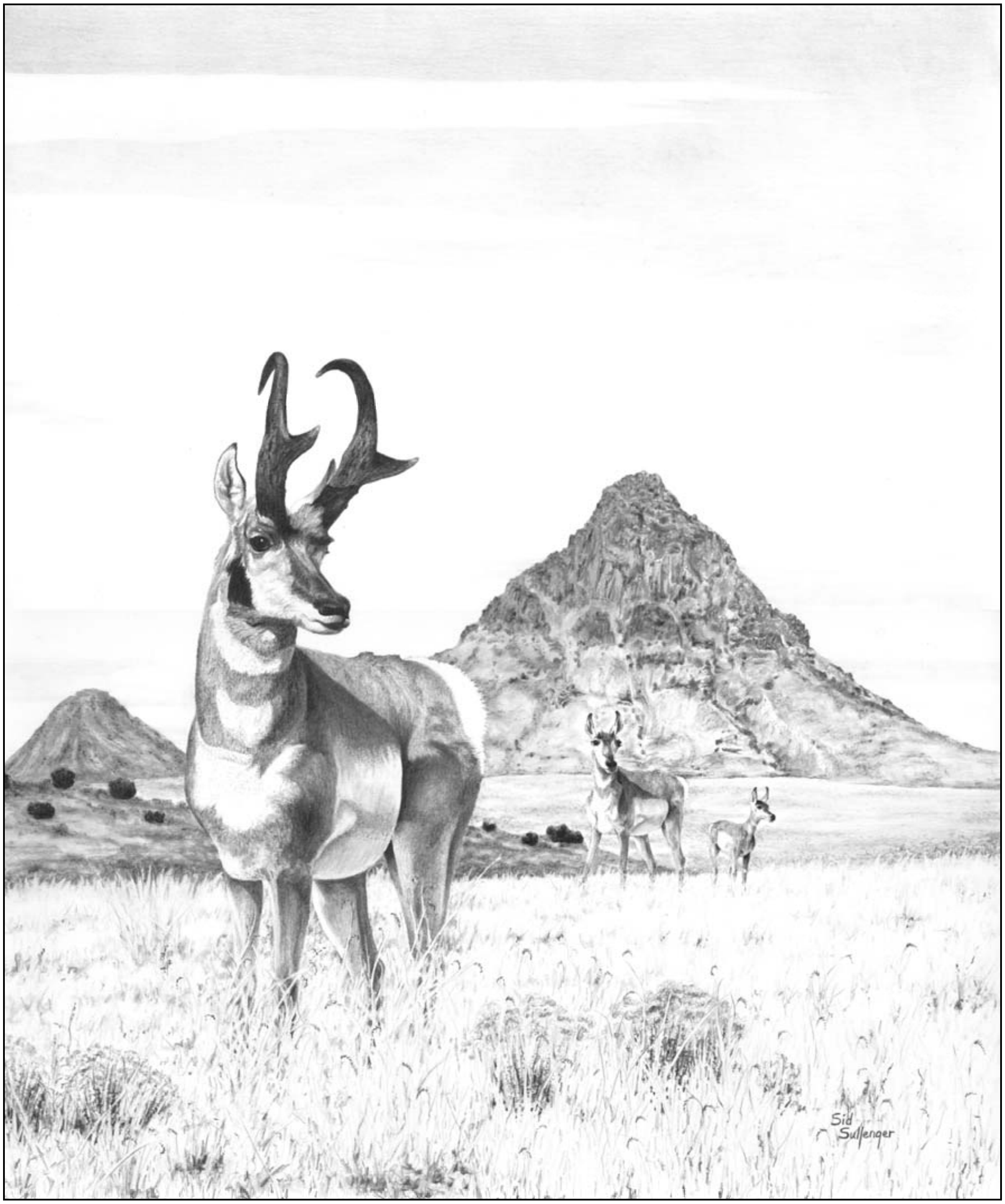
Proceedings

Pronghorn Symposium 2006



August 15-17, 2006

Alpine, Texas

Editors: **Kenneth A. Cearley, Texas Cooperative Extension**
Steve Nelle, Natural Resources Conservation Service

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LIFE HISTORY AND ECOLOGY OF PRONGHORN

LOUIS A. HARVESON, Department of Natural Resource Management, Sul Ross State University, Alpine, Texas 79832; 432-837-8488, harveson@sulross.edu

Abstract: The pronghorn (*Antilocapra americana*) is unique among ungulates in North American. Pronghorn occur throughout the arid regions of North America, are associated with shrub-steppe and grassland ecosystems, and their abundance is tied directly to fluctuations in precipitation. Populations of pronghorn are able to recover quickly from catastrophic weather (snow or drought). The diet of pronghorn is largely composed of forbs and to a lesser extent shrubs. A thorough understanding of the life history and ecology is a prerequisite to managing pronghorn in Trans-Pecos, Texas.

Taxonomy

The pronghorn (*Antilocapra americana*) has had a colorful past in the history and culture of North America. Native Americans mirrored their nomadic movements across the Great Plains and Intermountain West in their pursuit of food and fur. Prior to European settlement, pronghorn populations likely exceeded 30 million (McCabe et al. 2004).

Although commonly referred to as antelope, the North American pronghorn is not related to the antelope of Asia or Africa. Pronghorn have the unique distinction among mammals to be the only members of the order Antilocapridae and the Genus *Antilocapra*. Pronghorn only occur in North America and historically ranged from the Mississippi River to the Pacific Coast and from southern Canada to mid-Mexico. Today, the distribution of pronghorn in North America is but a fraction of its' historic range (O'Gara and Yoakum 2004). Primary causes for population and distribution declines include loss of habitat (agriculture, urban), artificial barriers (highways, fences), and isolation from other populations. Within that distribution 5 subspecies are acknowledged: American pronghorn, Oregon, Mexican, Sonoran, and Penisular (Yoakum 1978, O'Gara and Yoakum 2004).

Description

Physically, the pronghorn would be difficult to confuse with any other native ungulates of North America. Pronghorn weigh between 70-140 lbs, with males weighing 1.25x females, and reach adult size by their second year. Both sexes are horned, although the horns in females are relatively small and rarely exceed the length of their ears. Horns on males are forked or pronged (hence their name) and covered with a hairy sheath that sheds annually (Yoakum and O'Gara 2000).

Pronghorn are generally two-toned with a rust-brown color along their backs and sides and white on their rump, legs, and underside. Males have a distinctive black neck patch which is absent in females. Pronghorn also possess abnormally large eyes and long legs(Yoakum and O'Gara 2000).

Physiology

Pronghorn have evolved various traits to survive arid (hot or cold) and open habitats. To maintain body temperature following sprints or long movements, pronghorn are able to cool their blood supply with counter-current exchange for oxygen flow to their brain. Pronghorn have developed lungs, diaphragm, and esophagus to maximize air flow and a high blood volume relative to their body size. Further, hemoglobin, the primary blood constituent used to supply oxygen, is also abnormally high in pronghorn (O'Gara and Yoakum 2004).

With few exceptions, pronghorn occupy relatively arid habitats. Pronghorn have adapted to arid environments over the last million years. Some of their adaptations to surviving arid lands include increasing their efficiency in maintaining water. Specifically, pronghorn are able to reduce water intake by decreasing food intake during critical times; pronghorn have concentrated urine, thus minimizing water loss; and pronghorn conserve water via their concurrent exchange of oxygen (Yoakum 1978).

Fawns experience very rapid growth and reach adult size within the first 2 years of life. Pronghorn can live as long as 15 years, but average life span is 9 years or less (Yoakum 1978).

Reproduction

Pronghorns begin breeding as early as 16 months and breed annually until they are 8-10 years. Onset of rut varies from year to year and is dependent on weather conditions (e.g., rainfall). The length of the breeding season varies considerably across their distribution with southern pronghorn subject to an extended rut (3 months) and northern pronghorn to a shorter rut (3 weeks). If females are not bred, they will come into estrus again.

The gestation period for pronghorn is fairly consistent across their range at 250 days. Female pronghorn are very susceptible to malnutrition during pregnancy and frequently resorb 1 or more fetuses if nutrition is not adequate. Twinning is most common on healthy rangelands in their northern distribution, but triplets have been documented. Birthing to single fawns is more common on southern rangelands. But twinning becomes more common on southern rangelands during years of good nutrition provided by adequate precipitation. The sex ratio of embryos favors males (112:100), but those ratios skew toward females with age. In the Trans-Pecos, fawn production (fawn: 100 doe) ranges from 10-75% and averages 38% (Simpson et al. 2006).

Nutritional Requirements

Pronghorn are considered concentrate selectors; that is their primary diet is forbs (broad leafed weeds). However, their diets are very elastic and vary by biome (grassland vs. shrubland), season, and with availability (Autenrieth et al. 2006). In general forbs provide the most nutrients per bite compared to browse and grasses. Although browse has generally high levels of protein, much of the protein is not digestible because of secondary compounds. Forbs are also high in water content and help pronghorn maintain water balance during critical times (gestation, lactation). Browse (including succulents) ranks second in importance and use by pronghorn. Availability of forage plays an important role in the diet of pronghorn. Although pronghorn consume grasses, their total annual use is <10%. Pronghorn obtain water from free standing supplies, from preformed sources (in vegetation), and from metabolism (side product of various chemical reactions; O'Gara and Yoakum 2004).

Behavior

Pronghorn are known for their herding behavior and herds may range from 2-1,000 animals/herd. The gregarious behavior is an adaptation of evolving in a open ecosystem, where the probability of mortality to 1 individual in the herd is equal to 1/herd size. In northern latitudes, herd units are more discrete with a set number of members and specific boundaries. In these ecosystems, herd boundaries are typically barriers to their movement (rivers, fences, roads, etc…). In shrublands and southern grasslands, herds are less discrete. At certain times of the year herds are partitioned into bands. For females, bands occur on summer foraging sites. For males, bands (bachelor groups) are formed prior to the rut (Yoakum 1978).

The breeding systems implemented by pronghorn are fairly unique. A given breeding system may be implemented one year and not another and is thought to be dependent upon pronghorn density and resource availability. Most territoriality is displayed in spring to early fall (March-October). The breeding system described for pronghorn is resource-defense polygyny. In resource-defense polygyny, male pronghorn establish a territory based on the resources (habitat) available to them. In this system, the ability of a male pronghorn to reproduce with 1 or more females will depend on his selection of a territory and the subsequent use of that territory by breeding females. The second system used by pronghorn is harem-defense polygyny. Harem-defense polygyny is more common among North American ungulates. Male pronghorn will defend the harem (of females) regardless of where they roam in the harem-defense polygyny system. Males commonly mark their territories with their scent gland, urine, and feces. Territories are generally larger in open habitats (grasslands) and smaller in more rugged terrain (shrublands or sloping grasslands). Although not quantified with molecular techniques, dominant males are thought to breed most receptive females in their harem (Yoakum 1978, O'Gara and Yoakum 2004).

Although not truly migratory (latitudinal), pronghorn likely exhibited a nomadic nature as early explorers described the walls of pronghorn in early literature. Today, most long-range movements are restricted to some extent by various man-made barriers (fences, roads, agriculture, etc…). In northern latitudes, where severe winters are coupled with snowfall, pronghorn will descend to lower elevations where forage is more available. However, when snowfall is scarce in these regions, pronghorn will remain year-round. Thus, movement rates and range sizes of pronghorn varies considerably by habitat, season, and from year-to-year. Most pronghorn populations travel no more than 10-20 miles between summer and winter sites. Range sizes also vary. In good habitat (or years where habitat is optimal), range size may only be 8 mi^2. However in poorer habitats along the periphery of their distribution, range size may exceed 441 mi^2. Seasonally these ranges are even more restricted (0.01-20 mi^2; Yoakum and O'Gara 2000).

Few studies have documented the extent of communication in pronghorn herds. Modes of communication in pronghorn include sight, smell, and sound. When alerted, pronghorn communicate with their herd by emitting a pungent odor via their rump gland. Additionally pronghorn use visual cues when alerted by involuntarily erecting their rump hairs to signal distant members of their herd. Males and females also communicate with one another using a variety of scents, primarily to communicate reproductive status and to defend territories (O'Gara and Yoakum 2004).

Population Dynamics

Populations of pronghorn have the ability to recover quickly from population crashes. This is primarily attributed to their high productivity. Specifically, in good years, pronghorn have been known to average 1.9 fawns/doe.

However, the most important factor in population growth for pronghorn is fawn survival. High predation rates because of poor nutrition, suboptimal habitat (screening cover), or predation can minimize population growth. Fawn survival (No./100 doe) to 5 months old can vary as much as 7-82% (O'Gara and Yoakum 2004).

For pronghorn, mortality comes in a variety of packages. In the north, cold winters are a major mortality factor, whereas in the south, drought is equally potent.
When weather patterns result in die-offs, pronghorn mortality is primarily in the form of malnutrition resulting in starvation or predation. When habitat conditions are poor regardless of the cause (weather induced or poor management), malnutrition and predation of pronghorn will ensue. Good year-round habitat is the ultimate weapon against predation (Autenreith et al. 2006).

Few studies have documented the ill-effects of over-harvesting of pronghorn by man. The only exceptions are in isolated and already low populations. Most harvest regulations of pronghorn are conservative and allow for maximum sustained yield.

Throughout their range, the top predators of pronghorn are coyotes, bobcats, golden eagles, and mountain lions. Pronghorn are also susceptible to a variety of diseases, but their impacts are unknown. Likewise the impacts of parasites on pronghorn are also unknown (O'Gara and Yoakum 2004).

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PRONGHORN HABITAT REQUIREMENTS

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Abstract: Two of the most important characteristics of quality antelope habitat concern visibility and mobility. Because the pronghorn's primary means of self-defense are vision and speed, conditions that interfere with these abilities will, in the long-term, decrease their chances of survival. An important habitat characteristic that impacts pronghorn health and productivity is the freedom to make occasional long-distance movements to locate quality forage, water, and thermal cover. Barriers that interfere with the pronghorn's ability to roam the range (fences, divided highways, brush thickets, etc.) will impact herd health and survival. An important aspect concerning the vegetative component of antelope habitat is fawning cover. Nothing is more critical to fawn survival than adequate hiding cover (primarily bunchgrasses with a few shrubs and/or cacti). The 3 factors that dictate whether fawns will have adequate hiding cover are precipitation, livestock grazing management, and the presence of a few shrubs and desert succulents. Pronghorn in the Trans Pecos (and elsewhere) prefer forbs, although woody plants are critical when forbs are not available (seasonally and during drought). Grasses are the least important forage class, but immature grasses may be seasonally important (eg., early spring) in some areas. Small herds of pronghorn exist in arid regions with little or no free water, but good water distribution probably improves herd health and productivity in the Trans Pecos region of Texas.

Introduction

In the 1920's pronghorn numbers in the Trans Pecos were at an all-time low of 692 animals following decades of commercial harvest and unregulated sporthunting. After restocking efforts in the 1940's and 1950's, pronghorn numbers in the Trans Pecos climbed to more than 12,000 in 1961. Over the next 5 decades, the Trans-Pecos pronghorn population fluctuated widely from a low of less than 5,000 animals to a high of 17,000 animals. These oscillations occurred in close association with long-term weather patterns, and the population has often exhibited increases or decreases of 50% from one year to the next. Dramatic fluctuation in wildlife numbers is a normal and necessary phenomena in arid regions such as the Trans Pecos where weather and forage conditions fluctuate dramatically. Similar to livestock grazing in West Texas, serious habitat degradation would occur if numbers of large herbivores (deer, elk, pronghorn) remained high during prolonged drought.

The drought that began in 1993 and ended in 2002 for most areas of the Trans Pecos was one of the worst since the area was settled in the 1880's. As expected, pronghorn numbers declined substantially. However, pronghorn are a resilient species with a tremendous ability to recover from weather-related declines, once conditions improve. Beginning in 2002, improved precipitation led to a pronghorn population increase in the Trans Pecos in each of the past 4 years (2006 surveys had not been conducted when this paper was written). However, with gradually shrinking habitat (brush encroachment and increasing subdivisions), recent pronghorn population increases have been modest. Temporary weather-related declines are of little concern compared to the gradual decline in size and integrity of grasslands in West Texas, and the associated trend in wildlife species that rely on healthy grassland and savanna habitats. West Texas species such as the Aplomado falcon, Montezuma quail, lesser prairie chicken, eastern meadowlark, and the pronghorn have gradually declined (not just during the recent drought) as a result of grassland degradation and human developments. For those concerned about the pronghorn, it is vital to understand the changes occurring in grassland habitats and the actions needed to reverse those trends or at least minimize their impacts. The first step to understanding how these gradual changes are impacting pronghorn is to understand their basic habitat requirements.

Habitat Requirements

Like other wildlife, pronghorn need quality forage, water, cover, sufficient space to live, and proper arrangement of these basic requirements to thrive.

Food

Several food habit studies were conducted in West Texas to gain information about annual and seasonal pronghorn diets (Buechner 1950, Hailey 1979, Roebuck et al. 1982). The research indicated similar results for annual diets, ranging from 51-70% forbs, 25-40% browse, and 5-9% grass. Detailed results of these and other food habit studies are presented in these proceedings in *Food Habits of Pronghorn Antelope in the Trans Pecos*.

Annual and perennial forbs are highly preferred by pronghorns, and they tend to consume them seasonally in proportion to their availability with heaviest use often occurring in fall. Forbs are very palatable and are an excellent source of nutrients for pronghorns. Perennial forbs are more important to pronghorn nutrition than annual forbs because they are available most of the year rather than for a brief period following precipitation. Browse species are second in importance in antelope diets and tend to be used most in spring and summer. However, woody plants can become especially important to pronghorn survival during dry seasons when forbs are not available. Grasses are generally considered the least important forage category in pronghorn diets, as grasses typically represent less than 10% of their annual diet. Although grasses represent a limited proportion of the annual diet, grasses can be very important to pronghorns on a seasonal basis. Pronghorns have difficulty digesting mature grasses. Tender grass shoots, on the other hand, are highly palatable, nutritious, and contain low amounts of indigestible components such as lignin and cutin. The heaviest use of grasses by pronghorns is often during March and April, with grasses sometimes representing 20-30% of the diet during this brief period. Following a severe, dry winter, succulent grass shoots can provide a “nutritional bridge” until woody plants produce new foliage and forbs increase in availability. Although grasses are primarily used in spring, some use of sprouting cool-season grasses occurs during late fall and early winter.

Comparison of diets among 4 species of ruminants indicated that pronghorn selected the highest quality diet, followed in order by domestic sheep, cattle, and then bison (Schwartz et al. 1977). Pronghorn stomachs are about half the size of stomachs found in domestic sheep, which evolved primarily as grass eaters. During experimental feeding trials, pronghorn consumed only 58% as much forage as slightly smaller sheep (Severson et al. 1968). The smaller stomach compartments of pronghorn not only limit daily forage intake, but their digestive system is somewhat inefficient in digesting low-quality, high fiber forage. Their small stomach capacity and small 3rd and 4th stomach compartments (omasum and abomasum) suggest that pronghorn are adapted and limited to use of highly digestible forage such as forbs and fresh shoots of woody plants. Most nutritional studies of pronghorn forage indicate that they select plants containing 10-22% protein, although herds can survive seasonally on forages of 7-9% protein. Forage digestibility is normally high, often ranging from 65-75% total digestible nutrients.

The four greatest influences on pronghorn nutrition include plant diversity, precipitation, numbers of grazing and/or browsing animals (livestock and wildlife), and restrictions on long-distance movements. As previously mentioned, the production and quality of perennial forbs preferred by pronghorn, as well as the presence of annual forbs, are directly tied to rainfall. Under good forage conditions, there is very little diet overlap between cattle and pronghorns. Yoakum and O'Gara (1990) found less than 30% overlap in 9 out of 10 food habit studies. During drought, declining quantity and quality of grasses force cattle to consume increasing amounts of woody plants and perennial forbs, resulting in an increasing diet overlap with pronghorns. If livestock numbers are not substantially reduced during persistant drought, there can be a detrimental impact on pronghorn nutrition (and fawning cover). When a pronghorn herd is contained in a pasture fenced with net-wire, several years of good rainfall can allow them to increase above the long-term carrying capacity of the range. A subsequent local drought can result in a die-off when the herd is unable to move beyond the fence in search of improved forage conditions. The pronghorn is a resilient species that can thrive in arid country, but not when they are prevented from making long-distance movements when necessary.

Water

Pronghorn water requirements and water consumption will vary seasonally and from day-to-day depending on physiological state, physical activity, precipitation, temperature, humidity, and availability of green, succulent vegetation. Consumption of water decreases with low temperatures, high humidity, rainfall, and succulent forage. Conversely, it increases with low humidity, dry vegetation, and higher temperatures. Daily water consumption rates for adults can range from almost no intake of free water during a wet winter or spring to more than a gallon per day in August. However, a close relationship often exists between pronghorn distribution and the location of available water. The vast majority of pronghorn (95%) in the Red Desert (Wyoming) were found within 4 miles of a water source (Sundstrom 1968). In the desert Southwest, most pronghorn are found within 2 miles of water (Ockenfels et al. 1994, Clemente et al. 1995). However, a few small herds (Sonoran pronghorn) exist in arid regions with little or no available water. Dew and water content of cacti and other forage may be sufficient to provide necessary water requirements for adult survival, but may not meet the needs of lactating does (Fox 1997). In southwestern Arizona, the average distance of pronghorn from water was 3.7 miles and the average distance to water did not change between wet and dry seasons (Hughes and Smith 1990). Occasionally, adult males in Arizona have been observed 40 miles from water. In southern New Mexico, pronghorn ranged farthest from developed water in summer when precipitation was greatest and green forage was most available (Clemente et al. 1995).

Differing research results and opinions about pronghorn water needs is influenced greatly by location, season, and forage quality. However, apparent water needs are further confounded by the pronghorn's ability to conserve water through physiological mechanisms. These mechanisms allow them to endure considerable time periods without water, making them particularly suited to their dry, unpredictable environment. When water is unavailable, the animal's primary response is behavioral—conserving urinary, fecal, and respiratory water (Whisler and Lindstedt 1983). The pronghorn's long nose and extensive turbinal bones of the nose cool the air being exhaled and conserve water through condensation of water vapor on the turbinals. Additionally, pronghorn have very large kidneys, primarily an adaptation to conserve body fluids.

