

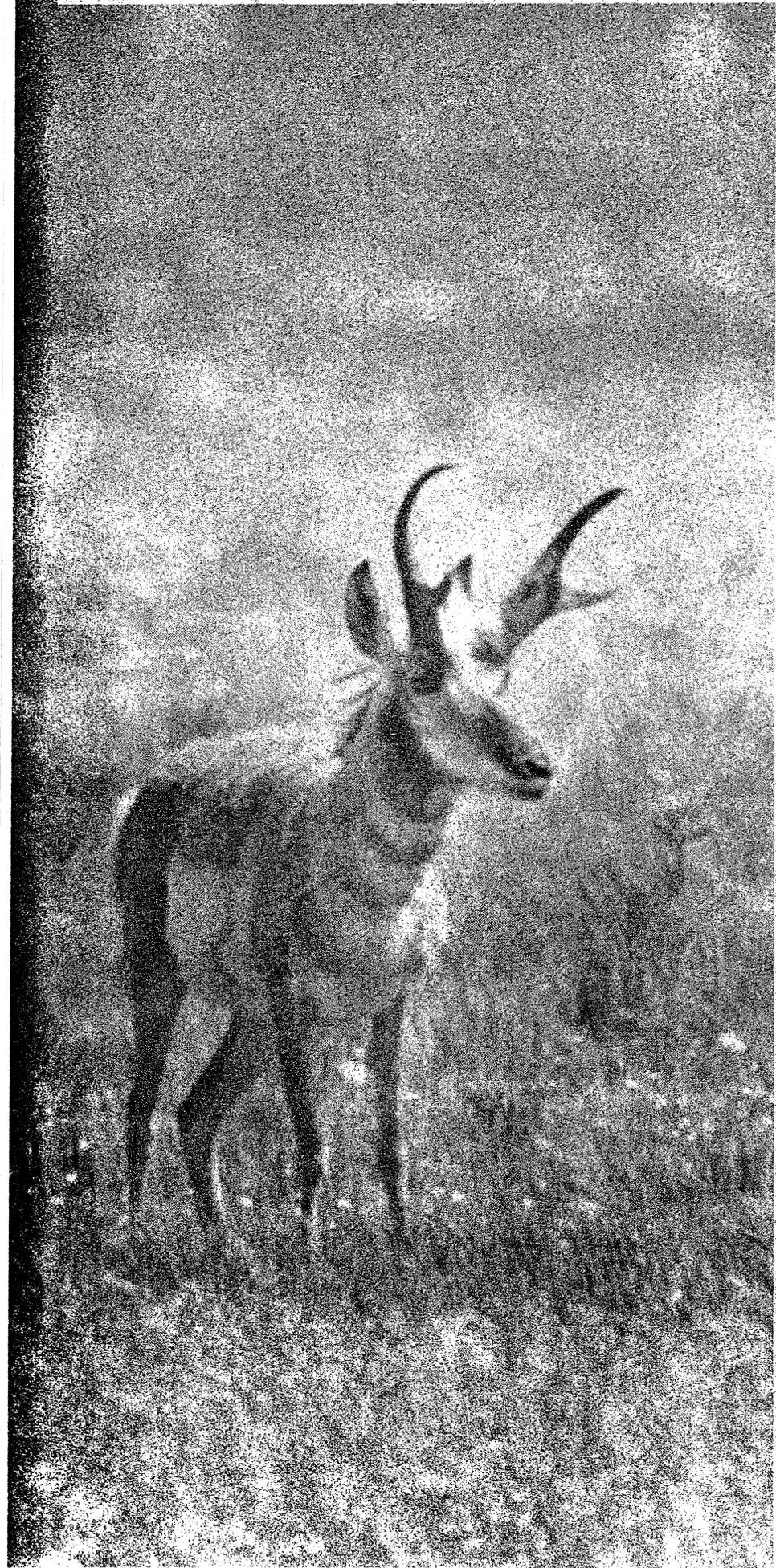
HOME RANGES,
MOVEMENT PATTERNS,
AND HABITAT SELECTION
OF PRONGHORN IN
CENTRAL ARIZONA

A Final Report

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March 1994

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RESTORATION PROJECT

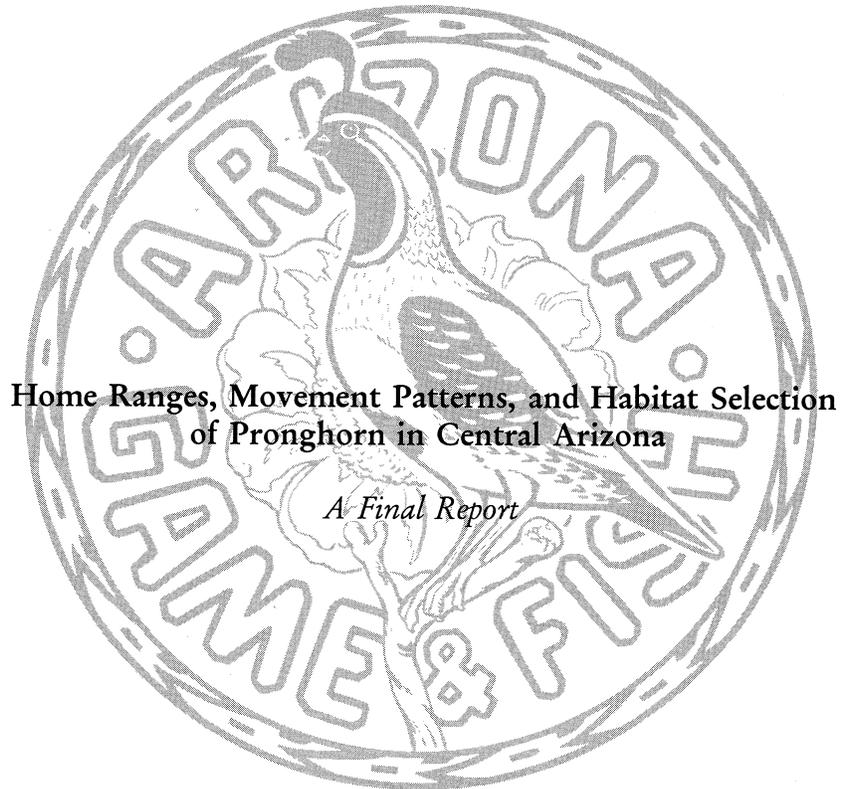


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To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

Arizona Game and Fish Department
Research Branch

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of Pronghorn in Central Arizona**

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Home Ranges, Movement Patterns, and Habitat Selection of Pronghorn in Central Arizona

Richard A. Ockenfels, Amber Alexander,
Cindy L. Dorothy Ticer, and William K. Carrel

Abstract: We captured, marked with radio transmitters, and located 47 (29♀, 18♂) pronghorn (*Antilocapra americana*) during 1989-92 in portions of Game Management Units (GMUs) 19A and 21 to determine home ranges, movements, and habitat selection patterns. Home-range and movement data are needed to determine key use areas, identify movement corridors and barriers, and document if population fragmentation occurs. Habitat selection data are needed to determine quality of habitat and if any specific habitat characteristics create problems for pronghorn. Pronghorn in GMU 19A used smaller ($P = 0.001$) home ranges than those in GMU 21. Home-range size in GMU 21 for 9 (7♀, 2♂) migratory pronghorn ($\bar{x} = 270.6 \text{ km}^2$) was much greater ($P = 0.001$) than for 20 pronghorn that did not migrate ($\bar{x} = 52.4 \text{ km}^2$). Interstate Highway 17 was an effective movement barrier between GMUs 19A and 21. Tree and brush invasion and human encroachment threaten the 3 identified movement corridors joining northern and southern portions of GMU 21. Fenced, paved highways and large tracts of tall, dense brush separated populations in GMU 19A into 3 sub-populations (Orme, Cherry, and Fain). Orme and Cherry sub-populations are below recommended minimum viable limits and extirpation is likely without intervention. Pronghorn selected ($P < 0.001$) flat to undulating terrain with slopes $< 10\%$ and avoided ($P < 0.001$) northerly exposures with dense vegetation on slopes $\geq 10\%$. Plant species richness in sites used by pronghorn changed ($P < 0.001$) seasonally, with greatest richness occurring in spring as forb growth peaked. Pronghorn strongly selected ($P < 0.001$) areas with vegetation $< 0.61 \text{ m}$ in height. Pronghorn in Orme and Cherry used lower-quality habitats than pronghorn elsewhere; little high-quality habitat was available to them. Pronghorn avoided areas $< 0.4 \text{ km}$ from identified water sources ($P < 0.001$) and areas $< 0.4 \text{ km}$ from fenced, paved highways ($P < 0.001$). Preventing population isolation and habitat fragmentation, maintaining movement corridors, and controlling brush and tree invasion are management priorities for pronghorn in central Arizona.

INTRODUCTION

In Arizona, pronghorn occupy approximately 52,000 km² of habitat in a wide band across the northern part of the state and in isolated pockets between southern mountain ranges (Anon. 1987). They once inhabited a greater portion of Arizona, but were extirpated from numerous areas prior to 1922 (Nelson 1925, Ockenfels In Prep.). Since the 1920s, attempts have been made to re-establish pronghorn in historical ranges. Many reintroductions have been successful, but others have failed for unknown reasons (R. M. Lee, Ariz. Game and Fish Dep., pers. commun.). Some failures are believed to have been caused by inadequate area and/or quality of habitat within the transplant areas. Additional information about pronghorn habitat requirements is necessary to ensure higher rates of transplant success.

Considering habitat quality in management planning and improving habitat for pronghorn

ensure their long-term survival, increased population levels, and wider distribution. Such planning requires considerable knowledge about pronghorn home ranges and movements. Pronghorn home-range sizes and movement patterns have been studied elsewhere (e.g., Bayless 1969, Hailey and DeArment 1972, Amstrup 1978, Wiltse 1978, Hoskinson and Tester 1980). However, O'Gara (1978:4) noted 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." With the exception of studies on endangered Sonoran pronghorn (*A. a. sonorensis*) in southern Arizona (Wright and deVos 1986, deVos 1990) and American pronghorn (*A. a. americana*) fawns in central Arizona (Ockenfels et al. 1992), home-range and movement characteristics of pronghorn in Arizona have not been documented.

Pronghorn move within their home ranges in response to influences such as water and food

availability, irritating disturbances, and weather conditions. Traditional movements (i.e., year to year) from 1 seasonal use area to another, commonly called migrations, typically follow the same route or corridor (Autenrieth 1978). Barriers often restrict or prevent pronghorn movements (Yoakum 1980). Movement barriers, both natural (e.g., dense vegetation, canyons, lakes, major waterways) and human-made (e.g., fences, highways, canals, housing developments), can have serious impacts on pronghorn populations and need to be identified.

Knowledge of how pronghorn specifically use home ranges helps managers improve habitat and protect important areas. Identification of key seasonal (e.g., winter) foraging areas and movement patterns between areas can be used to modify livestock grazing allotment plans or to otherwise improve habitat. Programs to prevent human-related encroachment (e.g., housing developments, fencing, roads) into key pronghorn habitats can be instituted. Detailed knowledge of selection or avoidance of specific habitat components also can be used to evaluate historic ranges as potential reintroduction sites.

Documenting whether pronghorn populations are isolated from others increases a resource manager's ability to monitor and manage pronghorn. Fragmentation of populations into isolated herds can be caused by movement barriers such as net-wire fences or railroad and highway rights-of-way (Fig. 1; Buechner 1950). Isolation of populations is important because genetic interchange can be lost and inbreeding can occur, thereby resulting in low heterozygosity (i.e., genetic diversity of alleles). If populations drop below minimum viable levels they suffer reduced fertility, increased mortality of young, and higher probabilities of local extirpation due to random or systematic events (Samson et al. 1985, Reed et al. 1986, Soule 1986).

Pronghorn occur mainly in grasslands, but also at lower densities in open woodlands, coniferous forests, and low desert areas (Autenrieth 1978, Yoakum 1980, Neff 1986). Knowledge of pronghorn habitat use patterns has accumulated over the years (Sundstrom et al. 1973; Yoakum 1974, 1979; Autenreith 1978, 1982; Hailey 1979; Kindschy et al. 1982); much of this is applicable to Arizona. Patterns, however, are variable and specific information is needed at a

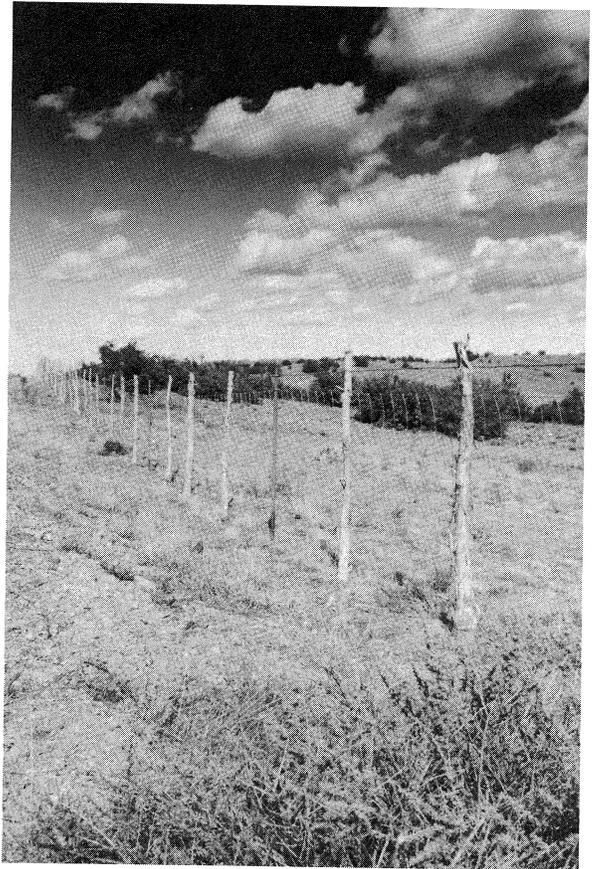


Figure 1. Fences, particularly those with net-wire construction, can be pronghorn movement barriers.

local level for managers to adequately plan.

Neff (1986) listed 7 key factors that he believed determined present pronghorn distribution in Arizona: (1) residential and commercial development, (2) coyote predation, (3) inaccessible suitable habitat, (4) inadequate water distribution, (5) range management practices, (6) livestock fencing, and (7) density of woody plants. Although Neff (1986) did not mention railroad and highway rights-of-way, these must be considered along with other problems (Buechner 1950).

This study was initiated to study pronghorn home ranges, movements, and habitat selection in GMUs 19A and 21. Our objectives were to:

- Determine home-range size and factors affecting home-range size.
- Document movement patterns and determine whether pronghorn in central Arizona are migratory.

- Determine whether barriers isolate pronghorn populations from one another.
- Estimate if isolation of populations has caused them to drop below minimum viable levels.
- Determine habitat use and selection patterns.
- Determine effects of water distribution on habitat use.
- Determine effects of different road types on habitat use.
- Prepare management options that can be used by resource managers to mitigate actions adversely affecting pronghorn in Arizona.



Distribution of waters affect pronghorn.



STUDY AREA

The study area encompassed 1,367 km², ranging from desert areas near Black Canyon City (630 m in elevation) to montane coniferous forest at 2300 m on Mingus Mountain (Fig. 2). Most of the area was 950-1700 m in elevation.

Climate was mild, with monthly average temperatures above freezing (Sellers and Hill 1974). Long-term minimum and maximum daily temperature in January averaged 0 and 13 C, respectively, at Cordes (the nearest weather-reporting station), whereas July temperatures averaged 19 and 35 C, respectively. Temperatures often exceeded 38 C at Cordes during the first 2 weeks of July. Intense thunderstorms from mid-July to September accounted for 40% of annual precipitation, and irregular, gentle winter storms in December-February accounted for most of the remainder. Snow cover seldom lasted more than several days except along the northwestern edge where snow could last up to 2 weeks after major storms.

Dominant vegetation biomes were grassland, chaparral, and woodland (Fig. 3; Brown 1982).

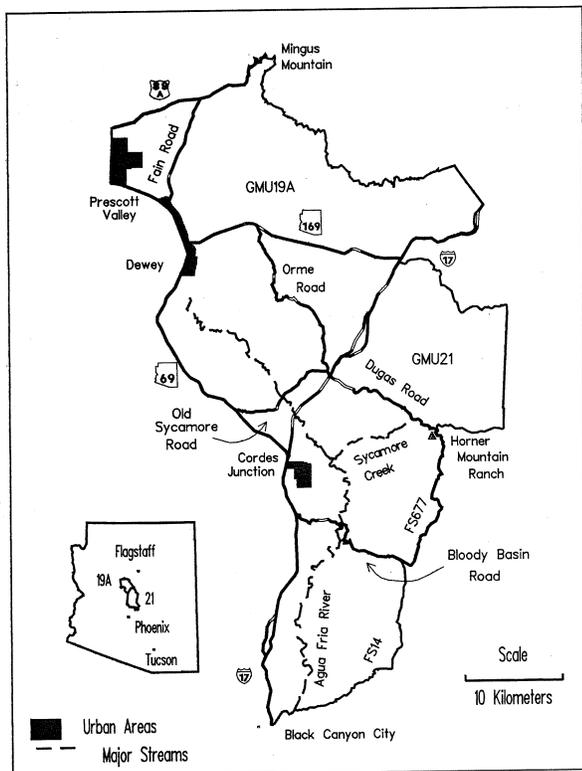


Figure 2. Location of pronghorn study area, GMUs 19A and 21, central Arizona, 1989-92.

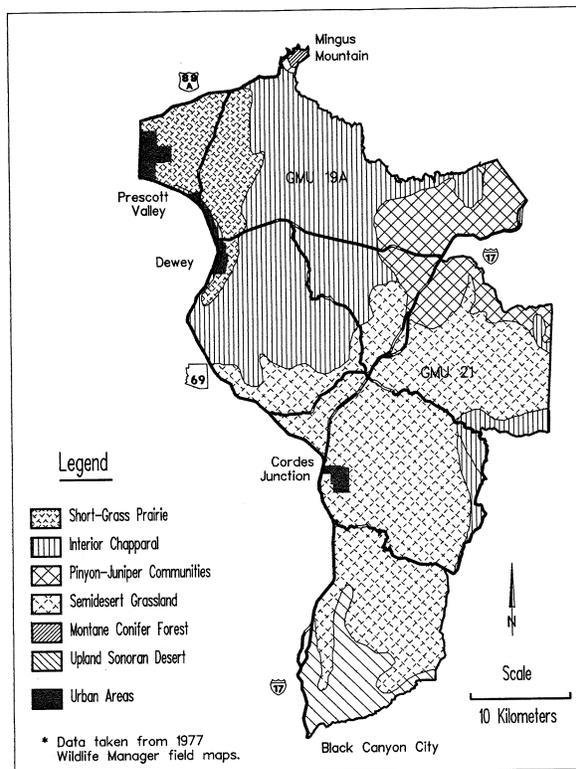


Figure 3. Map of major biotic communities (Brown 1982) within the pronghorn study area, GMUs 19A and 21, central Arizona, 1989-92.

Grasslands included semidesert grasslands and short-grass prairies. Wooded areas included pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) woodlands and montane coniferous forest.

Semidesert grasslands were predominantly grass-shrublands, in which grass stands of tobosa (*Hilaria mutica*) and grama (*Bouteloua* spp.) were interspersed with shrub-form mesquite (*Prosopis juliflora*), catclaw acacia (*Acacia greggii*), scrub oak (*Quercus turbinella*), skunk-bush (*Rhus trilobata*), and Wright's buckwheat (*Eriogonum wrightii*) (Fig. 4). Poor-condition sites were dominated by broom snake-weed (*Gutierrezia sarothrae*), prickly pear cacti (*Opuntia* spp.), and numerous annual grasses, primarily red brome (*Bromus rubens*) and cheatgrass (*B. tectorum*). Plant taxonomy follows Kearney and Peebles (1960).

Short-grass prairie areas occurred on flat to undulating terrain at the western edge of the study area (Fig. 5). Ring muhly (*Muhlenbergia torreyi*) and grama grasses dominated short-grass prairies, which did not have as much shrubs or trees as did semidesert grasslands. Shrubs and trees occurred mainly in major drainages and on north-facing

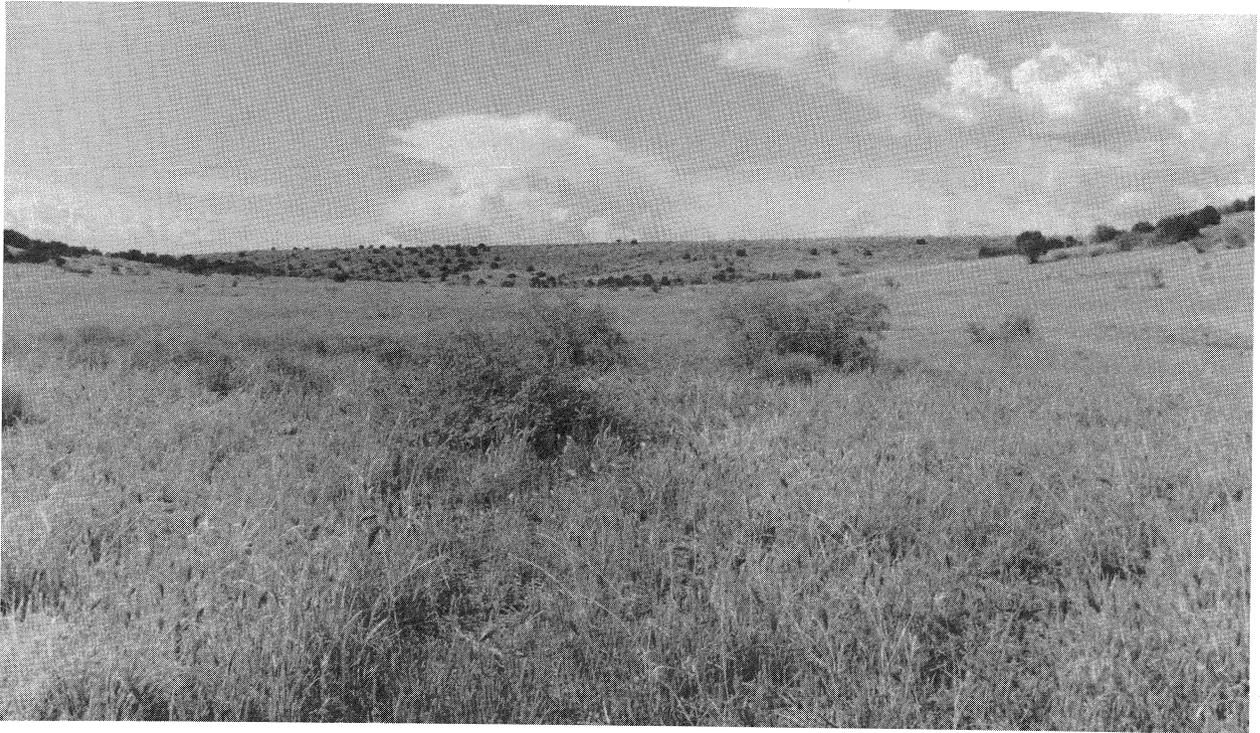


Figure 4. Semidesert grasslands occur throughout central and southeastern Arizona. Tobosa stands are interspersed with numerous shrubs and cacti.



Figure 5. Areas of short-grass prairie extend into central Arizona. Grama and ring muhly are predominant grass species. Shrubs and trees occur mainly along drainages.

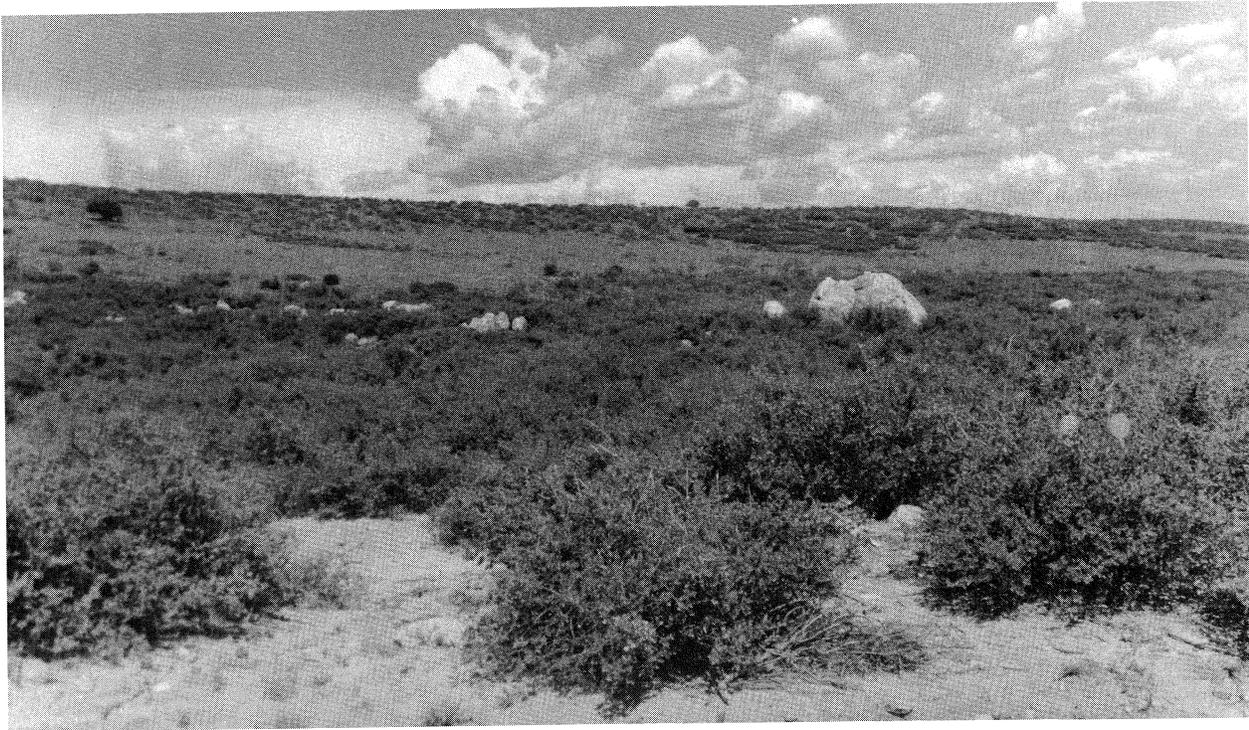


Figure 6 . Dense chaparral habitat occurs throughout central Arizona. Chaparral stands are comprised of shrubs like scrub oak and skunk-bush.

