

Home Ranges and Movements of Pronghorn in Northern Arizona

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Abstract. During October 1992, we captured 17 adult pronghorn (*Antilocapra americana*) within the environs of Wupatki National Monument (NM), Arizona, and 20 adults in or near Petrified Forest National Park (NP), Arizona. Each animal was relocated over the next two years to determine home-range sizes, movement patterns, and movement barriers. The greatest distance between any two consecutive locations was the only variable having a substantial effect on home-range size; neither animal gender or mean distance between locations added to the predictive ability. Multiple core use areas were more evident for females and their home ranges were significantly larger in Wupatki NM than in the Petrified Forest NP environs. Unfenced, 2-lane paved roads did not restrict pronghorn movements within either park, and no peak crossing periods were discernible. However, fenced, paved 2-lane roads and fenced, divided 4-lane highways outside of the parks constituted movement barriers. Furthermore, fenced railroad rights-of-way were barriers and influenced shapes of pronghorn home ranges. Pronghorn populations in northern Arizona can, therefore, be partially defined by highway and railroad barriers. These barriers could be modified to facilitate pronghorn interchange by either: (1) removing fencing; (2) expanding rights-of-way dimensions, then modifying fences; or (3) relocating rights-of-way out of pronghorn habitat. Knowledge of pronghorn home ranges and movements can be used to better manage populations, plan land uses, and mitigate human-related activities.

Key words: Antelope, *Antilocapra americana*, fences, geographic information systems, highways, home ranges, movements, Petrified Forest National Park, pronghorn, railroads, rights-of-way, Wupatki National Monument.

Pronghorn (*Antilocapra americana*) are a species of special concern in Arizona and intensified management is necessary to ensure that adequate populations are maintained throughout the state. Knowledge of pronghorn movement patterns is needed for effective land-use planning, mitigating effects of human-related activities, and practicing sensible game management (e.g., harvest rates).

In managing pronghorn, human-related activities are of concern because they can lower habitat quality (Neff 1986). With increased knowledge of pronghorn movements, land planners and managers can improve the design of developments, better place livestock water sources, and improve the design of fence placement. Pronghorn herd management strategies in Arizona are accomplished through hunt structures based on game management units (GMUs). Although natural landscape features are sometimes used to define GMU boundaries, more often boundaries are major roads.

In some areas, it is believed that highway and railroad fenced rights-of-way fragment pronghorn habitat and restrict movements, thereby isolating populations or preventing movements to seasonal ranges (Buechner 1950, O'Gara and Yoakum 1992, Ockenfels et al. 1994). Pronghorn are generally considered a nomadic animal, moving within habitats in response to changing conditions due to drought, winter storms, human disturbances, forage changes, and water availability (O'Gara and Yoakum 1992, Ockenfels et al. 1994). With increased habitat fragmentation, fewer pronghorn populations can respond to perturbations and maintain traditional migratory behavior (O'Gara and Yoakum 1992). Determining if highways and railroads are movement barriers can assist in better management of pronghorn populations.

This study was initiated to examine home ranges and movement patterns of pronghorn in two study areas in northern Arizona. Our objectives were to: (1) document pronghorn movement patterns; (2) determine home-range sizes for female and male adult pronghorn; (3) determine whether interchange occurred among neighboring herds; and (4) identify what types of barriers isolated pronghorn.

Study Areas

We chose two locations in northern Arizona, each delineated by a GMU and also centered around a national park. Our northeastern study area was most of GMU 2A that encompassed Petrified Forest National Park (NP) (Fig. 1). The north-central study area contained Wupatki and Sunset Crater National Monuments (NM) and encompassed most of GMU 7E (Fig. 2).

Northeastern Study Area

We centered our efforts south of I-40, in or near Petrified Forest NP, excluding lands administered by the Navajo Nation. Most of this area was

