The Influence of Transportation Corridors on the Movement of Pronghorn Antelope Over A Fragmented Landscape in Northern Arizona

Charles van Riper, III
Northern Arizona University
Flagstaff, AZ

Richard Ockenfels
Arizona Game & Fish
Phoenix, AZ

Abstract

We studied distribution and movement patterns of 37 radio-collared pronghorn antelope within the environs of three national parks in northern Arizona, analyzing and modeling data with an Arc Info Geographic Information System. Differences in movement patterns were in large part determined by major transportation corridors and the amount of habitat fragmentation caused by those corridors within our study areas. Aside from pronghorn gender differences, individual animal and herd movements were specifically influenced by fencing along main thoroughfares, rates of traffic and train flows, historical animal presence, and permanently available water sources. If pronghorn are to be properly managed over a large fragmented landscape in northern Arizona, managers will have to alter several of their present land management practices. Potential changes will have to deal with how pronghorn are harvested and how to provide acceptable movement corridors so that connection can occur among presently genetically isolated groups of animals.

Key words: antelope, *Antilocapra americana*, fences, geographic information systems, highways home ranges, movement corridors, national parks, partnerships, pronghorn, railroads, rights-of-way, transportation corridors.

Introduction

Pronghorn (*Antilocapra americana*) are a species of special concern in Arizona, and intensified management is necessary to ensure that populations can be maintained throughout the state. Because pronghorn have large home ranges, the diverse land ownership patterns in northern Arizona (e.g., checkerboarding) and major transportation corridors that bisect the state, each have the potential to influence animal distributional patterns. The proper management of pronghorn can occur only if the species is managed uniformly across land-ownership boundaries.

Pronghorn are generally considered a nomadic mammal, moving among habitats in response to changing conditions due to drought, winter storms, forage changes, and water availability (O'Gara and Yoakum 1992). In some areas (e.g., Texas and Wyoming), it is believed that fenced rights-of-way sometimes fragment pronghorn habitat and restrict movements, thereby isolating populations or preventing migrations to seasonal ranges (Buechner 1950; O'Gara and Yoakum 1992). With increased habitat fragmentation that is occurring throughout the west, pronghorn populations are having a more difficult time in maintaining traditional migratory behavior (Ockenfels et al. 1994; O'Gara and Yoakum 1992).

This study was initiated to examine how management of lands and transportation corridors in northern Arizona influenced home ranges and movement patterns of pronghorn. Our objectives were to: 1) document pronghorn movement patterns; 2) determine home-range sizes for adult female and male pronghorn; 3) identify what types of barriers isolated pronghorn; and, 4) ascertain how present management practices influenced pronghorn populations.

Study Areas

We chose two locations in northern Arizona, each centered around a National Park and bisected by at least one major transportation corridor. Our northeastern study area encompassed Petrified Forest National Park and had a 4-lane interstate highway (I-40) and a transcontinental railroad through the study area's center (Figure 1). Lands of the northeastern study are characterized by 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 is the only major waterway and is not deeply incised. Yearly precipitation is low (1941-70: $\underline{x}$ = 18.7 cm), with over one-half of the rainfall occurring during brief thunderstorms in July-September (Sellers and Hill 1974). Average snowfall is only 12.4 cm. Great Basin grassland (Brown 1994) and juniper (*Juniperus* spp.) woodland dominate the landscape. Blue grama (*Bouteloua gracilis*) and alkali-sacaton (*Sporobulus airoides*) are the predominant grasses. Sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.), rabbitbrush (*Chrysothamnus* spp.), and Mormon-tea (*Ephedra* spp.) are scattered throughout, often forming small thickets. Snake-weed (*Gutierrezia* spp.) is abundant in localized poorer-condition sites. Plant nomenclature follows Kearney and Peebles (1960).

