

# The Influence of Habitat Types, Water Sources, and Movement Barriers on Pronghorn Antelope Home Ranges in Northern Arizona

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**Abstract.** We studied distribution and movement patterns of 17 radio-collared pronghorn antelope within the environs of Wupatki National Monument in northern Arizona. Aside from pronghorn gender differences, individual animal and herd movements were specifically influenced by fencing along main thoroughfares, historical presence of animals, forage succulence and permanently available water sources. From data analyzed and modeled with an Arc Info Geographic Information System, the extreme fragmentation that we observed in our study animals in northern Arizona leads us to believe that rights-of-way fences are a major factor affecting pronghorn movements. To facilitate movement and interchange among herds, it is imperative to reduce the effect of fenced rights-of-way so that pronghorn can freely move as perturbations occur (e.g., winter storms, droughts, fire). Another factor affecting localized movement and influencing homerange is permanently available water, particularly within Wupatki NM. Draw down of the water table by wells, along with anthropogenic manipulation of former natural watering sites, have negatively influenced locations where animals historically watered. This has resulted in no permanent water sources remaining within Wupatki NM. In fact, we found greatest movement out of the park to secure water during September, that time of year when pronghorn are most heavily harvested in northern Arizona. If wildlife managers desire to better manage and coordinate pronghorn populations over a large fragmented landscape in northern Arizona, they will have to pay closer attention to fenced transportation corridors and to the distribution of water sources.

**Key words:** pronghorn antelope, *Antilocapra americana*, movements, homeranges, fences, livestock grazing, GIS, highways, Wupatki National Monument.

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## INTRODUCTION

Pronghorn antelope (*Antilocapra americana americana*) are widely distributed across northern Arizona and occur in isolated patches of habitat throughout the central and southern state. Historically, this species ranged over a large portion of Arizona but in the early 1900s were extirpated from many areas (Nelson 1925). Surveys found only 700 pronghorn in Arizona in 1924, but primarily due to transplants from neighboring states, this number had increased to over 10,000 by the mid 1980's. Despite increases in state-wide numbers, northern Arizona herds appear to have experienced a recent decline (Ockenfels 1994), raising concern for the long-term welfare of pronghorn in Arizona. Additional information about pronghorn home ranges, movements and habitat requirements is needed in order to better manage the present herds and to help ensure their continued survival.

Pronghorn home ranges and movement patterns have been studied in many areas of western North America (e.g., Bayless 1969, Tucker and Garner 1984). Clemente et al. (1995) found that adult pronghorn home ranges averaged 22.5 km<sup>2</sup> in southern New Mexico. Ockenfels et al. (1994) reported home ranges in central Arizona averaged 88 km<sup>2</sup> with some individual animals migrating between northern and southern areas. Based on a review of the literature, Allen et al. (1984) concluded that pronghorn movements are directly controlled by the basic habitat requirements of water and forage as affected by seasonal weather. They felt that pronghorn move large distances only if forced to do so by extreme weather or habitat conditions. O'Gara (1978) stated that "sizes of home and seasonal ranges vary so much with habitat and weather conditions that results of studies seldom have application to another area, or even another year." Thus, to better manage pronghorn in northern Arizona there is a need for research into the basic habitat requirements of these herds.

Pronghorn require a variety of habitats for their essential life activities. They use land forms typified by low, rolling expansive terrain, and although known to occur mainly in grasslands, they also use drier shrub-grass plains, steppes and deserts (Yoakum 1974). Studies of feeding habits have found that pronghorn select forbs when available, turning to browse and grass at other times of the year (Dirschl 1963, Hoover 1966, Taylor 1972, Mitchell and Smoliak 1971, Hailey 1979, Barrett 1980, Roebuck et al. 1982, Howard et al. 1982 and Koerth et al. 1984). Beale and Smith (1970) found that during summers of above average rainfall, forbs made up over 90% of the pronghorn diet. Grass is commonly utilized in early spring and occasionally at other times if new growth appears. Other summaries of dietary preference (Sundstrom et al. 1973, Autenrieth 1978, Allen et al. 1984) agree that pronghorn are opportunistic and selective, taking the most palatable and succulent forage available at each season.

In addition to necessary forage requirements, pronghorn require adequate water sources. Water distribution may restrict movements or cause animals to move into less suitable areas. Ranges that produce and maintain high pronghorn densities have water available every 1.6 km-8.0 km. In Wyoming, 95% of more than 12,000 pronghorn were within a 4.8 km - 6.4 km distance of water (Sundstrom 1968). Boyle

and Alldredge (1984) found that pronghorn numbers observed within 6.4 km of water sources increased through late spring and summer to a maximum of 92% in August - just after measurements of forage moisture content were lowest. Despite the importance of water to productive antelope herds, we found only one study in Arizona that addressed permanent water sources in relation to animal distributions. Ockenfels (1994) found that the majority of pronghorn locations were within a 1.6 km radius of water; however, most of the study area was also within 1.6 km of water.

In addition to biotic factors influencing pronghorn numbers and distributions, many anthropogenic factors influence distribution and population patterns. Human encroachment, in the form of residential and commercial development, as well as road construction reduces and fragments suitable pronghorn habitat. Range management practices of livestock fencing can further fragment and isolate adjacent populations. Overgrazing and trampling from cattle reduces suitable forage and may reduce cover that would serve as pronghorn fawn shelter and seclusion from predators. In addition, overgrazing may allow more rapid tree encroachment into grassland areas, thereby reducing suitable habitat (Neff 1986, Ockenfels 1994). These various limits to pronghorn movements may result in decreased genetic interchange, ultimately leading to low genetic diversity. Populations that drop below minimum viable levels could experience lower fertility, higher fawn mortality and may be more greatly influenced by severe weather, disease or random catastrophic events.

Our study was initiated on land surrounding Wupatki National Monument, to provide much needed information on northern Arizona pronghorn antelope. Wupatki National Monument contains grassland habitats that have not been grazed for over 10 years but are immediately adjacent to currently grazed grasslands, providing a unique opportunity to study pronghorn using multiple habitat types. Monument staff have noted that pronghorn were frequently sighted within the Monument boundaries during fall and winter, but were not as often observed in the spring and summer. Since visitors have indicated that large animal sightings greatly increased their enjoyment of a trip to the Monument (Lee and Stephens, 1995), the park was interested in knowing if and why the animals were leaving. The objectives of our study were to:

- Determine pronghorn home range sizes and core use areas in and around Wupatki National Monument.
- Document the effects of roads and fences on pronghorn movement patterns.
- Determine pronghorn habitat use and their selection of vegetation, slope and aspect variables.
- Determine the effects of water distribution on pronghorn movements.
- Determine the abundance and moisture content of forbs, grasses and shrubs.
- Determine if there are monthly differences in pronghorn distributions and habitat preferences inside and outside the Monument.

## STUDY AREA

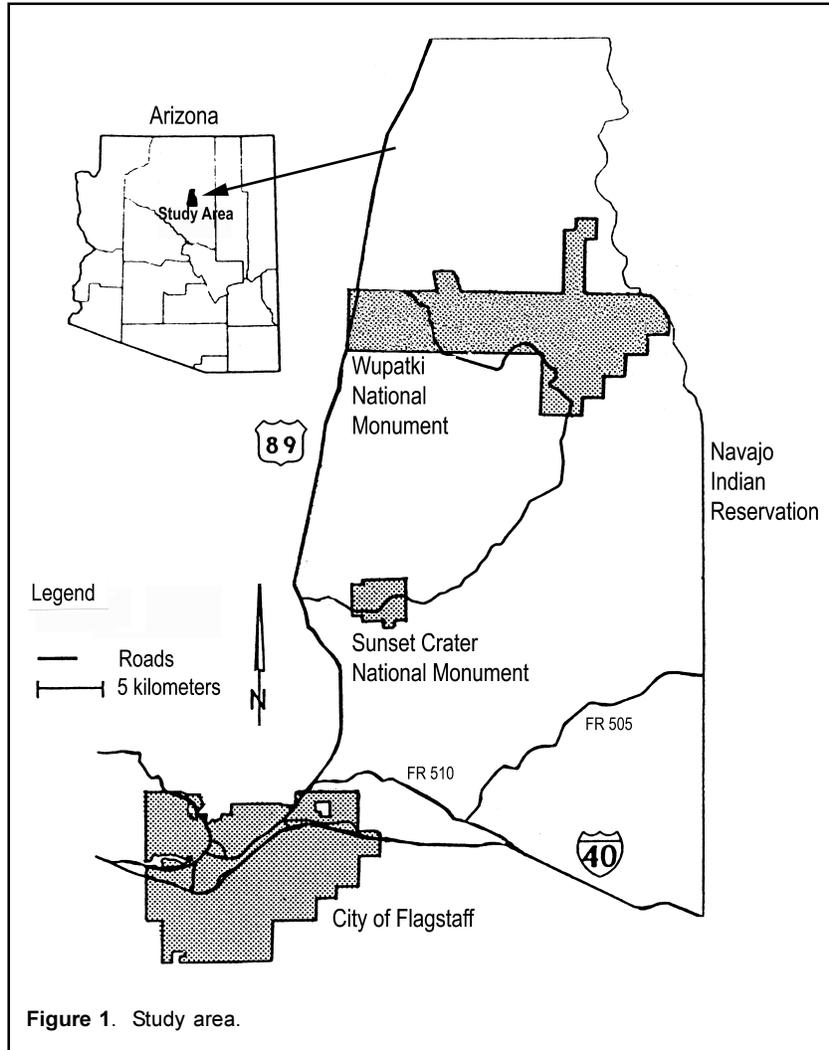
Our study area was centered on Wupatki National Monument, located in north central Arizona, approximately 35 kilometers northeast of Flagstaff (Fig. 1). Terrain was flat to rolling in the north to steeper mountainous areas further south. Chinle badland formations were common in the east while basalt rock outcrops were scattered throughout the study area. Elevations range from 1300 meters north of the Monument to over 2700 meters on O'Leary Peak to the south. Elevations within Wupatki National Monument are generally between 1500 and 1800 meters.

Local climate regimes within the study area vary with elevation. Lower elevations are located in a "rain shadow," northeast of the San Francisco Peaks, where summers are hot, with average high temperatures around 30°C, and lows in the teens. Annual precipitation is 21 cm and most occurs during July and August in the form of brief, heavy but local thundershowers (monsoons). Winters are cooler with high temperatures around 5°C and lows below freezing, with one or two isolated snow showers occurring during this time. The higher elevations to the south are much cooler with considerably more precipitation, mostly in the form of winter snows.

Vegetation varied with elevation, with lower elevations characterized by Great Basin Cold Desert shrublands and grasslands, while middle elevations consisted mostly of open juniper woodlands. Coniferous forests interspersed with open grassland parks occurred in the higher elevations.

The Great Basin Cold Desert Shrub community comprised the lowest elevations (1320 to 1535 meters) of our study area. Topography was rough and broken by several major drainages. Shrubs occurred mainly on scattered hummocks separated by intervening empty areas of deep, black cinders. Dominant shrub species occurring in this community were four-wing saltbush (*Atriplex canescens*), broom snakeweed (*Gutierrezia sarothrae*), Apache plume (*Fallugia paradoxa*), shadscale (*Atriplex confertifolia*), Mormon teas (*Ephedra* spp.), sand sage (*Artemisia filifolia*) and several species of flythicket (*Brickellia* spp.). Grasses constituted less than 5% of ground cover and included galleta (*Pleuraphis* spp.), threeawns (*Aristida* spp.), and bush mulhy (*Muhlenbergia porteri*). The principal forbs were globemallow (*Sphaeralcea subbistata*), buckwheats (*Eriogonum* spp.), spurges (*Euphorbia* spp.), and prince's plume (*Stanleya pinnata*).

Grasslands within the study area were generally flat to rolling terrain. These grasslands were made up of a mixture of grasses dominated by galleta, black grama (*Bouteloua eriopoda*) and New Mexican feathergrass (*Stipa neomexicana*). Rubber rabbitbrush (*Chrysothamnus nauseosus*) and broom snakeweed were the most common shrubs. Other shrubs included threadleaf groundsel (*Senecio longilobus*) and four-wing saltbush. Winter fat (*Krascheninnikovia lanata*), an important forage plant for wildlife, occurred in low density, particularly in the ungrazed National Monument. Common forbs in this community were Russian thistle (*Salsola kali*), globemallow, spurge and several species of aster (*Aster* spp.).



Woodlands occurred on elevations above the grasslands, 1800 meters and higher, where slopes were steeper and the land broken in several areas by deep ravines. The main vegetative components were open and closed stands of one-seed juniper (*Juniperus monosperma*). Snakeweed and rabbitbrush also occurred interspersed throughout these woodlands with a variety of grasses of which galleta grass was the most dominant. Black grama, Fendler threeawn (*Aristida fendleriana*), mesa dropseed (*Sporobolus flexuosus*) and Indian ricegrass (*Oryzopsis hymenoides*) were also common.