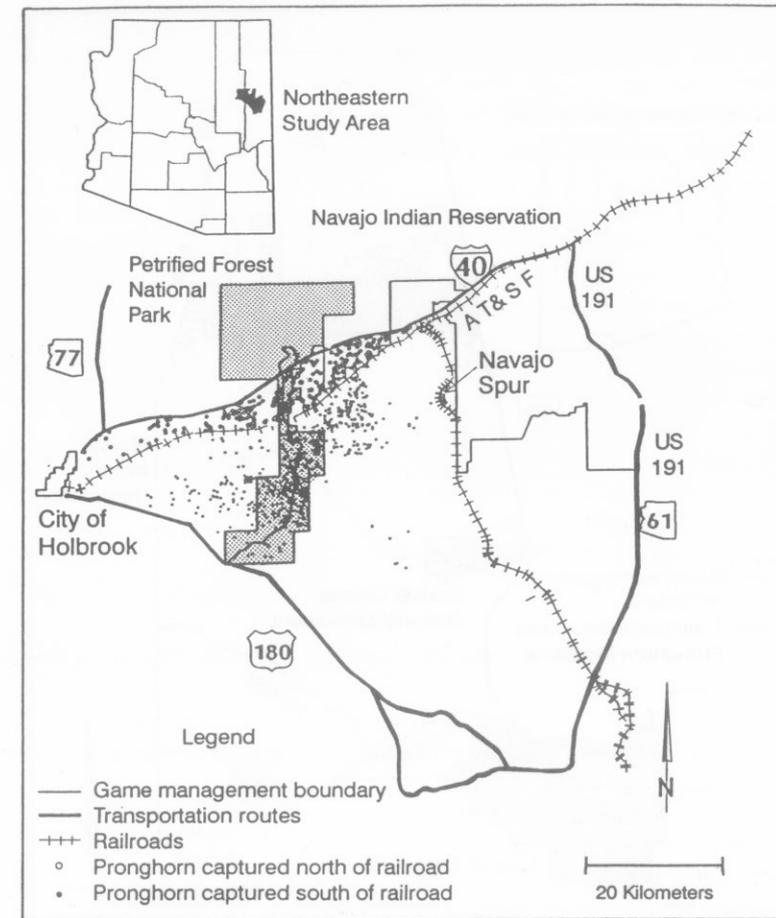


Fig. 1. Locations of radio-equipped adult pronghorn sightings, from 1992–94, within our northeastern Arizona study area. The study area was bounded by Game Management Unit 2A and centered on Petrified Forest National Park.

undulating terrain with rugged mesas or hills throughout, and numerous gullies extending from highly-eroded cliffs. Elevation ranged from 1,650 to 1,800 m. The Puerco River was the only major waterway but was not deeply incised.

This study area contained four sub-areas based on highways and railroads: (1) the area north of I-40 to the Navajo Indian Reservation; (2) the area between I-40 and north of the fenced Atchison, Topeka, and Santa Fe (AT&SF) railroad right-of-way; (3) the area south of the AT&SF right-of-way to U.S. 180 and east to the Navajo railroad spur line; and (4) the area east of the Navajo spur line (Fig. 1).

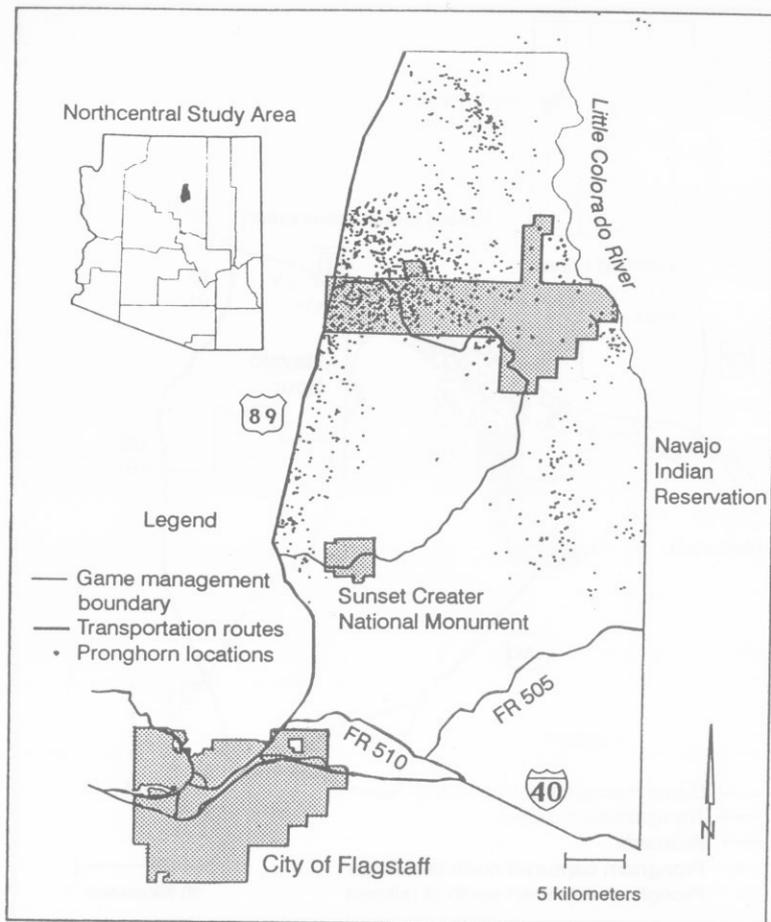


Fig. 2. Locations of radio-equipped adult pronghorn sightings, from 1992–1994, within our north-central Arizona study area. The study area, bounded by Game Management Unit 7E, was centered on Wupatki-Sunset Crater National Monuments.

