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Evaluation of Habitat Use by Rocky Mountain Elk (Cervus elaphus nelsoni) in North-Central New Mexico using Global Positioning System (GPS) Radio Collars

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James Biggs, Kathryn Bennett, and P.R. Fresquez

ABSTRACT

In 1996 we initiated a study to identify habitat use in north-central New Mexico by Rocky Mountain elk (*Cervus elaphus nelsoni*) using global positioning system (GPS) radio collars. We collared six elk (5 cows/1 bull) in the spring of 1996 with GPS radio collars programmed to obtain locational fixes every 23 h. Between April 1, 1996 and January 7, 1997, we collected >1200 fixes with an approximately 70% observation rate. We have interfaced GPS locational fixes of elk and detailed vegetation maps using the geographical information system to provide seasonal (calving, late summer, fall, winter) habitat use within mountainous regions of north-central New Mexico. Based on habitat use and availability analysis, use of grass/shrub and pinon/juniper habitats was generally higher than expected during most seasons and use of forested habitats (ponderosa pine, mixed conifer) was lower than expected. Most of the collared elk remained on LANL property year-round. We believe the application of GPS collars to elk studies in north-central New Mexico to be a more efficient and effective method than the use of VHF (very-high frequency) radio collars.

INTRODUCTION

Radiotelemetry has provided increased opportunities to examine activity patterns, habitat use, and behavior of wildlife species (Samuel and Fuller 1994). At present, there are generally three methods of using telemetry for tracking large mammals: 1) a very-high frequency (VHF) radio-telemetry system, which consists of hand-held devices that receive transmissions from a radio collar containing a transmitter that is placed around the animals neck (Samuel and Fuller 1994); 2) the use of VHF receivers which are attached to "permanent tracking stations" that are strategically located in a defined study area (Hansen et al. 1992; Loft and Kie 1988; Deat et al. 1980); and 3) satellite telemetry.

Satellite telemetry also uses radio collars implanted with transmitters. However, the signal is picked up via satellites orbiting the earth and are either stored in the collar until downloaded by the researcher or relayed to a data servicing center. Until recently satellite telemetry studies involved the use of platform transmitter terminals placed on animals (Heide-Jorgensen, et al., 1992; Hansen et al., 1992; Keating et al. 1991). However, a newer and much more innovative form of tracking has been developed. This involves the use of geographic positioning system

(GPS) units attached to radio collars. This system utilizes on-board microelectronics to not only receive and store locational data but also to allow for the uplinking of this information into a storage satellite for ultimate data dissemination by a data management center (i.e., Argos Inc.). Because this is such a newly evolving technique, there have been very few studies that have investigated its usefulness and effectiveness in animal studies under various environmental conditions (Bennett et al. 1997; Rempel et al. 1995).

From 1978 to 1980, an extensive study on elk inhabiting north-central New Mexico was conducted using VHF radiotelemetry to investigate movement patterns and certain population characteristics (White et al. 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 very high rate (Allen 1996, Biggs et al. 1996). Previous studies have shown that in north-central New Mexico, 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). No other studies have intensively studied elk movements and/or habitat use in this area.

The objectives of this study were to test the usefulness of a new wildlife telemetry system (GPS collars deployed on elk), and to apply spatial and temporal analysis of data to evaluate habitat use by elk in north-central New Mexico.

STUDY AREA

Los Alamos National Laboratory (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 Bandelier National Monument (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.