Our north-central study area contained Wupatki and Sunset Crater National Monuments and had a 2-lane paved highway (US 89-A) running along the edge (Fig. 1). This study had undulating terrain broken by volcanic cinder hills and lava flows. Because of the wide elevational range, climate in this area varied considerably. In the lower elevation northern portion, precipitation was low (1956-62: $\underline{x}$ = 13.1 cm), with some December-January snowfall ($\underline{x}$ = 21.8 cm). Because of higher elevation caused by 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 greater (Flagstaff 1950-70 $\underline{x}$ = 50.3 cm). A short-grass prairie of *Hilaria* spp. and alkali-sacaton predominates the northern portion of this study area, while the southern portion is predominantly Rocky Mountain Coniferous Forest, comprised almost entirely of ponderosa pine (*Pinus ponderosa*). Juniper woodlands occupy 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*) occur in the juniper woodlands (Brown 1994).

Methods

Capture and Location

Using a net-gun fired from a helicopter, we captured adult pronghorn in mid-October 1992. All animals were radio-equipped, ear-tagged, and released at their capture sites. We located pronghorn aerially and from the ground each month between October 1992 and September 1994. The UTM coordinates of detections were derived to the nearest 0.1 km from USGS 7.5-min maps, and we also used a Global Positioning System (GPS) receiver to calculate coordinates. All UTM-coordinate files were transferred into an Arc-View Geographic Information System (GIS). Statistical tests were performed with SPSS/PC+ software (Norusis 1990).

Movements

Using features in HOME RANGE (Ackerman et al. 1990), we calculated movement for each animal. The 100% minimum-convex polygon method was selected as our estimate of home range size, with a 50% convex polygon as the estimate of high use areas. We tested for site or gender-related differences, as well as site x gender interactions, in home range and core use size with 2 x 2 ANOVAs. We used t-tests within each site for gender-related comparisons.

Results

Capture and Relocation

In our northeastern study area, we captured, radio-collared and ear-tagged 20 (15 F, 5 M) pronghorn. These animals were relocated 1,736 times (Fig 2). We then captured, radio-collared and ear-tagged 17 (13 F, 4 M) adult pronghorn in the north-central study area. Five animals were captured within Wupatki NM, the rest to the north. We relocated these animals 1,671 times over the next two years (Fig 3).

General Movements

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 (Normality tests). 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 x 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 ® = 0.64, $n = 37$, $P < 0.001$) between mean movements and greatest movements.

Specific Movements Within Study Sites

For the 20 adult pronghorn captured in the northeastern study 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). Of the 17 adult pronghorn in the north-central study 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 greater than 10 km.

Rights-of-way Crossings

Crossings, by both females and males, of the **paved but unfenced** road in the national parks occurred throughout the two years of this study, with 165 crossings of the unfenced paved road within Wupatki NM. However, **no pronghorn crossed paved highways or railroad tracks that were fenced** (Figs. 2 & 3). The volume of traffic undoubtedly contributed to the pronghorn confinement, in that during 1996 in our study areas Interstate-40 averaged 14,900 and US 89-A averaged 7,500 vehicles each day (AZ DOT records). In fact, some of the home ranges seemed bounded by the transportation corridors. In addition, no crossings of the AT&SF or Navajo spur railroad rights-of-way were recorded (Fig. 2). For example, pronghorn captured north of the AT&SF had home ranges bounded by the railroad right-of-way and I-40, resulting in a linear shape, while those captured south of the railroad and in the north-central study area all had circular home ranges.

Home Ranges and Core Use Areas

Home range sizes clustered at 75-125 km^2, with few encompassing <50 km^2, while 3 home ranges >250 km^2 were for females what had made large-scale seasonal movements (Table 2). 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; $P = 0.158$). However, home range sizes and variability were larger ($t = 2.15$, df = 22.32, $P = 0.042$) in the north-central study area (Table 2). There was no ($F = 0.06$; df = 1,36; $P = 0.805$) site x gender interaction. The greatest influence on home range shapes of the pronghorn at both study areas was human-related development, particularly, fenced highways, railroad rights-of-way, and water catchments.

