DETERMINATION OF HABITAT PREFERENCES OF PRONGHORN (*Antilocapra americana*) ON THE ROLLING PLAINS OF TEXAS USING GIS AND REMOTE SENSING

Robin A. Aiken, B.S.

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APPROVED:

Earl G. Zimmerman, Major Professor
Kenneth L. Dickson, Committee Member
Samuel F. Atkinson, Committee Member
Arthur J. Goven, Chair of Biological Sciences
Sandra L. Terrell, Dean of the Robert B. Toulouse School of Graduate Studies

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The Rocker b Ranch on the southern Rolling Plains has one of the last sizeable populations of pronghorn (*Antilocapra americana*) in Texas. To investigate habitat utilization on the ranch, pronghorn were fitted with GPS/VHF collars and were released into pastures surrounded by a variety of fences to determine how fence types affected habitat selection. Habitat parameters chosen for analysis were vegetation, elevation, slope, aspect, and distances to water, roads, and oil wells. Results showed that pronghorn on the ranch crossed modified fencing significantly less than other types of fencing. Pronghorn selected for all habitat parameters to various degrees, with the most important being vegetation type. Habitat selection could be attributed to correspondence of vegetation type with other parameters or spatial arrangements of physical features of the landscape. Seasonal differences in habitat utilization were evident, and animals tended to move shorter distances at night than they did during daylight hours.

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INTRODUCTION

Evolutionary History

The American pronghorn (*Antilocapra americana*) is endemic to prairies of North America (Nelson 1925) and is the only surviving species of the family Antilocapridae, which contained a wide variety of members before the extinctions of the Late Pleistocene (Frick 1937). Pronghorn have few large predators at present, such as the coyote (*Canis lantras*), grey wolf (*Canis lupus*), and cougar (*Felis concolor*). However, during the Pliocene and Pleistocene, it inhabited the same grassland habitat as several predators, including the North American lion (*Panthera leo atrox*), jaguar (*Panthera onca*), the saber-toothed cat (*Smilodon fatalis*) and the American cheetah (*Acinonyx trumani*) (Byers 1997). Several characteristics of the pronghorn are testament to its evolution on the flat, open terrain of the prairies with swift-mowing predators: such as its speed, with recorded running velocities ranging from 72 to 100 kph (Einarsen 1948, Hailey 1979, Byers 1997); its stamina, resulting from the ability to consume and process oxygen far surpassing most mammals (Lindstedt et al. 1991); and its range of vision, equivalent to a human looking through 8x binoculars (Einarsen 1948; Byers 1997).

Habitat Requirements

An important requisite of pronghorn habitat is an unobscured view of the landscape. The average shoulder height for males is 87.5 cm and 86 cm for females (O'Gara 1978), therefore vegetation with an average height of 25 to 46

cm is preferred while vegetation over 63 cm is avoided (Yoakum 1980). Pronghorn will utilize landscape with trees as long as the canopy does not exceed 20% of the area (Ockenfels 1995). In preferred habitats, pronghorn tend to choose areas where 50% is covered with vegetation while the other half is either rock or bare ground (Yoakum 1980).

Pronghorn also select habitat in response to seasonal changes and physiology. During the fawning season in Texas, pronghorn occupy flat grasslands and adjacent rolling terrain, where taller vegetation would be available for concealment (Buechner 1950, Hailey 1979). In the winter, they may inhabit flat grasslands or move to brushy or south-facing slopes to protect themselves from north winds (Buechner 1950, Hailey 1979).

Furthermore, rangelands selected by pronghorn are heterogeneous, including a variety of vegetation types, such as grasslands with patches of forbs and brush, as opposed to homogeneous landscapes (Autenrieth 1983, Sundstrom et al. 1973). The pronghorn diet consists of grasses, forbs, and browse, and the overall composition is dependant upon which of the two main biomes the pronghorn utilizes, the grasslands or the shrub-steppe. Pronghorn of the grasslands tend to favor forbs, while grasses and browse are consumed far less frequently (Buechner 1950, Hailey 1979, Yoakum 1980, Ockenfels 1994, Lee et al. 1998). In the shrub-steppe biome, browse is the dominant vegetation consumed, though food habit studies have determined forbs are preferred (Lee et al. 1998). Buechner (1950) found that forbs are the main vegetation

consumed in west Texas, with the highest use in spring. Browse usage peaks during the fall, when forbs are not as abundant, and continues throughout the winter. Grasses are the least consumed vegetation, but are more important in the fall and summer.

Pronghorn rarely stray more than 6.4 km away from water sources (Sundstrom 1968, Yoakum 1980). Due to the arid climate of the southwest, demand for water is greatest during the fawning season and does will typically select a radius of less than 1.6 km from water during fawning and post fawning periods to ensure adequate resources for lactation (Ockenfels 1995). Accessibility to water becomes more important during drought conditions when the moisture content of vegetation is reduced (Ockenfels 1995). In the mid 1960's, 65 to 82% of several pronghorn populations herd in west Texas perished from starvation as a result of a yearlong drought (Hailey 1979).

The fencing of open rangeland has inhibited the movement of pronghorn and most populations travel from one location to another within an area based on seasonal physiological requirements and forage availability, rather than migration (Einarsen 1948, Hailey 1979). Pronghorn in northern regions may move over 320 km to escape deep snow or to locate viable winter grasses (Riddle 1990), while in southern regions they may travel long distances to reach water sources (Buechner 1950). In west Texas, daily pronghorn movements average from 4.8 to 6.4 km a day over a 3.2-km radius (Buechner 1950).

Behavior

Pronghorn social groups also vary throughout the year, and these groups can be separated by season based on pronghorn behavior and physiology. Byers (1997) observed these seasons while investigating pronghorn in Montana, and literature concerning Texas pronghorn confirms the behavior (Hailey 1979, Buechner 1950). In winter, pronghorn aggregate into large groups consisting of both sexes. In March, these groups dissolve; males are solitary or form small groups, while does form groups with one dominant male. In fawning season, does separate individually from their groups to give birth, and the groups reform in the nursing season with the new fawns. During the rutting season in August, mature males become territorial and form harems with up to eight females. Nonterritorial males form larger groups during rutting season and attempt to mate with does in harems.

Range and Abundance

Five subspecies of pronghorn are recognized; *Antilocapra americana americana*, *A.a. mexicana*, *A.a. peninsularis*, *A.a. oregona*, and *A.a. sonoriensis* (O'Gara 1978). In his classic work on pronghorn in the Trans-Pecos region of Texas, Buechner (1950) stated that the physiological features of some pronghorn in the area represent an "intergrade" of the Mexican and American subspecies, although the majority of this species west of the Pecos River were, in his opinion, *A.a. mexicana*. Recent studies indicate several West Texas populations possess genetic characteristics of both subspecies (Lee et al. 1994). One of these

populations includes pronghorn on the Rocker b Ranch in Irion and Reagan counties.

The historical range of the American pronghorn covered south central Canada, a major portion of the western United States, and southward to central Mexico. The highest densities were probably found in short grass prairies, where pronghorn migrated with buffalo herds (Yoakum 1978). Pronghorn still inhabit roughly the same regions, but in small, isolated populations that represent less than 25% of the habitat they once occupied (Lee et al. 1998). The first extensive survey of pronghorn numbers was conducted from 1922 to 1924 and estimated that 26,600 individuals inhabited the United States (Nelson 1925). By 1954, the population had risen to 360,000 (Yoakum 1980), and current populations may be as high as one million (Lee et al. 1998). In Texas, pronghorn once ranged over the western two-thirds of the state, but the species is currently restricted to the upper half of the Texas Panhandle on the High Plains, scattered areas of the Rolling Plains, and a major portion of the Trans Pecos (Davis and Schmidly 1994). Few ranches in the Southern Rolling Plains support populations of pronghorn, and of those, the Rocker b Ranch has one of the last sizeable populations of the region (Texas Parks & Wildlife Department personal communication). Located in Irion and Reagan counties, the Rocker b Ranch includes 173,000 acres (70,011 hectares) on the Southern Rolling Plains of Texas.

Nelson's (1925) study in 1922 estimated the Texas pronghorn population to be approximately 2,400 animals. This number rose to 3,500 animals in 1978 (Hailey 1979), and by 1999, the population was estimated to be 10,000 (Ticer and Devos 2001). At the Rocker b Ranch, pronghorn numbers followed a similar trend (TPWD data). The population averaged around 1,000 animals through the 60's and 70's. In the 1980's, the numbers increased, peaking at 2,722 individuals, but populations have been steadily declining up to the present day. Estimates place the Rocker b population at 217 individuals in 2002 (Lee Miller, Texas Parks and Wildlife Department, personal communication).

Overview of Research

Habitat selection research involving American pronghorn has been conducted since the mid 1900's. The earliest comprehensive literature concerning pronghorns included mainly observational information on selection (Einarsen 1948). Buechner (1950) published the first major study on Texas pronghorn that investigated habitat selection, movement, and home range composition and size. Still other studies have examined one or more of these factors, typically for a specific region (Bayless 1969, Sundstrom et al. 1973, Yoakum 1974, Barrett 1980, deVos 1990, Schuetze 1992). With the increasing use of geographic information systems (GIS), current research has utilized this new technology to determine factors affecting pronghorn habitat selection. Ockenfels and Wennerland (1994) investigated pronghorn habitat selection around water sources and near highways, while Perry and Miller (1995) used

GIS to create a habitat model for pronghorn within north central Arizona. Two in-depth studies were also conducted in central Arizona by the Arizona Game and Fish Department. One was to determine the habitat selection, home ranges, and movement patterns of resident pronghorn (Ockenfels et al. 1994). The other study developed a system using GIS to rate habitat in Arizona based on pronghorn habitat requirements (Ockenfels et al. 1996).

In general, studies to determine resource selection for animals on temporal and spatial scales increased in the 1990s as a result of the availability of a new tool to scientists and wildlife managers, global positioning system (GPS) collars. Since that time GPS collars have been utilized to investigate habitat selection, home range, and animal movement, such as a study in Minnesota to determine long-range movement of four wolves (*Canis lupus*) (Merrill 2000) and another to determine the factors that effects movement and habitat selection of woodland caribou (*Rangifer tarandus caribou*) (Johnson et al. 2002b). Data recorded by GPS collars can then be incorporated with other data, such as elevation, slope, vegetation type, etc., and analyzed using GIS technology.

GPS technology tends to be more precise spatially and has fewer biases than other systems, radio telemetry for example (Johnson et al. 2002a), though research conducted to ascertain the reliability of GPS collars has determined sources of inaccuracy and bias. For example, several independent researchers collared wild free-ranging moose (*Alces alces*) to assess the influence of different boreal habitat on the performance of GPS collars. All concluded that fewer

locations were collected from the collars when the animals were within mature forests, as opposed to areas with no or thin canopy cover, or on highly sloping terrain (Rempel et al. 1995, Moen et al. 1996, Dussault et al. 1999). Additionally, from 1996 to 1999, GPS collars deployed on female caribou in boreal forests of British Columbia recorded an average of only 59% of attempts to acquire a location (Johnson et al. 2002a). Before May 2000, the precision and accuracy of GPS location information was intentionally degraded with selective availability (SA) practices by the U.S. Department of Defense and without correction, the location error could be as high as 80 m (Rempel et al. 1995). With SA disabled, the accuracy of GPS increased from 4- to 5-fold (Hulbert and French 2001).

As indicated above, the American pronghorn has been extirpated from a vast portion of its historical range and now exists in isolated populations. Unfortunately, one of these populations, located on the Rocker b Ranch near San Angelo, has experienced a decline over the past two decades. Several factors may account for the decrease, although below average precipitation for the area is one of the most obvious causes. Over the last 10 years, average precipitation has been approximately 8 cm below average rainfall (averaged for the past 25 years; NOAA 2004). Restriction of movements to suitable forage by fencing may also contribute to the decrease. Numerous observations document the tendency for pronghorn to avoid jumping (Einarsen 1948, Autenrieth 1978, Hailey 1979), and the behavior can result in starvation, especially in winter months, when an occupied pasture becomes overgrazed, and animals refuse to

jump fences to gain access to another pasture (Buechner 1950). Recent efforts on the Rocker b Ranch to alleviate this problem include replacing restrictive net wire fencing with barb wire/woven wire fencing that allows more unrestricted movements of animals over the ranch. The impact of this modified fencing has not been investigated. Through the use of GPS collars and GIS technology, a better understanding can be gained for modified fencing use by pronghorn and those habitats they prefer when unrestricted. Such a study could enhance the management plan for the population, as well as other populations in the area.

Testable hypotheses for the study include:

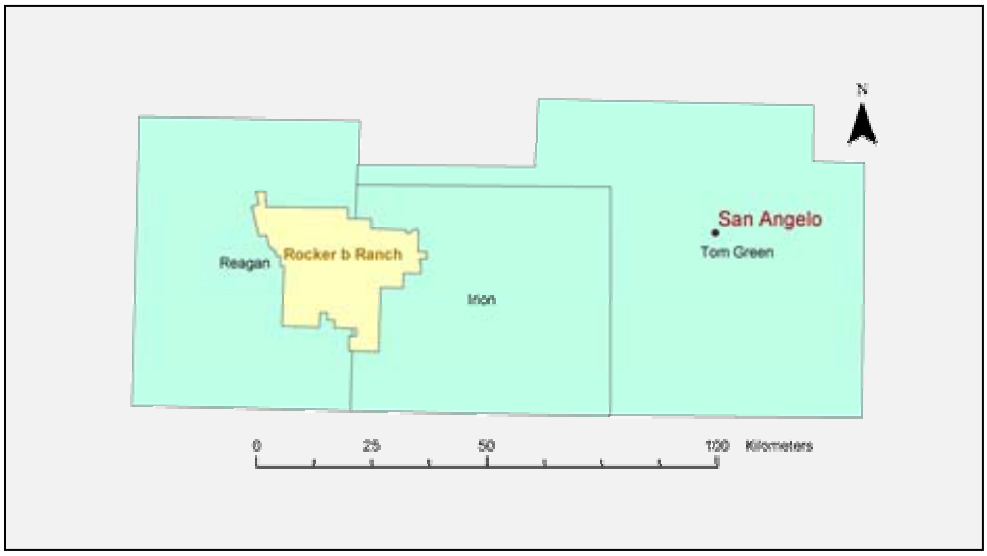
- For the parameters of vegetation, elevation, slope, aspect, soils, and distance to water, roads, and oil pumps, significant differences do not exist between observed and expected parameter selection by pronghorn. Also significant differences do not exist between the parameter selected for by pronghorn whether they are within their release pastures or have escaped.
- For fences, significant differences do not exist between crossing frequencies of different types of fences and significant differences do not exist between pronghorn and the frequency in which they cross different fence types.
- For home ranges, significant differences do not exist between areas of home ranges for pronghorn on a seasonal basis.

- For movement, significant differences do not exist between pronghorn for distances traveled and significant differences do not exists between the diurnal or nocturnal distance moved on a seasonal basis.

Study Area

Encompassing approximately 70,010 hectares (173,000 acres), the Rocker b Ranch straddles the counties of Irion and Reagan in west Texas (Figure 1). Located on the western edge of the Edwards Plateau, the environmental conditions resemble the arid grasslands of the Permian Basin, rather than the rolling hills of the eastern portion of the Edwards Plateau. The elevation ranges

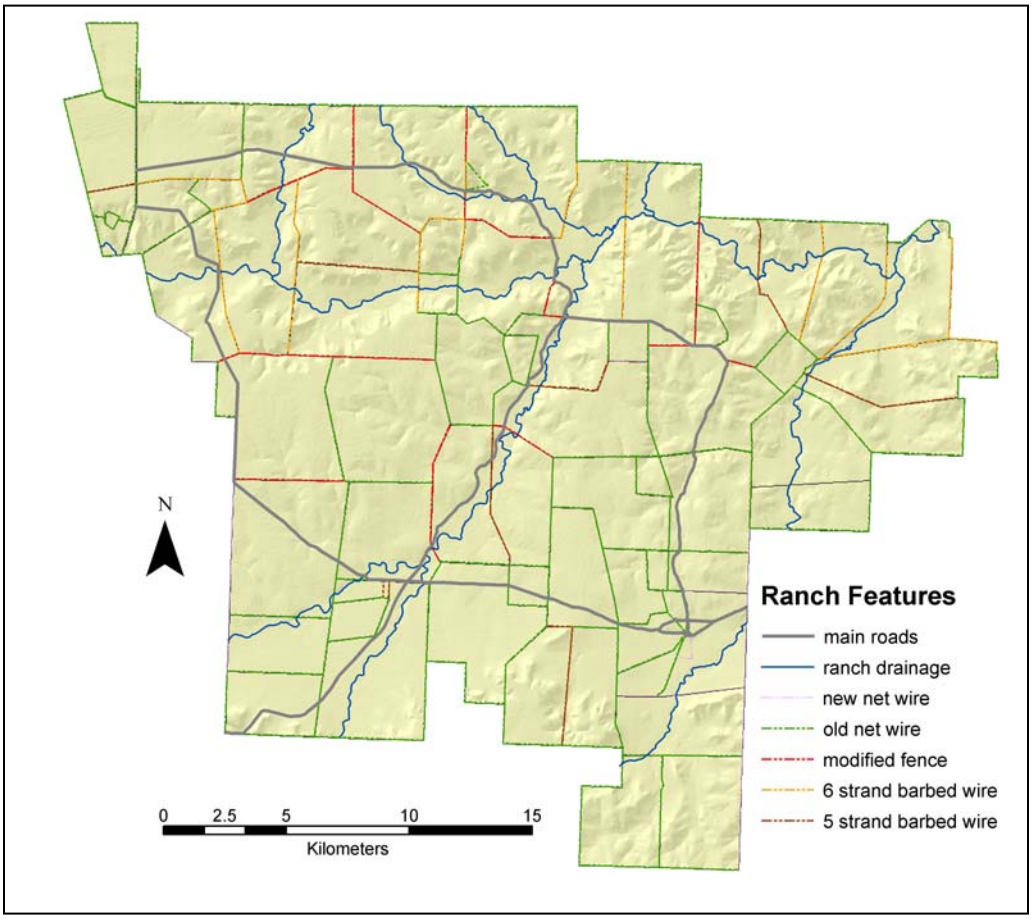
Figure 1. Location of Rocker b Ranch in West Texas.



from 695 to 846 m, with the higher elevations found on the southern and northwestern areas of the ranch. The central portion is basin-like with minimal slope and two intermittent streams bordered by riparian vegetation run east-west in the north and north-south (Figure 2). An average annual precipitation of 51.3

cm and an average temperature of 18.1°C (NOAA 2004) result in vegetation adapted to an arid climate, such as grasses, forbs, shrub, juniper, mesquite, and cacti.

Figure 2. Features of the Rocker b Ranch.



Recently, mesquite has invaded many parts of the ranch where it did not occur in the past due to: the decrease of fires which previously reduced the amount of woody vegetation, the reduction of natural grasses which prevented establishment of seedlings, and the decline of prairie dog populations that

controlled the spread of mesquite by destroying their root systems (Nelle 1993). This increase of brushland has been detrimental to both pronghorn and cattle as the forbs, grasses, and browse are replaced.

As a working ranch, cattle graze the same habitat on the Rocker b as pronghorn. To manage the ranch for cattle, the Rocker b has been heavily fenced with 5- and 6-strand barbed wire, wire fencing, and some modified fencing to allow pronghorn movement (Figure 2). Also, several main roads cross the ranch, and numerous secondary roads lead to oil pumps that dot the landscape.