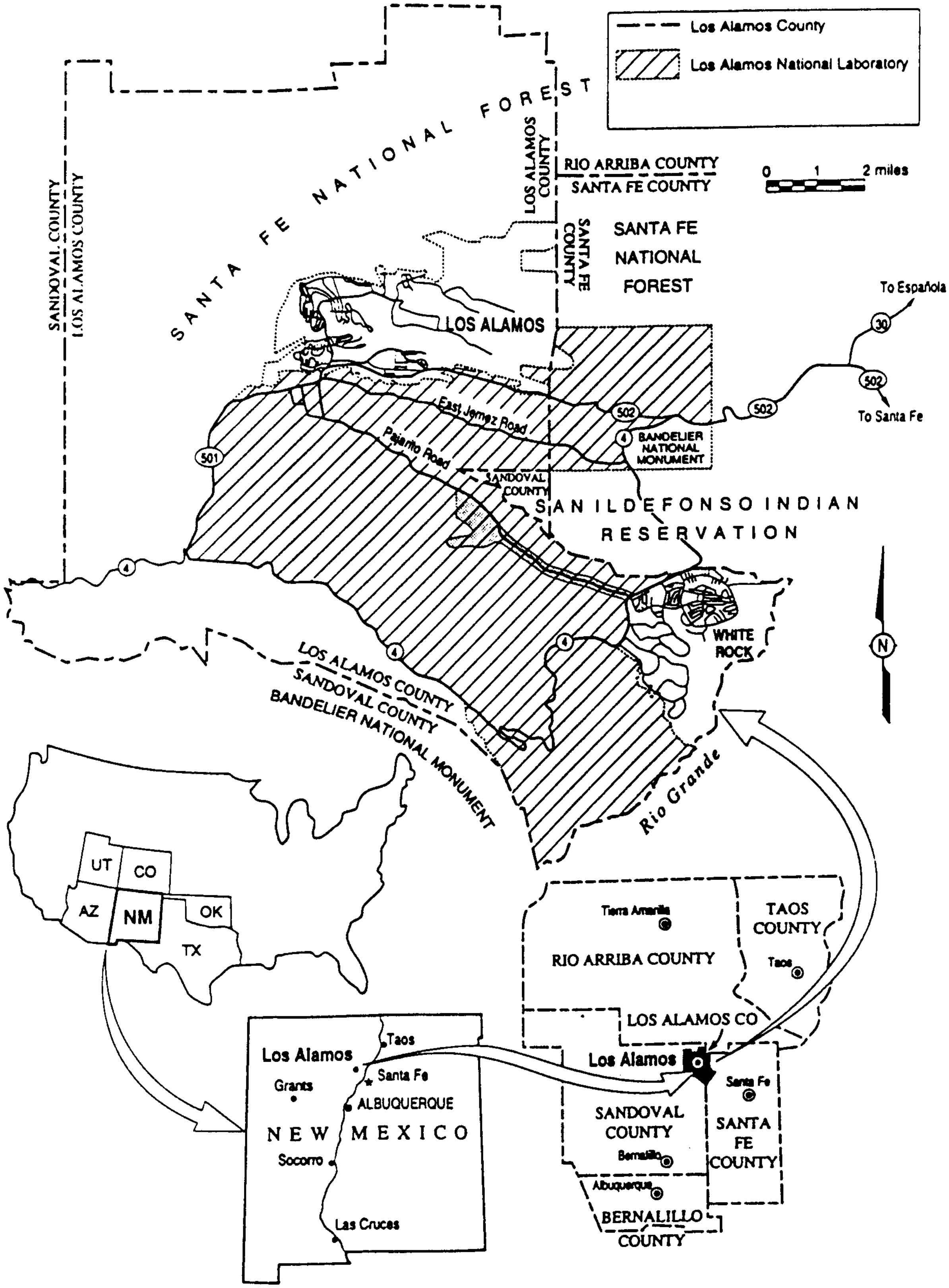


Figure 1. The location of Los Alamos National Laboratory within New Mexico.

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.

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 pinon pine (*Pinus edulis*), both species typical of the Great Basin Conifer Woodland. Pinon pine and juniper are common at higher elevations (1860 to 2070 m or 6200 to 6900 ft) and occur on much of the mesa tops. Ponderosa pine (*Pinus ponderosa*) is a common species at about 2070 to 2250 m (6900 to 7500 ft) on the higher mesa tops and along many of the north-facing canyon slopes. Species of fir (*Psuedostuga* 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.

METHODOLOGY

Site Selection

Three sites in two areas of LANL were selected for trapping elk based on three criteria:

- previous movement data 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; therefore, trapping locations were located near a radioactive-waste burial site and outfall effluent sources (artificial water sources).

One site was located in the vicinity of an outfall effluent water source in the southwest portion of LANL and at a location of high elk activity. This area is characterized by a ponderosa pine-dominated forest with scattered open expanses of grass and shrubs. It is also in an area of moderately high human activity. The second and third sites were located in the northeast portion of the Laboratory near a LANL-fenced waste burial site and near San Ildefonso Pueblo property. Both sites were located in a pinon/juniper woodland with one site located in a semi-remote shallow canyon and the other located near semi-permanent water sources and a moderately-heavily used highway.

Geographical Information System Coverages/GPS Locational Fix Overlays

Habitat use and availability was evaluated by overlaying elk locational positions on to a vegetation land cover map delineating dominant overstory vegetation (Koch et al. 1996). Ground truthing of LANDSAT thematic mapper images that detect reflected radiation from the earth's surface (infrared wavelengths) were classified into six land cover types (plus one unknown category) used for this study:

Cover Type

Unvegetated/Developed lands	Aspen forests
Mixed-conifer forests	Ponderosa pine forests
Pinon-juniper woodlands	Grass/Shrublands
Undetermined	

Trapping

We deployed GPS collars on six elk. We collected data on physical measurements, blood diseases, age, weight, and length of 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 collapsable 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.

Collar Programming

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 test 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 varying habitats and terrain throughout LANL property (Bennett, et al. 1997). No significant differences were found in the mean locational error between mesa tops 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 (α=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.

RESULTS

Trapping

We captured six elk (five cows and one bull) during March and April 1996. Estimated age of cow elk ranged from 2 to 5 years (Table 1). Four of the cows were captured in shallow canyons dominated by pinon/juniper. The other cow and bull were captured on a mesa top 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 2 miles northeast of LANL property.

Table 1. Elk Captured and Radio Collared During 1996 Trapping Effort.

ID NUMBER	DATE OF CAPTURE	LOCATION OF CAPTURE	SEX	ESTIMATED AGE	EST. WEIGHT	REMARKS
16033	April 2, 1996	Southwest LANL	Cow	~ 2 to 3 yrs	545 lbs	
16034	March 19, 1996	Northeast LANL	Cow	4 to 5 yrs	617 lbs	Possibly pregnant
16035	March 26, 1996	Northeast LANL	Cow	undetermined	525 lbs	Harvested on 12/20/96 within 1 mi southeast of LANL
16036	March 15, 1996	Northeast LANL	Cow	~ 2 yrs	545 lbs	
16037	March 12, 1996	Northeast LANL	Cow	~ 4 to 5 yrs	650 lbs	Possibly pregnant
16038	April 23, 1996	Southwest LANL	Bull	~ 2 yrs	659 lbs	Harvested 9/13/96 0.5 to 1 mi NE of LANL

Approximately 1200 fixes were obtained between March 1996 and January 7, 1997 for all six elk combined. We calculated an approximately 70% (SD=8%) reception success rate (# of actual fixes/total # of potential fixes) for all animals combined (range of 59 to 81%) (Figure 2).