Discussion

In our discussion we will first compare pronghorn movements and home ranges between our study sites. Secondly, we will discuss what did, or did not, constitute a movement barrier. The third topic that we will deal with is the potential role transportation corridors play in the management of pronghorn in northern Arizona. The last aspect of our discussion will deal with what management actions are necessary to ensure equitable harvest and to reconnect isolated herds of pronghorn antelope.

Movement and Home Range Comparisons

Movements -- Proximately, 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. Historically, pronghorn 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. Recruitment into this pronghorn population could, therefore, be adversely affected by the loss of quality summer range.

Another factor that contributed to movement differences between sites was the availability of a permanent water source. At our northeastern study site, within Petrified Forest National Park the Puerco river provided permanent water throughout the year. However, at the north-central site, there is no permanent water within Wupatki NM and during drier months the pronghorn had to leave the park for livestock water sources.

Ultimately, the greatest influence on pronghorn movement in northern Arizona were barriers created by fenced transportation corridors. In each of our study areas, pronghorn herds were completely isolated by the fenced corridors. In over 3,000 relocations, not a single animal was found to have successfully crossed any of the fenced major transportation corridors.

Home range Comparisons – Pronghorn in our north-central study area had significantly larger home ranges than the northeastern animals. Weather certainly did have 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 also a major contributing factor to the increase in home range sizes. Ockenfels et al. (1994) also showed that in central Arizona water played a dominant role in pronghorn Home range sizes.

We found that fenced transportation corridors had the greatest influence on the shape of pronghorn home ranges. In our northeastern study area, one group of pronghorn had a long linear home range because of confinement between a major freeway (I-40) and fenced railroad right-of-way (Fig. 2). Although the home range area was not significantly different between these pronghorn and other groups in our study, the animals confined between the railroad and I-40 were the only ones with a non-circular home range pattern. The linear home range would place increased energetic demands on movement when compared to pronghorn who foraged out from a central location in a circular home range.

Movement Barriers

Fenced highway right-of-way -- Buechner (1950), working in Texas, first observed the negative effect highway rights-of-way fences had on pronghorn movements. White (1969) documented that fenced highways blocked the movement 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. From over 3,000 relocations during this study, not a single animal successfully crossed a fenced highway; but we did find a radio-collared female dead on the north side of Highway 89-A.

Fenced railroad right-of-way -- The AT&SF railroad line roughly follows the 35th parallel in northern Arizona, crossing through the middle of Petrified Forest NP. In our northeastern study area we demonstrated that pronghorn are isolated into two populations by the AT&SF railroad right-of-way. Similar fragmentation probably occurs in many other areas in the state and throughout the West, particularly if train traffic is high and the tracks are tightly fenced on both sides.

Unfenced rights-of-way-- Although considerable traffic occurs 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 dirt roads (e.g., Dugas Road) in central Arizona.

Management Implications

The extreme fragmentation of pronghorn populations, in our northern Arizona study areas, leads us to conclude that transportation corridors with fenced rights-of-way, are the major factor affecting pronghorn movements. Arizona's current survey and harvest management program for pronghorn is designed around Game Management Units (GMUs), most of which have been in existence since 1958. Many of these GMUs are crossed by numerous transportation corridors. Because of the absence of movement across fenced transportation corridors observed during our study, some GMUs would contain multiple pronghorn populations. For example, our north-central study area contains portions of GMU 7, which 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.

The lack of animal movement among herds that are presently separated by fenced transportation corridors, will ultimately affect survival and genetics of those herds. If GIS methodology could be used to estimate the extent of the problem, pronghorn management strategies could be easily modified to acknowledge such fragmentation. Moreover, to facilitate movement and interchange among herds, it is imperative to reduce the effect of fenced rights-of-way on pronghorn populations. In some key regions, emergency plans could be established to remove fences from transportation corridors during periods of severe weather to allow movement to and back from lower elevation habitat. To do so effectively, however, would require extensive knowledge of movement corridors. Pronghorn would then be able to freely move as natural perturbations occur, and the extensive winter kills as described by White (1969) could be avoided.