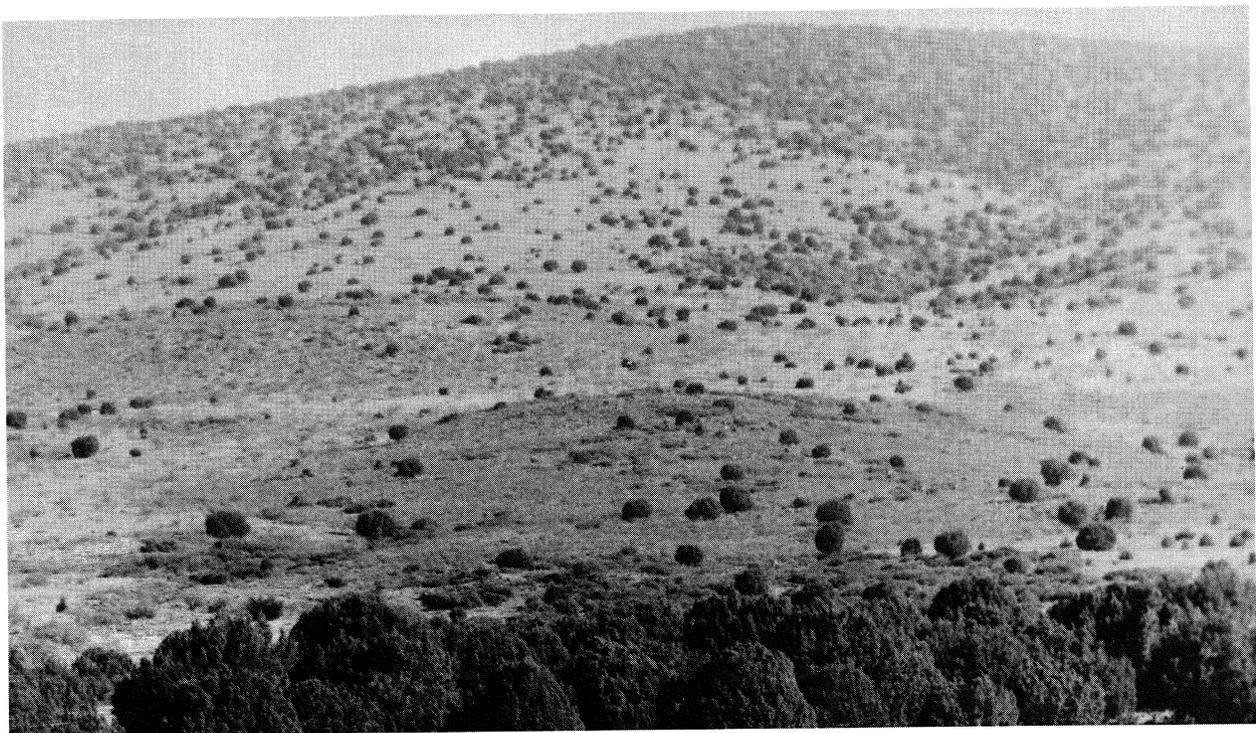


Figure 7 . Pinyon-juniper woodlands occur throughout much of Arizona and range from savanna conditions to dense stands with little herbaceous understory.

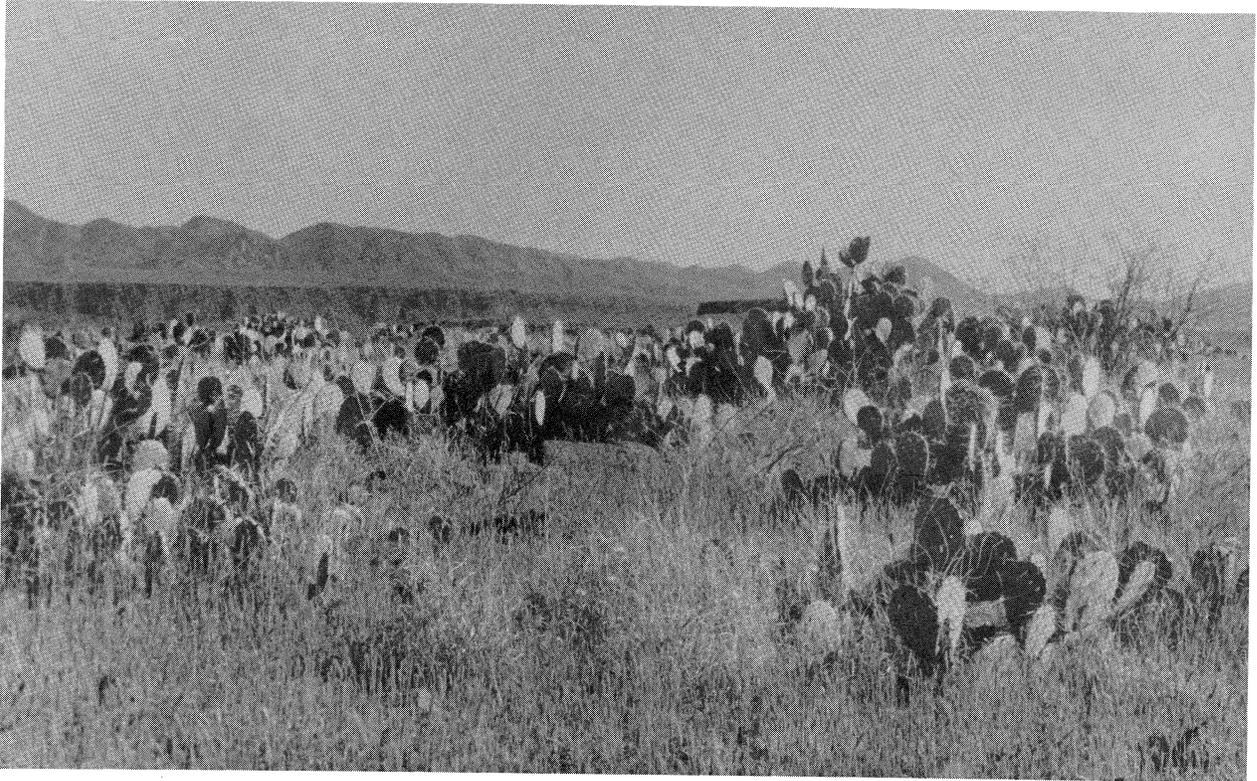


Figure 8 . Much of Black Mesa and Perry Mesa was invaded by prickly pear and shrub-form mesquite.

aspects. Poor-condition sites were dominated by snake-weed, prickly pear, and cholla.

Chaparral and woodland occupied most of the remaining areas. A band of dense chaparral, mainly scrub oak and skunk-bush, separated semidesert grasslands and short-grass prairie areas (Figs. 3, 6). Pinyon-juniper woodlands, which were mainly junipers, occurred mainly along the eastern and northeastern edges of the study area, and in small stands in other habitats (Fig. 7). A small area of ponderosa pine (*Pinus ponderosa*) forest occurred on the northern edge, but was separated from grasslands by expansive areas of chaparral or woodland habitats.

The Agua Fria canyon bisected the southern end of the study area. This major canyon was at the south end of disclimax-semidesert grasslands; these areas were heavily overgrazed, repeatedly burned, and invaded by weedy species and/or cactus (Fig. 8). Black Mesa was on the western side of the Agua Fria and Perry Mesa was to the east. Numerous rugged mesas were present here, extending northward several kilometers. Mesa areas provided a rugged, broken terrain of small

flats, rolling hills, and steep drainages; elsewhere in GMUs 19A and 21, areas of flat to undulating terrain were separated by rolling or broken hill country.

We used potential barriers (e.g., dense chaparral, steep slopes, canyons, and fenced highways) to subdivide the study area into general "capture" areas for analyses (Fig. 9). GMU 19A areas were designated as Fain, Orme, and Cherry. Topography at Fain was undulating hills and flats, Orme was typically hilly country, whereas Cherry was mainly broken hills. GMU 21 areas were Black/Perry Mesa, East Pasture, and Marlow Mesa. Topography at Black/Perry Mesa consisted of flats and rolling hills on mesa country. East Pasture was flats and hilly country, whereas Marlow Mesa was rugged mesa country of flats and rolling hills rising above East Pasture. A large, broken hills-and-mesa area, considered marginal pronghorn habitat, occurred between Black/Perry Mesa and the other 2 capture areas of GMU 21.

Numerous range allotments occupied the study area (Appendix 1). Larger cattle operators

typically stocked the range in deferred rest-rotation operations on U.S. Forest Service (USFS) allotments. Smaller operators and State Land Department (SLD) permittees tended to use perennial/ephemeral grazing operations to take

advantage of the bimodal precipitation pattern. Goats were used in several allotments for experimental brush control. V-Bar (Orme) Ranch was operated under a Savory grazing system (Savory 1988).

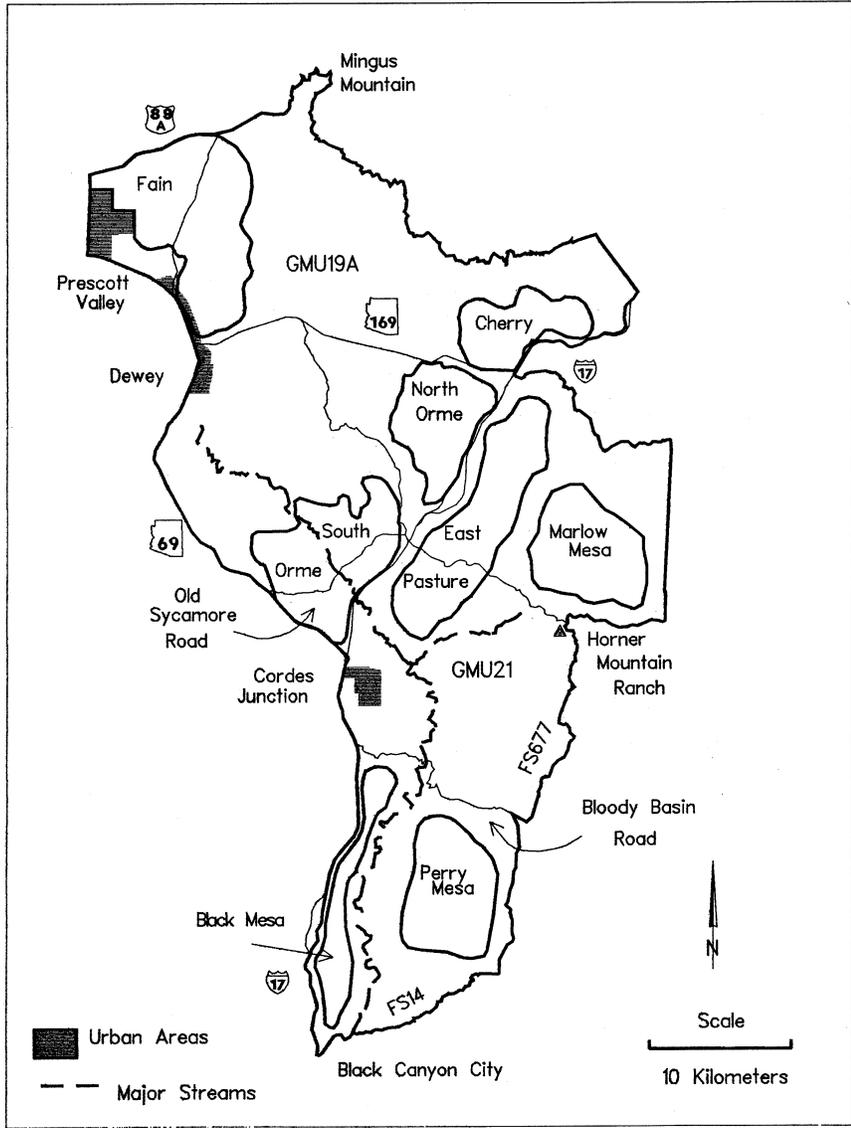


Figure 9. Approximate capture areas for pronghorn study, central Arizona, 1989-92.



METHODS

Capture and Telemetry

Pronghorn in each of the 6 capture areas were captured in October or March, using a net-gun fired from a helicopter (Fig. 10; Firchow et al. 1986). Each pronghorn was identified with a color-coded, radio-transmitter collar and individually numbered ear-tags.

We conducted aerial-location flights once per week during October-March, and twice per week from April-September. Airplanes were equipped with a forward-phased, twin-Yagi antenna array mounted on wing struts for general signal location, and a belly-mounted, rotatable, 2-element "H" antenna to pinpoint locations (Carrel 1972a,b). Locations of radio-collared pronghorn were plotted on 7.5' U.S. Geological Survey (USGS) topographic maps.

We later derived Universal Transverse Mercator coordinates (UTMs) to the nearest 0.1 km from mapped locations. Slope (%) at each mapped location was derived from USGS topographic map contour lines with a standard slope-class-indicator template. Aspect was visually estimated from maps with an 8-class circular mylar overlay.

We also located pronghorn from the ground once per week. Location UTMs and elevation (m) were estimated from topographic maps. We took air temperature (C), wind speed, and wind direction at locations with a field thermometer, wind gauge, and compass, respectively. Slope (°) was taken with a clinometer. Aspect (8 classes) was visually estimated.

Vegetation Sampling

Pronghorn Use Sites. We called ground-based pronghorn locations "use sites" and used circular nested plots to estimate vegetation characteristics (Fig. 11). We used base plots (40 m²) to measure most vegetation features, but used subplots (0.5 m²) to estimate grass and forb cover and extended plots (400 m²) to measure some characteristics of larger plants.

Within base plots, we measured species richness, plant height, and cover of vegetation. Species richness was estimated by counting species of grasses, forbs, shrubs, cacti, and trees. We ocularly estimated plant visual obstruction height (i.e., height at which visibility was substantially

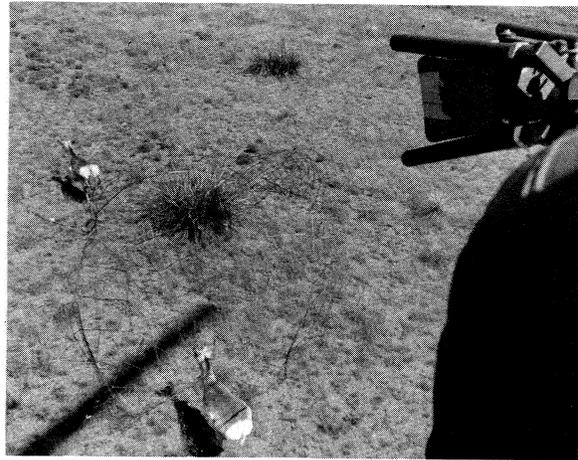


Figure 10 . Pronghorn were captured using a net fired from a net-gun in a helicopter.

obstructed) for grass, forb, shrub, cactus, and tree categories. Numbers of plants >0.61 m in height were counted for each category. We ocularly estimated percent ground or canopy cover for vegetation categories using a U.S. Soil Conservation Service visual guide as a means of reducing observer bias (U.S. Dep. Agric., unpubl. rep. M7-L-2291).

Fewer measurements were made in subplots and extended plots. In subplots, we ocularly estimated cover of grasses and forbs. Counts in

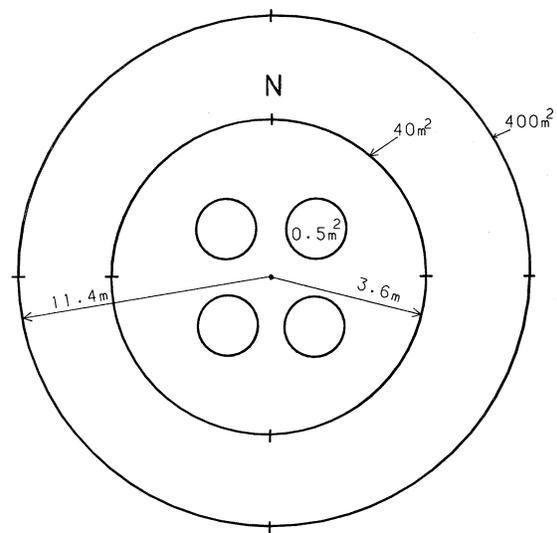


Figure 11 . Nested vegetation plot system used to estimate habitat characteristics at pronghorn locations, GMUs 19A and 21, central Arizona, 1989-92.

extended plots included number of species (for species richness) and number of plants >0.61 m high by plant category.

Random Points and Plots. We estimated availability of habitat characteristics from randomly-selected points (Marcum and Loftsgaarden 1980). Using a Geographic Information System (GIS), we created a buffer around the study area and generated (with SPSS pseudo-random generator; Norusis 1990) 2,500 random points, 984 of which fell within the study area; these points were plotted on topographic maps. As with aerial locations, we derived slope (%) at random points with a standard slope-class-indicator template and aspect with an 8-class mylar overlay.

To locate random points in the field, we estimated distance (m) and compass direction from the nearest road; distance was then paced off in the direction indicated. Circular nested plots (Fig. 11) were established at the random point locations to measure availability of the same habitat variables collected at pronghorn locations. Because of manpower and time constraints, we completed field work at random plots only for GMU 21 ($n = 495$).

Habitat Mapping

We identified water sources on topographic maps, verified them in the field, and digitized them into a GIS overlay (Appendix 2). Additional water sources were digitized into the overlay as encountered in the field.

Fence locations were digitized into a GIS overlay from existing USFS and SLD range allotment maps (Appendix 3). We used horses to ride fence lines for field verification and to map additional fences.

A GIS road overlay for the study area was created from an existing SLD database and field verified. Biotic communities (Brown 1982) were field mapped (1:117,000 scale) in 1977 by Wildlife Managers and we developed a GIS habitat overlay from that database.

Data Analysis

We initially checked frequency distributions of our data to determine appropriate statistical tests and to see if study design influenced data. If graphical representation of frequency distributions did not reflect normality, we used Kolmogorov-

Smirnov one-sample tests to evaluate departure from normality (Zar 1984:91). Nonparametric tests were used if non-normality was indicated by data; otherwise, standard parametric tests were employed. Statistical significance was set at $\alpha = 0.05$. Most statistical tests were performed with SPSS/PC+ software (Norusis 1990).

Home Ranges and Movements. Location data were analyzed for home-range size using minimum convex polygons with software HOME RANGE (Ackerman et al. 1990). We modified .PLT plot-coordinate files from HOME RANGE and transferred them to GIS for plotting home ranges. Fifty-percent convex polygons were created to estimate core (high use) areas (Ackerman et al. 1990).

Mann-Whitney *U*-tests were used to test for home-range size differences between sexes, between GMUs, and between migratory and non-migratory pronghorn. Kruskal-Wallis analysis of variance (ANOVA) was used to test for home-range size differences among capture areas.

We normally located pronghorn only once every several days to reduce the probability of auto-correlated data for home range and movement calculations (Ackerman et al. 1990); occasionally we located them more than once per day. Aerial and ground-based locations were lumped for analyses. Using HOME RANGE, we calculated mean distances between consecutive locations for each animal. We then averaged these individual means by capture area in order to get average mean (\pm SE) distance by area. We defined distances ≥ 10 km between consecutive locations as significant movements and totalled number of movements ≥ 10 km, ≥ 15 km, and ≥ 20 km for each pronghorn. The largest single movement for each animal was averaged by capture area to yield mean (\pm SD) maximum movement distance by area. Effects of average mean and maximum distances moved on home-range size were tested by linear regression, and differences by sex were tested with Mann-Whitney *U*-tests. Kruskal-Wallis ANOVA was used to test for differences among capture areas in distances pronghorn moved.

Sub-areas (i.e., subdivisions within capture areas) were subjectively delineated based on topography, vegetation, and presence of graded roads or unfenced, paved roads (Fig. 12). Percent of locations within sub-areas was determined for

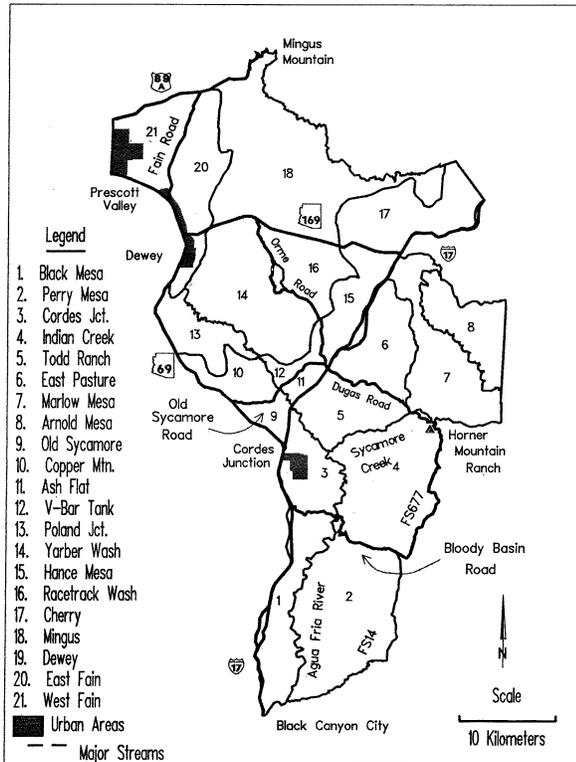


Figure 12. Sub-areas for pronghorn study, GMUs 19A and 21, central Arizona, 1989-92.

each pronghorn by GIS overlay of locations on the sub-area map.

Locations in GMU 21 were plotted to scale and overlaid on USGS topographic maps. By using map terrain features and knowledge of existing vegetation, we identified movement corridors between sub-areas.

Landscape Use and Selection. Slope estimates at aerial and ground locations were classed into 10% intervals. We tested for differences in slope class between aerial and ground locations with a 2x3 Chi-square contingency table. To ensure proper Chi-square analysis, we lumped slope data until all expected cell totals had ≥ 1 location and $< 20\%$ of the expected cells had < 5 locations (Zar 1984:49). This procedure was done whenever Chi-square analysis was used.

To determine if pronghorn gender affected use of slope classes, we tested aerial locations with a 2x3 Chi-square contingency table. We then separately determined if female and male pronghorn selected or avoided particular slope classes by testing aerial locations against random-point estimates with 2x3 Chi-square contingency

tables. We did not know the exact expected distributions, and because random-point sample sizes affect estimates of availability, we did not use Chi-square goodness-of-fit tests (Thomas and Taylor 1990).

If contingency tables indicated significant differences, Bonferroni simultaneous confidence intervals were calculated for sex and slope class combinations to determine slope avoidance or selection (Neu et al. 1974, Byers et al. 1984). If avoidance or selection was detected for a cell, Jacobs' *D* was calculated to indicate direction and magnitude of avoidance or selection (Jacobs 1974). We also tested aerial locations with a 3x6 Chi-square contingency table to determine if pronghorn from different capture areas used slope classes the same.

We tested pronghorn aerial locations on slopes $\geq 10\%$ for differences in aspect use against estimated aspect availability with a 2x8 Chi-square contingency table, Bonferroni simultaneous confidence intervals, and Jacobs' *D*. Differences in aspect use among capture areas was tested with a 6x8 Chi-square contingency table and associated tests.

Vegetation Use and Selection. Mean numbers of species of grasses, forbs, shrubs, cacti, and trees in pronghorn use sites were used as estimates of species richness. Differences in mean species richness at female and male pronghorn use sites were tested with a 2-group, independent *t*-test (for grass species) and Mann-Whitney *U*-tests (for forbs, shrubs, cacti, and trees). One-way ANOVA was used to examine differences in grass species richness by month, whereas Kruskal-Wallis ANOVA was used for forb, shrub, cactus, and tree richness by month. Differences in species richness estimates for shrubs, cacti, and trees at pronghorn use sites versus those in random plots (i.e., availability) in GMU 21 were tested by Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacobs' *D*. Number of grass and forb species change seasonally with addition and loss of annuals, but our random plots were not read year-round. Therefore, we did not compare pronghorn use sites against availability for grass and forb richness.

We calculated mean ground cover of grasses and forbs and mean shrub, cactus, and tree canopy cover at pronghorn use sites for each month.

Ground- and canopy-cover ocular estimates for pronghorn use sites and random plots were lumped into 10% classes. Differences in use of ground-cover and canopy-cover classes by gender and by capture area were tested with Chi-square contingency tables. For GMU 21 areas, we used Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacobs' *D* to test for avoidance or selection of ground-cover and canopy-cover classes.

We initially lumped plant visual obstruction height estimates from ground locations and random plots into 0.33-m height classes; further lumping was done as necessary. Differences in use of height classes between gender and among capture areas were tested with Chi-square contingency tables. For GMU 21 areas, we used Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacobs' *D* to test for avoidance or selection of different plant obstruction height classes by pronghorn.

We calculated number and percent of locations in which vegetation in plant categories was >0.61 m in height. Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacobs' *D* were used to test whether pronghorn in GMU 21 used sites with given densities of shrubs, cacti, and trees >0.61 m in height in proportion to their availability. As with base use sites, we tested extended use sites for capture area differences in number of plants >0.61 m in height and for pronghorn avoidance or selection of tall vegetation.

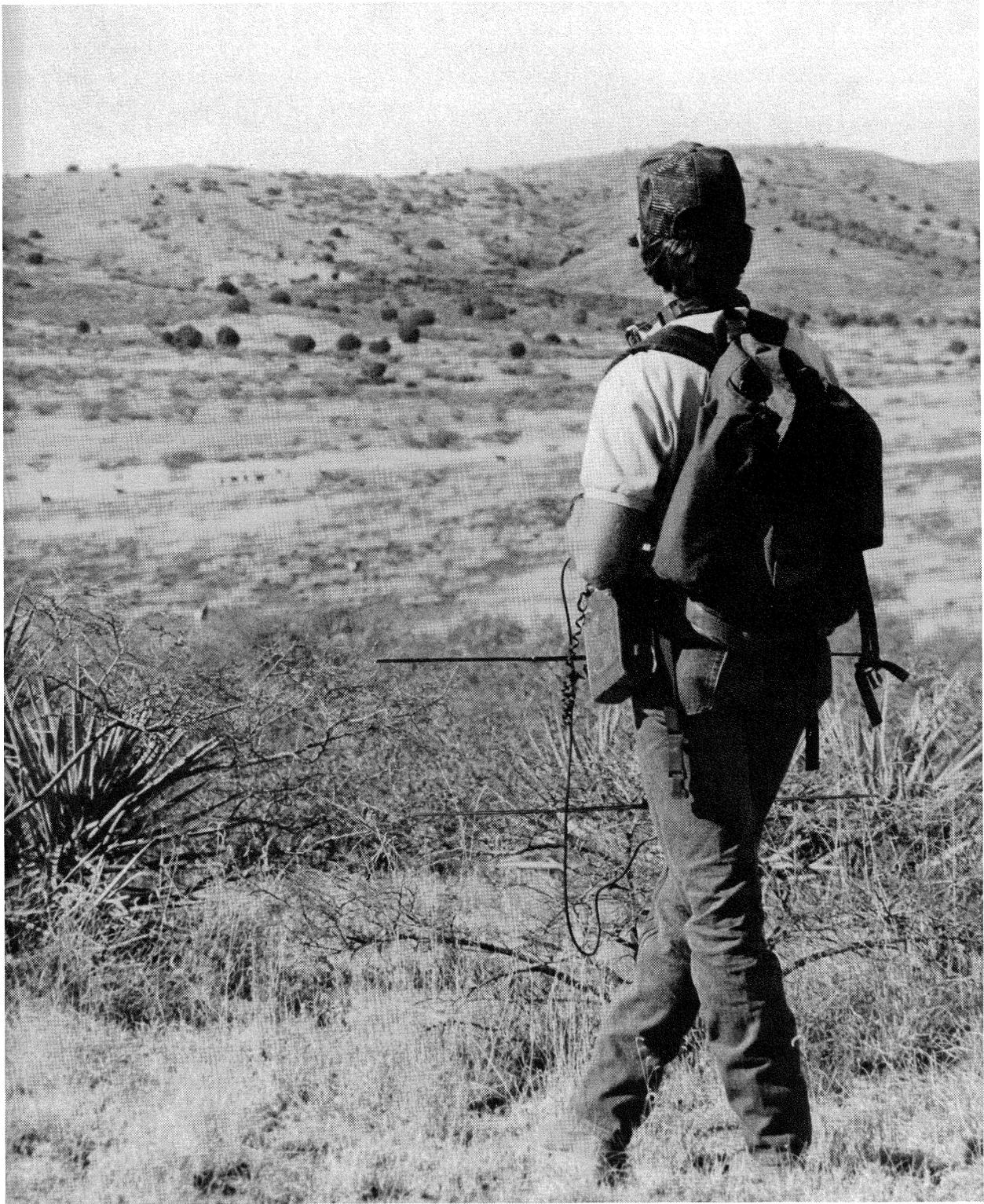
Waters and Roads. In order to evaluate pronghorn use patterns relative to water, we used GIS technology to estimate the distance (0.40-km classes) of each location from the nearest identified water source. Gender differences in distance to water were tested with a 2×5 Chi-square contingency table. We measured area (km^2) within a concentric series of isometric buffers ($=0.40$ -km wide) around identified water sources as an expected distribution, and we independently compared female and male distributions among buffers to the expected distribution with Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacobs' *D*. We also calculated female and male mean monthly distances to identified water sources to evaluate gross seasonal distribution patterns. Kruskal-Wallis ANOVA tests were used to evaluate

gender-related monthly differences in distance to identified water sources. We tested with linear regression the relationship between distance pronghorn were to the nearest identified water source and temperature measured at time of location.