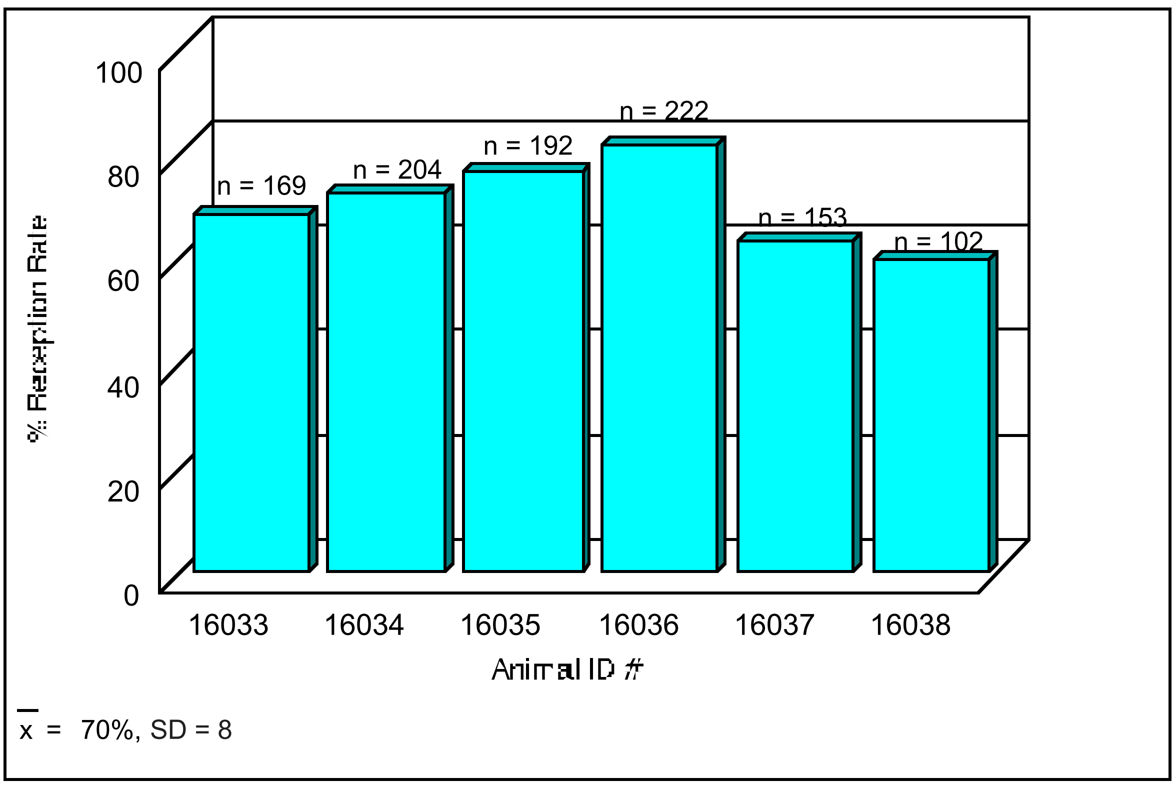


Figure 2. Locational fix reception rates (%) for GPS radio collared elk.

Seasonal Habitat Use by Individual Animal

We examined seasonal habitat use for each GPS-collared elk (Figure 3). The most frequently used habitats by most cow elk during calving and fall were grass/shrub areas and the most frequently used habitats during late summer and winter were grass/shrub and pinon/juniper areas. The bull spent the majority (>50%) of his time in forested habitats of ponderosa pine, mixed conifer, and aspen. In addition, approximately 40% of his fix locations were undetermined due to their locations occurring outside of the delineated vegetation cover map. However, all of these fixes were located west of LANL in higher elevation areas dominated by ponderosa pine, mixed conifer, and aspen stands with high montane meadows.

Habitat Use and Availability

Based on previous graphs of habitat use by elk, it appears that pinon/juniper and grass/shrub areas are being used more than what would be expected, based on the amount of those habitats that are available. However, by taking into account the amount of a particular habitat that is available to the amount that is used, we attempted to identify if specific habitat types were being utilized more than expected throughout the year.

We compared the percent relative occurrence of locational fixes for cows (chi-squared test, α=0.05, n=5) by each habitat to the amount of the habitat that is available (Figure 4). We did not conduct the chi-squared analysis for the bull elk due to only one bull being tracked. We observed significant differences ($x = 279.7$, $DF = 5$, $n = 992$, $p<0.001$) between the amount of habitat available and the amount used throughout the year. Cow elk utilized ponderosa pine and mixed conifer forests less than expected (>50% difference between expected and observed locational fixes) but utilized grass/shrub areas greater than expected (>50% difference between observed and expected).

Seasonal Habitat Use and Availability

We compared seasonal use by cow elk of each habitat by the total amount of each habitat available. Significant differences (α=0.05) in habitat use and availability were observed for all seasons examined (Figure 5). During calving season and fall, cow elk utilized grass/shrublands greater than expected and utilized mixed conifer less than expected (>50% difference between expected and observed values). In late summer, cow elk again utilized mixed conifer less than expected but also utilized grass/shrub habitat less than expected. Finally, during winter, cow elk utilized grass/shrublands and pinon/juniper woodlands greater than expected and utilized ponderosa pine and mixed conifer forests less than expected.