Pronghorn prefer to drink from ground-level water sources such as stock tanks or windmill overflows, but they will use most water facilities designed for livestock. The majority of pronghorn range in Texas is adequately watered because of widespread watering systems for livestock. Therefore, water availability on pronghorn range is often taken for granted. However, situations regarding water availability arise in ranching operations that can impact the pronghorn herd. For example, when livestock are removed from pastures for marketing or pasture management reasons, pronghorn can become stressed if water locations are not maintained, especially during summer or prolonged drought. See *Managing Pronghorn Habitat in West Texas* in these proceedings for recommendations on improving water availability for pronghorn.

<u>Cover</u>

Thermal Cover

Pronghorn use vegetation and terrain as thermal cover from extreme weather. If available, pronghorn will use juniper, pinyon, hackberry, oaks, and other trees for shade in hot weather. However, many pronghorn habitats do not have trees or tall shrubs to provide shade. In hot weather pronghorn will use shade where they can find it, including under cholla, yucca, mesquite, and various other woody plants. Some pronghorn herds do not have access to shade and do not seem to suffer from the lack of it, even during periods of high temperatures (Yoakum 2004). Trees and shrubs can also provide some degree of protection during hail storms.

Topography that provides protection during snow storms is especially important for northern herds. However, ridges, draws and swales can provide critical thermal protection for pronghorn herds in the Trans Pecos during infrequent but severe winter storms by reducing the wind speed and chill factor.

Fawning Cover

The primary factor influencing the long-term success or failure of an antelope herd is fawn survival. Nothing is more critical to fawn survival than adequate hiding cover (even more important than predator numbers). Predation losses are substantially reduced when sufficient fawning cover is available. There are 3 factors that dictate whether fawns will have adequate hiding cover. The first factor, precipitation, is beyond the manager's control (although maintaining herbaceous ground cover greatly improves rainfall effectiveness). Livestock grazing management is the second factor influencing fawning cover, which is controlled directly by the manager through stocking rates and pasture deferment. The third factor is the presence of low shrubs and/or desert succulents. See *Managing Pronghorn Habitat in West Texas* for recommendations on improving and maintaining fawning cover.

Characteristics of security cover at fawn bedding sites has been one of the most investigated aspects of pronghorn/habitat relationships during the past 3 decades. In general, herbaceous vegetation (grass and forbs) is the most important feature at fawn bedding sites. Vegetation height of 10-18" provides adequate fawning cover, but pronghorn does often select slightly taller grasses and forbs as fawning areas. In the Trans Pecos the average vegetation height at fawn bedding areas was 22" (Canon and Bryant 1997). Fawn survival often increases when herbaceous vegetation is accompanied by scattered shrubs and succulents. Yucca, cholla, and woody plants not only provide additional lateral screening cover from mammalian predators but provide shade and overhead cover from avian predators. As expected, when grass and forb height decreases, shrubs and cacti become more important at fawn bed sites. An overabundance of shrubs can provide more stalking cover for predators, thereby increasing fawn losses to predators (Bodie 1978).

<u>Space</u>

Pronghorn were not restricted by highways, fences, cities, and subdivisions 150 years ago and, presumably, roamed widely. Today, most pronghorn herds are resident populations. In West Texas and other areas of the desert southwest, the home range of most pronghorn is within a 25-square mile area. In the northern extremes of their range (Wyoming, Montana), pronghorn sometimes migrate more than 100 miles to avoid deep winter snows. The Texas antelope herds are not migratory; however, they do move on a limited basis in response to seasonal availability of forage. Although they can move greater distances, a movement of only 5 or 10 miles may be critical during dry periods when forb production is limited and woody plants and cacti on an adjacent range become necessary for survival.

The unobstructed movement of an antelope herd during all seasons is a key factor in maintaining a healthy and productive herd. Moving to a new vegetation type is the only means available to pronghorn for dealing with seasonal and weather-related changes in forage conditions. The most common barrier that restricts free movement of pronghorn is fencing. Because antelope tend to negotiate fences by diving under or going between wires, a net-wire fence or a sheep-proof, barbed-wire fence can be a serious barrier to pronghorn movements. See *Managing Pronghorn Habitat in West Texas* in these proceedings for recommendations regarding fence modifications to benefit pronghorn.

Characteristics of Pronghorn Habitat

Habitat Visibility

The most obvious feature of quality pronghorn habitat is openness. Can pronghorns survive in habitats where visibility is poor? Yes (at least for awhile)-- we have all seen antelope meandering though some brushy vegetation. A more appropriate question is "Will a pronghorn herd remain healthy and productive over the long-term in habitat with poor visibility?" The answer is no.

Habitats with low-growing vegetation (less than 25” in height) and undulating terrain provide optimal conditions for the pronghorn’s “sight and flight” behavior. Research in Texas and throughout the range of the pronghorn has documented herds occupying habitats that range from 5-30” in vegetation height. However, examination of the largest and most productive herds suggests that a vegetation height of 10-18” is optimum, with 15” being the average. Vegetation exceeding 30” in height is seldom used by pronghorn, especially when the canopy cover is more than 5%.

Reduced visibility in pronghorn habitat results in subtle problems that take effect over time--it doesn't cause immediate mortality of the herd, and it won’t necessarily cause the herd to abandon the site (although there is ample documentation of pronghorn herds abandoning habitat with poor visibility). Habitats with poor visibility simply reduce, over the long-term, survival rates of fawns and even adults. Just as important, pronghorns instinctively avoid areas with poor visibility (unless they are somewhat desperate to fulfill a survival requirement). Encroaching brush effectively reduces their available acres of foraging habitat. Open grasslands and grassland-savannas are critical not only because of good visibility—there are several interacting factors that improve pronghorn survival (predator detection, predator avoidance, visual/social cues among herd members, herbaceous fawn cover, superior foraging habitat, freedom to make unobstructed, long-distance movements).

It is not necessary for 100% of the pronghorn habitat to be high in visibility. Pronghorn require good browse diversity during winter and during drought. This can easily be provided with less than 5% cover of woody species and desert succulents, as long as there is a good diversity of browse (lightly scattered yucca, cholla, ephedra, catclaw, mesquite, juniper, oak, prickly pear, littleleaf sumac, lotebush, and to a lesser extent tarbush). In addition, woody plants located along draws and among low rolling hills provide thermal protection for pronghorns during winter and summer. However, the majority of pronghorn habitat must have good visibility for long-term health and productivity of the herd. See *Managing Pronghorn Habitat in West Texas* in these proceedings for recommendations on maintaining openness of pronghorn habitat.

Mobility for Escape

Pronghorns have tremendous speed and endurance. Habitats that allow them to use their natural abilities for self-defense without interference are critical to the long-term success of the herd. Historically, gray wolves were the primary predator of pronghorn herds in Texas. With considerable endurance and persistence, they hunted in packs and provided a real threat to an adult pronghorn. As the gray wolf was gradually extirpated in the early and mid-1900's, coyotes (kept in check by wolf predation) were allowed to expand in numbers and distribution. They are now the primary predator of pronghorns, followed by bobcats, eagles, and mountain lions. Unable to assume the long-distance-pursuit role of the wolf, coyotes have resorted to a primary strategy of preying on fawns, usually before they are 2 months old. Coyotes are seldom a match for healthy, adult pronghorns on open range. However, in marginal habitat coyotes can have an impact on adult pronghorn. When pronghorns must negotiate brush thickets or a series of barbed-wire fences to escape pursuing coyotes, odds of success lean toward the predator. When fleeing pronghorn are turned by net-wire fencing (or hung up or injured as they attempt to run through), this provides the pursuing predators with an even greater advantage. It does not take long for a coyote to understand that net-wire fences, steep slopes, and dense brush are effective barriers for fleeing antelope and that these barriers can be used to their advantage. Several accounts have been documented of coyotes using fence corners to hem up a fleeing pronghorn for capture.

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FOOD HABITS OF PRONGHORN ANTELOPE IN THE TRANS-PECOS

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Abstract: Pronghorn antelope in the Trans-Pecos, and elsewhere in the Southwest, feed primarily on forbs (broadleaf weeds, herbs and wildflowers). They also make significant use of browse when forbs become less available. At times, pronghorn make heavy use of cholla and pricklypear as a source of emergency feed. They are also known to consume moderate amounts of juniper. Pronghorn consumption of grasses is limited, even when they are green and abundant. Pronghorn often use plants that are toxic to livestock, such as paperflower, groundsel, broom snakeweed and goathead. Available methods to maintain an adequate pronghorn food supply include: modification of net-wire fences to allow greater access to forage; conservative grazing management; selective mechanical brush control; range planting; and development of emergency food sources. The large scale use of the herbicide Spike is probably not conducive to maintaining an abundant and diverse supply of pronghorn food, although research is needed to verify the impacts in the Trans-Pecos.

"What do they eat?"

This is one of the first questions that should be asked to properly manage any species of wildlife or livestock. Fortunately, we know the answer to that question for pronghorn antelope. Some very good scientific information has been gathered over a long period of time that defines the food habits and forage preferences of antelope here in the Trans Pecos and in New Mexico and Arizona. These studies confirm that antelope have very similar food habits across a very wide geographic area.

Based on these studies, antelope are primarily forb eaters. Forbs normally make up 50 to 80% of the diet. Browse is also important, especially during nutritionally stressful periods. Browse normally makes up 15 to 40% of the diet, although at times it can make up over half of the diet. Grasses are a fairly minor part of the diet, normally making up less than 10% of the diet. The major forbs used by pronghorn in the Trans Pecos include: cutleaf daisy, spurges, paperflower, groundsel, dalea, fleabane, annual broomweed, perennial broomweed, bladderpod, goathead, zinnia, bundleflower, rock daisy, snakeherb, croton, gaura, wild buckwheat, lazy daisy and peavine. The major woody plants and cacti used by pronghorn include: cholla, apache plume, hackberry, old man's beard, juniper, skeletonleaf goldeneye, butterflybush, pricklypear, ephedra, and little walnut. Grasses, which make up a small part of the diet include: blue grama, cane bluestem, sideoats grama, black grama, Johnsongrass, vine-mesquite, and tobosagrass. Refer to Table 1 for a summary of six different diet studies.

Buechner Study, Marfa Flat

A detailed food habit study was conducted by Helmut Buechner (1950) in the Marfa Flat for 11 months in 1947. He carefully followed antelope and observed what they were eating through high power scopes. He made note of nearly 5000 different feeding observations and logged over 3000 minutes of actual antelope feeding. In addition to observing what plants were being eaten and the number of minutes of feeding, he also noted the time spent in various activities. His observations show that antelope spend about 70% of daylight hours feeding, 21% lying down, 7% standing and 2% walking and running. It is clear that feeding is the primary daytime activity of antelope. They also spend considerable nighttime hours feeding.

In this study, antelope were observed to consume 228 different plant species, consisting of 124 species of perennial forbs, 36 species of annual forbs, 46 species of woody plants, 7 species of cactus and "succulents", and 15 species of grass. This is an amazing variety of plant life and may indicate the necessity and value of good plant diversity for the well being of pronghorn. The majority of plant species and the majority of the diet content were made up of perennial forbs; annual forbs were much less important. The staple of pronghorn are the long-lived, deep rooted perennial species, not the annuals that come and go with rainfall fluctuations.

The overall yearlong diet (based on minutes of feeding) in this study was 67% forbs, 30% browse, and 3% grass. In this study, the variation between seasons was not pronounced. The seasonal percentage of forbs in the diet varied from 55% to 71%. The seasonal percentage of browse in the diet varied from 25% to 38%, and the percentage of grass varied from 1% to 7%. The top ten plants in the Buechner study are summarized in Table 2.

Hailey Study, Trans Pecos

Another diet study was conducted in Texas by Tommy Hailey (1979), Texas Parks and Wildlife, during 1965 – 1967. Pronghorn from six different habitat types across a wide geographic range within the Trans Pecos were collected. Stomach contents from 90 pronghorn were examined and analyzed. Stomachs were collected each month during this 24 month study and segregated by season. The overall average yearlong diet in this study was 51% forbs, 40% browse and 9% grass. The top ten plants in the Hailey study are summarized in Table 3.

In this study, there was considerable difference between seasons. Forbs were more important than browse during fall and winter. Browse was more important than forbs during spring and summer. This is probably a function of rainfall and availability rather than a true seasonal preference. The author noted that rainfall during the study period varied from abundant to very dry. Table 4 summarizes the seasonal variation.

The only plant to receive heavy use during all four seasons was cholla. The joints as well as the fruits were used. The author expressed the belief that cholla is an extremely important plant for pronghorn during critical periods, and that it may help prevent die-offs.

Russell Study, New Mexico

A series of four diet studies was conducted in New Mexico during 1956-1959 by Paul Russell (1964), New Mexico Department of Game and Fish. Three of these studies are summarized here, since they have relevant application for Trans Pecos conditions.

On a ranch north of Roswell, in desert grassland, 31 pronghorn stomachs were sampled. The overall yearlong diet at this location was 94% forbs, 5% browse and 1% grass. The top ten plants in this study are summarized in Table 5.

The second study site was in the High Plains region of northeastern New Mexico, where 27 stomachs were examined. The overall yearlong diet was

67% forbs, 29% browse and 4% grass. This site was characterized by sandy soils. The top ten plants in this study are summarized in Table 6.

The third study site was in the Western Plains of New Mexico, near the Arizona state line, where 25 pronghorn stomachs were examined. The overall yearlong diet was 84% forbs, 15% browse and 1% grass. The top ten plants in this study are summarized in Table 7.

These studies, conducted over a wide geographic area, verify that pronghorn depend very heavily on forbs. Browse made up a modest part of the diet, and grasses appear to be generally of minor importance.

Brown Study, Arizona

The most recent pronghorn diet study was conducted during 2003 and 2004 in west central Arizona in a mesquite – tobosagrass habitat (Brown et al. 2006). In this study, fresh fecal pellets were collected each month from at least five different pellet groups. A procedure known as microhistological examination was used to identify plants that had been eaten and the percent composition of these plants in the diet. The overall yearlong diet across the 24 month period was 82% forbs, 16% browse and 2% grass. The top ten food plants in the Brown Study are summarized in Table 8

Toxic Plants

It is interesting to note that pronghorn make significant use of several plants that are known to be toxic to livestock. Broom snakeweed, known to cause abortion in cattle, made up 7% and 5% of the diet in winter and spring in the Trans Pecos, Hailey Study (1979). It also made up 14% of the diet in the Russell Study (1964) near Roswell, and 10% of the diet in the High Plains location. Broom snakeweed is a drought hardy, tap rooted perennial that provides green leaves during late winter and early spring.

Woolly paperflower, which can cause emaciation and death in sheep, was the number two plant for pronghorn in the Buechner Study (1950) in the Marfa Flat, making up 11% of the annual diet. Wooly paperflower is often extremely common in the Trans Pecos, sometimes covering the pastures with its bright yellow flowers.

Two species of groundsel or senecio were important parts of the diet in the Buechner Study. These plants can cause permanent liver damage in cattle and horses. Threadleaf groundsel (also called woolly senecio), and Riddell groundsel, when grouped together, was the number 4 plant in the diet and made up 5% of the annual diet. According to Buechner, threadleaf groundsel is a staple for pronghorn in all seasons of the year.

Goathead was the number three plant in the Buechner Study, and made up 6% of the annual diet. It may have been the most important plant eaten in the summer. Goathead can cause photosensitization in sheep and probably in cattle.

Apparently, in most cases, pronghorn have the capacity to consume toxic plants with little or no ill effect. Pronghorn may have a very specialized liver that can detoxify the chemicals in these plants. The combination of paperflower, groundsel, goathead and broom snakeweed made up 23% of the annual pronghorn diet in the Buechner Study on the Marfa Flat.

There are a few cases where toxic plants have caused sickness and death for pronghorn. Loco was eaten in spring and summer in the Buechner Study (1950), and when sufficient quantities were eaten, pronghorn showed symptoms similar to loco poisoning in cattle. Tarbush, also known as blackbrush, made up 4% of the winter and spring pronghorn diet in the Hailey Study (1979) with no adverse effect. However, in another study, Hailey and others (1966) documented that a major pronghorn die off in the Marfa Flat in 1965 was due to very high consumption of tarbush in combination with general malnutrition, drought, over-stocking and depletion of the range. All of these factors were made more acute by the net-wire fences and the inability of pronghorn to move to more favorable feeding grounds. Toxic amounts of tarbush were apparently consumed as a last resort.

Nutritional Requirements

No studies are known which would indicate what the nutritional requirements are for pronghorn. However, since pronghorn consume a high percentage of forbs and browse, and a low percentage of grasses, it can be presumed that they have fairly high nutritional requirements. Forbs provide the highest level of protein, energy and minerals of all the forage types. Browse is generally next in nutritional quality. Grasses usually have the lowest levels of nutrition compared to forbs and browse.

Dietary Overlap and Competition

One of the roles of the ranch manager is to match the various kinds and amounts of vegetation on the range to the appropriate kinds and numbers of grazing animals. Certain mixtures of animals fit together very well and are complimentary. Other animal mixtures do not fit together as well and can become competitive. Pronghorn generally fit together very well with cattle since their food habits are very different. This makes sense when considering the historic grazing relationships between pronghorn and bison, which co-existed for thousands of years. Pronghorn do not fit very well together with sheep or with goats since their food habits are somewhat similar. This is especially true where pronghorn are confined in the same pastures as sheep or goats with net-wire fencing. Pronghorn and mule deer also have somewhat similar diets; however, these two species tend to segregate into different habitat types, making the dietary overlap of less importance.

Table 9 provides a general comparison of the diet for several species sometimes found together in pronghorn range. It should be noted that the percentages shown in Table 9 are approximate and should be used for comparison purposes only. Food habits for most animals will change from season to season, and year to year, and from place to place, based largely on availability. Animals often have the ability to switch from one plant type to another as conditions change. Animals such as sheep, goats and exotics can readily switch from their preferred diet of forbs and browse to a diet of grasses if needed. Pronghorn seem to be able to switch at least partially to browse and cactus during stressful periods. Pronghorn, on the other hand, apparently cannot switch to a diet of grass. In the absence of forbs or browse, pronghorn cannot survive.

How to Maintain or Improve the Pronghorn Food Supply

Good pronghorn range should have at least some pronghorn food plants growing on nearly every square yard. Although the majority of the plant life in pronghorn range will usually be grasses, there should also be a good distribution and variety of perennial forbs and browse. Ranchers interested in pronghorn should learn to recognize many of the forbs and browse plants used by antelope. The following paragraphs offer some specific ideas and techniques that can be used to maintain or increase the food supply.

Accessibility to Forage

One of the greatest needs of pronghorn is the ability to move about freely over large areas and great distances to find adequate feed. When pronghorn are confined with net-wire fences, their access to feed is likely to be impaired in dry periods. David Brown and others (2006) found that pronghorn must change locations when desired forage becomes scarce due to drought or livestock competition. Pronghorn cannot change their diet to grasses to compensate for a lack of forbs and browse. The instinct of the pronghorn is to wander long distances in search of areas that provide adequate food. The modification of net-wire fences to allow antelope to pass under is a critical need on some pronghorn range in the Trans Pecos. Maintaining good access to water is also important as pronghorn move about in search of green forage.

Grazing Management and Rainfall Effectiveness

On most ranges in the Trans Pecos, the most feasible method for maintaining an adequate supply of perennial forbs is to practice good, conservative grazing management. Keeping a good cover of grass is the best insurance to maximize rainfall infiltration and maintain soil moisture. Bare ground and sparse vegetation result in poor rainfall penetration, high runoff, erosion and desertification. By maximizing the amount of rain that soaks in, both grass and forb production will be improved. Perennial forbs generally have very deep root systems and are able to extract moisture and retain green leaves even when grasses are dormant. Conservative, light stocking rates, adjusted for prevailing conditions is the key to retaining a grass cover and maximizing rainfall effectiveness. Providing periodic planned rest periods from grazing will also help to favor the most desirable forbs. De-stocking during drought should be considered an essential part of ranching in the Trans-Pecos.

In preferred pronghorn feeding areas, ranchers may pay special attention to cattle feeding patterns. If cattle are observed feeding regularly in prime pronghorn areas, a decision can be made to move cattle to a different area. One cow, consuming 85% grass and 15% forbs is actually eating more forbs each day than one pronghorn. Be sure to keep the water available even if cattle are moved.

Juniper and Mesquite Control

On ranges where juniper or mesquite is increasing, the pronghorn manager may choose to use selective mechanical brush control methods to thin the density of these species. Dead brush slash should normally be left to lie on the ground instead of raking and piling. The dead brush will help provide some shade and mulch and physical protection to newly establishing forbs.

Spike

The application of Spike (tebuthiuron) herbicide pellets for control of creosotebush (greasewood), and tarbush (blackbrush), is a commonly recommended practice for improvement of grasslands and cattle range. Good results are often observed, with a good brush kill and an improvement in desirable forage for cattle. However, Spike is active on many, if not most, broadleaf plants including desirable forbs and browse and remains active in the soil for several years. This herbicide favors grass production at the expense of broadleaf plants. Since pronghorn are not grass eaters, and since the herbicide will injure or kill many species of forbs and browse, the application of Spike is not a recommended practice to maintain or increase the pronghorn food supply. Studies have not been conducted in the Trans Pecos to document the extent of damage to pronghorn food plants or to determine how long the damage will last. Studies in other areas indicate substantial reductions in forbs and browse after Spike applications. It is possible that the detrimental impact to pronghorn food plants is temporary and that the restoration of good grassland conditions will outweigh the negative effects. If mid grass fawning cover is lacking, some strategic Spike application may be desired to create better grassland habitat. These applications should generally not be large contiguous applications.