MATERIALS AND METHODS

Data Acquisition using GPS Collars

During the winter of 2001-02, pronghorn were captured by officials of the Texas Parks and Wildlife Department (TPWD) on the Rocker b Ranch using corral traps and net guns. Sex and age were determined for each animal, and a global positioning system (GPS) radio collar utilizing very high frequency (VHF), was fitted to each individual before it was released. The original plan for the study was to place half of the collared pronghorn in one pasture, the Basin pasture, which was surrounded by net wire fencing to restrict movement out of the pasture. The other half was to be released in two areas, Graston and Lower West Hollow pastures, which are enclosed by a variety of fencing, including modified fencing (Figure 3). Modified fencing has the bottom wire of a barbed wire replaced with a smooth wire about 40 cm above the ground. This modification allows pronghorn to crawl under the fence, while cattle movement is prevented (Autenrieth 1978).

The net wire fencing enclosing the Basin pasture did not restrict the pronghorn, as they escaped by either jumping cattle guards or crawling through holes in the fence. Based on preliminary statistical tests, the three pastures in which pronghorn were released into were significantly different from one another for categorical variables (chi-square test for proportions, $P<0.001$). For continuous variables, the pastures were significantly different from one another (Kruskal-Wallis, $P<0.001$), and a Tukey's nonparametric multiple comparison test

(α = 0.05) separated the rank sums of the three pastures into three statistically different groups for all parameters except distance to water. Therefore, the pastures were treated as three separate habitats. For Basin, Graston and Lower West Hollow groups of pronghorn, habitat selection within the pasture was compared to habitat selected by pronghorn that escaped from the release pasture.

GPS/VHF collars were programmed to collect and store each animal's location (accurate to 3 m) every 4 hours for 12 months. Data from certain pronghorn collared initially were not used in final analyses due to a variety of factors, e.g., mortality of individuals during the 12-month period; only three females were collared and their data did not represent a suitable sample size for analysis. When mortality of collared individuals occurred, the collar was located via the VHF receiver, and a new animal was captured and fitted with the collar. When the study was terminated, the collars were released remotely using a VHF signal that triggered a latch release. After removal of the collar, the information was downloaded into a database (GPS pronghorn collar database, GPCD), and a shapefile was created for each pronghorn with each recorded position represented as a point. This resulted in locations for eight and fourteen pronghorn in restricted and unrestricted areas, respectively, for which sufficient data were available for valid statistical analyses (Table 1).

Table 1. Selected information on pronghorn used for statistical analyses.

ID	Age	Area	Date Deployed	Date Terminated
12182	3.5	Basin	1/16/2002	1/8/2003
12186	3.5	Basin	2/27/2002	1/2/2003
12188	2.5	Basin	1/16/2002	1/8/2003
12192	4.5	Basin	1/21/2002	1/8/2003
12194	4.5	Basin	1/21/2002	1/14/2003
12196	1.5	Basin	1/16/2002	10/9/2002
12198	2.5	Basin	1/16/2002	1/8/2003
12229	3.5	Basin	3/6/2002	1/8/2003
12187	4.5	Graston	1/28/2002	10/8/2002
12189	2.5	Graston	1/28/2002	7/9/2002
12193.1	1.5	Graston	7/9/2002	1/8/2003
12195	4.5	Graston	1/28/2002	3/12/2003
12199	2.5	Graston	7/9/2002	12/9/2002
12231	4.5	Graston	3/20/2002	1/14/2003
12234	2.5	Graston	6/17/2002	1/9/2003
12183	2.5	Lower West Hollow	1/17/2002	1/14/2003
12185	4.5	Lower West Hollow	1/17/2002	1/9/2003
12191	4.5	Lower West Hollow	1/17/2002	1/8/2003
12193	0.5	Lower West Hollow	1/17/2002	7/8/2003
12197	3.5	Lower West Hollow	1/21/2002	8/9/2002
12197.1	2.5	Lower West Hollow	8/23/2002	1/14/2003
12201	4.5	Lower West Hollow	2/4/2002	1/8/2003

Digital Data Acquisition for GIS Analysis

Pronghorn habitat parameters, the digital data used to evaluate the parameter, and the file types, format, sources, dates, suppliers of the data, and how the data were obtained are provided in Table 2. To ensure spatial agreement between data types, all data were reprojected into Universal

Transverse Mercator (UTM) zone 14, North American datum (NAD) 1983 coordinate systems.

Table 2. Habitat parameters obtained in digital format for data analysis using GIS.

Parameter	Data	Data Type	Format	Source	Creation Date	Supplier	Acquisition Method
Vegetation	Landsat-7 ETM+ Image	Image	NDF	USGS	8/23/2002	TNRIS	CD
Elevation	DEM	Raster	GRID	USGS	6/1999	USGS	Download
Slope	DEM	Raster	GRID	USGS	6/1999	USGS	Download
Aspect	DEM	Raster	GRID	USGS	6/1999	USGS	Download
Soil	STATSGO	Vector	Shapefile	USDA	1994	NRCS	Download
Roads	DOQ	Raster	SID	TOP	2/1996	TNRIS	Download
Oil Pumps	DOQ	Raster	SID	TOP	2/1996	TNRIS	Download
Fences	Unknown	Vector	Shapefile	TPW	2001	TPW	CD
Water	Unknown	Vector	Shapefile	TPW	4/1/2002	TPW	CD
Home Range	Unknown	Vector	Shapefile	TPW	4/1/2002	TPW	CD
Movement	Unknown	Vector	Shapefile	TPW	4/1/2002	TPW	CD

Data Processing

A satellite image (August 23, 2002) of the San Angelo area was obtained from Texas Natural Resources Information System (TNRIS). The image was initially acquired from the Enhanced Thematic Mapper Plus (ETM+) instrument aboard Landsat-7, operated by the United States Geological Survey (USGS). The data, in National Land Archive Production System (NLAPS) data format (NDF), were corrected both radiometrically and geometrically, eliminating the need for removal of errors by the researcher. All processing of the image was conducted in ERDAS IMAGINE® 8.6 imagery software (Leica Geosystems,

Switzerland, www.gis.leica-geosystems.com). For easier use in analysis, a shapefile of the Rocker b Ranch provided by the TPWD was used to clip a subset of the ranch from the original satellite image using ERDAS IMAGINE. Sub-setting reduces the size of the image in disk storage and, subsequently, the amount of processing time required for each data set.

The Landsat-7 image consisted of 30 x 30-m pixels, each possessing a brightness value determined by the amount of electromagnetic radiation reflected in that region in space (Jensen 2000). The process of classifying involved the assignment of each value to a particular class. However, due to the arid environment, the normalized vegetation index (NDVI) was utilized first to enhance differences between the vegetation classes (Jensen 2000). With the transformed reflectance values, an image file was created for use in classification. Two methods of classification were used, supervised and unsupervised. Unsupervised classification was utilized first and consisted of inputting the number of vegetation classes desired and allowing ERDAS IMAGINE to sort the pixels based on brightness value. For the Rocker b image, 150 classes were initially chosen. To reduce the number of classes, supervised classification was then employed using the following procedure:

- 48 GPS points were taken in April 2003, along with digital photos of the area for each point, with field notes on habitat type for each point.
- All GPS points were imported into a shapefile and imported into ArcMap™ 8.3 geographic information systems software (Environmental Systems

Research Institute ESRI®, Redlands, CA, www.esri.com). Hotlinks to the digital photos were added, and vegetation descriptions were included as attributes to the points for easier reference during classification.

- Points in the shapefile were then assigned to one of five vegetation type or landform categories (Table 3).
- In ERDAS IMAGINE, the points were laid over the clipped Landsat image and, using digital photos as visual aids, a region based on similar spectral values was grown ("region grow" function of ERDAS IMAGINE) on the image and saved as signatures in the signature editor.
- The signatures were then input into a supervised classification performed by ERDAS IMAGINE, and a classified image was the resultant output.
- The output classification was grouped by category. Classes that appeared suspect to inaccuracy were masked and reclassified. This masked classification was mosaiced to the original output to create the final product.

Table 3. Vegetation/landform classes used by pronghorn on the Rocker b Ranch.

Vegetation Type	Code	Description
Bare	B	Bare soil; rock; sparse forbs
Grass/Forb	G/F	Grass; forbs; sparse shrub
Shrub	S	Moderate shrub; cacti; sparse juniper; sparse mesquite
Moderate Mesquite	MM	Moderate mesquite; grass savannas
Dense Mesquite	DM	Dense mesquite and other trees/bushes
Juniper	J	Moderate to dense juniper; cacti; sparse mesquite

Since the vegetation/landform layer was crucial to the validity of an accurate assessment of habitat utilization by pronghorn, it was important to have an accurate classification. On the classified image, 250 random points were generated and the vegetation type for each point per was recorded. In May 2003, groundtruthing was performed, whereby each accessible point, 204 out of the original 250, was compared to the actual location in the field to verify the accuracy of the produced image (Jensen 2000). Producer and user accuracies were determined from the results.

For each of the habitat parameters, the following methods are pertinent to the GIS analyses:

- Elevation, slope, and aspect — digital elevation model (DEM) data for 7.5-min units were obtained to calculate elevation, slope, and aspect of the study area. To cover the ranch, 13 quadrangles with 30- x 30-m pixels were downloaded and later compiled into one mosaic image in ArcInfo™ 8.3 geographic information systems software (Environmental Systems Research Institute ESRI®, Redlands, CA, www.esri.com).
- Soil — the preferred data for use in soil studies is Soil Survey Geographic (SSURGO) data. Unfortunately, surveys for Irion and Reagan counties had not been completed, and State Soil Geographic (STATSGO) data for the study area were utilized as an alternative.
- Roads and oil pumps — digital orthophoto quadrangles (DOQs), in 1-m resolution, were used to digitize roads, and oil pumps in the study area. In

ArcMap, using the Edit function, arcs were generated along roads and points were created at oil pumps. To determine distance from roads, and oil pumps, the Distance function in ArcMap's Spatial Analyst created a raster file for each factor.

- Water and fences — shapefiles of water wells and fences were created and procured from TPW. The Distance function in ArcMap's Spatial Analyst was utilized again to create a raster file for water.

Data Integration

After the data needed for the habitat parameters were processed into a usable form, each parameter dataset was integrated with the pronghorn collar database. To accomplish the task, an ArcView™ 3.1 geographic information systems software (Environmental Systems Research Institute ESRI®, Redlands, CA, www.esri.com) extension, getGridValue 2.1, was employed. In ArcView, each parameter was added as a layer in one project and any files not in raster (or GRID) form were converted. Then a GPCD shapefile was added individually for each pronghorn, and getGridValue was run for each layer. This process was repeated for each GPCD shapefile.

Table 4. Seasons for pronghorn based on physiology of animals.

Season	Code	Beginning	Ending
Winter1	W1	January 16, 2002	March 31,2002
Fawning	F	April 1, 2002	May 31, 2002
Nursing	N	June 1, 2002	July 31, 2002
Rutting	R	August 1, 2002	September 30, 2002
Winter2	W2	October 1, 2002	January 21, 2003

Subsequently, each GPCD was divided into seasonal databases based on animal physiology (Schuetze and Miller 1992). Since the study started in January 2002 and ended in January 2003, winter was delegated as two seasons, winter1 and winter2. Each season and its range of dates is shown in Table 4.

Home Ranges

An evaluation of home ranges for the three groups of pronghorn was preformed in ArcView using the Animal Movement (Hooge 1999) extension for ArcView. Only 15 animals were used due to the lack of data for some seasons. If a season of an individual pronghorn contained significantly less data (< 50%) than the same season for other pronghorn, the data were not included. The minimum convex polygon (MCP) and kernel estimators (95% and 50%) were used to determine the area of each pronghorn's home range for each season. Shapefiles for MCP, 95% kernel estimator, and 50% kernel estimators were generated for each pronghorn's seasonal home ranges.

Movement

To analyze pronghorn movement, polylines from one GPS point to another were created for each pronghorn in ArcView using the Animal Movement (Hooge 1999) extension for ArcView. The lengths of the polylines were calculated and added to a database separate from the GPCD produced for the other parameters. The pronghorn were separated into their respective groups and analysis of seasonal movement as well as diurnal and nocturnal movement was conducted.

Statistics

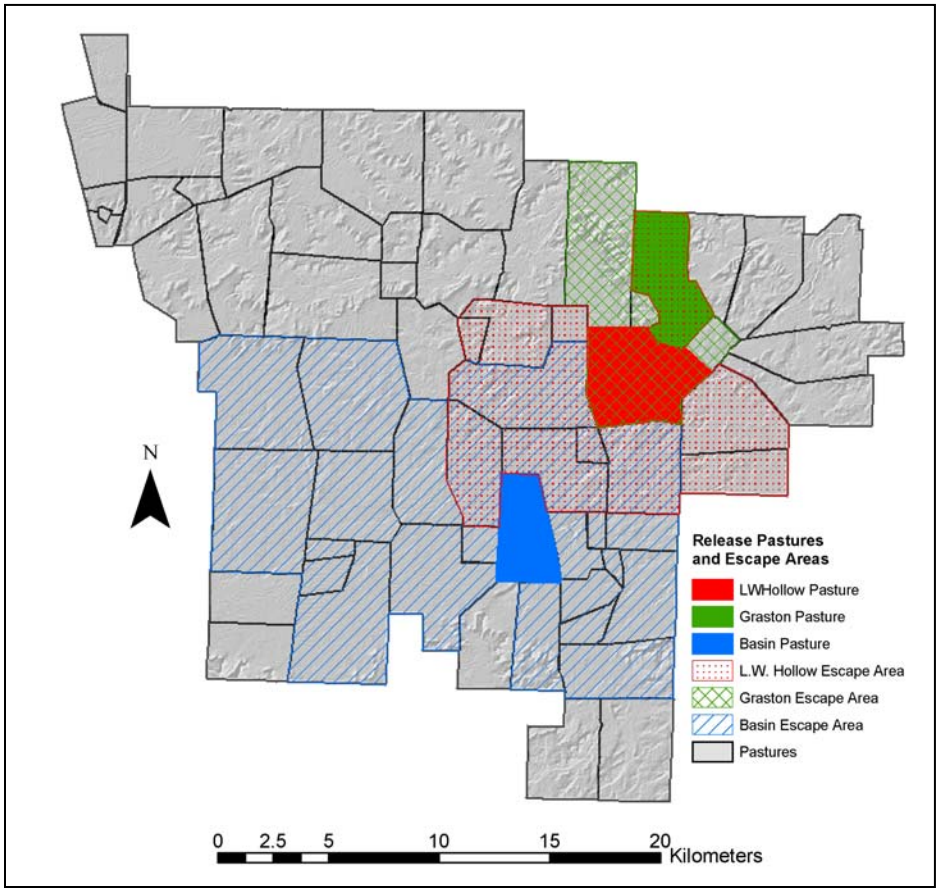
SPSS11.0 for Windows® statistical software (SPSS Inc., Chicago, IL, www.spss.com) was used for all statistical analyses, except for the chi-Square difference test, for which Microsoft® Excel database software (Microsoft Corporation, Redmond, WA, www.microsoft.com) was utilized. Table 5 lists information on each habitat parameter, whether the variable is continuous or categorical, tests used to determine if there is selection or avoidance of a particular parameter, and tests used to compare the release pasture data with the escape data.

Table 5. Statistics used for various analyses of habitat and movement of pronghorn on the Rocker b Ranch.

Parameter	Data	Selection or Avoidance	Comparisons
Vegetation	Categorical	chi-square	chi-square
Elevation	Continuous	Mann-Whitney	Mann-Whitney
Slope	Continuous	Mann-Whitney	Mann-Whitney
Aspect	Categorical	chi-square	chi-square
Soil	Categorical	chi-square	chi-square
Water	Continuous	Mann-Whitney	Mann-Whitney
Roads	Continuous	Mann-Whitney	Mann-Whitney
Oil Pumps	Continuous	Mann-Whitney	Mann-Whitney
Fences	Categorical	chi-square	n/a
Home Ranges	Continuous	n/a	ANOVA
Movement	Continuous	n/a	Mann-Whitney

Pronghorn investigated in this study did not utilize the entire Rocker b Ranch, as stated in the Study Animals section. Several shapefiles were created for the purpose of using habitat data only for those areas that pronghorn utilized. Two shapefiles were created for each pasture group: one for the pasture itself to encompass the restricted habitat, hereon referred to as the release pasture (RP); and the other for the habitat utilized by the pronghorns when they escaped from their release pastures, hereon referred to as the escape pasture (EP) (Figure 3).

Figure 3. Boundaries of release pastures and escape areas for pronghorn released on the Rocker b Ranch. Corresponding escape and release areas are color-coded with similar colors. Black lines indicate fences.



Random points were then generated in each pasture area, including release pastures and escape areas, and the resulting habitat parameter data were added to the database similar to the method used for the GPCD. This produced frequencies for each parameter for the whole that were later used in Mann-Whitney and chi-square analyses as the expected frequencies.

For each habitat parameter, a test for normality was performed initially to determine if parametric or nonparametric statistical analyses could be used. Subsequent to this, the following statistical tests were conducted for each pronghorn group (Basin, Graston, and L.W. Hollow).

RESULTS

Image Classification and Vegetation Types

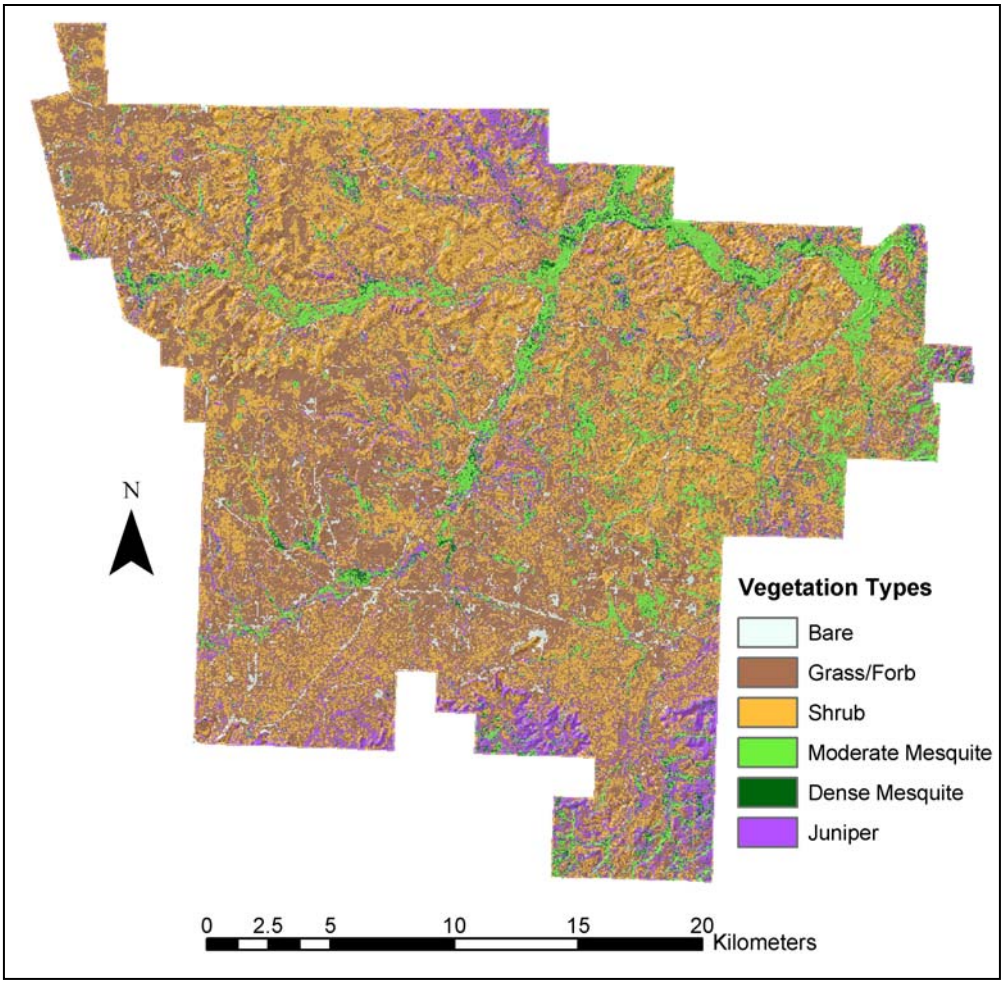
Extensive analysis of vegetation types that could be resolved from satellite imagery resulted in six vegetation/landform types on the Rocker b Ranch that could be classed on a reliable basis. These included bare rock or soil (with seasonal forb growth), grassland/forb, shrubland, moderate mesquite, dense mesquite, and juniper. Overall accuracy for the classification was 85.29%, with a lower limit of 85% being considered as acceptable (Jensen 2000). Errors of omission (producer's accuracy) and errors of commission (user's accuracy) for classification of the 2002 Landsat-7 ETM+ image are shown in Table 6, and a graphic representation of the vegetation classification for the ranch is in Figure 4.