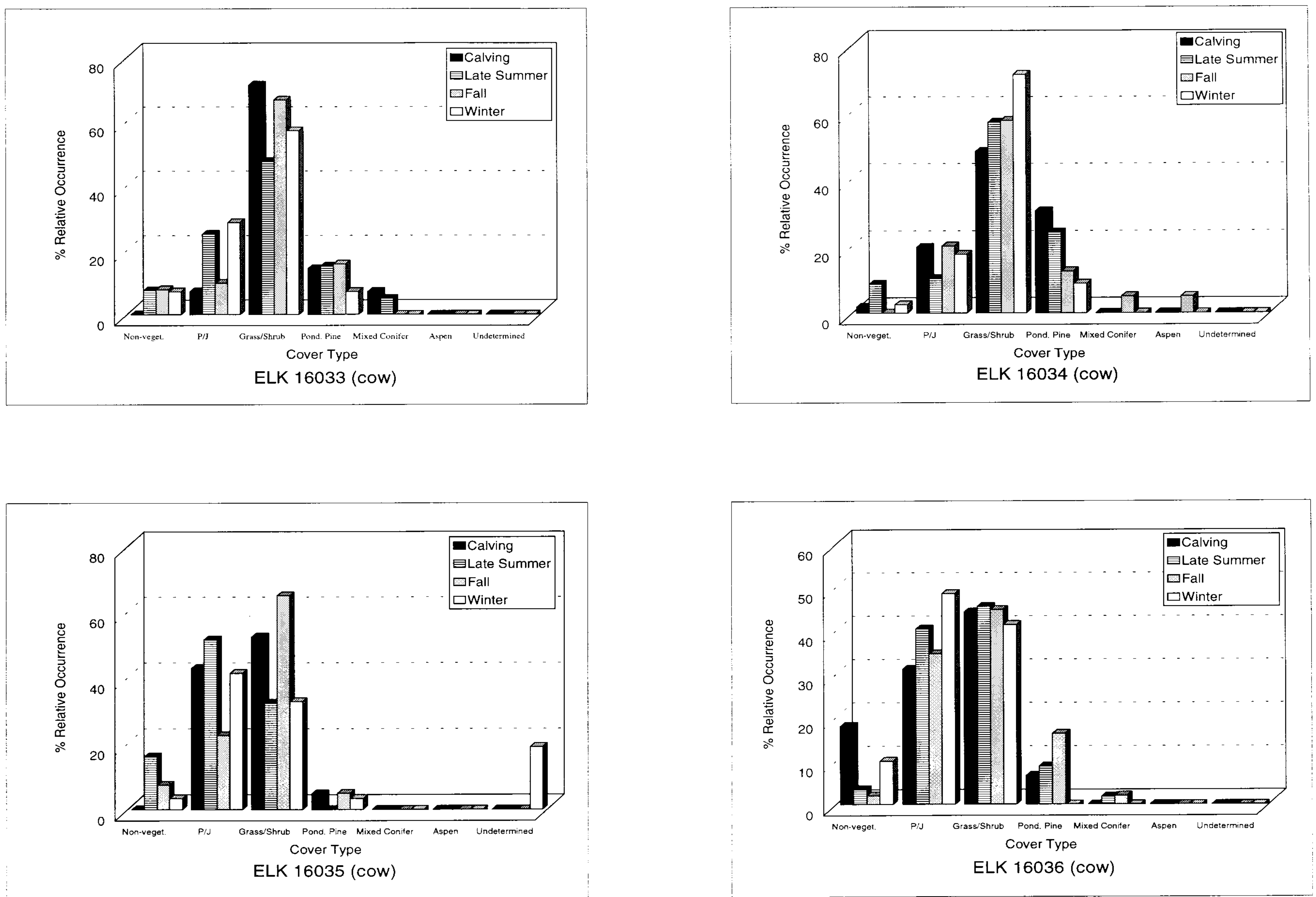
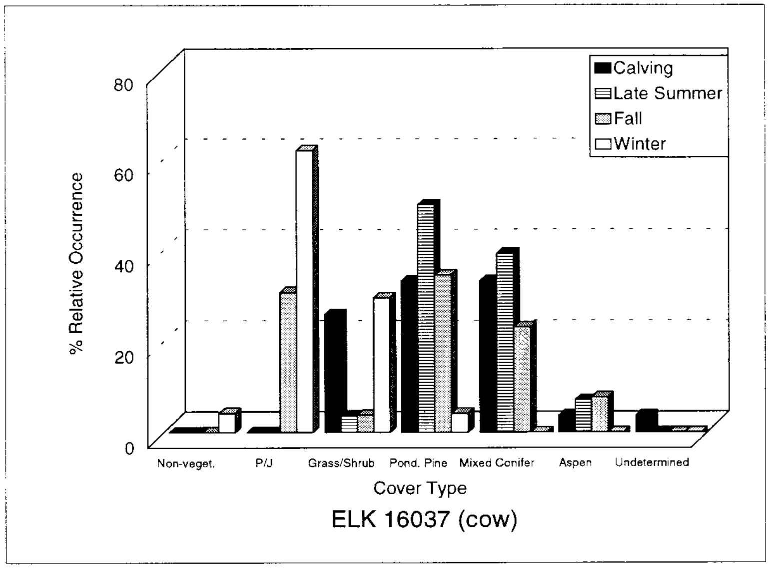


Figure 3. Seasonal habitat use by individual GPS-collared elk.