Coniferous forests occurred at the highest elevations of our study area, dominated by ponderosa pine (*Pinus ponderosa*) with some pinyon pine (*Pinus edulis*). Cliffrose (*Purshia stansburiana*) and apache plume were common shrubs among the pines. Common grasses were little bluestem (*Andropogon scoparius*), sand bluestem (*Andropogon hallii*) and blue grama (*Bouteloua gracilis*). Several species of penstemon (*Penstemon* spp.) and skyrocket (*Gilia aggregata*) were the dominant forb species, with many other forbs present (Bateman 1976).

## METHODS

### *Capture and Relocation*

Using a net-gun fired from a helicopter, 17 pronghorn antelope were captured in October 1992. Each animal (13 females and 4 males) was fitted with a radio transmitter collar and individually numbered ear tags. Pronghorn were then aerially located twice a month until September 1994 and located on the ground from January 1993 until September 1995. Locations were plotted on 7.5' U.S.G.S. topographical maps and Universal Transverse Mercator coordinates (UTMs) derived to the nearest 0.1-kilometer from mapped locations. Global Positioning System equipment was used during ground surveys to record animal locations. Data collected at each ground site included date, time, dominant vegetation type, slope, aspect, weather variables such as wind speed, temperature, and precipitation. We also recorded pronghorn group size, structure and activity. Data were entered into a computer using FoxPro, verified and then imported into an ArcView Geographic Information System.

### *Home Ranges and Movements*

#### **Home Ranges**

Relocations of collared pronghorn were analyzed using features of the program TELEM (McKelvey 1997). Using the adaptive kernel method (Worton 1989), the 95% contour was used as an estimate of home range size while the 50% contour was used to determine core use areas. Including both aerial and ground locations, pronghorn were located once a week for home range calculations in order to reduce the possibility of auto-correlated data from more frequent observations (White and Garrott 1990). To determine if pronghorn were using the National Monument and the adjacent ranch differently throughout the year, we tested numbers of locations in and out of the Monument by month using chi-square tests. Gender related differences in home range size and differences between home range sizes of animals

captured inside and outside the Monument were tested with t-tests. Interactions between gender and capture location were tested with an ANOVA.

### **Movements**

Pronghorn movements were analyzed by calculating the distance between consecutive locations for individual animals. Consecutive locations were most often between 5 and 9 days apart, with a few more than 10 days. To determine if length of time between locations had an effect on mean distance moved, we tested the movements of a random selection of 5 (of 17) animals to determine whether there was a difference between total relocations and only those between 5 and 9 days. Distance moved was tested for gender and seasonally related differences with ANOVA. Additionally, distance moved between consecutive locations in the Monument and consecutive locations on the ranch were tested seasonally to determine if average consecutive movements differed between the Park and adjacent habitats.

Paved roads and fences were classified by type, digitized and imported into GIS coverages. Number of times pronghorn crossed these potential movement barriers was determined by sorting the data file by individual animal and date, and then counting all movements across roads and fences.

### ***Habitat Mapping***

For habitat preference analyses (vegetation, slope and aspect), in order to have adequate numbers of animal observations in each cell for chi-square tests, we divided the calendar year into three seasons based on local temperature and precipitation regimes. Spring comprised the months March through June and was characterized by warm days, cool nights and low precipitation. Average daily high was 24°C, average low 8°C, and precipitation averaged 4 cm. Summer was classified as July through October. Both day and night temperatures were considerably higher with more precipitation. Average daily high was 30°C, low 15°C and precipitation averaged 9 cm. The third seasonal category was winter (November through February), characterized by cool days and below freezing nights. Average high temperatures were 9°C, low -3°C while precipitation averaged 6 cm.

### **Vegetation Mapping**

This portion of the study tested whether pronghorn use habitats randomly or if they preferentially select habitats, based on the premise that visibility and mobility are important selection factors. A detailed vegetation map was created for Wupatki and the surrounding area by ground-truthing an existing vegetation map for the National Monument and a map of the Babbitt (CO Bar) Ranch, taking into account shrub heights, densities, and density of juniper cover. The map was digitized into a Geographic Information System and then existing polygons corrected from field data. New vegetation polygons were created in the field, when necessary, using a Global Positioning System to produce a final vegetation coverage. The map encompassed over 90% of our pronghorn locations.

We compared the number of times radio-collared pronghorn were observed in each habitat type to expected frequencies based on the area of that vegetation class,

using chi-square tests. When the null hypothesis was rejected (i.e., that all habitat types were not used equally), simultaneous 90% Bonferroni confidence intervals were made for the proportion of times animals used a specific type. To determine whether a habitat type was preferred or avoided, the confidence interval was checked for overlap with the availability proportion of the corresponding habitat type (Neu et al. 1974, Byers et al. 1984, White and Garrott 1990). Differences in preferences for habitat types were analyzed between sexes and among seasons.

### **Slope and Aspect Mapping**

We analyzed slope and aspect preferences by creating coverages and overlaying pronghorn relocations. This was done using USGS digital elevation models and converting them to a grid. We then reclassified the grids into classes: slopes were grouped into three classes (0-9% slope, 10-19% slope and over 20% slope); aspects were grouped into nine classes, north, northeast, east, southeast, south, southwest, west, northwest and no aspect where slopes were less than one percent. These grid coverages were then converted into final polygon coverages for use in ArcView.

Number of times radio collared pronghorn were relocated within each slope and aspect class was compared to expected numbers using chi-square tests, based on the relative abundance of total area for each class. Preference or avoidance of slope and aspect classes were determined using simultaneous Bonferroni confidence intervals. Differences in preferences between sexes and seasons were also analyzed.

### ***Forage Abundance and Succulence***

During the active growing season (March through August), abundance and moisture content of forbs, grasses and shrubs within grassland habitat were collected to determine moisture content differences.

#### **Forage Abundance**

Using vegetation coverage and GIS random plotting technology, six random points a week (three in the Monument and three on adjacent habitats) were selected. We located these points using the navigator feature on the global positioning system. At each point, using a tape measure, two 50 meter straight lines were laid out along the ground in random directions from the point based on spinning a compass dial. We used the line intercept method of Canfield (1941) to determine relative abundance of forbs, grasses and shrubs, by summing up the distance (in cm) of each of these vegetation classes intercepting the tape. Total distance of each vegetation class from a line was averaged and used for analyses. At each random point, we ocularly estimated percent grass cover. Differences in abundance of each vegetation class between transects inside and outside the Monument were analyzed using t-tests. We used ANOVA to test for monthly differences in abundance, linear regressions to determine the relationship between monthly precipitation and average high temperature on the abundance of forage.

#### **Succulence**

Forage moisture content was determined by collecting one sample of each vegetation class (forb, grass, shrub) at the six points each week. Samples were clipped

with scissors, placed in individual brown paper bags, weighed immediately in the field and recorded. Samples were then allowed to air dry in the bags and weight was recorded weekly until 3 consecutive weights were equal, ensuring that each sample had dried completely, then the final dry weight was recorded. Differences between wet and dry weight, divided by wet weight was used to determine percent moisture content of each sample (Kitchen 1974, Rowlands pers. comm. 1995). Percent moisture content for each vegetation class was used to test for differences inside and outside the Monument and for monthly differences. We utilized linear regressions to determine the relationship between monthly precipitation and average high temperature on the succulence of forage.

### *Water Sources*

A GIS coverage of available water was created by locating all water sources within our study area, determining if they were accessible to pronghorn, and if they contained seasonal or year-round water. Accessible waters were digitized in the field using a GPS. Concentric buffers of 2 km were drawn around each water source up to a distance of 10 km. This final GIS coverage was used to analyze pronghorn preferences around water sources, comparing numbers of locations by season within each buffer, to expected numbers based on relative areas of each buffer.

Using the near command in ArcView, the distance to the closest water source was calculated for every pronghorn location. These distances were analyzed by ANOVA to determine differences by sex and season. To determine significant factors affecting pronghorn distances to water, forage abundance, forage succulence, precipitation and average daily high temperature were plotted against each other and analyzed with a forward stepwise regression.

## RESULTS

### *Capture and Relocation*

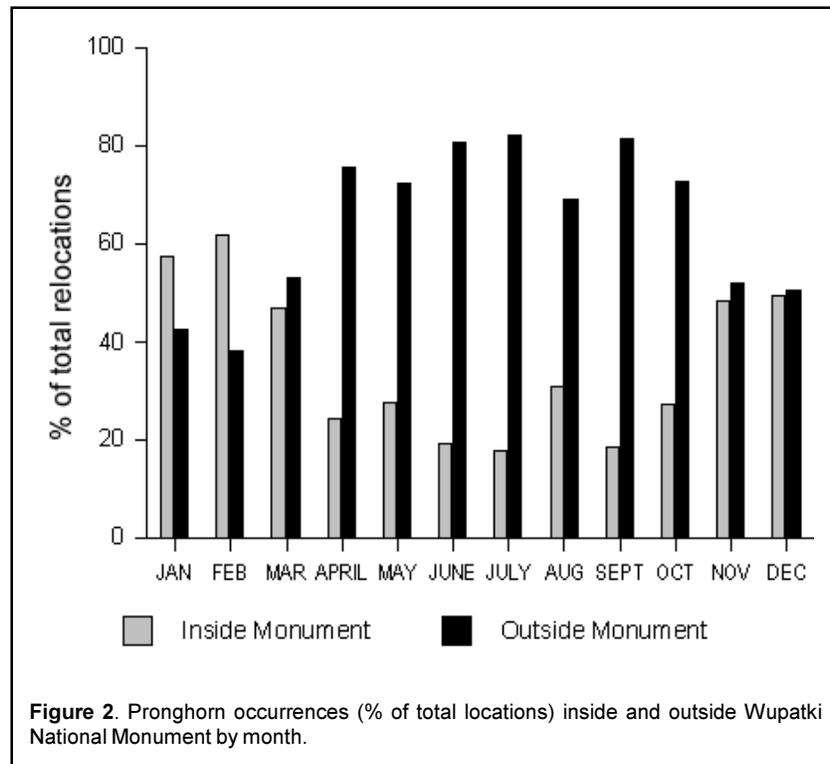
Seventeen pronghorn antelope (13 females and 4 males) were captured and outfitted with radio transmitters. Four females and one male were captured inside Wupatki National Monument while nine females and three males were captured on the CO Bar Ranch. These animals were relocated a total of 1,831 times during the course of this study.

Pronghorn did not use the ranch and the Monument equally ( $\chi^2=158, P<0.05$ , Fig. 2). Pronghorn were located within the Monument as often or more often from November through March. During the remainder of the year, pronghorn were significantly more common outside the Monument.

### *Home Ranges and Movements*

#### **Home Ranges**

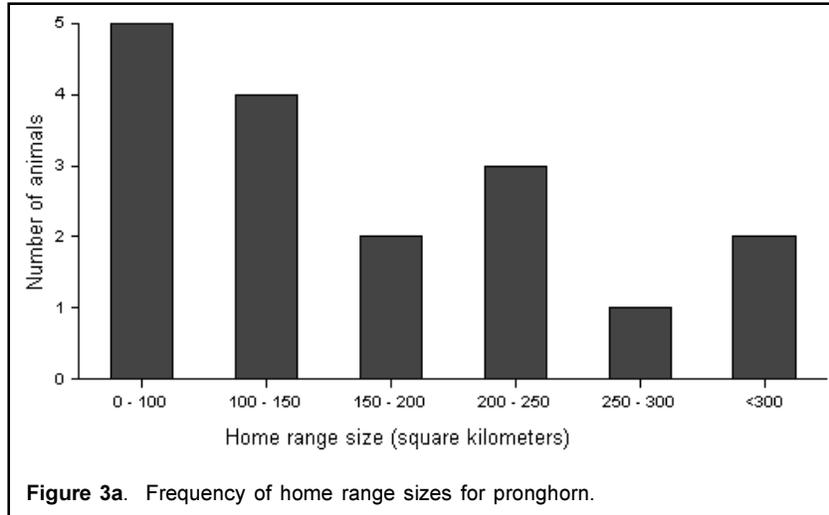
Analysis for normality indicated that home range and core use area size tended to come from a normally distributed population, thus t-tests and ANOVA were used to analyze these data. Home range size varied from 83.6 km<sup>2</sup> to 359.0 km<sup>2</sup>.