Using GIS technology we estimated the distance (km) from each pronghorn location to 3 classes of roads. Road classes, based on structure and traffic volume, were: (1) primary and secondary fenced, paved highways; (2) maintained dirt roads and urban streets; and (3) non-maintained dirt roads or 4-wheel-drive trails. We lumped distances from maintained dirt roads and streets into 1-km classes because of the limited number of such roads. Gender differences were tested with a 2×7 Chi-square contingency table. For non-maintained dirt roads and trails, we lumped distances into 0.40-km classes and tested for gender differences with a 2×5 Chi-square contingency table.

We measured the area (km^2) within the above isometric buffers from each road class as an expected distribution, and we compared the distribution of pronghorn locations to the expected distribution with Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacob's *D*.

Our initial capture sampling scheme did not enable us to easily test impacts of highways on pronghorn habitat use patterns throughout the study area. Therefore, we buffered highways with a 2-km maximum distance and selected only those pronghorn locations within the 2-km buffer for analysis. Distances to highways for pronghorn locations were calculated with GIS technology and lumped into 0.40-km-wide zones ($n = 5$ zones). Using GIS, we then estimated the area of each 0.40-km distance zone. We tested for gender differences in distribution with a 2×5 contingency table. Avoidance or selection of zones by females and males were tested with Chi-square contingency tables, Bonferroni simultaneous confidence intervals, and Jacob's *D*.



Biologist observing pronghorn after radio-locating them.



RESULTS

Captures and Locations

Forty-seven pronghorn were captured and radio-collared during 4 capture operations in 3 years (Table 1, Appendix 4). The initial capture sampling scheme was completed in October 1989, but because of high mortality rates (Ockenfels 1994) 3 additional captures (March, October 1990; October 1991) were necessary. Of the 61 pronghorn netted, 14 (23%) died during capture.

We made 4,996 locations of the radio-collared pronghorn (Appendix 5). They were distributed temporally as follows: 5.4% in 1989, 41.2% in 1990, 42.8% in 1991, and 10.6% in 1992. Female locations comprised 66.1% of the sample versus 33.9% for males. Pronghorn captured at Black/Perry Mesa had 17.2% of the locations, East Pasture had 17.8%, Marlow Mesa had 16.7%, Orme had 21.0%, Cherry had 11.3%, and Fain had 15.9%. Based largely on these locations, we present the following aspects of pronghorn home ranges, movements, and habitat selection in GMUs 19A and 21.

Gender-related Differences

Few differences existed between females and males in their home ranges, movements, and habitat use (Table 2). For those factors that did show statistical differences, we tested data separately for females and males, even though we found no gender-related differences that seemed biologically important enough for management concern.

Home Ranges

We determined home-range sizes for 47 pronghorn (Appendixes 6, 7). Home-range sizes varied by an order of magnitude and were bimodally distributed, reflecting the presence of both migratory and non-migratory individuals. Thus, for gross comparison only, we calculated a biased, mean home-range size of 88.0 km² (SD = 104.1, $n = 47$).

Home-range sizes for GMU 19A were smaller ($U = 110.0$, $P = 0.001$) than for GMU 21 (Table 3). Home-range size also differed ($K-W \chi^2 = 17.68$, $P = 0.003$) among captured sub-populations (Table 3). A greater proportion of pronghorn captured in East Pasture displayed migratory

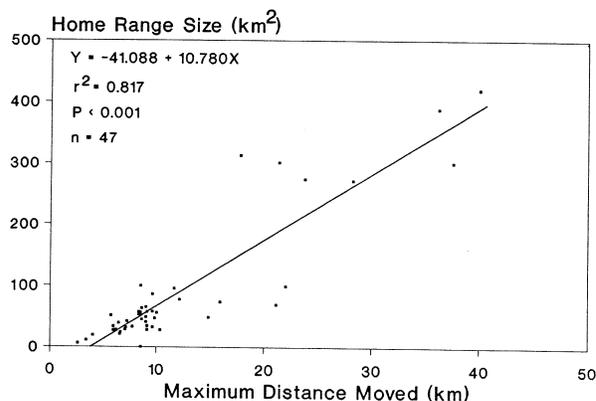


Figure 13. Relationship between maximum distance pronghorn moved between any 2 consecutive locations and home-range size, GMUs 19A and 21, central Arizona, 1989-92.

behavior than was the case in other areas, and mean home-range size for East Pasture pronghorn was 2.3 times larger than that for pronghorn in any other area.

About one-third (9 of 29) of the pronghorn in GMU 21 migrated annually between northern and southern portions of the GMU. Their home ranges ($\bar{x} = 270.6$ km, SD = 117.2) were about 5 times larger ($U = 6.00$, $P = 0.001$) than for the 20 non-migratory animals in the GMU ($\bar{x} = 52.4$ km, SD = 23.8). These migratory pronghorn used much of their home ranges simply as movement corridors.

Large scale movements, such as migrations, influenced home-range sizes and shapes more than daily movements. This is indicated by the fact that home-range size was highly dependent upon the largest movement (maximum distance) between any 2 consecutive locations made by an individual (Fig. 13). Mean distance between consecutive locations, a common measure of magnitude of animal movements, had no effect ($r^2 = 0.07$, $P = 0.066$, $n = 47$) on home-range size.

Movements

Individual pronghorn varied in their tendency to move long distances (Appendixes 8, 9, 10). Fifteen of 47 pronghorn (all in GMU 21) had maximum consecutive location (i.e., "single") movements ≥ 10 km; 8 had single movements ≥ 20 km. The longest single movements were made during migrations. We were not sure all these movements were made in a single day as we

Table 1. Pronghorn radio-collared in capture areas, Game Management Units (GMU) 19A and 21, central Arizona, 1989-92.

| Unit | Capture area | Capture year | Females | Males | |
|--------------|--------------|--------------|---------|-------|----|
| GMU 19A | Orme | 1989 | 2 | 2 | |
| | | 1990 | 2 | 0 | |
| | | 1991 | 0 | 1 | |
| | Cherry | 1989 | 1 | 1 | |
| | | 1990 | 2 | 0 | |
| | | 1991 | 0 | 1 | |
| | Fain | 1989 | 2 | 1 | |
| | | 1990 | 2 | 1 | |
| | | 1991 | | | |
| | | GMU Total | | 11 | 7 |
| | GMU 21 | Black/Perry | 1989 | 3 | 1 |
| 1990 | | | 1 | 1 | |
| 1991 | | | 2 | 2 | |
| East Pasture | | 1989 | 2 | 1 | |
| | | 1990 | 2 | 0 | |
| | | 1991 | 2 | 1 | |
| Marlow Mesa | | 1989 | 3 | 2 | |
| | | 1990 | 2 | 1 | |
| | | 1991 | 1 | 2 | |
| | | GMU Total | | 18 | 11 |

Table 2. Gender-related differences in pronghorn habitat use patterns, Game Management Units 19A and 21, central Arizona, 1989-92.

| Variable | Statistical ^a test | Value | df | P | n |
|-------------------------------------|-------------------------------|-----------|------|--------|------|
| Home-range size (km ²) | <i>U</i> | 227.00 | | 0.457 | 47 |
| Maximum distance moved ^b | <i>U</i> | 193.00 | | 0.137 | 47 |
| Mean distance moved ^c | <i>U</i> | 205.00 | | 0.220 | 47 |
| Slope (10% classes) | χ^2 | 31.63 | 2 | <0.001 | 3655 |
| Distance to water ^d | χ^2 | 12.53 | 4 | 0.014 | |
| Distance to roads ^e | | | | | |
| Maintained/urban | χ^2 | 65.47 | 6 | <0.001 | 4996 |
| Non-maintained | χ^2 | 101.16 | 4 | <0.001 | 4996 |
| Highways | χ^2 | 43.99 | 4 | <0.001 | 2217 |
| Species richness ^f | | | | | |
| Grasses | <i>t</i> | 0.21 | 1304 | 0.839 | |
| Forbs | <i>U</i> | 190152.50 | | 0.901 | 1304 |
| Shrubs | <i>U</i> | 189164.00 | | 0.777 | 1304 |
| Cacti | <i>U</i> | 183620.00 | | 0.213 | 1304 |
| Trees | <i>U</i> | 185872.00 | | 0.264 | 1304 |
| Ground or Canopy cover ^g | | | | | |
| Grasses | χ^2 | 2.81 | 3 | 0.421 | 1305 |
| Forbs | χ^2 | 3.46 | 3 | 0.326 | 1306 |
| Shrubs | χ^2 | 1.31 | 3 | 0.726 | 1305 |
| Cacti | χ^2 | 1.32 | 3 | 0.725 | 1305 |
| Trees | χ^2 | 2.86 | 3 | 0.414 | 1305 |
| Plant height ^h | | | | | |
| Grasses | χ^2 | 2.32 | 2 | 0.328 | 1273 |
| Forbs | χ^2 | 1.50 | 1 | 0.221 | 1109 |
| Shrubs | χ^2 | 1.91 | 3 | 0.591 | 1408 |
| Cacti | χ^2 | 5.18 | 2 | 0.075 | 800 |
| Trees | χ^2 | 0.62 | 1 | 0.433 | 270 |

- ^a *U* = Mann-Whitney rank test, χ^2 = Chi-square contingency, *t* = 2-group *t*-test.
- ^b Maximum distance (km) moved between 2 consecutive locations (per individual).
- ^c Mean distance (km) moved between 2 consecutive locations (per individual).
- ^d Distance (km) from pronghorn location to nearest water source using 0.40-km concentric buffers to estimate availability.
- ^e Distance (km) from pronghorn location to road using 1-km buffers along maintained dirt/urban streets to estimate availability. Non-maintained dirt/4wd trails and paved highways were buffered at 0.40 km intervals.
- ^f Number of species counted in 40-m² plot at pronghorn location.
- ^g Ocular estimate of percent cover at pronghorn locations.
- ^h Visual obstruction height ocularly estimated in 40-m² plots at pronghorn locations.

Table 3. Mean home-range sizes^a (km²) of pronghorn for 6 capture areas, Game Management Units (GMU) 19A and 21, central Arizona, 1989-92.

| Unit | Capture area | Females | | Males | | All | |
|---------|--------------|----------------------|----------|----------------------|----------|----------------------|----------|
| | | km ² (SD) | <i>n</i> | km ² (SD) | <i>n</i> | km ² (SD) | <i>n</i> |
| GMU 19A | | | | | | | |
| | Orme | 41.64 (16.34) | 4 | 55.85 (7.50) | 3 | 47.73 (14.49) | 7 |
| | Cherry | 21.80 (10.53) | 3 | 26.58 (8.41) | 2 | 23.71 (8.94) | 5 |
| | Fain | 38.79 (8.75) | 4 | 22.79 (24.36) | 2 | 33.45 (15.26) | 6 |
| | All areas | 35.19 (14.17) | 11 | 38.04 (20.23) | 7 | 36.30 (16.27) | 18 |
| GMU 21 | | | | | | | |
| | Black/Perry | 100.12 (100.79) | 6 | 66.17 (14.63) | 4 | 86.54 (77.60) | 10 |
| | East Pasture | 220.48 (172.65) | 6 | 152.25 (168.43) | 2 | 203.42 (162.30) | 8 |
| | Marlow Mesa | 128.81 (125.94) | 6 | 43.63 (20.01) | 5 | 90.09 (100.35) | 11 |
| | All areas | 149.80 (138.60) | 18 | 71.57 (69.03) | 11 | 120.13 (121.88) | 29 |

^a Home-range size (\pm standard deviation) determined by program HOME RANGE using minimum convex polygon method.

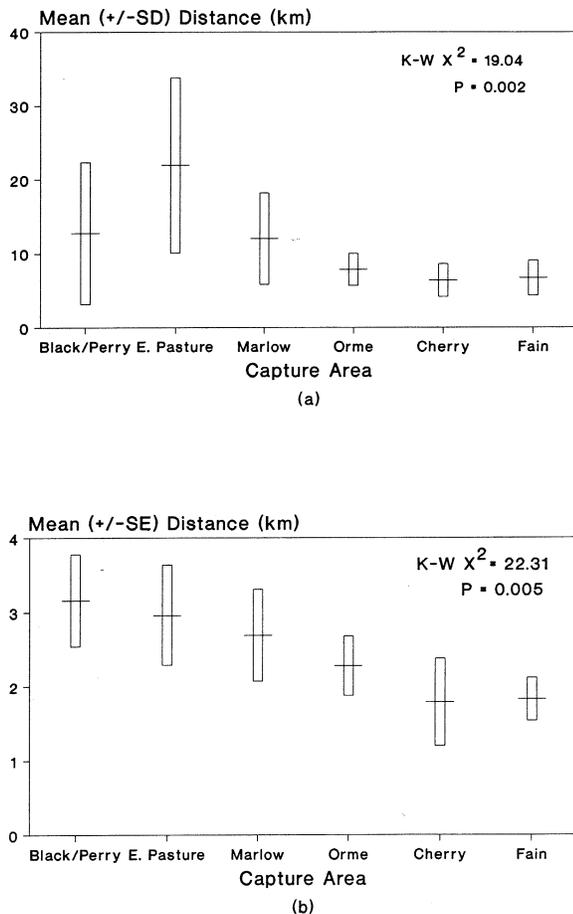


Figure 14. Maximum distance (a) and average distance (b) between consecutive locations for pronghorn in 6 capture areas, GMUs 19A and 21, central Arizona, 1989-92.

typically located animals 1-2 days apart, but sometimes 3-5 days elapsed between locations.

Migratory pronghorn used sub-areas for varying lengths of time and long-distance movements between sub-areas typically occurred during winter and late summer. Four pronghorn (3♀, 1♂) in GMU 21 had 10 or more single movements ≥ 10 km within their home ranges. Seasonal movements back and forth between East Pasture and Black Mesa accounted for most of the long-distance movements.

Females made the largest long-distance movements. In December 1989, we located female No. 12 (F12) on Black Mesa 40.0 km south of her previous location in East Pasture. This was the largest single movement observed. Other examples of > 30 km in a single movement were a

37.5-km movement made by F17 in November 1989 from Black Mesa to the north end of Marlow Mesa, and a 36.2-km movement by F18 in January 1992 from Black Mesa north to East Pasture. Based on our field observations of plant condition, we suspect such winter movements were initiated to locate better foraging areas.

Some males also moved long distances. For example, in December 1989 M5 moved from his capture area in East Pasture south 28.2 km to Perry Mesa. This male made several more movements back and forth between East Pasture and Perry Mesa in winter 1989-90. Male M36 moved back and forth many times between Black Mesa and the Cordes Junction area, a distance exceeding 10 km. Pronghorn had to cross under numerous livestock fences during these migrations. At sites where we observed pronghorn crossing livestock fences, we judged bottom fence strands to be higher than in nearby portions of the fence.

Mean maximum-distances and average mean-distances moved by pronghorn captured in GMU 19A (i.e., Cherry, Fain, Orme) were smaller than for those captured in GMU 21 (Fig. 14). Both measures of movement suggest that pronghorn in GMU 19A were more restricted in their ability to move than those in GMU 21. Differences in movement patterns were related to presence of barriers; most notably, fenced, paved highways obstructed movements within the study area.

Interstate 17, which separated GMUs 19A and 21, was an effective movement barrier to pronghorn. Importantly, after 3 years of effort and nearly 5,000 locations, we never located pronghorn captured in GMU 19A in GMU 21; conversely, pronghorn captured in GMU 21 did not use GMU 19A. Suitable habitat existed on both sides of and adjacent to I-17.

Use of Sub-areas

Individual pronghorn captured in GMU 19A used fewer sub-areas (Fig. 12) than those in GMU 21 and sometimes used just 1 (Table 4). Four animals captured in Cherry (sub-area 17) were never located outside of that sub-area. Cherry was surrounded by effective barriers—I-17 to the east; SR 169 to the south; kilometers of dense chaparral to the west; and steep, densely-vegetated gradients to the north. Only 1 pronghorn (F35) in sub-area 17 moved out; she exited northward

Table 4. Percentage of times an individual pronghorn was located in a sub-area, Game Management Unit 19A, central Arizona, 1989-92. Bold denotes capture sub-area.

| ID | Sub-area ^a | | | | | | | | | | | | |
|----------------|-----------------------|-------------|------|------|------|------|-------------|-------------|-------|------|-------------|--------------|------|
| | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
| Females | | | | | | | | | | | | | |
| 14 | 15.2 | 84.8 | | | | | | | | | | | |
| 19 | 47.7 | 35.2 | 17.1 | | | | | | | | | | |
| 28 | | | | | | 0.7 | 55.5 | 43.8 | | | | | |
| 34 | | | | 0.7 | | 1.3 | 85.4 | 12.6 | | | | | |
| 4 | | | | | | | | | 100.0 | | | | |
| 29 | | | | | | | | | 100.0 | | | | |
| 35 | | | | | | | | | 100.0 | | | | |
| 6 | | | | | | | | | | 2.6 | 76.3 | 21.1 | |
| 21 | | | | | | | | | | | 1.3 | 98.7 | |
| 26 | | | | | | | | | | | 1.1 | 98.9 | |
| 32 | | | | | | | | | | | 97.7 | 2.3 | |
| Males | | | | | | | | | | | | | |
| 3 | 14.6 | 58.6 | 19.2 | 5.4 | 0.8 | 1.3 | | | | | | | |
| 7 | 25.8 | 6.4 | 41.9 | 16.1 | | 9.7 | | | | | | | |
| 60 | | | | | | 3.7 | 63.0 | 33.3 | | | | | |
| 9 | | | | | | | | | 100.0 | | | | |
| 51 | | | | | | | | | 100.0 | | | | |
| 15 | | | | | | | | | | 3.5 | 96.0 | 0.5 | |
| 33 | | | | | | | | | | | | 100.0 | |

^a See Figure 12:

- | | |
|------------------|---------------------|
| (9) Old Sycamore | (15) Hance Mesa |
| (10) Copper Mtn. | (16) Racetrack Wash |
| (11) Ash Flat | (17) Cherry |
| (12) V-Bar Tank | (18) Mingus |
| (13) Poland Jct. | (19) Dewey |
| (14) Yarber Wash | (20) East Fain |
| | (21) West Fain. |

Table 5. Percentage of times an individual pronghorn was located in a sub-area, Game Management Unit 21, central Arizona, 1989-92. Bold denotes capture sub-area.

| ID | Sub-area ^a | | | | | | | | Offsite | |
|---------|-----------------------|-------------|------|------|-------------|-------------|-------|------|---------|------|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | | |
| Females | | | | | | | | | | |
| 1 | | 79.8 | | 20.2 | | | | | | |
| 10 | | 100.0 | | | | | | | | |
| 17 | 45.4 | | 23.7 | | 26.7 | 2.7 | 1.1 | 0.4 | | |
| 24 | | 100.0 | | | | | | | | |
| 55 | | 100.0 | | | | | | | | |
| 57 | | 100.0 | | | | | | | | |
| 12 | 6.5 | | 0.4 | 0.4 | 9.3 | 71.1 | 11.4 | 0.8 | | |
| 18 | 13.0 | 6.7 | 13.0 | 0.4 | 54.2 | 12.3 | 0.4 | | | |
| 22 | | | | 57.1 | 33.3 | | 9.5 | | | |
| 27 | | 10.9 | 1.8 | 7.3 | 23.6 | 36.4 | 16.4 | 3.6 | | |
| 52 | 62.8 | | 18.6 | | 18.6 | | | | | |
| 53 | | | | | 37.2 | 14.0 | 46.5 | | | 2.3 |
| 2 | | | | | | | 100.0 | | | |
| 8 | | | | | | | 92.3 | | | 7.7 |
| 16 | | | | | | 9.4 | 70.1 | 19.7 | | 0.9 |
| 23 | | 9.2 | | 57.7 | | 0.8 | 25.4 | | | 6.9 |
| 25 | 30.7 | | 63.2 | | 5.3 | | 0.9 | | | |
| 63 | | | | | | | 73.8 | 21.4 | | 4.8 |
| Males | | | | | | | | | | |
| 11 | | 97.7 | | | | | | | | 2.3 |
| 36 | 74.5 | | 24.5 | | 0.9 | | | | | |
| 56 | | 100.0 | | | | | | | | |
| 58 | | 100.0 | | | | | | | | |
| 5 | | 5.9 | | 3.5 | 23.8 | 60.9 | 5.4 | 0.5 | | |
| 54 | | | | | | | 51.9 | 33.3 | | 14.8 |
| 13 | | | | | | | 93.8 | 3.8 | | 2.5 |
| 20 | | | | | | | 98.5 | 1.5 | | |
| 31 | | | | | | | 86.3 | 6.3 | | 7.5 |
| 61 | | | | | | 78.6 | 10.7 | 10.7 | | |
| 64 | | | | | | 7.4 | 81.5 | 7.4 | | 3.7 |

^a See Figure 12:

- | | |
|---------------------|------------------|
| (1) Black Mesa | (5) Todd Ranch |
| (2) Perry Mesa | (6) East Pasture |
| (3) Cordes Junction | (7) Marlow Mesa |
| (4) Indian Creek | (8) Arnold Mesa. |

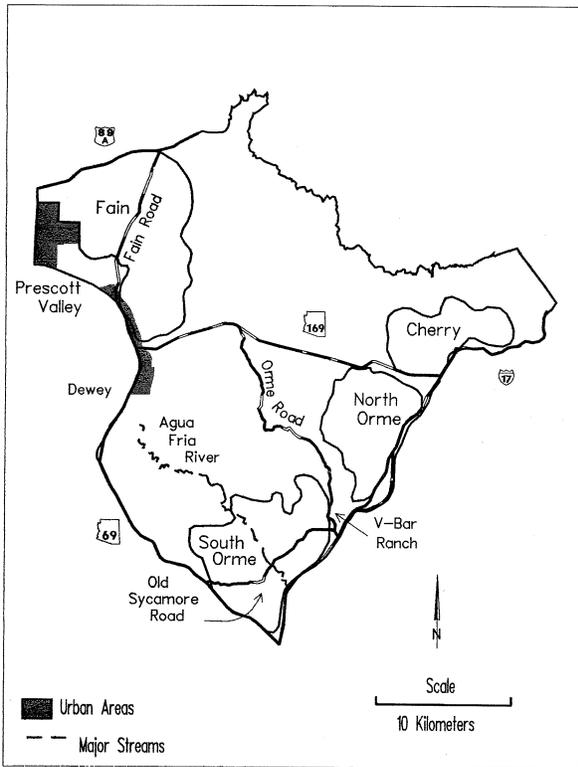


Figure 15. Approximate boundaries of isolated pronghorn sub-populations as indicated by movements of radio-collared individuals, GMU 19A.

and moved nearly into the Verde River Valley, but quickly returned.

Animals captured in GMU 19A north of Orme Road rarely left sub-areas 15 and 16. Conversely, those captured south of Orme Road rarely left sub-areas 9 and 10. For animals in these herds, I-17 prevented movement to the east, and habitat normally avoided--dense stands of tall shrubs, cacti, or trees--dominated sub-areas 11, 12, and 14 that separated 9 and 10 from 15 and 16. No pronghorn moved into the dense chaparral habitat that separated Fain sub-areas from Cherry and Orme sub-areas.

In Fain, pronghorn captured in sub-area 20 were rarely found in sub-area 21, and those captured in sub-area 21 were seldom located in sub-area 20. "Game standard" fencing along Fain Road apparently hindered movement between sub-areas 20 and 21 (see also Ockenfels et al. [1992]).

In contrast to the situation in GMU 19A, pronghorn in GMU 21 moved more freely between sub-areas, but the number of sub-areas used by individuals varied (Table 5). For example,

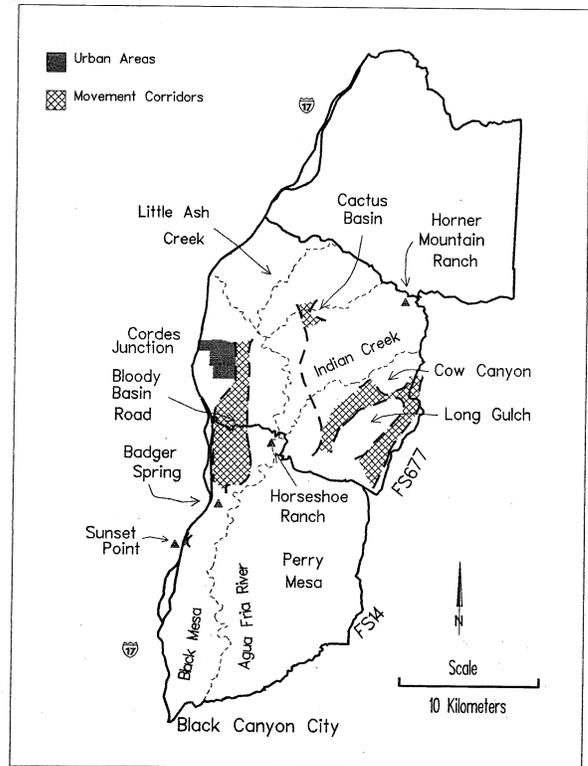


Figure 16. Approximate boundaries of the identified pronghorn movement corridors as indicated by movements of radio-collared individuals, GMU 21.

pronghorn captured in sub-areas 5, 6, and 7 used many sub-areas, whereas those captured in sub-area 2 were seldom located elsewhere. Numerous pronghorn moved between northern and southern parts of GMU 21.

Movement Corridors

GMU 19A. Because little movement occurred between sub-areas in GMU 19A, no movement corridors were identified. Thus, pronghorn in Cherry, Orme, and Fain must be considered 3 sub-populations. We also suspect that little, if any, movement occurred between northern and southern portions of Orme. We also considered these 2 Orme herds to be isolated sub-populations (Fig. 15).

GMU 21. We identified 3 movement corridors connecting northern and southern parts of GMU 21 (Fig. 16). One paralleled I-17 near the western edge of the GMU, 1 lay near the middle of the GMU, and 1 was situated near the eastern edge of the GMU.

The well-defined corridor along the western edge allowed pronghorn interchange between East

Pasture and Black Mesa. Pronghorn moving south in this corridor started along the eastern fence line of Cordes Junction and followed ridges through rolling hills within 1 km of I-17 to the Bloody Basin Road (Fig. 17a,b). This corridor continued along I-17 west of the Agua Fria River to the Badger Springs area, then crossed the northern end of Black Mesa until reaching a bottleneck at the turnoff for Sunset Point rest stop. Here, pronghorn apparently used a gas line road to cross a steep side canyon of the Agua Fria River rather than moving along I-17 itself; they then were able to disperse across the southern half of Black Mesa.

To use this western-most corridor, pronghorn passed through a narrow strip of hills between the Agua Fria River and Cordes Junction to circumvent development at Cordes Junction. This strip of hills had higher densities of trees and tall (>0.61 m) shrubs than did the flats on which Cordes Junction was developed. We saw no evidence that movements occurred through Cordes Junction itself, which we suspect was the corridor route before development occurred (Fig. 17a).

Movements from East Pasture to the lower-elevation Black Mesa occurred primarily at 2 times--in winter and just prior to the spring fawning season. We judged Black Mesa to have more green forage available in winter than did northern, higher-elevation portions of GMU 21. Some return movements north from Black Mesa occurred throughout winter, but most occurred in late spring or early summer. Doe bands migrated south to Black Mesa for the 3 winter study periods and remained there for 2 of the 3 fawning seasons of the study.

Only in 1992 did wintering does return north to Cordes Junction for fawning. Not only did water during fawning seem more available at Cordes Junction in 1992 than in 1990 or 1991, livestock grazing pressure on Black Mesa in 1992 seemed to be greater than at Cordes Junction.

Occasional locations we made after summer 1992 indicated that movements to Black Mesa also occurred in winter and spring, 1992-93. It seems likely that movements to Black Mesa occur yearly and that Black Mesa is an important winter foraging and spring fawning area for doe bands that normally spend other seasons in East Pasture or Cordes Junction sub-areas.