Table 6. Accuracy assessment for satellite imagery classification of vegetation on the Rocker b Ranch.

Vegetation Type	Producer's Accuracy	User's Accuracy
Bare	84.62%	78.57%
Grassland/Forb	92.86%	98.48%
Shrubland	87.72%	84.75%
Moderate Mesquite	73.91%	80.95%
Dense Mesquite	75.00%	65.22%
Juniper	76.19%	76.19%

From the classification using Landsat 7 imagery, the most widespread vegetation type on the ranch was grassland/forb, comprising 41.84% of the land cover, while shrubland was the second most common vegetation type, with 34.49% (Table 7). The greatest deviations from this composition found in

Figure 4. Vegetation classification of Rocker b Ranch using Landsat-7 satellite imagery.



the release pastures (RPs) and escape areas (EAs) (Table 8) were in the Basin pasture. There were almost three times more bare areas and approximately 20% more grassland/forb vegetation types within the Basin RP compared to the ranch as a whole (Table 8). Both regions of the Graston and L.W. Hollow Areas contained more shrubland and moderate mesquite and less of the other vegetation types than the composition found on the entire ranch (Table 8).

Table 7. Overall vegetation types and percent occurrence resolved for the Rocker b Ranch from Landsat-7 satellite image.

Vegetation Type	Percent of type
Bare	2.34%
Grassland/forb	41.84%
Shrubland	34.49%
Moderate Mesquite	9.69%
Dense Mesquite	2.64%
Juniper	9.00%

Table 8. Vegetation types and percent occurrence resolved for release pastures and escape areas for Basin, Graston and L.W. Hollow areas.

Regions		Bare	Forb/ Grass	Shrub land	Moderate Mesquite	Dense Mesquite	Juniper
Release Pasture	Basin	6.64%	60.64%	25.80%	3.40%	0.80%	2.82%
	Graston	0.53%	25.32%	45.57%	17.84%	4.07%	6.67%
	L.W. Hollow	0.93%	36.61%	45.67%	13.89%	1.41%	1.49%
Escape Area	Basin	3.04%	49.45%	29.64%	6.91%	1.89%	9.07%
	Graston	1.30%	36.67%	39.13%	14.30%	2.79%	5.81%
	L.W. Hollow	1.21%	34.70%	39.41%	14.97%	3.19%	6.52%

Vegetation and Habitat Selection

In the Basin RP, pronghorn selected for bare areas and moderate mesquite for three out of the five seasons, and avoided shrubland (Table 9). Pronghorn strongly selected for bare areas in the Basin RP in all seasons except the first winter and avoided juniper in all but the rutting season. For both the Graston RP and EA, pronghorn strongly selected for shrubland (Table 10).

There was avoidance of moderate mesquite, dense mesquite and juniper in the Graston RP, but avoidance of moderate mesquite in the EA during the first winter, nursing, and rutting seasons. Pronghorn in the L.W. Hollow RP selected for shrubland, except in the nursing season, and avoided moderate mesquite in all but the nursing season, in which the vegetation type was selected for (Table 11). In the L.W. Hollow EA, pronghorn selected for shrubland in both winter and rutting seasons, avoided moderate mesquite during fawning, rutting, and second winter, and avoided juniper every season.

Table 9. Pronghorn vegetation type selection using chi-square analysis for the Basin area of Rocker b Ranch.[1]

Vegetation type	Basin Release Pasture					Basin Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
B	+	+	ns	+++	+	ns	+++	+++	+++	+++
FG	ns	ns	ns	-	ns	ns	+	+++	ns	ns
S	ns	--	--	--	-	ns	ns	--	ns	ns
MM	+	ns	+	+++	+++	ns	--	ns	ns	ns
DM	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
J	ns	ns	ns	ns	ns	--	-	-	ns	---

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 10. Pronghorn vegetation type selection using chi-square analysis for the Graston area of Rocker b Ranch.[1]

Vegetation type	Graston Release Pasture					Graston Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
B	ns	ns	ns	ns	ns	+++	ns	ns	ns	ns
FG	ns	ns	ns	ns	ns	--	ns	ns	ns	ns
S	+++	+++	+++	+++	+++	+++	+++	++	+++	ns
MM	--	--	---	---	---	--	ns	-	--	ns
DM	---	ns	--	-	---	ns	ns	ns	ns	ns
J	---	ns	---	--	---	ns	ns	ns	-	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 11. Pronghorn vegetation type selection using chi-square analysis for the L.W. Hollow area of Rocker b Ranch.[1]

Vegetation type	L.W. Hollow Release Pasture					L.W. Hollow Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
B	ns	ns	ns	ns	ns	ns	ns	ns	+	ns
FG	--	ns	ns	ns	--	ns	++	ns	-	ns
S	+++	++	ns	+++	+++	++	ns	ns	+++	+++
MM	---	---	++	-	--	ns	--	ns	---	---
DM	ns	ns	ns	ns	ns	ns	ns	ns	ns	--
J	ns	ns	ns	ns	ns	--	--	--	-	---

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

A comparison of vegetation chosen in the Basin RP and EA (Table 12) shows that, while there were significant differences, no trends were followed. For the Graston area (Table 13), pronghorn in the RP selected shrubland significantly more during the nursing, rutting and second winter seasons than in the Graston EA. Similar to the Basin Area, the comparison of vegetation selected for in the L.W. Hollow RP and EA (Table 14) shows that there were some significant differences, although no trends were followed.

Table 12. Mann-Whitney comparison of vegetation type selection between the Basin release pasture (RP) and escape area (EA) of the Rocker b Ranch.[1]

Vegetation type	Basin				
	W1	F	N	R	W2
B	R	ns	ns	ns	ns
FG	ns	ns	ns	ns	ns
S	E*	ns	ns	E	ns
MM	ns	ns	ns	ns	R
DM	ns	ns	ns	ns	ns
J	ns	E	ns	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 13. Mann-Whitney comparison of vegetation type selection between the Graston release pasture and escape area of the Rocker b Ranch.[1]

Vegetation type	Graston				
	W1	F	N	R	W2
B	ns	ns	ns	ns	ns
FG	ns	R	ns	E	ns
S	ns	ns	R**	R*	R
MM	ns	ns	ns	ns	E**
DM	ns	ns	ns	ns	ns
J	ns	ns	E*	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 14. Mann-Whitney comparison of vegetation type selection between the L.W. Hollow release pasture and escape area of the Rocker b Ranch.[1]

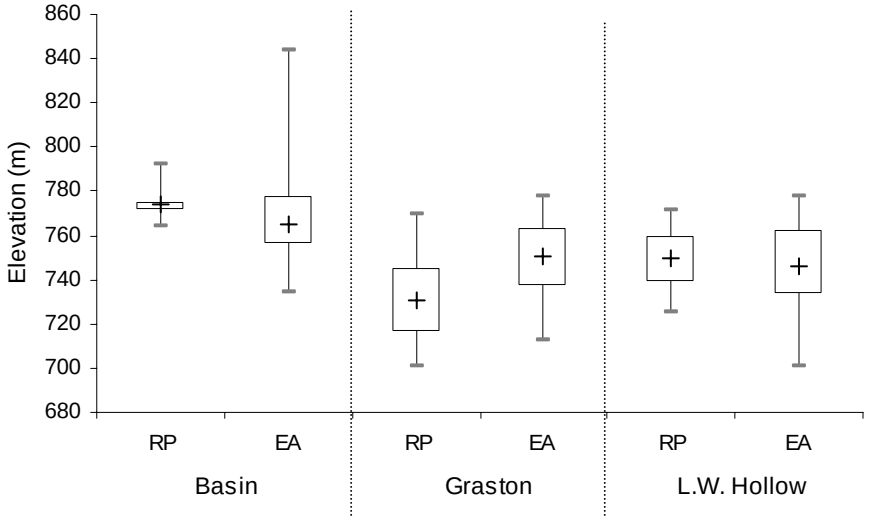
Vegetation type	L.W. Hollow				
	W1	F	N	R	W2
B	ns	ns	ns	ns	ns
FG	ns	ns	E	ns	ns
S	R*	ns	ns	ns	ns
MM	ns	ns	R	ns	ns
DM	ns	ns	ns	ns	ns
J	ns	ns	ns	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Elevation and Habitat Selection

Elevations on the Rocker b Ranch range from 695 to 846 m above mean sea level. Generally, the highest elevations occur on the northwest and southeast portions of the ranch, although no collared pronghorn ranged in these areas. The central portion of the ranch is lower and less undulating. The median elevations for all regions varied from 731 m in the Graston RP to 774 m in the Basin RP (Figure 5). For the regions utilized by pronghorn, the smallest range of elevation was found in the Basin RP, in which, only 28 m separated the minimum from the maximum elevations (Figure 5). Other RP's and EA's had ranges in elevation two or three times this amount (Figure 5).

Figure 5. Five-number summary of elevations for release pastures and escape areas utilized by pronghorn on the Rocker b Ranch.



When the RPs and EAs were examined for the Basin, Graston or L.W. Hollow areas, elevations selected for by pronghorn on Rocker b Ranch were fairly consistent from season to season. Pronghorn in the Basin RP chose elevations with medians ranging from 771 to 774 m, while pronghorn in the EA selected a wider variation of elevations with lower medians of 760 to 766 m (Figure 6). The opposite occurred in the Graston area, in which pronghorn chose for higher elevations in the Graston EA than the RP, medians from 743 to 751 m and 760 to 772 m, respectively (Figure 7). Elevations chosen in the L.W. Hollow area remained constant in both regions and neither deviated much from the mid-700's (Figure 8).

Figure 6. Five-number summary of elevations (in meters) selected for by pronghorn in the Basin release pasture (RP) and escape area (EA) on the Rocker b Ranch.

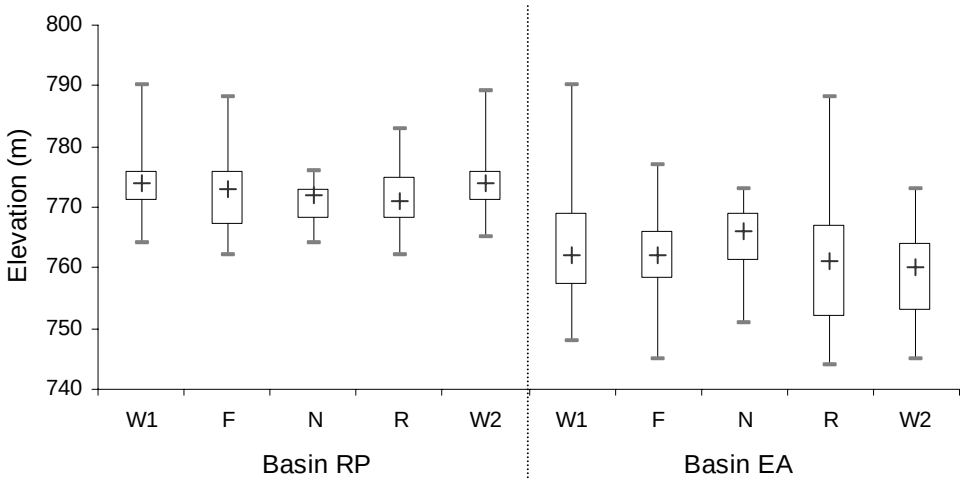


Figure 7. Five-number summary of elevations (in meters) selected for by Pronghorn in the Graston release pasture (RP) and escape area (EA) on the Rocker b Ranch.

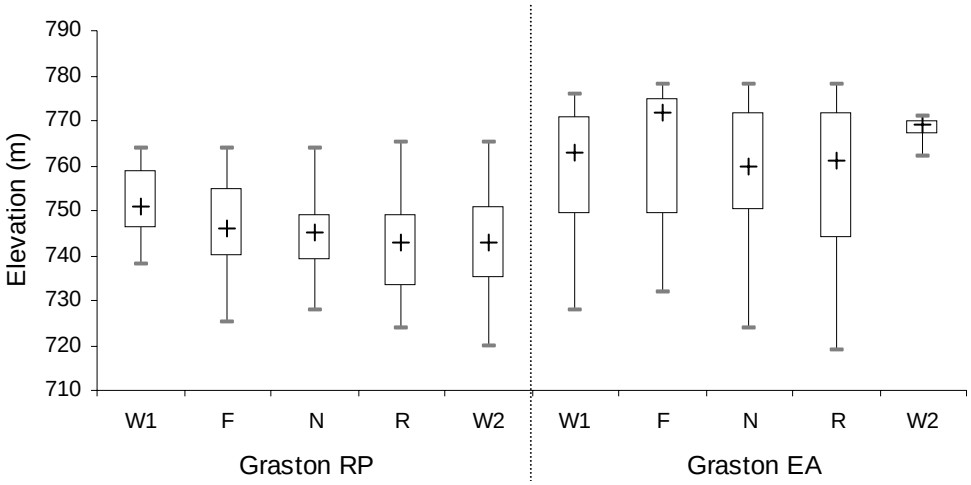
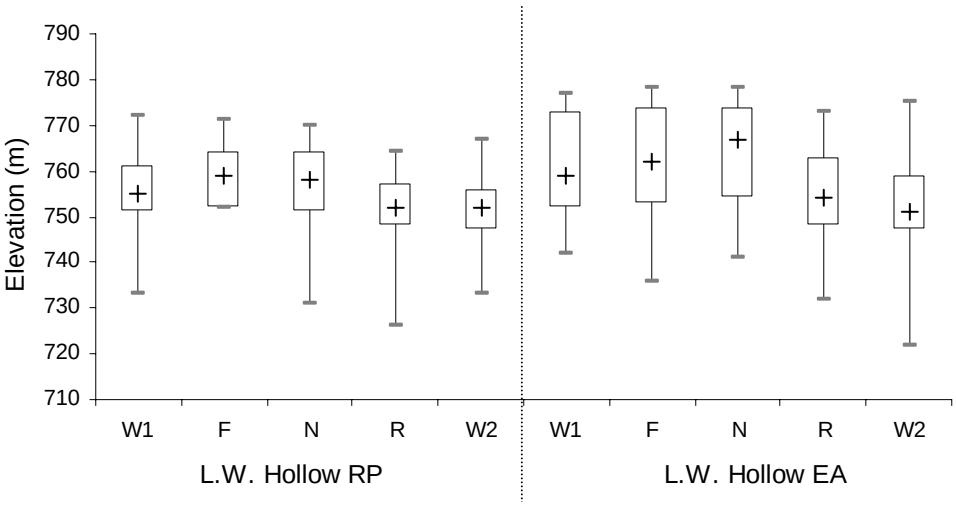


Figure 8. Five-number summary of elevations (in meters) selected for by pronghorn in the L.W. Hollow release pasture (RP) and escape area (EA) on the Rocker b Ranch.



To determine if the seasons were significantly different from one another in each area, Tukey's nonparametric multiple comparison test (α=0.05) was utilized to separate elevations for each of the five seasons into statistically different groups for each region (Table 15). In the Basin RP, pronghorn selected for higher elevations in the fawning and both winter seasons compared to rutting and nursing seasons (Table 15). Pronghorn in the Basin EA selected higher elevations in the nursing season, compared to all other seasons (Table 15). In the Graston RP, significantly higher elevations were chosen in the first winter (Table 15) and no seasons were significantly different in the Graston EA (Table 15). Pronghorn in the L.W. Hollow EA selected for higher elevations in the nursing season than in the first winter, rutting, and second winter seasons (Table 15). In the L.W. Hollow RP, pronghorn selected lower elevations in the second winter and rutting seasons (Table 15).

Table 15. Tukey's multiple comparison test on ranked elevations for the Basin, Graston, and L.W. Hollow areas. Seasons are arranged in descending order.

Region		Relationship
Basin	RP	W2 W1 F R N
	EA	N W1 F R W2
Graston	RP	W1 F N W2 R
	EA	W2 F R N W1
L.W. Hollow	RP	N F W1 R W2
	EA	N F W1 R W2

Pronghorn selected elevations in the Basin RP that were not significantly different compared to random points (Table 16). In the Basin EA, pronghorn actively selected for lower elevations in all seasons except nursing (Table 16). Pronghorn in the Graston area chose greater elevations in both regions for the whole year. Greater elevations were also chosen in both regions of the L.W. Hollow area, excluding the rutting season in the RP (Table 16).

When the EA and the RP where compared in each area, pronghorn in the Basin RP selected for significantly greater elevations than when they escaped for every season (Table 17). The opposite occurred in the Graston area, as

Table 16. Mann-Whitney analysis of elevations (in meters) selected for by pronghorn in the three release pastures (RP) and escape areas (EA) on the Rocker b Ranch compared to random points. [1]

Regions		Season				
		W1	F	N	R	W2
Basin	RP	ns	ns	ns	ns	ns
	EA	L	L**	ns	L**	L**
Graston	RP	G**	G**	G**	G**	G**
	EA	G**	G**	G**	G**	G*
L.W. Hollow	RP	G**	G**	G**	ns	G**
	EA	G**	G**	G**	G**	G*

[1] "ns" = not significant, "L" = lower ($P < 0.05$), "L*" = lower ($P < 0.01$), "L**" = lower ($P < 0.001$), "G" = greater ($P < 0.05$), "G*" = greater ($P < 0.01$), "G**" = greater ($P < 0.001$).

pronghorn in the EA chose significantly greater elevations compared to the RP (Table 17). In the L.W. Hollow area, greater elevations were selected for in the RP in every season but the second winter (Table 17).