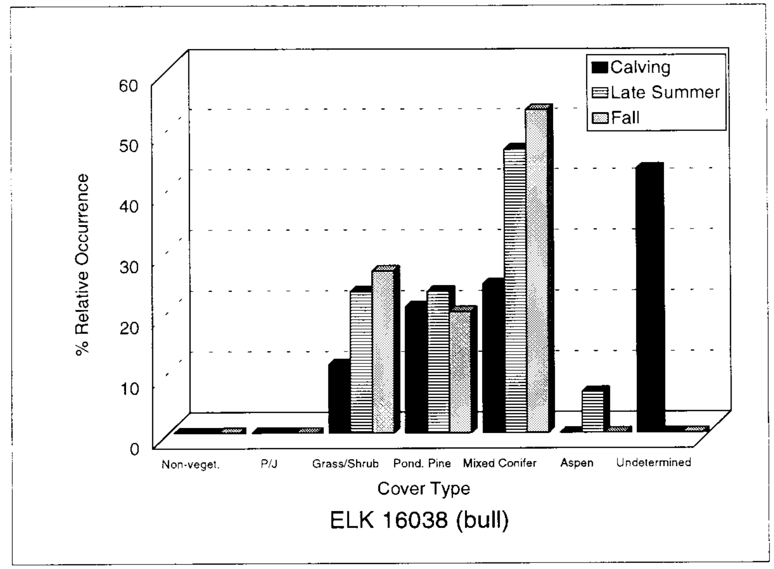


Figure 3 (cont.). Seasonal habitat use by individual GPS collared elk.

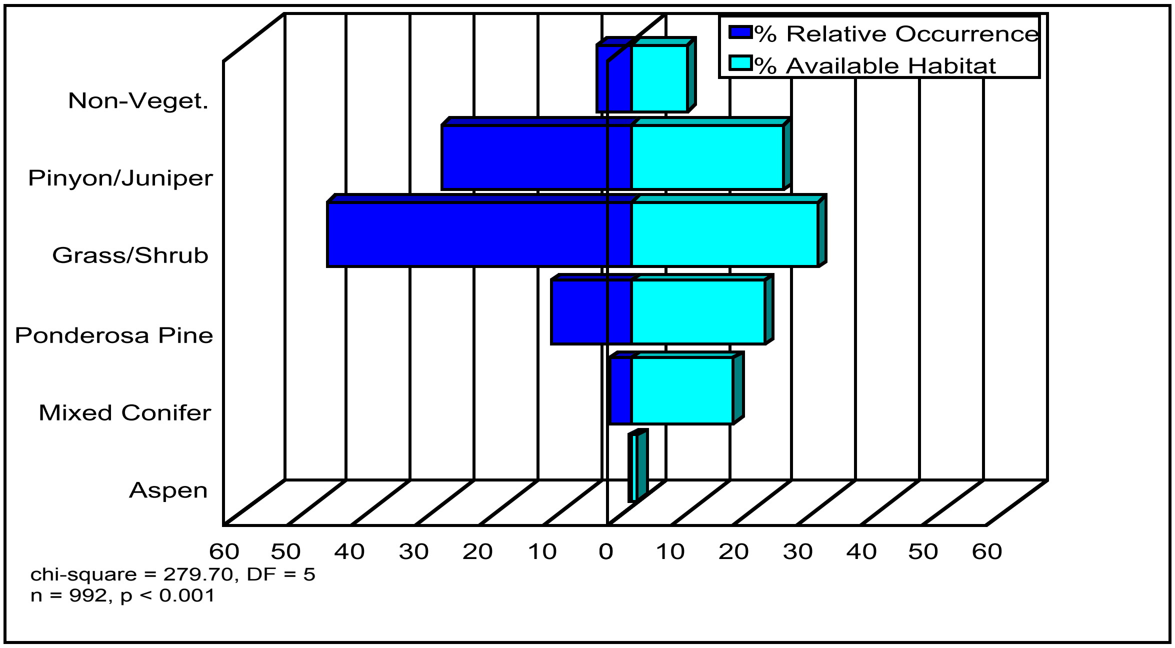
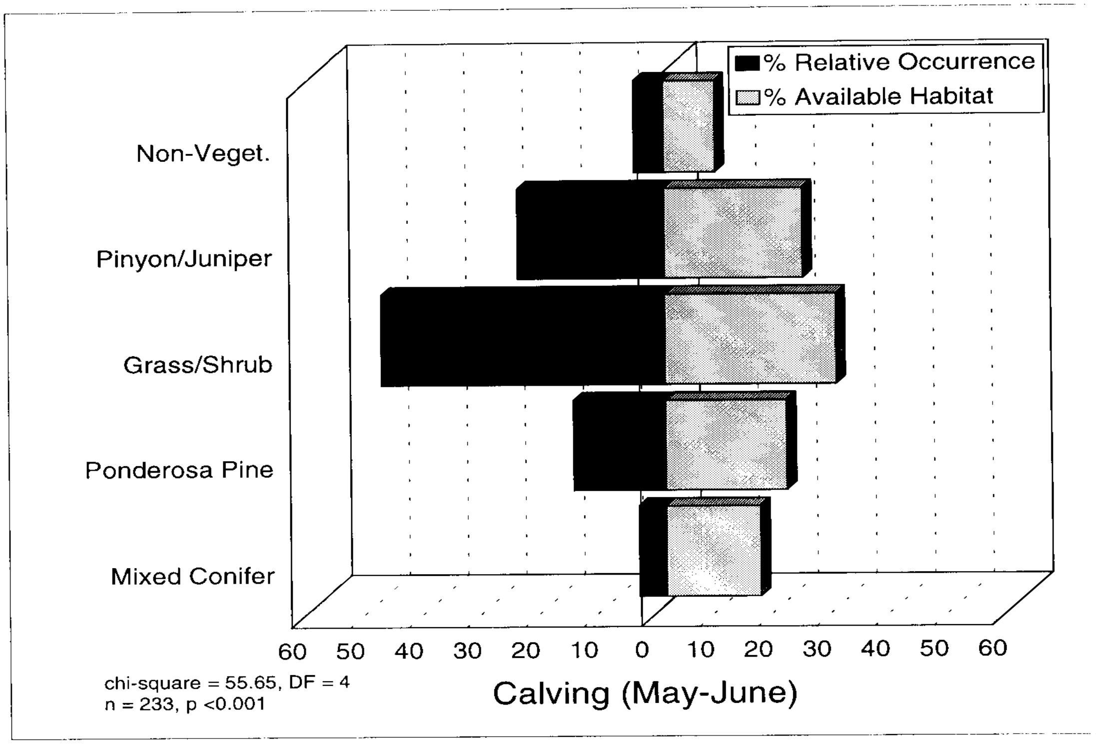