The middle movement corridor, less well-defined than the western 1, served as a passageway between East Pasture and Perry Mesa (Fig. 16). Pronghorn seemed to move south from East Pasture to Cactus Basin by crossing Sycamore Creek and Sycamore Mesa at several locations. Pronghorn continued south across Indian Creek, and then dispersed across the flat east of Horseshoe Ranch. Fewer movements occurred in this corridor than the other 2 corridors during the study period.

Pronghorn used the third corridor to move between Marlow Mesa and Perry Mesa. When moving southward they followed FS 677 (22 Mesa Road) until reaching Long Gulch Canyon, then turned west and followed a narrow ridge between Cow Canyon and Long Gulch until a flat was reached east of Horseshoe Ranch. After reaching this flat, pronghorn dispersed across Perry Mesa, both north and south of Bloody Basin Road.

Landscape Use

Slope. Aerial locations ($n = 3,665$) differed ($\chi^2 = 51.38$, 2 df, $P < 0.001$) from ground locations ($n = 1,326$) in estimating slope class use, but we suspect methodology caused the difference. Rather than present results of both methods, the analyses that follow are based on mainly aerial locations. We chose aerial locations over ground locations because of the larger sample size and fewer observers involved in aerial data collection; we specify when ground locations were used. For management purposes, either method was adequate.

Females tended to select ($\chi^2 = 31.63$, 2 df, $P < 0.001$, $n = 3,665$) gentler slopes than did males (Fig. 18; Appendixes 11, 12, 13). We expected this slight difference because we captured mostly sub-dominant males, and dominant males often force sub-dominants to use less suitable habitat. Both females and males spent most of their time in areas of <20% slope.

Use of slope classes differed ($\chi^2 = 606.20$, 10 df, $P < 0.001$, $n = 3,665$) by capture area (Fig. 19). We located pronghorn at Orme and Cherry more often in areas of $\geq 10\%$ slope; pronghorn in other capture areas used mainly areas with <10% slope. Both Orme and Cherry had more broken terrain than did other capture areas. The steepness of slope used in Orme was less dramatic than that in Cherry.



Figure 17a. Aerial view of Cordes Junction in 1966. Pronghorn likely used this grassy flat as a movement corridor to Black Mesa.



Figure 17b. Aerial view of Cordes Junction in 1990. Development has forced pronghorn to change their movement corridor to the east (right).

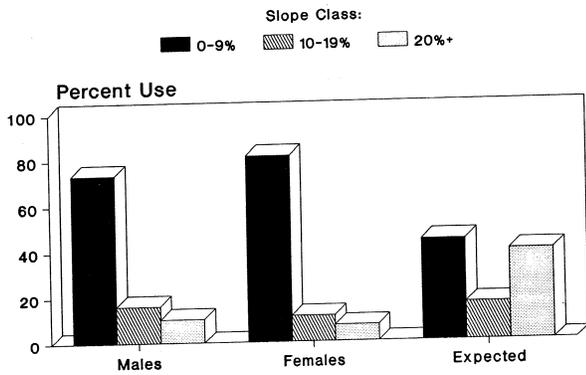


Figure 18. Use of slope classes by male and female pronghorn, and expected use based on slope availability, GMUs 19A and 21, central Arizona, 1989-92.

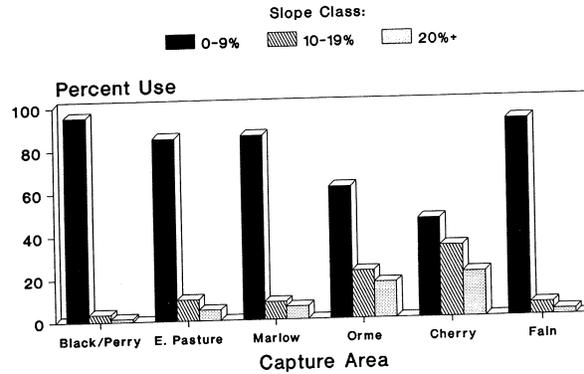


Figure 19. Slope class use by pronghorn in 6 capture areas, GMUs 19A and 21, central Arizona, 1989-92.

Comparing ground locations of pronghorn with random points, we found that neither females nor males used slope classes according to availability (Table 6). Females selected for slopes <10% and avoided slopes $\geq 10\%$. Males used slightly steeper terrain than did females; they selected slopes <10%, used 10-19% slopes as expected, and avoided slopes $\geq 20\%$.

Aspect. We found that on slopes $\geq 10\%$ (i.e., those with a noticeable aspect), pronghorn did not use aspect in proportion to availability (Table 7). Southerly exposures, which tended to have fewer trees and tall shrubs than other exposures, were used either as expected or selected for. Other aspects, particularly northerly exposures that had numerous trees and tall shrubs, were avoided.

Capture area, the area in which pronghorn were captured in and where they tended to spend the majority of their time, affected ($\chi^2 = 169.15$, 35 df, $P < 0.001$, $n = 781$) use of aspect. Pronghorn captured in Orme and Cherry, areas with more rolling hills and rugged terrain relative to flats and undulating terrain, used aspect differently than did pronghorn in the remaining 4 capture areas, again suggesting these 2 sub-populations were having to use less suitable habitat than those in the other areas (Fig. 20). We suspect Orme and Cherry pronghorn spent more time on southern exposures and less on the other exposures because of the relatively dense woody vegetation on non-southerly aspects.

Vegetation Use

Species Richness. Plant species richness within pronghorn use sites differed by month; all plant

categories showed differences (Table 8, Fig. 21). The greatest species richness normally occurred during spring, and lower species richness typically occurred during winter. Forb species richness at use sites peaked just prior to and during pronghorn parturition.

Pronghorn did not use areas of shrub, cactus, and tree species richness in proportion to availability (Table 9). Pronghorn selected 40-m² sites with <3 species of shrubs and strongly avoided sites with ≥ 3 shrub species. Pronghorn used sites with fewer cactus species than were randomly available; they strongly avoided 40-m² sites with ≥ 3 cactus species. Most of the time, pronghorn selected for 40-m² sites with no tree species and avoided areas with ≥ 1 tree species.

Plant Cover. Mean ground- and canopy-cover estimates at pronghorn use sites showed several interesting patterns (Fig. 22). Mean grass cover fluctuated around 15% as perennial and annual grasses grew and cured. Forb ground cover peaked in April-May, coinciding with fawning, and showed a second, smaller peak in September after summer monsoons occurred. Shrub canopy cover averaged near 10%; it peaked in December, reflecting the tendency for pronghorn in winter to feed on shrubs (Sundstrom et al. 1973, Autenrieth 1978, Kindschy et al. 1982). Tree canopy cover at 40-m² use sites was low most of the year; it peaked during June-August, because pronghorn sometimes used isolated trees for thermal cover during this hot, dry period (Fig. 23).

Cover estimates for grasses, shrubs, cacti, and trees at pronghorn 40-m² use sites differed among capture areas (Table 8; Fig. 24). We found more

Table 6. Use of slope classes by pronghorn compared with slope availability^a, Game Management Units 19A and 21, central Arizona, 1989-92.

| Sex | Slope class (%) | No. of locations | % of locations | Bonferroni 90% CI | No. of random points | % of random points | No. of locations expected | Jacobs' <i>D</i> ^b |
|---------|-----------------|------------------|----------------|-------------------|----------------------|--------------------|---------------------------|-------------------------------|
| Females | 0-9 | 1968 | 81.4 | 79.7 - 83.1 | 434 | 44.1 | 1066 | 0.69 |
| | 10-19 | 275 | 11.4 | 10.0 - 12.8 | 162 | 16.5 | 398 | -0.21 |
| | ≥20 | 174 | 7.2 | 6.1 - 8.3 | 388 | 39.4 | 953 | -0.79 |
| | Total | 2417 | | | | | | |
| Males | 0-9 | 916 | 73.4 | 70.7 - 76.1 | 434 | 44.1 | 550 | 0.55 |
| | 10-19 | 202 | 16.2 | 14.0 - 18.4 | 162 | 16.5 | 205 | |
| | ≥20 | 130 | 10.4 | 8.6 - 12.2 | 388 | 39.4 | 492 | -0.70 |
| | Total | 1248 | | | | | | |

^a Availability estimated following Marcum and Loftsgaarden (1980).

^b Use differed from availability for females ($\chi^2 = 591.61$, 2 df, $P < 0.001$, $n = 2417$) and males ($\chi^2 = 277.65$, 2 df, $P < 0.001$, $n = 1248$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.

Table 7. Aspect use (on slopes ≥ 10%) by pronghorn compared with aspect availability^a, Game Management Units 19A and 21, central Arizona, 1989-92.

| Aspect | No. of locations ^b | % of locations | Bonferroni 90% CI | No. of random points | % of random points ^b | No. of locations expected | Jacobs' <i>D</i> ^c |
|--------|-------------------------------|----------------|-------------------|----------------------|---------------------------------|---------------------------|-------------------------------|
| E | 56 | 7.2 | 4.9 - 9.5 | 65 | 11.8 | 92 | -0.27 |
| N | 37 | 4.7 | 2.8 - 6.6 | 62 | 11.3 | 88 | -0.44 |
| NE | 44 | 5.6 | 3.5 - 7.7 | 47 | 8.5 | 66 | -0.22 |
| NW | 37 | 4.7 | 2.8 - 6.7 | 66 | 12.0 | 94 | -0.47 |
| S | 230 | 29.4 | 25.3 - 33.5 | 95 | 17.3 | 135 | 0.33 |
| SE | 184 | 23.6 | 19.8 - 27.4 | 69 | 12.5 | 98 | 0.37 |
| SW | 130 | 16.6 | 13.3 - 19.9 | 87 | 15.8 | 123 | |
| W | 63 | 8.1 | 5.7 - 10.5 | 59 | 10.7 | 84 | -0.15 |

^a Availability estimated following Marcum and Loftsgaarden (1980).

^b Observed based on number of 781 aerial locations on slopes ≥ 10%. Percent of random points based on 550 random points on slopes ≥ 10%.

^c Use differed from availability ($\chi^2 = 95.02$, 7 df, $P < 0.001$, $n = 781$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.

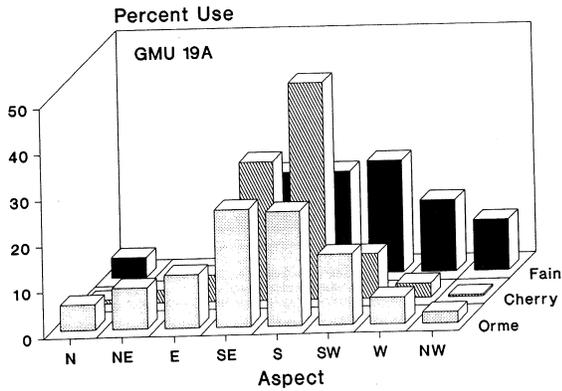
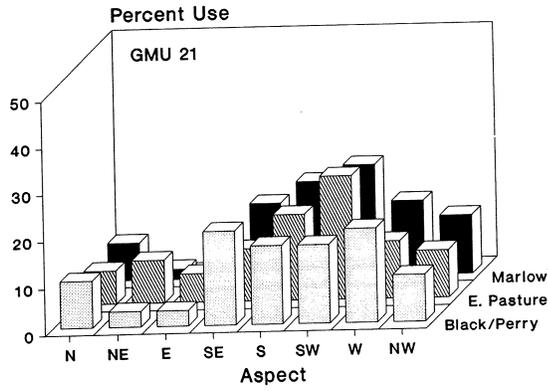


Figure 20. Aspect use (on slopes $\geq 10\%$) by pronghorn in 6 capture areas, GMUs 19A and 21, central Arizona, 1989-92.

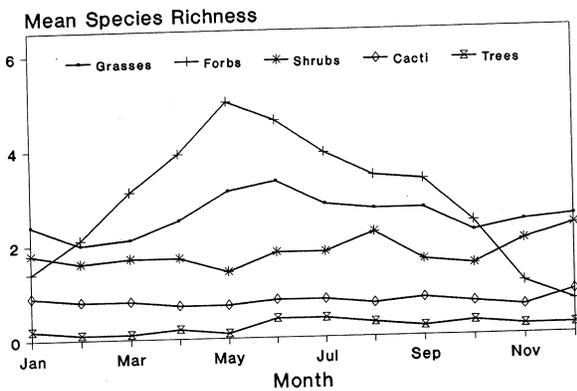


Figure 21. Mean number of plant species (richness) counted by month in 40-m² plots at pronghorn use sites, GMUs 19A and 21, central Arizona, 1989-92.

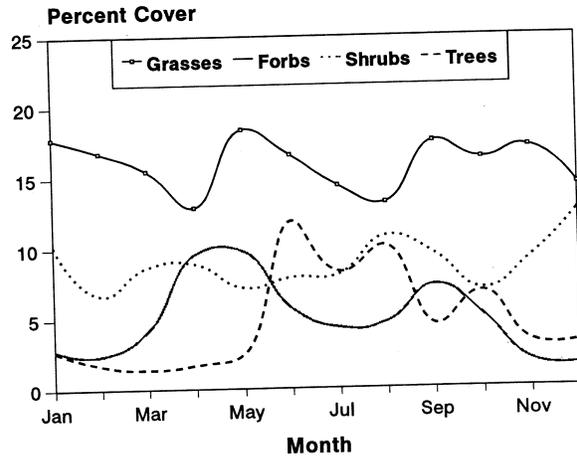


Figure 22. Mean ground and canopy cover estimated in 40-m² plots at pronghorn use sites. Values were smoothed to better illustrate trend patterns.

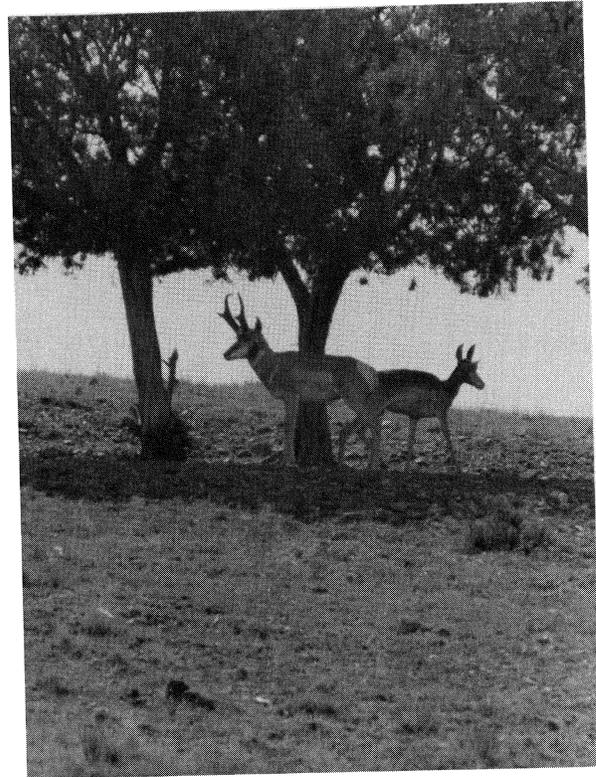


Figure 23. During summer months in central Arizona, 1989-92, pronghorn often used isolated large trees for shade from the sun.

Table 8. Statistical comparisons of vegetative characteristics among 6 pronghorn capture areas, Game Management Unit 19A and 21, central Arizona, 1989-92.

| Variable | Statistical ^a test | Value | df | P | n |
|--|-------------------------------|--------|----|--------|------|
| Species richness by month ^b | | | | | |
| Grasses | F | 12.40 | 11 | <0.001 | 1307 |
| Forbs | K-W χ^2 | 571.03 | | <0.001 | 1307 |
| Shrubs | K-W χ^2 | 44.16 | | <0.001 | 1307 |
| Cacti | K-W χ^2 | 20.81 | | 0.035 | 1307 |
| Trees | K-W χ^2 | 36.79 | | <0.001 | 1307 |
| Ground and canopy cover | | | | | |
| Grasses | χ^2 | 63.16 | 10 | <0.001 | 1305 |
| Forbs | χ^2 | 17.69 | 10 | 0.061 | 1306 |
| Shrubs | χ^2 | 122.22 | 10 | <0.001 | 1305 |
| Cacti | χ^2 | 47.83 | 10 | <0.001 | 1305 |
| Trees | χ^2 | 97.44 | 10 | <0.001 | 1305 |
| Plant height ^c | | | | | |
| Grasses | χ^2 | 41.07 | 10 | <0.001 | 1273 |
| Shrubs | χ^2 | 58.99 | 15 | <0.001 | 1048 |
| Cacti | χ^2 | 150.58 | 10 | <0.001 | 800 |

^a F = One-way analysis of variance, K-W χ^2 = Kruskal-Wallis analysis of variance, χ^2 = Chi-square contingency tables.

^b Number of species counted in 40-m² plot at locations.

^c Visual obstruction height at locations.

Table 9. Number of plant species in 40-m² plots at pronghorn use sites compared with number available^a in 40-m² random plots, Game Management Unit 21, central Arizona, 1989-92.

| Plant category | No. of species | No. of locations | % of locations | Bonferroni 90% CI | No. of random plots | % of random plots | No. of locations expected | Jacobs' D ^b |
|----------------|----------------|------------------|----------------|-------------------|---------------------|-------------------|---------------------------|------------------------|
| Shrubs | 0 | 169 | 27.0 | 23.0 - 31.0 | 45 | 9.1 | 57 | 0.57 |
| | 1-2 | 330 | 52.6 | 48.1 - 57.1 | 205 | 41.4 | 260 | 0.22 |
| | 3-4 | 119 | 19.0 | 15.5 - 22.5 | 219 | 44.2 | 277 | -0.54 |
| | ≥5 | <u>9</u> 627 | 1.4 | 0.3 - 2.5 | 26 | 4.8 | 30 | -0.56 |
| Cacti | 0 | 248 | 39.6 | 35.2 - 44.0 | 164 | 33.1 | 207 | 0.14 |
| | 1 | 285 | 45.5 | 41.0 - 50.0 | 196 | 39.6 | 248 | 0.12 |
| | 2 | 87 | 13.9 | 10.8 - 17.0 | 94 | 19.0 | 119 | -0.18 |
| | ≥3 | <u>7</u> 627 | 1.1 | 0.2 - 2.0 | 41 | 8.3 | 52 | -0.78 |
| Trees | 0 | 534 | 85.2 | 82.2 - 88.2 | 352 | 71.1 | 446 | 0.40 |
| | 1 | 84 | 13.4 | 10.5 - 16.3 | 125 | 25.3 | 159 | -0.37 |
| | ≥2 | <u>9</u> 627 | 1.4 | 0.4 - 2.4 | 18 | 3.6 | 23 | -0.45 |

^a Availability estimated following Marcum and Loftsgaarden (1980).

^b Number at pronghorn locations differed from its availability in random plots for shrubs ($\chi^2 = 125.10$, 3 df, $P < 0.001$), cacti ($\chi^2 = 43.01$, 3df, $P < 0.001$), and trees ($\chi^2 = 33.36$, 2 df, $P < 0.001$). Jacobs' D indicates direction-magnitude of avoidance-selection.

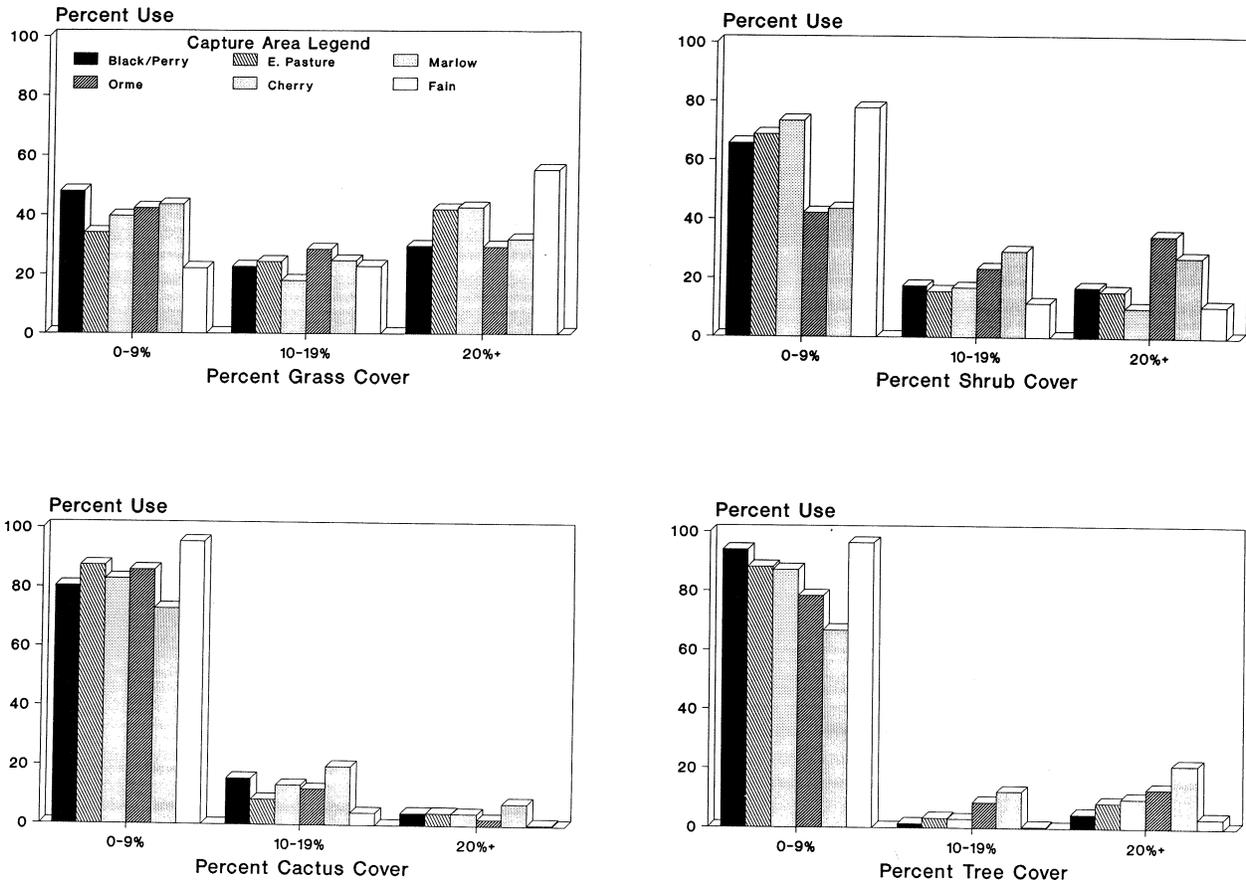


Figure 24. Ground and canopy cover estimated in 40-m² plots at pronghorn use sites in 6 capture areas, GMUs 19A and 21, central Arizona, 1989-92.

locations in Fain with $\geq 20\%$ grass cover than in the remaining capture areas; Fain was short-grass prairie and other areas were semidesert grasslands. Orme and Cherry pronghorn were located more times in $\geq 20\%$ shrub cover than pronghorn in the other areas. Many areas within Orme and Cherry were heavily infested by catclaw and snake-weed. Although cactus cover at pronghorn 40-m² use sites also differed among capture areas, we believe differences were not biologically important. Orme and Cherry areas had more locations in 40-m² sites with $\geq 10\%$ tree canopy cover than did other capture areas. We judged Orme and Cherry to have more juniper invasion into grasslands and more juniper woodlands than other areas.

Pronghorn in GMU 21 did not use ground and canopy cover-classes as available (Table 10). They selected 40-m² sites with $< 10\%$ grass cover and avoided sites with $\geq 50\%$; other grass cover-classes were used in proportion to availability or nearly so. Grass cover alone, if not so great as to prevent forb or shrub growth, did not seem to be important. Pronghorn selected 40-m² areas with $< 10\%$ shrub cover and avoided areas with $\geq 10\%$ shrub cover. Areas with $\geq 20\%$ cactus cover were selected; a number of radio-collared does from Black Mesa and East Pasture spent considerable time during fawning seasons on Black Mesa, which was heavily infested by prickly pear. Tree canopy at 40-m² use sites in GMU 21 was bimodal, differing greatly from that available. Pronghorn selected sites with $< 10\%$ tree canopy

Table 12. Number of plants >0.61 m tall in 40-m² plots at pronghorn use sites compared with the number available^a in 40-m² random plots, Game Management Unit 21, central Arizona, 1990-92.

| Plant category | No. of plants | No. of locations | % of locations | Bonferroni 90% CI | No. of random plots | % of random plots | No. of locations expected | Jacobs' <i>D</i> ^b |
|----------------|---------------|------------------|----------------|-------------------|---------------------|-------------------|---------------------------|-------------------------------|
| Shrubs | 0 | 282 | 73.6 | 68.2 - 79.0 | 221 | 44.7 | 171 | 0.55 |
| | 1 | 45 | 11.7 | 7.8 - 15.6 | 71 | 14.4 | 55 | |
| | 2 | 27 | 7.0 | 3.9 - 10.1 | 53 | 10.7 | 41 | -0.23 |
| | 3 | 10 | 2.6 | 0.6 - 4.5 | 32 | 6.5 | 25 | -0.44 |
| | 4 | 12 | 3.1 | 1.0 - 5.2 | 24 | 4.9 | 19 | |
| | ≥5 | <u>7</u> | 1.9 | 0.2 - 3.6 | <u>93</u> | 18.6 | 71 | -0.84 |
| | | 383 | | | 495 | | | |
| Cacti | 0 | 303 | 79.1 | 74.4 - 83.8 | 340 | 68.7 | 263 | 0.27 |
| | 1 | 57 | 14.9 | 10.8 - 19.0 | 83 | 16.8 | 64 | |
| | 2 | 17 | 4.4 | 2.1 - 6.7 | 42 | 8.5 | 33 | -0.34 |
| | ≥3 | <u>6</u> | 1.6 | 0.2 - 3.0 | <u>30</u> | 6.0 | 23 | -0.59 |
| | | 383 | | | 495 | | | |
| Trees | 0 | 333 | 86.9 | 83.0 - 90.8 | 354 | 71.5 | 274 | 0.45 |
| | 1 | 33 | 8.6 | 5.4 - 11.8 | 89 | 18.0 | 69 | -0.40 |
| | 2 | 14 | 3.7 | 1.5 - 5.9 | 33 | 6.7 | 26 | -0.30 |
| | ≥3 | <u>3</u> | 0.8 | 0.2 - 1.8 | <u>19</u> | 3.8 | 15 | -0.66 |
| | | 383 | | | 495 | | | |

^a Availability estimated according to Marcum and Loftsgaarden (1980).

^b Number of plants at pronghorn locations differed from the number in random plots for shrubs ($\chi^2 = 98.69$, 5 df, $P = 0.001$), cacti ($\chi^2 = 19.58$, 3 df, $P < 0.001$), and trees ($\chi^2 = 31.90$, 3 df, $P < 0.001$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.

woodlands than did the other areas (Fig. 27). In general, we found height ranges of plants at Orme and Cherry sites to differ from those in other areas.

Analysis of the number of plants >0.61 m in 400-m² sites also showed that pronghorn avoided tall vegetation (Table 13). Pronghorn selected extended sites in which all shrubs were less than 0.61 m high and avoided sites where ≥5 shrubs per plot exceeded 0.61 m. They avoided areas where ≥1 cactus plant in 400-m sites exceeded 0.61 m and selected sites with 0 plants above that height. They selected extended sites that contained no trees >0.61 m.