Most home ranges were between 80 - 150 km<sup>2</sup> (Fig. 3a). Average home range size for all animals was 169.85 (SE 20.4) km<sup>2</sup>. There were no differences in home range size by sex. Females tended to have larger home ranges, 181.2 (SE 25.1) km<sup>2</sup>, versus 132.8 (SE 25.4) km<sup>2</sup> for males but this difference was not statistically significant ( $t=1.4$ ,  $P>0.05$ ). However, because there were only 4 male versus 13 female pronghorn, unequal sample sizes may have influenced our ability to detect differences.

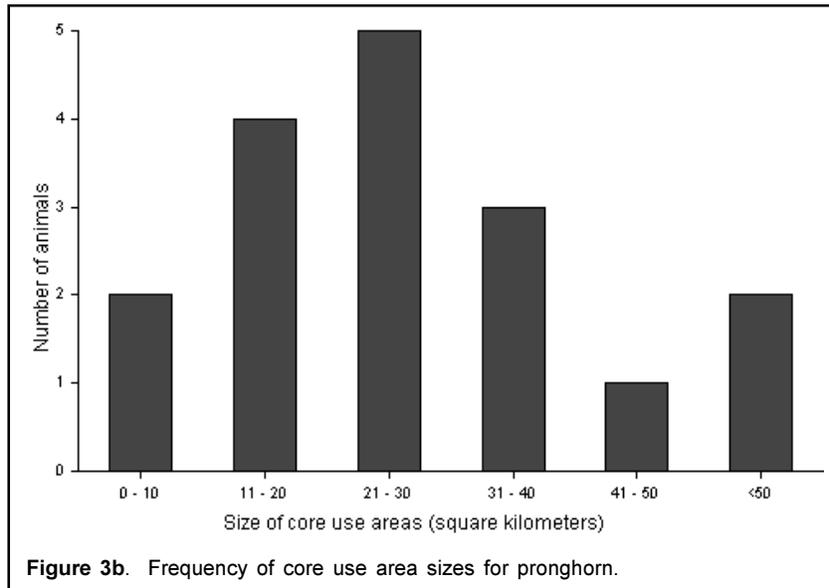
Average home range size for animals captured within the Monument ( $n=5$ ) was 162.6 (SE 36.6) km<sup>2</sup> versus 172.8 (SE 25.5) km<sup>2</sup> for those captured outside ( $n=12$ ). However, these were not significant differences ( $t=0.22$ ,  $P>0.05$ ). Of the 17 pronghorn studied, 15 had home ranges encompassing parts of both the grazed ranch and ungrazed Monument. Two of the pronghorn had home ranges exclusively on the ranch property.

Core use areas of territories also did not differ by sex or capture location. Core use size averaged 27.68 (SE 4.5) km<sup>2</sup>, ranging from 8.8 km<sup>2</sup> to 72.6 km<sup>2</sup>, and clustered around 11 - 30 km<sup>2</sup> (Fig. 3b). Females tended to have larger core use areas, 31.4 (SE 5.4) km<sup>2</sup> compared to 15.6 (SE 3.2) km<sup>2</sup> for males but this was not significant ( $t=1.5$ ,  $P>0.05$ ). Animals captured outside the Monument had larger core use areas than those captured inside, 28.8 (SE 6.1) km<sup>2</sup> and 24.9 (SE 5.0) km<sup>2</sup> respectively, but this also was not a statistically significant difference ( $t=0.43$ ,  $P>0.05$ ).



### Movements

Since no significant difference was detected between using all relocations versus using only those between 5 and 9 days, all relocations were used to determine mean distance moved between consecutive locations. Normality tests revealed that mean distance moved was likely sampled from normally-distributed populations. Mean distance moved by females was 3.42 (SE 0.1) km and males 3.12 (SE 0.1) km and these distances were not significantly different ( $t=1.75$ ,  $P>0.05$ ).

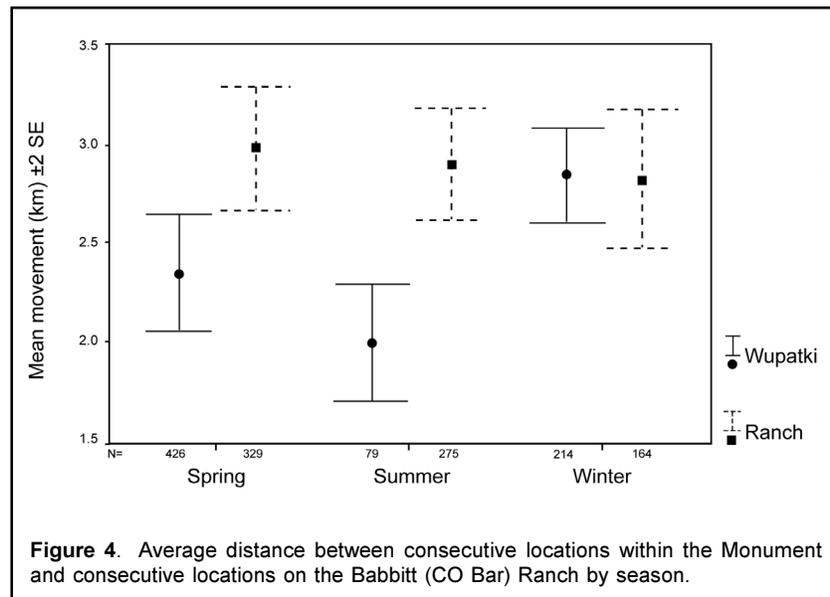


Mean distance moved by month of the year was tested using ANOVA and was significantly different ( $F=2.0, P<0.05$ ). Tukey-HSD test indicated that the only significant monthly differences were between April, with the highest mean distance (3.85 km) and October with the lowest mean distance (2.54 km).

When pronghorn were in the National Monument, they did not move as far between consecutive locations during the spring and summer seasons as when on the ranch ( $t=2.95, P<0.05, t=4.43, P<0.05$ ; Fig. 4). Average distance moved between consecutive locations during spring on the Monument was 2.35 (SE 0.14) km compared to 2.98 (SE 0.15) km on the ranch. During the summer season, movements on the Monument averaged 2.01 (SE 0.14) km compared to 2.90 (SE 0.14) km on the ranch. Movements between consecutive locations during the winter did not differ between animals on the ranch and Monument ( $t=0.14, P>0.05$ , ranch  $2.82 \pm 0.17$  km, Monument  $2.85 \pm 0.12$  km).

Our study area was bounded on the west by US Highway 89, which is a paved two-lane highway with fenced rights-of-way. During the course of the study, no crossings of this highway were recorded for any pronghorn. In fact, several home ranges appeared to be bounded by this highway. The Wupatki-Sunset Crater loop road is a paved, two-lane road without any fences. Pronghorn crossed this road 230 times during the course of the study, and several pronghorn had home ranges straddling this road.

The livestock fence on the north of Wupatki National Monument has been modified to pronghorn standards suggested by O'Gara and Yoakum (1992). It has three strands of barb wire, with the lowest strand smooth wire, and at least 50 cm



above the ground. Pronghorn were located within one kilometer of this fence 189 times during the course of the study and crossed the fence 238 times. The fence on the southern boundary of Wupatki National Monument has not been modified to allow easier access for pronghorn. It is four-strand barbed wire fence with the lower strand only 32 cm above the ground. Pronghorn were located within one kilometer of this fence 117 times but crossed this fence only 75 times. Additional four strand barbed wire interior pasture fences occurred on the CO Bar Ranch, but did not appear to pose crossing problems for pronghorn.

### *Habitat Selection*

#### **Vegetation Selection**

Using a vegetation map created for this study (Fig. 5), the following classes existed within the area encompassing more than 90% of our pronghorn relocations:

Grassland: grasses were the main component with less than 20% cover of 0-60 cm high shrubs.

Shrub-grassland: shrubs were between 20-30% cover but still less than 60 cm high. The main shrubs in this category were either rubber rabbitbrush, snakeweed or shadscale.

Open Juniper grassland: juniper cover was 5-20% and the understory was primarily grasses, with shrubs having less than 20% cover.

Open Juniper shrubland: juniper cover was 5-20% and the understory was made up of more than 20% shrub cover.

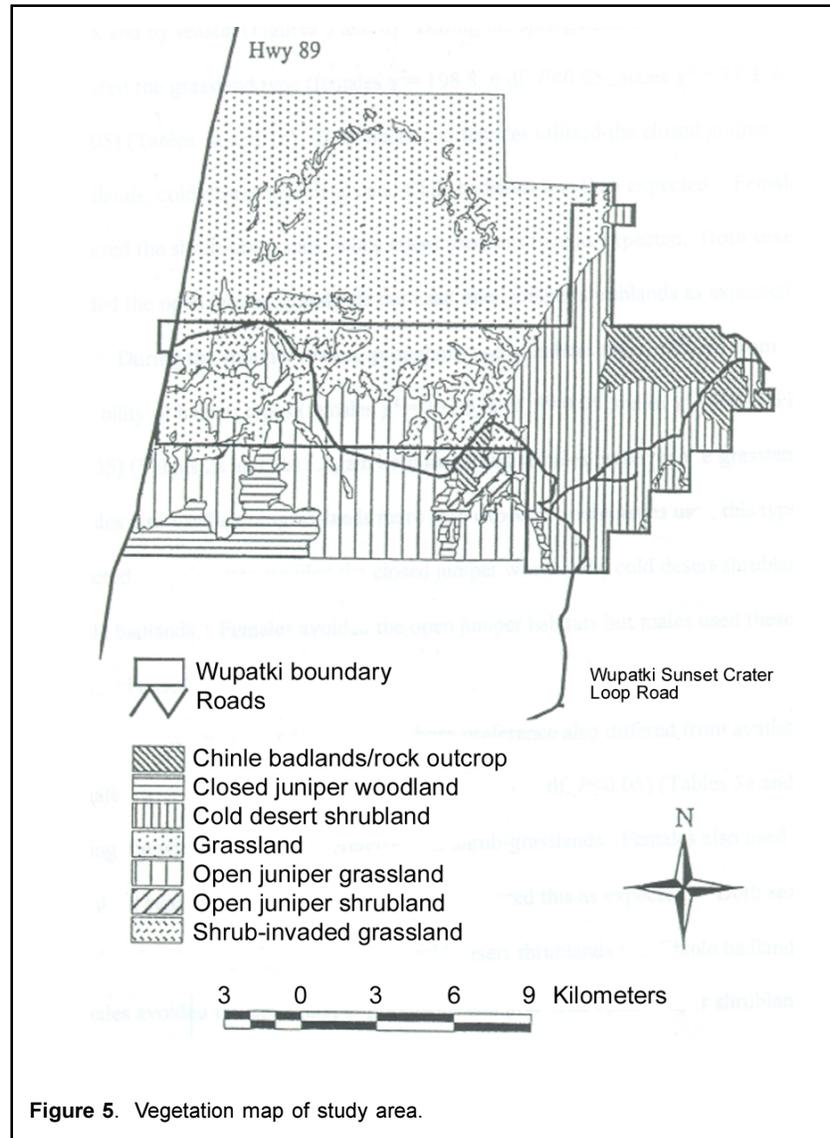
Closed juniper woodland: juniper cover was greater than 20%.

Cold Desert Shrubland: shrubs were the main vegetation (greater than 30% cover) and typically greater than 60 cm high. Common shrubs were Mormon tea, Apache plume, squawbush, snakeweed, rabbitbrush, four-wing saltbush.