Yearly precipitation was low (1941–1970: \bar{x} = 18.7 cm), with over one-half of the rainfall occurring during brief thunderstorms in July–September (Sellers and Hill 1974). Average snowfall was only 12.4 cm, and snow seldom remained on the ground more than a few days.

Great Basin grassland (Brown 1994) and juniper (*Juniperus* spp.) woodland dominated the landscape. Blue grama (*Bouteloua gracilis*) and alkali-sacaton (*Sporobolus airoides*) were the predominant grasses. Sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.), rabbitbrush (*Chrysothamnus* spp.), and Mormon-tea (*Ephedra* spp.) were scattered throughout, often forming

small thickets. Snake-weed (*Gutierrezia* spp.) was abundant in localized poorer-condition sites. Plant nomenclature follows Kearney and Peebles (1960).

North-central Study Area

We selected this study area east of U.S. 89 (Fig. 2). Elevation ranged from 1,350 m along the Little Colorado River to 2,700 m at Sunset Crater NM. Undulating terrain throughout the area was broken by volcanic cinder hills and lava flows.

Because of the wide elevational range, climate in this area varied considerably. In the low-elevation northern portion, precipitation was low (1956–1962: \bar{x} = 13.1 cm), with some December–January snowfall (\bar{x} = 21.8 cm). Because of the presence of the nearby San Francisco Peaks, snowfall in the southern portion was substantially greater, resulting in extensive snow cover. Summer (July–September) rainfall in the southern portion was more consistent than in the northern portion, and year-round precipitation was greater (Flagstaff 1950–1970: \bar{x} = 50.3 cm).

A short-grass prairie of *Hilaria* spp. and alkali-sacaton predominated the northern portion of this study area (Brown 1994). The southern portion was predominantly Rocky Mountain Coniferous Forest (Brown 1994), which was comprised almost entirely of ponderosa pine (*Pinus ponderosa*). Juniper woodlands occupied most of the eastern edge, as well as a band between the pine forest and short-grass prairie. Localized, dense stands of cliffrose (*Cowania mexicana*) and Apache plume (*Fallugia paradoxa*) occurred in the juniper woodlands.

Methods

Capture and Location

Using a net-gun fired from a helicopter (Firchow et al. 1986), we captured adult pronghorn in mid-October 1992. All animals were radio-equipped, ear-tagged, and released at their capture sites. In the northeastern study area, we captured pronghorn on and near Petrified Forest NP, but only in sub-areas south of I-40 and west of the Navajo spur line (Fig. 1). At our north-central study location, we captured pronghorn on or near Wupatki NM, all east of U.S. 89 and north of U.S. Forest Service roads (FR) 510 and 505.

We aerially located pronghorn two to three times per month, between October 1992 and September 1994, from various modified, high-wing, single engine aircraft. Each aircraft had a forward-phased, twin-Yagi antenna array mounted to the wing struts for signal detection and general signal direction, and a rotatable, belly-mounted, two-element antenna used to pinpoint pronghorn locations (Carrel 1972a,b). During flights, we plotted animal

locations on U.S. Geological Survey (USGS) 7.5-min topographic maps. After each flight, Universal Transverse Mercator (UTM) coordinates for each location were defined to the nearest 0.1 km.

We also located pronghorn one to two times per month on the ground using a handheld two-element antenna. The UTM coordinates were derived to the nearest 0.1 km from USGS 7.5-min maps; we also used a Global Positioning System (GPS) receiver to calculate coordinates. After encoding and verifying the data, we merged ground and aerial locations, then transferred the UTM-coordinate files into a Geographic Information System (GIS).

Data Analysis

Statistical significance was set at $\alpha = 0.10$. We decreased chances of accepting a false null hypothesis (Type II error) by choosing 0.10 instead of 0.05, but increased the probability of rejecting the null when it was indeed true (Type I error; Zar 1984). To provide management recommendations, with anticipated small sample sizes, we deemed Type II errors more important than Type I. Statistical tests were performed with SPSS/PC+ software (Norusis 1990).

Movements

Using features in HOME RANGE (Ackerman et al. 1990), we calculated (in km) the distance between consecutive locations and mean distance for each animal (which we defined as a movement). For each animal, we counted the number of movements ≥ 10 km and ≥ 20 km, and also recorded the largest movement and date (month, day, year) of that completed move.

Frequency distributions of movement variables (\bar{x} distance, ≥ 10 km, ≥ 20 km, greatest distance) were assessed for normality with Kolmogorov-Smirnov (K-S) one-sample tests (Zar 1984). For descriptive purposes, we calculated gender-specific descriptive statistics (\bar{x} , SD, range) for normally-distributed variables in each study site, then pooled data and calculated descriptives for all adult pronghorn.