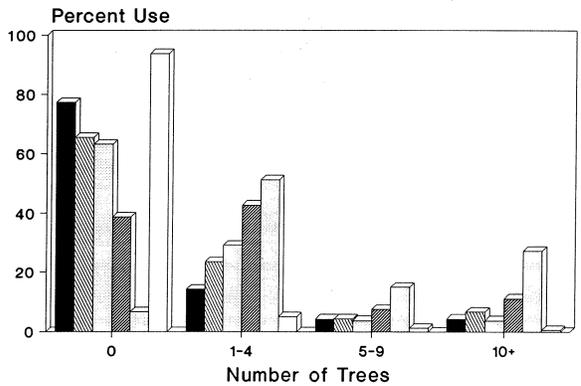
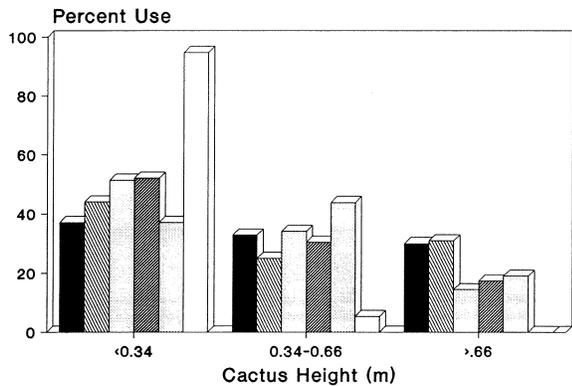
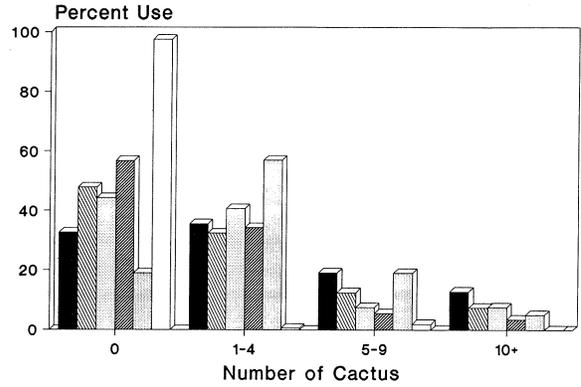
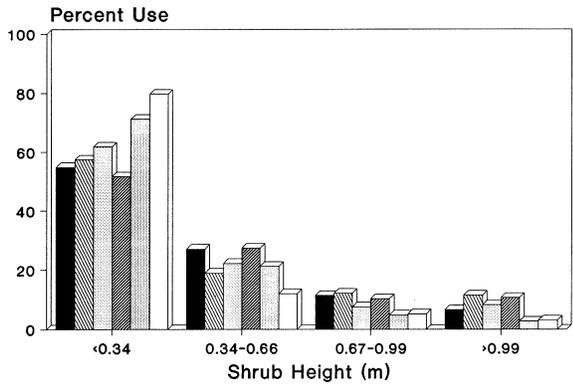
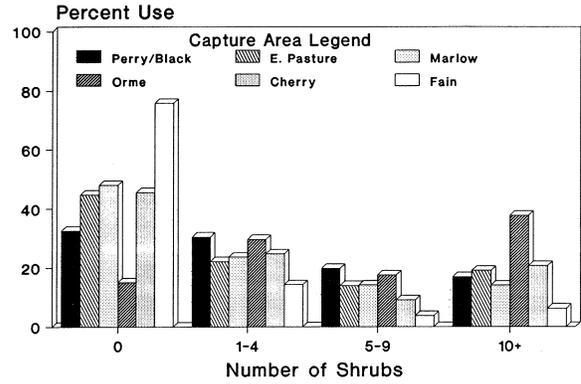
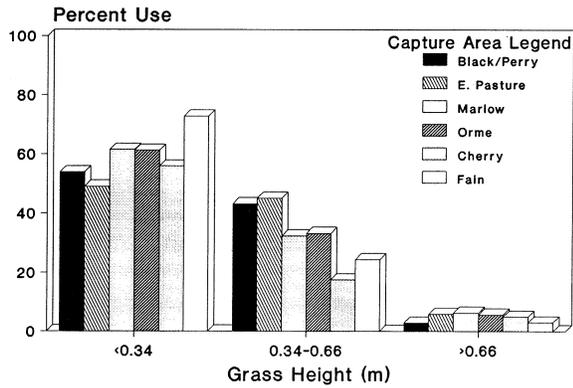


Figure 25. Visual obstruction height of plants in 40-m² plots at pronghorn use sites in 6 capture areas, GMUs 19A and 21, central Arizona, 1989-92.

Figure 26. Number of shrubs, cacti, and trees >0.61 m tall counted in 400-m² plots at pronghorn use sites, GMUs 19A and 21, central Arizona, 1989-92.

Table 13. Number of plants >0.61 m tall in 400-m² plots at pronghorn use sites compared with the number available^a in 400-m² random plots, Game Management Unit 21, central Arizona, 1990-92.

| Plant category | No. of plants | No. of locations | % of locations | Bonferroni 90% CI | No. of random plots | % of random plots | No. of locations expected | Jacobs' <i>D</i> ^b |
|----------------|---------------|------------------|----------------|-------------------|---------------------|-------------------|---------------------------|-------------------------------|
| Shrubs | 0 | 366 | 42.3 | 38.3 - 46.3 | 71 | 14.3 | 124 | 0.63 |
| | 1-4 | 210 | 24.3 | 20.8 - 27.8 | 105 | 21.2 | 183 | |
| | 5-9 | 114 | 13.2 | 10.4 - 16.0 | 102 | 20.6 | 178 | -0.26 |
| | 10-14 | 59 | 6.8 | 4.8 - 8.8 | 72 | 14.5 | 125 | -0.40 |
| | 15-19 | 28 | 3.2 | 1.8 - 4.6 | 33 | 6.7 | 58 | -0.37 |
| | ≥20 | <u>88</u> | 10.2 | 7.7 - 12.7 | 112 | 22.6 | 195 | -0.44 |
| | | 865 | | | | | | |
| Cacti | 0 | 451 | 52.1 | 48.0 - 56.2 | 153 | 30.9 | 267 | 0.42 |
| | 1-4 | 276 | 31.9 | 28.1 - 35.7 | 178 | 36.0 | 311 | -0.09 |
| | 5-9 | 89 | 10.3 | 7.8 - 12.8 | 89 | 18.0 | 156 | -0.31 |
| | 10-14 | 23 | 2.7 | 1.4 - 4.0 | 48 | 9.7 | 84 | -0.59 |
| | 15-19 | 11 | 1.3 | 0.3 - 2.2 | 12 | 2.4 | 21 | -0.30 |
| | ≥20 | <u>15</u> | 1.7 | 0.6 - 2.8 | 15 | 3.0 | 26 | -0.28 |
| | | 865 | | | | | | |
| Trees | 0 | 501 | 57.9 | 53.9 - 61.9 | 170 | 34.3 | 297 | 0.45 |
| | 1-4 | 238 | 27.5 | 23.9 - 31.1 | 192 | 38.8 | 336 | -0.25 |
| | 5-9 | 51 | 5.9 | 4.0 - 7.8 | 76 | 15.4 | 133 | -0.49 |
| | 10-14 | 33 | 3.8 | 2.2 - 5.4 | 35 | 7.1 | 61 | -0.32 |
| | 15-19 | 17 | 2.0 | 0.9 - 3.1 | 11 | 2.2 | 19 | |
| | ≥20 | <u>25</u> | 2.9 | 1.5 - 4.3 | 11 | 2.2 | 19 | |
| | | 865 | | | | | | |

^a Availability estimated following Marcum and Loftsgaarden (1980).

^b Number of plants at pronghorn locations differed from the number in random plots for shrubs ($\chi^2 = 149.82$, 5 df, $P = 0.001$), cacti ($\chi^2 = 82.47$, 5 df, $P < 0.001$), and trees ($\chi^2 = 85.58$, 5 df, $P < 0.001$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.



Figure 27. Pronghorn will sometimes use open woodlands if visibility is adequate for them to detect predators.

Waters and Roads

Water. Both females and males avoided the first 400 m around water sources (Table 14). However, nearly all locations of females (93.8%) and males (93.6%) occurred <1.6 km from a water source, partly because there were few places on the study area ≥ 1.6 km from water. Our study area was very well "watered" and pronghorn simply could not get far enough away from water for water scarcity to become a problem for them.

We tested female and male monthly distributions with respect to distance from water sources (Fig. 28). Females altered ($K-W \chi^2 = 29.53, P = 0.002, n = 3,301$) only slightly their monthly distribution with respect to water sources, whereas males did not ($K-W \chi^2 = 12.75, P = 0.310, n = 1,695$) alter their distribution. We did not consider these slight differences biologically important. Interestingly, distance to water sources was not related ($r^2 = 0.001, P = 0.246, n = 1,276$) to air temperature we measured at time of location.

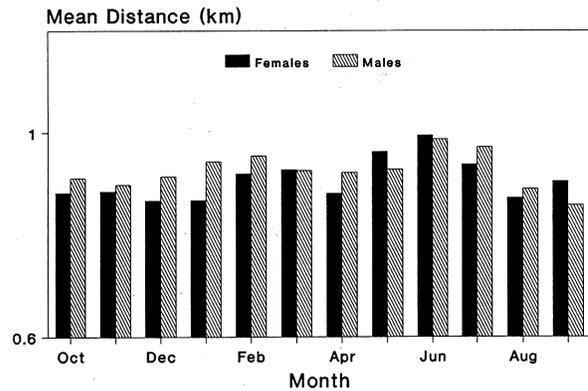


Figure 28. Mean monthly distances from pronghorn locations to nearest identified water source, GMUs 19A and 21, central Arizona, 1989-92.

Roads. Female and male pronghorn slightly avoided areas within 1 km of maintained roads/urban streets, but such avoidance did not suggest that improved roads alone were likely to cause poorer reproduction or higher mortality (Table 15). Our data did suggest that males

avoided areas ≥ 6 km from maintained dirt roads, but we suspect no cause-effect relationship; the only place within our study area that far from such roads was the low-elevation southern end of Black Mesa. Only females during fawning consistently used this area; such doe bands included few bucks.

Females and males also showed weak avoidance of areas near non-maintained dirt

roads/4-wheel-drive trails (Table 15). As with maintained roads/urban streets, these variations from expected use patterns were small enough to suggest that problems with reproduction or mortality caused solely by roads did not exist.

Female pronghorn slightly avoided areas < 0.4 km from highways; males showed a stronger avoidance of areas close to highways (Table 16). Traffic disturbances probably caused this avoidance.

Table 14. Distances of pronghorn locations from identified water sources compared with percent area within isometric distance buffers from water sources, Game Management Units 19A and 21, central Arizona, 1989-92.

| Sex | Distance class (km) | No. of locations | % of locations | Bonferroni 90% CI | % of area ^a | No. of locations expected | Jacobs' <i>D</i> ^b |
|---------|---------------------|--------------------|----------------|-------------------|------------------------|---------------------------|-------------------------------|
| Females | 0 - 0.39 | 399 | 10.3 | 9.1 - 11.5 | 13.7 | 452.2 | -0.16 |
| | 0.40 - 0.79 | 1101 | 33.4 | 31.5 - 35.3 | 31.5 | 1039.8 | |
| | 0.80 - 1.19 | 1056 | 32.0 | 30.1 - 33.9 | 31.9 | 1053.0 | |
| | 1.20 - 1.59 | 600 | 18.2 | 16.6 - 19.7 | 22.1 | 729.5 | -0.12 |
| | ≥ 1.60 | <u>205</u> 3301 | 6.2 | 5.2 - 7.2 | 0.7 | 23.1 | 0.81 |
| Males | 0 - 0.39 | 189 | 11.2 | 9.4 - 13.0 | 13.7 | 232.2 | -0.11 |
| | 0.40 - 0.79 | 484 | 28.6 | 26.0 - 31.1 | 31.5 | 533.9 | -0.07 |
| | 0.80 - 1.19 | 595 | 35.1 | 32.4 - 37.8 | 31.9 | 540.7 | 0.07 |
| | 1.20 - 1.59 | 318 | 18.8 | 16.6 - 2.0 | 22.1 | 374.6 | -0.10 |
| | ≥ 1.60 | <u>109</u> 1695 | 6.4 | 5.0 - 7.8 | 0.7 | 11.9 | 0.81 |

^a Based on GIS-derived percent area within isometric distance class buffers.

^b Distances from water to pronghorn locations differed from expected (based on area availability) for females ($\chi^2 = 175.62$, 4 df, $P < 0.001$) and males ($\chi^2 = 92.08$, 4 df, $P < 0.001$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.

Table 15. Distances of pronghorn locations from maintained dirt roads/urban streets and non-maintained dirt roads/trails compared with percent area available in isometric distance buffers from roads, Game Management Units 19A and 21, central Arizona, 1989-92.

| Sex | Distance class (km) | No. of locations | % of locations | Bonferroni 90% CI | % of area ^a | No. of locations expected | Jacobs' <i>D</i> ^b |
|---|---------------------|------------------|----------------|-------------------|------------------------|---------------------------|-------------------------------|
| Maintained dirt roads and urban streets | | | | | | | |
| Females | 0 - 0.99 | 547 | 16.6 | 15.0 - 18.2 | 18.7 | 617.3 | -0.07 |
| | 1 - 1.99 | 612 | 18.5 | 16.8 - 20.2 | 16.6 | 548.0 | 0.07 |
| | 2 - 2.99 | 658 | 19.9 | 18.2 - 21.6 | 14.7 | 656.9 | 0.18 |
| | 3 - 3.99 | 412 | 12.5 | 11.1 - 13.9 | 12.7 | 419.2 | |
| | 4 - 4.99 | 306 | 9.3 | 8.1 - 10.5 | 10.7 | 353.2 | -0.08 |
| | 5 - 5.99 | 225 | 6.8 | 5.7 - 7.9 | 8.6 | 283.9 | -0.12 |
| | ≥ 6.00 | <u>541</u> | 16.4 | 14.8 - 18.0 | 18.1 | 597.5 | -0.06 |
| | | 3301 | | | | | |
| Males | 0 - 0.99 | 276 | 16.3 | 14.1 - 18.5 | 18.7 | 317.0 | -0.08 |
| | 1 - 1.99 | 373 | 22.0 | 19.5 - 24.5 | 16.6 | 281.4 | 0.17 |
| | 2 - 2.99 | 269 | 15.9 | 13.7 - 18.1 | 14.7 | 249.2 | |
| | 3 - 3.99 | 290 | 17.1 | 14.9 - 19.3 | 12.7 | 215.3 | 0.17 |
| | 4 - 4.99 | 180 | 10.6 | 8.8 - 12.4 | 10.7 | 179.7 | |
| | 5 - 5.99 | 131 | 7.7 | 6.1 - 9.3 | 8.6 | 146.8 | |
| | ≥ 6.00 | <u>176</u> | 10.4 | 8.6 - 12.2 | 18.1 | 306.8 | -0.31 |
| | | 1695 | | | | | |
| Non-maintained dirt roads and trails | | | | | | | |
| Females | 0 - 0.39 | 1006 | 30.5 | 28.6 - 32.4 | 38.1 | 1257.7 | -0.17 |
| | 0.40 - 0.79 | 918 | 27.8 | 26.0 - 29.6 | 27.8 | 917.7 | |
| | 0.80 - 1.19 | 719 | 21.8 | 20.1 - 23.5 | 24.0 | 792.2 | -0.06 |
| | 1.20 - 1.59 | 346 | 10.5 | 9.3 - 11.7 | 9.1 | 300.4 | 0.08 |
| | ≥ 1.60 | <u>312</u> | 9.5 | 8.3 - 10.7 | 8.3 | 273.9 | 0.07 |
| | | 3301 | | | | | |
| Males | 0 - 0.39 | 675 | 39.8 | 37.0 - 42.6 | 38.1 | 645.8 | |
| | 0.40 - 0.79 | 544 | 32.1 | 29.5 - 34.7 | 27.8 | 471.2 | 0.10 |
| | 0.80 - 1.19 | 288 | 17.0 | 14.9 - 19.1 | 24.0 | 406.8 | -0.21 |
| | 1.20 - 1.59 | 92 | 5.4 | 4.1 - 6.7 | 9.1 | 154.2 | -0.27 |
| | ≥ 1.60 | <u>96</u> | 5.7 | 4.4 - 7.0 | 8.3 | 140.7 | -0.20 |
| | | 1695 | | | | | |

^a Based on GIS-derived percent area within isometric distance class buffers.

^b Actual distances differed from expected for maintained roads (females $\chi^2 = 16.33$, 6 df, $P = 0.012$; males $\chi^2 = 63.79$, 6 df, $P < 0.001$) and non-maintained roads (females $\chi^2 = 28.78$, 4 df, $P < 0.001$; males $\chi^2 = 46.05$, 4 df, $P < 0.001$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.

Table 16. Distances of pronghorn locations from fenced, paved highways compared with percent area available within isometric distance buffers from fenced, paved highways, Game Management Units 19A and 21, central Arizona, 1989-92.

| Sex | Distance class (km) | No. of locations ^a | % of locations | Bonferroni 90% CI | % of area ^b | No. of locations expected | Jacobs' <i>D</i> ^c |
|---------|---------------------|-------------------------------|----------------|-------------------|------------------------|---------------------------|-------------------------------|
| Females | 0 - 0.39 | 255 | 16.5 | 14.3 - 18.7 | 21.8 | 337.9 | -0.17 |
| | 0.40 - 0.79 | 422 | 27.2 | 24.6 - 29.8 | 20.3 | 314.7 | 0.19 |
| | 0.80 - 1.19 | 338 | 21.8 | 19.4 - 24.2 | 20.0 | 310.0 | |
| | 1.20 - 1.59 | 284 | 18.3 | 16.0 - 20.5 | 19.2 | 297.6 | |
| | 1.60 - 1.99 | <u>251</u> | 16.2 | 13.8 - 18.2 | 18.7 | 289.9 | -0.09 |
| | | 1550 | | | | | |
| Males | 0 - 0.39 | 68 | 10.2 | 8.4 - 12.0 | 21.8 | 145.4 | -0.42 |
| | 0.40 - 0.79 | 127 | 19.0 | 16.7 - 21.3 | 20.3 | 135.4 | |
| | 0.80 - 1.19 | 163 | 24.4 | 21.9 - 26.9 | 20.0 | 133.4 | 0.13 |
| | 1.20 - 1.59 | 158 | 23.7 | 21.2 - 26.2 | 19.2 | 128.1 | 0.13 |
| | 1.60 - 1.99 | <u>151</u> | 22.6 | 20.1 - 25.1 | 18.7 | 124.7 | 0.12 |
| | | 667 | | | | | |

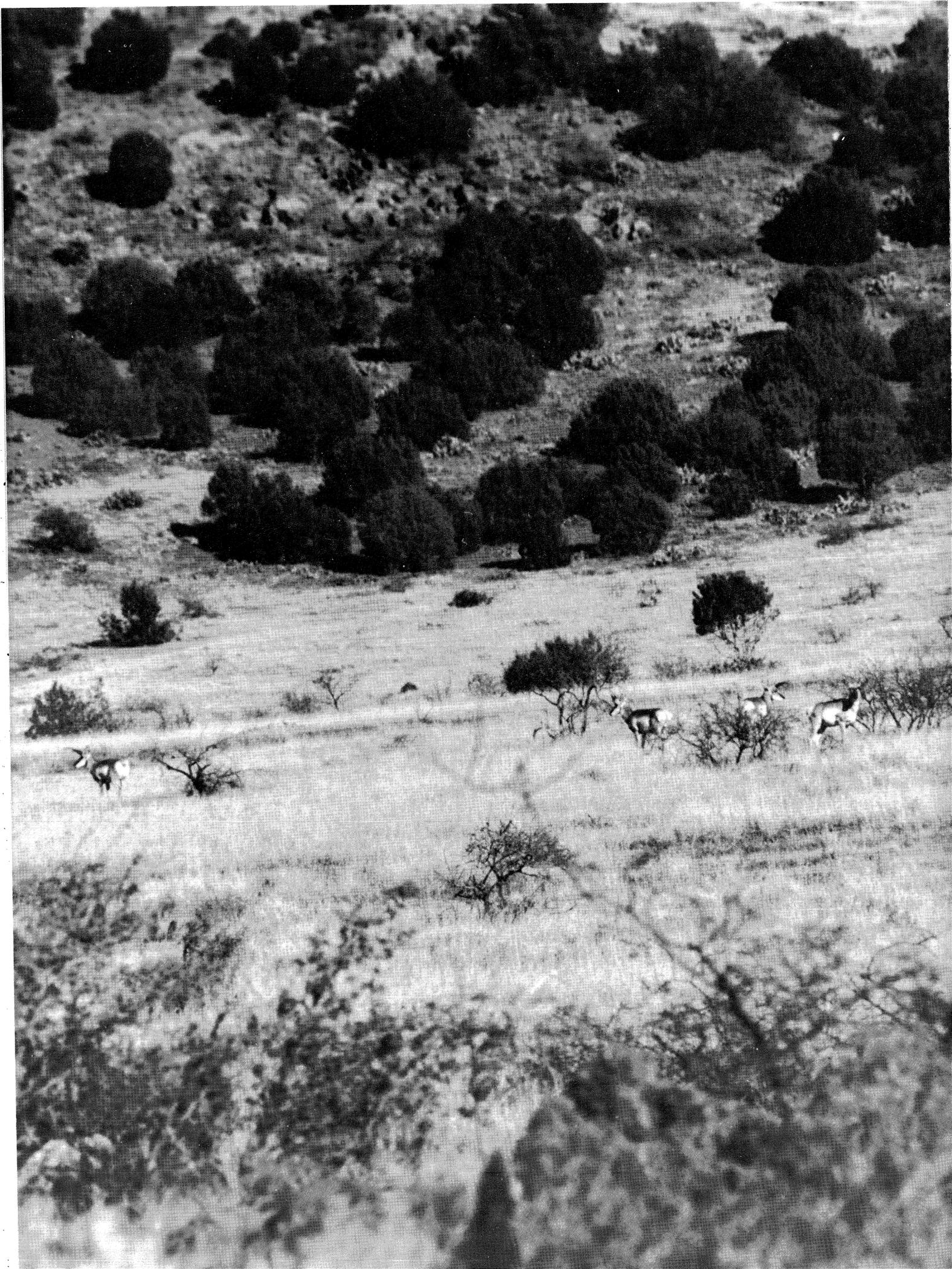
^a Only those locations occurring within 2 km of highway.

^b Derived from GIS-derived percent area within isometric zones of 2-km buffer. Locations expected based on percent area within the buffer.

^c Actual distance differed from expected for females ($\chi^2 = 31.55$, 4 df, $P < 0.001$) and males ($\chi^2 = 36.93$, 4 df, $P < 0.001$). Jacobs' *D* indicates direction-magnitude of avoidance-selection.



Biologist and veterinarian releasing radio-collared doe.



DISCUSSION

A number of pronghorn management issues need discussion. Isolation of pronghorn herds from each other in GMUs 19A and 21, and likely elsewhere in Arizona, has occurred and is continuing to occur. Such isolation of pronghorn populations, caused largely by movement barriers that prevent pronghorn herds from interchanging, is a critical issue.

Pronghorn clearly select specific vegetative and other habitat characteristics, and brush and tree invasion often decreases the suitability of the habitat. Human-related impacts, both positive and negative, are widespread and long-term in pronghorn habitat.

Population Isolation

Analyses of home ranges and movement patterns in GMUs 19A and 21 indicated that pronghorn populations in these units were isolated from each other by human-made barriers. Additionally, these populations seem to be demographically different, probably because hunting activities and mountain lion predation differ between the areas (Ockenfels 1994).

As populations become more isolated and thus smaller, they are more susceptible to extirpation from effects of weather, continual habitat loss, poaching, or over-harvest. Small populations are also more affected by negative changes in gene frequency, which can alter birthrates, recruitment, or deathrates, all critical factors in the long-term survival of a population (Soule 1986).

Managers should try to maintain genetic diversity in populations. Large populations and those that exchange individuals with other populations maintain greater genetic diversity than small, isolated populations. In large and non-isolated populations, inbreeding is relatively low because the presence of many breeding-age individuals provides more breeding combinations (Samson et al. 1985, Reed et al. 1986).

Polygamous species such as pronghorn need larger populations than do monogamous species to maintain genetic diversity (Samson et al. 1985, Reed et al. 1986). In monogamous species, numerous males contribute evenly to the gene pool, ensuring long-term maintenance of genetic diversity in the population, but in polygamous

species only a few males contribute genes in any given year. To prevent loss of heterozygosity in polygamous species requires either large populations or rapid replacement of breeding males (Samson et al. 1985, Reed et al. 1986).

GMU 21 has a single, large pronghorn population that is probably not faced with immediate danger of extirpation or inbreeding. Existing movement corridors ensure genetic interchange between northern and southern population segments of GMU 21. In addition, controlled harvesting of bucks increases the rate of turnover of breeding males. Preventing loss of existing movement corridors is critical to preventing fragmentation of this large population; this and the harvesting of breeding bucks will help maintain genetic diversity.

Populations are more fragmented in GMU 19A. Some of the small, isolated sub-populations could be lost through any of the random or deterministic events noted above. Inbreeding could cause problems. Maintaining the viability of small populations in GMU 19A over long periods could require considerable intervention.

The Fain area of GMU 19A has a pronghorn population that is quite large, even though the area itself is relatively small (140 km²). This area may currently have 1 of the highest pronghorn densities in the state. Several times we observed more than 170 pronghorn in a single herd, and once over 200 pronghorn were counted in a single day from the ground. Based upon total animals counted during annual GMU surveys and our own field observations, we suspect that more than 400 pronghorn exist in the Fain area. This population level, given existing sex and age ratios, is above minimum viable threshold limits necessary for maintenance of genetic diversity (Soule 1986).

Although the pronghorn population in Fain is likely secure for the short term, the long-term picture is less promising. Continual human encroachment is causing habitat loss and population fragmentation. Since the 1970s, residential and commercial development and highway construction around Dewey and Prescott Valley have reduced the habitat's suitability for pronghorn. This development has already caused population fragmentation; development at Prescott Valley from SR 69 to US 89A effectively separated pronghorn on Glassford Hill, the area west of

Prescott Valley, from pronghorn in Fain in less than 20 years (Fig. 29a,b,c). Although some residents feel pronghorn at Glassford Hill seasonally move from the area into Fain, there is no evidence from our study or others to support this contention.

A possible movement corridor exists between Glassford Hill and Fain, though we saw no evidence that it was used during our study. It is a small, undeveloped opening on Roberts Road at the headwater of the Agua Fria River. Development persists and has accelerated since 1991 in this area, but rapid intervention could ensure that this potential corridor is preserved, or even expanded.

Urban development at Dewey has resulted in significant habitat loss. Grassland/shrubland habitat near Dewey has been lost west of SR 69 in GMU 20A. In GMU 19A, loss has occurred east of SR 69 on the south side of SR 169. Development continues to encroach into pronghorn habitat north of SR 169, although pronghorn still exist there because this portion of Dewey is contiguous with habitat at Fain. Further fragmentation and loss of habitat near Dewey need to be prevented to ensure long-term protection of pronghorn.

In contrast with the relatively large pronghorn population of Fain, we estimate that no more than 15-25 and 45-70 pronghorn inhabit Cherry and Orme, respectively. Orme may have 2 sub-populations; if so, then <40 exist in north Orme and <30 inhabit south Orme. For pronghorn, the proposed minimum viable population limit is 50 breeding adults (Samson et al. 1985, Reed et al. 1986, Soule 1986, Scott 1990). Populations in Cherry, north Orme, and south Orme all fall below this level and are probably in danger of extirpation. Immigration and emigration in these sub-populations seem to be minimal or lacking. Also, these populations are not heavily hunted and a few dominant males control reproduction, thereby increasing the likelihood of inbreeding.

The situation at Cherry seems more urgent than that in the rest of the study area. Marked pronghorn in Cherry had relatively small home-range sizes and tended to use marginal habitats. Although small home ranges typically reflect superior habitat quality (Yoakum 1978), home-range size, population density, and habitat quality do not always go hand-in-hand (Van Horne 1983,



Figure 29a. Prescott Valley area in 1966.



Figure 29b. Prescott Valley area in 1976.



