.5
1603501	1996	Spring								
home range			1.4	0	0	6.5	84.2	1.2	3.2	2.9
core area			0	0	0	2.4	69	0	4.8	0
1603601	1996	Spring								
home range			3.2	<1	<1	8.9	77.3	1.1	3.4	5.4
core area			1.2	0	0	3.2	88.9	<1	4.7	1.3
1603701	1996	Spring								
home range			1.7	7.7	1.4	49.1	20.8	<1	11.2	7.7
core area			2.6	1	0	54.1	19.5	0	21.8	<1
1603301	1997	Spring								
home range			1.1	5.9	1.9	50.3	23.6	<1	14.8	2.1
core area			1	6.9	3.1	55.7	9.9	<1	20.3	3
1603401	1997	Spring								
home range			4.6	<1	0	13.1	74.5	1.3	2.8	3.3
core area			1.7	0	0	19.9	71.8	1.1	2	3.4
1603701	1997	Spring								
home range			3.2	0	0	1	64.2	1	2.3	28.5
core area			1	0	0	2.5	62	1.3	3.2	30.1
1603802	1997	Spring								
home range			1.9	1.7	0	51.4	16.5	0	23.3	4.9
core area			1.7	0	0	52.8	3.9	0	41	1
1603302	1998	Spring								
home range			1	9.7	1.7	51.2	18	<1	6.7	11.2
core area			1	9.9	1	69.3	7.7	<1	10	2.4
1603402	1998	Spring								
home range			1	7.5	1.4	54.9	16.1	0	9.3	9.8
core area			1.1	9.7	<1	59.5	13.3	<1	7.4	8.4
1603502	1998	Spring								
home range			1.3	2.6	0	42.5	42	1	4.5	6.1
core area			<1	2.3	0	33.6	60.1	0	3.6	0

Table C-2. Percent Relative Land Cover Type Composition of Home Range and Core Areas for Elk, 1996–98 (Cont.)

Animal ID	Year	Season	Bare		Mixed	Ponderosa		Juniper		Developed
			Ground	Aspen		Pine	Piñon-Juniper	Woodland	Grassland	
1603802	1998	Spring								
home range			0	3.6	6.3	55.9	9.9	0	21.4	2.3
core area			1.5	0	0	43.5	9.8	0	39.3	5.9
1603301	1996	Calving								
home range			1	1	5.3	62.4	10.8	<1	17.6	1.7
core area			1	0	0	62.3	14.1	0	21.5	1
1603401	1996	Calving								
home range			1.8	<1	3.8	37.5	44.2	1	6.2	5.3
core area			1.4	0	0	19.6	73.8	1	2.5	1.4
1603501	1996	Calving								
home range			4.1	<1	<1	14.3	69.1	1.4	3.2	7
core area			1	0	0	11.4	84.2	<1	3.1	0
1603601	1996	Calving								
home range			2	<1	1	22.3	66.1	1	4.7	2.9
core area			5.2	0	0	6.8	80.6	1.2	6.1	0
1603701	1996	Calving								
home range			0	10.6	56	7.4	<1	0	25.7	0
core area			<1	13.8	46.7	13.7	1.1	0	24.7	0
1603801	1996	Calving								
home range			0	5.9	53.7	20.6	0	0	19	0
core area			<1	5.2	54.1	23.9	1	0	16.1	0
1603301	1997	Calving								
home range			1	1.2	7.5	57.8	10.2	<1	18	4.6
core area			1.4	0	2	56.2	13.3	<1	21.4	5.5
1603401	1997	Calving								
home range			16.2	0	0	0	71.9	9.3	2	0
core area			16.6	0	0	0	77.2	5.1	1.2	0
1603701	1997	Calving								
home range			1	1.2	7.5	57.8	10.2	<1	18	4.6
core area			0	13.4	62.5	5.7	<1	0	17.8	0
1603802	1997	Calving								
home range			0	10	46.3	26.1	3.3	0	12.6	1.1
core area			1	8.7	20	50.9	7	<1	9.6	3.2
1603402	1998	Calving								
home range			0	2.7	25.6	44.9	13.2	0	6.2	6.7
core area			1	<1	32.8	49.9	6.6	<1	3.3	6.3

Table C-2. Percent Relative Land Cover Type Composition of Home Range and Core Areas for Elk, 1996–98 (Cont.)