Range Planting

In some cases, it may be possible to increase the pronghorn food supply with range plantings. Range plantings are not normally recommended in the region due to low and erratic precipitation and the high risk of failure. However, in some years, conditions are favorable for success. If the manager is willing to wait for favorable conditions and take the risk, range seeding projects may be an option. Good soil moisture is the primary prerequisite for successful establishment. Adequate seedbed preparation is also important. Most range plantings will include native grasses such as blue grama, sideoats grama, green sprangletop, and others. In addition to these grasses, native perennial forbs such as bush sunflower, engelmanndaisy can be added. Australian saltbush, an introduced perennial forb can be used south of I-20. Yellow sweet clover can also be added as a short-lived re-seeding legume. Fourwing saltbush can also be added to the mix as a desirable long-lived evergreen browse plant. Ranchers who are conducting mechanical brush control may want to seed the disturbed areas in hopes of getting some of these species established. Timely rainfall and grazing management for one to three years following re-seeding will be critical to the success of the planting.

Maintaining an Emergency Food Supply

Several of the diet studies indicate that cactus is often an important part of the pronghorn diet. Hailey (1979) emphasized the importance of cholla and other researchers documented the importance of pricklypear, especially during nutritional stress periods. Some areas of moderate cholla and/or pricklypear within each pasture should be considered desirable for the well being of pronghorn. Many pronghorn areas already have an adequate amount of cactus, while other areas may be lacking in these emergency food sources. Where cactus is already present, but in small amounts, it can be increased by mechanical spreading, by dragging with rails, chains or cables. This technique should be done when there is some soil moisture and a high likelihood of pads and joints taking root. This unorthodox technique should be done carefully and in moderation to avoid creating excessive amounts of cactus.

Summary

No one really seems to know for sure what the weak link(s) may be for the various pronghorn populations across the Trans Pecos. Some would say predators. Some say drought. Others will say confinement by net-wire fences. Yet others will say brush encroachment. One thing we do know for sure is that pronghorn have fairly specific food and nutrition requirements that affect their health on a daily basis. Ranchers interested in the long term well being of pronghorn can pay special attention to grazing management and the need for these animals to move about freely. One of the best methods for increasing pronghorn forage is maximizing the effectiveness of rainfall by maintaining a good cover of desirable vegetation. In some cases, more aggressive habitat management practices may help maintain or increase the food supply for pronghorn.

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Table 1 . Summary of six pronghorn diet studies.

	% of Annual Diet		
Study and Location	**Forbs**	**Browse**	**Grass**
Buechner, Marfa Flat	67	30	3
Hailey, Trans Pecos	51	40	9
Russell, Roswell, NM	94	5	1
Russell, High Plains, NM	67	29	4
Russell, West NM	84	15	1
Brown, Arizona	82	16	2

Table 2. Top ten pronghorn food plants, Buechner study, Marfa Flat, 1947.

Plant Species	% of Diet
Cutleaf Daisy	16
Woolly paperflower	11
Goathead	6
Groundsel	5
Hackberry	3
Old man’s beard	3
Fleabane	3
Juniper	3
Gaura	2
Butterflybush	2

Table 3. Top ten pronghorn food plants, Hailey study, Trans-Pecos, 1965-1967.

Plant Species	% of Diet
Spurges	37
Cholla	8
Apache plume	6
Gregg dalea	4
Annual broomweed	4
Juniper	3
Bladderpod	3
Skeletonleaf goldeneye	3
Plains zinnia	3
Bundleflower	3

Table 4. Seasonal variation in diet, Hailey study, Trans Pecos, 1965-1967.

	% of Diet			
	Spring	Summer	Fall	Winter
Forb	35	36	77	55
Browse	45	59	20	36
Grass	20	5	3	9

Table 5. Top ten pronghorn food plants, Russell study, New Mexico desert grassland, 1956-1959.

Plant Species	% of Diet
Stendandrium	17
Broom snakeweed	14
Wild buckwheat	12
Aster	8
Spurge	7
Gaura	5
Rushpea	3
Apache plume	2
Mexican sagewort	2
Plains zinnia	1

Table 6. Top ten pronghorn food plants, Russell study, New Mexico High Plains, 1956-1959.

Plant Species	% of Diet
Yellow woolly-white	16
Sand sage	13
Plains zinnia	11
Perennial broomweed	10
Mesquite	9
Cactus	7
Spurge	6
Cutleaf daisy	4
Rushpea	2
Portulaca	2

Table 7. Top ten pronghorn food plants, Russell study, New Mexico Western Plains, 1956-1959.

Plant Species	% of Diet
Sagewort	57
Wild buckwheat	15
Cactus	11
Spurge	4
Portulaca	3
Juniper	2
Skunkbush	2
Bluets	1
Rabbitbrush	1
Bladderpod	1

Table 8. Top ten pronghorn food plants, Brown study, West Central Arizona, 2003, 2004.

Plant Species	% of Diet
Wild buckwheat	15
Sagewort	9
Filaree	9
Globemallow	8
Borage	8
Cactus	7
Ragweed	4
Tallow weed	3
Common mallow	3
Ratany	3

Table 9. Generalized food habit comparison of wildlife and livestock in West Texas.

	% in Diet		
Animal	**Forbs**	**Browse**	**Grass**
Pronghorn	70	25	5
Cattle	10	10	80
Domestic Sheep	40	20	40
Goats	30	50	20
Mule Deer	30	60	10
Aoudad Sheep	20	40	40
Elk	20	40	40

HOME RANGE AND SURVIVAL OF PRONGHORN IN THE TRANS-PECOS REGION OF TEXAS[1]

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PART I. HOME RANGE OF TRANS-PECOS PRONGHORN

Abstract: We determined home ranges of pronghorn (Antilocapra americana) over a 3-year period in the Trans-Pecos region of Texas. Male pronghorn consistently had smaller ($P < 0.05$) home ranges than females; males ($n = 8$) and females ($n = 28$) averaged 25.1 ± 4.5(SD) and 42.4 ± 10.1 km^2, respectively. Drought conditions influenced home ranges of females. In 1990, below average precipitation occurred from January-August; home ranges of females ($n = 36$) during the post-fawning season (18 June-20 August) were larger ($P < 0.05$) than female home ranges ($n = 36$) during the fawning season (15 April-17 June), averaging 32.5 ± 14.5 and 17.1 ± 8.3 km^2, respectively. During 1991, a year of above average precipitation, home ranges were similar ($P > 0.05$) between fawning and post-fawning females ($n = 11$, each group). Home ranges of females during the fawning season were similar ($P > 0.05$) between 1990 and 1991, averaging 17.1 ± 8.3 and 17.2 ± 9.5 km^2, respectively. However, in 1990 females during the post fawning season had larger ($P < 0.05$) home ranges than those in 1991, averaging 32.5 ± 14.5 and 20.4 ± 6.2 km^2, respectively. We concluded that pronghorn in the Trans-Pecos require larger home ranges than pronghorn occurring in more optimal habitats of their geographic range, that females require larger home ranges than males, possibly related to greater nutritional demands, and that monthly precipitation, which affects forage quantity and quality, influences home range size for females, particularly during the post-fawning period.

Introduction

Little information is available on home ranges of pronghorn (Antilocapra americana). Studies have been limited to Montana (Bayless, 1969; Kitchen, 1974), Idaho (Hoskinson and Tester, 1980; Reynolds, 1984), New Mexico (Sanchez, 1993; Clemente et al., 1995), and Arizona (Wright and deVos, 1986). Although these studies make important contributions toward understanding pronghorn home ranges, differences between geographic regions and environmental conditions make specific comparisons between studies ambiguous. Additionally, widespread use of different home range estimators makes direct comparisons of home range sizes difficult (Boulanger and White, 1990).

Although the Trans-Pecos region of Texas represents important habitat for pronghorn, no specific information is available on home ranges. Thus, we conducted a 3-year study to examine home ranges of pronghorn. Specifically, our objectives were to quantify and compare home ranges for adult male and female pronghorn in the Trans-Pecos region of Texas.

Materials And Methods

The study was conducted in Hudspeth County, Texas, on the Double U Ranch, which is part of the University of Texas Lands System. Topography of the study area in the Trans-Pecos ranges from steep to gentle hills on the west side bordering the Hueco Mountains, to open flats on the east side. Typical rangeland sites include stony hills, clay flats, gypsum flats, and deep uplands (Correll and Johnston, 1970). Annual precipitation of this semi-arid region is about 30 cm, most of which occurs during late summer. Annual temperatures range from -18 to 38°C. Important vegetation types are yucca (Yucca elata) savannahs, grama (Bouteloua spp.) grasslands, and creosote bush (Larrea tridentata)-tarbush (Flourensia cernua) shrublands.

The vegetation community is further characterized by Canon (1993). On 5 March 1990, we trapped pronghorn with a corral-type trap and applied mortality-sensing, radio collars (3-5 year life expectancy) to 50 females and eight males. Females also were marked with numbered ear tags. We used telemetry to obtain general locations of collared individuals then made visual observations to determine specific locations. We marked each location on U.S. Geological Survey topographic maps. The entire study area was accessible by vehicles and ATV ; the open terrain easily permitted identification of marked individuals without disturbance. Locations of animals were recorded randomly as other research activities were being conducted during April-August, 1990-92. We obtained additional locations 1-2 times per month during September-March, 1990-92. Locations were taken in daylight hours and are not representative of nighttime activity areas. However, overall home-range estimates are presumed to include these areas based on our knowledge of marked animals and the study area.

We converted locations to Universal Transverse Mercator coordinates for computer analyses. No estimates of triangulation error associated with individual locations were computed since collared individuals were visually observed and the exact locations were recorded on maps. Location error could occur by incorrectly plotting or misreading topographic maps. However, we believe less error was involved using our method than in obtaining locations through triangulation of unobserved individuals. We used the 90% harmonic mean estimator (Dixon and Chapman, 1980), based on findings presented in Canon (1993), to generate home range estimates using the Microcomputer Program for Analysis of Animal Locations software (Stuwe and Blohowick, 1985).

We chose to combine data from 1991 and 1992 for comparisons between male and female pronghorn, due to reduced observations resulting from radio collar failure (up to 90% by the last year of study) and after preliminary analysis (nine animals with $\geq$25 locations each for 1991 and 1992) indicated home ranges were similar between years.

We separated the summer period into two distinct temporal periods, the fawning season and the post-fawning season. The fawning season was the period extending from two weeks prior to the first known fawn birth date to two weeks following the last known fawn birth date (15 April-17 June); the post-fawning season was the period from the end of the fawning season to the time when fawns readily accompany females at 60-120 days of age (late August). We compared the effects of season on female home range size for 1990 and 1991 only, since insufficient sample size in 1992 and too few observations negated comparisons between 1991 and 1992 to determine if data from both years could be pooled.

We determined overall (3-year) home-range estimates using those pronghorn that survived through the study and had ≥100 locations. Estimates for 1990 and 1991-92 included only those animals with ≥50 locations for each period. Fawning and post-fawning seasonal estimates included only those females with ≥15 locations per season. We used t-tests for comparisons of mean home ranges for sex, season, and year variables.

Precipitation was not recorded on the study area. Thus, we estimated monthly precipitation by averaging rainfall records from the two closest weather stations, the El Paso East (8 km west) and Cornudas (30 km north) stations (NOAA, 1990-92).

Results And Discussion

Home range estimates across the 3-year study were determined for eight male and 28 female pronghorn (Table 1). Overall, we found home range sizes in male and female pronghorn averaged 25.1 ± 4.5(SD) and 42.4 ± 10.1 km^2, respectively. With the understanding that different estimators yield different home range sizes, pronghorn in our study appeared to have larger home ranges than those found in more optimal habitats. In southeastern Idaho, Reynolds (1984) reported home range of 16 pronghorn was 11.9 ± 2.1(SD) km^2 (0.25 km^2 grid method). Additionally, Hoskinson and Tester (1980) found pronghorn from different areas in southeastern Idaho and southwestern Montana ranged from 0.97 to 1.5 km^2 (minimum area method). However, we report smaller home ranges than found in Arizona (Wright and deVos, 1986). Wright and deVos (1986) attributed large (41 to 1,213 km^2) home ranges of the Sonoran pronghorn (A. americana sonoriensis) to limited forage availability.

For 1990 and 1991-92, six males and 22 females were used for comparisons (Table 1). Home range was consistently larger for females than for males. These results differ from other studies, in which males had larger home ranges (Wright and deVos, 1986) or both sexes had similar home ranges (Reynolds, 1984; Clemente et al., 1995). In south-central New Mexico, Sanchez (1993) compared mean home range sizes of two adult male and two adult female pronghorn over a 14-month period (two observations per month). His estimates, based on the minimum convex polygon method, were 16.6 and 11.9 km^2 for males and females, respectively. These estimates were substantially lower (by 34 and 74%, respectively) than home range sizes we found. Clemente et al. (1995) found water sources were important in determining home range sizes, in which middle points of home ranges were no farther than 3 km from permanent water. However, permanent water sources (established for cattle) on our study area were relatively evenly distributed at about 1 per 2.6 km^2 (inclusion of naturally occurring wetlands would further increase water sources).

In our study, differences between sexes may be related to behavior. Based on the high incidence of fawn predation on the study area (Canon, 1993), predator avoidance and escape strategies may have caused females to move greater distances. Additionally, nutritional requirements of females during lactation are greater than at any other time. Although more energy is expended as home range increases, lactation demands may require expansion of home range to find adequate forage, particularly during periods of below average range conditions.

For comparisons between fawning and post-fawning seasons, 36 and 11 females were used during 1990 and 1991, respectively (Table 2). In 1990, mean home range of females was larger ($\underline{P} < 0.05$) in the post-fawning period than was found for females during the fawning period. The trend was similar in 1991 but the difference was not significant ($\underline{P} > 0.05$). Mean home range during the fawning period was similar ($\underline{P} > 0.05$) both years.

Annual precipitation during 1990-92 (34.6, 44.9, and 32.9 cm, respectively) was higher (^{2} = 9.5, df = 2, $\underline{P} < 0.05$) than the long term average (29.4 cm; years 1985-92), of which precipitation in 1991 was substantially higher (86% of generated ^{2} value). However, monthly precipitation appeared to be a more important factor in influencing home range sizes. Drought conditions occurred from September 1989 through June 1990 (Fig. 1) resulting in less favorable habitat conditions. Although not significantly different ($\underline{P} > 0.05$), mean home range of males in 1990 was larger (by 3.9 km^2) than home ranges during 1991-92 (years when monthly rainfall was consistent with or greater than long-term precipitation rates). Also, mean home range in females averaged 6.2 km^2 larger ($\underline{P} < 0.05$) in the 1990 than in 1991-92. In 1990, females during the post-fawning season had significantly ($\underline{P} < 0.05$) larger home ranges than those during 1991 (Table 2). However, females during the fawning season in both years exhibited nearly identical home-range sizes (Table 2). This suggests that maternal protective instincts may have been the overriding factor affecting size of home range during this period, at least until fawns become more mobile and could keep up with their mothers (i.e., post-fawning period). These results suggest that management strategies must take into account the effects of variable precipitation rates that can directly affect forage quantity and quality, which in turn, influences home range size in pronghorn.

In summary, we found that female pronghorn ranged farther than males. Females during the post-fawning season had larger home ranges than those during the fawning season, particularly when below average precipitation occurred during spring and summer months. Whereas, females during fawning and post-fawning seasons had similar home range sizes under conditions of normal or above normal precipitation. Our results suggest that during extended periods of low rainfall, females, particularly during the post-fawning season, must range greater distances to meet their nutritional requirements in the Trans-Pecos region of Texas.

We are grateful to S. Hartman of University of Texas Lands for providing major financial support and access on the Double U Ranch and to S. Sullenger for assistance. We acknowledge and thank B. and A. Beard for logistical support. We thank J. Teer and L. Drawe of the Welder Wildlife Foundation for their advice and consultation, and the Welder Wildlife Foundation for financial support. This is Welder Wildlife Foundation publication No. 458 and publication No. 06-130 of the Caesar Kleberg Wildlife Research Institute.

PART II. SURVIVAL RATES OF TRANS-PECOS PRONGHORN

Abstract- Survival rates are an important aspect of population profiles that provide insight into population fluctuations. We examined survival and causes of mortality in pronghorn (Antilocapra americana) from the Trans-Pecos region of Texas during 1990-93. We trapped 79 adult and 101 fawn pronghorn, from which 9 adult males, 46 adult females, and 78 fawns were used to estimate survival rates using a modified Kaplan Meier procedure. For the 3 years combined, adult survival was estimated to be $S(t) = 0.85$; male and female survival was $S(t) = 1.0$ and $S(t) = 0.82$, respectively. Survival did not differ ($P > 0.05$) between adult males and females. Overall, fawn survival was estimated at $S(t) = 0.11$. Comparisons among years found fawn survival varied ($P < 0.05$) only between 1991 ($S(t) = 0.18$) and 1992 ($S(t) = 0.06$). Of 101 fawns initially marked, 80% died within the first 30 days of life. They survived on average 18, 19, and 10 days for each of 3 fawning seasons (1 May-30 August, 1990-92), respectively. Survival estimates were similar ($P > 0.05$) between 40 male and 38 female fawns ($S(t) = 0.10$ and $S(t) = 0.12$, respectively). Fifty-four percent of the variation in current-year fawn production was explained by total precipitation occurring in the previous year. About 81% of fawn mortality was attributed to predation, of which most resulted from coyote (Canis latrans). Other predators included mountain lion (Felis concolor), bobcat (Lynx rufus), and golden eagle (Aguila chrysaetos). We concluded that high survival of adult pronghorn coupled with low fawn survival under conditions of normal precipitation resulted in a relatively stable pronghorn population during 1990-93 in the Trans-Pecos region of Texas.

Introduction

Successful animal populations depend upon a balance between reproductively active adults, recruitment, and survivorship. Thus, it is necessary to determine survival estimates and the causes of mortality in specific animal populations to provide a better understanding of their population dynamics and to develop appropriate management strategies. Mortality of pronghorn has often been caused by predation (Lehti 1947, Thompson 1949, Bruns 1970, Hailey 1986, Gese et al. 1988). Although various predators are capable of killing adult pronghorn, particularly under severe winter conditions, high levels of predation are largely confined to fawns. Coyote predation was responsible for 71% of fawn mortality in southeastern Colorado (Firchow 1986, Gese et al. 1988). Other studies have shown evidence of coyote predation on pronghorn fawns varying from 12-31% (Barrett 1978, Beale 1978, Bodie 1978, Autenreith 1982). Beale and Smith (1973) found 61% of fawns that died within 4 months of age were killed by bobcats. Autenreith (1982) reported 33% of 24 known predator kills on fawns were the result of golden eagle predation. Although various predators can opportunistically prey upon pronghorn, abundant predators that commonly occur within specific geographic regions likely represent the major source of predator mortality.

Fawn mortality from other causes includes "weak fawn syndrome" (Bodie and O'Gara 1980), disease, starvation, abandonment, and stress. However, studies conducted in Montana (Von Gunten 1978, Corneli 1979) indicated that disease, abandonment by dams, precipitation, and food availability did not significantly affect fawn survival.

In the Trans-Pecos region, pronghorn mortality from disease is minimal (Hailey 1986). However, drought and infrequent severe winters have caused large losses in isolated herds (Buechner 1950, Hailey 1986). Severe weather in combination with barriers (i.e., net-wire fences) that prohibit movement of herds and competition with domestic sheep have resulted in large dieoffs from starvation (Hailey et al. 1966). These instances are less common now with the shift from sheep to cattle ranching in the Trans-Pecos.

Although many studies have examined factors that influence pronghorn survival, few have actually determined age-specific survival rates of pronghorn over extended periods of time. We conducted a 3-year study to estimate survival rates of both adult and fawn pronghorn, determine causes of mortality, assess general characteristics of herd population dynamics, and provide management recommendations for Trans-Pecos pronghorn.

We are grateful to S. Hartman of University of Texas Lands for providing major financial support and access on the Double U Ranch and to S. Sullenger for assistance. We acknowledge and thank B. and A. Beard for logistical support. We thank J. Teer and L. Drawe of the Welder Wildlife Foundation for their advice and consultation, and the Welder Wildlife Foundation for financial support. This is Welder Wildlife Foundation publication No. 458 and publication No. 06-130 of the Caesar Kleberg Wildlife Research Instutite.

Study Area

We conducted the study in northern Hudspeth County, Texas, on University of Texas Lands (UTL) property, primarily in the 6,500-ha Buckhorn Pasture of the Double U Ranch. Topography ranges from steep to gentle hills on the west side bordering the Hueco Mountains, to open flats on the east side of the study area. Typical range sites are stony hills, clay flats, gypsum flats, and deep uplands (Correll and Johnston 1970). Climate includes dry winters and wet summers; most of the annual precipitation occurs in late summer. Temperatures range from -18 to 38°C.

The most important vegetation types are yucca (Yucca elata) savannahs, grama (Bouteloua spp.) grasslands, and creosote bush (Larrea tridentata)-tarbush (Flourensia cernua) desert shrub areas (Correll and Johnston 1970). Canon (1993) further characterized the flora of the study area. The study area was managed by UTL personnel. Management practices included a coyote control program. This program has been in effect since 1982, which included aerial shooting of coyotes prior to and during the fawning season. Also, UTL personnel conducted annual aerial surveys to evaluate pronghorn fawn production (fawn per doe ratio). The UTL leased cattle grazing rights to the Double U Ranch. Cattle were rotated between 2 pastures, one of which included the Buckhorn Pasture, on a 3-month rotation. Annual stocking rates were approximately 35 ha/animal unit as cooperatively agreed to by the UTL manager and the Double U Ranch.

Methods

We trapped adult pronghorn on 5 March 1990 with a corral drive trap and helicopter. Pronghorn were collared with numbered radio transmitters. Additionally, females were marked with numbered ear tags. Approximate ages were determined using horn length and mandibular dentition techniques (Buechner 1950, Dow and Wright 1962). We radio-tracked pronghorn daily beginning about 2 days post-capture. Tracking was done from a vehicle using a hand-held H-antenna. Visual observations were obtained by reading ear-tag or collar numbers with binoculars or spotting scope; locations were marked on topographic maps. Data were gathered in this manner from March-August 1990-92. From September-February of all 3 years, we located animals 1-2 times per month to monitor survival. Although triangulation was originally considered as a way of obtaining telemetry fixes on animals, visual locations of collared individuals were facilitated by the open terrain and proved to be an efficient and accurate way of locating animals with minimal disturbance. We could identify specific individuals with spotting scopes up to about 500 m. Most (90%) of the study area was accessible by standard vehicles; the remainder was surveyed with all terrain vehicles (ATV's).