Figure 29c. Prescott Valley area in 1985. Continual development has isolated pronghorn sub-populations on the Glassford Hill area to the west and on Fain Ranch to the east.

Hobbs and Hanley 1990). Small home ranges may simply be caused by the inability of pronghorn to move across barriers. Based on observed habitat use patterns at Cherry, we believe home ranges were smaller than for other capture sites because SR 169, I-17, and dense chaparral habitat restricted pronghorn movements.

Cherry and Orme populations have had little recruitment in recent years and appear to be slowly declining in numbers (Steve Andrews, Ariz. Game and Fish Dep., pers. commun.). Poor habitat conditions could have resulted in poor physical condition of females, which normally translates to low recruitment (Yoakum 1978). However, inbreeding also could have occurred in these small populations, causing lower male viability and reduced female fertility, and thus contributing to low recruitment (Samson et al. 1985, Soule 1986).

Habitat quality in Cherry and Orme, particularly in the V-Bar Tank area between north and south Orme, may be decreasing because of brush encroachment. These areas have shrubs or shrub-form trees in densities avoided by pronghorn. In Cherry, areas along SR 169 and near Mistake Tank have significant brush invasion and juniper encroachment. Further declines in habitat quality could lead to even smaller populations than now exist.

Shrub and tree densities can be affected by livestock grazing. Type of animal, timing of grazing, or number of animals can all influence woody plant abundance (Stoddart et al. 1975). For example, heavy cattle grazing has been shown to promote increased shrub densities by reducing perennial grass cover (Stoddart et al. 1975). Sheep and goats show more dietary overlap with pronghorn than do cattle, and losses to pronghorn populations would be expected under heavy grazing pressure from sheep and goats (Schwartz et al. 1977, Hailey 1979, Yoakum and O'Gara 1990).

Movement Barriers

Pronghorn movements have been associated with seasonal changes in forage availability (Hailey 1979, Neff et al. 1985, deVos 1990), water availability (Autenrieth 1978, Yoakum 1978), and weather conditions (Hailey and DeArment 1972, Wiltse 1978, Rosendale et al. 1980, Neff et al. 1985), and with selection of fawning areas

(Buechner 1950). Fenced and paved highways; some fences alone; residential development; and expanses of tall, dense vegetation can restrict pronghorn movements.

As early as 1950, fenced highways were found to restrict pronghorn movements (Buechner 1950). Buechner (1950) noted that pronghorn occasionally crossed such highways but most were frightened away by traffic, usually when they attempted to cross. Highway fences are designed to prevent livestock and large animals from entering highway rights-of-way and endangering traffic, and they can reduce or, as with I-17, eliminate pronghorn movements across highways (Ward et al. 1976, 1980).

Buechner (1950) concluded that net-wire fences and railroad rights-of-way fences also are effective barriers to pronghorn. Net-wire fences in our area had short runs, but some pronghorn areas in Arizona have extensive net-wire fence networks. In such areas, pronghorn movements to locate water and forage or to avoid predators or deep snow would be hindered (Hailey 1979, Yoakum 1979). Railroad rights-of-way fences were not present on our study area, but the Arizona Game and Fish Department and the National Park Service are conducting a study in northern Arizona to evaluate whether such fences restrict pronghorn movements.

Pronghorn avoid areas in which canopy cover of trees and/or tall shrubs exceeds 30% (Autenrieth 1978, Yoakum 1979). Movements along FS 677 in GMU 21 could be threatened by increases in abundance of trees and tall shrubs. The ridge between Cow Canyon and Long Gulch has several narrow areas (<0.40 km wide) that pronghorn navigate when moving between Perry Mesa and northern sub-areas. Increases in trees or tall shrubs at these narrowings could easily sever this corridor.

Habitat Selection

Pronghorn are adapted to "sight and flight" behavior and select habitats that favor this behavior. Visibility, thus detection of predators, tends to be excellent in open, gentle terrain. Vegetation or terrain features that hinder visibility or the ability of pronghorn to run at full speed are typically avoided. Pronghorn in central Arizona selected areas of gentle terrain with few tall shrubs or trees; such areas do not hinder sight

or flight. Pronghorn less commonly used areas with slightly reduced visibility.

Previous studies have suggested that pronghorn are adapted to flat to undulating or rolling topography of mostly <30% slope (Yoakum 1980, Kindschy et al. 1982). In our area pronghorn selected slopes of <10% and made only limited use of slopes from 10% up to 40%. Fain provided the best topography with its gentle slopes and few deep drainages and hilly areas; other capture areas had numerous steep slopes, many deep drainages, and considerable hilly or mountainous terrain.

Vegetation composition and structure have long been known to influence pronghorn use of an area (Yoakum 1980). Based upon numerous studies (e.g., Yoakum 1974, 1979, 1980), we believe that within our area short-grass prairie in Fain came closest to optimum vegetation structure for pronghorn. It had low-growing grasses and shrubs; isolated, large trees; and diverse grass, forb, and shrub species. In the other capture areas, all of which were semidesert grassland, vegetative conditions were less favorable. Many shrubs and cacti were tall and trees were prevalent.

A key vegetative component within areas of $\leq 10\%$ slope is density of plants >0.61 m in height. Such plants obstruct visibility for pronghorn and provide cover for predators. It has been suggested that plant height should be 0.25-0.60 m for optimum pronghorn use (Sundstrom et al. 1973; Kindschy et al. 1978, 1982). Yoakum (1980) believed that a mean vegetation height to ensure pronghorn use would be 0.38 m, that areas with appreciable amounts of vegetation >0.61 m tall would be less preferred, and that areas with vegetation >0.76 m tall would be infrequently used. Our data suggest that areas in central Arizona with considerable amounts of vegetation >0.61 m tall are not simply less preferred as suggested by Yoakum (1980), they are avoided. Avoidance of areas in our study began as vegetation height exceeded 0.33 m.

Pronghorn use of areas with some vegetation >0.61 m tall may be necessary in winter or mid-summer, when forb availability is low or non-existent (Bayless 1969, Sundstrom et al. 1973, Bruns 1977, Neff and Woolsey 1979, Barrett 1980, Smith and Beale 1980). Gay (1984) found areas with tall vegetation in northern Arizona to be winter and early spring feeding sites. Pronghorn

concentrate on the most nutritious shrubs for a forage base during these periods (Yoakum 1990).

Brush and Tree Invasion

The presence of closely-spaced plants such as catclaw, shrub-form mesquite, prickly pear, young junipers, and chaparral shrubs reduce habitat quality for pronghorn. Invasion of these plants into southwestern grasslands or grassland-shrublands is well documented (Brown 1950, Fisher 1950, Branscomb 1958, Paulsen and Ares 1961), and has reduced pronghorn habitat quality over large areas.

Pronghorn used open woodlands in Cherry and Orme, and use of open woodlands has been reported by others (Yoakum 1974, 1980; Neff 1986). Use alone is not an indicator of quality; in some cases pronghorn were simply using the best of what was available.

Both shrub and tree invasions, we believe, are reducing habitat suitability in central Arizona. These processes are slow, often taking decades to occur, and providing scientific documentation is difficult at best. Certainly, we could not prove shrub and tree invasion advanced over the 3-year period of our study. Nevertheless, we believe areas such as Orme and Cherry have serious problems because of ongoing invasions. If the trend continues, extirpation of pronghorn in these areas is likely. In the other capture areas, the situation has not become as critical, but management intervention is still necessary to maintain or improve key pronghorn use areas.

Human Impacts

Human-related activities that affect pronghorn home ranges, movements, and habitat use patterns include provision of livestock and wildlife waters, urban development, highway alignments, livestock fencing, livestock grazing, and fire suppression in grasslands. These activities can have either positive or negative impacts on pronghorn.

Humans have helped pronghorn populations by increasing water availability. Livestock water sources built in previously water-less areas enhance pronghorn survival and lead to more uniform distribution of pronghorn (Stoddart et al. 1975). Water is particularly important to pronghorn survival and recruitment in the Southwest. Beale and Holmgren (1975) concluded that pronghorn cannot live without water during

hot weather, even if forage succulence is above average, and that lack of water most dramatically affects fawns. The optimal pronghorn water distribution is for all areas to be within 1.6 km of water (Kindschy et al. 1978). Most of our study area fell within this distance from water.

Many water sources are not specifically designed for pronghorn. They are often in drainages where abundant shrubs and trees or rough topography provide predator hiding cover. Many waters are fenced so that pronghorn entry is restricted or prevented.

Concentration of livestock at water sources on arid rangelands sometimes causes severely denuded areas (Stoddart et al. 1975), which pronghorn avoid. Pronghorn avoidance of areas within 400 m of water in our study may be related to range abuse. Simply adding more water sources to overused ranges does not always solve the problem, and changes in livestock type and stocking density as well as grazing rotation need to be considered (Stoddart et al. 1975).

Pronghorn in our study often avoided urban development, though they tolerated, under certain circumstances, high human activity levels associated with development. Pronghorn use of areas near development in Prescott Valley and at Cordes Junction seems to attest to at least some adaptation. Still, urban developments need to be planned with pronghorn in mind to prevent further loss of habitat and fragmentation of populations.

Roads affected pronghorn movements and use patterns, but roadbeds alone were not serious obstacles. Though pronghorn tended to avoid areas near roads, we suspect this was caused by noise from traffic and not changes in the habitat. Onlookers stopping along roads also may alarm pronghorn, particularly in areas where hunting normally occurs.

Highways isolated pronghorn populations. This is a serious management problem because resource managers often have little control over alignment, design, and construction of highways. Under current designs, roadside fencing combines with traffic to impose an effective barrier to movement. Removal of fencing would allow pronghorn to cross paved roads regardless, we suspect, of traffic volume; likewise, traffic closures would allow pronghorn to locate acceptable spots along fences to cross. Unfortunately, animal

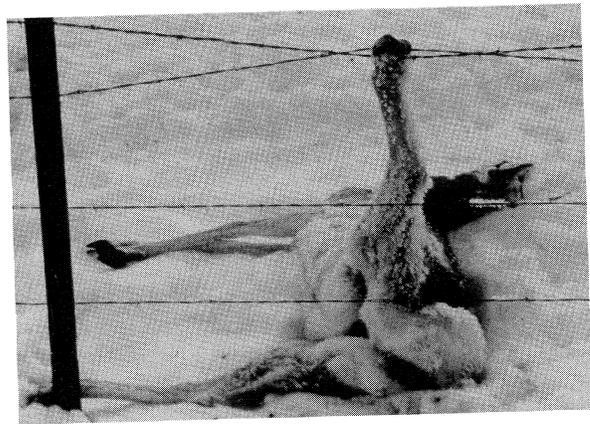


Figure 30. Entanglement in fences can occur when pronghorn attempt to jump fences when they cannot find suitable locations to go under the bottom strand.

movements across highways pose public safety risks. Some mitigation may be possible regardless of associated problems.

Fences are designed for many purposes: to protect traffic from livestock, to protect crops from pests, or to control human access to sensitive areas and private property (O'Gara and Yoakum 1992). Fences also restrict or prevent pronghorn passage, and sometimes reduce pronghorn survival through entanglement (Fig. 30; Yoakum 1979). Although pronghorn in our study did not have serious problems with fence entanglement, their movements were drastically affected.

Poor fence design and placement can adversely affect pronghorn (Spillett et al. 1967; Hailey 1979; Yoakum 1979, 1980; O'Gara and Yoakum 1992). In areas of severe winter weather and heavy snowfall, fences often block migration routes to winter range, and heavy losses to pronghorn populations can result (White 1969, Hailey 1979, LeCount 1987). Poorly-designed fences also block access to forage or water during drought, and cause high mortality (Hailey and DeArment 1972). Modifying fence design and fence placement are possible. Effects of livestock fences will be easier for resource managers to mitigate than will effects of highway rights-of-way fences.

Impacts of livestock on pronghorn are difficult to prove, because they are often slow in developing and are manifested only in the long term. Livestock have negative impacts on pronghorn populations. Livestock grazing

sometimes alters plant structure and species composition of rangelands (Kindschy et al. 1982). Heavy livestock grazing and dissemination of seeds in their droppings promote shrub growth at the expense of perennial grasses (Fisher 1950, Stoddart et al. 1975). Livestock grazing can indirectly control fire by reducing fuels, thereby enhancing brush encroachment (Brown 1950). Livestock use also affects recovery of rangelands following drought periods (Paulsen and Ares 1961). Improper grazing can cause accelerated erosion of soils and loss of fertility, thereby affecting plant nutrient levels (Stoddart et al. 1975), which are important to pronghorn for body maintenance and reproduction. Additionally, sheep and goats compete directly with pronghorn for forbs and winter browse (Stoddart et al. 1975).

We suspect all of these conflicts with livestock affected pronghorn in our study area. The most obvious area affected was Black Mesa, with its heavy infestations of prickly pear and its predominantly annual grasses caused by long-term range abuse and fire suppression.

Brush and tree invasions in our study area, in general, likely are also a result of a combination of historical range abuse by livestock and continual fire suppression. There is good evidence that periodic recurrence of wildfire historically maintained grasslands relatively free of woody species (Brown 1950, Branscomb 1958, Stoddart et al. 1975), and that control of fire in grasslands and grassland-shrublands increases shrub and tree encroachment (Stoddart et al. 1975).

Pronghorn feed in recently burned areas because abundant forbs and grasses sprout after a burn (Autenreith 1978). Spring burning of tobosa grasslands in our study area increased the production and nutrient content of forbs eaten by pronghorn (Boren 1985). Programs designed to reduce woody species abundance in central Arizona should directly benefit pronghorn.



CONCLUSIONS

Home-range characteristics and movement patterns indicated that pronghorn in GMUs 19A and 21 are 2 separate populations. Pronghorn we studied in GMU 19A are 3 sub-populations: (1) Cherry, (2) Fain, and (3) Orme. Cherry and Orme sub-populations are in danger of extirpation. Moreover, without rapid intervention the Orme sub-population will soon be fragmented into northern and southern sub-populations, if this has not already occurred. Further research on the degree of fragmentation of pronghorn populations in central Arizona should be considered. Research into the effects of fragmentation on genetic diversity and pronghorn survival is warranted.

GMU 21 currently has a single, secure population. However, movement corridors between northern and southern areas are narrow and threatened by shrub and tree encroachment and human development. Loss of movement corridors could fragment GMU 21 pronghorn into northern and southern herds.

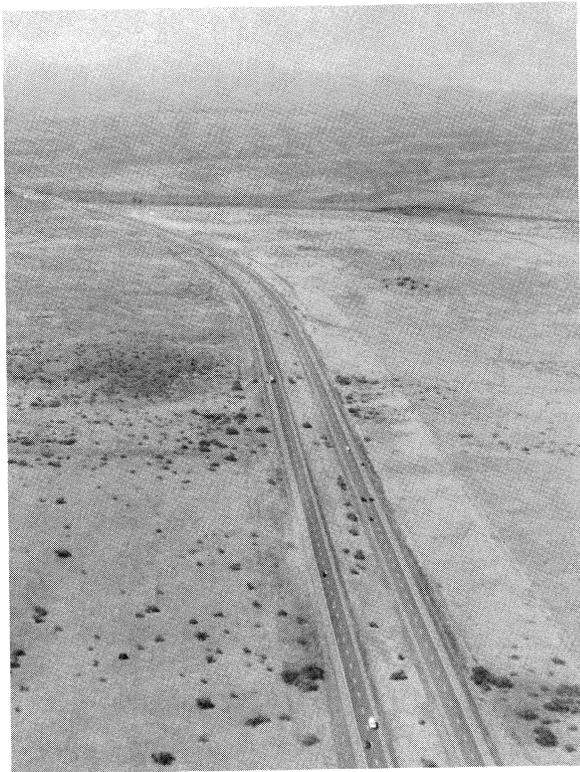


Figure 31. Interstate Highway 17 that separates GMUs 19A and 21, central Arizona, has isolated pronghorn into separate populations.

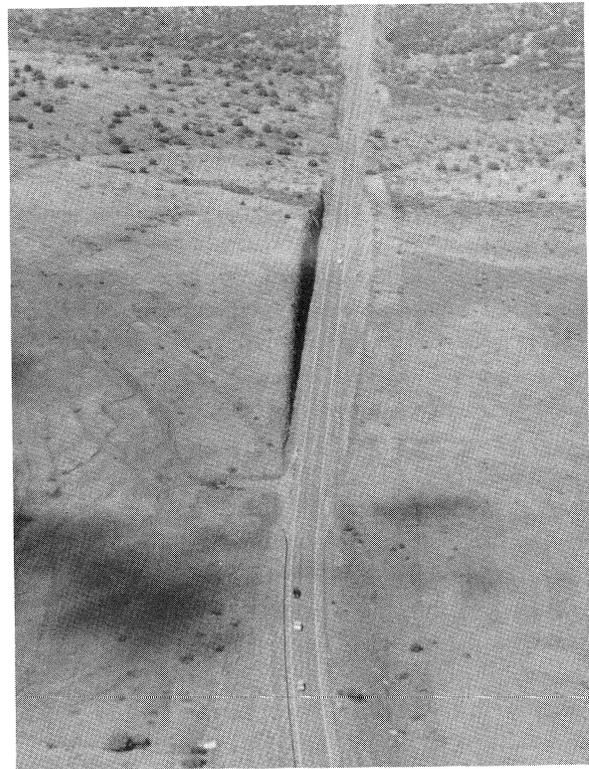


Figure 32. Fencing and paving improvements on State Route 169 in GMU 19A, central Arizona, separated pronghorn in the Cherry area (right) from those at Orme (left).

Fenced, paved highways are effective barriers to pronghorn movements. Interstate 17, the legal boundary between GMU 19A and 21, is a physical barrier restricting pronghorn movements between these 2 GMUs (Fig. 31). Within GMU 19A, SR 169 separated pronghorn into Cherry and Orme sub-populations (Fig. 32). Research on ways to mitigate effects of highways on pronghorn movements is critical.

Vegetation can also pose a barrier to pronghorn movements. Dense chaparral between the Fain area and the Cherry and Orme areas restricted or prevented interchange between pronghorn sub-populations. Barriers between our study area and the Verde Valley, including dense chaparral, extensive closed woodland or forest habitat, and steep, heavily-vegetated gradients, may have blocked movements into the Verde Valley. Research on effects of vegetation removal on pronghorn movements should be conducted.

Urban development can fragment pronghorn populations. Development at Prescott Valley

between SR 69 and US 89A seemed to separate pronghorn at Fain from those in the Glassford Hill area. A migration corridor along I-17 within GMU 21 is not secure from similar human encroachment. Expanding development east of Cordes Junction would constrict, if not sever, the narrow corridor between East Pasture and Black Mesa. Additional human disturbance or development at the corridor bottleneck near Sunset Point could easily fragment southern Black Mesa pronghorn from the rest of the GMU 21 population. Research on effects of urban development on pronghorn movements and home-range patterns, and on ways to mitigate adverse effects, should be undertaken.

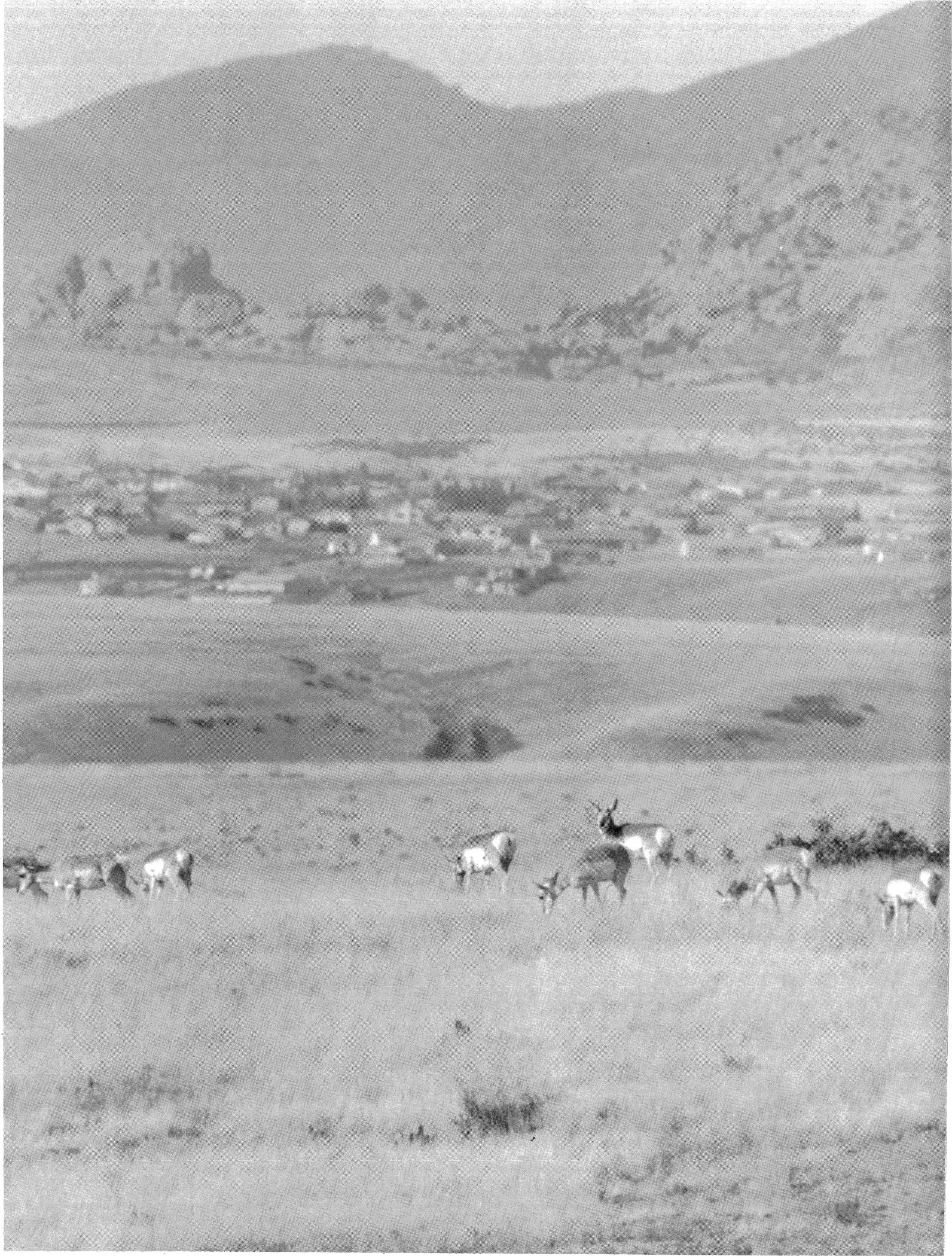
Pronghorn select areas of low relief and with vegetation that provides good visibility. By these criteria, pronghorn in Orme and Cherry are using substantial amounts of marginal habitat. Other sub-populations have better habitats available. In our study area, habitat characteristics in the Fain area seem to be closest to optimum for pronghorn. Further research on pronghorn habitat use patterns and on the effects of density of tall vegetation, particularly tree densities in woodland and forest situations, is critical to better understand Arizona's pronghorn distribution.

Ready access to water is required to maintain high densities of pronghorn (Autenreith 1978, Hailey 1979, O'Gara and Yoakum 1992). Water distributed so that most areas are <1.6 km from the nearest source is adequate. A maximum distance of 16.0 km between (= 8.0 km radius from) water sources should be the minimum standard (Yoakum 1978). By these measures, our study area was well-watered. Further research is needed to determine proper spacing of waters to optimize pronghorn distribution.

Roads, in addition to being movement barriers, affect pronghorn habitat use patterns. Slight avoidance by pronghorn in our study of habitats along fenced, paved highways was probably caused by disturbances associated with traffic. Further research into reasons for avoidance of roads (e.g., noise levels, traffic volume, and harassment by onlookers) seems to be warranted.



Biologist measuring habitat characteristics at pronghorn 40-m² use site.



MANAGEMENT OPTIONS

Based on this study, pronghorn management in Arizona should include: reducing herd fragmentation; restoring, maintaining, or improving grasslands; and intensively managing small, isolated populations. Highway rights-of-way, livestock fencing, and brush encroachment are major issues relative to fragmentation.

Recommended habitat maintenance and restoration include: proper management of livestock grazing; use of fire; and control of shrub, cactus, and tree invasion. Active intervention is necessary because climate and non-use alone may not heal the landscape (Paulsen and Ares 1961, Stoddart et al. 1975). Water source development or modification and range reseeding also should be considered. Predator control, transplanting pronghorn, and herding may be needed to manage small, isolated populations.

The reader is cautioned that the following options are intended for pronghorn management in Arizona. Options are designed to maintain or increase pronghorn numbers in a given area. Options may not be suitable for managing other species of wildlife, which may not respond to them in the same way as pronghorn. It is likely that option combinations will be the most beneficial. These options are starting-point guidelines for improving pronghorn management, and further inquiry into individual options is suggested.

Mitigating Highway Rights-of-Way Impacts

Resource managers need to coordinate with highway planners to properly mitigate highway impacts on pronghorn populations. Discussion items should include: fencing structure and placement; pronghorn movement corridors; and highway alignments in pronghorn habitat.

Remove Fences. One option is to remove rights-of-way fences that block movement corridors. Based on our knowledge of pronghorn crossing unfenced, paved roadways (e.g., Dugas Road near I-17, Wupatki National Monument loop road, and the Petrified Forest National Park road), removing highway fences would allow pronghorn to freely cross roads. Although this option has tremendous potential for relieving population fragmentation, it is unlikely that it could be widely used because of increased risks of

vehicles colliding with pronghorn. In areas of low traffic volume, however, this option should be seriously considered. For example, SR 169 may have a low enough traffic volume that some sections of fencing could be removed to accommodate pronghorn movements; interference with livestock control would be reduced if areas coincided with rested pastures in deferred-pasture and rest-rotation livestock grazing schedules.

Modify Fencing Standards. Existing mitigation procedures used by Arizona Department of Transportation (ADOT) allow for use of standard wildlife (game) fencing. These game fences consist of 4 wire strands; the bottom wire (smooth) is placed at a minimum height of 41 cm and the top 3 strands are barbed wire. If traffic volume is low enough, raising bottom strands to 51-56 cm at likely sites would increase the likelihood that pronghorn would cross highways. Pronghorn fence passes could also be installed along existing highways (Mapston 1970). On the negative side, an increased risk to public safety and more road-killed pronghorn could result.

Move Fences Farther Away. Highway standard fences combined with heavy traffic volume seems to be a greater barrier to pronghorn movement than either alone. By moving fences farther from paved roads, managers might improve the likelihood of pronghorn crossing. Wyoming's highway department is currently testing this feature near Rock Springs (Phil Riddle, Wyoming Game and Fish Department, pers. commun.).

Provide Underpasses. This option likely has limited application given that Ward et al. (1976) found that pronghorn did not use underpasses along I-80 in Wyoming during a 2-year study period. Further work noted only 1 crossing through an underpass during a 6-year period (Ward et al. 1980). That underpass had a dirt rather than concrete floor. The I-80 (4-lane divided-highway) underpass was 33.5 m long (i.e., transverse to highway), 9.1 m wide (i.e., parallel to highway), and 4 m high. It is possible that the darkness in the long, narrow underpass may have restricted visibility and thereby precluded pronghorn use. Underpasses for 2-lane highways would likely be less than 33.5 m long and might accommodate pronghorn passage if width is >9.1 m. We suspect pronghorn could be herded through underpasses that provide good visibility. Additional research is needed on underpass

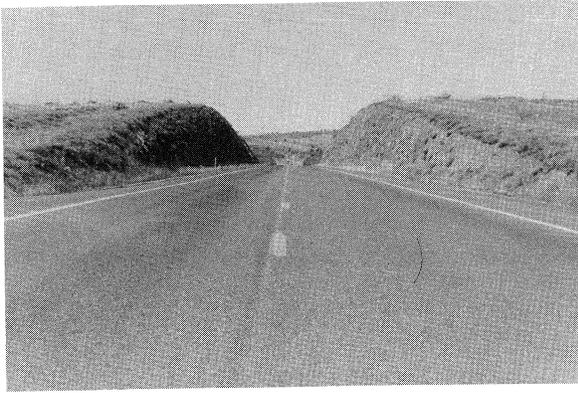


Figure 33. A possible site to build and test a highway overpass to accommodate pronghorn movements exists at a narrow cut along SR 169, west of I-17, GMU 19A, central Arizona.

dimensions necessary to accommodate pronghorn passage.