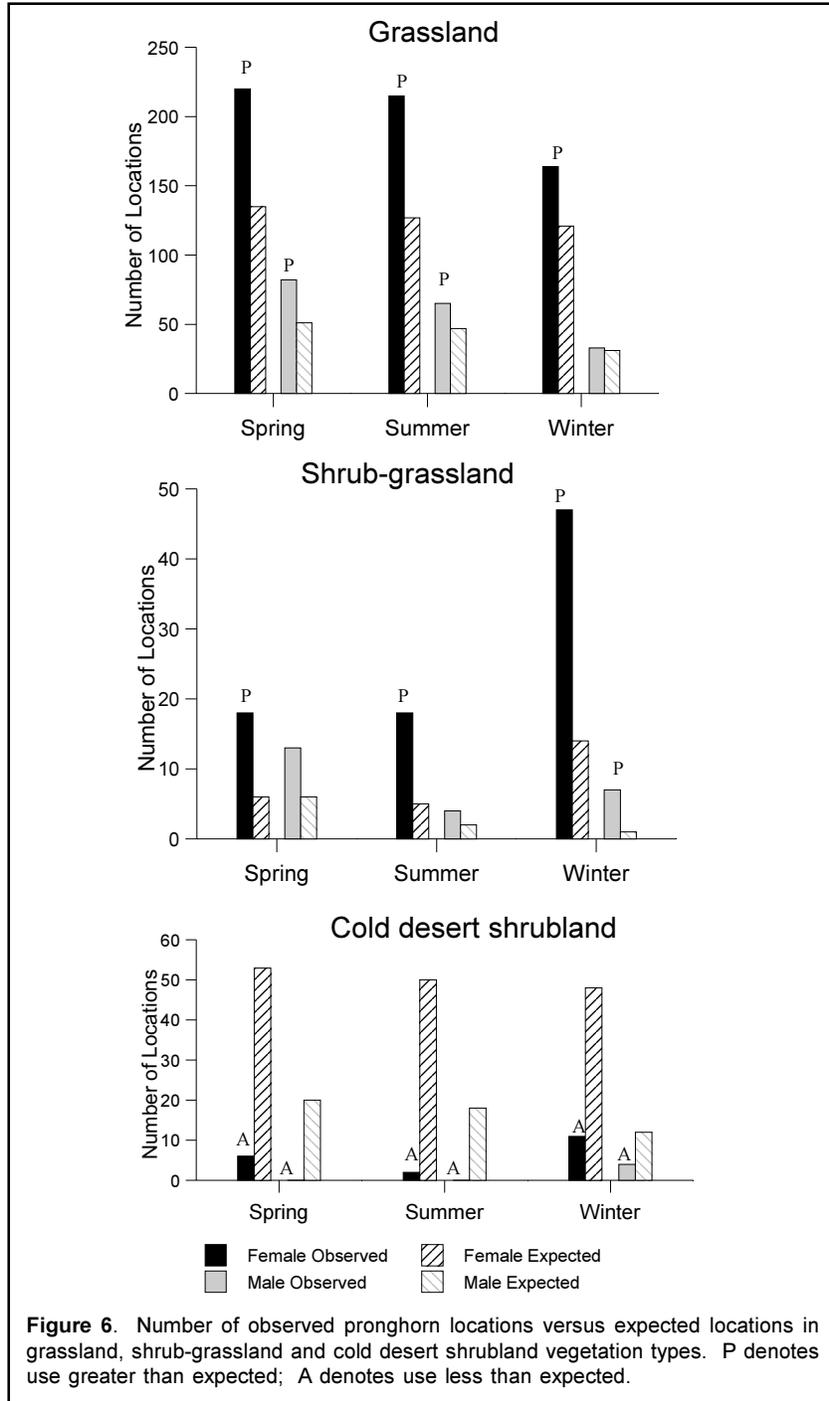
Chinle Badlands/ Rock Outcrops: bare ground or deep cinders predominated.

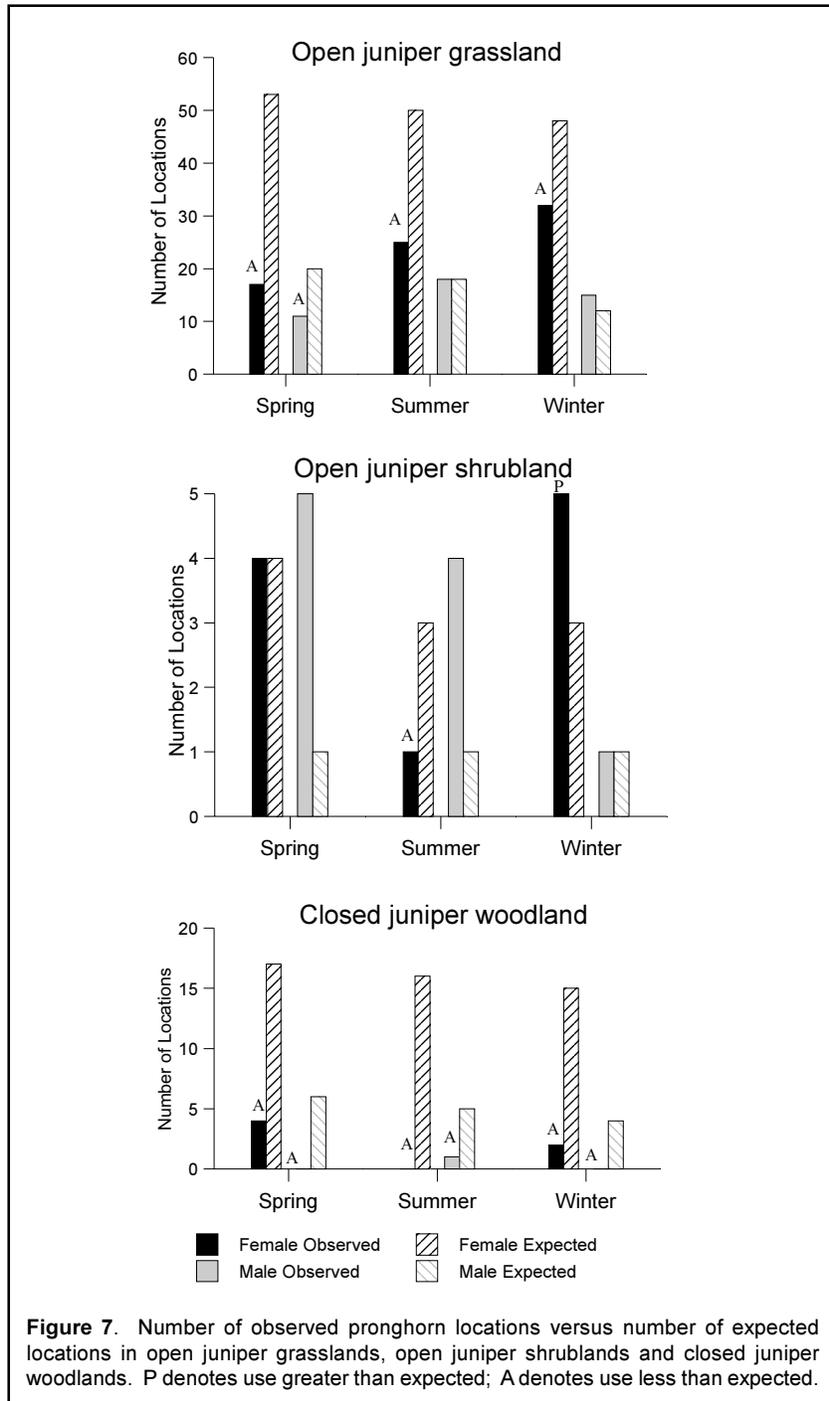
In testing pronghorn relocations against expected numbers, based on area of each vegetation type, we found that animal use of vegetation types differed from expected based on area by sex and by season (Figs. 6 and 7). During the spring season both females and males preferred the grassland type (females  $\chi^2 = 198.8$ , 6 df,  $P < 0.05$ , males  $\chi^2 = 73.3$ , 6 df,  $P < 0.05$ ; Tables 1a and 1b). Males and females utilized the closed juniper woodlands, cold desert shrublands and Chinle badlands less than expected. Females also preferred the shrub-grasslands, while males used this type as expected. Both sexes avoided the open juniper grasslands but used open juniper shrublands as expected.

During the summer season, pronghorn use differed from availability of habitat types (females  $\chi^2 = 191.5$ , 6 df,  $P < 0.05$ ; males  $\chi^2 = 54.9$ , 6 df,  $P < 0.05$ ; Tables 2a and 2b). Males and females preferred the grassland type. Females used shrub-grasslands more than expected while males used this type as expected. Both sexes avoided the closed juniper woodlands, cold desert shrublands and Chinle badlands. Females avoided the open juniper habitat, but males used this type as expected.



During the winter season, pronghorn habitat preference differed from availability (females  $\chi^2=168.1$ , 6 df,  $P<0.05$ ; males  $\chi^2=77.1$ , 6 df,  $P<0.05$ ; Tables 3a and 3b), with both sexes preferring the shrub-grasslands. Females also used the grassland type more than expected, while males used it as expected. Both sexes avoided the closed juniper woodlands, cold desert shrublands and Chinle badlands. Females avoided the open juniper grasslands and preferred open juniper shrublands, while males used both types as expected.





**Table 1a.** Use of vegetation classes by female pronghorn compared to availability of vegetation classes in spring (March-June). Use differed from availability ( $\chi^2=198.8$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	220	135	0.444	0.65 - 0.79	Prefer
Shrub-grassland	18	6	0.019	0.02 - 0.09	Prefer
Open juniper grassland	17	53	0.176	0.02 - 0.09	Avoid
Open juniper shrubland	4	4	0.012	0.00 - 0.03	
Closed juniper woodland	4	17	0.057	0.00 - 0.03	Avoid
Cold desert shrubland	6	53	0.176	0.00 - 0.03	Avoid
Rock outcrops	0	16	0.053		Avoid

#### Slope and Aspect Selection

Pronghorn did not use slopes as expected based on availability. In addition, use of slope-classes differed by sex and season. During spring season, females preferred gentle slopes, used intermediate slopes equal to their availability, and avoided steeper slopes ( $\chi^2=20.3$ , 2 df,  $P<0.05$ ). Males avoided steeper slopes and showed no preferences for either gentle or intermediate slopes ( $\chi^2=9.4$ , 2 df,  $P<0.05$ ; Table 4a).

During the summer, females preferred gentle slopes between 0-9% and avoided intermediate (10%-19%) and steeper slopes ( $\chi^2=45.2$ , 2 df,  $P<0.05$ ). Males preferred intermediate slopes, avoided steep slopes and used gentle slopes as expected ( $\chi^2=16.4$ , 2 df,  $P<0.05$ ; Table 4b).

During the winter season, females preferred gentle while avoiding intermediate and steep slopes ( $\chi^2=59.4$ , 2 df,  $P<0.05$ ). Males avoided steep slopes but demon-

**Table 1b.** Use of vegetation classes by male pronghorn compared to availability of vegetation classes in spring (March-June). Use differed from availability ( $\chi^2=73.3$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	82	515	0.444	0.60 - 0.82	Prefer
Shrub-grassland	13	6	0.019	0.00 - 0.06	
Open juniper grassland	11	20	0.176	0.02 - 0.16	Avoid
Open juniper shrubland	5	1	0.012	0.00 - 0.09	
Closed juniper woodland	0	6	0.057		Avoid
Cold desert shrubland	0	20	0.176		Avoid
Rock outcrops	1	6	0.053	0.01 - 0.03	Avoid

**Table 2a.** Use of vegetation classes by female pronghorn compared to availability of vegetation classes in summer (July-October). Use differed from availability ( $\chi^2=191.5$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	215	127	0.444	0.68 - 0.81	Prefer
Shrub-grassland	18	5	0.019	0.03 - 0.09	Prefer
Open juniper grassland	25	50	0.176	0.04 - 0.13	Avoid
Open juniper shrubland	1	3	0.012	0.00 - 0.01	Avoid
Closed juniper woodland	0	16	0.057		Avoid
Cold desert shrubland	2	50	0.176	0.00 - 0.02	Avoid
Rock outcrops	0	5	0.053		Avoid

strated no preference for gentle or intermediate slopes ( $\chi^2=13.2$ , 2 df,  $P<0.05$ ; Table 4c, Fig. 8).

No selection of any aspect classes was detected for pronghorn during the spring season ( $\chi^2=7.4$ ,  $P>0.05$ ; Table 5a), but they did not use aspect classes equal to availability during summer and winter seasons ( $\chi^2=29.2$  and  $\chi^2=44.6$  respectively,  $P<0.05$ ; Tables 5b and 5c). During the summer season, pronghorn selected for or used, as expected, the cooler northern exposures but avoided hot and windy southerly exposures. During the winter season, pronghorn selected the northeast aspect or areas with no aspect (slope < 1%) and avoided southern aspects. All other slope aspects were used as expected.

### *Forage Abundance and Succulence*

#### *Forage Abundance*

Forbs and grasses were significantly more abundant on our transects within

**Table 2b.** Use of vegetation classes by male pronghorn compared to availability of vegetation classes in summer (July-October). Use differed from availability ( $\chi^2=54.9$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	65	47	0.444	0.49 - 0.74	Prefer
Shrub-grassland	4	2	0.019	0.01 - 0.08	
Open juniper grassland	18	18	0.176	0.07 - 0.26	
Open juniper shrubland	4	1	0.012	0.01 - 0.08	
Closed juniper woodland	1	5	0.057	0.01 - 0.03	Avoid
Cold desert shrubland	0	18	0.176		Avoid
Rock outcrops	0	5	0.053		Avoid

**Table 3a.** Use of vegetation classes by female pronghorn compared to availability of vegetation classes in winter (November-February). Use differed from availability ( $\chi^2=168.1$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	164	121	0.444	0.52 - 0.68	Prefer
Shrub-grassland	47	14	0.019	0.03 - 0.08	Prefer
Open juniper grassland	32	48	0.176	0.07 - 0.17	Avoid
Open juniper shrubland	5	3	0.012	0.02 - 0.04	Prefer
Closed juniper woodland	2	15	0.057	0.00 - 0.02	Avoid
Cold desert shrubland	11	48	0.176	0.01 - 0.07	Avoid
Rock outcrops	0	14	0.053		Avoid

than outside Wupatki National Monument. Forbs inside were 12.3 cm (SE 1.6) while they were only 6.4 cm (SE 0.87) outside ( $t=3.3$ ,  $P<0.05$ ). Grasses inside were 60.5 cm (SE 1.3) and 52.4 (SE 0.9) outside ( $t=5.0$ ,  $P<0.05$ ). Shrubs did not differ significantly in abundance being 6.2 cm (SE 1.2) inside and 5.3 cm (SE 1.3) outside ( $t=0.4$ ,  $P>0.05$ ; Fig. 9).