We captured fawns within 5 days of parturition during April-June (primary fawning month was May) 1990-92 and fitted each fawn with a mortality-sensing, ear-tag transmitter (approximately 32 g). Surgical gloves were used in handling fawns; transmitters were placed in plastic bags containing leaves of the creosote bush to mask our scent prior to ear attachment. We did not take body measurements to minimize disturbance of the fawns and decrease potential abandonment by the dams. Handling time of fawns was about 1-2 minutes.
We were uncertain whether pronghorn dams would accept their fawns following handling, thereby biasing survival estimates. We monitored the first 3 marked fawns to determine how the dams would react. None of the dams exhibited adverse reactions to their fawns or the transmitters. Thus, we continued fawn-marking operations. Daily relocation of fawns was critical in determining cause of death; therefore, we radio tracked fawns daily and visually evaluated their general condition. We approached bedded fawns with caution to minimize disturbance; in most instances, they remained bedded.

We carefully examined dead pronghorn for cause of death. Carcasses and the area surrounding the site were searched thoroughly for predator-specific evidence (i.e., tracks, hair, feathers, evidence of a struggle, etc.) generally following the procedures outlined by O'Gara (1978). All information was recorded and photographs were taken of the site and surrounding area. After preliminary inspection, we froze fawn carcasses or remains thereof for later inspection. In all instances of fawn mortality, we had observed individual fawns alive the previous day.

We estimated precipitation on the study area by averaging annual precipitation from the 2 nearest weather stations, the El Paso East (EPE; 8 km west) and the Cornudas (COR; 22 km east of the study area) weather stations (NOAA 1992).

Statistical Analyses

We estimated fawn and adult survival using the Kaplan Meier (1958) procedure, modified for staggered entry of animals (Pollock et al. 1989). This approach allows for newly marked individuals to be added to the model as they are captured. To reduce possible bias caused by trapping stress, we eliminated all fawns that died $\leq$3 day's post-capture from survival analyses. Fawns that survived this period are hereafter noted as test fawns.

We used chi-square tests to compare fawn survival by year and sex, and adult survival by sex. A z-test was used to compare fawn survival between years (Pollock et al. 1989).

We used simple linear regression to make comparisons between previous year's precipitation and UTL fawn production estimates. We also compared the estimated date of birth (DOB) with number of days fawns survived. We estimated fawn DOB, based primarily on condition of the umbilical cord and motor skill development. Number of days survived was the number of days from the estimated DOB to the date of death or to the end of the field season in surviving fawns.

Results

We trapped 79 adult pronghorn, of which 8 (10%) were <2 years old, 43 (55%) were 2-3 years, and 28 (35%) were $\geq$4 years old. We attached mortality-sensing radio collars to 8 males and 51 females. Additionally, 1 yearling doe, too small to be fitted with a collar, was ear tagged and 1 additional buck was marked with a numbered collar. These 2 animals were seen frequently for the duration of the study and were included in survival estimates. Overall, 9 adult males, 46 adult females, and 78 fawns were used for survival estimates (Table 1).

Adult Survival

Five adult females were lost within 2 weeks of trapping; cause of death or disappearance was primarily attributed to trapping stress. However, 1 female was apparently killed by a mountain lion. Three of 5 females that died within 2 weeks were $\geq$4 years old; the other 2 females were 2 years old. These 5 individuals were excluded from survival analysis calculations.

Adult survival from March-February 1990-93 was S(t) = 0.85 (Table 1). Survival estimates for males and females were S(t) = 1.00 and S(t) = 0.82, respectively, and were not different (P > 0.05, ^{2} = 1.80). However, the male survival estimate is not representative of the male population because harvesting of collared males was not permitted. Typically, bucks-only hunting is allowed on most ranches in the Trans-Pecos region.

Eight females used for survival estimates died during the study (15%). We could not determine the cause of death in 3 females. In 1990, after an extended dry period, 1 female died from compaction of the rumen caused by eating cactus (*Opuntia* spp.). In 1991, 1 female died during parturition and the other was killed by a mountain lion. Two other females were presumed dead, because they were not radio-located, found dead, or observed. Seven of the 8 (88%) females that died were $\geq$5 years of age; the other female was 4 years old.

Fawn survival

We found 80% of all fawns (n = 101) and 73% of test fawns (n = 78) died within 30 days of birth. Although survival estimates apparently varied among sex within years (probably the result of low sample sizes), overall survival estimates were similar (P >

0.05) between the 40 male and 38 female fawns (Table 2). Survival of test fawns from 1 May-30 August was S(t) = 0.11 across the 3 fawning seasons. Fawn survival in 1990, 1991, and 1992 was 0.15, 0.18, and 0.06, respectively (Table 1). Survival rates during 1991 and 1992 were different ($\underline{P} < 0.05$) for among-year comparisons (Table 2). Average age of all 101 fawns at death in 1990, 1991, and 1992 was 18, 19, and 10 days, respectively. Mean age at death of test fawns was 28, 20, and 12 days, respectively.

Fawning season ranged from the latter part of April until early June. The peak of fawning, based on estimated DOB of fawns captured, was 12-14 May. There was no relationship ($\underline{r}^2 < 0.05$) between DOB and number of days that fawns survived. Estimated DOB of surviving fawns ranged from 1-24 May, and nonsurviving fawns from 30 April-2 June. Eight of 12 (67%) surviving fawns were born within 3 days of the peak of fawning season. Mean DOB's of surviving fawns (12 May), nonsurviving test fawns (12 May), and all nonsurviving fawns (13 May) were similar ($\underline{P} > 0.05$).

We found predation to be the primary cause of fawn mortality (Table 3). Two fawns in 1990, 1 in 1991, and 2 in 1992 were categorized as "missing". These 5 fawns were lost within 2 days of tagging and were likely the result of predation. Coyotes were the primary predator involved in the predation losses, accounting for 78% of predation losses in test fawns and 82% in all fawns (Table 4). Mountain lions, bobcats, and golden eagles also preyed upon fawns. Total losses attributed to these 3 predators combined were 22% in test fawns and 18% in all fawns. We did not attempt to estimate predator densities, but predator-specific mortality rates on fawns were likely related to the relative abundance of each predator species on the study area.

Estimated fawn production of tagged fawns (% survived) were generally less than UTL survey estimates of fawn production for the study pasture, although these were comparable in 1990 and 1992 (Table 5). During our study, coyote-control efforts in the study pasture resulted in the elimination of only 2 coyotes per year. On the nearby UTL-Baylor Ranch, UTL fawn-production estimates were 0.61 and 0.75 in 1991 and 1992, respectively, following 2 winters of intensive coyote-control efforts (78 and 104 coyotes, respectively). These fawn production estimates are 6- and 7-fold greater than 1990 Baylor estimates (Table 5) when minimal coyote control occurred. Although variation in annual precipitation rates likely contributed to this difference, increases in fawn production were much greater than corresponding increases on the Double U Ranch, and on overall UTL in the Trans-Pecos (Table 5).

We found a relationship ($\underline{P} < 0.05$) between previous year's precipitation at the EPE and COR stations and UTL 8-year survey of fawn production. About 54% of the variation in current-year fawn production was explained by total precipitation occurring in the previous year.

Discussion

Stability of animal populations has often been correlated with predation rates and environmental conditions. Our study was conducted primarily in years of relatively good moisture. Consequently, the herd we studied appeared to be relatively healthy and maintained an optimal number of breeding animals. High survival rates by adults compensated for low fawn recruitment.

This allowed for a relatively stable pronghorn population during our study.

Predation, primarily from coyotes, was the most significant mortality factor in pronghorn in the Trans-Pecos region. However, predation was mainly limited to fawns in the first month of life. Some adult females were preyed upon, possibly because of their smaller size (compared to adult males) and lack of horn development. Fawns that survived the first 3-4 months of life were likely to reach adulthood. Our results tend to support findings from other geographic regions that suggest the first 30-60 days of life are the most critical (Vriend and Barrett 1978, Autenreith 1982, Barrett 1984, Hailey 1986).

Synchronization of births is thought to be a strategy of some ruminants to reduce predation rates on newborns by swamping predators with more prey than they can consume (Rutberg 1987). Although pronghorn produce fawns during late April through early June, with peak production in mid-May, we found no relationship between DOB and length of time fawns survived. However, 8 of 12 (67%) surviving fawns were born within 3 days of the peak of fawning season. This could have enhanced survival of these fawns born at or near the peak of the fawning season. However, this strategy may be less important during periods of normal range conditions when pronghorn populations are at or near carrying capacity.

Apparently, precipitation can indirectly influence fawn survival rates. Hailey (1986) suggested that precipitation the previous year was related to pronghorn population levels the following year. We also found this relationship on our study area. Correlations between precipitation and fawn production over an 8-year period accounted for over half of the variation in fawn production.

Comparisons of fawn production on our study area to other areas within the region indicated that mortality of tagged fawns may have been higher than that found in the general population. Fawn production for test fawns (15.6%) and all tagged fawns (12.3%) were lower than estimates from aerial surveys for the study pasture (22.0%) and Double U Ranch, overall (27.0%). While the largest difference between fawn production of tagged fawns and survey fawns in the study pasture was in 1991, the major reason for the overall low survival of tagged fawns resulted from mortalities occurring in 1992, where only 3 of 47 fawns survived.

There are several possible explanations for the high fawning-season mortality in 1992. Higher mortality may have been the result of unusually high precipitation that occurred during May, the primary fawning month. Fawning season normally occurs during the driest time of the year, but precipitation was 5 times greater than average (6.4 vs. 1.3 cm). The ability of coyotes to locate fawns by smell may have been enhanced by the increased moisture; and, the pale brown color of fawns (for concealment in senescent vegetation) was less effective in the green vegetation that resulted from this rainfall. Second, predators may learn to identify or spot ear-tagged fawns. Third, higher densities of prey may concentrate predators (Corneli 1980, Drewek 1980, Autenreith 1982). Average density of pronghorn (1987-92) in the Buckhorn pasture was 1 pronghorn/57 ha, compared to 1/85 ha on the remainder of the Double U Ranch, and 1/111 on all UTL in the Trans-Pecos region. Thus, during the fawning season, our study area may have been more attractive to predators.

Management Implications

A common pronghorn management objective in the Trans-Pecos region is the maintenance of a harvestable surplus of pronghorn. Based on our results, we believe long-term average fawn production of 15-20% should be sufficient to maintain a stable population. Fawn production of >20% should allow a population to increase under normal environmental conditions. When major declines in the population occur from long-term drought conditions, greater fawn survival will more rapidly restore populations to desired levels, once the drought ended. Although coyotes were the primary cause of fawn losses, it does not necessarily follow that annual coyote control is required. If pronghorn populations are relatively stable then intensive coyote control is unnecessary. However, if pronghorn populations are below desired levels, short-term coyote control may be effective. Application of either high-intensity, short-term control, or selective control of denning coyotes in the period before and possibly during the fawning season can be beneficial. This would be especially beneficial following periods of drought when pronghorn populations are low. Increased survival of fawns would then be needed to return the population to carrying capacity.

Harvest of "bucks only" is normally the policy in the Trans-Pecos, and as such, less likely to have an impact on pronghorn populations (harem mating system) that have an optimal number of reproductively active females. Annual harvest rates should be based on long-term population trends. Biennial surveys to evaluate pronghorn densities may be sufficient during periods of normal precipitation, but annual surveys should be conducted during periods of long-term drought. Determination of harvest rates in years with no survey would be based on long-term population trends and the previous year's precipitation.

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Table 1. Average home range of adult pronghorn by sex and year variables for the period 1990-92 on the Double U Study Area, Hudspeth County, Texas.

Year	Sex	n[1]	X[2,3]	SD
1990	Male	6	25.8A[4]	6.3
	Female	22	39.2B*	9.5
1991-92[5]	Male	6	21.9A	2.5
	Female	22	32.9B*	7.7
All years	Male	8	25.1A	4.5
	Female	28	42.4B	10.1

[1] Number of pronghorn individuals with ≥50 locations were used in yearly comparisons, and those with ≥100 locations were used in ll year comparisons.
[2] Home range in km^2.
[3] Home range estimates were calculated using the 90% harmonic mean estimator.
[4] Values not followed by a common letter for within year comparisons are different ($P < 0.05$). Values followed by (*) are different ($P < 0.05$) between years. Data from "all years" were not tested against other years.
[5] Data for 1991 and 1992 were combined.

Table 2. Home range comparisons of adult female pronghorn during fawning and post-fawning seasons, 1990-91, on the Double U Study Area, Hudspeth County, Texas.

Year	Season[1]	n[2]	X[3,4]	SD
1990	Fawning	36	17.1A[5]	8.3
	Post-fawning	36	32.5B*	14.5
1991	Fawning	11	17.2A	9.5
	Post-fawning	11	20.4A*	6.2

[1] Fawning season is from 15 April-17 June; Post-fawning season is from 18 June-20 August.
[2] Number of pronghorn with ≥15 locations per season.
[3] Home range in km^2.
[4] Home range estimates were calculated using the 90% harmonic mean estimator.
[5] Values not followed by a common letter for within year comparisons are different ($P < 0.05$). Values followed by (*) are different ($P < 0.05$) between years.

Table 3. Adult and fawn pronghorn survival estimates, S(t), standard errors (SE), and confidence intervals by sex and year(s) on the Double U Study Area, Hudspeth County, Texas, 1990-93.

Age	Period	Sex [a]	n [b]	S(t)	SE	95% CI
Adult	1990-93	M	9	1.00	0.00	1.00-1.00
		F	46	0.82	0.06	0.71-0.94
Fawn	1990	M	4	0.00	0.00	0.00-0.00
		F	9	0.21	0.13	-0.05-0.48
Fawn	1991	M	17	0.17	0.09	-0.01-0.34
		F	14	0.25	0.12	0.01-0.49
Fawn	1992	M	19	0.08	0.06	-0.03-0.19
		F	15	0.03	0.03	-0.03-0.10
Fawn	1990-92	M	40	0.10	0.04	0.02-0.19
		F	38	0.12	0.05	0.03-0.21

[a] M = male, F = female.

[b] Only tagged fawns surviving >3 days (test fawns) were used in this analysis.

Table 4. Log rank test (χ^2) comparisons by year and sex in pronghorn fawns (1990-92), and sex only in adults (1990-93) on the Double U Study Area, Hudspeth County, Texas.

Comparisons [a]	Age	χ^2 [b]	df [c]	$E(d^{ij})$ [d]	$Var(d_{ij})$ [e]
1990 vs. 1991	Fawn	0.01	1	24.23	7.30
1990 vs. 1992	Fawn	2.39	1	26.26	9.39
1991 vs. 1992	Fawn	5.93*	1	25.98	12.68
Female vs. Male	Fawn	0.33	1	32.69	16.38
Female vs. Male	Adult	1.80	1	1.45	1.16

[a] Fawn comparisons are between fawns surviving >3 days (test fawns). Fawn comparisons by sex are for all 3 field seasons combined. Adult comparisons by sex are for the period March 1990-February 1993.

[b] The χ^2 values followed by an asterisk (*) are significant at the $P < 0.05$.

[c] df = degrees of freedom.

[d] d_{ij} = total number of deaths in both years or sexes and $E(d_{ij})$ = expected value of d_{ij}.

[e] $Var(dij)$ = Variance associated with d_{ij}.

Table 5. Fates of pronghorn fawns for the period 1 May-30 August, 1990, 1991, and 1992 on the Double U Study Area, Hudspeth County, Texas.

Category	Class [a]	Year 1990	Year 1991	Year 1992	Total	% [b]
Fawns tagged	All	20	34	47	101	100
	Test	13	31	34	78	100
Fawns survived	All	2	7	3	12	12
	Test	2	7	3	12	15
Fawns missing	All	2	1	2	5	5
	Test	0	0	0	0	0
Unknown cause of death	All	1	1	1	3	3
	Test	1	1	1	3	4
Death by predation	All	15	25	41	81	80
	Test	10	23	30	63	81

[a] Class "All" represents all fawns captured and tagged. Class "Test" represents fawns included in survival analyses.

[b] Percentage of the class total in each category.

Table 6. Predator-related pronghorn fawn mortality, 1 May-30 August 1990, 1991, and 1992 on the Double U Study Area, Hudspeth County, Texas.

		Year				
Category	Class [a]	1990	1991	1992	Total	% [b]
Coyote	All	10	18	38	66	81
	Test	6	16	27	49	78
Mountain lion	All	4	2	0	6	7
	Test	4	2	0	6	10
Bobcat	All	0	3	2	5	6
	Test	0	3	2	5	8
Golden eagle	All	1	2	1	4	5
	Test	0	2	1	3	5
Totals	All	15	25	41	81	
	Test	10	23	30	63	

[a] Class "ALL" represents all fawns captured and tagged. Class "Test" represents fawns included in survival analyses.

[b] Percentage of the class total in each category is expressed as percentage of predation losses only, not total fawns tagged.

Table 7. Fawn production comparisons among test fawns (1990-92) from Buckhorn Pasture, Double U Ranch, Baylor Ranch, and all U.T. Lands; and average annual precipitation of the 2 closest weather stations to the study area, Hudspeth County, Texas.

Year	Test fawns [a]	Study pasture	Double U Ranch	Baylor Ranch	All U.T. Lands	PPT [b] (cm)
1985	-	na	0.65	0.78	0.61	20.1
1986	-	na	0.42	0.09	0.34	33.3
1987	-	0.57	0.56	0.84	0.56	20.6
1988	-	0.38	0.23	0.15	0.22	26.2
1989	-	0.26	0.16	0.11	0.17	22.2
1990	0.15	0.16	0.16	0.10	0.16	34.6
1991	0.23	0.40	0.35	0.61	0.43	44.9
1992	0.09	0.11	0.30	0.75	0.40	32.9
Mean [c]	0.15	0.22	0.27	0.56	0.34	-

[a] Fawn production is based on proportion of test fawns surviving (fawns reaching >3 days of age) and fawn:doe ratios in the other columns.

[b] PPT is the average annual precipitation of the El Paso East and Cornudas weather stations.

[c] Mean fawn production during the 3-year study.

INTERPRETING PHYSICAL EVIDENCE OF PREDATION ON PRONGHORN

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Abstract: Effective predator management efforts undertaken for the benefit of enhancing pronghorn (*Antilocapra americana*) populations depend on an accurate determination of the specie(s), if any, responsible for pronghorn mortalities. Mortality factors may include predation, malnutrition, starvation, disease, and accidents. Major predators of pronghorn include coyotes, bobcats, mountain lions, and golden eagles—fawns are especially vulnerable. Causal evidence associated with pronghorn mortalities must be scrutinized objectively to arrive at an accurate assignment of blame. Objective assessment of a mortality scene depends on the observer's background knowledge about pronghorn habits and ecology, objectivity, and skills pertinent to the situation. An integrated pest management (IPM) approach should be adopted to provide information that is essential to appropriate decision making with regard to predator management. IPM relies on systematically applying basic principles which include: scouting to assess population levels and trends, choosing the appropriate tool from a wide array of options (both lethal and non-lethal), aiming at selectivity and effectiveness, recognizing economic feasibility and thresholds, being mindful of safety, and anticipating environmental effects.

Introduction

Predation has been identified as one of the factors which affect pronghorn population levels (Yoakum 1978). Fawns are the most vulnerable age class (Einarsen 1948, Yoakum 1978). Conditions such as drought, malnutrition, disease, and high predator populations can exacerbate the problem with white-tailed deer (Beasom 1974), and potentially likewise with pronghorns. In areas where pronghorn populations are below carrying capacity, and an increase in population level is desired, predator management can be an appropriate management tool to accomplish that end. The major species of predators relative to pronghorns include coyotes, bobcats, mountain lions, and golden eagles (Canon 1993). Some of these species can be managed directly (e.g., coyotes) whereas others can only be addressed indirectly (e.g., golden eagles). Other mortality factors include malnutrition, starvation, disease, and accident (Yoakum 1978).

Predator management efforts should only be undertaken if evidence conclusively points to predation as the cause of death. Objectively assessing the physical evidence associated with the death of a pronghorn is important for accurate determination of cause. Avoiding unsubstantiated conclusions in that regard can be beneficial economically and operationally.

Beasom (1974) cautioned that following very intensive predator control program a more intensive hunter harvest would probably be needed to hold white-tailed deer populations below the density level where starvation, diseases, or other factors began to take a toll. It is largely unknown whether such would be the case with pronghorns.

To increase the accuracy of one's diagnoses, the observer needs to possess certain attributes. These include background knowledge relative to pronghorn habits and ecology, objectivity, experience, attention to detail. A knowledge of, and appreciation for, an Integrated Pest Management (IPM) approach will enhance the observer's decision-making process (Rollins 2001).

The IPM Approach

The basic concepts of IPM include:

1. Recognizing "pests" versus "beneficials"
2. Scouting population trends
3. Determining economic thresholds
4. Utilizing selective control
5. Choosing from an array of control technologies (lethal and non-lethal)
6. Ability to monitor response following a treatment and adjust plans accordingly.

Before implementing a predator management practice consider the idea that a predator that is known to prey on the species of interest could be a pest or it could be beneficial. Identifying which is the case depends on what corresponding effects would be realized if the predators' numbers were reduced. A predator has the potential of being either a help or a hindrance. The reduction in one species may result in the increase of another to unacceptable or undesirable numbers. Anticipate which is likely to be the case in your situation.

The ability to monitor the population level of a particular predator, and the trend over time can be helpful when deciding whether or not intensive removal efforts are warranted. Effective monitoring includes watching for tracks and droppings (scats) on roads, digs under fences, and incidental sightings of movements.

A certain level of predation may be acceptable before it becomes necessary to implement a predator management program. Commonly called the economic threshold, this is the level of predation at which the expense of predator management efforts is justified by the return, i.e. increased pronghorn survival in this case.

Selective control involves choosing the predator management method that will be most likely to affect the target species' population positively. Unnecessary and unfruitful activities can be avoided in this manner.

Choose from the full range of tools available. Giving careful consideration to non-lethal as well as lethal means will enable the manager to appropriately and effectively apply control technology. The right tool always yields the best results.