Provide Overpasses. We did not locate research findings involving pronghorn use of highway overpasses, but desert mule deer (*Odocoileus hemionus crooki*) and other wildlife species used overpasses (water overshoots) that bridged the Central Arizona Project canal in western Arizona (Krausman and Hervert 1984). We suspect pronghorn might use a dirt-floored structure with low, flared-out side barriers that increase visibility. Research to test this type of structure could be done in central Arizona, just west of the junction of I-17 and SR 169 at a narrow cut on SR 169 between mileposts 11 and 12 (Fig. 33; UTM's EW4058, NS38197). If pronghorn use an overpass here, north Orme and Cherry pronghorn populations could interchange.

Restrict Building of New Highways. To prevent further pronghorn population fragmentation, new fenced, paved highways could be routed outside of pronghorn habitat. Other wildlife species seem better able than pronghorn to cross highways and probably would not be as strongly impacted (Ward et al. 1976, 1980).

Modify Location of Planned Highways. If new highways must be built through pronghorn habitat, construction could be partially mitigated by judicious placement of rights-of-way. Maximizing the sizes of pronghorn habitat fragments and allowing for pronghorn movements to seasonal ranges should be standard wildlife mitigation features in highway planning and design.

Remove or Take Down Fencing during Severe Winter Weather. In areas where snow depth could be >41 cm for considerable periods and thus prevent pronghorn from going under fences along highways (White 1969, LeCount 1987), we recommend that coordinated planning by agencies, permittees, and landowners determine appropriate locations to remove or take down fence wires. Without the ability to move past such fences, migrating pronghorn often die from starvation, exposure, or predation, and populations are severely reduced (White 1969, LeCount 1987).

Mitigating Livestock Fencing Problems

Mitigating adverse effects of fencing must be a high priority for pronghorn management on western rangelands (O'Gara and Yoakum 1992). Using no fences is the best option for management because we cannot assume pronghorn will adapt to fences (O'Gara and Yoakum 1992). But given that fences are likely to stay in most pronghorn range, fence structure (i.e., fence type, number and type of strands, height above ground of individual strands), placement, and density become important. Spillett et al. (1967), Autenreith (1978), Howard et al. (1983, 1990), and O'Gara and Yoakum (1992) describe design options for fences. In general, we believe the impacts of fencing on pronghorn can be minimized by using the following options in descending order of preference.

Use No Fences. This option is best where other management techniques could effectively control livestock distribution (O'Gara and Yoakum 1992).

Use Electric Fences. Electric fences are desirable over standard wildlife fences. Our observations and those by Brown (1990) indicate electric fencing is less restrictive than other kinds of fencing to pronghorn movement.

Modify Barbed-Wire Fences. If electric fences cannot be used, modified barbed-wire fences should be used. Smooth bottom strands should be raised from the current standard of 41-46 cm above ground to 51-56 cm off the ground. Without question, interior pasture fences should be modified immediately; allotment boundary fences should be modified if adjacent livestock permittees and landowners agree. The Verde Ranger District of Prescott National Forest is currently working with grazing permittees on

such modifications and permittees have not reported livestock management problems associated with the fence modifications. (Douglas T. McPhee, U.S. For. Serv., pers. commun.).

Use Standard Game Fences. As a minimum, pronghorn fences of 3-strand barbed-wire design with a maximum height of 86 cm and a smooth bottom strand 41-46 cm above ground should be used (O'Gara and Yoakum 1992).

Use Barbed-Wire Fences. Barbed-wire fencing without wildlife considerations, although better than net-wire fencing, is still undesirable. If livestock fences do not meet pronghorn fencing standards, fence passes should be installed at strategic locations (Mapston 1970). Additionally, barbed-wire fences should be modified over time to meet or exceed game fencing standards.

Restrict Use of Net-wire Fences. Under no circumstances should permanent net-wire fences be allowed on federal or state lands. Temporary use of net-wire fencing for livestock control should consider pronghorn seasonal movement patterns (O'Gara and Yoakum 1992). To prevent pronghorn populations from being fragmented, land management agencies and planning-zoning commissions should restrict further use of net-wire fences in existing pronghorn range and in potential reintroduction sites. Removal of existing net-wire fences is essential for uninhibited pronghorn movements.

Providing Movement Corridors

Maintain Corridors. Pronghorn movement corridors need to be identified and threatened areas located so that fuelwood cuts, prescribed burning, and brush clearing can be used to maintain the corridors. Comparison of past and present aerial photographs could be used to identify corridors.

Paved roads cutting through corridors need road signs to alert drivers about possible pronghorn movements. Wyoming is testing the use of road signs on a paved road to see if hazards to humans and pronghorn can be minimized; in the tests, fences were moved >0.40 km away from roads to encourage pronghorn to cross (Phil Riddle, Wyoming Game and Fish Dep., pers. commun.).

Create Corridors Through Human Developments. Coordination with local planning-zoning commissions could expedite corridor

maintenance and promote re-opening of original movement corridors where human developments may intrude or have intruded. This is extremely important where future developments are likely to extend from 1 fenced, paved highway to another (e.g., Prescott Valley). Fences and other structural barriers within existing areas of development need to be eliminated or modified to allow pronghorn passage. For example, intervention along Roberts Road, at the Agua Fria drainage headwater in Prescott Valley, may re-establish pronghorn interchange between Glassford Hill and Fain. Research is necessary to determine minimum corridor width, but we suspect it should exceed 0.40 km.

Reduce New Development in Existing Corridors. The number of fences and human-related disturbances increases as urban development proceeds; these may cause pronghorn to abandon corridors. For example, pronghorn use the eastern fence boundary of Cordes Junction as a movement corridor between East Pasture and Black Mesa, and further housing development could obstruct that corridor. Prescribed burns, brush clearing, and fuelwood cuts, together with appropriately planned development, could maintain or widen corridors.

Reducing Tall, Woody Vegetation Densities

Mechanical Control. Height and density of woody vegetation is an important issue, because pronghorn avoid areas where vegetation >0.61 m tall exceeds 30% canopy cover (Autenreith 1978; Yoakum 1979, 1982; O'Gara and Yoakum 1992). Maintaining existing pronghorn movement corridors or re-creating old ones can be done by mechanical removal of trees and/or tall shrubs. An old pronghorn movement corridor between Fain and Orme along Yarber Wash near SR 169 (Steve Andrews, Ariz. Game and Fish Dep., pers. commun.) should be re-established by chaparral removal. Anchor chaining should be considered for reducing brush and tree densities (Stoddart et al. 1975, Autenreith 1978, Yoakum 1979, O'Gara and Yoakum 1992); other mechanical devices also are available for use.

Mechanical control of sprouting species such as mesquite requires companion treatment with fire, chemicals, or livestock browsing; proper timing of companion control is essential for success (Stoddart et al. 1975). Because pronghorn

forage on woody plants in winter, control of woody vegetation must be selectively directed at invading species of low nutritional value, such as mesquite and catclaw.

Chemical Control. Chemical spraying is a technique often used to reduce shrub densities (Stoddart et al. 1975, Autenreith 1978, O'Gara and Yoakum 1992). Chemical control has numerous disadvantages, 1 being that although spraying typically does not harm native grasses, forb and browse loss can be significant (Autenreith 1978). Also, chemical control affects high-quality browse and forb species as well as low-quality invading species (Stoddart et al. 1975). Thus chemical control must be timed to coincide with forb senescence and applied to minimize destruction of pronghorn browse. Selecting a proper time to apply chemicals could be difficult in the Southwest—although forbs are scarce in winter, many invading shrubs are cold-deciduous and probably cannot be killed in winter. Companion treatments with other techniques may be necessary to better ensure successful treatment.

Prescribed Burning. Prescribed burning benefits pronghorn (Autenreith 1978), and prescribed fires could be used for movement corridor maintenance and for widespread brush control (Fig. 34). Prescribed fires control brush, increase forage yield, improve wildlife habitat, and control rangeland plant diseases (McPherson et al. 1986). Native grasses and forbs are not harmed by properly timed burns, and shrub, cactus, and tree densities may be reduced. Sufficient fine fuels must be present to ensure a burn (Stoddart et al. 1975). Concentration of livestock after the burn must be prevented (McPherson et al. 1986).

Mesquite plants <3.5 years of age are easily killed and cactus is readily damaged by fires (Britton et al. 1987). Cactus kill rates increase 1-3 years after burning if insect activity is sufficient or chemical spraying is used as a supplemental treatment (Britton et al. 1987). Fires are a cost-effective means of controlling junipers, and pretreatment chaining of juniper areas increases burn effectiveness (Rasmussen et al. 1986).

Desirable fire frequency for tobosa grasslands ranges from once every 5 years for bottomlands to once every 8 years for uplands (Britton et al. 1987). Juniper woodlands should be burned every 10-20 years to maintain a productive wildlife community (Rasmussen et al. 1986).



Figure 34. Prescribed burning can be used to reduce shrub and tree densities in pronghorn habitat.

Fuelwood Cuts. Many grasslands or grassland-shrublands have been invaded by juniper trees (Stoddart et al. 1975). Tree densities can be reduced with planned fuelwood cuts. Woodland tree densities should be <38 per ha to ensure at least moderate use by pronghorn (Alexander and Ockenfels In Prep). Large trees, which pronghorn often use for shade, should be left to achieve a savanna landscape.

Tree re-establishment in treated areas is likely if overgrazing by livestock or wildlife occurs (Stoddart et al. 1975); thus grazing practices influence the effectiveness of clearing. Reseeding should aid grassland restoration in fuelwood cut areas.

Livestock Grazing Management. Use of livestock to control shrub or tree densities is possible. Stoddart et al. (1975) noted that, to ensure any success with this biological control, permittees and agency officials must: (1) control the selected livestock type, (2) ensure that livestock graze only "target" species of shrubs, (3) ensure the availability of replacement local forage species or reseeding mixture, and (4) schedule grazing at the most susceptible time of year. Stoddart et al. (1975) should be used as a starting point to determine which livestock type should be used to help control shrubs; goats are most often used.

If grazing is used as a range improvement technique, it must be done properly to prevent further deterioration of pronghorn habitat.

Making Habitat Improvements

Reseed Ranges with Native Mixtures. After treating sites with mechanical or chemical methods, fire, or biological control, site restoration should be considered. Restoration sites should be small because artificial seeding programs that result in monoculture communities over large (>2,000 ha) areas have little benefit for pronghorn (Yoakum 1980, O'Gara and Yoakum 1992). A variety of local grasses, forbs, and shrubs in the seeding mixture is recommended (Autenreith 1978, Yoakum and O'Gara 1992).

Optimize Water Distribution. All pronghorn habitat should be <8.0 km from a reliable water source (Yoakum 1978); most areas should be <1.6 km from water to maintain maximum pronghorn numbers (Kindschy et al. 1978). Interestingly, most neonatal fawn bedsites in short-grass prairies of central Arizona are ≤ 1 km from water during the critical first 2 weeks of life (Ockenfels et al. 1992).

GIS technology can be used to assist in strategic placement of waters to minimize the number of waters necessary for the desired coverage level. Waters should be on flat to undulating terrain away from predator hiding cover and, if fencing of water sources is necessary for livestock management, smooth bottom strands of wire should be used and set >56 cm above ground.

Managing Isolated Populations

Control Predators. Udy (1953) recognized that predators often have a negative effect on pronghorn populations. For populations of <20-30 pronghorn threatened with extirpation because reproduction is too low to sustain the population, intensive predator control may allow pronghorn to maintain or increase their numbers until fragmentation is rectified and habitat improvement benefits are realized.

It has long been known that pronghorn recruitment is correlated with predator control (O'Gara and Yoakum 1992). Aerial gunning from a helicopter, if done selectively and intensively prior to the peak of fawning, is a cost-effective predator control technique for enhancing pronghorn fawn survival in Arizona (Smith et al. 1986).

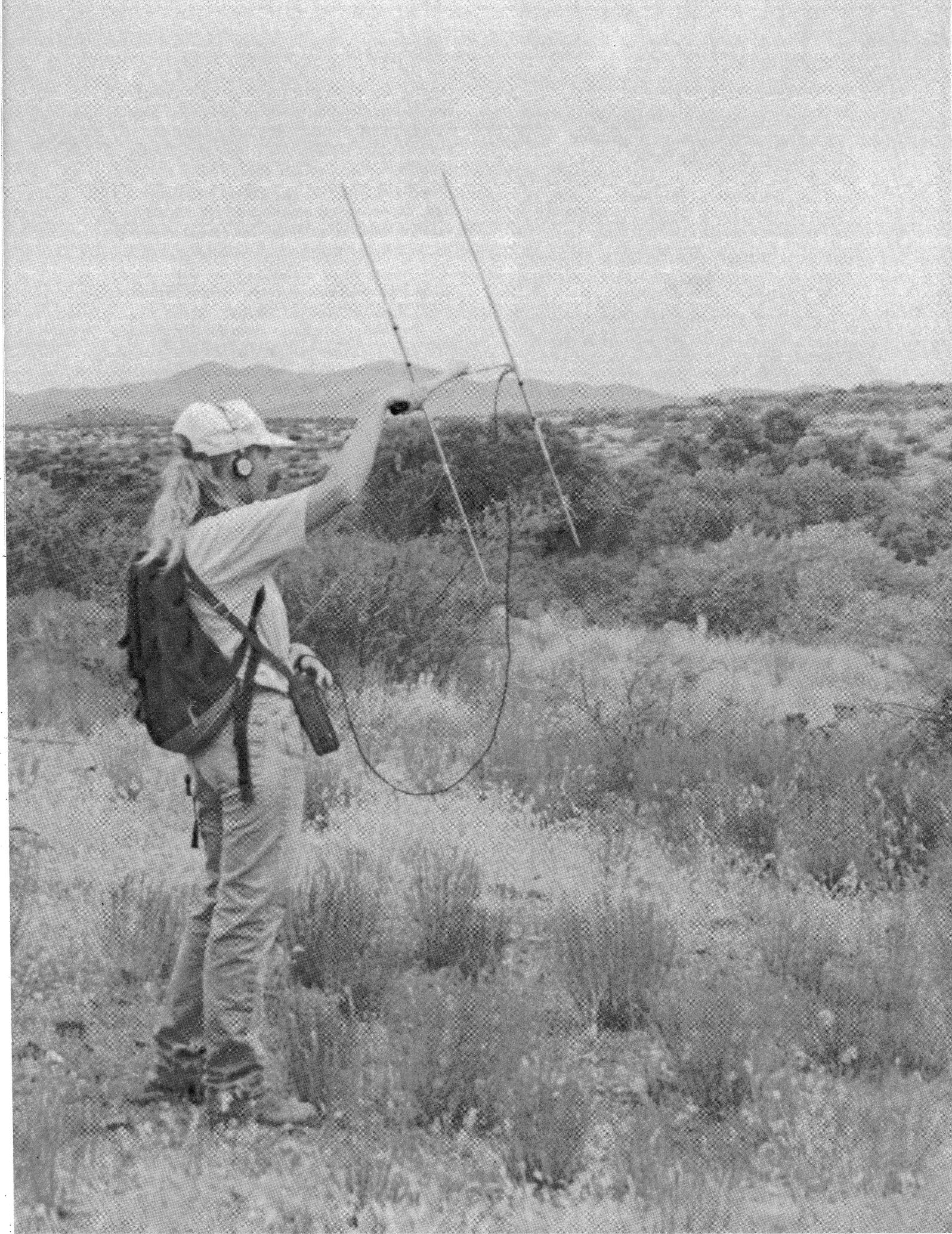
Use Hunts to Remove Dominant Males. Dominant bucks do most of the breeding in free-

ranging pronghorn populations; random breeding is not likely to occur (Yoakum 1978). For small, isolated pronghorn populations, genetic diversity can be maintained longer by ensuring that more males breed (Samson et al. 1985, Reed et al. 1986). Removal of dominant bucks could accomplish this. Capturing these bucks is little better than shooting them, as we found that net-gunning large (>38-cm-long horns) bucks has a high probability of capture-related mortality. Capture drugs could be used instead, but high capture-related mortality is still likely (O'Gara and Yoakum 1992).

Transplant Pronghorn. Pronghorn populations with breeding numbers below 50 (Scott 1990) could be augmented by transplants to enhance genetic diversity. The number of pronghorn necessary to maintain isolated populations depends on existing sex and age ratios and the number of dominant breeding males, but numbers need to be greater than 50 breeding adults.

Transplant stock could be taken from pronghorn populations that are at high densities. For example, pronghorn from Fain could be relocated to nearby Cherry and Orme. Negative aspects to consider are the expenditures for the transplant program and the associated capture and transport mortalities.

Herd Pronghorn. Some pronghorn populations in Arizona are isolated by urban development where private land ownership precludes active habitat management by government agencies. It may be possible to move such isolated pronghorn herds across highways by herding. Removing fences along rights-of-way for short distances, building cloth wings, and controlling traffic during the actual drive need to be coordinated with ADOT and local government officials. Use of horses and helicopters might facilitate such an operation. Because of the associated risks to humans and pronghorn, we believe this option should be used only if pronghorn are in critical danger of local extirpation.



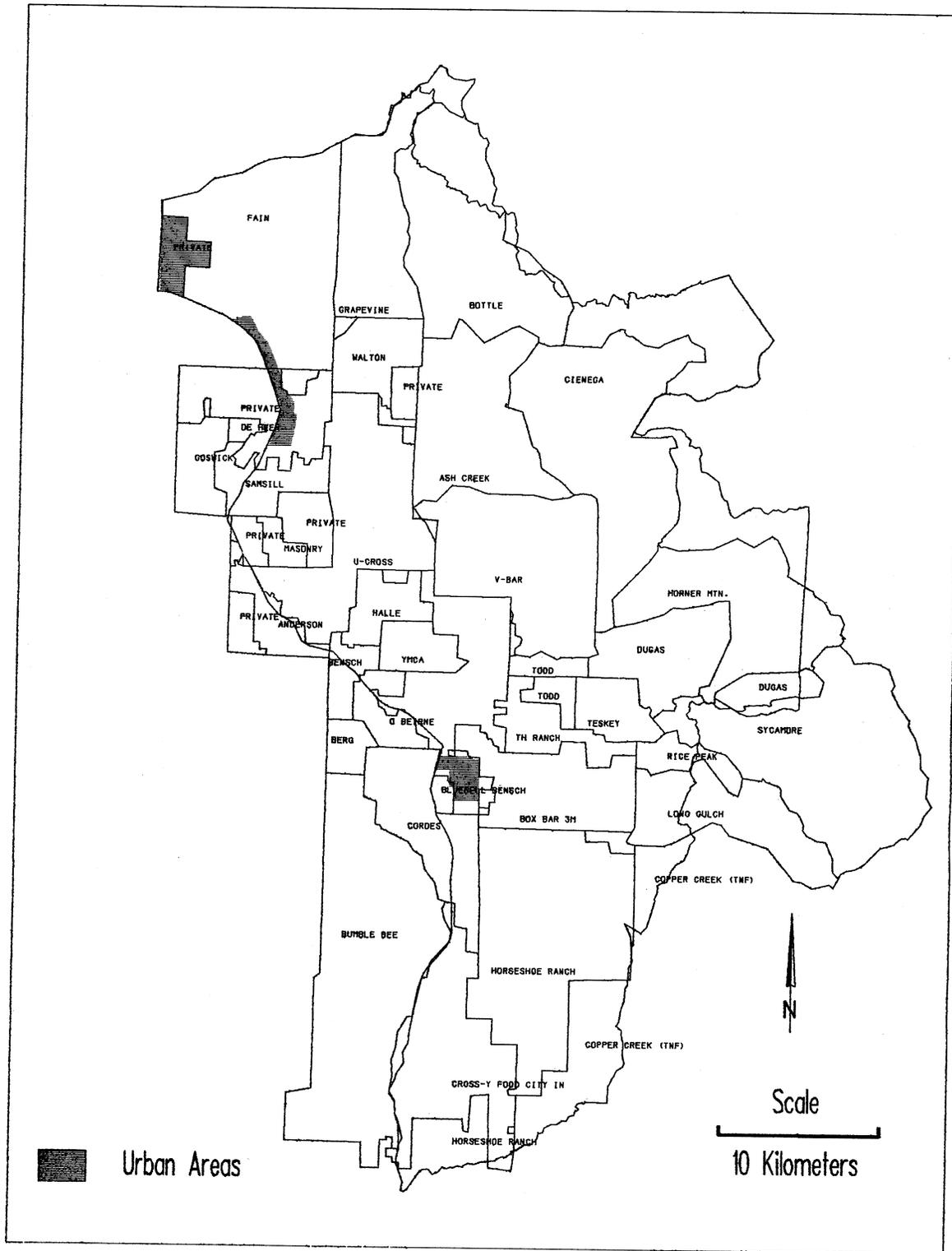
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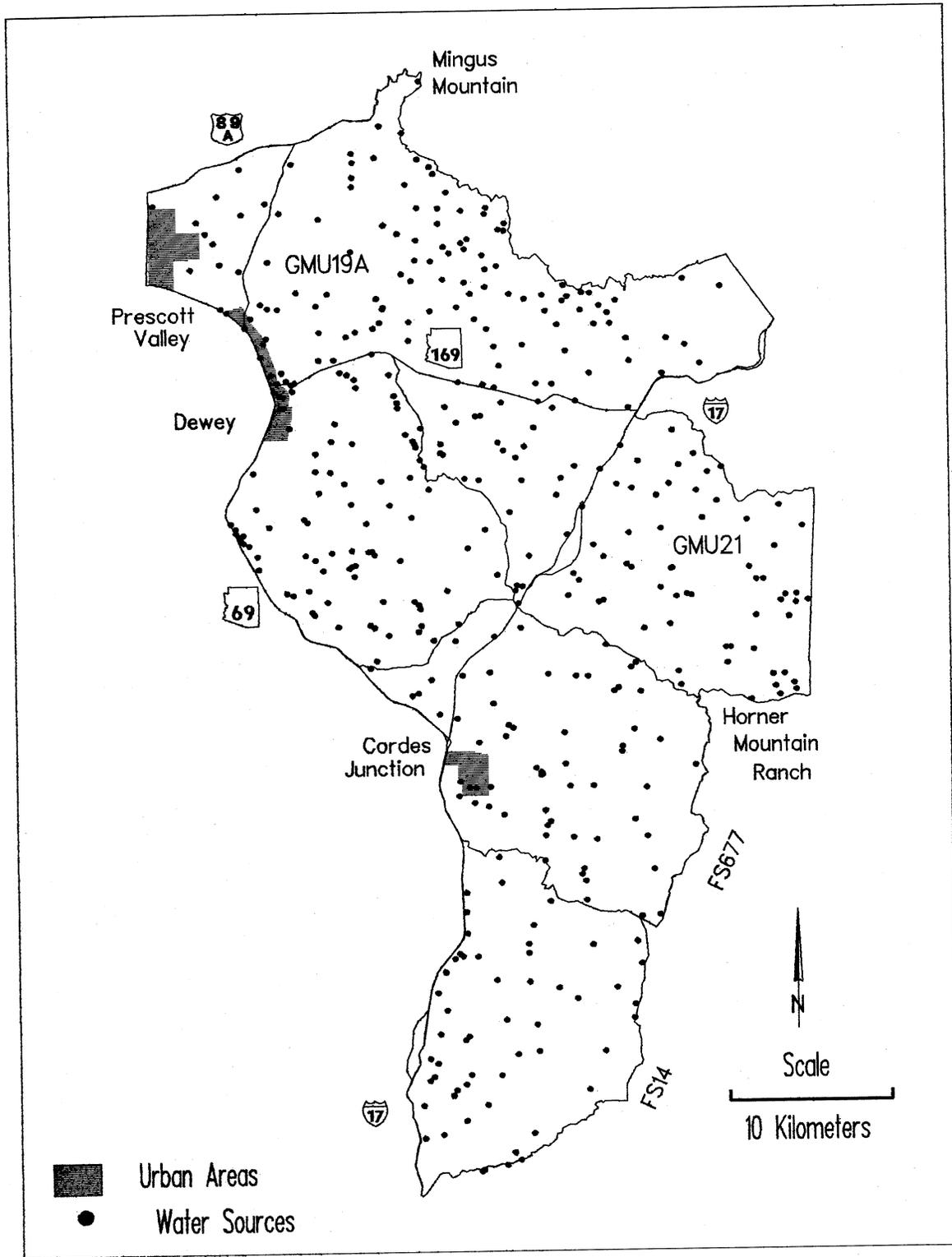
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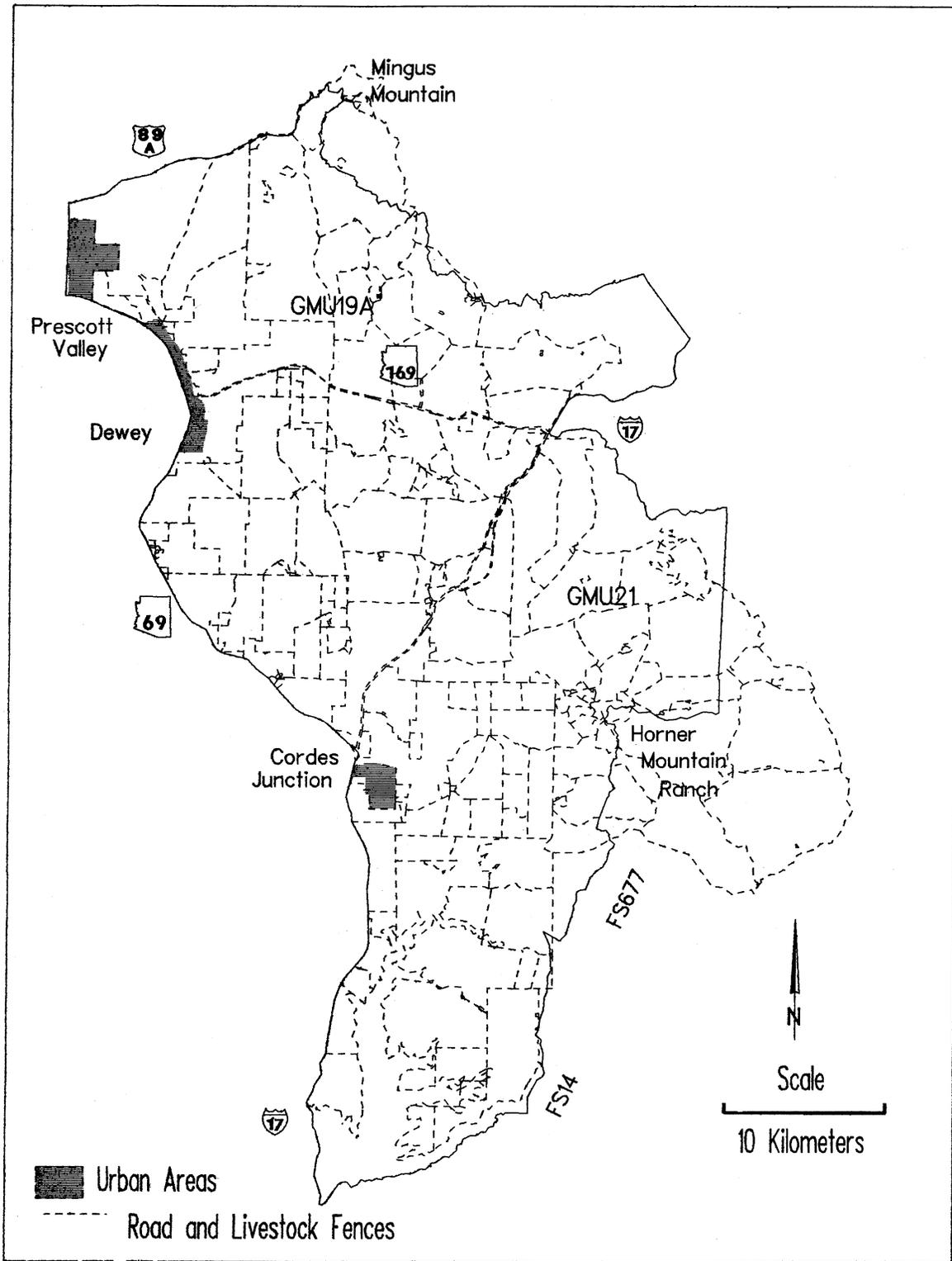
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Appendix 1. Locations of range allotments within pronghorn study area, Game Management Units 19A and 21, central Arizona, 1989-92.