Another factor affecting localized movement and influencing home range in northern Arizona is permanently available water, particularly at Wupatki NM (van Riper et al. 1997). Draw-down of the water table by wells, along with anthropogenic manipulation of former watering sites, have negatively influenced historic springs, resulting in no permanent water sources remaining within the park. In fact, van Riper et al, (1997) found greatest movement out of the park to secure water during September, that time of year when pronghorn are most heavily harvested in northern Arizona.

Although pronghorn have been found not to utilize tunnels under transportation corridors (Ward et al. 1980), building expansive bridges across lower elevational areas (e.g., drainages), might permit connection of presently isolated pronghorn populations in northern Arizona. Other possible mitigation features that might be undertaken include: (1) removing fences along some rights-of-way stretches ; (2) expanding rights-of-way dimensions by placing fences further from the road or railroad, then modifying the fences to permit better movement of pronghorn between fenced areas; (3) relocating rights-of-way out of pronghorn habitat; (4) consider relocating animals, particularly to the section of Petrified Forest NP north of Interstate 40; (5) providing permanent water sources in Wupatki and Sunset Crater NM; and, (6) providing signs on unfenced park roads warning visitors of wildlife movement corridors. Careful attention should also be given to preventing any fencing of presently unfenced roads, highways, and railroads.

The issues confronting land and transportation managers in dealing with pronghorn in northern Arizona, even in national parks, is only an indication of a much larger problem facing protected areas and countries around the world. If managers wish to have their protected areas function as species reservoirs (i.e., 'sources' instead of 'sinks'), they have to: 1) begin to forge active partnership with transportation managers and contiguous land owners to manage resources on an ecosystem basis; 2) then decide to what degree they are willing to allow 'hands on' active management to occur when transportation corridors on their managed lands do not adequately permit movement of species; and finally, 3) standardize (or partition) management practices among <u>all</u> parties involved in managing resources within each ecosystem, so that the costs of mitigation can be borne on a proportional basis.

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Table 1

Movement characteristics of adult pronghorn antelope from 1992-94 in the environs of Petrified Forest national park and Wupatki/Sunset Crater national monuments in northern Arizona.

	Petrified Forest NP		Wupatki and Sunset Crater NM		
Variable	Females	Males	Females	Males	Overall
n	15	5	13	4	37
Mean distance moved[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
No. movements ≥10km[b]	36	7	66	4	113
No. movements ≥20km[b]	3	0	5	2	10
Mean of greatest distance moved[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

[a] Km between 2 consecutive locations for each animal as calculated by HOME RANGE (Ackerman et al. 1990), then averaged for mean distance.

[b] Distance between 2 consecutive locations.

Table 2
Home range characteristics of adult pronghorn antelope from 1992-94 in the environs of Petrified Forest national park and Wupatki/Sunset Crater national monuments in northern Arizona.

	Petrified Forest NP		Wupatki and Sunset Crater NM		
Variable	Females	Males	Females	Males	Overall
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

[c] Home range size using 100% minimum convex polygon and core use area using 50% minimum convex polygon from HOME RANGE (Ackerman et al. 1990).