With all vegetation classes (forb, grass and shrub), abundance differed significantly by month ( $F=5.8$ ,  $P<0.01$ ;  $F=2.4$ ,  $P=0.04$ ;  $F=2.5$ ,  $P=0.03$  respectively; Table 6). There were significantly more forbs in March and April, while differences between other months were not significant. Grasses on our grazed transects were least abundant in May and June. However, in the Monument transects, grass abundance was lowest in March and April.

#### Succulence

Mean moisture content of forbs ( $t=1.8$ ,  $P>0.05$ ) and new growth on shrubs ( $t=1.6$ ,  $P>0.05$ ) did not differ inside and outside the Monument throughout the

**Table 3b.** Use of vegetation classes by male pronghorn compared to availability of vegetation classes in winter (November-February). Use differed from availability ( $\chi^2=77.1$ , 6 df,  $P<0.05$ ).

Vegetation Class	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
Grassland	33	31	0.444	0.31 - 0.62	
Shrub-grassland	7	1	0.019	0.01 - 0.19	Prefer
Open juniper grassland	15	12	0.176	0.09 - 0.34	
Open juniper shrubland	1	1	0.012	0.00 - 0.05	
Closed juniper woodland	0	4	0.057		Avoid
Cold desert shrubland	4	12	0.176	0.01 - 0.12	Avoid
Rock outcrops	0	4	0.053		Avoid

**Table 4a.** Use of slope classes by pronghorn compared with slope availability during the spring (March-June) season. Use differed from availability for females ( $\chi^2 = 20.3$ , 2 df,  $P < 0.05$ ) and males ( $\chi^2 = 9.4$ , 2 df,  $P < 0.05$ ).

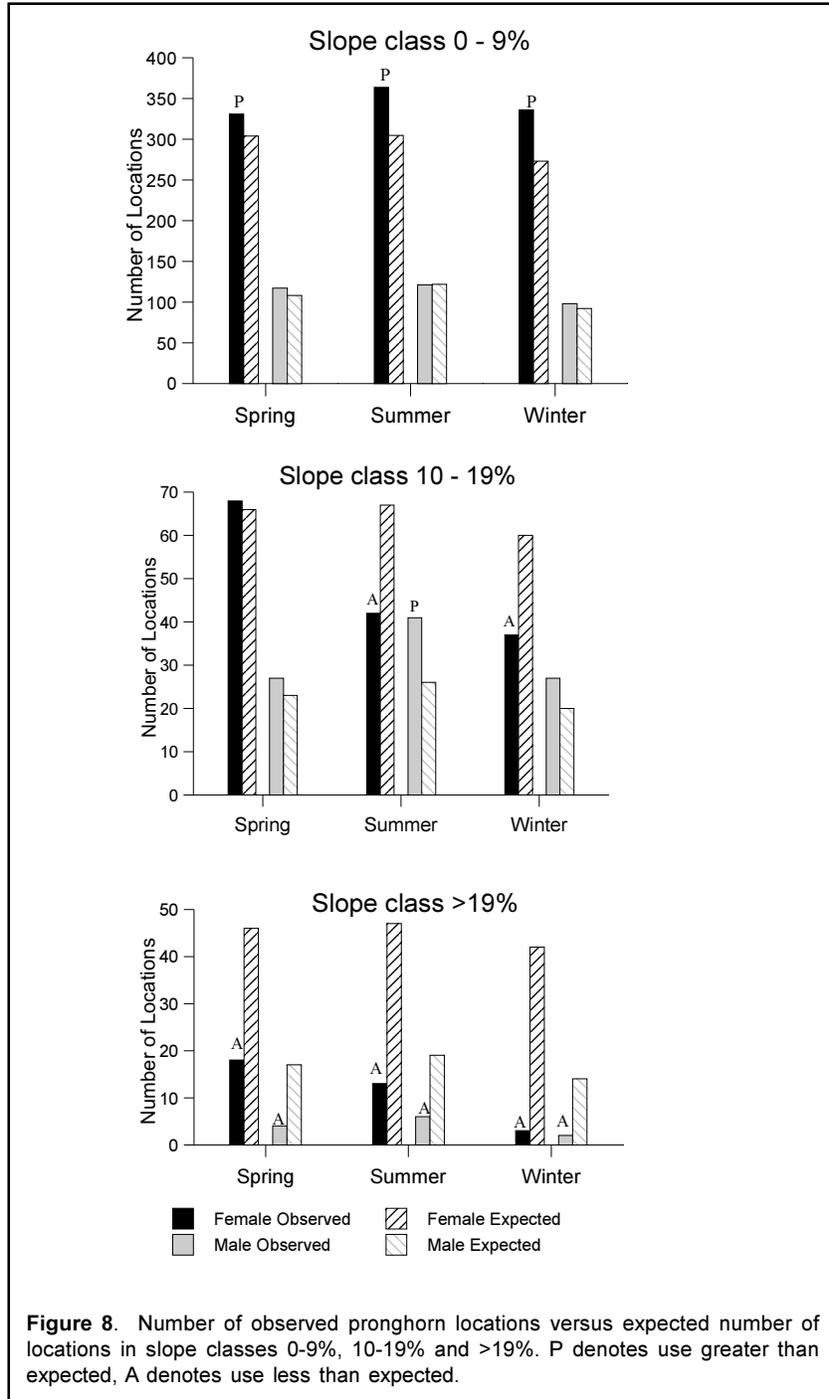
Sex	Slope Class (%)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 9	331	304	0.73	0.75 - 0.84	Prefer
	10 - 19	68	66	0.16	0.12 - 0.20	
	≥ 20	18	46	0.11	0.02 - 0.06	Avoid
Male	0 - 9	117	108	0.73	0.71 - 0.86	
	10 - 19	27	23	0.16	0.11 - 0.25	
	≥ 20	5	17	0.11	0.00 - 0.07	Avoid

**Table 4b.** Use of slope classes by pronghorn compared with slope availability during the summer (July-October) season. Use differed from availability for females ( $\chi^2 = 45.2$ , 2 df,  $P < 0.05$ ) and males ( $\chi^2 = 16.4$ , 2 df,  $P < 0.05$ ).

Sex	Slope Class (%)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 9	364	305	0.73	0.83 - 0.90	Prefer
	10 - 19	42	67	0.16	0.07 - 0.13	Avoid
	≥ 20	13	47	0.11	0.02 - 0.05	Avoid
Male	0 - 9	121	122	0.73	0.64 - 0.80	
	10 - 19	41	26	0.16	0.17 - 0.32	Prefer
	≥ 20	6	19	0.11	0.00 - 0.07	Avoid

**Table 4c.** Use of slope classes by pronghorn compared with slope availability during the winter (November-February) season. Use differed from availability for females ( $\chi^2 = 59.4$ , 2 df,  $P < 0.05$ ) and males ( $\chi^2 = 13.2$ , 2 df,  $P < 0.05$ ).

Sex	Slope Class (%)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 9	336	273	0.73	0.86 - 0.93	Prefer
	10 - 19	37	60	0.16	0.06 - 0.13	Avoid
	≥ 20	3	42	0.11	0.00 - 0.02	Avoid
Male	0 - 9	98	92	0.73	0.69 - 0.85	
	10 - 19	27	20	0.16	0.13 - 0.29	
	≥ 20	2	14	0.11	0.00 - 0.04	Avoid



**Table 5a.** Use of aspect classes by pronghorn compared with aspect availability during the spring (March - June) season. Use did not differ from availability ( $\chi^2 = 7.44$ , 8 df,  $P > 0.05$ ).

Aspect	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
North	115	107	0.17	0.15 - 0.22	
Northeast	122	123	0.20	0.16 - 0.24	
East	106	105	0.17	0.13 - 0.21	
Southeast	90	90	0.15	0.11 - 0.18	
South	51	59	0.10	0.05 - 0.11	
Southwest	35	31	0.05	0.03 - 0.08	
West	34	33	0.05	0.03 - 0.078	
Northwest	45	53	0.09	0.05 - 0.10	
No Aspect	18	11	0.01	0.00 - 0.07	

**Table 5b.** Use of aspect classes by pronghorn compared with aspect availability during the summer (July - October) season. Use did not differ from availability ( $\chi^2 = 29.2$ , 8 df,  $P > 0.05$ ).

Aspect	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
North	136	98	0.17	0.20 - 0.29	Prefer
Northeast	118	112	0.20	0.17 - 0.25	
East	88	95	0.17	0.12 - 0.20	
Southeast	62	82	0.15	0.08 - 0.14	Avoid
South	51	54	0.10	0.06 - 0.12	
Southwest	19	28	0.05	0.01 - 0.053	
West	22	30	0.05	0.02 - 0.06	
Northwest	48	48	0.09	0.05 - 0.11	
No Aspect	16	10	0.01	0.01 - 0.05	

**Table 5c.** Use of aspect classes by pronghorn compared with aspect availability during the winter (November - February) season. Use differed from availability ( $\chi^2 = 44.6$ , 8 df,  $P < 0.05$ ).

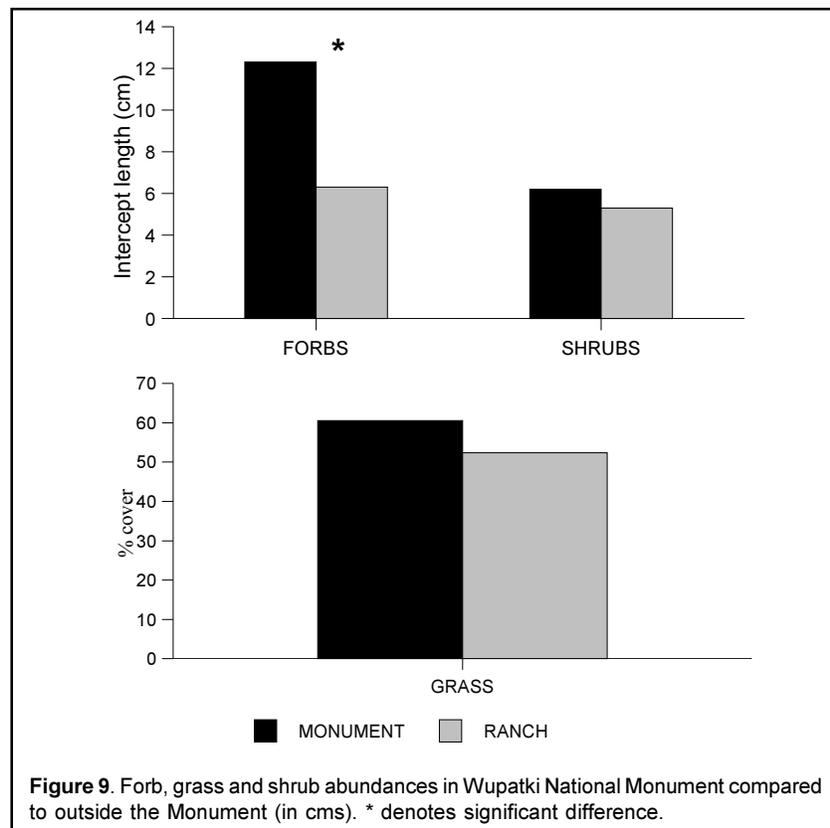
Aspect	Observed # of locations	Expected # of locations	Proportion of area available	Bonferroni 90% CI	Preference
North	79	88	0.17	0.11 - 0.20	
Northeast	137	100	0.20	0.22 - 0.32	Prefer
East	89	86	0.17	0.13 - 0.22	
Southeast	62	73	0.15	0.08 - 0.16	
South	27	48	0.10	0.03 - 0.08	Avoid
Southwest	21	25	0.05	0.02 - 0.06	
West	28	27	0.05	0.02 - 0.08	
Northwest	38	43	0.09	0.04 - 0.10	
No Aspect	22	9	0.01	0.02 - 0.07	Prefer

collection period. Average forb moisture content in the Monument was 44.8% (SE 1.6%) and outside 40.9% (SE 1.4%). New growth on shrubs averaged 37.7% (SE 0.9%) on grazed sites and 35.9% (SE 0.7%) on the ungrazed transects. Grasses were significantly more succulent in the grazed sites (27.2 SE 1.1%) than in ungrazed transects (21.2 SE 1.5%), ( $t=3.3$ ,  $P<0.05$ ; Fig. 10).