Table 17. Mann-Whitney comparison of elevations (in meters) selected between the release pastures and escape areas of the Rocker b Ranch. [1]

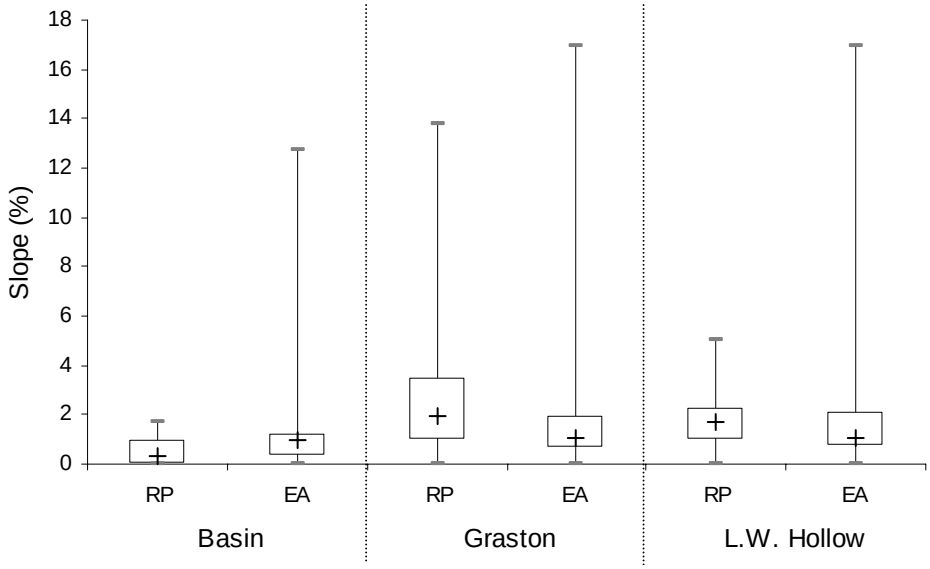
Elevation	Season				
	W1	F	N	R	W2
Basin	R**	R**	R**	R**	R**
Graston	E**	E*	E**	E**	E**
L.W. Hollow	E**	E**	E**	E	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Slope and Habitat Selection

Slope on the Rocker b Ranch ranges from 0 to 25.3%, although greatest slopes are generally found in the northwest and southeast, corresponding to the higher elevations. Medians for the Basin, Graston and L.W. Hollow areas vary from 0.34 to 1.91% (Figure 9). Compared to other regions, the Basin RP had the least amount of slope, with the least amount of variation as well (Figure 9). Higher slopes occur in the Basin EA and the Graston and L.W. Hollow areas.

Figure 9. Five-number summary of slopes (%) for release pastures and escape areas utilized by Pronghorn on the Rocker b Ranch.



Slopes chosen by pronghorn on the Rocker b Ranch were lowest in the Basin RP and EA (Figure 10), with medians ranging from 0 to 1.07%. Median slopes chosen in the Graston and L.W. Hollow regions were over two or three times greater than these amounts, from 1.20 to 3.65% and 1.26 to 2.65%, respectively (Figures 11 & 12). In the Graston and L.W. Hollow areas, escaped pronghorn selected maximum slopes much greater than while in the RP's, though none chose slopes over 12% (Figures 11 & 12).

Figure 10. Five-number summary of slopes (%) selected for by pronghorn in the Basin release pasture and escape area on the Rocker b Ranch.

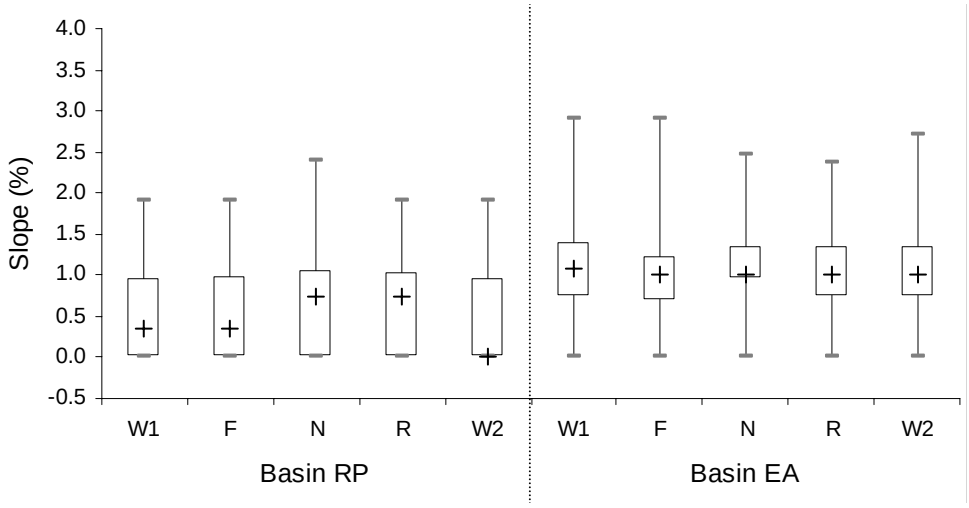


Figure 11. Five-number summary of slopes (%) selected for by pronghorn in the Graston release pasture and escape area on the Rocker b Ranch.

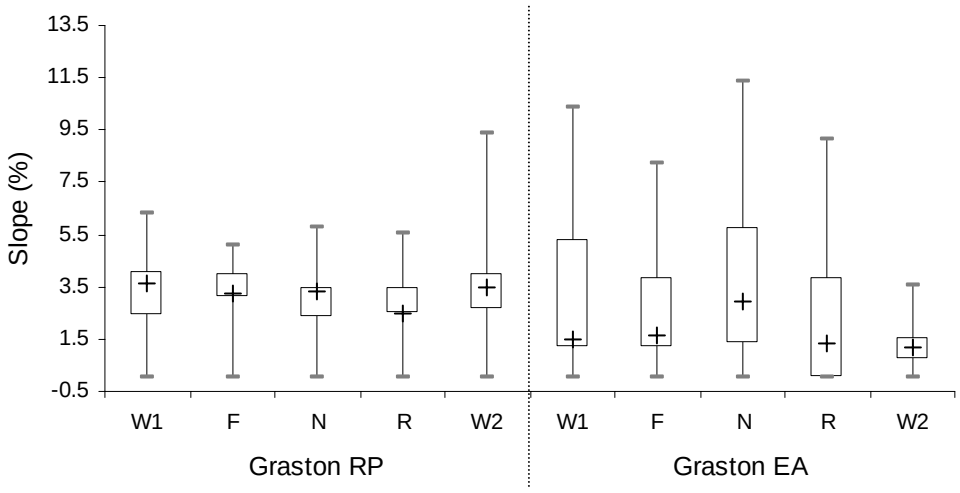
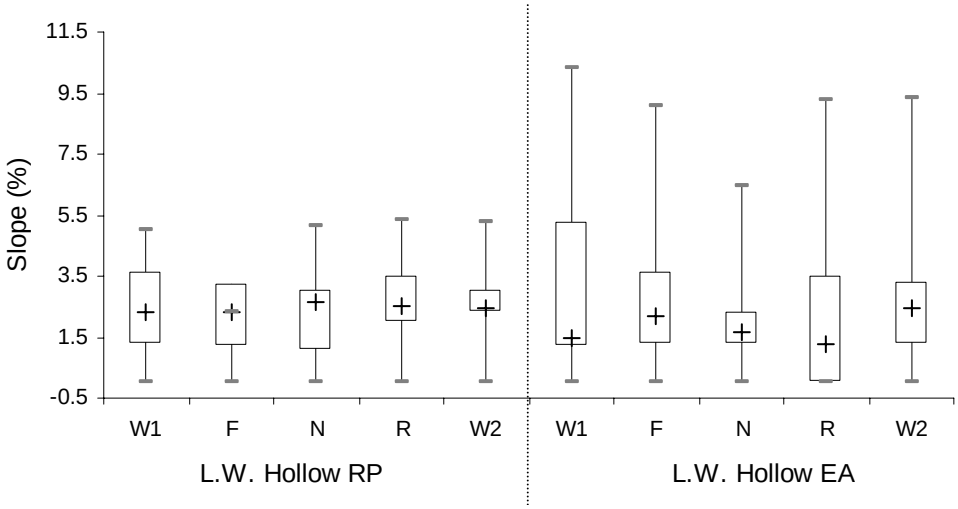


Figure 12. Five-number summary of slopes (%) selected for by pronghorn in the L.W. Hollow release pasture and escape area on the Rocker b Ranch.



Tukey's nonparametric multiple comparison test (α=0.05) was utilized to separate elevations for each of the five seasons into statistically different groups for each region (Table 18). In the Basin RP, pronghorn selected for greater slope in the rutting, nursing and fawning seasons, while selection in the Basin EA was not significantly different between seasons (Table 18). Pronghorn in the Graston RP chose greater slope in the first winter compared to the rutting season and in the Graston EA, pronghorn chose greater slope in the first winter than the second (Table 18). In the L.W. Hollow RP, the rutting and second winter seasons contained greater slope selection than the other seasons (Table 18). The L.W. Hollow EA was divided into three different groups, with greater selection of slope found in the second winter and rutting compared to the other seasons (Table 18).

Table 18. Tukey's multiple comparison test on ranked slopes for the Basin, Graston, and L.W. Hollow areas. Seasons are arranged in descending order.

Region		Relationship
Basin	RP	R N F W1 W2
	EA	W1 N W2 R N
Graston	RP	W1 F W2 N R
	EA	W1 N F R W2
L.W. Hollow	RP	R W2 W1 F N
	EA	W2 R W1 F N

Slopes chosen by pronghorn in the Basin RP did not differ significantly from random for any season, but pronghorn in the Basin EA selected greater slopes in both winter seasons and the nursing season (Table 19). Conversely, pronghorn in the Graston area selected for greater slopes in the RP (Table 19). Pronghorn in the Basin area consistently selected for greater slopes in the RP with strong significance from season to season compared to the EA (Table 20). Conversely, pronghorn in the Graston area chose greater slopes in the EA's, although more erratically throughout the year than the pronghorn in the Basin area (Table 20).

Table 19. Mann-Whitney analysis of slopes (%) selected for by pronghorn in the three release pastures (RP) and escape areas (EA) on the Rocker b Ranch compared to random points. [1]

Regions		Season				
		W1	F	N	R	W2
Basin	RP	ns	ns	ns	ns	ns
	EA	G	ns	G	ns	G
Graston	RP	G	G	G	ns	G
	EA	ns	ns	G	ns	ns
L.W. Hollow	RP	ns	ns	ns	ns	ns
	EA	ns	ns	ns	ns	G

[1] "ns" = not significant, "L" = lower ($P < 0.05$), "L*" = lower ($P < 0.01$), "L**" = lower ($P < 0.001$), "G" = greater ($P < 0.05$), "G*" = greater ($P < 0.01$), "G**" = greater ($P < 0.001$).

Table 20. Mann-Whitney comparison of slopes (%) selected for by pronghorn in the release pastures and escape areas of the Rocker b Ranch. [1]

Region	Season				
	W1	F	N	R	W2
Basin	E**	E**	E**	E**	E**
Graston	ns	R**	ns	R**	R
L.W. Hollow	ns	E**	E**	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Aspect and Habitat Selection

Aspect on the Rocker b Ranch varies a great deal from region to region. In the Basin RP there are considerably more flat areas, although percentage of aspects found in the Basin EA and regions in the Graston and L.W. Hollow areas have more equal distributions across all exposures (Table 21).

Table 21. Aspect and percent occurrence for release pastures and escape areas for Basin, Graston and L.W. Hollow areas.

Regions		E	Flat	N	NE	NW	S	SE	SW	W
Release Pasture	Basin	13.0%	43.4%	7.2%	11.0%	11.0%	4.0%	4.4%	3.4%	2.6%
	Graston	9.9%	7.1%	13.6%	14.3%	11.9%	13.6%	11.9%	10.6%	7.1%
	L.W. Hollow	17.4%	10.3%	3.8%	15.0%	3.8%	15.0%	18.3%	9.4%	7.0%
Escape Area	Basin	10.9%	22.3%	10.0%	11.4%	11.2%	8.0%	10.5%	9.5%	6.2%
	Graston	12.0%	15.2%	8.3%	12.7%	11.2%	8.7%	12.4%	10.6%	8.9%
	L.W. Hollow	10.8%	14.2%	10.0%	12.7%	12.4%	8.8%	11.5%	10.8%	8.8%

In the Basin RP, pronghorn selected for eastern aspects in only the first winter and rutting seasons, and selected for southwestern exposures in all other seasons (Table 22). They also avoided flat aspects for the nursing and rutting season (Table22). In the Basin EA, pronghorn avoided flat aspects and selected for southwestern in all seasons except for the first winter (Table 22). Pronghorn in the Graston RP exhibited more selection and avoidance of exposures throughout the year compared to pronghorn in the EA. Graston RP pronghorn avoided flat and southwestern aspect and chose for north exposures in all

seasons except for the first winter and fawning (Table 23). Additionally, pronghorn in the Graston RP chose for southeastern aspects for all seasons but the first winter (Table 23). In the L.W. Hollow RP, pronghorn selected for western aspects in the nursing and both winter seasons (Table 24). There was an avoidance of eastern aspects in all except the rutting season and avoidance of flat aspect for the whole year (Table 24). In the L.W. Hollow EA, pronghorn selected for eastern aspects in all but the nursing season (Table 24).

Table 22. Pronghorn aspect selection using chi-square analysis for the Basin area of Rocker b Ranch.[1]

Aspect	Basin Release Pasture					Basin Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
E	++	ns	ns	+	ns	ns	ns	ns	-	ns
F	ns	ns	-	---	+	ns	---	---	--	-
N	ns	ns	ns	ns	ns	ns	ns	++	++	ns
NE	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
NW	ns	ns	ns	ns	ns	ns	ns	-	ns	ns
S	-	ns	ns	ns	ns	ns	ns	ns	-	ns
SE	ns	ns	ns	+++	ns	+	ns	ns	ns	--
SW	ns	+	+++	++	ns	ns	+	+++	+++	+++
W	ns	ns	ns	ns	ns	+	ns	+	ns	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 23. Pronghorn aspect selection using chi-square analysis for the Graston area of Rocker b Ranch.[1]

Aspect	Graston Release Pasture					Graston Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
E	ns	ns	ns	ns	-	ns	ns	ns	ns	ns
F	ns	ns	-	-	---	ns	ns	ns	ns	ns
N	ns	ns	++	+++	+++	ns	ns	ns	ns	ns
NE	ns	-	ns	ns	ns	-	ns	-	++	ns
NW	ns	ns	ns	-	ns	ns	ns	+	-	ns
S	ns	ns	ns	--	---	ns	+++	ns	ns	ns
SE	ns	+++	+++	+++	+	++	ns	ns	ns	ns
SW	ns	ns	--	---	---	ns	ns	ns	-	ns
W	ns	ns	ns	++	ns	ns	ns	++	ns	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 24. Pronghorn aspect selection using chi-square analysis for the L.W. Hollow area of Rocker b Ranch.[1]

Aspect	L.W. Hollow Release Pasture					L.W. Hollow Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
E	---	-	---	ns	-	++	+	ns	++	+++
F	---	--	--	--	---	ns	ns	ns	---	---
N	ns	ns	ns	ns	ns	ns	ns	ns	ns	+
NE	ns	-	ns	+++	ns	ns	ns	ns	ns	+++
NW	ns	+++	+++	ns	+	--	-	ns	ns	ns
S	ns	ns	ns	-	ns	ns	ns	ns	ns	ns
SE	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SW	++	ns	++	ns	ns	ns	ns	ns	ns	--
W	+++	++	ns	ns	+++	ns	ns	ns	ns	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

In a comparison of the Basin RP and the Basin EA, there were significant differences in which aspects the pronghorn selected and avoided, with flat exposures consistently avoided more and southwestern aspects chosen more in the Basin EA (Table 25). For the Graston RP, flat regions were avoided more in all but the second winter and northern exposures were selected for in the fawning, nursing, and rutting seasons (Table 26). In the L.W. Hollow area, the differences in selection did exist between the RP and EA, but no clear trends were followed (Table 27).

Table 25. Mann-Whitney comparison of aspect selection between the Basin release pasture and escape area of the Rocker b Ranch. [1]

Aspect	Basin				
	W1	F	N	R	W2
E	ns	ns	ns	R**	R
F	R**	R**	R**	R**	R**
N	ns	ns	E**	E**	ns
NE	ns	ns	ns	ns	E
NW	ns	ns	R*	ns	ns
S	E	ns	ns	ns	E
SE	E**	ns	ns	ns	ns
SW	E**	E**	E**	R**	E**
W	E	ns	E	ns	E*

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 26. Mann-Whitney comparison of aspect selection between the Graston release pasture and escape area of the Rocker b Ranch. [1]

Aspect	Graston				
	W1	F	N	R	W2
E	ns	ns	ns	ns	ns
F	E	E	E**	E**	ns
N	ns	R*	R*	R**	ns
NE	R	ns	ns	ns	ns
NW	ns	ns	ns	ns	ns
S	ns	ns	ns	ns	ns
SE	ns	R*	R*	ns	ns
SW	ns	E	E*	ns	ns
W	ns	ns	ns	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 27. Mann-Whitney Comparison of aspect selection between the L.W. Hollow release pasture and escape area of the Rocker b Ranch. [1]

Aspect	L.W. Hollow				
	W1	F	N	R	W2
E	E*	ns	E*	ns	E
F	ns	E**	E**	ns	ns
N	E	ns	ns	ns	E*
NE	ns	ns	ns	R	ns
NW	ns	ns	R*	ns	ns
S	R*	R	ns	ns	R
SE	ns	ns	ns	ns	ns
SW	R*	ns	ns	ns	R
W	ns	ns	ns	ns	R*

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Soils and Habitat Selection

Soils found on the Rocker b Ranch consisted of the Rio Concho series (TX474), the Conger series (TX020), the Ector series (TX156 & TX159), the Angelo series (TX017), and the Tobosa series (TX 565) (Table 28). The Ector series comprised more than half of the soil on the ranch. In the regions utilized by pronghorn, the Angelo series (TX017) made up almost 95% of the soil in the Basin RP (Table 29). Ector gravely loam (TX156) was the major soil type in the other areas, comprising over 60% of the Graston RP and over 80% of the L.W. Hollow RP (Table 29).

Table 28. Soil Types on the Rocker b Ranch.

Series	Soil Type	Soil Texture	Percent of Ranch
Ector	TX156	Gravely Loam	45.80%
Conger	TX020	Loam	16.10%
Rio Concho	TX474	Silty Clay Loam	18.00%
Ector	TX159	Stony Loam	16.50%
Angelo	TX017	Silty Clay Loam	1.00%
Tobosa	TX565	Clay	2.60%

Table 29. Soil Types found in release pastures and escape areas of Rocker b Ranch (see Table 28 for definitions).