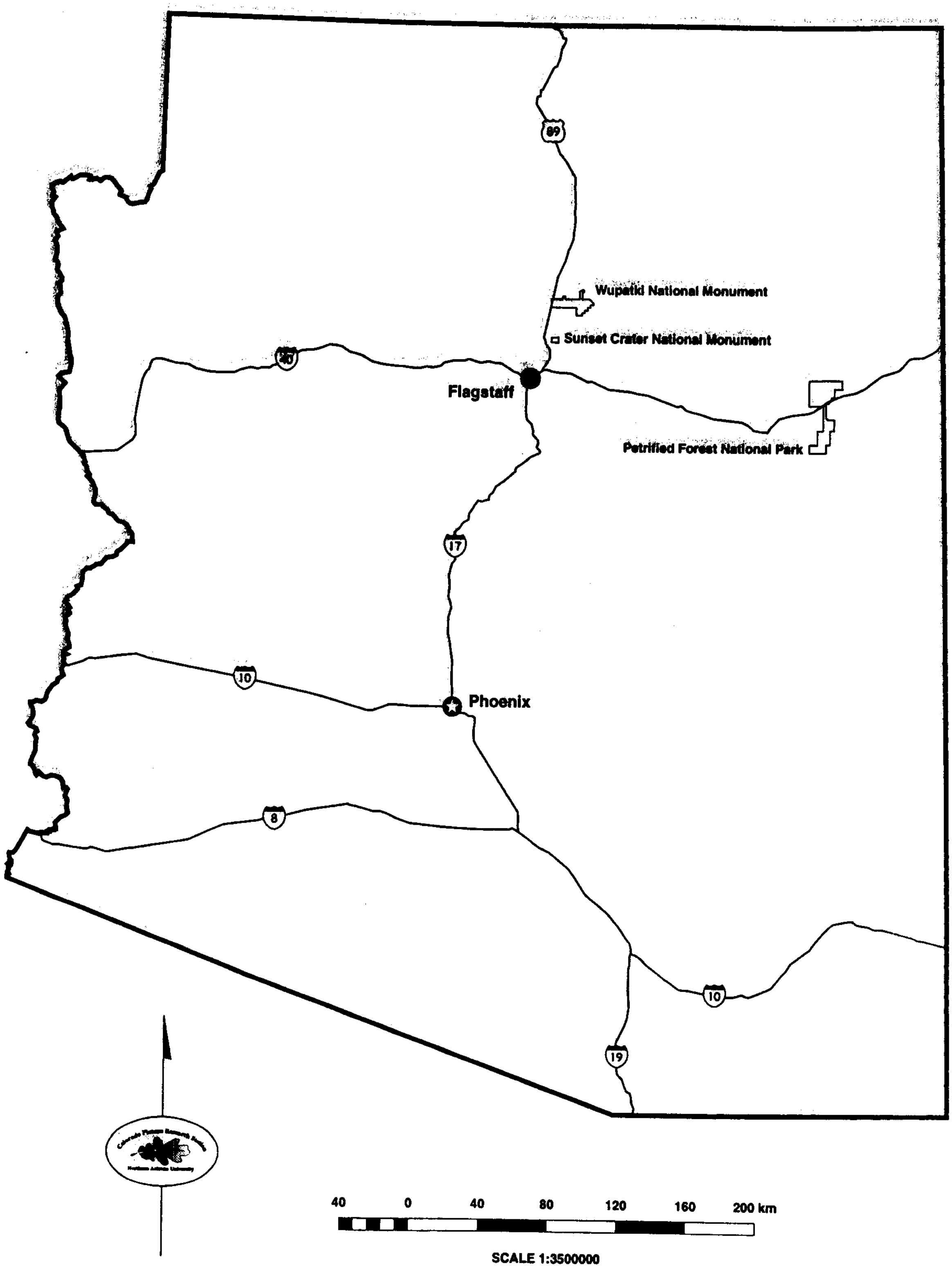

Figure 1
Map of Arizona with three national parks that served as the core for our Northeastern and North-central study areas.