Of these components the one most immediately relevant to interpreting the physical evidence of predation on pronghorns is scouting population trends. An adequate understanding of current population levels of known resident or suspected predators serves as the foundation for predator management decisions.

Scouting

Predator populations ebb and flow in relation to, among other factors, precipitation, prey numbers, and disease (Connolly 1978). Knowledge of the trend in predator numbers over time and in particular areas is valuable in assessing the potential for predator problems. It helps the manager assess both the risk faced by pronghorns and the relative likelihood of a particular predator being responsible for a mortality when physical evidence at the scene is limited.

Precipitation and buffer prey

Coyotes and bobcats are opportunistic in their feeding habits. The existence of other prey that might be encountered before or with more frequency than pronghorns can be favorable for pronghorn survival. Well-timed and adequate precipitation often produces an increase in lagomorph (rabbit) and rodent populations, resulting in a relatively high plane of nutrition and enhanced reproduction for coyotes and bobcats. With more mouths to feed encounters with all prey, including pronghorns, can be anticipated. Keep track of rainfall, and subsequent rodent and rabbit numbers, as an indication of the likelihood of a future increase in predator numbers and a potential increase in predation on pronghorns.

Scats on roads

Counting scats on ranch roads at a certain time of year is a useful means of monitoring coyotes and bobcats—they both frequent roads where available. Be sure to collect (remove) the scats as you find them to avoid multiple counts. Look for scats at the same time of year, on the same roads, for the same period of time in order to make the counts objective and comparable year-to-year.

Sightings

Keep track of sightings which occur incidental to regular ranch duties. Record the date and number seen. Make note of first sightings each year and their location in relation to areas inhabited by pronghorn during fawning season.

Scent stations

Scent stations are a method used by wildlife biologists to assess relative abundance of mammalian predators. The technique may be useful to managers, also. Place one-yard diameter track monitoring stations at 1-2 mile intervals along roads. Choose a bare area or clear the surface of the ground of vegetation and loose rocks. Cover the area with enough flour, fine sand, or slacked lime to provide a substrate for identifying tracks of visiting animals. Place a cotton ball-tipped stick upright in the center. Soak the cotton ball with bobcat urine (available from trapping suppliers), or use a commercially available scent tablet (also available from trapping suppliers). Leave your knuckle imprint as a gauge of readability of subsequent track imprints. Check the station the next day for visits, and for two successive days, replenishing the substrate as needed and smoothing the surface. Do not attempt to estimate how many individuals visited per night, only the species. If you cannot see your knuckle imprint the next day due to wind or precipitation consider the night's information invalid. The number of scent station nights in which particular predators left tracks provides a measure of activity which can be compared to other time periods (months, seasons, years, depending on desired frequency of monitoring).

Clues

Vicinity

When a dead pronghorn is discovered particular attention should be given to the immediate vicinity of the carcass to look for tracks as well as other basic telltale signs such as scats and scrapes. Coyote tracks are longer than wide, generally show the nail marks of only the two middle toes, and possess a pad with bi-lobed rear edge. Coyote scats are cylindrical, moderately segmented, and usually have a tapered end. Bobcats and mountain lions have a more rounded track with no nail marks showing, and a pad with tri-lobed rear edge. Bobcat scats are cylindrical, strongly segmented, and obviously tapered on the end, often with hairs of its prey protruding from the end. Scrapes, or areas on the ground that have been scratched or "scraped" may be evident, sometimes accompanied by urination (Rollins et al. 2004).

Strong evidence of a cat kill is the carcass having been cached, or hidden, by covering with grass, leaves, or other organic debris. Often the prey will be killed, fed upon and the remaining portion cached with the intent to return for subsequent feedings until spoilage or total consumption, at which time another item of prey is actively sought.

Much like a dog, coyotes will sometimes bury portions of food items that cannot be consumed at the first feeding (Young and Jackson 1951). At times they will urinate on the buried prey.

Mode of attack

The method used in the kill is often the most telling of the clues that remain after pronghorn mortalities. Look for subcutaneous hemorrhage by skinning the neck, throat, and back area of the carcass. Hemorrhage indicates that the animal was alive when the skin was punctured or torn. If canine punctures exist, the spacing can aid in identification of the attacker. The spacing between canine punctures for bobcats is about 1 to 1.25 inches, coyotes about 1.5 inches, and mountain lions about 2.5 inches.

Punctures and extensive hemorrhage found in the throat and lower jaw region of the dead animal is an indication of predation by coyotes. Coyotes tend to attack those areas in an attempt to restrain and eventually suffocate the prey (Rollins et al 2004). They sometimes bite the side and back of the skull of small prey such as pronghorn fawns (Young and Jackson 1951).

If punctures and hemorrhage are found on the back of the neck and/or the lower portion of the skull bobcat or lion predation may be indicated. Accompanying cat evidence may include teardrop-shaped punctures in the sides of the animal which result from catching and holding with the claws. Additional evidence of cat predation is the appearance of scruffy patches of fur on the prey carcass, or areas where hair was pulled out.

Golden eagles will usually attack from overhead using their talons to catch prey. The result is numerous relatively large diameter and widely spaced punctures on the back and sides of the prey.

External appearance and condition of carcass

The overall external appearance and condition of a dead pronghorn should be scrutinized carefully. Ask yourself: 1) Is the position of the carcass natural, or is does it look like it has been moved after death? 2) Are there any signs of a struggle? 3) If it is a newborn fawn, what is the condition of the hooves? Are they pliable and un-used as would be the case if the fawn was still-born? Or, do they show signs of the fawn having walked? 4) Is the animal emaciated or dehydrated, with sunken eyes or prominent ribs, indicating death by “natural causes” such as malnutrition or being orphaned? 5) Is blood present on the exterior of the carcass? 6) Are punctures or bites evident? 7) Has it been fed upon? Was it fed upon by scavengers or predators? Was it fed upon after it died or was the feeding the cause of death?

Consumption of prey

The pattern of feeding can be indicative of particular predators. Some difficulty may be encountered however in the spring, summer, and early fall when vultures are resident. They have the ability to rapidly locate carcasses and consume practically all of the animal but the hide and bones. This can limit the amount of information which can be gleaned by the discovery of a dead pronghorn unless it is found by the manager soon after death. Turkey vultures typically soar and search for carrion, then continue soaring in the vicinity for some time before descending for feeding. Watching for circling vultures can be helpful, even though some feeding by vultures may have begun by the time the manager finds the carcass.

Coyotes will often consume large portions of the prey (Young and Jackson 1951), especially if more than one coyote is involved. Some of the hide may be consumed, as well as some of the bones, much like the feeding habits of a domestic dog.

Bobcats will characteristically consume less at a feeding than coyotes, mountain lions somewhat more. Both exhibit more delicate eating habits than coyotes.

Eagles will usually feed on the softer tissue initially, eventully picking bones clean with the use of their beak as they hold the carcass down with their feet. Ribs will sometimes be "pruned" off at the backbone during this process (Rollins et al. 2004).

Summary

Halting the decline of pronghorn numbers and enhancing their populations may involve some form of predator management. To determine if predators are a limiting factor in a given situation care must be given to objective appraisal of the physical evidence associated with pronghorn mortalities. An integrated approach, utilizing all the diagnostic tools that are feasible, will likely yield the most accurate diagnosis. As a result the pronghorn manager's time, effort, and financial resources will be more effectively spent.

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MANAGING PRONGHORN HABITAT IN WEST TEXAS

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Abstract: It is important that managers recognize the basic needs of pronghorn and be aware of critical impacts such as intensive grazing on fawning cover and changes in plant succession. Grazing systems should be planned around the needs of livestock and pronghorn. Modifying fences, providing easily accessible, escapable, permanent water sites, and providing fawning cover can help pronghorn survivability and recruitment. To produce optimal benefits for pronghorn and all wildlife healthy habitat must be fostered.

Most ranchers and natural resource managers with pronghorn habitat realize the fragility of the land and the importance of their decisions when operating within the desert environment of West Texas. It is also important to realize that any decisions about habitat management should be site specific. It is not unusual for someone to hear of, or see results, and want to duplicate the effort on their own place which may or may not be similar.

In order to properly manage pronghorn and pronghorn habitat, one must understand the animal's life history and understand what pronghorn habitat is. For these reasons it is important to read and understand the basic pronghorn ecology and habitat requirement papers in these proceedings before continuing.

The First Step – Evaluate

First and foremost, a landowner / manager must evaluate their present habitat. Ask yourself: Is there sufficient food, water, cover, and space for the species? A good manager will know what they have, and where they are going. You cannot begin to improve upon the habitat without knowing what you have to work with, prioritizing your target areas, and setting goals. These goals should be set out in a ranch management plan.

Some common goals for pronghorn management include:

1. Restore plant diversity
2. Improve ground cover
3. Increase forage for livestock
4. Improve water distribution
5. Improve fawn survival

In managing pronghorn habitat one must set out to manipulate vegetation and to influence abundance, distribution, composition, average height, and productivity of plants. A good manager will also manage exotic plants and animals to keep competition to a minimum.

Working With Habitat Components

<u>Food</u>

When discussing pronghorn habitat food and shelter are difficult to talk about separately.
A good inventory of your resources is important because you must know which plant communities are present on your ranch. More importantly, you need to know which plant communities are in need of improvement.

Areas that will have the best response to manipulation, such as sites with deeper soils, should be your high priority areas. Shallow gravelly soils have low productive potential and should be lower on your list of areas to attempt to manipulate.

When deciding how to manipulate the habitat, it is important to guard against removing too much of the shrub component. Shrubs provide nutritional needs when forbs are absent in desert grasslands and are a very important food source in winter as well as during severe drought. It is essential to understand the importance of cholla and other succulents as an important source of food and water as well as good screening cover and shelter (shade).

Besides good land stewardship, another reason to maintain a high nutritional plane or a healthy ecosystem is that it provides a scenario in which the resultant healthy animals can better tolerate most parasites and many diseases. A more accurate statement cannot be made than that by Jim Yoakum in the book *Pronghorn Ecology and Management*. He wrote: "the most pressing concern in sustaining pronghorn populations are unhealthy vegetation conditions and inadequacy of existing vegetation relative to pronghorn requirements for nutritious forage and fawn concealment".

<u>Water</u>

In the literature there are still questions about whether or not pronghorn need free standing water. With proper vegetation pronghorn appear to get by; however, if water is available they will use it. After working with ranches in West Texas where water distribution has been improved and pronghorn have moved into those areas and utilized the water I believe that water location, quality, quantity, and availability is important.

It is important to keep water available to wildlife in all pastures even when livestock are moved out of a pasture. It is also important to provide escape ramps inside water troughs, and provide water troughs that are no taller than 24", accessible to both young and mature pronghorn. In large expanses of habitat in which water line installation is not economically feasible, wildlife water catchments (guzzlers) are an option. Contact Texas Parks & Wildlife at 1-800-792-1112 and request TPWD publication PWD BK 7100-032 Water for West Texas Wildlife for details, or access the publication on the Internet at http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0032.pdf

<u>Cover</u>

A critical component of pronghorn habitat and often the most discussed cover type needed is fawning cover. Increasing pronghorn populations is dependent upon herd recruitment through fawn survival. Maintaining ground cover throughout the fawning season is important. It is also important to remember that pronghorn need residual cover (old growth from the previous year) as well as new growth to aid in their concealment.

Horizontal cover, known as screening cover, is also important. In desert grasslands, brush species offer more than just food. Taller brush species such as sand sagebrush, fourwing saltbush, and even cholla can provide screening cover and can help improve fawn survival when grass cover is lacking. Shelter from the harsh summer sun is provided through the shadows of taller vegetation such as Spanish daggers, mesquite trees, and cholla.

Space

One of the most significant things a manager can do for pronghorn is the removal or modification of the main barrier to their movement in West Texas – net-wire fences. Abandoned fences should be removed. If they can't be removed, fences should be modified to allow passage of pronghorn. At a minimum, 100 – 200 yard sections of established net-wire fences should be raised to 16 inches, the proper height to facilitate movement of pronghorn and improve their ability to escape from predators. Implementing these raised sections in corners and other strategic places which exhibit significant pronghorn activity will allow pronghorn to follow rainfall, access available forage, and escape predators thereby increasing their chances of survival.

When building new fences, make them "pronghorn friendly" by using barbed or electric wire and making sure the bottom wire is 16" above the ground to allow for easy pronghorn movement. Use smooth wire for the bottom wire where feasible.

Buechner (1950) showed daily movement for pronghorn to be about 2 miles stating that home ranges could be as small as 10 square miles and as large as 50 square miles. Most West Texas pronghorn populations today have home ranges limited by net wire fences.

Rangeland Improvements And Restoration

Rangeland restoration is problematic in West Texas because of low and unreliable rainfall. It is important that one understand plant responses to every habitat management or restoration technique before embarking on any habitat treatments.

Desert grasslands often turn into mesquite shrublands or greasewood communities. In most instances an increase of woody plants makes an area less favorable to pronghorn. This can be caused by livestock over grazing, suppression of fire, and climatic patterns.

Interspersion of shrubs within grasslands is important to pronghorn habitat. These shrubs provide important components of winter habitat—food and thermal cover. Be mindful of the need to maintain interspersion of the two when using any treatment whether chemical, mechanical, or biological to bring back desert grasslands and improve pronghorn habitat.

Although predator influence on pronghorn is covered in another paper in these proceedings, it should be noted that it is well documented that predators influence pronghorn numbers less on healthy rangelands than unhealthy ones.

Biological Methods (Using Livestock)

Choosing the class of livestock compatible with pronghorn is a critical issue when managing pronghorn habitat. One must not only think of direct competition for preferred forage, but also of indirect competition such as decline of vigor, loss of the ability of forage plants to reproduce, loss of important cover types and replacement with less favorable communities, as well as general changes and reduction of the kind, quality and amounts of vegetation.

It is important to realize that cattle and pronghorn are compatible. Very little overlap is found within their food habits. Short term overgrazing by cattle has little effect on pronghorn foraging and food supply (Buechner 1950). However, for many reasons sheep and pronghorn have been found to be incompatible. Sheep wire (net wire) fences are a critical issue regarding pronghorn movement and survival. Intense forage competition occurs between pronghorn and sheep. Yoakum (1995) found overgrazing by domestic sheep to be detrimental to pronghorn.

I would be remiss if I did not mention Aldo Leopold, known as the father of wildlife management, and his thoughts in a paper on managing wildlife habitat. Aldo Leopold wrote in *Game Management* in 1933, "...game can be restored by the creative use of the same tools which have heretofore destroyed it, the ax, plow, cow, fire, and gun." Leopold often referred to the "cow" as an effective wildlife management tool. He believed that the same tools that disrupted wildlife habitat could be used to bring it back to good health. The ax, cow, plow, fire, and a gun can be used to maintain healthy ecosystems. This holds true for pronghorn habitat. Cattle can be used as a tool to manipulate and enhance wildlife habitat and plant diversity.

Addressing grazing management and the various livestock grazing systems and their benefit to pronghorn is beyond the scope of this paper and is addressed in the grazing management paper in these proceedings. Good land stewardship and the management practices associated with it will help pronghorn flourish.

Using Fire

When used properly, and with adequate follow up rainfall, fire can increase the abundance of forbs, increase grass and shrub nutrient content and palatability, and increase plant diversity. Fire also can slow the invasion of shrubs. Burning shrub land may increase herbaceous plants immediately after the fire depending on rainfall and will increase the nutritional value and availability of browse.

A very good example of the usefulness of fire was on a ranch in Elko County, Nevada. The ranch was online to receive pronghorn to augment a small but stable population of pronghorn. After a succession of small fires followed by favorable rainfall the herbaceous vegetation increased and the pronghorn population more than doubled in ten years (1985 – 1995). This negated the need for a translocation.

If you are interested in using fire in managing your pronghorn habitat contact your local Texas Parks & Wildlife Biologist or Natural Resource Conservation Service Range Conservationist.

Using Chemical And Mechanical Means

The scope of this paper does not lend itself to exploring and explaining all the chemical and mechanical methods available. There are many good sources for more reading on these methods of rangeland manipulation. Contact Texas Cooperative Extension at http://tcebookstore.org or 888-900-2577 for the Brush Sculptors Symposium proceedings and for the RAWHIDE Symposium proceedings, both good sources of information on chemical and mechanical means of brush work.

When using chemical or mechanical means to control woody plants, remember that interspersion of brush is important to pronghorn. The goal of the manager should not be to remove all brush, but to set back the plant community, as pronghorn prefer diverse plant communities. Spike is used successfully on creosote-tarbush communities. It kills most brush (not mesquite) and should be used carefully. Remedy is used fairly successfully to kill mesquite. Avoid using chemical or mechanical methods in riparian areas for brush control. There are many mechanical methods to use to manipulate brush. Dozing, root plowing, chaining, furrowing, discing, and range reseeding are just a few of the methods used to restore pronghorn habitat. Caution should be used when using any of them on the highly erodable soils of West Texas.

Conclusion

As with most wildlife species in North America, loss of habitat is a critical problem for pronghorn, with fragmentation a significant issue. Comprehending the complexity of pronghorn habitat and the relationship between factors affecting pronghorn is the beginning of an understanding of sound pronghorn management. To prevent loss of the species, it is imperative that we manage currently existing useable habitat to the best of our ability to benefit pronghorn populations.

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PRONGHORN NUMBERS ON LATE AND MID SERAL CHIHUAHUAN DESERT RANGELANDS

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Abstract: Seasonal pronghorn (Antilocapra americana) censuses were conducted between May 1990 and April 1991 on Chihuahuan Desert rangelands in south-central New Mexico in late- and mid -seral ecological condition. Aerial census, walked transects, and motor driven transects were used to enumerate pronghorn. All three census methods showed higher pronghorn populations on late- than mid-seral rangelands in all seasons sampled (spring, summer, winter). Walked transects overestimated pronghorn compared to driven and aerial census methods. Vegetation surveys showed higher shrub cover (41 versus 14%) and lower grass cover (12 versus 21 %) on mid- compared to late-seral rangelands. Pronghorn diets evaluated through fecal analysis contained a higher forb and a lower shrub content on late- than mid-seral rangelands. Better visibility and higher availability of preferred foods (forbs) appear to explain the higher numbers of pronghorn observed on late- compared to mid-seral Chihuahuan Desert rangelands. This and other studies indicate rangelands in a late-seral ecological condition provide better habitat for pronghorn than those in lower seral stages.

Key Words: Wildlife, ruminants, Arid lands, livestock, grazing.

Introduction

Pronghorn populations have been restored throughout much of their former range (Yoakum et al. 1996). They are now the third most numerous big game species in the United States after white-tailed deer and mule deer (Yoakum et al. 1996). The three principal habitats inhabited by pronghorn are grassland, shrub-grassland, and desert (Yoakum et al. 1996). Desert populations have been the least studied (Yoakum et al. 1996). Information on impacts of differing range ecological conditions on pronghorn populations in the Chihuahuan Desert is limited (Smith et al. 1996, Nelson et al. 1997).

Domestic animals such as cattle, sheep, and goats have modified Chihuahuan Desert environments, altering rangeland ecological conditions on a large scale basis (Dick-Peddie 1965, McCormick and Galt 1993, Holechek 1996). Cattle are the principal domestic ungulate in New Mexico. Their impacts on pronghorn populations are not fully understood. The main objectives of this study were to evaluate the effects of late- and mid-seral ecological condition classes on pronghorn densities and diet botanical composition in the Chihuahuan Desert of south-central New Mexico.

Materials And Methods Study Area

The 2 study ranges are located 37 km north of Las Cruces, N.M. Their western boundaries are adjacent to Interstate 25. The study area is on the southern end of the Jornada Del Muerto Plain, a desert basin which varies from 1,1878 to 1,371 m in elevation with level or gently rolling hills. Pasture soils are primarily shallow, fine sandy loams of the Simona-Cruces association (fine loamy, mixed, thermic, typic Haplargids). The topography is relatively flat with all slopes less than 5%. Seasonal patterns of precipitation are characterized by small amounts (8 to 10%) in spring and a peak (20 to 25%) in late summer (August) with gradually reduced amounts during fall. A smaller peak (13 to 15%) occurs in early winter (Pieper and Herbel 1982). Mean temperatures reach a peak (35°C) in June and decline until December (13°C) (Pieper andHerbe11982). In 1990 annual precipitation across the study area averaged 271 mm (115% of long term average). Total study area precipitation in 1991 averaged 385 mm (163% of the long term average).

Vegetation on the Jornada Plain is classified as Chihuahuan Desert grassland and shrub land (Paulsen and Ares 1962). Most of the grassland areas have been invaded by brushy species during the last 100 years (Brown 1950, Dick-Peddie 1965).

The principal grassland types are black grama *(Bouteloua eriopoda* Torr.) and tobosa *(Hilaria mutica* [Buckley] Benth.) With mesa dropseed *(Sporobolus flexuosus* [Thurb.] Rydb.) intermixed (Paulsen and Ares 1962, Pieper and Herbel 1982). The shrub types are mesquite *(Prosopis glandulosa* Torr.) sandhills, creosotebush *(Larrea tridentata* Lar.) and tarbush *(Flourensia cernua* D. C.) with snakeweed *(Gutierrezia* spp.) invading certain sites. Annual forbs include leather croton *(Croton pottsii* Lam.), nightshades *(Solanum* sp.), globemallow *(Sphaeraclea* sp.), and Russian thistle *(Salsola iberica* L.). The presence of these forbs is dependent on seasonal precipitation.

Grazing History

The grazing history of the 2 study areas appears fairly similar until 1922, when the College Experimental Ranch was established (Holechek et al. 1994). Prior to that time, most of both study areas was apparently black grama grassland with a minor brush component (mostly mesquite). In the mid-1920's the College Ranch was fenced and a large herd of wild horses were driven from the College Ranch onto the adjacent federal land. During the 1930's and the 1940's, the College Ranch was stocked conservatively about 40 ha per animal unit (Knox et al. 1951) and the forage utilization averaged 35%. In contrast, forage utilization averaged somewhere between 50 and 60% on the Bureau of Land Management (BLM) study range.