March and April forb moisture content averaged  $51.9 \pm 12.3\%$ . Average succulence for the remainder of the collection period was  $40.1 \pm 7.9\%$ . Differences between monthly forage succulence were significant ( $F=6.4$ ,  $P<0.01$ ). Tukey's HSD tests revealed that forbs had significantly more moisture in the early spring in the Monument and grazed sites.

Average moisture content in July for shrubs was  $40.1 \pm 4.0\%$ . It was lowest in March with an average of  $32.8 \pm 3.6\%$ . Moisture content for new growth on shrubs differed by month ( $F=4.0$ ,  $P<0.01$ ). Tukey's HSD test showed that new growth on shrubs had more moisture later in the summer than spring.

Grasses also differed significantly in moisture content by month ( $F=3.1$ ,  $P=0.02$ ). Tukey's HSD tests revealed that grasses were significantly more succulent in April ( $t=30.8 \pm 8.9\%$ ). August had the lowest average succulence ( $t=19.8 \pm 8.3\%$ ).



**Table 6.** Monthly mean abundance of forbs, shrubs and grasses in the park and on the grazed CO Bar Ranch.

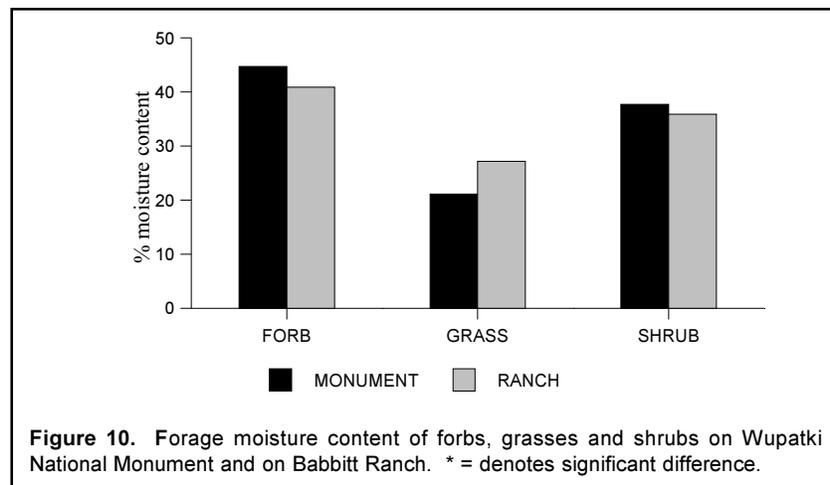
Month	Forbs (cm)		Shrub(cm)		Grass (%)	
	Park	Grazed	Park	Grazed	Park	Grazed
March	21.0	1.2	6.2	19.3	61.6	57.5
April	25.9	11.5	12.6	5.0	51.1	54.4
May	10.2	3.7	3.3	1.0	63.3	45.5
June	10.8	5.7	3.9	5.5	60.5	47.2
July	5.8	5.22	4.0	1.9	63.9	55.2
Aug	7.3	6.9	6.8	8.5	62.8	55.0

Neither average daily high temperature ( $r^2 = 0.44$ ,  $P > .05$ ), nor precipitation ( $r^2 = 0.62$ ,  $P > .05$ ) was significantly related to the monthly abundance of forbs. However, monthly succulence level of forbs was inversely related to the average monthly high temperatures ( $r^2 = 0.66$ ,  $P < .05$ ). As temperatures rose, succulence dropped in forbs. Precipitation levels were not statistically significant in determining succulence ( $r^2 = 0.53$ ,  $P > .05$ ).

### Water Use

#### 2 km Concentric Buffers

Pronghorn did not use the 2 km buffers around water sources as would be expected based on area within these buffers. During the year, 84% of all pronghorn locations were less than 6 km from a water source (Fig. 11). In the spring season, use of buffers differed from availability for females and males (females  $\chi^2 = 86.5$ , 4 df,



$P < 0.05$ ; males  $\chi^2 = 103.586.5$ , 4 df,  $P < 0.05$ ; Table 7a). Females preferred the 0-1.99 km buffer and avoided areas greater than 8 km, with all other buffers being used as expected. Males preferred 0-3.99 km buffers, and avoided areas greater than 6 km.

During the summer season, buffer use differed from availability for females and males (females  $\chi^2 = 126.3$ , 4 df,  $P < 0.05$ ; males  $\chi^2 = 74.4$ , 4 df,  $P < 0.05$ ; Table 7b). Throughout the summer they preferred buffers up to 3.99 km from water. Males avoided areas greater than 6 km while females avoided those greater than 8 km from water.

During the winter season (Fig. 12), buffer area use differed from availability, but females and males used the buffers similarly (females  $\chi^2 = 122.6$ , 4 df,  $P < 0.05$ ; males  $\chi^2 = 64.4$ , 4 df,  $P < 0.05$ ; Table 7c). During winter, both sexes preferred the 2-3.99 km buffer and used the 0-1.99 km and 4-5.99 km buffers as expected, but avoided areas greater than 6 km from water.

#### **Mean Distance from Water**

Mean distance of pronghorn sightings to water did not differ significantly by year during this study ( $F = 0.52$ ,  $P > 0.05$ ), but mean distance to water differed by sex and season, and by location within and outside the Monument. Female pronghorn were found farther from water sources than males during the spring season ( $t = 3.43$ ,  $P < 0.01$ ) but there was no difference between sexes during the summer or winter. Females were significantly ( $F = 13.7$ ,  $P < 0.05$ ) closer to water during the summer (2845 SE 91 m) than spring or winter, the latter not being significantly different (spring 3,514 SE 102 m, winter 3,475 SE 106 m). Males were farther from water in the winter (3,332 SE 145 m) than either spring or summer ( $F = 6.0$ ,  $P < 0.05$ ), which did not differ (spring 2,732 SE 123 m, summer 2,738 SE 148 m) (Fig. 13).

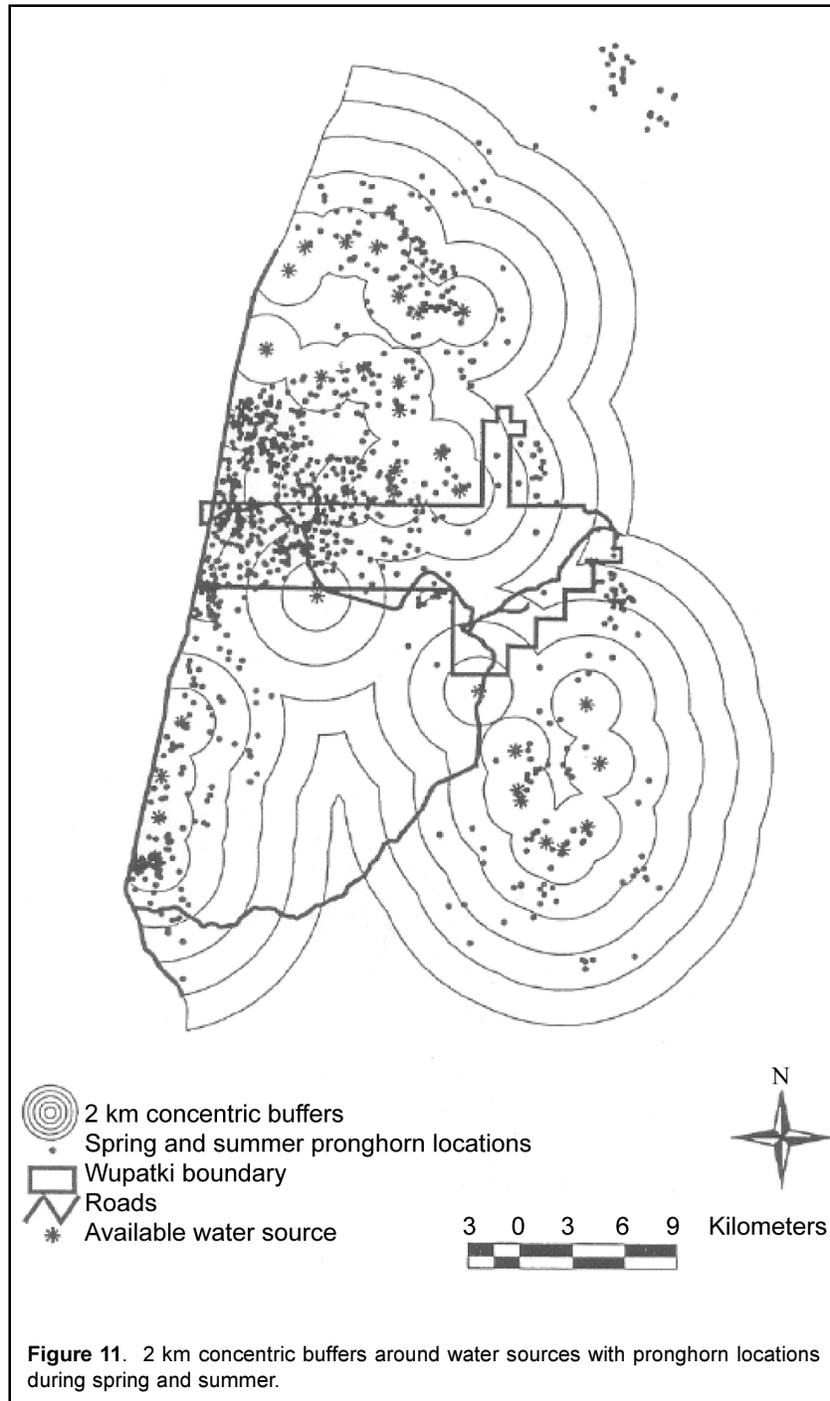
Pronghorn, when located within the Monument boundaries, were significantly farther from water than when located outside the Monument ( $t = 9.47$ ,  $P < 0.05$ ). Mean distance within was  $4,305 \pm 73.7$  meters compared to  $3,285 \pm 78.5$  meters outside the Monument.

When forb succulence, forage abundance, monthly average high temperatures, and precipitation were used to determine relationships to distance-from-water, only monthly high temperature was significant ( $r^2 = 0.66$ ,  $P < 0.05$ ). As temperatures rose, pronghorn moved closer to available waters. Neither forb succulence ( $r^2 = 0.21$ ,  $P > 0.05$ ), forage abundance ( $r^2 = 0.10$ ,  $P > 0.05$ ), nor precipitation ( $r^2 = 0.30$ ,  $P > 0.05$ ) were significantly correlated with distance to water.

## **DISCUSSION**

### ***Home Ranges, Movements and Distribution***

Home range size for all radio-collared pronghorn that we studied averaged 16,900 ha and were considerably larger than the 156 - 2300 ha reported as typical home range sizes by Kitchen and O'Gara (1982). They were almost twice the size of home ranges reported by Ockenfels et al. (1994) from central Arizona. Most of our radio-



**Table 7a.** Distances of pronghorn locations from identified water sources compared with area within isometric 2.0 km concentric buffers around water sources during spring. Use differed from availability for females ( $\chi^2 = 86.5, 74.4, df, P < 0.05$ ) and males ( $\chi^2 = 103.5, 4 df, P < 0.05$ ).