We tested for study site or gender-related differences, as well as site \times gender interactions, in mean distance and greatest distance moved with 2×2 analysis-of-variances (ANOVAs). ANOVA was used because we were simultaneously testing >2 categories of normally distributed variables. Within study sites, we used *t*-tests for gender comparisons.

A Mann-Whitney (M-W) comparison was utilized for gender-related differences in long distance movements. The numbers of movements ≥ 10 km were not normally distributed, so a 2-group rank test had to be used. We also used a M-W comparison to test if site affected the number of movements ≥ 10 km made by females.

Rights-of-way Crossings

To determine if pronghorn crossed unfenced roads and highway or railroad rights-of-way, using GIS, each study area was subdivided by fenced rights-of-way and park roads. We then overlaid locations on this sub-area cover to match each location. Lastly, we sorted the file by animal identification and date, counting movements between appropriate sub-areas. For each study area, we summed the crossings by gender for each month from October 1992 to September 1994.

The 100% minimum-convex polygon method was selected as our estimate of home-range size, using a 50% convex polygon as the estimate of core (high use) areas (Ackerman et al. 1990). For each site, we calculated gender-specific descriptive statistics (\bar{x} , SD, range) for home-range and core use sizes, and assessed frequency distributions of home-range and core area size for normality with K-S one-sample tests. We then pooled the data and calculated descriptives for all adult pronghorn. We tested for site or gender-related differences, as well as site \times gender interactions, in home-range and core use size with 2×2 ANOVAs. As with movement data, we used *t*-tests within each site for gender-related comparisons.

To determine significant factors affecting home-range size, we plotted all variables against each other, ran a correlation matrix, then used forward, step-wise regression.

Results

Capture and Location

In our northeastern study area, we captured, radio-collared, and ear-tagged 20 (15F, 5M) pronghorn. Four does were captured north and the remaining 16 pronghorn south of the AT&SF right-of-way. These animals were relocated 1,736 times (Fig. 1). Most locations were during daylight, between 0500 and 2000 Mountain Standard Time (MST).

We captured, radio-collared, and ear-tagged 17 (13F, 4M) adult pronghorn in the north-central study area. Five animals (4F, 1M) were captured within Wupatki NM, the rest captured to the north. We relocated these animals 1,671 times over the next two years, mostly between 0500 and 2000 MST (Fig. 2).

General Movements

Normality tests indicated that long distance movements were not normally distributed, whereas mean distance and greatest distance between any two consecutive locations were likely sampled from normally-distributed populations (Table 1).

Table 1. Movement and home-range characteristics of adult pronghorn in two areas of northern Arizona, 1992–1994.

Variable	Northeastern study area		North-central study area		Overall
	Females	Males	Females	Males	
<i>n</i>	15	5	13	4	37
Mean distance ^a	3.3	2.7	3.4	3.1	3.2
SD	0.6	0.4	0.5	0.5	0.6
Range	2.5–4.4	2.0–2.9	2.5–4.0	2.4–3.6	2.0–4.4
Number of movements ≥ 10 km ^b	36	7	66	4	113
Number of movements ≥ 20 km	3	0	5	2	10
Mean of greatest distance ^a	14.4	9.0	16.8	13.2	14.4
SD	8.0	2.0	6.4	7.1	7.0
Range	6.0–35.0	6.5–10.6	7.6–33.7	7.8–22.8	6.0–35.0
Mean home-range size (km ²) ^c	124.0	81.7	195.2	135.6	144.6
SD	59.6	40.9	130.1	59.4	95.7
Range	56.5–243.2	44.4–140.0	80.5–552.0	72.8–211.1	44.4–552.0
Mean core use area (km ²) ^c	21.2	9.2	36.7	27.7	25.7
SD	5.4	7.4	25.4	31.9	20.2
Range	9.7–28.1	2.1–20.6	16.1–104.7	7.7–75.0	2.1–104.7

^aKm between two consecutive locations for each animal as calculated by HOME RANGE (Ackerman et al. 1990), then averaged for mean distance.

^bDistance between two consecutive locations.

^cHome-range size using 100% minimum convex polygon and core use area using 50% minimum convex polygon from HOME RANGE (Ackerman et al. 1990).

Mean movements did not differ ($F = 1.01$; $df = 1,36$; $P = 0.321$) by site, but did ($F = 5.34$; $df = 1,36$; $P = 0.027$) by gender (Table 1); females ($\bar{x} = 3.3$ km, $SD = 0.5$, $n = 28$) tended to move more in their home ranges than did males ($\bar{x} = 2.9$ km, $SD = 0.5$, $n = 9$). No site \times gender interactions were observed ($F = 0.72$; $df = 1,36$; $P = 0.404$). Much of the gender-related difference can be explained by a correlation ($r = 0.64$, $n = 37$, $P < 0.001$) between mean movements and greatest movements.