Appendix 2. Locations of known water sources and existing road networks within pronghorn study area, Game Management Units 19A and 21, central Arizona, 1989-92.

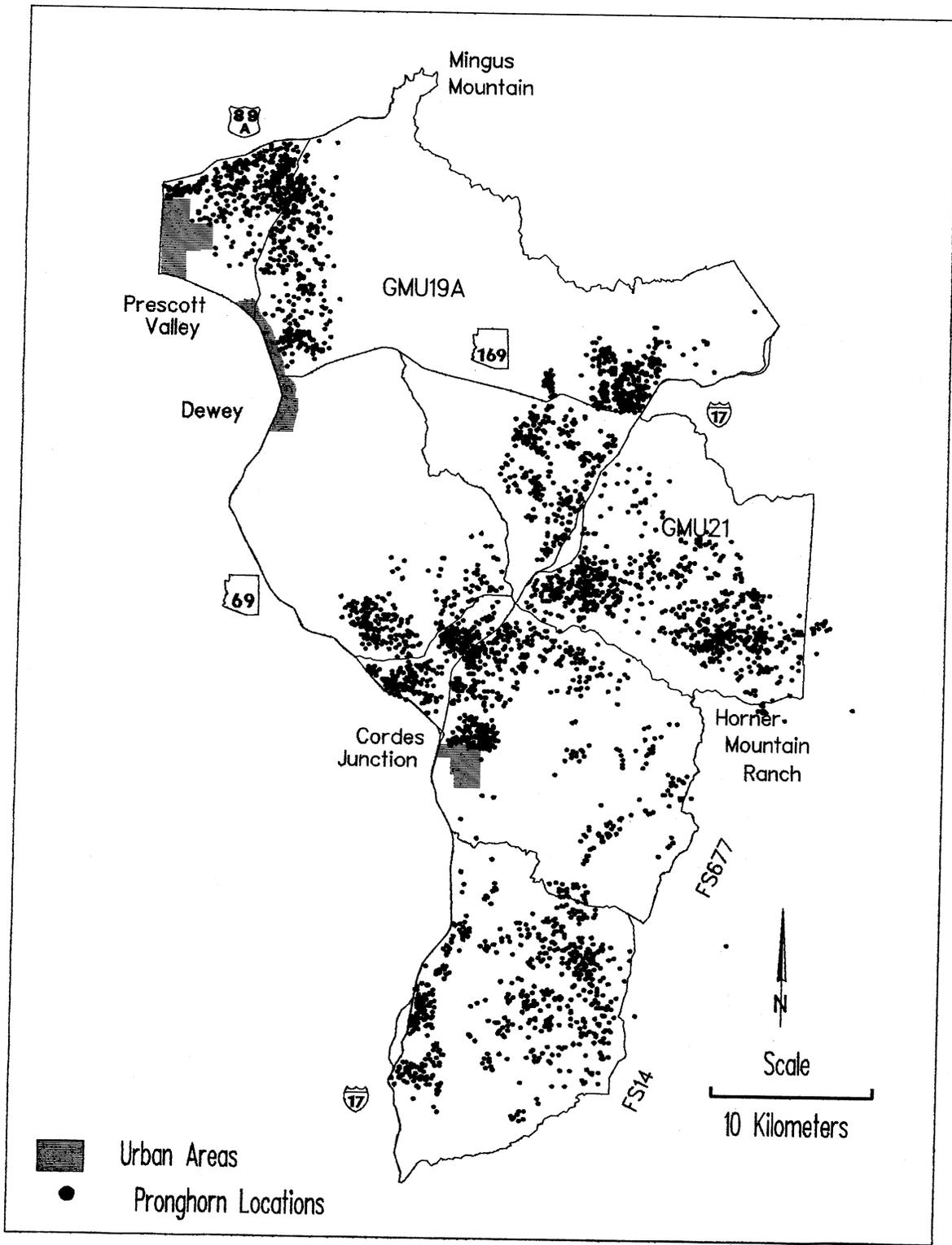


Appendix 3. Locations of fences within pronghorn study area, Game Management Units 19A and 21, central Arizona, 1989-92.

Appendix 4. Capture data for pronghorn, Game Management Units 19A and 21, central Arizona, 1989-92.

| Unit | Capture area | Females | | | Males | | |
|--------------|--------------|-------------|--------------|----------------------------|----------|--------------|----------------------------|
| | | ID | Capture date | Last location ^a | ID | Capture date | Last location ^a |
| 19A | Orme | 14 | 10/9/89 | 5/3/90 | 3 | 10/9/89 | 4/6/92 |
| | | 19 | 10/9/89 | 8/8/91 | 7 | 10/10/89 | 4/6/92 |
| | | 28 | 10/5/90 | 5/29/92 | 60 | 10/15/91 | 4/6/92 |
| | | 34 | 10/5/90 | 5/29/92 | | | |
| | Cherry | 4 | 10/10/89 | 3/20/90 | 9 | 10/10/89 | 9/16/91 |
| | | 29 | 10/5/90 | 5/29/92 | 51 | 10/15/91 | 4/6/92 |
| | | 35 | 10/5/90 | 5/29/92 | | | |
| | Fain | 6 | 10/10/89 | 4/19/90 | 15 | 10/10/89 | 9/27/91 |
| | | 21 | 10/10/89 | 5/29/92 | 33 | 10/5/90 | 8/20/91 |
| | | 26 | 3/16/90 | 9/27/91 | | | |
| | | 32 | 10/5/90 | 5/29/92 | | | |
| | 21 | Black/Perry | 1 | 10/10/89 | 6/13/91 | 11 | 10/10/89 |
| 10 | | | 10/10/89 | 2/28/90 | 36 | 10/5/90 | 9/6/91 |
| 17 | | | 10/11/89 | 5/29/92 | 56 | 10/16/91 | 4/6/92 |
| 24 | | | 3/16/90 | 3/29/91 | 58 | 10/16/91 | 4/6/92 |
| 55 | | | 10/16/91 | 5/29/92 | | | |
| 57 | | | 10/16/91 | 1/14/92 | | | |
| East Pasture | | 12 | 10/9/89 | 5/29/92 | 5 | 10/9/89 | 9/26/91 |
| | | 18 | 10/9/89 | 5/29/92 | 54 | 10/15/91 | 4/6/92 |
| | | 22 | 3/16/90 | 5/17/90 | | | |
| | | 27 | 10/5/90 | 5/6/91 | | | |
| | | 52 | 10/16/91 | 5/29/92 | | | |
| Marlow Mesa | | 53 | 10/16/91 | 5/29/92 | | | |
| | | 2 | 10/9/89 | 1/29/90 | 13 | 10/9/89 | 8/17/90 |
| | | 8 | 10/9/89 | 12/27/89 | 20 | 10/9/89 | 7/20/90 |
| | | 16 | 10/9/89 | 1/11/91 | 31 | 10/5/90 | 7/11/91 |
| | 23 | 3/16/90 | 7/5/91 | 61 | 10/15/91 | 4/6/92 | |
| | 25 | 3/16/90 | 5/29/92 | 64 | 10/15/91 | 4/6/92 | |
| | 63 | 10/15/91 | 5/29/92 | | | | |

^a Does not always equal date at which a mortality occurred.



Appendix 5. Pronghorn radio-telemetry locations, Game Management Units 19A and 21, central Arizona, 1989-92.

Appendix 6. Number of locations and home-range sizes of pronghorn in Game Management Unit 19A, central Arizona, 1989-92.

| Capture area | Females | | | Males | | |
|--------------|---------|------------------|-------------------------------|-------|------------------|-------------------------------|
| | ID | Number locations | Home range in km ² | ID | Number locations | Home range in km ² |
| Orme | 14 | 46 | 18.46 | 3 | 239 | 52.45 |
| | 19 | 199 | 44.63 | 7 | 237 | 64.45 |
| | 28 | 153 | 56.79 | 60 | 27 | 50.66 |
| | 34 | 151 | 46.66 | | | |
| Cherry | 4 | 30 | 10.50 | 9 | 192 | 32.53 |
| | 29 | 162 | 23.56 | 51 | 28 | 20.63 |
| | 35 | 155 | 31.33 | | | |
| Fain | 6 | 38 | 48.32 | 15 | 200 | 40.01 |
| | 21 | 226 | 41.44 | 33 | 14 | 5.56 |
| | 26 | 185 | 38.06 | | | |
| | 32 | 132 | 27.33 | | | |

Appendix 7. Number of locations and home-range sizes of pronghorn in Game Management Unit 21, central Arizona, 1989-92.

| Capture area | Females | | | Males | | |
|--------------|---------|------------------|-------------------------------|-------|------------------|-------------------------------|
| | ID | Number locations | Home range in km ² | ID | Number locations | Home range in km ² |
| Black/Perry | 1 | 163 | 98.89 | 11 | 87 | 85.78 |
| | 10 | 24 | 56.12 | 36 | 53 | 68.87 |
| | 17 | 263 | 300.53 | 56 | 28 | 54.49 |
| | 24 | 103 | 55.26 | 58 | 27 | 55.53 |
| | 55 | 43 | 62.23 | | | |
| | 57 | 15 | 27.71 | | | |
| East Pasture | 12 | 246 | 419.86 | 5 | 202 | 271.34 |
| | 18 | 253 | 387.96 | 54 | 27 | 33.15 |
| | 22 | 21 | 27.36 | | | |
| | 27 | 55 | 312.29 | | | |
| | 52 | 42 | 98.76 | | | |
| | 53 | 43 | 76.63 | | | |
| Marlow Mesa | 2 | 22 | 48.48 | 13 | 80 | 32.25 |
| | 8 | 13 | 26.50 | 20 | 67 | 26.40 |
| | 16 | 117 | 94.99 | 31 | 81 | 30.61 |
| | 23 | 130 | 301.54 | 61 | 27 | 56.05 |
| | 25 | 228 | 274.06 | 64 | 27 | 72.82 |
| | 63 | 42 | 27.29 | | | |

Appendix 8. Distances pronghorn moved between consecutive locations, Game Management Units (GMU) 19A and 21, central Arizona, 1989-92.

| GMU | Capture area | Females | | Males | |
|---------|--------------|------------------------------|---------------------------------|------------------------------|---------------------------------|
| | | Mean km ^a (SE) | Maximum km ^b (SD) | Mean km ^a (SE) | Maximum km ^b (SD) |
| GMU 19A | Orme | 2.06 (0.31) | 8.00 (2.72) | 2.58 (0.33) | 7.67 (1.74) |
| | Cherry | 1.48 (0.20) | 6.53 (3.10) | 2.26 (0.76) | 6.20 (0.42) |
| | Fain | 1.95 (0.16) | 7.20 (1.28) | 1.61 (0.43) | 5.80 (4.53) |
| | All areas | 1.86 (0.33) | 7.31 (2.24) | 2.21 (0.59) | 6.71 (2.30) |
| GMU 21 | Black/Perry | 2.89 (0.59) | 13.32 (11.89) | 3.55 (0.50) | 11.93 (6.14) |
| | East Pasture | 2.96 (0.80) | 23.05 (12.43) | 2.95 (0.15) | 18.65 (13.51) |
| | Marlow Mesa | 2.63 (0.31) | 14.40 (6.96) | 2.76 (0.92) | 9.18 (3.91) |
| | All areas | 2.83 (0.58) | 16.92 (11.02) | 3.08 (0.75) | 11.90 (6.96) |

^a Mean km is the average of the mean distances individual pronghorn moved between consecutive locations as determined by program HOME RANGE.

^b Maximum km is the average of the maximum distances individual pronghorn moved between any 2 consecutive locations as determined by program HOME RANGE.

Appendix 9. Movement distances of pronghorn in Game Management Unit 19A, central Arizona, 1989-92.

| Sex | Capture area | ID | Number of movements for distance between consecutive locations (km) | | | | Maximum | Mean |
|---------|--------------|------|---|------|------|-----|---------|------|
| | | | ≥ 10 | ≥ 15 | ≥ 20 | | | |
| Females | Orme | 14 | 0 | 0 | 0 | 4.0 | 1.68 | |
| | | 19 | 0 | 0 | 0 | 8.6 | 2.33 | |
| | | 28 | 0 | 0 | 0 | 9.6 | 2.29 | |
| | | 34 | 0 | 0 | 0 | 9.8 | 1.95 | |
| | Cherry | 4 | 0 | 0 | 0 | 3.4 | 1.28 | |
| | | 29 | 0 | 0 | 0 | 6.6 | 1.48 | |
| | | 35 | 0 | 0 | 0 | 9.6 | 1.67 | |
| | Fain | 6 | 0 | 0 | 0 | 9.0 | 2.08 | |
| | | 21 | 0 | 0 | 0 | 7.2 | 2.06 | |
| | | 26 | 0 | 0 | 0 | 6.4 | 1.89 | |
| | | 32 | 0 | 0 | 0 | 6.2 | 1.75 | |
| | Males | Orme | 3 | 0 | 0 | 0 | 8.3 | 2.62 |
| 7 | | | 0 | 0 | 0 | 9.0 | 2.23 | |
| 60 | | | 0 | 0 | 0 | 5.7 | 2.88 | |
| Cherry | | 9 | 0 | 0 | 0 | 5.9 | 1.72 | |
| | | 51 | 0 | 0 | 0 | 6.5 | 2.80 | |
| Fain | | 15 | 0 | 0 | 0 | 9.0 | 1.91 | |
| | | 33 | 0 | 0 | 0 | 2.6 | 1.30 | |

Appendix 10. Movement distances of pronghorn in Game Management Unit 21, central Arizona, 1989-92.

| Sex | Capture area | ID | Number of movements for distance between consecutive locations (km) | | | | | |
|--------------|--------------|-------------|---|-----|-----|---------|------|------|
| | | | ≥10 | ≥15 | ≥20 | Maximum | Mean | |
| Females | Black/Perry | 1 | 0 | 0 | 0 | 8.5 | 2.06 | |
| | | 10 | 0 | 0 | 0 | 8.3 | 3.60 | |
| | | 17 | 11 | 7 | 5 | 37.5 | 2.50 | |
| | | 24 | 1 | 0 | 0 | 10.0 | 2.65 | |
| | | 55 | 0 | 0 | 0 | 8.6 | 3.38 | |
| | | 57 | 0 | 0 | 0 | 7.0 | 3.16 | |
| | East Pasture | 12 | 6 | 2 | 2 | 40.0 | 3.15 | |
| | | 18 | 10 | 6 | 2 | 36.2 | 2.92 | |
| | | 22 | 1 | 0 | 0 | 10.3 | 1.53 | |
| | | 27 | 4 | 1 | 0 | 17.7 | 3.47 | |
| | | 52 | 3 | 2 | 2 | 22.0 | 3.87 | |
| | | 53 | 2 | 0 | 0 | 12.1 | 2.82 | |
| | Marlow Mesa | 2 | 2 | 0 | 0 | 14.8 | 3.10 | |
| | | 8 | 0 | 0 | 0 | 5.9 | 2.74 | |
| | | 16 | 1 | 0 | 0 | 11.6 | 2.32 | |
| | | 23 | 5 | 3 | 2 | 21.3 | 2.75 | |
| | | 25 | 11 | 10 | 3 | 23.7 | 2.25 | |
| | | 63 | 0 | 0 | 0 | 9.1 | 2.67 | |
| | Males | Black/Perry | 11 | 0 | 0 | 0 | 9.6 | 2.83 |
| | | | 36 | 13 | 2 | 1 | 21.1 | 3.96 |
| | | | 56 | 0 | 0 | 0 | 8.5 | 3.65 |
| 58 | | | 0 | 0 | 0 | 8.5 | 3.76 | |
| East Pasture | | 5 | 8 | 3 | 2 | 28.2 | 2.84 | |
| | | 54 | 0 | 0 | 0 | 9.1 | 3.05 | |
| Marlow Mesa | | 13 | 0 | 0 | 0 | 7.7 | 2.14 | |
| | | 20 | 0 | 0 | 0 | 6.1 | 2.45 | |
| | | 31 | 0 | 0 | 0 | 7.1 | 1.80 | |
| | | 61 | 0 | 0 | 0 | 9.1 | 4.00 | |
| | | 64 | 1 | 1 | 0 | 15.9 | 3.40 | |

Appendix 11. Number of pronghorn aerial locations in slope classes, Game Management Units 19A and 21, central Arizona, 1989-92.

| Unit | Capture area | Sex | Slope classes (%) | | | Total locations |
|--------------|--------------|-------------|-------------------|-----------|-----------|-----------------|
| | | | 0-9 | 10-19 | ≥20 | |
| 19A | Orme | Females | 230 | 98 | 68 | 396 |
| | | Males | 236 | 69 | 58 | 363 |
| | Cherry | Females | 122 | 80 | 49 | 251 |
| | | Males | 69 | 58 | 38 | 165 |
| | Fain | Females | 376 | 17 | 10 | 403 |
| | | Males | <u>130</u> | <u>15</u> | <u>3</u> | <u>148</u> |
| | Total | | 1163 | 337 | 226 | 1726 |
| | 21 | Black/Perry | Females | 429 | 14 | 3 |
| Males | | | 178 | 8 | 5 | 191 |
| East Pasture | | Females | 444 | 39 | 21 | 504 |
| | | Males | 129 | 27 | 12 | 168 |
| Marlow Mesa | | Females | 367 | 27 | 23 | 417 |
| | | Males | <u>174</u> | <u>25</u> | <u>14</u> | <u>213</u> |
| Total | | | 1721 | 140 | 78 | 1939 |

Appendix 12. Number of pronghorn aerial locations by individual in slope classes, Game Management Unit 19A, central Arizona, 1989-92.

| Sex | Capture area | ID | Slope classes (%) | | | Total locations |
|---------|--------------|------|-------------------|-------|-----|-----------------|
| | | | 0-9 | 10-19 | ≥20 | |
| Females | Orme | 14 | 9 | 10 | 14 | 33 |
| | | 19 | 75 | 33 | 24 | 132 |
| | | 28 | 70 | 31 | 15 | 116 |
| | | 34 | 76 | 24 | 15 | 115 |
| | Cherry | 4 | 7 | 8 | 7 | 22 |
| | | 29 | 65 | 33 | 16 | 114 |
| | | 35 | 50 | 39 | 26 | 115 |
| | Fain | 6 | 25 | 4 | 0 | 29 |
| | | 21 | 152 | 4 | 4 | 160 |
| | | 26 | 114 | 5 | 5 | 124 |
| | | 32 | 85 | 4 | 1 | 90 |
| | Males | Orme | 3 | 89 | 43 | 39 |
| 7 | | | 132 | 20 | 16 | 168 |
| 60 | | | 15 | 6 | 3 | 24 |
| Cherry | | 9 | 60 | 50 | 31 | 141 |
| | | 51 | 9 | 8 | 7 | 24 |
| Fain | | 15 | 127 | 15 | 3 | 145 |
| | | 33 | 3 | 0 | 0 | 3 |

Appendix 13. Number of pronghorn aerial locations by individual in slope classes, Game Management Unit 21, central Arizona, 1989-92.

| Sex | Capture area | ID | Slope Classes (%) | | | Total locations |
|---------|--------------|----|-------------------|-------|-----|-----------------|
| | | | 0-9 | 10-19 | ≥20 | |
| Females | Black/Perry | 1 | 113 | 2 | 1 | 116 |
| | | 10 | 18 | 1 | 0 | 11 |
| | | 17 | 178 | 7 | 2 | 187 |
| | | 24 | 71 | 4 | 0 | 75 |
| | | 55 | 37 | 0 | 0 | 37 |
| | | 57 | 12 | 0 | 0 | 12 |
| | East Pasture | 12 | 155 | 21 | 10 | 186 |
| | | 18 | 178 | 7 | 2 | 187 |
| | | 22 | 9 | 6 | 2 | 17 |
| | | 27 | 35 | 1 | 0 | 36 |
| | | 52 | 33 | 1 | 6 | 40 |
| | | 53 | 36 | 2 | 1 | 39 |
| | Marlow Mesa | 2 | 15 | 0 | 1 | 16 |
| | | 8 | 10 | 1 | 0 | 11 |
| | | 16 | 63 | 9 | 11 | 83 |
| | | 23 | 85 | 9 | 7 | 101 |
| | | 25 | 165 | 2 | 0 | 167 |
| | | 63 | 29 | 6 | 4 | 39 |
| Males | Black/Perry | 11 | 64 | 3 | 3 | 70 |
| | | 36 | 64 | 5 | 2 | 71 |
| | | 56 | 25 | 0 | 0 | 25 |
| | | 58 | 25 | 0 | 0 | 25 |
| | East Pasture | 5 | 110 | 25 | 9 | 144 |
| | | 54 | 19 | 2 | 3 | 24 |
| | Marlow Mesa | 13 | 49 | 5 | 5 | 59 |
| | | 20 | 44 | 4 | 4 | 52 |
| | | 31 | 45 | 5 | 4 | 54 |
| | | 61 | 15 | 8 | 1 | 24 |
| | | 64 | 21 | 3 | 0 | 24 |

Appendix 14. List of dominant plant species occurring in pronghorn use areas (40 m²) in Game Management Units 19A and 21, central Arizona, 1989-92. Random plot (40 m²) data from Unit 21. Plant nomenclature follows Kearney and Peebles (1960).

| Species code | Species name | Orme | Cherry | Fain | Black/PerryMesa | East Pasture | Marlow Mesa | Random Plots |
|----------------|--------------------------------|------|--------|------|-----------------|--------------|-------------|--------------|
| Grasses | | | | | | | | |
| AGSP | <i>Agropyron spicatum</i> | | | | | | | x |
| ARIS | <i>Aristida</i> spp. | x | x | x | x | x | x | x |
| AVFA | <i>Avena fatua</i> | | | x | | | | x |
| BOCU | <i>Bouteloua curtispindula</i> | x | x | x | x | x | x | x |
| BOER | <i>Bouteloua eriopoda</i> | x | | x | | | | x |
| BOGR | <i>Bouteloua gracilis</i> | x | x | x | | | | x |
| BOHI | <i>Bouteloua hirsuta</i> | x | | | | | x | x |
| BOUT | <i>Bouteloua</i> spp. | x | x | x | x | | | |
| BROM | <i>Bromus</i> spp. | x | | | x | | | x |
| BRRU | <i>Bromus rubens</i> | x | x | x | x | x | x | x |
| BRTE | <i>Bromus tectorum</i> | x | x | | | x | | x |
| CYDA | <i>Cynodon dactylon</i> | | | | x | x | x | |
| HIBE | <i>Hilaria belangeri</i> | x | x | x | x | x | x | x |
| HIMU | <i>Hilaria mutica</i> | x | x | x | x | x | x | x |
| HIRI | <i>Hilaria rigida</i> | | | | | | | x |
| HOJU | <i>Hordeum jubatum</i> | x | x | x | x | x | x | x |
| HOPU | <i>Hordeum pusillum</i> | | | | x | | | x |
| HORD | <i>Hordeum</i> spp. | | | | x | | | |
| LEFI | <i>Leptochloa filiformis</i> | x | x | | | x | x | x |
| MUHL | <i>Muhlenbergia</i> spp. | | | x | | | | |
| MUTO | <i>Muhlenbergia torreyi</i> | x | | x | | | | x |
| PAOB | <i>Panicum obtusum</i> | | | | | | x | x |
| SPCR | <i>Sporobolus cryptandrus</i> | | | | | | | x |
| TRPU | <i>Tridens pulchellus</i> | x | | x | x | | x | x |
| VUOC | <i>Vulpia octoflora</i> | | | | | | | x |

Appendix 14. (continued)

| Species code | Species name | Orme | Cherry | Fain | Black/PerryMesa | East Pasture | Marlow Mesa | Random Plots |
|--------------|-------------------------------|------|--------|------|-----------------|--------------|-------------|--------------|
| Trees | | | | | | | | |
| CEMI | <i>Cercidium microphyllum</i> | | | | | x | | x |
| CHLI | <i>Chilopsis linearis</i> | | | | | | | |
| JUNI | <i>Juniperus</i> spp. | x | x | x | x | x | x | x |
| PIED | <i>Pinus edulis</i> | | | | | | | |
| PRJU | <i>Prosopis juliflora</i> | x | x | | x | x | x | x |
| QUEM | <i>Quercus emoryi</i> | | | x | | | | x |
| SALI | <i>Salix</i> spp. | | | | | | | x |
| TAPE | <i>Tamarix pentandra</i> | | | | | | | x |

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Abstract: We captured, marked with radio transmitters, and located 47 (29♀, 18♂) pronghorn (*Antilocapra americana*) during 1989-92 in portions of Game Management Units (GMUs) 19A and 21 to determine home ranges, movements, and habitat selection patterns. Pronghorn in GMU 19A used smaller ($P = 0.001$) home ranges than those in GMU 21. Home-range size in GMU 21 for 9 (7♀, 2♂) migratory pronghorn ($\bar{x} = 270.6 \text{ km}^2$) was much greater ($P = 0.001$) than for 20 pronghorn that did not migrate ($\bar{x} = 52.4 \text{ km}^2$). Interstate Highway 17 was an effective movement barrier between GMUs 19A and 21. Tree and brush invasion and human encroachment threaten the 3 identified movement corridors joining northern and southern portions of GMU 21. Fenced, paved highways and large tracts of tall, dense brush separated populations in GMU 19A into 3 sub-populations (Orme, Cherry, and Fain). Orme and Cherry sub-populations are below recommended minimum viable limits and extirpation is likely without intervention. Pronghorn selected ($P < 0.001$) flat to undulating terrain with slopes $< 10\%$ and avoided ($P < 0.001$) northerly exposures with dense vegetation on slopes $\geq 10\%$. Plant species richness in sites used by pronghorn changed ($P < 0.001$) seasonally, with greatest richness occurring in spring as forb growth peaked. Pronghorn strongly selected ($P < 0.001$) areas with vegetation $< 0.61 \text{ m}$ in height. Pronghorn in Orme and Cherry used lower-quality habitats than pronghorn elsewhere; little high-quality habitat was available to them. Pronghorn avoided areas $< 0.4 \text{ km}$ from identified water sources ($P < 0.001$) and areas $< 0.4 \text{ km}$ from fenced, paved highways ($P < 0.001$). Preventing population isolation and habitat fragmentation, maintaining movement corridors, and controlling brush and tree invasion are management priorities for pronghorn in central Arizona.

Key Words: antelope, *Antilocapra americana*, Arizona, fragmentation, habitat selection, home ranges, movement corridors, pronghorn, roads, waters.

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Key Words: antelope, *Antilocapra americana*, Arizona, fragmentation, habitat selection, home ranges, movement corridors, pronghorn, roads, waters.

Ockenfels, R.A., A. Alexander, C.L. Dorothy Ticer, and W.K. Carrel. 1994. **Home Ranges, Movement Patterns, and Habitat Selection of Pronghorn in Central Arizona**, Arizona Game and Fish Dep. Tech. Rep. 13. 80pp.

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