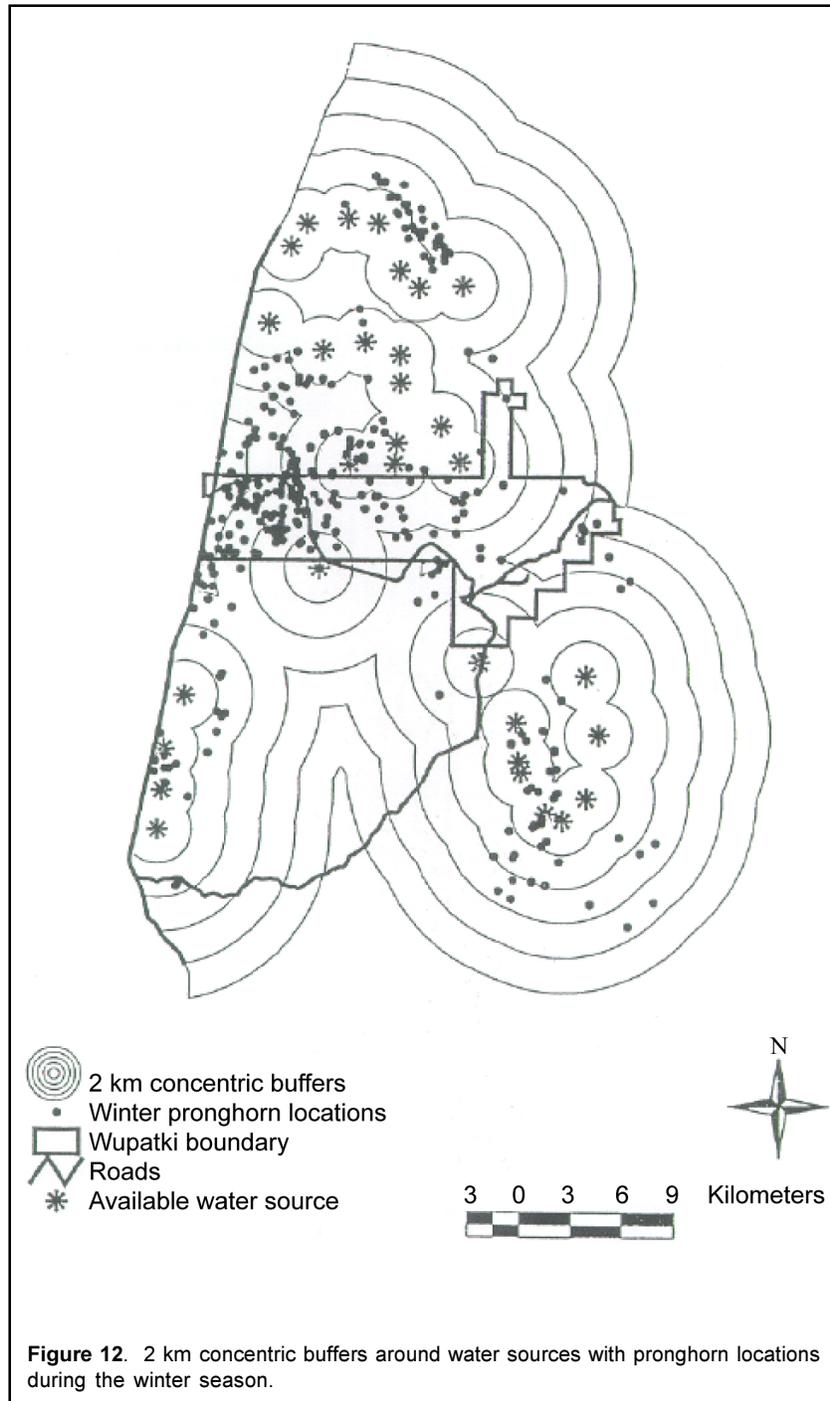
Sex	Distance Class (km)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 1.99	130	102	0.202	0.21 - 0.30	Prefer
	2.0 - 3.99	134	117	0.232	0.22 - 0.31	
	4.0 - 5.99	133	111	0.219	0.22 - 0.31	
	6.0 - 7.99	102	90	0.179	0.16 - 0.24	
	8.0 - 9.99	7	84	0.166	0.00 - 0.03	Avoid
Male	0 - 1.99	55	32	0.202	0.25 - 0.43	Prefer
	2.0 - 3.99	75	37	0.232	0.37 - 0.56	Prefer
	4.0 - 5.99	25	35	0.219	0.08 - 0.22	
	6.0 - 7.99	5	28	0.179	0.00 - 0.06	Avoid
	8.0 - 9.99	0	26	0.166		Avoid

collared pronghorn had home ranges encompassing parts of the grazed ranch and ungrazed Monument.

Individual pronghorn varied in their tendency to move long distances. Two females moved from the lower elevation grassland area of the National Monument to open parks in high elevation ponderosa pine forest each spring, returning to the grasslands in the late fall. One other female moved from grassland habitats on the

**Table 7b.** Distances of pronghorn locations from identified water sources compared with area within isometric 2.0 km concentric buffers around water sources during summer. Use differed from availability for females ( $\chi^2 = 126.9, df, P < 0.05$ ) and males ( $\chi^2 = 74.45, 4 df, P < 0.05$ ).

Sex	Distance Class (km)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 1.99	157	91	0.202	0.29 - 0.40	Prefer
	2.0 - 3.99	133	105	0.232	0.24 - 0.34	Prefer
	4.0 - 5.99	92	99	0.219	0.16 - 0.25	
	6.0 - 7.99	67	81	0.179	0.11 - 0.18	
	8.0 - 9.99	3	75	0.166	0.00 - 0.01	Avoid
Male	0 - 1.99	50	29	0.202	0.25 - 0.44	Prefer
	2.0 - 3.99	60	33	0.232	0.31 - 0.51	Prefer
	4.0 - 5.99	27	31	0.219	0.10 - 0.26	
	6.0 - 7.99	7	25	0.179	0.00 - 0.09	Avoid
	8.0 - 9.99	0	23	0.166		Avoid

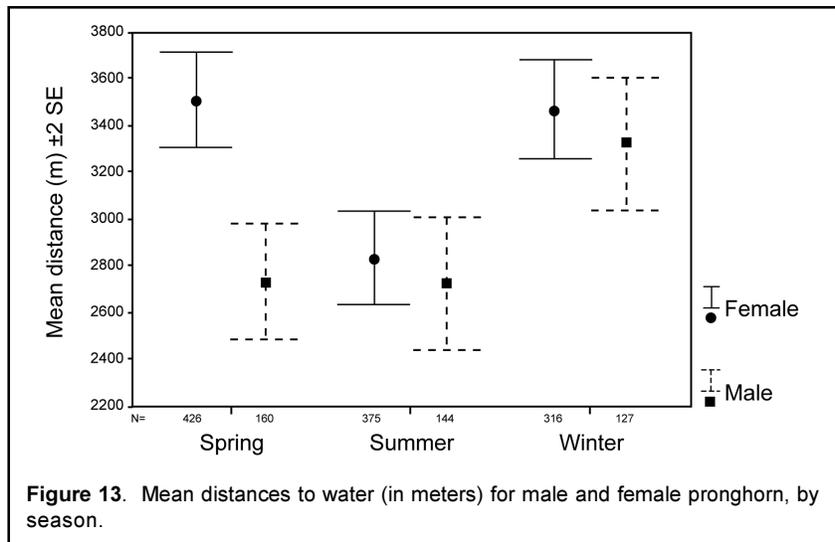


**Table 7c.** Distances of pronghorn locations from identified water sources compared with area within isometric 2.0 km concentric buffers around water sources during winter. Use differed from availability for females ( $\chi^2 = 122.6$ , df,  $P < 0.05$ ) and males ( $\chi^2 = 64.3$ , 4 df,  $P < 0.05$ ).

Sex	Distance Class (km)	Observed # of locations	Expected # of locations	Proportion area available	Bonferroni 90% CI	Preference
Female	0 - 1.99	91	82	0.202	0.17 - 0.27	
	2.0 - 3.99	168	95	0.232	0.35 - 0.46	Prefer
	4.0 - 5.99	94	90	0.219	0.18 - 0.28	
	6.0 - 7.99	53	73	0.179	0.08 - 0.17	Avoid
	8.0 - 9.99	4	68	0.166	0.00 - 0.02	Avoid
Male	0 - 1.99	26	25	0.202	0.12 - 0.29	
	2.0 - 3.99	63	29	0.232	0.39 - 0.60	Prefer
	4.0 - 5.99	26	27	0.219	0.12 - 0.29	
	6.0 - 7.99	12	22	0.179	0.03 - 0.15	Avoid
	8.0 - 9.99	0	21	0.166		Avoid

ranch, across the Little Colorado River, to desert shrubland habitat on the Navajo Reservation each spring prior to fawning, returning to the ranch in late summer. All of the other pronghorn showed migratory behavior but did not tend to move such large distances, having maximum movements between 10 km and 20 km, comparable to movements reported by Ockenfels (1994) in central Arizona.

We found that the mean distance moved by pronghorn between consecutive locations averaged 3.3 km. Hailey (1979) reported mean distance moved as 1.2 km,



and Ockenfels (1994) found average distance moved in central Arizona herds to be 2.5 km, somewhat smaller than found in this study. However, pronghorn herds in central Arizona are much more confined by man-made barriers (e.g., roads, fences, housing developments), than are animals in the more remote area of our study. Ockenfels (1994) reported that the area he studied was “well watered” with very few areas farther than 1.6 km from water, while over 80% of our study area was greater than 1.6 km from water.

Some fences (i.e., net wire or fences with a low bottom wire), highways and railroads may pose barriers to pronghorn movement, thereby fragmenting habitat, restricting movement and isolating populations (Buechner 1950, O’Gara and Yoakum 1992, van Riper and Ockenfels et al. 1998). Pronghorn move within habitats in response to drought, forage and water availability, winter storms, human disturbances and other changing conditions. Highway 89, a paved and fenced two-lane road was an effective movement barrier separating herds to the east and west. At no time, during the 3 years of this study, did we document any pronghorn crossing this highway. However, the paved but unfenced two-lane Monument road did not appear to pose movement problems for pronghorn. Pronghorn commonly crossed, and several home ranges straddled, this road.

Livestock fences at Wupatki National Monument, with lower strands modified for pronghorn, as described by O’Gara and Yoakum (1992), did not appear to deter pronghorn from crossing pasture boundaries. Pronghorn did not cross a fence without lower strand modifications as often, but several pronghorn had home ranges encompassing both sides of these fences. However, we simply counted the number of times pronghorn crossed these fences. If pronghorn came to the fence and had trouble or decided not to cross, this would not be revealed by our data. In times of stress, such as pursuit by a predator or deep winter snow cover, these fences may still pose problems.

Although pronghorn used the ranch and Monument, they used these habitats differently during the course of the year. During winter months animals were frequently located within the National Monument boundaries, but during the rest of the year were far more common on Babbitt Ranch property. From these distribution patterns, it is apparent that the pronghorn in this study need to utilize components of habitats on both the ranch and Monument in order to meet their annual essential life requirements.

Aside from the grazing regimes, there are two main differences between Babbitt Ranch and the Monument: (1) the ranch has several water sources available to the pronghorn while the Monument has none; and (2) the Monument has more diverse habitat types. The ranch consists mostly of grassland (92%) with a few patches of shrub-grassland (6%) and juniper habitats (1%) while the Monument contains grasslands (25%), shrub-grasslands (12%) and open juniper habitats (13%). Within the grassland vegetation type, we found that the Monument had significantly more forbs available during the spring and summer.

### *Forage Succulence*

Pronghorn are considered to be opportunistic and selective, taking the most palatable and succulent forage available at all seasons (Sundstrom et al. 1973, Authenreith 1978, Allen et al. 1984). Beale and Smith (1970) and Baker (1953) found that forbs, which provide high quality nutrition, digestibility and moisture, represent 86% or more of pronghorn summer diets in the Great Basin. Other authors have reported that forbs are the main component of pronghorn diets, with browse becoming increasingly important as forbs decrease in abundance (Mitchell and Smoliak 1971, Koerth et al. 1984). Abundance of forage classes in our study differed between the grazed Babbitt Ranch and the ungrazed Wupatki National Monument. Throughout the collecting period, forbs were significantly more abundant within the Monument. Forbs were also more abundant in spring and early summer than in other months. Forbs are particularly important at this critical time of the year for late gestation, lactation and growth of fawns.

Despite the fact that the Monument had more forbs available during late spring and summer, this is the time of the year that pronghorn are found more frequently on the ranch, perhaps needing to remain closer to permanent water sources. During the spring and summer seasons, pronghorn utilizing the ranch moved larger distances between consecutive locations than when the animals were in the Monument. This may be due to lower forb production on the ranch, forcing the pronghorn to move greater distances to find adequate forage.

Besides abundance, succulence of forage is an important consideration for pronghorn. Beale and Smith (1970) found that water consumption of pronghorn in Utah varied inversely with the quantity and succulence of available forage. Although forbs were more abundant on the Monument, moisture content did not differ between the Monument and ranch. Forbs and grasses were significantly more succulent during the spring season. Shrubs provided more succulence during the late summer as forbs dried out.

### *Water Use*

Although consumption of succulent forage can help pronghorn meet water requirements, the importance of dependable and accessible water sources is not disputed, especially in the arid Southwest. Beale and Holmgren (1975) concluded that pronghorn cannot live without water during hot weather, even if forage succulence is above average, and that fawns are most affected by a lack of water. Texas droughts brought about a reduction in vitality of antelope which resulted in decreased fertility (Authenreith 1978). Whisler (1984) states that diurnal, xeric-dwelling ungulates such as pronghorn must tolerate large solar radiation heat loads, since they are less able to behaviorally avoid daily and seasonal temperature extremes in the open, often windswept, habitats that they typically occupy.

Placement of water sources plays an important role in determining pronghorn distributions and daily and seasonal movements. Boyle and Alldredge (1984) found that pronghorn in Wyoming began dispersing from winter ranges as snow cover

receded in spring and by June concentrated on adjacent summer ranges where drinking water was more abundant and dependable. In this study, pronghorn began moving onto the Babbitt Ranch in late spring, as forbs became available and were most succulent, and remained on the ranch where water sources were available throughout the summer months.