Regions		TX017	TX020	TX156	TX159	TX474	TX565
Release Pasture	Basin	0.70%	94.60%	4.70%	0.00%	0.00%	0.00%
	Graston	0.00%	1.10%	66.60%	0.00%	32.30%	0.00%
	L.W. Hollow	0.00%	12.00%	81.20%	0.00%	6.80%	0.00%
Escape Area	Basin	19.70%	25.70%	36.10%	6.90%	11.30%	0.30%
	Graston	0.00%	21.70%	61.00%	0.00%	17.30%	0.00%
	L.W. Hollow	0.00%	19.30%	59.40%	0.00%	21.30%	0.00%

Pronghorn selection of certain soil types was not always consistent from season to season. For example in the Basin RP, Angelo (TX017) was avoided for the first winter, fawning and winter seasons, but strongly selected for during the rutting season (Table 30). And in the Basin EA, Rio Concho (TX474) soil was avoided in all seasons (Table 30). Other patterns of selection and avoidance were observed in the Basin EA, with Angelo (TX017) avoided in all season except fawning, with Ector (TX0159) avoided in all seasons (Table 30). Pronghorn chose Conger (TX020) in all but the second winter season and Ector (TX156) in all but the fawning season (Table 30). Pronghorn in the Graston RP strongly selected for Conger (TX020) and Ector (TX156) while avoiding Rio Concho (TX474) (Table 31). The pattern was similar for the same for the EA, but Conger (TX020) and Ector (TX156) were selected for in fewer months and actually avoided in the second winter (Table 31). In the L.W. Hollow RP, pronghorn chose Ector (TX156) and avoided Rio Concho (TX474) (Table 32). In

the L.W. Hollow EA, Rio Concho (TX474) was also avoided and Conger (TX020) was selected for in the first winter, fawning and rutting seasons (Table 32).

Table 30. Pronghorn soil selection using chi-square analysis for the Basin area of Rocker b Ranch.[1]

Soil Type	Basin Release Pasture					Basin Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
TX017	-	ns	-	+++	--	---	ns	---	---	---
TX020	+	ns	ns	ns	++	+++	++	+++	+++	ns
TX156	ns	ns	+++	+	ns	++	ns	+++	+++	+
TX159	n/a	n/a	n/a	n/a	n/a	--	--	--	--	---
TX474	n/a	n/a	n/a	n/a	n/a	---	---	---	---	---
TX565	n/a	n/a	n/a	n/a	n/a	ns	ns	ns	ns	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 31. Pronghorn soil selection using chi-square analysis for the Graston area of Rocker b Ranch.[1]

Soil Type	Graston Release Pasture					Graston Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
TX020	+++	+++	+++	+++	+++	+++	+++	+++	ns	-
TX156	+++	+++	ns	+++	+++	ns	ns	ns	+++	+++
TX474	---	---	---	---	---	---	---	---	---	---

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Table 32. Pronghorn soil selection using chi-square analysis for the L.W. Hollow area of Rocker b Ranch.[1]

Soil Type	L.W. Hollow Release Pasture					L.W. Hollow Escape Area				
	W1	F	N	R	W2	W1	F	N	R	W2
TX020	+++	ns	ns	ns	ns	+++	+++	ns	+++	ns
TX156	+++	+++	+++	+++	+++	ns	--	ns	-	ns
TX474	---	---	---	---	---	--	---	--	--	ns

[1] "ns" = not significant, "+" = selected ($P < 0.05$), "++" = selected ($P < 0.01$), "+++" = selected ($P < 0.001$), "-" = avoided ($P < 0.05$), "--" = avoided ($P < 0.01$), "---" = avoided ($P < 0.001$).

Significant differences in selection of soil types between the Basin RP and EA occurred for Conger (TX020) and Ector (TX156) soil types for all seasons (Table 33). The same was true for the Graston area (Table 34), while the differences between the RP and EA in the L.W. Hollow area only occurred in the fawning and nursing season for the two soil types (Table 35).

Table 33. Mann-Whitney comparison of soil selection between the Basin release pasture and escape area of the Rocker b Ranch. [1]

Soil Type	Basin				
	W1	F	N	R	W2
TX017	ns	R**	ns	R**	ns
TX020	R**	E**	R**	R**	R**
TX156	E**	E*	E**	E**	E**
TX159	ns	ns	ns	ns	ns
TX474	ns	ns	ns	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 34. Mann-Whitney comparison of soil selection between the Graston release pasture and escape area of the Rocker b Ranch. [1]

Soil Type	Graston				
	W1	F	N	R	W2
TX020	E**	E**	E**	E**	E
TX156	R**	R**	R**	R**	R
TX474	ns	ns	ns	E	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Table 35. Mann-Whitney comparison of soil selection between the L.W. Hollow release pasture and escape area of the Rocker b Ranch. [1]

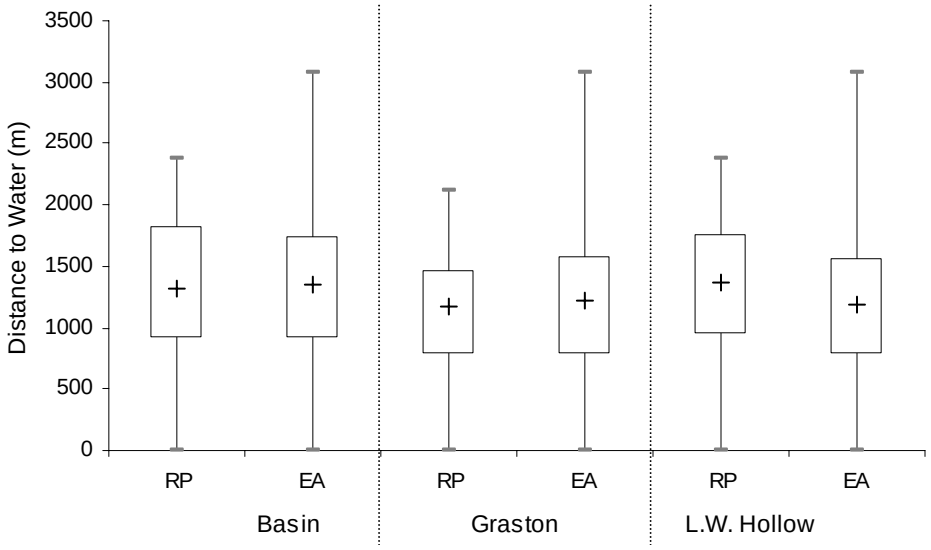
	L.W. Hollow				
Soil Type	W1	F	N	R	W2
TX020	ns	E**	E**	ns	ns
TX156	ns	R**	R**	ns	ns
TX474	ns	ns	ns	ns	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Water and Habitat Selection

In the Basin area, only one water well was within the RP boundary, while there were 28 in the EA. The Graston RP and EA each contained two water wells. Five water wells were within the L.W. Hollow RP and the EA included 15. Random points generated in each region of the Basin, Graston and L.W. Hollow areas of Rocker b Ranch indicated that the distance to water wells was fairly consistent, with the medians ranging from 1169 to 1373 meters (Figure 13). In addition, for each random point, the distance from a water source did not exceed 3100 m in any EA or 2400 m in any RP (Figure 13).

Figure 13. Five-number summary of water well distances in relation to random points for release pastures and escape areas utilized by pronghorn on the Rocker b Ranch.



Most of the median water well distances selected for by pronghorn in each region were slightly above the above medians. Median distances in the Basin area ranged from 1160 to 1550 m, with the lowest occurring noticeably in the nursing season in the Basin EA (Figure 143). In the Graston area, the medians varied from 940 to 1623 m and were not as consistent from season to season as in the Basin area (Figure 15). Also, the variance in distances to water was much greater in the Graston EA compared to the RP (Figure 15). Median distances in the L.W. RP were notably greater than in the EA, ranging from 1330 to 1490 m and 980 to 1190 m, respectively (Figure 16).

Figure 14. Five-number summary of water well distances selected for by pronghorn in the Basin release pasture and escape area on the Rocker b Ranch.

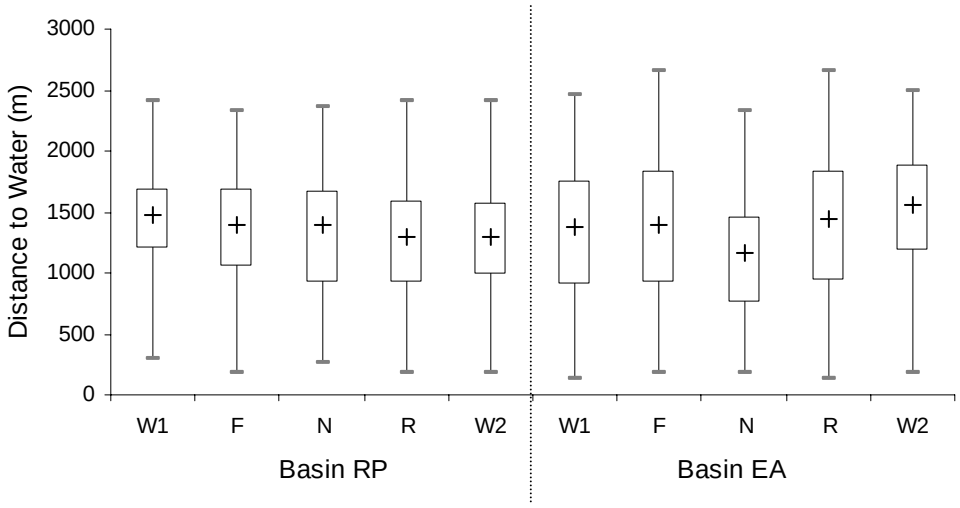


Figure 15. Five-number summary of water well distances selected for by pronghorn in the Graston release pasture and escape area on the Rocker b Ranch.

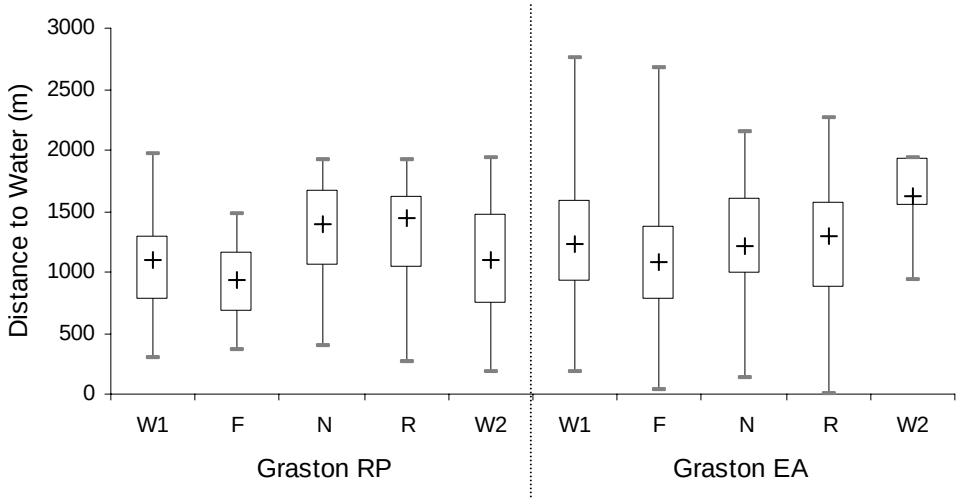
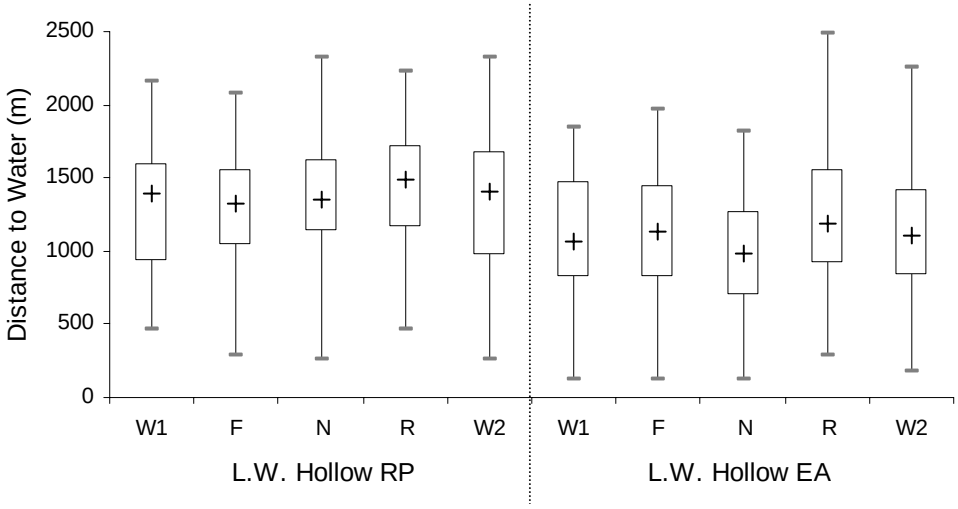


Figure 16. Five-number summary of water well distances selected for by pronghorn in the L.W. Hollow release pasture and escape area on the Rocker b Ranch.



Tukey's nonparametric multiple comparison test (α=0.05) was utilized to separate distances for each of the five seasons into statistically different groups for each region (Table 36). In the Basin RP, pronghorn selected for greater distances to water in the first winter compared to second winter and rutting seasons (Table 36). The nursing season contained significantly shorter distances compared to the other seasons in the Basin EA (Table 36). Pronghorn in the Graston RP selected greater distances in the rutting and nursing seasons as compared to the other seasons (Table 36). In the Graston EA, greater distances were chosen in the second winter season (Table 36). The L.W. Hollow RP contained greater distances to water during the rutting season compared to

the first winter and fawning season, while in the EA pronghorn in the nursing season selected for shorter distances (Table 36).

Table 36. Tukey's multiple comparison test on water well distances for the Basin, Graston, and L.W. Hollow areas. Seasons are arranged in descending order.

Region		Relationship
Basin	RP	W1 F N W2 R
	EA	W2 R F W1 N
Graston	RP	R N W2 W1 F
	EA	W2 W1 R N F
L.W. Hollow	RP	R N W2 W1 F
	EA	R W2 F W2 N

When compared to random points, distances to water well selected for by pronghorn did not differ significantly in the Basin RP, while distances were highly significantly greater in the EA for nursing and shorter in the second winter season (Table 37). Pronghorn chose shorter distances to water in the fawning season and greater distances in the second winter. Pronghorn in the Graston RP selected shorter distances to water for the fawning season and greater distances in the nursing and rutting seasons (Table 37). Active selection occurred place during the fawning season in the Graston EA, in which shorter distances were

chosen (Table 37). In the L.W. Hollow area, the EA pronghorn chose for shorter distances in the nursing season (Table 37).

In the Basin EA, pronghorn chose greater distances to water during the nursing season compared to the Basin RP (Table 38). During the second winter, however, significantly greater distances were chosen by pronghorn in the Basin RP. Pronghorn in the L.W. Hollow area selected for shorter distances in the EA for all seasons (Table 38).

Table 37. Mann-Whitney analysis of water well distances selected for by pronghorn in the three release pastures (RP) and escape areas (EA) on the Rocker b Ranch compared to random points. [1]

Regions		Season				
		W1	F	N	R	W2
Basin	RP	ns	ns	ns	ns	ns
	EA	ns	ns	L**	ns	G**
Graston	RP	ns	L**	G**	G**	ns
	EA	ns	L**	ns	ns	ns
L.W. Hollow	RP	ns	ns	ns	ns	ns
	EA	ns	ns	L**	ns	ns

[1] "ns" = not significant, "L" = lower ($P < 0.05$), "L*" = lower ($P < 0.01$), "L**" = lower ($P < 0.001$), "G" = greater ($P < 0.05$), "G*" = greater ($P < 0.01$), "G**" = greater ($P < 0.001$).

Table 38. Mann-Whitney comparison of distances to water selected between the release pastures and escape areas of the Rocker b Ranch. [1]

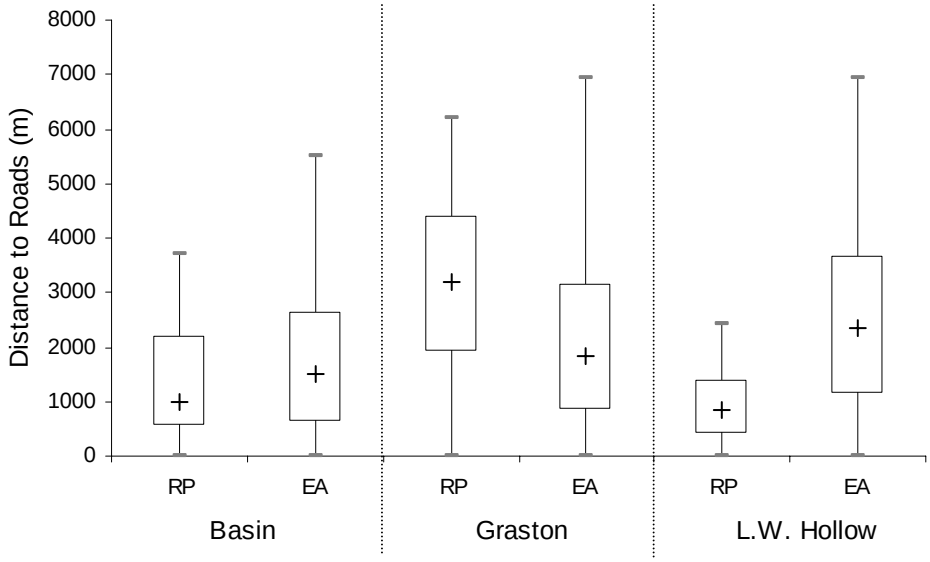
Water	Season				
	W1	F	N	R	W2
Basin	ns	ns	E**	ns	R**
Graston	ns	ns	ns	ns	E
L.W. Hollow	R**	R**	R**	R**	R**

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Roads and Habitat Selection

One major road runs east-west through the southern portion of the Basin RP, while this same road and another one running north-south traverses the EA. In the Graston area, one main road runs along the southwest pasture border of the RP and runs through the EA. A road running north-south crosses the L.W. Hollow RP and the EA. Random points generated in each region of the Basin, Graston and L.W. Hollow areas indicated that distances from roads varied quite widely, ranging from 838 to 3184 m (Figure 17). The greatest median distance, 3185 m, was found in the Graston RP and the lowest median, 840 m, was in the L.W. Hollow RP (Figure 17). No point was more than 7000 m from a road for all three areas (Figure 17).

Figure 17. Five-number summary of distances to roads for release pastures and escape areas utilized by pronghorn on the Rocker b Ranch.



Most of the median road distances selected for by pronghorn in the three areas varied widely, as well. Pronghorn in the Basin area selected median distances to water ranging from 470 to 1900 m (Figure 18) and pronghorn in the L.W. chose similar medians (Figure 20). In the Graston area, pronghorn chose for much higher distances than in the other two areas, ranging from 970 to 2300 m (Figure 19).

Figure 18. Five-number summary of distances to roads selected for by pronghorn in the Basin release pasture and escape area on the Rocker b Ranch.

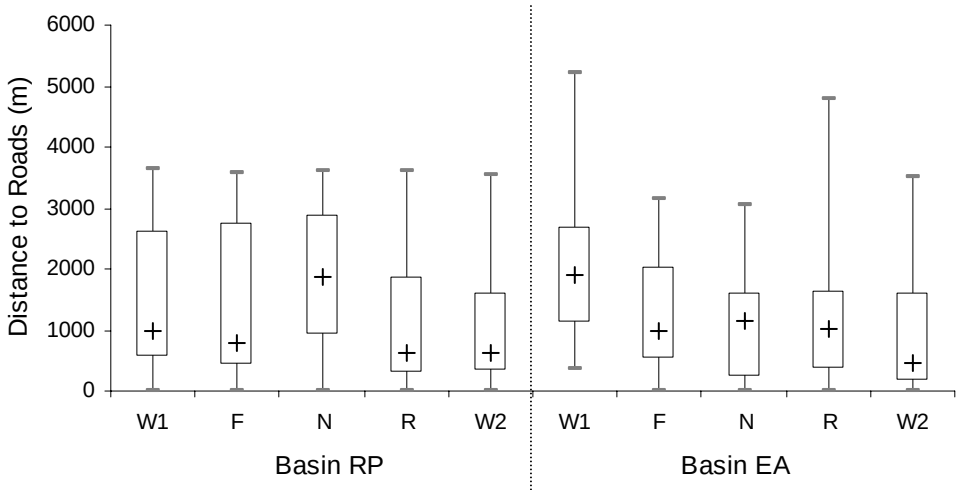


Figure 19. Five-number summary of distances to roads selected for by pronghorn in the Graston release pasture and escape area on the Rocker b Ranch.