In 1967, the College Ranch study area was placed under intensive grazing management and the stocking rate was reduced from 41 to 67 ha per animal unit (Beck 1978, Beck et al. 1987). Since then, utilization of the key forage species has averaged about 30%. The stocking rate has been increased from 67 ha per animal unit (1967) to 45 ha per animal (1986-1991) with no increase in degree of forage use or sacrifice in cattle performance (Beck and Kiesling 1991). Overall condition using the Soil Conservation Service approach developed by Dyksterhuis (1949) has improved from mid-fair to high-good (66% of climax) during the 24-year period (Holechek et al. 1994). Forage production at the end of the 1990 growing season was 356 kg/1m.

The grazing history of the BLM range is rather vague for the 1950 to 1980 period, but detailed records have been kept since 1981. Prior to 1981, the general grazing plan was to remove about 50% of the perennial grass production using continuous grazing. The stocking rate from the late 1960's to 1981 was 42 ha per animal unit. Stocking rate averaged 72 ha per animal unit for the 1981 to 1990 period. BLM records indicate conservative utilization of key forage species for the 1981 to 1991 period (20 to 40% use). In 1990 range condition was high-fair (40% of climax) (Holechek et al. 1994). Forage production at the end of the 1990 growing season was 124 kg/ha.

Eight permanent transects (6.4 km in length) were located in each study range (College Range and Bureau of Land Management ranges) for a total of 16 transects. Percent canopy cover was measured seasonally in the fall of 1988 using a modification (Holechek and Stephenson 1983) of the line intercept procedure outlined by Canfield (1941). A rod 1 meter in length, incremented in millimeters, was laid down every 100 paces perpendicular to the transect that was walked. On each of the 16 transects 64 points were sampled. Plants that were located on the plane vertically above the meter stick were measured and recorded.

Pronghorn Census

Pronghorn population densities were determined by aerial, walked transect, and driven transect methods on the mid- and late-seral study areas between May 1990 and April 1991. Both areas surveyed were about 40 km^2 in size (total of 80 km^2). The aerial pronghorn census involved flying the entire mid- and late-seral study areas and recording the total number of pronghorn observed. Two flights (replicates) were conducted in each of three seasons. These seasons were classified as warm dry (from April to June 1990), warm wet (July to November 1990), and cool dry (December to March 1991). Population densities were derived by dividing the total number of sighted pronghorn by the area (40 km^2) of each range condition class.

In addition, two line transect methods were used to estimate pronghorn population densities. The eight 6.4 km transects used for sampling vegetation in each area were surveyed by walking. Another seven 6.4 km transects in each area ($n = 14$) were surveyed from a vehicle.

Walked transects were separated from each other by 500 m. Transects were walked in the early morning within a period of 1 week. Two samples (replicates) were obtained for three seasons (warm dry 1990, warm wet 1990, and cool dry 1991).

Seven driven transects about 1.5 km apart were along established roads within each study area. They were sampled at night by using a 1,000,000 candle power spotlight from a pickup truck. Two samples (replicates) were obtained for each season/condition class as in walked transects and aerial census.

Perpendicular distances to observed animals were estimated when transects were walked and driven. Perpendicular distances (A) were estimated from the sighting distance (C) and sighting angle (b), as reported by Krebs (1989), where $A=C \sin b$. These sighting distances and sighting angles were measured directly from the field by using Tasco 7x50 mm binoculars equipped with a reticle to estimate distance to the objects and a bearing compass to measure the sighting angle.

Population densities are expressed in pronghorn-numbers/km^2 and were estimated by using the following equation: D = nf (0) / 2L, where f (0) was estimated using the method reported by Crain et a1. (1978). All population densities from the walking and driving methods were estimated by using the "Distance" computer program developed by Burnham et a1. (1980).

Pronghorn Diet Botanical Composition

Pronghorn food habits were determined by microhistological analyses of pronghorn fecal samples collected each season (warm dry 1990, warm wet 1990, cool dry 1991) within the two range condition classes. Four fecal group samples (at least 100g) were collected for each season/ecological condition class. Fecal samples were dried and ground using a Wiley mill equipped with a 1-mm screen. Five microscope slides (75 mm X 25 mm) were prepared from each fecal group following the method of Sparks and Malechek (1968) as modified by Holechek (1982). The microscope observer was trained using procedures of Holechek and Gross (1982a). Percent composition (PC) by species was determined using procedures described by Holechek and Gross (1982b).

Statistical Analyses

A randomized factorial analysis of variance was used to compare pronghorn densities among range condition classes, seasons, and methods of sampling. Each survey method was repeated twice for each condition class/season combination. These repeated surveys (2) served as replicates. The LSD test was used to separate means at the 5% significance level (Steel and Torrie 1980).
A randomized factorial analysis of variance was used to compare pronghorn diet among range condition classes and seasons. Fecal sample groups were used as replicates. The LSD test was used to separate means at the 5% significance level. A randomized analysis of variance was used to compare vegetation cover on late- and mid-seral study areas. The 8 transects sampled on each study area were used as replicates. The LSD test was used to separate means at the 5% significance level.

Results and Discussion

Pronghorn densities were higher ($P < 0.01$) on late-seral than mid-seral sites (0.39 versus 0.17 sightings/km^2) (Table 1). The interaction between site (late- and mid-seral) and census method (aerial, driving, walking) was significant ($P < 0.03$) (Table 2). Interactions between site and season ($P > 0.11$) and among site, census method, and season were non-significant ($P > 0.14$).

Census methods (aerial, driving, walking) differed in estimates of pronghorn densities ($P < 0.01$) (Tables 1 & 2). Walking gave higher estimates than aerial or driving methods. This was particularly true for the late-seral site (Table 2). More pronghorn were observed during the cool dry (December to March) than warm dry (April to June) season ($P < 0.02$) (Table 1). The interaction between census method and season was non-significant ($P > 0.28$).

Pronghorn diets were dominated by shrubs on both late- and mid- seral sites (Tables 3 & 4). Pronghorn consumed more shrubs on the mid- than late- seral site. Forb and grass consumption was highest on the mid-seral site. Key pronghorn food plants on the late-seral site were cactus, mesa drop seed, leatherleaf croton, and fourwing saltbush. On the mid-seral site honey mesquite, mormon tea, fourwing saltbush, and leatherleaf croton were primary pronghorn foods.

Grasses dominated vegetation cover on the late-seral site while the mid-seral site was dominated by shrubs (Table 3). Primary plants found on the late-seral site were mesa dropseed, black grama, threeawns, and broom snakeweed. The mid-seral site was dominated by honey mesquite, broom snakeweed, and mesa dropseed.

Our data show pronghorn made greater use of the late-seral than mid-seral site throughout the year. This agrees with Nelson et al. (1997) who found Chihuahuan Desert rangelands in high ecological condition tended to receive greater use by pronghorn than those that were degraded.

Croton, a key pronghorn food plant (Howard et al. 1990), was more available on the lateseral than mid-seral site. Pronghorn diets on the late-seral site contained more forbs than the mid-seral site (Table 3 & 4). In the critical warm wet season when pronghorn females have their highest nutritional requirement due to lactation, forbs comprised 39% of pronghorn diets on the late seral site but only 2% of diets on the mid-seral site. Howard et al. (1990) found availability of forbs played a critical role in pronghorn survival and reproductive success in southern New Mexico. New Mexico forbs are generally superior to grasses in concentrations of crude protein and phosphorus and have lower fiber levels (Howard et al. 1990). Forbs are also nutritionally superior to many shrubs such as mormon tea, honey mesquite, cactus, and broom snakeweed. An exception is fourwing saltbush, whose leaves compare favorably with alfalfa hay (Medicago sativa) in protein content.

We believe the higher proportion of open grassland in the late-seral compared to mid-seral site also explains differences in pronghorn sightings. Yoakum (1972) reported open grasslands receive greater use by pronghorn than shrub-grasslands. This preference by pronghorn for open grasslands is due to better ability to detect predators and fewer obstacles that impede mobility when evading predators.

Differences in pronghorn densities between seasons can be explained by pronghorn social behavior. Engelking (1969) and Prenzlow et al (1968) reported that from December to March (cool dry season) pronghorn form mixed sex herds. In this period adult territorial males join mixed subadult male, adult female, and subadult female herds for a one month period. Because of these herd size increases, pronghorn are easier to count than in the warm dry season when females seek isolation for parturition and in the wet dry season when females form loose groups for kid rearing. Ghaly (1980) on the Jornada plains found that during the warm-dry season females left the main herds for kidding.

Walking gave higher pronghorn density estimates than driving or aerial census. The probability of counting an animal twice or more was higher when using the walking method. When alarmed, pronghorn can run more than 500 m. Based on home range size and pronghorn movements reported by Clemente et al. (1995), the same animals in our study could have been counted on other transects even if they were not disturbed by observers. In contrast, with the driving transect sampling, this problem was minimized because distances between transects were longer and the entire study area was traversed on the same day. Conducting the sampling at night reduced the possibility of disturbing pronghorn and causing them to move great distances.

The differences between the aerial census and the walking method were higher on the late- seral than on the mid-seral site. However, trends were similar using both methods (Table 2). It appears there is an increase in overestimation using the walking method as the number of pronghorn in an area increase.

Choosing the appropriate sampling method is a critical consideration in conducting
population estimates. When accuracy in pronghorn population densities is of major importance, such as for harvest decisions, aerial census is recommended. However, when information is needed on population responses to grazing management or habitat manipulation practices, census techniques that assess relative populations such as driving or walking appear suitable.

In our study, driving appeared to give reliable estimates of pronghorn densities. We consider it a suitable pronghorn census method when roads are well distributed over the area to be surveyed, when vehicle traffic does not affect the presence of animals along roads, and when animals can be readily seen from a vehicle.

Based on our results and those from Nelson et al. (1997), Chihuahuan Desert rangelands in New Mexico in late-seral ecological condition appear to provide better pronghorn habitat than those in mid- or early-seral ecological condition. About 34% of the Chihuahuan Desert rangeland in New Mexico is late-seral or climax condition and 47% is in mid-seral condition (U.S. Department of Interior 1993). Rangelands in early-seral condition account for another 14%. Upgrading large areas of early- and mid-seral Chihuahuan Desert rangelands to late-seral or climax ecological condition should improve habitat for pronghorn and several other species of wildlife (Nelson et al. 1997). This would also improve cattle ranching profitability and watershed values (Holechek 1991, Holechek 1996). Research indicates a conservative stocking rate that removes 30-35% of key perennial grasses will permit progression of many mid-seral Chihuahuan Desert rangelands to the late-seral stage (Paulsen and Ares 1962, Holechek et a. 1994). Brush control will probably be required for meaningful improvement of Chihuahuan Desert rangelands in an early-seral stage (Gibbens et al. 1986).

We recognize our research has the limitation of a short time period. We recommend more study of pronghorn use of habitat and interactions with livestock in the Chihuahuan Desert.

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Table 1. Summary of effects of ecological condition, season, and method of sampling on estimates of pronghorn densities (numbers/km^2) in the Chihuahuan Desert of southcentral New Mexico.

Ecological Condition		Season			Method of Sampling		
Late-seral	Mid-seral	Warm dry	Warm wet	Cool dry	Aerial	Driving	Walking
0.39[a]	0.17[b]	0.15[b]	0.26[a,b]	0.42[a]	0.18[a]	0.20[a]	0.78[b]

a,b Means within each main effect with different superscripts differ at $P < 0.05$

Table 2. Estimates of pronghorn densities (numbers/km^2) pooled across seasons on late- and mid-seral sites using aerial, driving and walking census methods.

	Sites	
Census Method	Late-Seral	Mid-Seral
Aerial	0.18[c]	0.12[d]
Driving	0.20[c]	0.13[d]
Walking	0.78[a]	0.26[b]

a,b,c,d Means with different superscripts differ at $P < 0.05$

Table 3. Forage availability (% cover), relative percent forage availability, and pronghorn diet botanical composition by weight pooled across seasons on late- and mid- seral Chihuahuan Desert.

	Forage Availability				% Pronghorn Diet Composition	
	% Cover		% Rel. Cover		Late-seral	Mid-seral
Forage species	GC[3]	FC[4]	GC	FC		
GRASSES						
Aristida spp. (threeawn)	4.	1.8[b]	10.6[a]	3.3[b]	0	2
Bouteloua eriopoda (black grama)	3.9[a]	0.7[b]	10.P	1.3[b]	0	0
Digitaria californica (Arizona cottontop)	t	t	t	t	0	0
Hilaria mutica (tobosa)	t	t	t	t	0	0
Muhlenbergia porteri (bush muhly)	t	t	t	t	0	0
Setaria leucopila (plains bristlegrass)	t	t	t	t	9[a]	0[b]
Sporobolus flexuosus (mesa dropseed)	8.6[a]	5.3[b]	22.2[a]	9.6[b]	20	6
Other grasses	3.9	4.4	10.1	8.0	T	T
Total grasses	20.7[a]	12.4[b]	53.4[a]	22.4[b]	30[a]	8[b]
FORBS						
Croton potsii (croton)	1.7	0.1	3.0	0.2	1P	5[b]
Dithyrea wislizeni (spectacle pod)	t	t	t	t	0	T
Salsola austra1is (tumbleweed, Russian thistle)	t	t	t	t	T	0
Sphaeralcea subhastata (wrinkled globemallow)	t	t	t	t	5	0
Zinnia acerosa (desert zinnia)	t	t	t	t	0	2
Other forbs	3.0	2.0	7.7	3.6	T	T
Total forbs	4.6[a]	2.3[b]	11.8[a]	4.2[b]	18[a]	8[b]
SHRUBS						
Acacia constricta (whitethorn acacia)	t	t	t	t	6	0
Atriplex canescens (four-wing saltbush)	t	t	t	t	10	5
Ephedra trifurca (Mormon tea)	t	t	t	t	T	13
Flourensia cernua (tarbush, blackbrush)	t	t	t	t	T	0
Prosopis glandulosa (mesquite)	2.4[a]	23.8[b]	6.2[a]	43.1[b]	8[a]	60[b]
Gutierrezia sarothrae (broom snakeweed)	10.1	14.5	26.0	26.3	3	T
Opuntia spp. (cactus)	t	t	t	t	23[a]	5[b]
Yucca elata (soaptree yucca)	0.7	1.9	1.8	3.4	T	T
Total shrubs	13.	40.5[b]	34.8[a]	73.4[b]	52[a]	84[b]

[a,b,c,d] Means within rows with different superscripts differ at $P < 0.05$

Table 4. Effect of rangeland ecological condition and season on pronghorn consumption of grasses, forbs, and shrubs by weight in south-central New Mexico.

% Diet Composition						
			Season			
	Warm Dry - 1990		Warm Wet – 1990		Cool dry - 1991	
Diet Component	Late-seral	Mid-seral	Late-seral	Mid-seral	Late-seral	Mid-seral
Grasses	7[a]	12[b]	17[a]	5[b]	5[a]	12[b]
Forbs	0	0	39[a]	2[b]	22	24
Shrubs	33[a]	88[b]	43[a]	93[b]	73[a]	64[b]

a,b Means within rows and seasons with different superscripts differ at $P < 0.05$.

RESTORATION OF THE DUFF SPRINGS RIPARIAN AREA AND THE ASSOCIATED UPLAND GRASSLANDS TO INCREASE PRONGHORN HABITAT

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Abstract: Pronghorn require at least 50% vegetative cover with less than 35% shrub cover and accessible water in their habitat. A project was instituted at Duff Springs on the 02 Ranch, Brewster County, Texas to decrease shrub and bare ground cover and increase grass cover. In doing this there was also the potential to increase surface water through the habitat. The project included spraying mesquite and reseeding the loamy soils adjacent to Duff Springs. After two years the habitat now meets the vegetative cover and shrub cover requirements for pronghorn. The surface water flow has also been increased which has allowed an expansion in the pronghorn habitat.

Introduction

Adequate habitat is vital for sustaining pronghorn populations. Water is a requirement for pronghorn, especially during dry periods or periods of stress such as lactation. Upland vegetation is also an important part of pronghorn habitat. In semidesert habitats pronghorn are found in areas with at least 50% living vegetative cover with that cover being no more than 35% shrubs. Plants in the community are preferably short, less than 0.75m, to facilitate pronghorn detection of predators, but the plants must provide for fawning cover (Autenrieth et al. 2006).

Historic overgrazing and lack of fire has created a shift in many communities from open grassland to shrubland (Archer 1994). This creates a negative shift in habitat for pronghorn, with increases in mesquite (*Prosopis glandulosa*) and juniper (*Juniperus ashei* and *J. Pinchotii*), decreases in forb and grass cover, and increases in bare ground (Brown and Archer 1989, Foster 1917, Hennessey et al. 1983, Ueckert 1997). The goal of habitat restoration for pronghorn would be to reverse these trends.

Study Site

The site selected for habitat restoration was on the O2 Ranch, located 40 km south of Alpine in Brewster and Presidio counties, Texas. The ranch is owned by Lykes Brothers Inc. Livestock over grazing has historically occurred on the ranch, but grazing ended in many pastures and was reduced in others in 1998. The ranch encompasses approximately 111,288 ha of the southern portion of the Trans Pecos Ecological Region, and lies within the Chihuahuan Biotic Province of Texas (Blair 1950). The topography of the ranch includes desert shrubs, rolling hills, and plateaus. The ranch encompasses Green Valley and is bordered by the Santiago Mountains on the east, Crossen and Kokernot mesas on the north-west and by Nine Point and Bandera mesas on the south.

Mean annual rainfall on the ranch is approximately 35.9 cm, with peak rainfall occurring in summer months. The area is drained by Terlingua and Calamity creeks. Mean annual temperature on the ranch was 17.5ºC. Maximum temperature occurred in July at 26.2ºC, and minimum temperature occurred in January at 8.5ºC.

The restoration work was performed on the northern section of the ranch, and encompassed approximately 962 ha surrounding Duff Springs in Brewster County. Pronghorn are found in this area, so a restoration project would directly benefit the existing herd. Elevations on the study area ranged from 1,235 to 1,292 m. Four major vegetation types and seven soil series occur in the Duff Springs area. The Straddlebug, Gemelo, Beewon, Quadria, and Musgrave soils support a loamy desert grassland and shrubland. The Chilicotal, Scotal, and Holguin soils support gravelly desert grassland. An igneous hill and mountain desert grassland occurs on the Lingua and Ohtwo soils. The fourth vegetation type is the riparian corridor that occurs through the central portion of the study area. The loamy desert grassland vegetation type was selected for the restoration. This vegetation type has been the most degraded and due to the deep soils had the highest potential for grassland restoration. Restoration of this vegetation type also had the potential to increase water flow in Duff Springs as the surface vegetation could have a direct impact on the shallow, 10 to 15 m deep, water table.

Methods

Prior to restoration, four 100m vegetation transects were randomly located through the loamy desert grassland vegetation type. Herbaceous vegetation was inventoried using modified 1/8m^2 Daubenmire quadrats laid out every 5m along the transects. Shrub density and cover was inventoried using a line intercept and belt transect along each of the four transects.

Mesquite (*Prosopis glandulosa var. torreyana*) was then sprayed following the recommendations of Texas Cooperative Extension (Hart et al. 2003). Herbicide was applied by Northstar Helicopters using a helicopter equipped with a 13.7m spray boom. 0.028 (900-1000 micron droplet) accuflo nozzles were spaced every 0.15m along the boom. Reclaim ¼ lb a.i/acre and Remedy ¼ lb a.i/acre herbicides were applied with Induce surfactant (90% active nonionic, 0.5% v/v) at a 15 GPA total volume. This was applied to 130 ha at the Duff Springs study site. Applications were done the last week of June 2004. Applications were all completed before 1:00 P.M., with humidity greater than 20%, air temperatures less than 35˚C, and wind speeds less than 7mph.

Seeds of native 4 wing saltbush (*Atriplex canescens*) and alkali sacaton (*Sporobolus airoides*) were collected on the 02 ranch in May of 2004. These seeds were than scattered in natural depressions across the area sprayed in July of 2004. Seeding rates of 2 PLS lbs/acre were used and approximately 10% of the area was seeded.

Vegetation was monitored by measuring the four 100m transects in June 2006. Mesquite mortality was quantified in September of 2004, June of 2005, and June of 2006 at 8 randomly selected 1m x 100m belt transects. Live and dead plants were counted. Any plant with live leaves was counted as living no matter how much the overall canopy had decreased.

Monitoring of weather conditions was done with an Onset weather station located at the southwest side of the Duff

Springs study area. Precipitation has been monitored since the application of the herbicide.

Water table level monitoring began in January of 2004 with a Global water pressure transducer in a well immediately adjacent to the spring.

Results

In 2004 herbaceous vegetation on the four monitoring transects had a mean canopy cover of 7%±15%. Bare ground covered 63%±30% of the area. Shrubs covered 46%±14%, with mesquite making up 56% of shrub canopy. Apparent mesquite mortality in August, 2004 was 88.7%±4.3%. Total rainfall in 2004 was 25.13 in. with 18.90 in. falling after mesquite was sprayed and seeds were planted. Surface water was present in only approximately 30 m of Duff Creek.

In 2005 the four monitoring transects were not measured. Apparent mesquite mortality in June, 2005 was 82.3%±12.4%. Total rainfall in 2005 was only 8.00 in. Surface water had increased to 2.4 km.

In 2006 herbaceous vegetation on the four monitoring transects had a mean canopy cover of 60%±19%, with 70% of this cover being alkali sacaton. Bare ground cover had decreased to 31%±16%. Shrub cover was reduced to 31%±14%, with 4 wing saltbush making up 37% of the cover and mesquite making up only 7% of the cover. Apparent mesquite mortality had decreased to 51%±17%. There was no rainfall through June, 2006. Surface water decreased slightly to 2.1 km.

Discussion

Before the restoration program, the upland habitat immediately adjacent to Duff Springs was not suitable habitat for pronghorn. Shrub cover and bare ground were both higher than that found in pronghorn habitat. Because the loamy desert grassland area at Duff Springs is very near a water source and potential natural vegetation is grassland, this area has high potential as a fawning area.

The existing surface water source was also not ideal, as the small pool was surrounded by trees and steep igneous rock walls (Autenrieth et al. 2006). Less than 500m from the existing surface water source the channel opens up and in flood events the water would flow across an area of eroded igneous rock and create several pools. This area is very open and when water is present, pronghorn appear to prefer to water in this area.