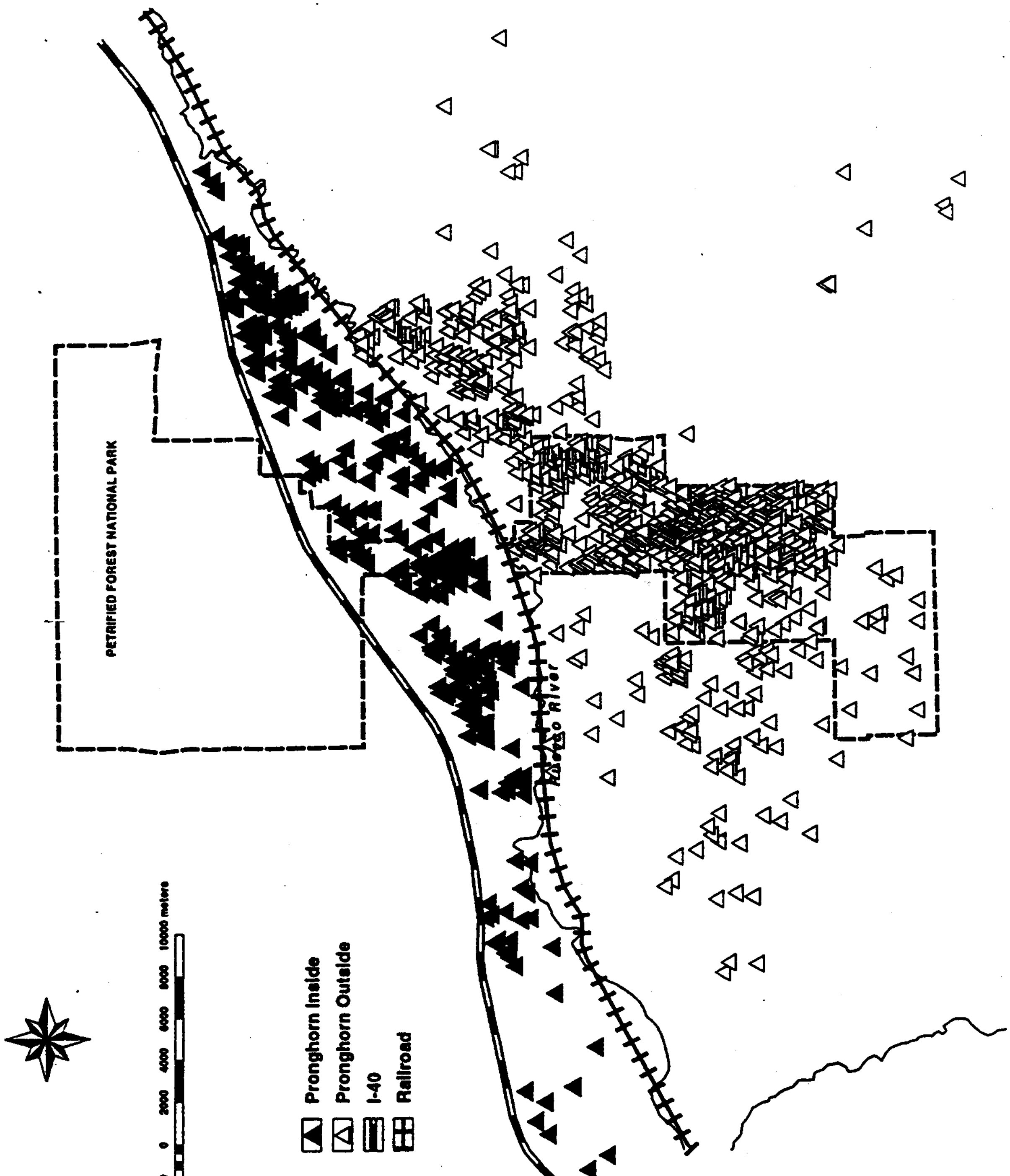

Figure 2
Locations of radio-equipped adult pronghorn sightings, from 1992-94, within our Northeastern Arizona Study Area. The study area is centered on Petrified Forest National Park.