Kindschy et al. (1978) stated that the optimal water distribution was for all pronghorn areas to be within 1.6 km of water, although Sundstrom (1968) found ranges that produced and maintained high pronghorn densities had water available every 1.6 - 8.0 km. In Wyoming Sundstrom (1968) found that 95% of more than 12,000 pronghorn locations were within 6.4 km of water. Ockenfels et al. (1994) found that nearly all pronghorn locations in central Arizona occurred < 1.6 km from water; however, there were very few areas in their study area that were more than 1.6 km from water.

In our study, the majority of pronghorn locations in all seasons (83% in spring, 87% in summer and 85% in winter) were within a 6 km radius of a water source. However, during spring and summer, both male and female pronghorn used areas only up to 4 km from a water source more often than expected. During the spring and summer, water demands are most likely the greatest for pronghorn. Females need increased water for late gestation, fawning, and lactation. Later in the summer, temperatures rise and forage dries out, creating an increased need for free standing water for male and female pronghorn. We found that areas greater than 6 km were avoided by males, and females avoided areas greater than 8 km from water.

During the winter, temperatures are much lower, and pronghorn became less dependant on permanent water sources. Both sexes ranged from 0 - 6 km from water as expected based on area. Again, areas greater than 6 km from water were avoided.

Although female pronghorn were located within 2 km of a water source more frequently than expected during the spring season, average distance to water for females was greater in spring than either summer or winter. Females need increased water for lactation during the spring. Forb production and moisture content were also highest at this time, and the need for free standing water may be lessened by the consumption of succulent forage. Beale and Smith (1970) found that pronghorn in Utah did not drink water when forbs were abundant and moisture content 75% or greater. Moisture content in this study hovered around 52%, so pronghorn would most likely still need additional water. However, if water requirements during spring were met mostly by forage consumption, females with young fawns may have ranged farther from water sources to avoid increased predation around the denuded vegetation closer to water sources.

Both male and female pronghorn were closest to water sources during the summer, when temperatures were high and forage less succulent. Both sexes ranged farther from water during the winter. During the winter, temperatures were much lower in this area, and thus the need for free standing water was decreased. In addition, brief snow showers provided ephemeral sources of drinking water from snowmelt. During the hot summer, as forb production decreased and the plants

lost moisture, pronghorn were most likely driven closer to water due to an increased need for free standing water.

When pronghorn were located within the National Monument boundaries, they were significantly farther from water sources than when they were located outside the Monument. However, forage production was significantly higher on the National Monument. The fact that there are no permanent sources of drinking water available to supplement the pronghorns' water requirements in the Monument may force them into areas outside the Monument that have lower forage production. Once pronghorn leave the Monument seeking water, they have to move greater distances in order to find sufficient quantities of nutritious forage, as evidenced by their larger consecutive movements on the ranch when compared to the Monument. These trade-offs between forage quality and water availability may help explain the large home range sizes and movements between the ranch and Monument made by the pronghorn in our study. This may also explain why pronghorn have home ranges and core use areas encompassing both the ranch and Monument, as components of both are necessary for this animal to meet its life requirements.

### *Habitat Selection*

In this study, pronghorn moved from Monument to ranch habitats in early spring, remained on the ranch throughout the summer, then returned to Monument habitat in the late fall and winter. During the winter, forb production is low and pronghorn must turn to browse and evergreen forage for food. Shrub and juniper habitats which provide this food source are much more common on the National Monument than the ranch. Additionally, temperatures are lower and snow provides an ephemeral source of water, lessening the need for free-standing water. Thus the pronghorn utilize Monument habitats more during the winter portion of the year.

In spring, forbs become abundant and are at their greatest succulence in grassland habitats. Pronghorn move to these grasslands at the north edge of the Monument and the ranch to utilize forbs. However, as summer approaches and temperatures rise drastically, water from the forage is insufficient to satisfy pronghorn water needs. The National Monument does not have any available permanent water sources. However, water impoundments for cattle that are accessible to pronghorn, are common on the ranch. Thus, during the summer pronghorn move onto the ranch in order to remain closer to water sources, which may leave them in areas of less desirable forage. As winter approaches, the animals move back toward the Monument for winter browse.

Because forb production is lower on the ranch during the spring and summer, pronghorn may need to range farther on the ranch to find adequate forage supplies. In fact, we documented larger consecutive movements when on the ranch at this time of the year, when compared to movements on the Monument. Making long movements and utilizing areas of lower quality forage could likely contribute to the large

home ranges seen in this study, and may also result in decreased pronghorn productivity and increased mortality.

In addition to forage and water needs, pronghorn utilize specific habitats throughout the year for other life requirements, such as mating and birthing, predator detection and avoidance and shelter from weather. Vegetation composition and structure have been long known to influence pronghorn use of an area (Yoakum 1980). Since vision and mobility contribute to predator detection and avoidance, pronghorn are thought to avoid tall, dense vegetation (Sundstrom et al. 1973, Kindschy et al. 1978, 1982). Pronghorn typically inhabit open grasslands, shrub-grasslands, steppes and deserts that provide adequate forage supplies, shelter, and hiding cover for fawns (Yoakum 1974). Numerous studies have determined that pronghorn do not use vegetation types in proportion to their availability. Yoakum (1974, 1979, 1980) found that pronghorn prefer vegetation less than 60 cm high. He considered vegetation over 60 cm as suboptimal because it obstructs views of the surrounding area. In addition, he found that areas with a dense ground cover of shorter shrubs was less preferred because it reduces the mobility of pronghorn and increases their vulnerability to predation. Willis et al. (1988) also reported that pronghorn select areas of low shrub volume.

Pronghorn in this study did not use vegetation classes based on their availability, with males and females selecting different habitat classes at different times of the year. As expected, pronghorn avoided the taller, closed juniper woodlands and cold desert shrublands, during all seasons, where shrub and tree height and density greatly reduce visibility and mobility. Chinle badland and rock outcrop classes where bare ground dominated were also avoided. Additionally, during all seasons, pronghorn preferred the grassland type, where shrubs made up less than 20% of the vegetation.

Pronghorn preferences for shrub-grasslands (shrubs 20-30%) varied by sex and season. Females selected the shrub-grasslands during the spring and summer, when fawning is occurring in northern Arizona. The heavier shrub component in the grassland may provide better access to good quality fawning areas for females and more fawn hiding cover. The presence of numerous, rather than a few isolated shrubs may make fawn detection by predators more difficult, thereby allowing for higher fawn survival.

During the winter, males and females used shrub-grasslands more than expected. This is most likely due to the fact that forb abundance was decreasing, and the pronghorn were turning to browse for forage. The importance of browse for pronghorn during the winter has been documented by numerous authors (Hoover 1966, Bayless 1969, Mitchell and Smoliak 1971, Taylor 1972, Barrett 1980). In all these studies, browse made up at least 80% of the pronghorn winter diet. Hailey (1979) noted movements of pronghorn in winter to brushy areas in Texas. Beale and Smith (1970) contend that browse is required to sustain pronghorn during winters or droughts.

Although open juniper is considered suboptimal habitat for pronghorn, because visibility and mobility are reduced (Yoakum 1980), female pronghorn used open juniper shrublands during the spring and winter. Although these habitats

increase risk of predation, Goldsmith (1989) found that pronghorn compensate for obstructed visibility and reduce the risk of predation by increasing vigilance. Pronghorn use of areas with taller vegetation in winter or early spring, when forb availability is low, has been documented in previous studies (Bayless 1969, Beale and Smith 1970, Sundstrom et al. 1973, Neff and Woolsey 1979, Barrett 1980). Dirschl (1963) found that pronghorn were concentrated during winter in areas where sagebrush and junipers provided evergreen forage for the animals. In northern Arizona, Gay (1984) found areas with taller vegetation to be winter and early spring feeding sites.

The female pronghorn in our study also used juniper shrublands during spring when fawning is occurring. The higher percentage of shrub cover may provide important fawning sites and hiding cover for developing fawns. Clemente et al. (1995) found that female pronghorn in southern New Mexico occupied mesquite vegetation classes, which would be considered suboptimal vegetation based on reduced visibility and mobility, in early spring and continued to occupy this type for 2-3 months coinciding with the fawning period.

Pronghorn typically inhabit open, gentle terrain because it provides enhanced visibility and mobility. Studies point out that the species is adapted to flat or undulating terrain of less than 20% slopes (Yoakum 1980, Kindschy et al. 1982). Pronghorn antelope in our study did not use slope classes equal to their availability. Male and female pronghorn avoided steep slopes (over 19%) during all seasons of the year. Female pronghorn preferred gentle slopes between 0 - 9% during all seasons. Males used both the gentle and intermediate slopes equal to their availability in all seasons, with the exception of summer when they favored the intermediate slopes, perhaps looking for cooler temperatures and shade from the intense summer sun.

No selection of aspect classes was detected for pronghorn during our spring season. During the summer season, pronghorn either selected for, or used as expected, the cooler northern exposures and avoided the hot and windy southern exposures. During winter, pronghorn selected the northeast aspect and avoided the southern aspects, again most likely avoiding the prevailing southwesterly winds.

### SUMMARY AND MANAGEMENT RECOMMENDATIONS

We found that pronghorn in northern Arizona had larger than average home ranges, and displayed longer than average movements than reported in the literature. Most of the pronghorn had home ranges utilizing the grazed Babbitt (CO Bar) Ranch property and the ungrazed Wupatki National Monument, but focused use of these areas at different times of the year. During the winter, pronghorn utilized the Monument as often or more frequently than the CO Bar Ranch. However during spring and summer, animals were more common on the ranch property. The ranch had permanent water sources available to animals while the Monument had none. Ranch vegetation was predominately grassland while the Monument contained grasslands, shrub-grasslands and open juniper habitats. These two differences and the seasonal requirements of pronghorn can readily explain movements between the ranch and Monument that we observed.

It appears that pronghorn are utilizing the ranch as summer range in a large part due to the availability of free-standing water. However, they must also use the Monument for winter range, exploiting its browse habitats. Constructing permanent water sources in the National Monument, in areas frequented by the pronghorn, would likely reduce long range movements. This may also increase fawn survival, as shrub habitats needed for fawn hiding cover are more abundant on the Monument. In addition, pronghorn might stay in or nearer the Monument boundaries during the early fall hunting season and during the summer months, which would enhance visitor's enjoyment of the Monument and perhaps increase visitor knowledge and appreciation for this animal.

### *Management Implication*

There are several water sources on the CO Bar Ranch that are inaccessible to pronghorn due to fencing. These fences could be modified to allow pronghorn access in order to increase numbers of available water sources. One tank, just north of the Wupatki boundary, if made accessible to pronghorn, would provide essential water much closer to areas of superior forage within the Monument.

The grazing status on National Forest lands south of Wupatki National Monument should be reviewed. Currently there are no cattle using this area and thus no need for the barbed wire fence along the southern park boundary. If it is determined that cattle may use this area in the future, the fence should be modified to pronghorn standards (as described by O'Gara and Yoakum 1992) in order to enhance pronghorn movement.

Park resource managers should coordinate with highway planners to reduce the impacts of Highway 89 on pronghorn populations in this area. Removing, modifying, or moving the fence further back from the highway are possible options that should be examined in order to allow pronghorn movement between isolated herds on both sides of this highway. The use of underpasses and overpasses constructed to facilitate pronghorn crossing of roadways would be a preferred alternative. Although Ward et al. (1980) found that pronghorn did not use underpasses along I-80 in Wyoming, modifications such as widening an existing underpass to allow better visibility may prove successful to enhancing movement across Highway 89.

Other possible mitigation features that could be undertaken by the national park service in northern Arizona could be: (1) removing fences along rights-of-way; (2) expanding rights-of-way dimensions by placing fences further away from the transportation corridor (e.g., road or railroad), then modifying the fences to permit better movement of pronghorn between fenced areas; (3) relocating rights-of-way out of pronghorn habitat; (4) consider relocating animals, particularly to isolated areas where pronghorn have been extirpated; (5) providing permanent water sources in Wupatki and Sunset Crater NM; and, (6) provide signs on unfenced park roads warning visitors of wildlife movement corridors. Careful attention should also be given to preventing any fencing of presently unfenced roads.

The issues confronting national park areas in dealing with pronghorn manage-

ment in northern Arizona, is only an indication of a much larger problem facing managers of protected areas around the world. If managers wish to have their protected areas function as species reservoirs (i.e., 'sources' instead of 'sinks'), they have to: 1) begin to forge active partnership with contiguous land owners to manage resources on an ecosystem basis; 2) then decide to what degree they are willing to allow active management to occur when their managed lands can not adequately support a species; and finally, 3) standardize (or partition) the degree of management among managers of all lands within each ecosystem.

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