Figure 4. Cow elk use and availability of habitats in north-central New Mexico.

DISCUSSION

We captured six Rocky Mountain elk on LANL property and deployed GPS collars to evaluate the use of GPS technology for wildlife studies and to aid in the development of long-term management strategies of this species. Prior to deployment on elk, one GPS collar was tested to estimate locational fix error associated with its use. The methodology and results of the collar testing is reported in detail in Bennett et al. (1997). That study reported that 79% of the locational fixes were within approximately 120 m (396 ft) of the actual location and had an overall mean of 106 m (350 ft). This error rate was not applied to data presented in this paper due to further modifications and revisement to the vegetation cover map being anticipated in the near future. Once the cover map has been finalized, locational errors will be applied to each locational fix.

Reception rates of about 86% were also reported by Bennett et al. In this study, we report an overall mean reception rate of 70%. The difference between rates may be a result of several factors. One, if animals are moving while a 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. Second, 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



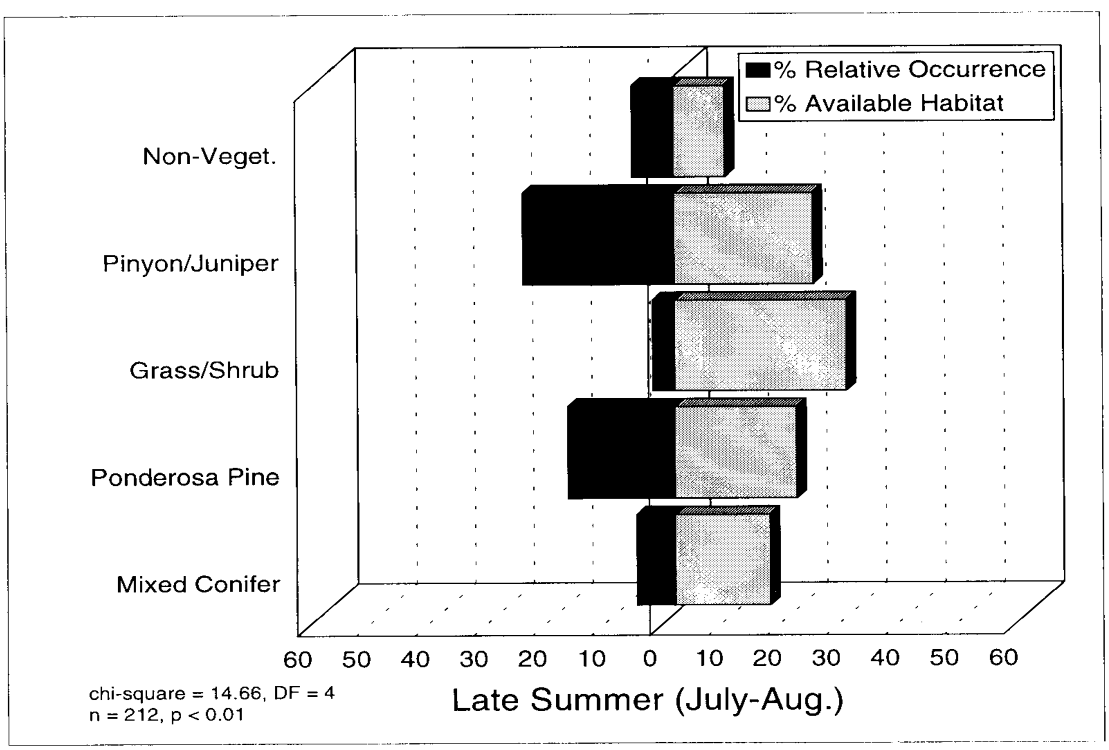
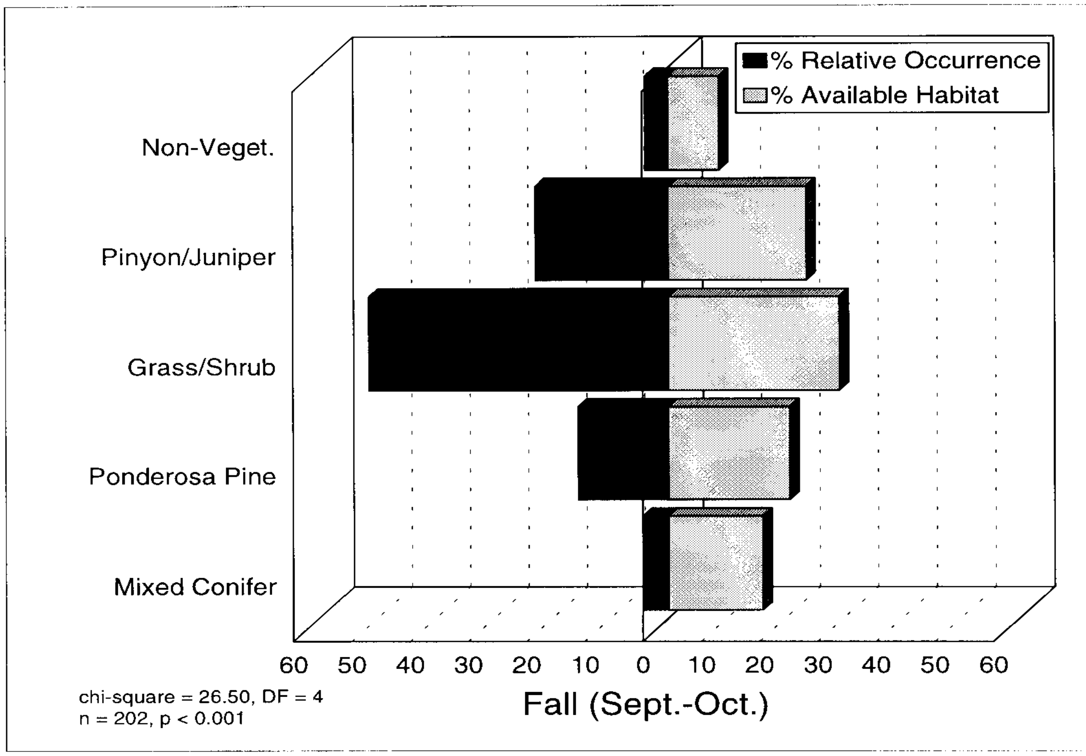