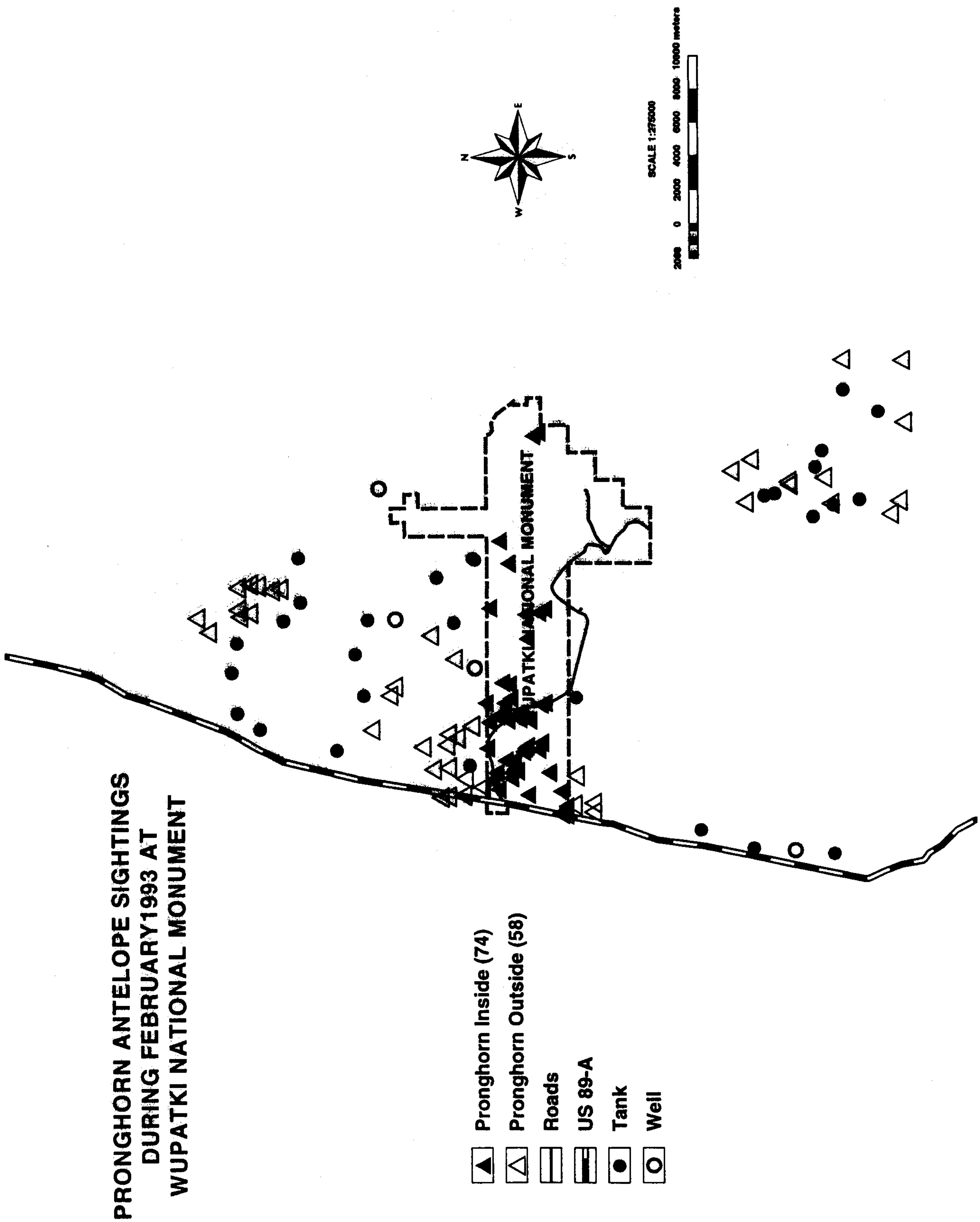

Figure 3
Locations of radio-equipped adult pronghorn sightings, from 1992-94, within our North-central Arizona Study Area. The study area, bounded by Game Management Unit 7E, is centered on Wupatki-Sunset Crater National Monuments.