Two years after spraying mesquite and reseeding, the loamy desert grassland at Duff Springs is much more suitable for pronghorn. The shrub cover has decreased. Mesquite is being replaced by 4 wing saltbush, which is a much better browse plant. Bare ground is being covered by grass which will provide fawning cover. The grass cover will also increase infiltration of precipitation which can lead to higher forb production.

Mesquite mortality was only 51%, but the decrease in canopy cover in the past two years has allowed the herbaceous canopy to become established. Further management, including spot spraying of mesquite, and prescribed fire, can enhance the shift from a mesquite/bare ground community to open grassland.

The increase in surface water flow that was precipitated by the removal of mesquite has increased the surface water flow. This has led to a perennial water source at the open igneous rock location preferred by pronghorn. It also increases the area that is accessible as a drinking water source, making the surrounding igneous hills better habitat as they are closer to a water source. .

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RELATIONSHIP OF TRANS-PECOS PRONGHORN TO PRECIPITATION TRENDS AND 30 YEARS OF LAND COVER CHANGE

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Abstract: Since 1978, pronghorn (*Antilocapra americana*) populations in the Trans-Pecos, Texas have experienced a 66% decline. The causative factors associated with the decline are unknown, but appear to be related to drought and brush encroachment. Thus, we evaluated the relationships between pronghorn population demographics (fawn production, buck:doe, population numbers) and precipitation (raw precipitation, Palmer Drought indices). Fawn production (range = 305-4,407) and population size (range = 5,061-17,266) showed high variability, whereas buck:doe ratio (range = 1:0.48-1:0.69) remained stable. Precipitation was also highly variable (18 to 57 cm). The relationship ($R > 0.86$, $P < 0.0001$) between fawn production and precipitation suggests that fawn survival may be more closely related to immediate moisture conditions, whereas pronghorn population size was more influenced by long-term population trends. Also evaluated were the relationships between pronghorn density and land cover proportions.

Introduction

Pronghorn numbers have been estimated to have been greater than 30 million in North America in the 1800s (Yoakum and O'Gara 2000). Pronghorn were distributed over the majority of western North America, ranging from southwestern Canada to north-central Mexico. Pronghorn populations in North America have declined from 1,052,912 in 1984 to 672,200 in 1997 (Yoakum and O'Gara 2000). In Texas, pronghorn populations were historically distributed over approximately two-thirds of Texas, including most areas west of the 97th meridian (Fig 1) (Buechner 1950). This distribution diminished substantially throughout the 1800s, only comprising a fraction of the original area by 1945 and numbering less than 2,500 by 1924 (Schmidly 2002). Current Texas pronghorn populations are limited to the Panhandle, Trans-Pecos, and Possum Kingdom wildlife districts (Fig 2). With 70% occurring in the Trans-Pecos, the statewide estimate was 9,600 in 1997 (Yoakum and O'Gara 2000). The Trans-Pecos population had a recent high of 17,226 animals in 1987 with a 20 year low of 5,061 in 2001.

The decline in pronghorn population has been attributed to many factors. Overgrazing of pronghorn habitat and unregulated hunting were causes of the declines of the late 1800's (Schmidly 2002). Hypotheses explaining the recent decline include prolonged drought, depletion of range resources causing semi-permanent habitat deterioration, predation, and disruption of natural occurrences such as fires (Sullins 2002).

Study Area

The Trans-Pecos region is approximately 7.3 million ha and lies within the Chihuahuan Desert Biotic Province. The Trans-Pecos is bordered to the north by New Mexico, to the south and west by the Rio Grande, and to the east by the Pecos River (Hatch et al. 1990). Elevation ranges from 762-2,667 m with scattered mountain islands. Lowlands and basins are more xeric, receiving 20-30 cm of precipitation while the higher elevations average 30-46 cm of annual precipitation. Soils found in this region rage from shallow rocky soils on the slopes and mountains, gravel in the lowlands, to deep sands in the desert washes.

Methods

Texas Parks and Wildlife Department conducted annual aerial fixed-wing surveys for pronghorn from 1978 to 2005. Transects were flown at low altitudes (approximately 100 ft.) 1 quarter mile apart. Buck, doe, and fawn counts were made.

Precipitation data were obtained from the National Climatic Data Center (ftp://ftp.ncdc.noaa.gov/pub/data/cirs/) for the Trans-Pecos climatic region. For the year preceding aerial surveys from 1977 to 2004 raw precipitation, PDSI, PDMI, PHDI, and ZNDX values were obtained. By summing the data for the period of August to July, monthly data for the Palmer indices were converted to annual data (Simpson et al, in press). The ecological regions do not exactly match the climatic regions, however, single values were used to represent regional scale weather conditions, and these differences were therefore deemed negligible (Bridges et al. 2001).

Using Pearson's correlation coefficients (MINITAB 2001) the relationships between precipitation and pronghorn productivity and abundance were evaluated using. All distributions were normal. (Simpson et al., in press). Coefficients of variation were calculated for pronghorn abundance, fawn production and precipitation.

National Elevation Dataset (NEDs) files were obtained for Trans-Pecos, Texas (TP). The NEDs were then combined as a mosaic and clipped down to the TP using ESRI's ArcMap® software with county vector data produced by the USGS as a clipping mask. Slope, aspect, and hill shade datasets were generated from the NED mosaic. These topological datasets were developed to assist in the interpretation of remotely sensed imagery.
Spatially referenced digitized pronghorn herd units were obtained from the Texas Parks and Wildlife Department (TPWD). These files were then converted from polylines to polygons and merged into one layer file.

Historical maps of pronghorn distribution were obtained from 1950 and 1994 (Buechner 1950, Schmidly 1994). The maps were scanned and then georectified using ArcMap®. Pronghorn distributions were then digitized on-screen from the rectified maps as vector polygons. The 2 distributions were then overlaid to produce 2 other datasets showing areas of distribution loss and gain between 1950 and 1994.

Landsat scenes were obtained from 2 periods (24 Oct 1985 and 23 Oct 1999). The scenes were clipped down to herd units 33 and 34a. Digital Orthophoto Quarter Quadrangle (DOQQs) images were obtained for 1996 to 1998.

Landsat images were then classified into 30 classes using a maximum likelihood unsupervised classification. Classes were then merged into four groups: bare ground, grassland, desert scrub, and dense brush by comparison with DOQQs. An accuracy assessment was performed on the 1999 classifications by comparing the classified images to the DOQQs at 200 random points.

Change detection was performed by extracting each class from both time periods.
Overlaying each class from the 1985 scene with each class from the 1999 scene and extracting the overlap developed a from-to change matrix. The change matrix was then corrected for the error in class proportions in the 1999 images.

The corrected change matrix was used to develop a simple Markov model. Using the Markov model, proportions of cover classes were estimated for each year from 1978 to 1999. Correlation analysis using the Spearman's rho method was performed between estimated cover proportions and pronghorn demographics using the statistics package SPSS®.

Results

In the Trans-Pecos, the pronghorn population ranged from 5,061-17,226 ($\bar{x}$ = 10,699) from 1977-2004, fawn production ranged from 305-4,407 ($\bar{x}$ = 1,976), and buck: doe ranged from1.44-2.05 ($\bar{x}$ = 1.71). From 1977 to 1987, pronghorn in the Trans-Pecos showed an increasing trend and then decreased through 2002 (Fig 3). Annual raw precipitation ranged between 56.6 cm and 18.1 cm, with a mean of 33.1 cm (Simpson et al., in press).

Population and fawn production showed a positive correlation with all precipitation indices ($R \geq 0.607$, $P \leq 0.001$). Typically, Palmer indices showed a stronger correlation to population size than raw precipitation. The PHDI and population had the strongest correlation($R = 0.790$, $P < 0.001$), while raw precipitation and population had the weakest correlation($R = 0.703$, $P < 0.001$). Raw precipitation was the strongest correlate to fawn production ($R = 0.864$, $P < 0.001$), while the weakest was PHDI ($R = 0.691$, $P < 0.001$) (Simpson et al., in press).

The overall accuracy of the 1999 classifications for herd units 33 and 34a were 77.9% and 54%, respectively. In herd unit 33, bare ground was overestimated by 7.50%, grassland by 6.97%, while desert scrub and dense brush were underestimated by 2.95 and 3.89%, respectively.

Correlations were not assessed for herd unit 34a due to the low accuracy of the classifications. Pronghorn density, buck density, and doe density were positively correlated to the proportion of grassland in herd unit 33. Also, they were negatively correlated to desert scrub and dense brush proportions (Table 1). Fawn density and fawn: doe were not significantly correlated to any cover type proportions.

Discussion

The relationship between precipitation measures and pronghorn abundance suggests that the population in the Trans-Pecos is more closely related to long-term moisture availability than short-term availability. PHDI was the strongest correlate to the population. The PHDI is considered a more long-term index than the ZNDX or raw precipitation (Palmer 1965, Heddinghaus and Sabol 1991). This suggests overall population size in the Trans-Pecos is related more closely to long-term precipitation trends (Simpson et al., in press).

The relationship between fawn production and precipitation indices suggests that fawn production in the Trans-Pecos region may be more closely related to immediate moisture conditions than those of the long term. Fawn production was most strongly correlated with annual raw precipitation and the ZNDX. These 2 measures of moisture, being more reflective of immediate moisture conditions (Palmer 1965, Heddinghaus and Sabol 1991), suggests that fawn production is more closely related to current moisture availability. Fawn production is vital to the overall population, and is closely related to spring forage availability (Yoakum and O'Gara 2000).

The positive correlation between pronghorn densities and proportion of grassland and the negative correlation with dense brush and desert scrub proportions suggests that increasing brush and scrub coverage may lead to the decreased capacity of a herd unit to support pronghorn. The lack of a significant relationship between fawn density and cover proportions suggests that other variables, perhaps relating to fawning cover, are more important factors influencing fawn production.

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Table 1. Pronghorn density and cover proportion correlations.

	Grassland	Desert Scrub	Dense Brush
Total Density	0.577 (p = 0.008)	-0.546 (p =0.013)	-0.577 (p =0.008)
Buck Density	0.594 (p =0.006)	-0.584 (p =0.007)	-0.594 (p =0.006)
Doe Density	0.644 (p =0.002)	-0.627 (p =0.003)	-0.644 (p =0.002)

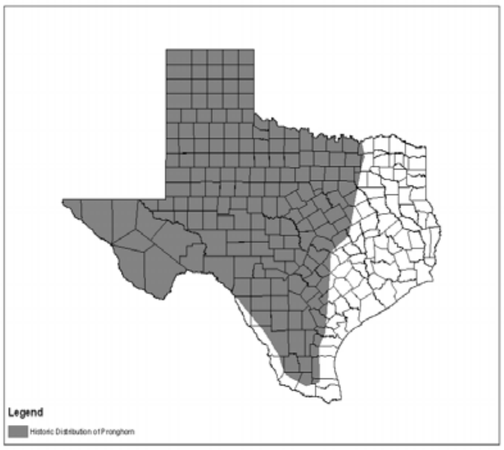

Figure 1. Historic distribution of pronghorn in Texas (adapted from Schmidly 1994).

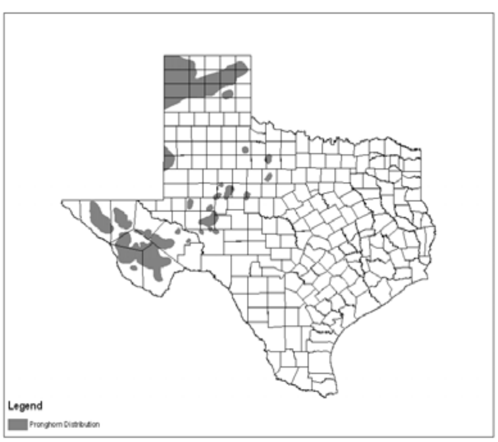

Figure 2. Current distribution of pronghorn in Texas (adapted from Schmidly 2004).

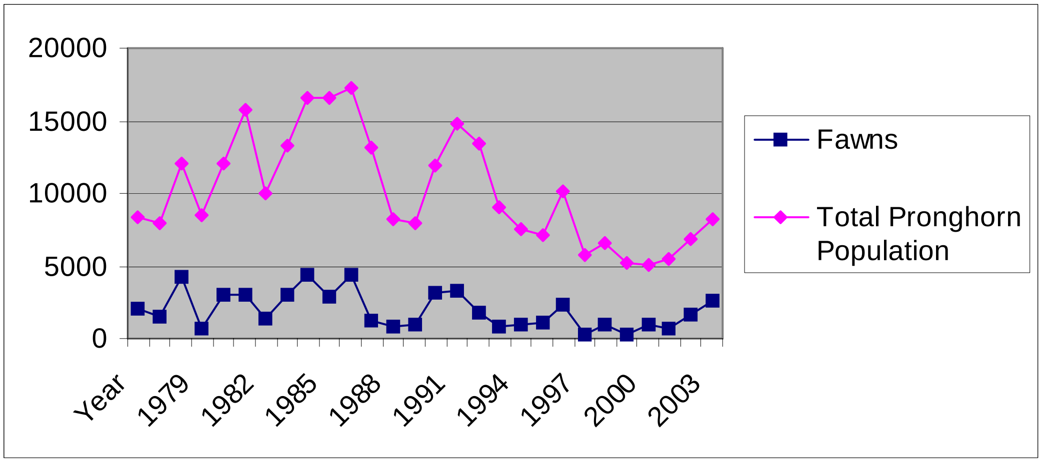

Figure 3. Trans-Pecos pronghorn population and fawn production.

FACTORS AFFECTING VARIATION IN PRONGHORN HORN GROWTH

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Abstract: Annual variations in male pronghorn horn size appear to be related to the age of the animal, the severity of winter during the growing period of the horn sheath, forage conditions prior to horn sheath growth, and the genetic makeup of particular populations. Knowing these factors might enable wildlife managers in favorable areas to increase the number of "trophy bucks" present.

Introduction

Arizona has long been famous for trophy-sized pronghorn (Allen 1877, Einarsen 1948, Seton 1953, Hoffmeister 1984). Seven of the top 10 pronghorn currently entered as trophies in the record book of the Boone and Crockett Club (BC) are from Arizona, and this state consistently produces more trophy animals than states having larger pronghorn populations (O'Gara and Morrison 2004). The conventional explanation for this phenomenon was that pronghorn live longer in Arizona due to the state's mild winters, and that the larger males are older aged animals (O'Connor 1961). Recent studies, however, have shown that the largest horns and greatest BC scores are from 2 to 6-year old animals (Mitchell and Maher 2001, Brown et al. 2002, Mitchell and Maher 2004).

A study in southern New Mexico (Brown et al. 2002) showed that horns of bucks >7 years were significantly smaller than those of younger animals (P <0.03). Considering the effects of pronghorn age alone, the horn sheaths of hunted animals on this ranch decreased by an average of 0.28 cm (0.11 in) of length and 0.53 BC points for every year of age. Winter precipitation (October through March) the year prior to the hunt exerted a significant negative effect on BC scores but not on horn sheath length.

Picard et al. (1994) suggested an explanation for this phenomenon when they concluded that horns were a major source of heat loss when growing. Because pronghorn are unique in having horn sheaths that grow mostly during the winter months (O'Gara 2004), and because southern states appeared to produce a disproportionate number of trophy animals compared to more northern states and provinces, we reasoned that winter temperatures might have something to do with horn size (Table 1). Indeed, a comparison of mean January temperatures close to each state and province's pronghorn population center showed a significant negative relationship with the number of pronghorn trophies per 1000 bucks harvested according to BC and Safari

Club International record books (r^2 = 0.35; P<0.01; Table 1 and figure 1).

To further test the assumption that pronghorn horn growth is negatively influenced by low winter temperatures, we compared winter temperature data with BC scores of pronghorn harvested on the Armendariz Ranch in southern New Mexico where "green" BC score have been collected since 1994. Although the annual variation in horn size on the Armendariz Ranch was not very large during this period, mean "green" BC scores for all pronghorn age classes negatively correlated with the numbers of days having temperatures $\leq$ 0º C during the previous winter (r^2 = 0.33; P< 0.06; Table 2).

Other environmental factors also appeared to be involved. Although winter precipitation amounts had no significantly positive effect on horn growth, adding April through August rainfall amounts received prior to or after the winter horn sheath growing season improved the correlation's probability value in a multiple regression equation (r^2 = 0.64; P<0.02; Table 2).

Later studies showed significant relationships between pronghorn population dynamics and the regional Palmer Drought Severity Index (PDSI), a monthly water balance index standardized to local climates, which considers both precipitation and temperature data to determine relative dryness and thus plant growth and foraging conditions (Palmer 1965). An index value of 0 is considered normal, a -2 is a moderate drought, -3 a severe drought, and -4 an extreme drought. When we compared the July PDSI for southwestern New Mexico preceding the onset of new horn sheath growth with the mean BC score recorded on the Armendariz Ranch the following year, the correlation coefficient had a value of r^2 = 0.63 and a probability value of P < 0.002. Figure 2). We therefore hypothesized that pronghorn horn growth not only varied with location but by year, and that the amount of this variation was determined in part, by environmental factors, *i.e.*, winter temperatures and moisture conditions.

To test this hypothesis in Arizona, we created a pronghorn trophy index by dividing that state's annual pronghorn harvest (Arizona Game and Fish Department 2006) into the number of pronghorn trophies recorded during the past 20 years in the Arizona Wildlife Federation's Wildlife Trophy book (Conrad 2005). We then compared regional climate data with the resulting number of "Trophies per 1000 Pronghorn Harvested.". For winter temperature data, we used mean monthly minimum temperatures $\leq$ 32º F ($\leq$ 0 º C) and $\leq$ 0º F ($\leq$ -17.8 ºC) for the October through March period recorded at Flagstaff (Western Regional Climate Data Center 2005). We used the Flagstaff station as being the most representative of the game management units producing most of the trophy bucks in Arizona (Conrad 2005). We also used the monthly PDSI index for north-central Arizona encompassing Flagstaff provided by National Weather Service web site.

Although there was no significant relationship between the number of "Trophies per 1000 Pronghorn Harvested" and the mean number of days having temperatures $\leq$ 0º C (P < 0.10), we found a weak relationship between the number of "Trophies per 1000 Pronghorn Harvested" and the mean number of days $\leq$ -17.8º C (r^2 = 0.17; P < 0.06). As in New Mexico, this relationship was strengthened when the July PDSI prior to the horn sheath growing season was added to a multilinear regression equation (r^2 = 0.38; P $\leq$ 0.04; Table 3 and figure 3).

We thus conclude that at least some of the variation in annual growth in male pronghorn is explained by environmental conditions such as winter temperatures and the availability of nutritious forage (Yoakum 2004). Although the most important factor affecting pronghorn horn size in the Southwest is probably body condition as measured by the PDSI prior to horn sheath growth, we found the severity of the winter during horn sheath growth also affects horn size.

The implication of this study to pronghorn management in the Southwest is that it may be possible to increase horn size in trophy males. Ranch managers of pronghorn habitats in moderate environments may, at least in theory, be able to increase the size of pronghorn horns by providing nutritious forage prior to and during the horn sheath growing season. Nonetheless, such efforts will probably not suffice to overcome natural weather phenomena such as cold winters and severe drought.

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Table 1. Pronghorn trophies per 1000 bucks harvested by province and state, 1935-2004.

State	Climatic Station	Lat.	Long.	Mean Jan. Temp. in Degrees F	Est. Harvest 1935-2001*	Mean % Bucks in Harvest**	Total Buck Harvest,1956-2004	Number of B&C Entries***	Trophies /1000 Bucks	Number of SCI Entries	Trophies/ 1000 Bucks
SK	Moose Jaw	50.4	105.6	7.3	75,224	60	45,135	14	0.3	7	0.2
AB	Medicine Hat	50	110.7	13.6	76,903	60	46,142	31	0.67	10	0.2
MT	Fort Peck	48	106.4	17.4	1,130,088	60	678,050	133	0.2	244	0.4
ND	Dickinson	46.9	102.8	12	73,846	51	37,661	13	0.35	0	0
SD	Belle Fourche	44.7	103.9	23.3	309,982	66	204,588	22	0.1	1	0
!D	Idaho Falls	43.5	112.1	21.1	86,019	65	55,912	24	0.43	23	0.4
OR	Malhuer	43.3	118.8	26.5	48,158	85.5	41,175	110	2.67	26	0.6
WY	Casper	42.9	106.5	21.3	2,367,572	60.4	1,430,013	681	0.48	904	0.6
NE	Alliance	42.1	102.9	24.3	38,742	89	34,480	20	0.58	6	0.2
CA	Alturas	41.5	120.5	30.7	15,865	92	14,596	38	2.6	21	1.4
UT	Dugway	40.2	112.9	27.6	22,292	80	17,834	60	3.36	24	1.3
NV	Battle Mtn.	40.6	116.9	29.8	25,696	94.4	24,257	164	6.76	32	4.7
CO	Fort Morgan	40.2	103.5	24.8	301,234	55	165,679	80	0.48	76	0.5
KS	Garden City	38	100.6	28.6	4,882	86.5	4,223	4	0.95	5	1.2
OK	Goodwell	36.6	101.6	33.2	902	60	541	1	1.85	0	0
NM	Fort Sumner	34.5	104.3	37	126,848	92	116,700	373	3.2	320	2.7
AZ	Chino Valley	34.8	112.5	37.9	32,392	91	29,285	264	9.01	113	3.9
TX	Big Springs	32.3	101.5	42.7	43,839	98	42,962	84	2	74	1.7
	Totals				4,780,484		2,989,233	2116		1886	

* Estimates from O'Gara and Morrison *in* O'Gara and Yoakum 2004

* * Extrapolated from harvest data in Pronghorn Workshop Proceedings

*** As of 8/17/2004 courtesy of Bill Keebler, Boone and Crockett Club

Table 2. Pronghorn horn measurement data from Armendaris Ranch, New Mexico.