We found no difference ($F = 1.54$; $df = 1,36$; $P = 0.224$) in greatest movements for the two study sites, but greatest movements differed ($F = 3.03$; $df = 1,36$; $P = 0.091$) by gender (Table 1); females ($\bar{x} = 15.5$ km, $SD = 7.3$) had larger maximum movements than males ($\bar{x} = 10.9$ km, $SD = 5.1$). As with mean movement, there was no site \times gender interaction ($F = 1.59$; $df = 1,36$; $P = 0.719$).

Females had more (M-W $Z = -2.01$, $P = 0.045$) movements ≥ 10 km than males. Few females or males had movements ≥ 20 km. Females in the north-central site had more (M-W $Z = -1.95$, $P = 0.051$) movements ≥ 10 km than females in the northeastern site.

Specific Movements Within Study Areas

For the 20 adult pronghorn captured in the northeastern site, females tended to move more ($t = 2.26$, $df = 18$, $P = 0.036$) than males, and greatest movements of females were more variable and exceeded ($t = 2.41$, $df = 17.63$, $P = 0.027$) those of males (Table 1). Most (65%) pronghorn made some movements ≥ 10 km, however, only 15% made infrequent movements ≥ 20 km.

The greatest single movement was 35.0 km, made between 10 and 17 May 1993, by a doe north of the AT&SF railroad right-of-way. Overall, this doe ranged east-west from the community of Navajo nearly to Holbrook (Fig. 1). A doe south of the right-of-way moved 28.3 km (prior to 5 May 1993).

Of the 17 adult pronghorn in the north-central site, females did not ($t = 0.93$, $df = 15$, $P = 0.393$) move about more than males, nor did female greatest movements exceed ($t = 0.94$, $df = 15$, $P = 0.363$) those of the males (Table 1). Most (76%) pronghorn exhibited at least some movements ≥ 10 km. Only 3 (17.6%) had movements ≥ 20 km, and these were infrequent (only 2–3 times). Unlike the northeastern location, where only females ($n = 3$) moved long distances, one male and two females in the north-central location had movements ≥ 20 km. One female moved 33.7 km between 31 March and 3 April 1993.

Rights-of-way Crossings

Crossings, by both females and males, of the paved but unfenced road in Petrified Forest NP occurred throughout the two years of this study (Fig. 3).