Figure 5. Cow elk use and availability of habitats by season.



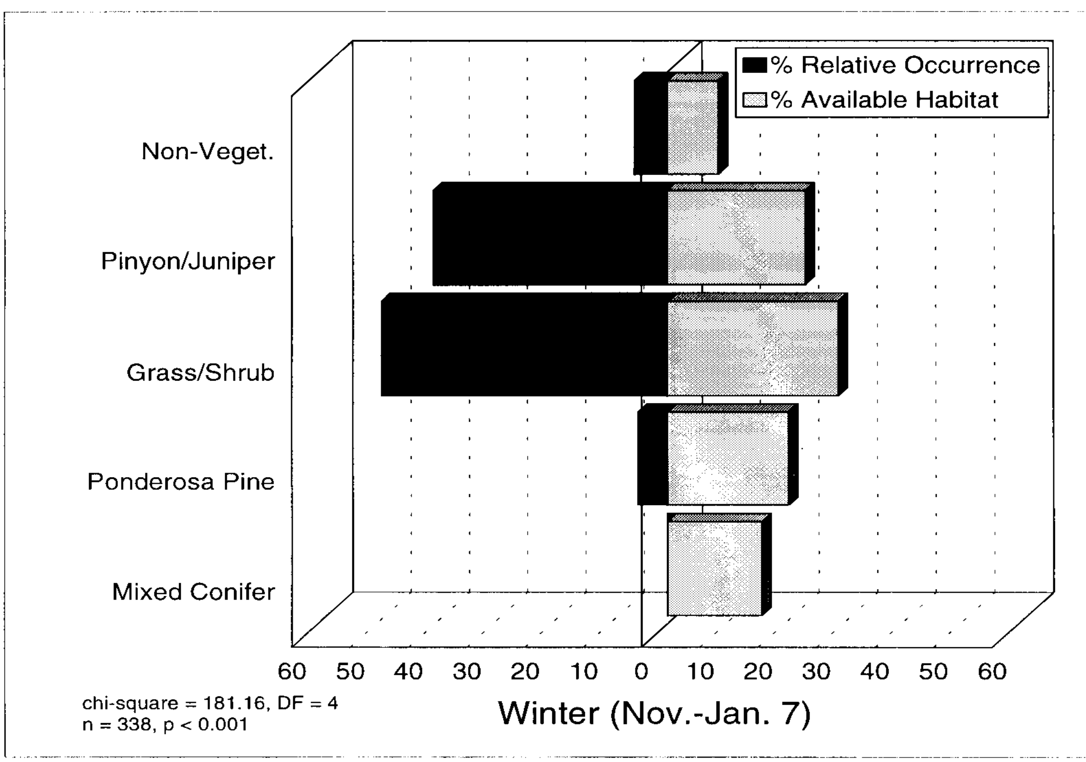


Figure 5 (cont.). Cow elk use and availability of habitats by season.

fixing or while data are uplinking due to animal behavior, or if the antenna has shifted on the animals 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. Other potential reasons for the different reception rates between the test collar and those deployed on elk include excessive cloud cover and human/mechanical errors associated with data transmission and dissemination from the data management center (i.e., Argos).