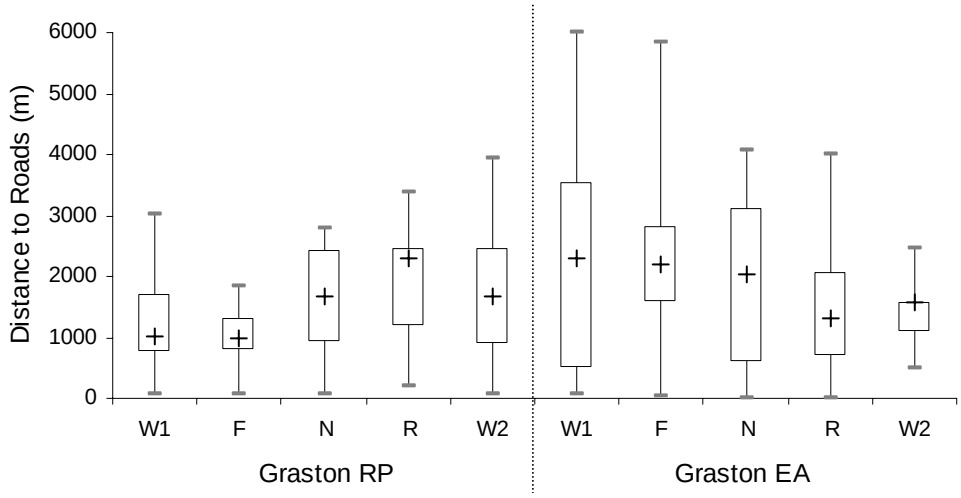
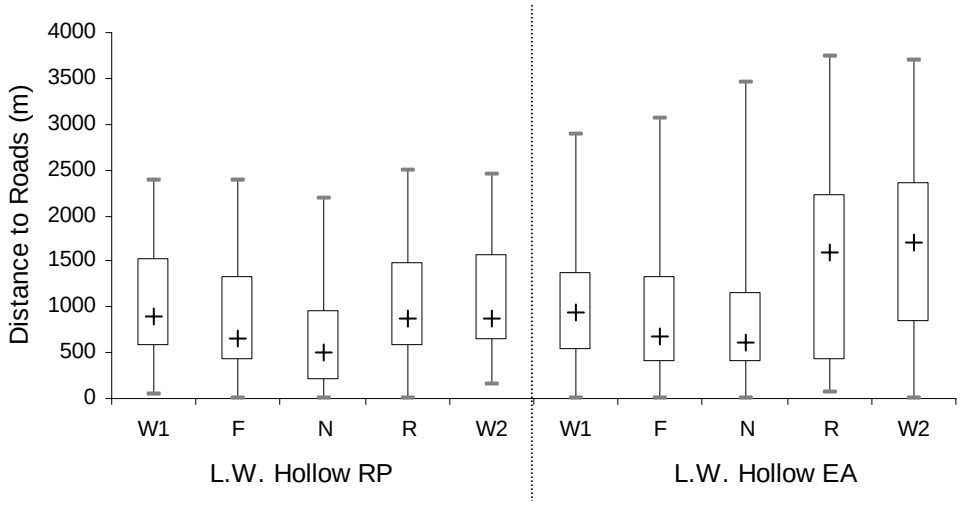


Figure 20. Five-number summary of distances to roads selected for by pronghorn in the L.W. Hollow release pasture and escape area on the Rocker b Ranch.



Tukey's nonparametric multiple comparison test (α=0.05) was utilized to separate distances for each of the five seasons into statistically different groups for each region (Table 39). In the Basin RP, pronghorn selected for greater distances to roads in the nursing season compared to second winter and rutting seasons (Table 39). The first winter season contained significantly greater distances compared to the other seasons in the Basin EA, while the second winter season had shorter distances than the fawning season (Table 39). Pronghorn in the Graston RP selected shorter distances in the first winter and fawning seasons as compared to the other seasons (Table 39). In the Graston EA, greater distances were chosen in the first winter season (Table 39). The L.W. Hollow RP contained shorter distances to water during the nursing season

and pronghorn in the EA selected for greater distances in the rutting and first winter seasons (Table 39).

Table 39. Tukey's multiple comparison test on ranked distances to roads for the Basin, Graston, and L.W. Hollow areas. Seasons are arranged in descending order.

Region		Relationship
Basin	RP	N W1 F R W2
	EA	W1 F N R W2
Graston	RP	R W2 N W1 F
	EA	W1 F N R W2
L.W. Hollow	RP	W2 W1 R F N
	EA	R W1 F W2 N

When compared to random points, most distances to roads selected for by pronghorn were significantly different in all regions of the Basin, Graston, and L.W. Hollow areas, indicating active selection of distances by the pronghorn. Pronghorn in the Basin RP selected shorter distances to roads in the second winter season (Table 40). Active selection also took place during all seasons in the Basin EA, with greater distances in the first winter and closer distances in the other seasons(Table 40). Pronghorn in the Graston RP selected distances to roads that were highly significantly closer for all seasons except rutting, while distances selected in the Graston EA was significantly less during the rutting

season (Table 40). In the L.W. Hollow area, pronghorn selected for shorter distances to roads most seasons (Table 40).

Pronghorn in the Basin EA selected for greater distances to roads during the first winter with strong significance (Table 41). However, in the second winter, the pronghorn the escaped from the Basin pasture chose shorter distance to roads in the EA (Table 41). In the Graston area, pronghorn selected distances much greater from roads in the EA in the first winter and fawning season, but shorter distances during the rutting season (Table 41). During the nursing, rutting and second winter seasons in the L.W. Hollow EA, pronghorn chose for greater distances from roads (Table 41).

Table 40. Mann-Whitney analysis of road distances selected for by pronghorn in the three release pastures (RP) and escape areas (EA) on the Rocker b Ranch compared to random points. [1]

Regions		Season				
		W1	F	N	R	W2
Basin	RP	ns	ns	G*	ns	L**
	EA	G*	L**	L**	L**	L**
Graston	RP	L**	L**	L**	ns	L**
	EA	ns	ns	ns	L	ns
L.W. Hollow	RP	ns	ns	L**	L**	L**
	EA	L**	L**	L**	L**	L**

[1] "ns" = not significant, "L" = less ($P < 0.05$), "L*" = less ($P < 0.01$), "L**" = less ($P < 0.001$), "G" = greater ($P < 0.05$), "G*" = greater ($P < 0.01$), "G**" = greater ($P < 0.001$).

Table 41. Mann-Whitney comparison of distances to roads selected between the release pastures and escape areas of the Rocker b Ranch. [1]

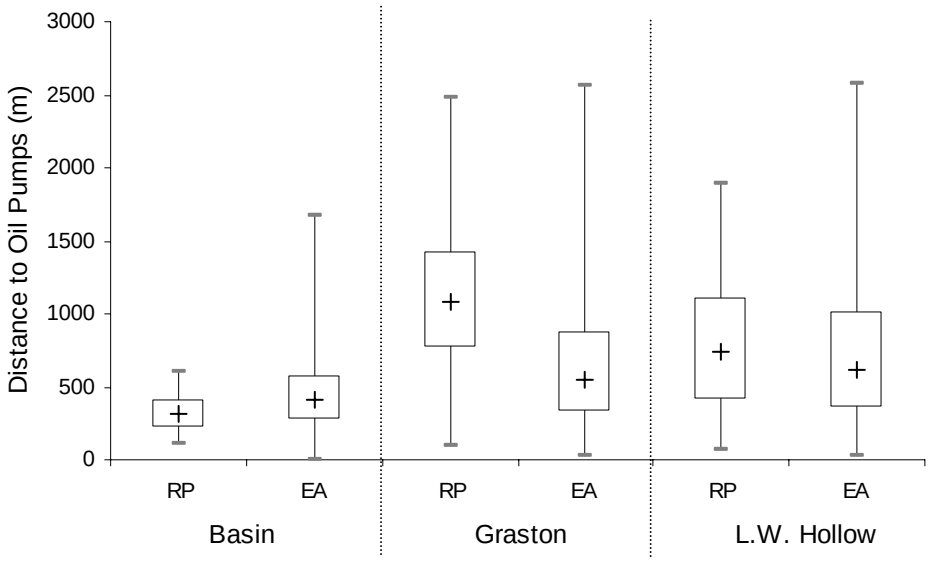
Regions	Season				
	W1	F	N	R	W2
Basin	E**	ns	ns	ns	R*
Graston	E**	E**	ns	R**	ns
L.W. Hollow	ns	ns	E**	E*	E**

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Oil Pumps and Habitat Selection

In the Basin area, 16 oil pumps lay within the RP fence boundary, while there were 280 in the EA. The Graston RP contained 2 oil pumps and its EA had 28. Ten water wells were within the L.W. Hollow RP and the EA included 75. It was not possible to determine how many of these pumps were actually functional. Random points generated in each region of the Basin, Graston and L.W. Hollow areas indicated that the distance to oil pumps on the Rocker b Ranch varied widely, as with the distances to roads (Figure 21). Distances to oil pumps were lowest in the Basin RP and highest in the L.W. Hollow RP, with medians of 310 and 735 m, respectively (Figure 21). No point was over 2600 m from an oil well in all three areas (Figure 21)

Figure 21. Five-number summary of distance to oil pumps for release pastures and escape areas utilized by pronghorn on the Rocker b Ranch.



For pronghorn selection in the Basin area, the median distances to oil pumps were greater in the RP compared to the EA and the escaped pronghorn also varied more in their distances (Figure 22). In the Graston RP, pronghorn selected for median distances to oil pumps ranging from 1240 to 2025 m, over twice the distances selected for in the other Areas. But median distances in the Graston EA were much lower, ranging from 330 to 700 m (Figure 23). Median distances to oil pumps in the L.W. Hollow area did not vary much between the RP and EA, but pronghorn in the L.W. Hollow EA did select for greater maximum distances, ranging as high as 2300 m (Figure 24).

Figure 22. Five-number summary of oil pump distances selected for by pronghorn in the Basin release pasture and escape area on the Rocker b Ranch.

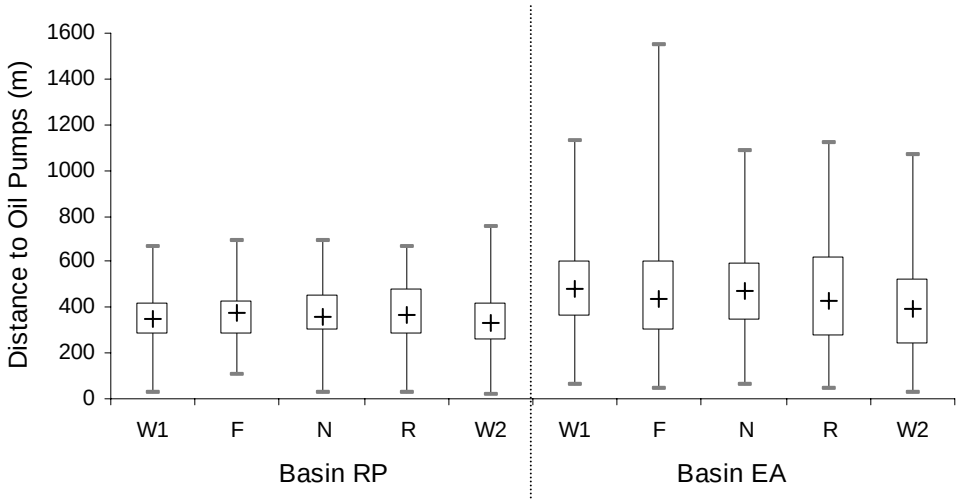


Figure 23. Five-number summary of oil pump distances selected for by pronghorn in the Graston release pasture and escape area on the Rocker b Ranch.

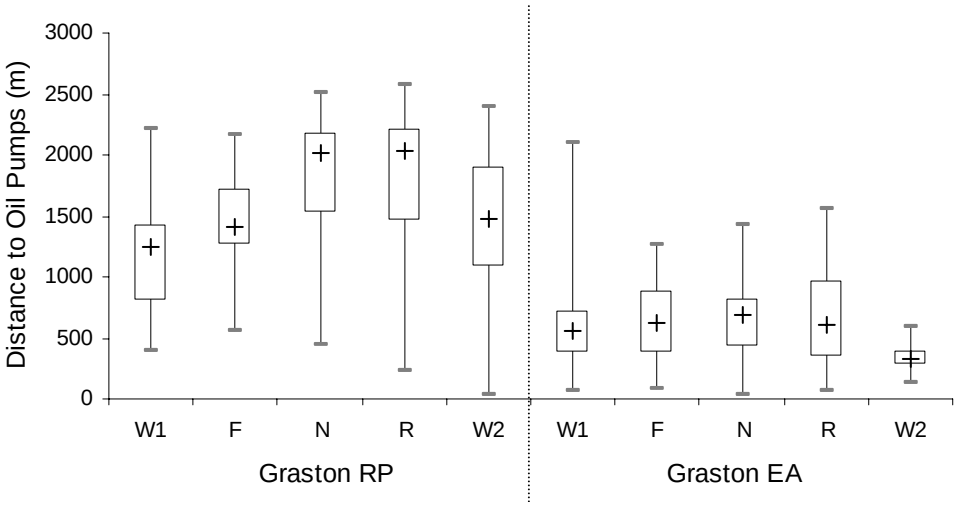
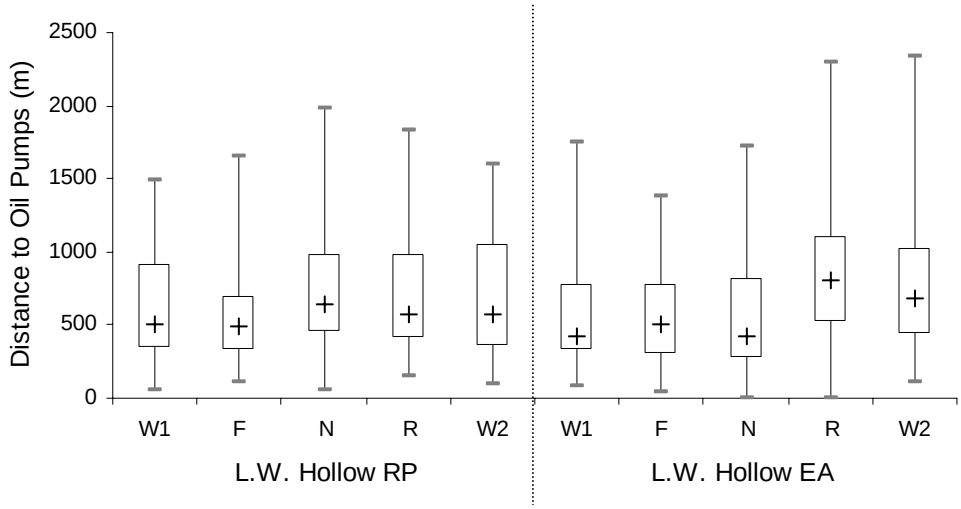


Figure 24. Five-number summary of oil pump distances selected for by pronghorn in the L.W. Hollow release pasture and escape area on the Rocker b Ranch.



Tukey's nonparametric multiple comparison test (α=0.05) was utilized to separate elevations for each of the five seasons into statistically different groups for each region (Table 42). In the Basin RP, pronghorn selection for distances to oil pumps was not significantly different between seasons (Table 42). Oil pump distances selected by pronghorn in the Graston RP were separated into three distinct groups, with the nursing and rutting season greater than the other seasons (Table 42). Compared to the nursing, fawning and rutting seasons, the pronghorn in the Graston EA selected shorter distances in the second winter season than the second winter season (Table 42). In the L.W. Hollow RP, the nursing season contained significantly greater distances when compared to only the fawning season (Table 42). Pronghorn in the L.W. Hollow EA selected for

greater distances to oil pumps in the rutting and second winter seasons (Table 42).

Table 42. Tukey's multiple comparison test on ranked distances to oil pumps for the Basin, Graston, and L.W. Hollow areas. Seasons are arranged in descending order.

Region		Relationship
Basin	RP	R N F W1 W2
	EA	W1 N F R W2
Graston	RP	N R W2 F W1
	EA	N F R W1 W2
L.W. Hollow	RP	N R W2 W1 F
	EA	R W2 F N W1

Distances to oil pumps selected for by pronghorn in the Basin area were not significantly different from normal, whereas more seasons contained active selection of distances in the Graston and L.W. Hollow areas (Table 43). Selection of oil pump distances was highly significantly greater than random for pronghorn in the Graston RP (Table 43). In the fawing and both winter seasons, pronghorn in the L.W. Hollow RP selected for shorter distances to oil pumps (Table 43). Pronghorn in the L.W. Hollow EA selected greater distances to oil pumps most of the year (Table 43).

Table 43. Mann-Whitney analysis of oil pump distance selected for by Pronghorn in the three release pastures (RP) and escape areas (EA) on the Rocker b Ranch compared to random points. [1]

Regions		Season				
		W1	F	N	R	W2
Basin	RP	ns	ns	ns	ns	ns
	EA	ns	ns	ns	ns	ns
Graston	RP	ns	G**	G**	G**	G**
	EA	ns	ns	ns	ns	ns
L.W. Hollow	RP	L**	G**	ns	ns	L
	EA	L*	G	G*	G**	G**

[1] "ns" = not significant, "L" = lower ($P < 0.05$), "L*" = lower ($P < 0.01$), "L**" = lower ($P < 0.001$), "G" = greater ($P < 0.05$), "G*" = greater ($P < 0.01$), "G**" = greater ($P < 0.001$).

When pronghorn were in the Basin EA, they consistently selected greater distances to oil pumps as opposed to when they were in the RP (Table 44). In the Graston EA, pronghorn selected shorter distances throughout the year compared to the RP (Table 44). In the L.W. Hollow Area, pronghorn chose shorter distances in the EA in the first winter and nursing seasons, but chose greater distances in the rutting season (Table 44).

Table 44. Mann-Whitney Comparison of distances to oil pumps selected between the release pastures and escape areas of the Rocker b Ranch. [1]

	Season				
Oil Pumps	W1	F	N	R	W2
Basin	E**	E**	E**	E	E*
Graston	R**	R**	R**	R**	R**
L.W. Hollow	ns	ns	R**	E*	ns

[1] "ns" = not significant, "R" = greater in RP ($P < 0.05$), "R*" = greater in RP ($P < 0.01$), "R**" = greater in RP ($P < 0.001$), "E" = greater in EA ($P < 0.05$), "E*" = greater in EA ($P < 0.01$), "E**" = greater in EA ($P < 0.001$).