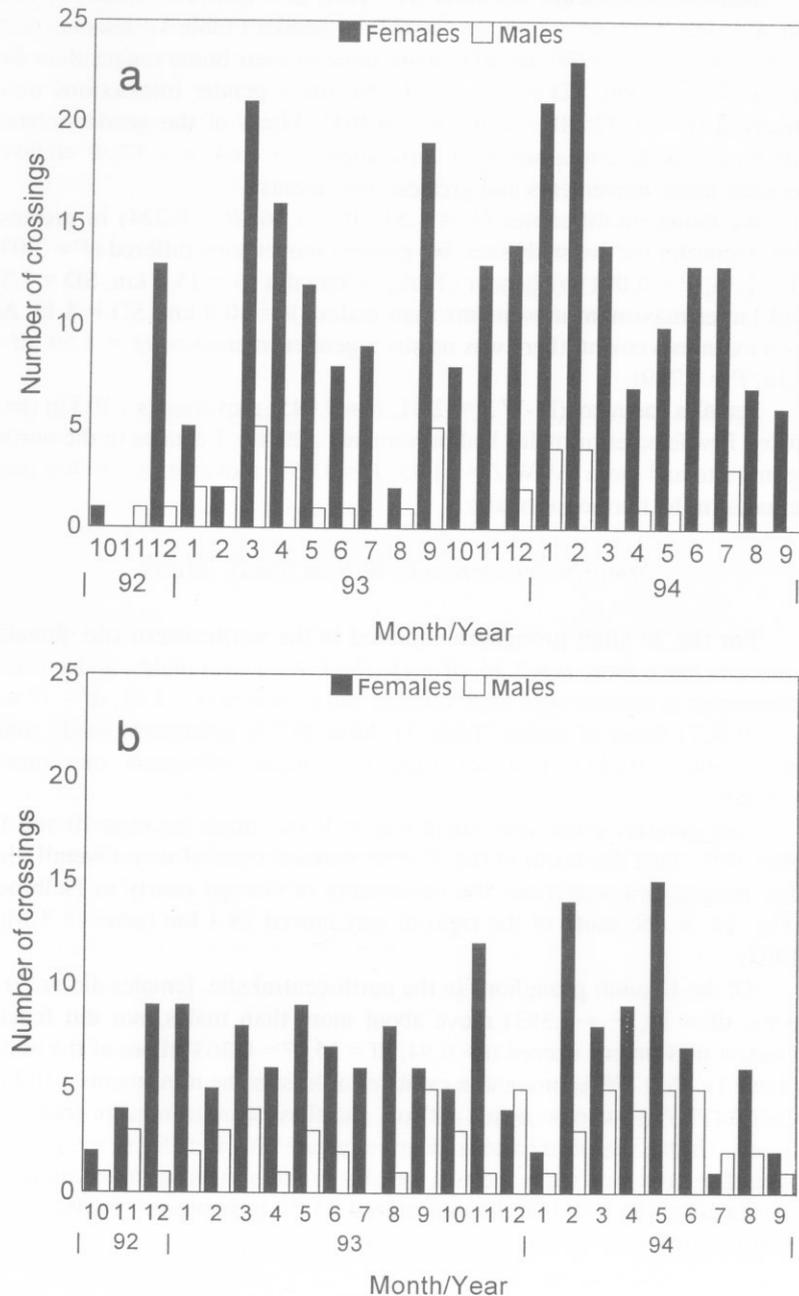


Fig. 3. Number of crossings during 1992–1994, by adult radio-equipped pronghorn, of unfenced, paved roads at (a) Petrified Forest National Park and (b) Wupatki National Monument.

No discernible crossing peak by either females or males was evident. Relative to the number captured, neither females or males seemed to cross more readily. Only two of the 15 females never crossed the road; one always stayed to the east, the other to the west. During the two years of this study, no females or males in the northeastern site crossed paved highways that were fenced (Fig. 1). Many pronghorn locations were within one km of I-40, US 191/AZ 61 and US 180; but no animals crossed. In fact, some of the home ranges seemed bounded by the roads. In addition, no crossings of the AT&SF or Navajo spur railroad rights-of-way were recorded (Fig. 1). For example, pronghorn captured north of the AT&SF had home ranges bounded by the railroad right-of-way and I-40, resulting in linear shapes, while those captured south of the railroad had non-linear home range shapes.

In our north-central study area, we documented 165 crossings of the paved, unfenced Wupatki NM road by females during the two years (Fig. 3b). One doe crossed a minimum of 46 times, including at least once in 21 of 24 months. Crossings occurred during all months and seemed to peak in winter and early spring of 93–94. For males, crossings ($n = 65$) occurred throughout the study by two of four bucks; one buck crossed a minimum of 44 times. One doe crossed the Little Colorado River, twice moving in the early spring onto the Navajo Indian Reservation to fawn (Fig. 2). No crossings of US 89 were documented, although numerous pronghorn locations were within 1 km of the fenced highway (Fig. 2).

Home Ranges and Core Use Areas

Home-range sizes clustered in the 75–125 km² range (Fig. 4). Few home ranges encompassed <50 km², and the three home ranges >250 km² were for females that had made large-scale seasonal movements. Core use areas were much smaller (Fig. 4). Home range and core use distributions were sampled from normal distributions (Table 1).

Home-range sizes varied by study site ($F = 5.05$; $df = 1,36$; $P = 0.031$), but not by gender ($F = 2.09$; $df = 1,36$; $P = 0.158$). Home-range sizes and variability were larger ($t = 2.15$, $df = 22.32$, $P = 0.042$) in the north-central study area than in the northeastern site (Table 1). There was no ($F = 0.06$; $df = 1,36$; $P = 0.805$) site \times gender interaction in home-range size.

Similarly, core size varied by site ($F = 7.02$; $df = 1,36$; $P = 0.012$), but not by gender ($F = 2.23$; $df = 1,36$; $P = 0.145$). As with home-range size, core size and variability were larger ($t = 2.48$, $df = 18.42$, $P = 0.023$) in the north-central site than in the northeastern site (Table 1). There was no ($F = 0.04$; $df = 1,36$; $P = 0.844$) site \times gender interaction.

The correlation between core and home-range size was only moderate ($r = 0.56$, $n = 37$, $P < 0.001$). Apparently other factors were influencing home-range size in our study areas. A forward, step-wise regression ($F = 71.98$; $df = 1,35$; $P < 0.001$) indicated that the greatest movement value was the only substantial variable affecting home-range size ($r^2 = 0.67$). Neither