Prior to this study, we radio collared four elk and one deer on LANL property with VHF units and attempted to obtain 1 to 2 locational fixes per week using triangulation techniques. The 70% reception rate we observed for the GPS collars appears to be as high, if not higher, than rates associated with the use of the VHF units. When considering that only 1 to 2 fixes were being obtained weekly with VHF units, we expended approximately 10 hours per week to locate those animals when locations were relatively constant (non-migratory periods) and in non-canyon (or other steep mountainous terrain) areas (i.e., mesa tops, foothills, open terrain). When animals were expected to be found in steeper canyons, tracking time increased by 50 to 100% due to the remoteness and inaccessibility of that terrain. If we attempted to obtain daily fixes (similar to the GPS collars) the cost would be prohibitively high and limitations on the number of locations we obtained would have been made, as well as the time allotted to obtain each fix. Furthermore, approximately 30 to 40% of the first attempts to locate animals in canyons and other challenging terrain were unsuccessful and attempted again the following day or week. Additional limitations on obtaining fixes included inaccessibility to remote areas during adverse weather conditions, restricted access to private or federal property, and limited access to LANL-secured areas. With the possible exception of excessively cloudy skies and the more steep and narrow canyons, GPS fixes were not limited by those variables. Although the GPS reception rate in canyons may be lower relative to mesa tops and other terrain more visible to satellites, we estimate a greater reception rate and more accurate locational fixes compared to VHF units. This is based in part on the number of revisits to obtain VHF triangulations in canyons and the large estimated triangulation errors frequently associated with those readings.

The lowest reception rates were observed in elk 16037 and 16038. The low reception rates for these animals may be a result of these two individuals spending the majority of their time in more mountainous terrain within ponderosa pine and mixed conifer habitats. These areas consist of steep mountain slopes with narrow canyons which 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.

The migration of elk from low-elevation winter range to high-elevation summer range has been well-documented (Frank and McNaughton 1992; Marcum and Scott 1985). 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 two of the six elk collared in our study exhibited migratory behaviour, one cow and the bull. These two animals moved off LANL property during calving season and remained off LANL until fall. The bull was harvested in September in mountainous terrain west of LANL and therefore it is unknown at what point he would have returned to LANL property. Although it is unknown if the cows we radio collared calved, the remaining four cows remained within LANL boundaries and immediately adjacent to San Ildefonso Pueblo property throughout all seasons. This is the first documented evidence that elk are remaining on LANL property and thus, the Pajarito Plateau on a year-round basis.

Our data showed a strong preference for grass/shrublands at LANL by cow elk during calving, fall, and winter seasons. This is consistent with what has been found in other habitat use studies (Irwin and Peek 1983; Frank and McNaughton 1992). The least amount of use through all seasons by most cows took place in mixed conifer and aspen forests. In contrast, the bull spent considerably more time in these habitats. During all seasons except summer, elk utilized grass/shrub habitats on the Pajarito Plateau greater than expected based on the percent available of each habitat, and utilized taller forested habitats throughout the study area less than expected. In contrast, White (1981) found limited use of open grass/shrublands outside of the winter period and greater use of the taller forested stands.

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 dessicate 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 dessicate 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 remained on the lower-elevation Pajarito Plateau throughout the dry period. The fact that we are now finding 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 (McCorquodale 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.

MANAGEMENT IMPLICATIONS

The use of GPS radio collars for tracking wildlife is not well-documented nor is its effectiveness compared to VHF radio collars. The application of GPS technology to the field of wildlife research is in its infancy stage and much needs to be examined before wide scale application will take place. Although Bennett et al. (1997) did not find significant differences in GPS collar reception rates between varying terrain and habitat types, the study was limited to the LANL area and further testing will be necessary to more accurately quantify GPS collar effectiveness. Rempel et al. (1995) did find significant differences in varying habitat types when testing reception rates of GPS collars in forested areas of Ontario, Canada. However, we estimate, based on previous studies involving VHF telemetry, that with the 70% reception rate we found, the usefulness of GPS collars far exceed VHF units. When using VHF units, we were limited to primarily 0600 to 2000 hrs to obtain fixes. This was due to property ownership accessibility approvals, security safeguards of LANL, and safety considerations related to the more hazardous terrain (steep canyons/slopes). Additionally, personnel labor costs necessary to obtain a similar number of locational fixes using VHF telemetry, would have been prohibitively high. We estimated the cost of acquiring GPS collars was recovered in approximately six months relative to using VHF units if all things were equal with respect to number of attempts to locate animals. This does not include the costs of other field gear, vehicles, etc., necessary to conduct VHF tracking. Locational errors associated with GPS collars is relatively high compared to hand-held GPS units. This is due in part to the current GPS collar model which is unable to record if the fix is 2-dimensional or 3-dimensional (i.e., how many and which satellites were viewed) and therefore differential correction cannot take place. This feature is expected to be added to GPS collars as technology of these collars progresses (S. Tomkiewicz, Telonics, Inc. personal communication).

The initial high cost of GPS collars can prohibit the purchase of multiple collars affecting the sample size of the target species being studied. However, to increase sample size, VHF units may be used in conjunction with GPS collars. The preprogramming capability of GPS collars for obtaining fixes provides the user an opportunity to select specific periods of the day/night by which to monitor the target animal.

We believe the use of GPS collars to be a superior method of tracking wildlife compared to VHF units based on (but not limited to) a greater estimated accuracy of locations, the preprogramming capability of the collars, the reduction in logistical concerns (i.e., access to remote or restricted areas), and the reduction of personnel labor needs and costs as the study progresses. However, the initial high cost per unit and uncertainties associated with the effectiveness of GPS collar use (i.e., locational error, reception rate) currently prohibits its widespread testing in wildlife research. Wildlife researchers should evaluate their data requirement needs (frequency of locational fixes), study area (terrain, vegetation cover types), and labor costs of tracking animals using VHF telemetry, prior to use of GPS radio collars.

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