Animal ID	Year	Season	Bare			Mixed		Ponderosa		Juniper		
			Ground	Conifer	Aspen	Pine	Piñon-Juniper	Woodland	Grassland	Developed		
1603802	1998	Calving	0	41.7	8	23.2	2.9	0	23	1		
home range			<1	60.6	11.3	12.4	1.6	0	13.7	<1		
core area												
1603301	1996	Summer	1	8.5	1.6	63.1	9.9	<1	12.1	3.8		
home range			1.2	1.3	0	48.3	14.5	0	24.3	9.1		
core area												
1603401	1996	Summer	1	6.3	1.3	51	24.2	<1	14	1.8		
home range			1.3	4.4	1.1	53	15.3	<1	21.8	2.5		
core area												
1603501	1996	Summer	2.5	0	0	4.9	80.7	1.1	2.6	8.4		
home range			1.5	0	0	6.9	78.8	1.5	3.9	6.5		
core area												
1603601	1996	Summer	2	<1	<1	15.9	70.8	1.4	3.3	6.6		
home range			1.8	0	0	2.9	85.4	1.2	4.9	2.9		
core area												
1603701	1996	Summer	<1	74.7	9.3	10.1	<1	0	5.4	0		
home range			0	69.7	7.4	20.8	0	0	1.9	0		
core area												
1603801	1996	Summer	<1	60.2	6.8	18.2	1	0	14.1	0		
home range			0	76.6	8.1	7.1	0	0	8.3	0		
core area												
1603301	1997	Summer	1.1	5.9	1.9	50.3	23.6	<1	14.8	2.1		
home range			1	6.9	3.1	55.7	9.9	<1	20.3	3		
core area												
1603701	1997	Summer	0	61	11.3	8.5	<1	0	18.8	0		
home range			0	55.6	11.6	10.1	<1	0	22.2	0		
core area												
1603802	1997	Summer	0	62.1	11.5	8.1	<1	0	17.9	0		
home range			0	54.9	14.6	11.2	1	0	18.6	0		
core area												
1603301	1996	Fall	<1	6.6	1.6	48	19.7	<1	22.6	1		
home range			1	5.4	0	46.7	17.4	0	28	1.7		
core area												
1603401	1996	Fall	1.5	2.4	<1	27	59.4	1	5.1	3.2		
home range			3	0	0	23.5	57.4	1.5	4.7	8.9		
core area												

Table C-2. Percent Relative Land Cover Type Composition of Home Range and Core Areas for Elk, 1996–98 (Cont.)

Animal ID	Year	Season	Bare			Mixed		Ponderosa		Juniper		Developed
			Ground	Conifer	Aspen	Conifer	Aspen	Pine	Piñon-Juniper	Woodland	Grassland	
1603501	1996	Fall										
home range			2.5	<1	<1			10.7	73.8	1.7	2.5	8
core area			1.2	0	0			2.7	86	1.3	4.5	2.9
1603601	1996	Fall										
home range			4.3	2	<1			25.3	49.4	1.9	9.4	7.6
core area			1.5	0	<1			12.7	78.9	1.4	2.8	2.7
1603701	1996	Fall										
home range			<1	53.5	6			23.3	5.7	0	9.8	1.3
core area			0	71.4	8.4			15.6	<1	0	4.1	0
1603802	1997	Fall										
home range			0	65.3	13.2			7.8	<1	0	34.3	0
core area			0	47.6	15.2			2.9	<1	0	13.2	0
1603301	1996–97	Winter										
home range			1.3	5.2	1.3			44.3	34.8	1	9.3	2.9
core area			0	4.4	0			52.1	23.9	0	17.8	1.2
1603401	1996–97	Winter										
home range			3.8	<1	<1			16.2	72.5	1	2.7	2.6
core area			1.6	1	0			26.9	61.1	1	2.8	4.2
1603601	1996–97	Winter										
home range			7.8	<1	<1			7.7	73.1	2.9	2.5	5.4
core area			5.2	0	0			3.2	84.2	1	2.9	3
1603701	1996–97	Winter										
home range			2.9	0	0			1.9	67.9	3.9	2	20.7
core area			0	0	0			1.1	79.9	0	3.8	14.7
1603802	1996–97	Winter										
home range			1	23.8	3.6			23.4	28.5	2.3	12.2	5.1
core area			1	3.4	<1			36.9	43.6	1	12.2	2

Figure C-1. Spring 1996.

Figure C-2. Calving 1996.

Figure C-3. Calving 1996.

Figure C-4. Summer 1996.

Figure C-5. Fall 1996.

Figure C-6. Winter 1996-97.

Figure C-7. Winter 1996–97.

Figure C-8. Spring 1997.

Figure C-9. Calving 1997.

Figure C-10. Summer 1997.

Figure C-11. Fall 1997.

Figure C-12. Winter 1997–98.

2 0 2 4 6 8 Miles

Figure C-13. Spring 1998.

Figure C-14. Calving 1998.