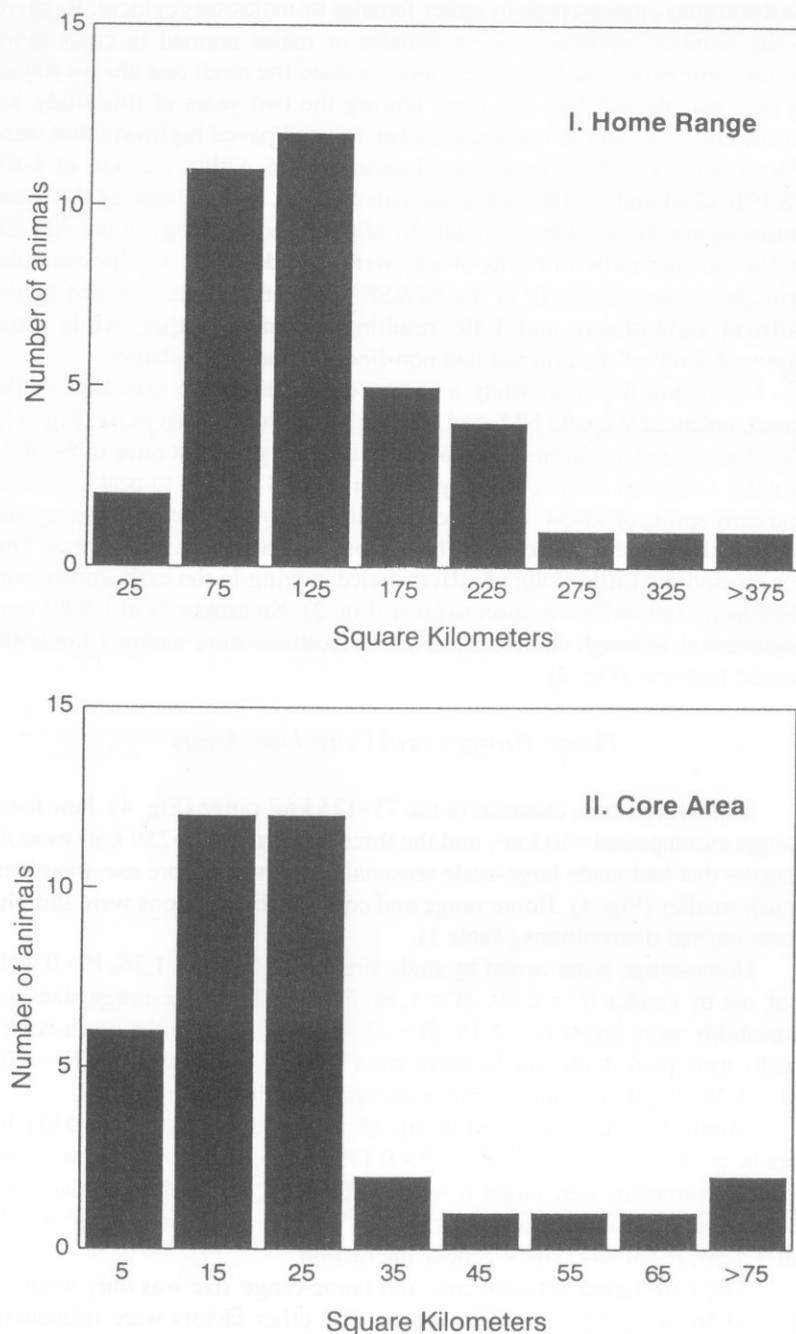


Fig. 4. Adult pronghorn (I) home-range and (II) core area sizes, in the northeastern and north-central Arizona study areas, 1992–1994.

the number of locations or gender added to r^2 nor did the mean distance between locations. However, when home range boundaries delineated by HOME RANGE, were overlaid with locations, most suggested fairly uniform movements throughout the home ranges.

The greatest influence on home range shapes of the pronghorn at both study areas was human-related development, particularly fenced highways and railroad rights-of-way.

Discussion

In our discussion we will deal with three major topics. First, we compare movements and home ranges between our study animals, then with findings from other areas of Arizona and the western United States. Secondly, we discuss what did, or did not, constitute a movement barrier. The third topic will deal with management actions that can be taken from the results of our research.

Movement and Home Range Comparisons

Movements

Mean pronghorn movements were not significantly different between our study sites. Furthermore, Ockenfels et al. (1994) found similar movement distances of pronghorn in central Arizona. There is nothing in the literature to indicate that mean movements (between relocation) in Arizona were different from pronghorn elsewhere. The nature of the species likely dictates at least a certain amount of movement to obtain daily requirements. These requirements should not differ substantially because of area if habitat conditions are reasonable.

Some of the differences in movements that we found between sites and gender can be accounted for by climatic influences. Pronghorn in our north-central study area were exposed to a regime of more variable precipitation and snowfall. Therefore, those pronghorn would sometimes have to move seasonally to prevent winter kill. This situation did not occur in our northeastern site, nor in central Arizona (Ockenfels et al. 1994). Historically, pronghorn in the north-central site used the higher elevations near Flagstaff for fawning and summer range. With human encroachment in many high elevation parks and meadows, suitable summer range areas have been reduced east of US 89. Recruitment into this pronghorn population could, therefore, be adversely affected by the loss of quality fawning and summer range.