Fences and Habitat Selection

To determine if there were significant differences between the numbers of times pronghorn crossed a fence, an analysis was performed to examine every incidence of two time sequential points occurring on opposites sides of a fence. Of course, it must be understood that such occurrences might indicate movement through a fence or over a cattle guard. Nevertheless, the count of occurrences for such crossings was determined for pronghorn on the Rocker b Ranch. Because the pronghorn in the Graston and L.W. Hollow areas had access to modified, pronghorn-friendly fencing, their crossings were compared to the pronghorn in the Basin area, which was surrounded by old net wire fencing. A total of 8 pronghorn were used for analysis in the Basin Area and 13 were used in the Graston/L.W. Hollow Area. Significant differences existed in the frequency of pronghorn crossings of various fence types (Friedman, $P<0.001$). Out of 790

crossings, 57.3% occurred for pronghorn released in the Graston/L.W. Hollow pastures. For all groups of pronghorn, old wire fencing was crossed most frequently, though the pronghorn released in the Graston and L.W. Hollow pasture crossed old net wire 86.53% of the time, even though modified fencing was available (Table 45). For Basin area pronghorn, 94.7% of movements through a fence were through old wire fencing (Table 45). Modified fencing was crossed 4.7% of the time by Basin area animals and 13.02% by Graston/L.W. Hollow area animals (Table 45). As expected, new net and 6-barb wire fences were not crossed and 5-barb wire was used very rarely (Table 45).

Significant differences existed between pronghorn in the Basin area and the frequency for which they crossed different fence types (Friedman, $P<0.01$).

Table 45. Pronghorn crossing percentages for different fence types in the Basin Area (n=453) and Graston/L.W. Hollow areas (n=337).

Area	Fence Types				
	Modifed	Old Wire	New Wire	5-barb	6-barb
Basin	4.70%	94.70%	0.00%	0.60%	0.00%
Graston/L.W. Hollow	13.02%	86.53%	0.00%	0.44%	0.00%

For Graston and L.W. Hollow area pronghorn, no significant differences were found between individual animal frequencies of crossing different fence types (Friedman, $P>0.05$). During rutting season, however, no significant differences existed between all groups for tendencies to cross a fence (Friedman, $P>0.05$).

Also, 25% of fence crossings occurred during rutting season, indicating animals had a higher likelihood of moving across a fence during this time. As rutting season is only two months out of the year, chi-square tests indicated significantly (P<0.001) greater movements across fences when compared to the expected frequency.

Home Ranges

Since the pronghorn in the Graston and L.W. Hollow areas had immediate access to modified, pronghorn-friendly fencing and the pronghorn were released in the Basin pasture, which is surrounded by old net wire fencing, comparisons were made between the groups. Only pronghorn that were collared in January 2002 and survived through January 2003 were used for home range analysis. A total of 8 pronghorn were used for analysis in the Basin area and 7 were used in the Graston/L.W. Hollow area. ANOVA tests indicate there were no significant differences between the home range areas of Graston/L.W. Hollow areas pronghorn and the Basin area pronghorn for 50% kernel estimates (P>0.05). The same was true for 95% kernel and MCP home ranges, as well.

The 50% kernels for the first winter season were larger than the other seasons in both areas, although in the Basin area there was much more variation in home range sizes (Figure 25). 95% kernel means ranged from 6.0 to 18.0 km^2 in the Basin area and 6.5 to 15.7 km^2 in the Graston/L.W. Hollow area (Figure 25). The 95% kernels during the nursing season were the smallest compared to

all seasons in both Areas (Figure 26). Means for the two areas were similar, ranging from 74.7 to 123.6 km^2 in the Basin area and 82.2 to 143.5 km^2 in the Graston/L.W. Hollow area, but the variation in home sizes were much bigger in the Basin area (Figure 26). MCP home ranges encompassed every point recorded by the GPS collar and varied much more than the kernels, as expected. Interestingly, seasons with the largest MCP sizes also had the largest degree of variation (Figure 27).

Figure 25. Home range mean ± 1 standard deviation (in km^2) for 50% kernel for pronghorn on the Rocker b Ranch.

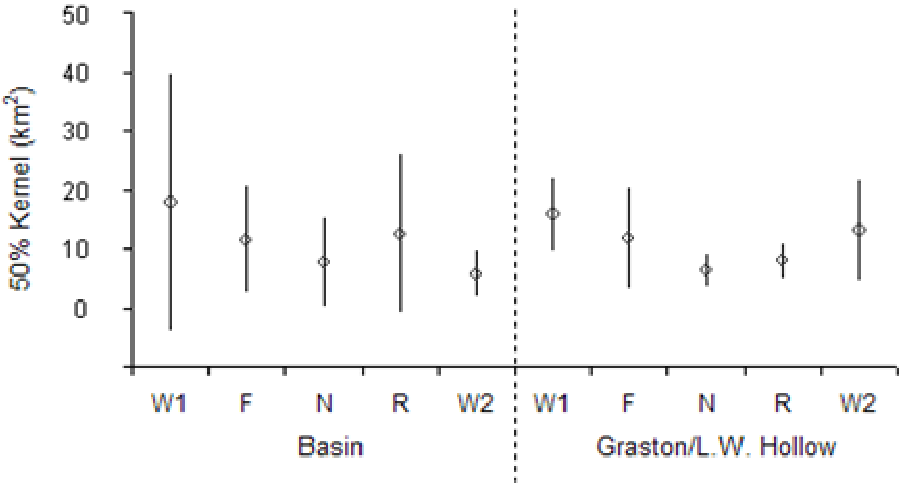


Figure 26 . Home range mean ± 1 standard deviation (in km^2) for 95% kernel for pronghorn on the Rocker b Ranch.

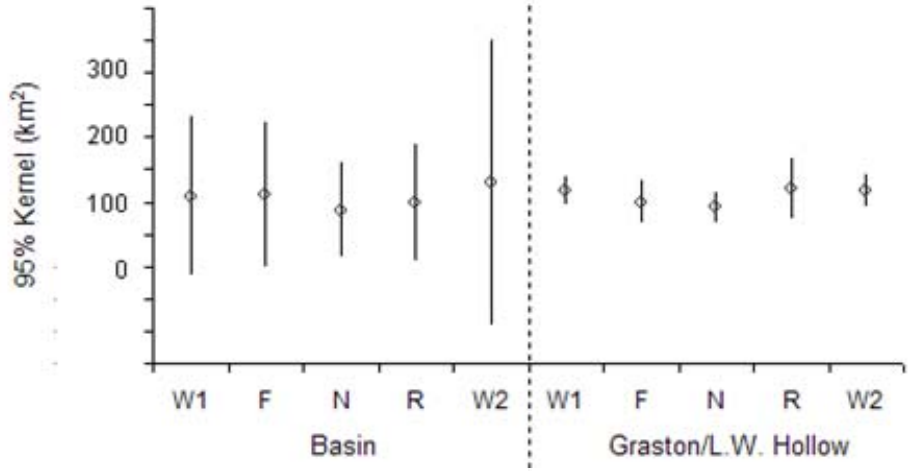
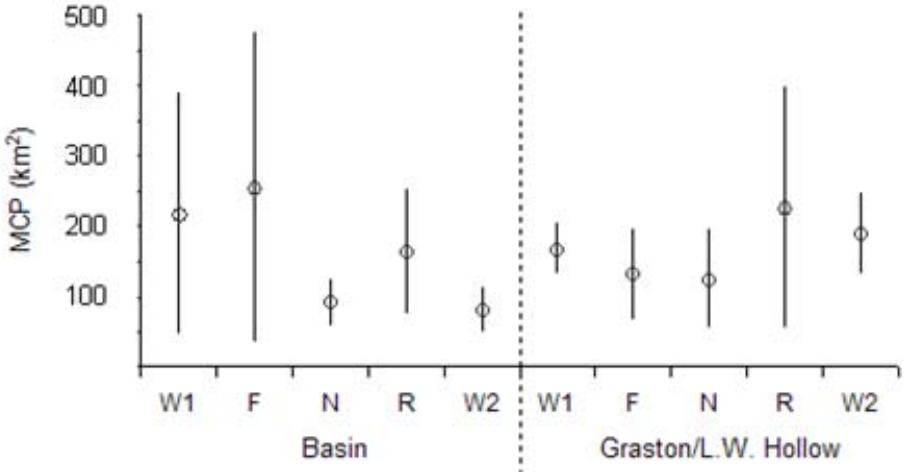


Figure 27. Home range mean ± 1 standard deviation (in km^2) for MCP for pronghorn on the Rocker b Ranch.



Movement

As with home ranges, comparisons were made between pronghorn in the Graston and L.W. Hollow areas, who had immediate access to modified fencing, and pronghorn released in the Basin pasture. Median 4-hr movements within the Basin area ranged from 395 to 507 m in the daytime and 295 to 377 m at night (Figure 28). In the Graston/L.W. Hollow area, medians ranged from 436 to 772 m in the daytime and 223 to 387 m at night (Figure 29).

Tukey's nonparametric multiple comparison test (α=0.05) indicated that pronghorn movement in the Basin area was significantly greater than the Graston/L.W. Hollow areas for every season. However, within the Basin and Graston/L.W. Hollow areas there were no significant differences between the seasons (Kruskal-Wallis, P>0.05). Also, for each season in both regions the length of diurnal movements were significantly longer compared to the length of and nocturnal movements, as determined by Tukey's nonparametric multiple comparison test (α=0.05).

Figure 28. 4-hour diurnal and nocturnal movement (in meters) for pronghorn in the Basin area.

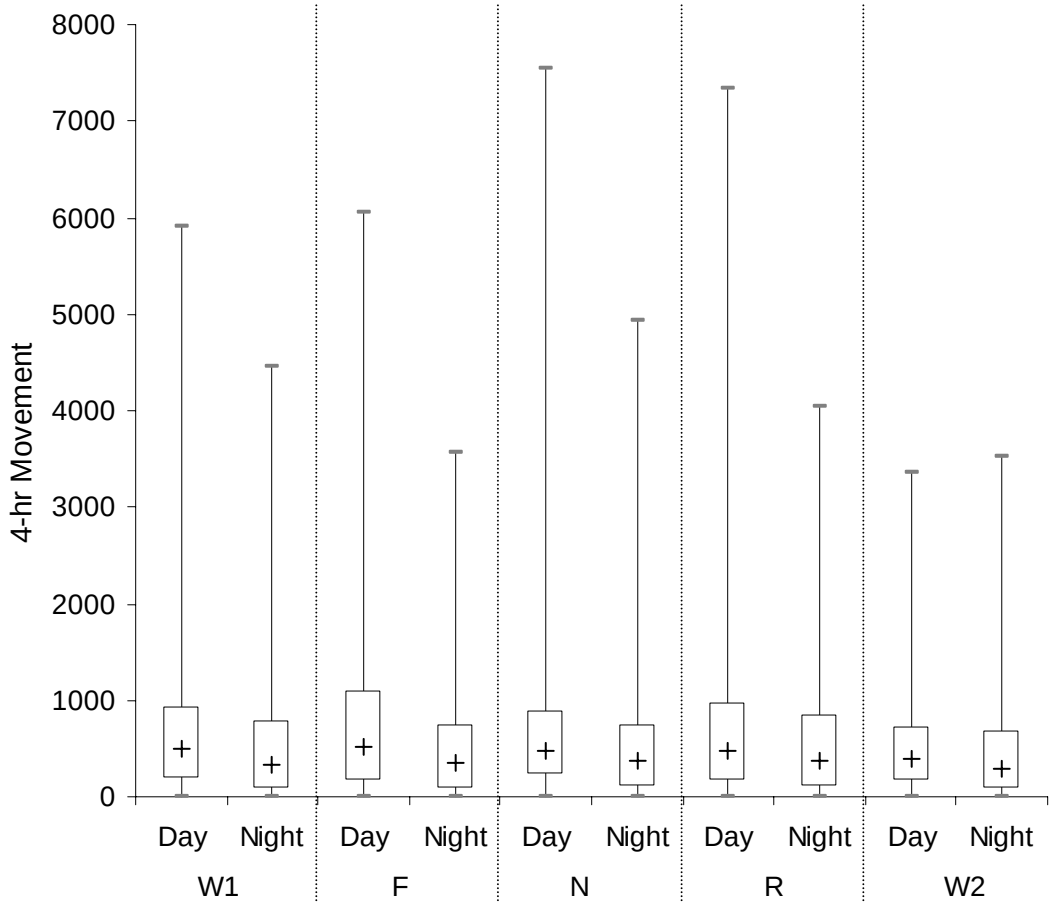
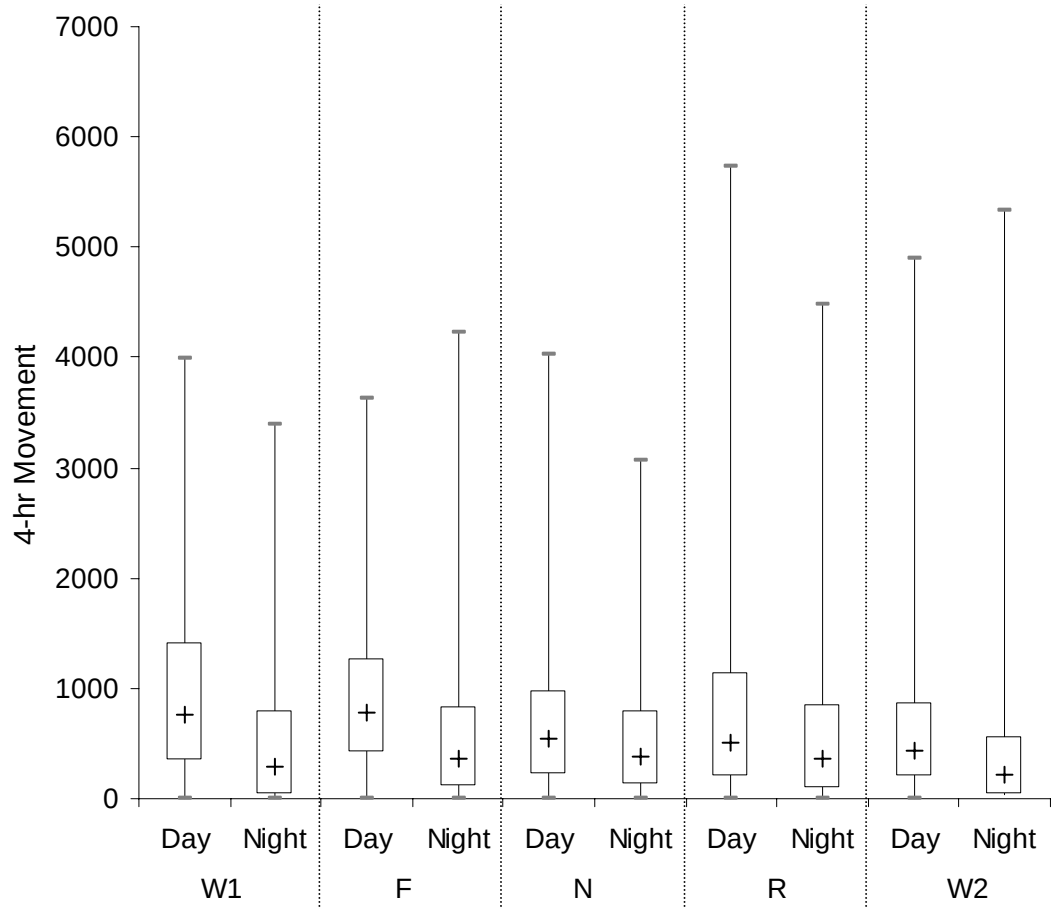


Figure 29. 4-hour diurnal and nocturnal movement (in meters) for pronghorn in the Graston/L.W. Hollow area.



DISCUSSION

Two large-scale studies have been conducted that involve habitat selection for pronghorn in the southwest. The first study examined the life history and ecology of pronghorn in the Trans-Pecos region of Texas to determine "range use by the prong-horned antelope and to increase knowledge of this remarkable animal" (Buechner 1950). An extensive analysis of forage habits was conducted, which included seasonal feeding habits. Activity studies established daily movement distances and home range sizes, while observations of the pronghorn's physical environment revealed preferences to factors such as aspect and slope.

Almost fifty years later, the second study utilized radio transmitters to obtain habitat selection, home range, and movement data for pronghorn in Central Arizona (Ockenfels et al. 1994). The coordinates of pronghorn were ascertained several times a week over the course of 4 years and, with geographic information systems (GIS), this information was integrated with a variety of habitat variables, such as vegetation, slope, aspect, and distance to roads and water. Sample plots were used to determine vegetation characteristics of the study site and this allowed for an examination of pronghorn selection for vegetation richness, cover, and height.

On the Rocker b Ranch, analysis of habitat use by pronghorn for vegetation type, elevation, slope, aspect, and distances to water, roads and oil wells revealed different types and levels of selection, based, to some degree on

difference in habitats. Overall, pronghorn actively selected for certain features within each parameter, however habitat choices made by pronghorn in their respective release pastures and escape areas differed. Although, these results often did not represent direct selection of specific habitat characteristic, they were sometimes due to the affect of another parameter and may not have resulted for biologically meaningful associations.

Basin Area

An examination of resource use exhibited by pronghorn in the Basin area indicates that selection for certain parameters was occurring. This was true not only when the availability within the Basin release pasture (RP) and escape area (EA) was compared to the choices made by the pronghorn in these areas, but also when the choices made by Basin RP and EA pronghorn were compared to each other.

Vegetation

Based on initial analyses of available vegetation type, pronghorn in the Basin area did not select grassland/forb to as high of a degree as has been observed in previous studies conducted in West Texas. This may be due to the 8-year drought the ranch was experiencing when the study was conducted. Only 36.6 cm of rain fell during 2002 in the San Angelo area, over 15 cm below the normal annual amounts (NOAA 2004). Research indicates that, during a drought, pronghorn will utilize shrubs more than forbs, because shrub browse is

more abundant during periods of decreased precipitation (Stephenson et al. 1985).

Several different factors affected the selection and avoidance of certain vegetation types in the Basin RP. In this region, there was no significant selection of the grassland/forb vegetation type, although pronghorn did utilize this vegetation type extensively, 59% compared to the other vegetation types. The Basin RP is over 60% grassland/forb, and pronghorn appeared to be utilizing the habitat in the proportion that it occurs. This usage is consistent with other studies. Buechner (1950) found that forbs and grasses together comprised about 70% of the diet for pronghorn in west Texas. Clearly, pronghorn in the Basin RP were selecting grassland/forb vegetation within the normal limits of pronghorn in the west Texas region, but the widespread availability of this vegetation type obscured the heavy usage. Also, drought conditions may have adversely affected the abundance or moisture content of the available forbs and grasses, and, as a result, pronghorn did not utilize this vegetation type as they would have with normal amounts of precipitation.

In the Basin RP, bare regions were favored throughout the year. Pronghorn may have chosen some bare regions due to their proximity to roads. Ground-truthing determined that forbs and grasses grew along the main road that runs through the southern part of the Basin pasture. These regions were classified as bare, because they were either devoid of vegetation at the time the satellite image was taken or the area was so close to the road that the spectral

signature for the pixel included the roadside vegetation and the road. This resulted in a high brightness value and the pixel would have been identified as bare during the unsupervised portion of the classification. These forbs and grasses at the roadsides might have been healthier than others in the Basin pasture. A study conducted in New Mexico found that during a drought, the forb availability was greatest along roadsides which received more runoff than did other areas (Stephenson et al. 1985). Of the bare areas chosen by pronghorn, a total of 20% were within 30 m of the road. Pronghorn that selected these sites may have actually been foraging for grasses and forbs along the roadside, vegetation which did not appear on satellite imagery due to the reflectance of the road.