The older age of pronghorn males captured in this study, particularly at the northeastern site, could be a significant factor in why gender-related movement differences were observed. Similar to central Arizona, young males tend to move more than mature, territorial individuals (Ockenfels et al. 1994).

Young males are often found in doe bands, and thus their movements are similar. Particularly during the breeding season, mature males move very little. With older males radio-collared in our study, one would expect less movement of this sex because of territorial constraints.

One other factor that contributed to movement differences between sites was the availability of permanent water sources. At our northeastern study site, the Puerco River provided permanent water throughout the year, especially within Petrified Forest NP. However, at the north-central site, there was no permanent water within Wupatki NM and pronghorn had to leave the park for livestock water sources to the north.

Home Range Comparisons

Pronghorn in our north-central study area had significantly larger home ranges than the northeastern animals. Weather certainly had an influence, as many of the north-central animals summered at higher elevations. However, lack of permanent water in the middle of our north-central study area (i.e., Wupatki NM), was probably a major contributing factor to the increase in home-range sizes. Ockenfels et al. (1994) showed that in central Arizona, water played a role in pronghorn home-range sizes. In fact, water in the West has a profound seasonal effect on the distribution of pronghorn (O'Gara and Yoakum 1992, Clemente et al. 1995).

Movement Barriers

Fenced Highway Rights-of-way

Buechner (1950), working in Texas, observed the negative effect highway rights-of-way fences had on pronghorn movements. White (1969) demonstrated that fenced highways blocked the movements of pronghorn in northern Arizona during a severe winter storm, resulting in losses of as much as 80% of some herds. In central Arizona, Ockenfels et al. (1994) provided further evidence of substantial fragmentation of pronghorn habitat and isolation of pronghorn herds by fenced highways.

After observing similar fragmentation in our study in northern Arizona, we are left to believe that rights-of-way fences are the major factor affecting pronghorn movements across their range.

Fenced Railroad Rights-of-way

Two transcontinental railroads traverse the entire width of Arizona. The AT&SF roughly follows the 35th parallel of northern Arizona, crossing much suitable pronghorn habitat. In addition to the two transcontinental lines, Arizona has many local rail lines, some of which could be in pronghorn habitat. In our northeastern study area, we demonstrated that pronghorn were

isolated into two populations by the AT&SF. Similar fragmentation probably occurs in many other areas in the state and throughout the West, particularly if the tracks are tightly fenced on both sides.

Unfenced Rights-of-way

Although considerable traffic occurred seasonally on Petrified Forest NP and Wupatki NM roads, these unfenced paved roads did not adversely affect the movement patterns of pronghorn during the two years of our study. Ockenfels et al. (1994) observed similar patterns relative to certain roads (e.g., Dugas Road) in central Arizona. Thus, for management purposes, mitigation efforts should concentrate on fenced rights-of-way. Nonetheless, preventing any fencing of unfenced roads, highways, and railroads should also be of paramount concern for resource managers.

Management Implications

Fragmentation of habitat by fenced rights-of-way impairs movement of pronghorn in northern Arizona and probably affects survival and genetics of those herds. To facilitate movement and interchange among herds, it is imperative to reduce the effect of fenced rights-of-way on pronghorn populations. The pronghorn can then freely move as perturbations occur. Survival rates and genetic flow likely would increase. Winter kills, as a result of fenced rights-of-way blocking seasonal movements from severe storms (e.g., White 1969), could be mitigated with reasonable intervention.

Possible mitigation features could be: (1) removing fences along rights-of-way; (2) expanding rights-of-way dimensions by placing fences further away from the road or railroad, then modifying the fences to permit better movement of pronghorn between fenced areas (O'Gara and Yoakum 1992, Ockenfels et al. 1994); or (3) relocating rights-of-way out of pronghorn habitat. The use of underpasses has been found not to be an effective pronghorn management tool (Ward et al. 1980). In some areas, emergency plans could be established to remove fences during periods of severe weather to allow movement to and back from lower elevation habitats. To do so effectively, however, would require extensive knowledge of pronghorn movement corridors.

Arizona's current survey and harvest management program for pronghorn is designed around GMUs, most of which have been in existence since 1958. Many of the boundaries delineating these GMUs were based on highway rights-of-way. Because of the absence of movement across fenced right-of-ways observed during our study, some GMUs contain multiple pronghorn populations because of multiple fenced highway rights-of-ways within their boundaries. For example, GMU 7 is divided into 7E and 7W (by US 89) for some hunts, but typically not for pronghorn. Yet our results point

out that animals do not interchange between 7E and 7W. Thus, isolated populations occur and combined survey and harvest data would not accurately reflect true pronghorn populations. Similar situations probably occur in other areas of the state, and perhaps throughout the West. If GIS methodology could be used to estimate the extent of the problem, pronghorn management strategies could be modified to better accommodate such fragmentation.

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