The selection for moderate mesquite by Basin RP pronghorn can be explained by the prevalence of savannah-like quality of the vegetation type on the ranch. This vegetation type usually occurs in low-lying areas and is, therefore, closer to the water table. Because of this, there were grasslands interspersed between the stands of brush and mesquite. Since the drought had affected the availability of the grassland/forb vegetation type, pronghorn probably selected these areas for forage, even though there were trees to obstruct their vision. Buechner (1950) found that pronghorn in the arid climate of the Trans-Pecos region of west Texas preferred wooded areas when they were associated with grassland. Hailey (1979) also stated that in his study of west Texas

pronghorn, brushy draws were chosen in the winter when the availability of forbs decreased.

The avoidance of shrubland by pronghorn was most likely a result of the high availability of forbs and grasses in the Basin RP. Pronghorn in grassland biomes have been found to consume much less browse and more forbs compared to animals in shrub-steppe habitats (Lee et al. 1998).

When pronghorn escaped from the Basin pasture, they increased their selection for bare areas. The choice of bare areas in the release pasture may have been due to proximity to roads; 19% of the bare areas selected by pronghorn were within 30 m of the main road. In addition, pronghorn in the EA selected for forb/grass habitat in the fawning and nursing seasons, but analysis also showed no statistical differences when this area was compared to the Basin RP. The EA had lower elevations than did the RP, so the surface soils were closer to the water table and may have supported healthier forbs and grasses.

Pronghorn in the Basin EA avoided shrubland less frequently than in the RP. This may be due to the smaller percentage of forb/grassland vegetation type available in the RP. In the Basin EA, pronghorn also avoided juniper, consistent with their general avoidance of dense vegetation.

Elevation

Pronghorn inhabit a variety of elevations, from herds in Mexico living at the sea level in Mexico (Lee et al. 1998) to those occurring at 2100 m in the mountains of Oregon (Einarsen 1948). Elevations on the Rocker b Ranch varied

from 695 m to 846 m, and pronghorn in the Basin Area rarely selected elevations greater than 780 m or less than 760 m. In the Basin RP, elevation did not vary appreciably from this preferred range, therefore pronghorn were not able to select elevations at levels significantly different from random. In the Basin EA, pronghorn had a greater range of elevations to select from, and they not only chose significantly lower elevations within the escape area, but also selected for lower elevations compared to the Basin RP. Pronghorn most likely chose these lower elevations because they were closer to the water table and the vegetation in the low-lying areas would have higher moisture content.

Slope

Researchers have found that pronghorn avoid slopes greater than 20% (Lee et al. 1998). Slope in the Basin area did not exceed 15%, although pronghorn rarely selected for grades this steep. Minimal variation in slope occurred in the terrain of the Basin RP, and no selection occurred as a result of this. The range of slopes available during the Basin EA was greater than in the RP, and pronghorn in the EA did select for greater slopes in the nursing and both winter seasons. Compared to pronghorn in the RP, escaped pronghorn chose greater slopes throughout the year. This selection of greater slope can be explained by several aspects in their biology. Pronghorn typically use rolling, expansive topography (Lee et al. 1998), so they often occur in areas with gentle slope. In the winter, pronghorn choose for slopes as a barrier against cold winds (Buechner 1950). Pronghorn studied in Arizona also used landscapes with

greater slope in the winter and nursing seasons and this was attributed to the need for early detection of predators (Schuetze and Miller 1992).

Aspect

Pronghorn in both regions in the Basin area selected for southwestern aspects and pronghorn chose southeastern aspects in the Basin RP. When pronghorn escaped from the Basin pasture, they selected for southwestern aspects at an even greater frequency than in the Basin RP. This supports the findings found in the other studies. Buechner (1950) found that pronghorn in West Texas selected south facing exposures for several reasons. These aspects contained more forbs and browse, provided protection from cold north winds in winter and received more sunlight than other aspects during the daytime. The use of southern aspects was also found in Arizona pronghorn (Okenfels et al. 1994). As stated earlier, pronghorn select rolling terrain, so it was not surprising that there was a strong avoidance of flat areas in the Basin RP, which covered over 43% of the region.

Soils

Pronghorn in the Basin area exhibited different preferences for soils between the RP and EA. In the Basin RP, pronghorn showed little selection of any soil type and no trends were observed. Conversely, pronghorn in the Basin EA exhibited strong preferences to certain types of soils. The escaped pronghorn avoided soils with higher percentages of clay, such as the Angelo (TX017) and Rio Concho (TX474) series, because dense vegetation occurred on

these soil types. About 50% the Rio Concho soil type supported moderate mesquite, dense mesquite, and juniper. Pronghorn in the Basin EA selected for Conger (TX020) and Ector (TX156), as these loamy soils support grassland/forb and shrubland vegetation types. A stony loam soil, Ector (TX159), was also avoided in the Basin EA, but this soil type was in a southern portion of the region that was rarely utilized due to steep slopes.

Distance to Water

During Okenfels' (1994) study of pronghorn in Arizona, he discovered that pronghorn avoided a 400-m radius around water sources and rarely traveled more than 1.6 km from water. Distances to water wells for bucks in the Basin RP were fairly consistent with the results found in Arizona. In the Basin RP and EA, 56.4 % and 52.1% of pronghorn locations in these respective regions fell between 500 and 1500 m from water wells. Pronghorn in the Basin area also did stray further from water than did the Arizona animals, with approximately 10% of the locations found over 2 km from water wells. This may be a result of physical distance between water sources. Water wells on the Rocker b Ranch were spaced from 0.5 to 3 km apart, while in the Arizona study, water sources were rarely more than 1.6 km from one another.

Distance to Roads

Although analyses indicated selection for roads occurred at various degrees in the different regions, this was most likely not due to the roads themselves, but to other factors such as vegetation type along the road sides. In

the Arizona study conducted by Ockenfels (1994), pronghorn distance from maintained and urban roads was determined with the use of GIS. Results indicated that male pronghorns slightly avoided areas within 1 km. Pronghorn in the Basin EA on the Rocker b Ranch, however, did not avoid proximity to roads to this degree. Of the escaped pronghorn GPS (global positioning system) points, 18% were located within 250 m of roads. As stated earlier, this close proximity to roads was likely due to the use of forbs and grass bordering the roads.

Distances to Oil Pumps

Pronghorn selected greater distances from oil pumps when they escaped the Basin RP. Although there was selection occurring for particular distances to oil pumps, the spatial distribution of the pumps may have contributed to this phenomenon. In the Basin RP, pumps are regularly spaced, and no oil pump was more than 610 m from an adjacent facility. In the Basin EA, the median distance of pronghorn localities from oil pumps was not appreciably higher than those in the RP, but the pumps occurred in clusters more frequently in the escape area. Data did not indicate any avoidance of oil pumps, and ranch hands have observed that pronghorn will stand close to active pumps and watch them operate (Lee Miller, Texas Parks and Wildlife Department, personal communication).

Graston Area

Vegetation

Similar to Basin area pronghorn, animals in the Graston area did not select grassland/forb vegetation type as highly as the literature has reported from other studies. In contrast, pronghorn strongly selected shrubland in both the Graston RP and EA. As was the case for the Basin area, shrubs are utilized by pronghorn more during droughts when forbs are not available. In the Graston RP, pronghorn avoided moderate mesquite, dense mesquite, and juniper. This is consistent with the literature. Overall, pronghorn in the EA did not avoid dense mesquite or juniper, because these vegetation types occur at such low frequencies in this area. The time spent in these areas by pronghorn was most likely due to travel from one location to another. Ockenfels (1995) noted that pronghorn do not utilize regions in which brush in over 63 cm when moving long distances.

Elevation

Pronghorn in the Graston area consistently selected for greater elevations in both the RP and EA. This may have been a result of the association between higher elevations and occurrence of shrubs. As stated in the vegetation section, pronghorn in the Graston area utilized more shrubland, and, on the Rocker b Ranch, shrubs generally occur on slopes and higher elevations. Also, consistent with the selection of higher elevations within their respective areas, when

pronghorn did escape from the release pasture, they chose higher elevations in the Graston EA compared to those in the RP.

Slope

Like those in the Basin area, pronghorn in the Graston RP selected for greater slopes, with a general preference for slopes, avoidance of cold winds during the winter, and better detection of predators. Additionally, the majority of the vegetation type preferred by the Graston pronghorn, shrubland, was found in the southwest portion of the pasture. This region corresponded to greater slopes, as well. In the Graston EA, pronghorn selected for greater slope only during the nursing season. The majority of slopes in the Graston EA are about 1% and the higher slopes that do exist tend to be extreme, up to 17%. This probably contributed to the lack of selection for greater slope by the pronghorn in the Graston EA.

Aspect

Pronghorn in the Graston area that escaped from their release pastures did not select for south-facing exposures as did the Basin area pronghorn and, unlike Basin area pronghorn exhibited a selection of southeastern aspect and an avoidance of southwestern aspects. This discrepancy indicates that aspect was not an important factor for habitat selection by these animals.

Soils

Pronghorn in the Graston RP and EA exhibited strong preferences for certain types of soils throughout most of the year. Pronghorn in both areas

avoided Angelo (TX017) and Rio Concho (TX474) soil series due to the dense vegetation supported by these soil types. Conger (TX020) and Ector (TX156) soils were selected by pronghorn in the RP and EA, as these loamy soils support shrubland vegetation types.

Distance to Water

The majority of pronghorn locations in the Graston area, 62.3 and 61.4% for the RP and EA, also fell between 500 and 1500 m from these water sources. Analyses indicated that pronghorn in both regions of the Graston area selected distances closer to water wells during the nursing season. Researchers have observed lactating does at closer distances to water during nursing season, but only males were used in this study. Some territorial bucks remain with their harems in the summer, rather than in bachelor herds (Buechner 1950), and these bucks may have adopted locations closer to water while guarding their females. In addition, the lowest amount of precipitation fell during the fawning season, 2.0 cm, and this might have encouraged the pronghorn to select areas closer to water. Accessibility to water becomes more important during drought conditions when the moisture content of vegetation is reduced (Ockenfels 1995), and convenient access to water is necessary to maintain a high density pronghorn population (Autenreith 1978, Hailey 1979).

Distance to Roads

Analysis indicated that pronghorn in the Graston RP selected for highly significantly shorter distances to roads than did those in the Graston EA. After

examination of major roads and vegetation types in the two regions, it was concluded that this discrepancy occurred because the only major road in the area ran along the southwest border of the Graston RP. A large percentage of shurbland vegetation, strongly selected for by the Graston area pronghorn, was located in the southern portion of the Graston pasture. Therefore, the pronghorn most likely chose locations close to roads based on the vegetation type available.

Distances to Oil Pumps

Pronghorn in the Graston area selected shorter distances to oil pumps when they escaped, unlike pronghorn in the Basin area. Again, this was most likely a result of the number and spatial arrangement of the oil pumps in the escape area. The Graston RP contained only two pumps, which were located far apart from one another in the northern region of the pasture, into which few collared pronghorn ventured. Pumps in the EA were more numerous and were spaced closer together, thus reducing the distance any animal might be in relation to an oil pump.

L.W. Hollow Area

Pronghorn in the L.W. Hollow area exhibited similar habitat use compared to those in the Graston area. This can be attributed to the greater similarity in the various habitat parameters between the L.W. Hollow and Graston areas. Slight deviations in preferences were found for vegetation type, slope, soil, and distances to water and oil pumps.

Vegetation

Pronghorn in the L.W. Hollow area selected vegetation types similar to those for animals in the Graston area, although they did not select for shrubland as consistently throughout the year. However, there was a tendency for pronghorn to avoid juniper more in the L.W. Hollow EA than in the RP, because there was a greater percentage of juniper vegetation type in the EA.

Slope

The choice for slope by pronghorn in the L.W. Hollow area did not differ significantly from random for either the RP or EA animals. Unlike the relationship between slope and vegetation that occurred in the Graston area, an examination of L.W. Hollow indicates that vegetation was more evenly distributed across the area.

Soils

Similar to the Graston area, pronghorn in the L.W. Hollow area selected Conger (TX020) and avoided the Angelo (TX017) and Rio Concho (TX474) soil series due to the dense vegetation supported by these soil types.

Distance to Water

Pronghorn in the L.W. Hollow area showed no preference for distances to water, although there were differences when the EA localities were compared to those in the RP. Number of water wells and their spatial arrangement contribute to this result as greater distances were selected for in the RP, because only two water wells occurred in the region.

Distances to Oil Pumps

Similar to pronghorn in the Basin area, greater distances from pumps were selected for by pronghorn in the L.W. Hollow EA. Likewise, spatial distribution of the oil pumps resulted in this phenomenon, as pumps occurred in clusters in the EA.

Fences

Pronghorn crossed old net wire fencing with much greater frequencies than modified fencing. This also occurred in Graston and L.W. Hollow, areas in which the modified fencing bordered the RPs and was easily accessible. After the pronghorn were collared, they were release back into the pastures in which they were captured. These pronghorn were familiar with their release pastures and knew the locations of the cattle guards and holes in the old net wires fences. The modified fencing was relatively new, so pronghorn with access to this fencing may have been more willing to jump cattle guards or go through holes in the non-modified fencing, than to use the new modified fencing. In addition, one pronghorn accounted for 40 out of the 59 crossings of modified fencing in the Graston/L.W. Hollow area. Whether the pronghorn actually crawled underneath the fence or crossed cattle guards is not known, but of the fences crossed by this buck, 44% were modified fences. Therefore, the higher frequency of modified fence crossings in the Graston/L.W. Hollow area was not attributable to the pronghorn group as a whole, but to a single animal.

While pronghorn on the Rocker b Ranch crossed the old net wire fences frequently, they did not cross newer net wire fences. Hailey (1979) noted that net wire fences were a serious problem to the movement of pronghorn, and, in the Marfa Flat area of west Texas, pronghorn losses ranged up to 90% in pastures that were enclosed by net wire fencing, because animals were denied access to winter-spring range.

Home Ranges

Overall, there was much more variation in the home range sizes of the Basin area pronghorn compared to those in the Graston/L.W. Hollow area. This was due to the greater distances traveled by a few of the Basin area pronghorn. For the most part, pronghorn in the Graston/L.W. Hollow area maintained more similar movement distances. Typically, most pronghorn remained within a certain pasture throughout the year, and 50% kernel sizes did not differ significantly between the Basin and Graston/L.W. Hollow animals. Larger 50% kernel sizes in the first winter for both groups was due to the pronghorn moving to different locations as the weather turned warmer. As noted by Buechner (1950), the large winter herds disassemble into smaller groups and move away from one another as spring approaches.

Movement

Pronghorn in the Graston/L.W. Hollow area moved greater distances during each 4-hr period compared to Basin area pronghorn. As discussed in the

pervious section, pronghorn in the Graston/L.W. Hollow area had access to larger pastures than did those in the Basin area. Graston/L.W. Hollow animals could, therefore, move longer straight-line distances before encountering fences. Also, the Basin area pronghorn exhibited greater maximum distances of travel due to a few animals that traveled much greater distances compared to the other Basin area pronghorn. Although statistical tests did not indicate differences between seasons within the specific regions, the first winter and fawning seasons contained greater 4-hr distances traveled for both areas compared to those for other seasons. As noted previously, the large winter herds break up into smaller groups and move away from one another as spring approaches, which would account for the greater movements in the winter. In addition, pronghorn does travel greater than normal distances to reach fawning grounds during the springtime (Buechner 1950, Hailey 1979).

In other west Texas studies, Buechner (1950) observed pronghorn traveling up to 5.6 km/day, while Hailey (1979) recorded pronghorn moving from an average of 3.2 km/day to a maximum of 8.0 km/day. On the Rocker b Ranch, pronghorn on the Basin area moved about 2.5 km/day based on the medians for night and day, and Graston/L.W. Hollow pronghorn moved 3.0 km/day. The numerous fences on the ranch most likely resulted in the lower distances traveled by pronghorn, and since GPS collars recorded points every 4 hrs, nonlinear movement which occurred between the points is unknown.

Recommendations for Future Studies

Due to the ability of pronghorn to escape the Basin pasture frequently, the original design of the study could not be applied. Instead of using the Basin pasture as a control, the habitat use by pronghorn that escaped was compared to those within the pasture, as was done with the Graston and L.W. Hollow pastures. As a result, three different groups were utilized in the study, and, since their habitat parameters were all significantly different, habitat selection could not be compared between these three groups of pronghorn. Ideally, the original design would be implemented, with pronghorn that had no escape from one pasture, either through holes in the fences for cattle crossings. Additionally, the pasture surrounded by modified fencing would have similar parameters to the control pasture so that accurate comparisons could be made between the two for habitat selected by pronghorn when they escaped the pastures.

Also, no female pronghorn were included in this study. While three females accepted GPS (global positioning system) collars, other females reacted violently, and a decision was made by TPWD (Texas Park and Wildlife Department) personnel to only collar males. It is assumed that the weight of the collar resulted in the adverse reactions. In Arizona, 29 female pronghorn were fitted with collars housing radio transmitters, so there is no indication the collar itself is the factor they are reacting towards. GPS collars are now available in smaller weights than those used in the study of pronghorn on the Rocker b

Ranch. If females are reacting to the weight, then females may accept the lighter collars, and future studies with GPS technology could include does. This would reveal valuable information as a large degree of movement by male pronghorns is due to habitat choice made by females (Byers 1997).

In addition, drought conditions on the Rocker b Ranch during the study period drastically affected the selection of certain habitat parameters by pronghorn. A study conducted during a normal precipitation year would be beneficial as it would reveal the typical habitat choices of pronghorn in the Rolling Plains.

Conclusion

Overall, pronghorn in the Basin, Grastons and L.W. Hollow areas did select for specific vegetation types, elevations, slopes, aspects, soils, and distances to water, roads, and oil pumps. This selection was highly variable and most selection could be attributed to one of two factors, vegetation type or spatial distribution. Either pronghorn habitat choices were based mainly on vegetation type which occurred at certain elevations, slopes, etc., or spatial arrangements of physical features resulted in selection without any biological significance. With less consistency, pronghorn selected for different habitat parameters within their respective release pastures compared to those in escape areas. Pronghorn also crossed different types of fence types with significantly different frequencies, as old net wire fencing was crossed more than modified fencing. Significant differences did exist between home range sizes for 50% and 95% kernels on a

seasonal basis, but no differences were found in home range sizes between pronghorn with access to modified fencing and those in pastures surrounded by net wire fencing. Seasonally, pronghorn with access to modified fencing traveled greater distances compared to those in the Basin area. Also, diurnal movement was greater than nocturnal movement for pronghorn in both areas for every season.

APPENDIX

FREQUENTLY USED ACRONYMS AND CODES

B	Bare vegetation class
DM	Dense mesquite vegetation class
EA	Escape area
F	Fawning season
FG	Forb/grassland vegetation class
GPCD	GPS pronghorn collar database
J	Juniper vegetation class
MCP	Minimum convex polygon
MM	Moderate mesquite vegetation class
N	Nursing season
R	Rutting season
RP	Release pasture
S	Shurbland vegetation class
TPWD	Texas Parks and Wildlife Department
TX017	Angelo silty clay loam soil series
TX020	Conger loam soil series
TX156	Ector gravely loam soil series
TX159	Ector stony loam soil series
TX474	Rio Concho silty clay loam soil series
TX565	Tobosa clay soil series
W1	Winter 1 season
W2	Winter 2 season

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