Year	Preceed. April-Aug. Precip*	Previous Oct.-Mar. Precip.*	Previous April-Aug. Precip*	Previous July PDSI	No. Days <32 deg.F	Mean Horn Base	Mean Horn Length	Length + Base	B&C Score**	Notes
1994	0.3	0	1.6	-6.16	99				74.75	
1995	1.6	3.95	4.28	-2.22	65	6.14	15.11	21.25	76.15	
1996	4.28	0.55	7.73	-0.24	63	6.09	15.13	21.22	77.77	
1997	7.73	2.1	9.56	1.01	55	6.4	15.75	22.15	81.93	
1998	9.56	0.78	5.5	-0.08	102	6.38	15.34	21.72	78.2	Nov. temperature data from Aleman Ranch
1999	5.5	2.3	8	1.19	66	6.46	15.56	22.02	80.42	
2000	8	1.06	4.4	1.95	80	6.5	15.39	21.89	81.56	Feb. temperature data from Aleman Ranch
2001	4.4	3.69	5.67	-0.8	91	6.21	15.02	21.23	74.17	January temperature data extrapolated
2002	5.67	1.03	7.77	-0.44	94	6.02	14.93	20.95	76.7	
2003	7.77	3.03	5.01	-3.24	81	6	14.53	20.53	75.52	
2004	5.01	3.86	4.95	-2.8	100	6.15	14.89	21.04	75.125	
2005	4.95	13.39	14.85	-1.98	61	6.33	14.78	21.11	75.97	

*Truth or Consequences climatic station

** "Green scores" taken at time of harvest

Table 3. Temperature, drought, and pronghorn trophy data from Arizona, 1984-2004.

Year	Mean Oct.-March min. temperature Flagstaff, AZ	Previous Year's July PDSI	Current Year's July PDSI	No. of Pronghorn Harvested	No. of Trophies Recorded	Trophies per 1000 Pronghorn
1984	20.7	4.86	1.62	614	27	4.4
1985	19.9	1.62	4.8	635	15	2.4
1986	23.3	4.8	1.78	596	17	2.9
1987	19.8	1.78	3.46	498	26	5.2
1988	21.3	3.46	4.27	599	16	2.67
1989	21.3	4.27	-3.52	606	22	3.63
1990	19.8	-3.52	0.21	545	16	2.93
1991	20.6	0.21	-0.25	543	21	3.87
1992	23.3	-0.25	4.67	553	11	1.99
1993	22.8	4.67	4.22	675	24	3.56
1994	21.5	4.22	-0.9	704	20	2.84
1995	22.9	-0.9	-0.28	693	11	1.59
1996	22.4	-0.28	-5.05	703	15	2.13
1997	21.2	-5.05	0.24	598	9	1.5
1998	20.7	0.24	2.82	593	20	3.37
1999	21.9	2.82	1.5	574	12	2.09
2000	21	1.5	-5.41	543	16	2.95
2001	21.3	-5.41	1.18	513	10	1.9
2002	21	1.18	-5.76	586	8	1.37
2003	23.5	-5.76	-4.04	415	11	2.65
2004	22.6	-4.04	-3.68	411	7	1.7

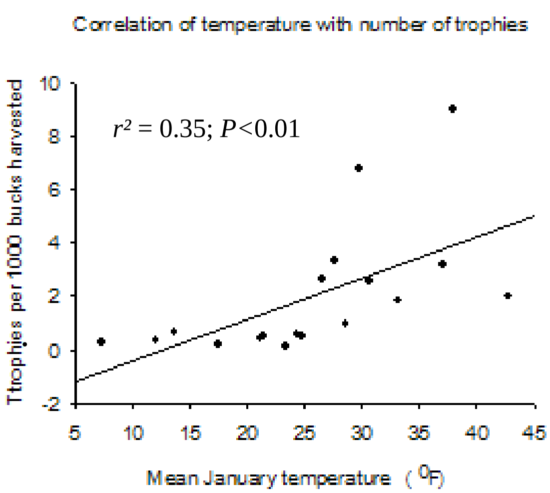

Figure 1. Correlation between mean January temperature and number of trophies per 1000 bucks harvested for 18 localities.

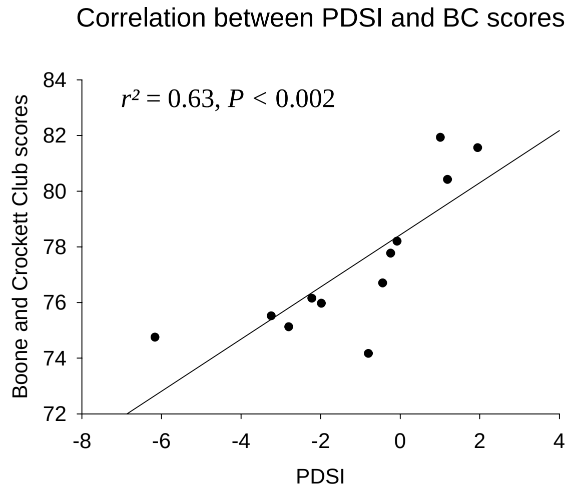

Figure 2. Correlation between Palmer Drought Severity Index (PDSI) and Boone and Crockett Club (BC) scores in Armendariz ranch in New Mexico.

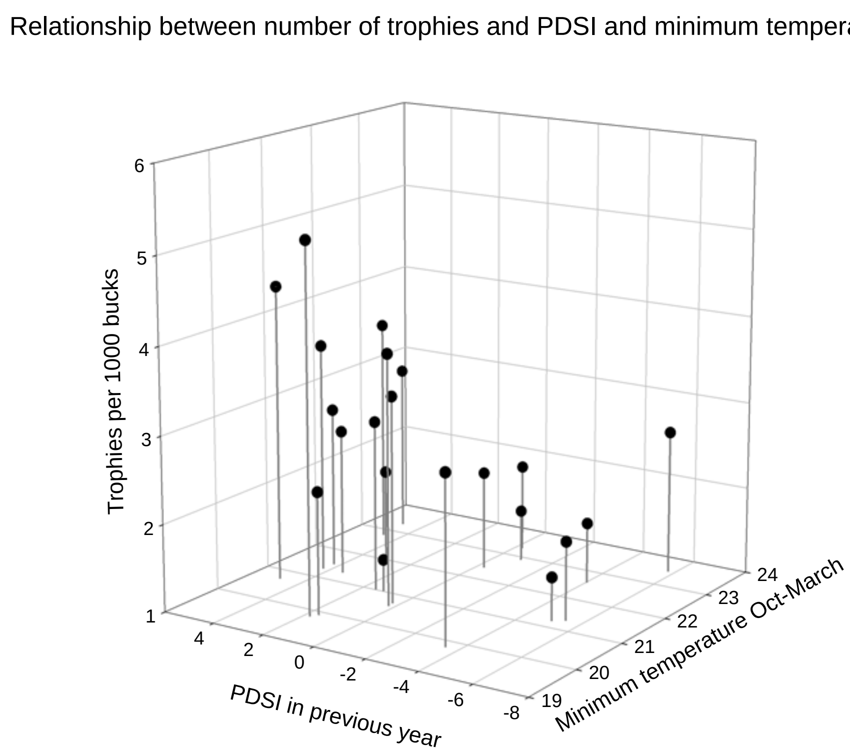

Figure 3. Correlation between number of trophies per 1000 bucks harvested in Arizona and the minimum October to March temperature and Palmer Drought Severity Index (PDSI) values.

TRANSPORTATION CORRIDORS AND PRONGHORN: WHAT DO WE KNOW AND WHAT CAN WE DO ABOUT IT

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Abstract: Since the mid-1900s, naturalists/biologists have known that transportation corridors, such as highway and railroad rights-of-way, can affect pronghorn populations. Beginning in 1983, we have radiomarked ~250 pronghorn (*Antilocapra americana*) across Arizona to determine population specific movement patterns and causes of mortality. During this over 20-year period, we conducted 3 studies on the Sonoran pronghorn (*A. a. sonoriensis*), 2 in the U.S. and 1 in Sonoran, Mexico, and 10 studies in Arizona, mostly in northern Arizona. With in excess of 34,000 radio telemetry locations, we have learned that transportation corridors in Arizona are significantly fragmenting pronghorn habitat and isolating populations in Arizona. Railroad rights-of-way at Petrified Forest National Park isolated a narrow band of habitat north of the heavily traveled Burlington Northern/Santa Fe (BNSF) primary line and south of I-40. Movements across paved roadways without right-of-way fences and low traffic volume, such as Dugas Road (GMU 21), Wupatki National Monument Road, Petrified Forest National Park Road, and the Drake-Williams Road did not seem to be restrictive barriers to pronghorn movements. However, 2-lane highways with typical rights-of-way fencing and substantial traffic volume do restrict movements, such as Hwy 69, SR 169, Hwy 89, Hwy 180, and Hwy 64. We have documented crossings of 2-lane, paved highways, but only in situations where fences have been set back from the highway, thereby widening the right-of-way on 1 or both sides, or where rights-of-way fences are in disrepair and traffic volume was low (e.g., Hwy 89A near Jerome). We have documented no crossings of Interstate Highways (I-8; I-40; I-17) during 2+ decades of work. Mortalities due to vehicle-wildlife collisions occur in specific situations. Mitigation features to improve the likelihood of pronghorn crossings include: 1) removing rights-of-way fences in pastures with deferred livestock grazing; 2) using right-of-way fence setbacks on 1 or both side; 3) building very large underpasses, such as expansive bridges in open terrain, since typical underpasses did not readily work for pronghorn; 4) constructing overpasses, but this is untested for pronghorn; 5) putting highways in underground tunnels—again, untested; and 6) physically capturing and moving pronghorn between populations. The current "Wildlife Missing Linkages" efforts are attempting to identify fragmentation across the state and plan for remedies to lessen the impact of transportation corridors on many species of wildlife, including pronghorn. Additional research on mitigation features is warranted.

PRONGHORN PERMIT ISSUANCE AND HARVEST DETERMINATION

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Prior to the 20th century, researchers have concluded that pronghorn (*Antilocapra americana*) occurred throughout most of Texas, west of the 97th meridian. Estimates of pronghorn populations, prior to the late 1800's, were in excess of a million animals. About the turn of the century, dramatic land use changes and unregulated hunting caused a marked decline in numbers. Easily harvested, pronghorn were a readily accessible supply of meat for railroad workers in the western part of the state. Additionally, many early ranchers considered pronghorn heavy competitors for livestock forage, and shot numerous animals. The increase in density of woody plants in the Southwest also transformed much of the state's grasslands to woodlands or savanna type vegetative communities, which were less desirable for pronghorn.

In 1903, the Texas Legislature established a closed season for pronghorn. However, unregulated hunting continued and numbers continued to decrease. In 1924, Nelson (1925) made a comprehensive survey of pronghorns in Texas. He estimated a total of 692 animals present in the Trans-Pecos, with 2,407 in the entire state. Several conservative ranchers had historically prohibited hunting, and these populations provided a source for an aggressive restocking effort that occurred from 1939 to 1956. During this time period, approximately 4,000 pronghorn were trapped and transplanted to areas of perceived suitable habitat in the Trans-Pecos, Panhandle and South Texas. Most of these transplants were from in-state sources, with some animals moved from other states. From 1972 to 1991, an additional 2,445 pronghorn were restocked in Texas.

Around 1944, the Texas Game, Fish and Oyster Commission (predecessor to the Texas Parks and Wildlife Department) began conservatively issuing pronghorn permits to landowners in Texas. In about the same period, Commission personnel began surveying pronghorn throughout Texas with fixed-wing aircraft. Initial permits were issued with a percentage allocated to the Commission. However, later that was changed so that the individual landowners received all the recommended permits. The original policy statement concerning issuance of permits said "To provide for the harvest of buck antelope which are considered surplus to the reproductive requirements of respective herds". Original harvest quotas were calculated to maintain a post-hunting season adult sex ratio of two does per buck. Through time, this ratio has increased to allow for greater hunter opportunity, without substantially impacting the resource. Currently, harvest quotas are calculated to maintain a post-hunt ratio of four does per buck.

Pronghorn doe permits have been issued in the Trans-Pecos when habitat conditions have indicated that possible harmful effects might result, if the total herd is not reduced. The harvest of does can assist in preventing die-offs and avert damage to important forage plants.

Pronghorn population estimates are made by conducting aerial strip counts of selected ranches, which comprise the primary range of pronghorn in Texas. Censuses are conducted annually during the period of mid June through July. Aerial counts are made of selected tracts by flying low altitude (100 feet or less) strip counts 1/4 mile apart. Aerial counts are augmented by ground counts of peripheral pronghorn range, when necessary. All pronghorns sighted are identified by sex and age when possible. Typical surveys by aircraft in the Trans-Pecos expend from 100 to 130 hours.

Collected data is used to formulate population characteristics including doe-buck ratios and fawn ratios and provide harvest quotas for permit issuance. Section 61.056 of the Parks and Wildlife Code requires that landowners or operators must apply in writing for their allotment of pronghorn antelope permits. To expedite this process, landowners are mailed an application card annually. By filling this card out and returning to TPWD, landowners who qualify for permits will be eligible to receive them.

Pronghorn permits are issued to landowners within particular management herd units. These herd units were established using both geographic and man-made barriers to pronghorn movement. Mountain ranges, canyons, railroads, highways and net-wire fences all prohibit, or seriously minimize, pronghorn movement and are the typical boundaries for a herd unit. Within each herd unit, individual landowners are allocated an estimated amount of pronghorn habitat acreage. Biologists survey each herd unit separately and record animals observed within that unit. For each herd unit, permits are divided among all the landowners within the unit, and allocated to each tract, based upon the estimated pronghorn habitat acreage.

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CASE STUDY: JOBE RANCH, CULBERSON COUNTY

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I manage the Jobe Ranch, 14 miles northwest of Kent, Texas. I was hired eight months after Stanley Jobe bought the ranch (January 2000).

The ranch includes a portion of the Apache Mountains, rolling hills, and gypsum flats. It is a nice mix of desert grasslands, mixed brush flats, low rolling hills with mixed brush, rolling to rough yucca hills, steep mountain slopes and canyons. Within the ranch there are approximately 40-50,000 acres of pronghorn habitat.

Although most of the fences are net wire, there are water gaps and corners that are barbed wire. In 2001 we installed an extensive pipeline and water trough system throughout the ranch. We re-established permanent water where it had been absent. In some places that was 5 years and in other pastures for as long as 20 years.

Initially all the gates between pastures were open with no cattle. In November of 2000 we stocked 400 stockers in the 7 pastures where we had water. In 2001/02 we had 130 first calf heifers, 2002/03 we had 160 cows and heifers, 2003/04 500 cows, 2004/05 600 cows, and presently, 2005/06, we have 500 cows.

When I started here I saw more coyotes than antelope. We hired a trapper in conjunction with our neighbors, used the Wildlife Services trapper, and shot as many as we could (approximately 50-60). We continue to control the coyotes and at this time they are at a tolerable level.

In 2000 there were approximately 20-25 antelope: 2 herds of approximately 8 pronghorn and 1 herd of 4. In 2006 there are approximately 60 head. Fawn crops have been consistent with four years' fawn crops of 40-50% (2000-2003). After the good rains of 2004 and 2005 the fawn crops increased to 70-80% in 2004 and 60-70% in 2005. In 2004 the ranch received one antelope permit. To my knowledge this was the first permit ever issued to the ranch.

With further fence modifications, continued predator management, maintaining permanent water, and light to moderate grazing I hope to increase the numbers of pronghorn to 100-150 head.

CASE STUDY: MACGUIRE RANCH, HUDSPETH COUNTY

JIM ALCORN

I have been manager of the MacGuire ranch since I graduated from Texas A&M in 1977. The ranch is currently 195,000 acres of which approximately 160,000 acres are pronghorn antelope habitat. We market quail, mule deer, and antelope hunts. We have an active mule deer and quail supplementation program which has allowed us to increase or maintain our population of both even through this droughty period which for us started in 1990. I have had no luck getting the antelope on any kind of feed program.

In the period from 1977 to 1990 we only had 1 year in which we recorded less than 10" of rainfall with our average being approximately 14". 2004 and 2005 were decent years, but between 1990 and 2003 we had only 1 year with greater than 10" of rainfall.

Currently we are in a very dry period and have had 1.3" of rain since October 2005. With no winter/spring moisture our "spring green-up" was non existent. We had virtually no weeds or yucca blooms, which are critical for a good antelope fawn crop. In 2006 we expect to have a very low fawn crop however our adult population appears hardy.

Cooperation from “Mother Nature" is by far the most important ingredient for a successful quality wildlife program. We practice conservative range management and request our hunters attempt to harvest mature/post mature bucks.

MARKETING YOUR HUNTING ENTERPRISE

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Abstract: As hunting income has become a more important component of a bottom-line oriented ranching enterprise, the ability to successfully promote and market these hunting opportunities has become more important as well. Marketing hunting opportunities has several fundamental similarities to marketing and selling most other goods and services, some of which include knowing your product, identifying your market, creating a practical and cost effective advertising package, and very importantly, delivering the goods. Today's market place in the hunting business is more competitive than ever before, and even though recent years have witnessed a "bullish" environment for the hunting business, those operations which have the ability to effectively market their hunts for top dollar, while streamlining operational costs, including advertising expenses, are often the ones that are most profitable. However, it should be pointed out that maximizing income from hunting operations will often demand time and energy relating to human resources, which may not be readily available; consequently, settling for "competitive" returns from hunting income may sometimes fit one's needs even better, which can generally be accomplished with a less demanding marketing program, or can perhaps be accomplished by relying on an outfitter or agent.

Fee based hunting programs have been common place, especially in Texas, for several decades. Historically, hunting income was viewed as supplementary to other traditional ranching activities such as livestock and farming practices. The last few decades, however, have witnessed a major shift from landowners placing less emphasis on livestock and farming, and more emphasis on recreational income as a means of trying to create or maintain a profitable ranching portfolio.

During these recent times of heightened emphasis on hunting revenue, we have also experienced a shift from landowners leasing their hunting rights under a traditional, passive type "season lease," to landowners who are now relying on outfitted or package type hunts. These package hunting operations take on a more commercial look and feel, and indeed the resource commitment in implementing and operating this type of hunting program is much greater than your traditional lease type programs. Though the market for these package hunts has been strong over the last several years, competition for this market is extremely competitive, and those hunting operators who are able to demand top dollar for their hunts are forced into having to pay more attention to marketing their service.

Basic Marketing Plan

A marketing plan is a hedge against throwing money at an advertising campaign and seeing no results, which can and does happen. Just like a well thought out business plan, a marketing plan should serve as a template, creating an organized strategy of how you can effectively and affordably sell your hunts, year after year.

Know Your Product

Knowing your product is more complex than most people realize. This begins by essentially conducting a "product analysis" of what other competitors are doing, including what they are offering, how they are offering it, and how they are pricing it. This provides you with a conceptual product image of how you would like to structure your hunting packages. Basic components of your hunting package may include things such as meals, lodging, guides, duration of hunt, bag limits, size limits, game care, alcoholic beverages, taxidermy arrangements, airport shuttle, equipment needs, and many other considerations. To get a full grasp on knowing your product, simply identifying these basic product components is not enough. You should then analyze each aspect of all of this. It is one thing to say that you are going to provide meals, but will it be three meals daily? Served on paperware or formal place settings? Desserts? Wine during the evening meal? Appetizers? Sack lunch in the field or nice picnic style lunch at a grand setting? Local cultural accent, such as Mexican food, or will those Yankees like salsa and guacamole? Can I afford the meal plan I prefer? And very importantly, who's going to do the cooking? These are all soft nuances of analyzing the components of your product, and you should look at it in this fashion for each component.

Other important considerations in getting to know your product are such things as customer service philosophies, risk management plans, payment policies, and various other things.

Knowing your product not only allows you to create and deliver the service that you intend to provide, but very importantly, it allows you to communicate intelligently with prospective clients. Your ability to answer their questions in an intelligent, confident manner and to provide them with a complete and interesting image of what you have to offer is exceptionally important in allowing you to convert a prospect into a paid client.

<u>Identifying Your Market</u>

Targeting a specific market is another fundamental marketing concept. Why spend money on advertising when your message is being heard by an audience who simply is not interested in what you have to offer, or maybe an audience that cannot afford your hunts.

Many different market segments exist in the hunting world, but for practical purposes some of the important ones that I would list include regional segments, income level segments, corporate groups, and choice of weaponry (i.e., archery versus rifles versus black powder, etc.).

A simple ad in the *Dallas Morning News* classifieds may likely yield numerous leads on prospective season lease hunters, but may also yield no results for a $4,000 four-day whitetail hunt. An ad in *American Hunter* magazine will more likely end up in the hands of someone interested in a $4,000 package deer hunt.

A booth at the Kerrville Wildlife Expo will likely provide conversation with a high percentage of people who are lower or middle income bracketed individuals, whereas a booth at Safari Club International Convention in Reno will expose you to a higher percentage of upper income level folks. However, these folks may likely be more discerning about the quality of food and lodging, as well as the quality of game they desire. Another form of advertising is based on market segments.

If you are not interested in bow hunters it makes no sense to run an ad in Bowhunter Magazine. But if you are conducting hunts in an area where it is easier to obtain a license for primitive weapon hunters than for others, this advertising option may make perfectly good sense.

Advertising

Advertising represents the nuts and bolts of a marketing plan, since this is where the majority of marketing dollars are spent. Today there are many—literally hundreds—of different outlets through which you can choose to advertise in the hunting business. In some ways this is good, but it also creates a confusing and complex matter, as the market has theoretically been split into many pieces, so you must make a prudent choice as to which advertising medium will yield the best results for you.

Before spending a penny on advertising, it is imperative that you have printed material available that you can send to a prospective client. If you are a small scale operation, then your budget will not likely allow you to have a large, multicolor brochure. Whatever you put together, it should be well written, informative, and appealing to the eye. Photos are alluring to a hunter, especially harvest photos that are of tasteful quality. If you have no harvest photos, perhaps live animal photos taken from a blind or during a helicopter survey may suffice. But they do not stir the excitement that quality harvest photos do. Photos of facilities can compliment a brochure as well. A well done website can serve the same purpose as a brochure but should not be considered a full substitute for printed material.

Various marketing outlets in the hunting business include magazines, newspapers, exhibit shows, television, direct mail, outdoor writers, and the internet. There is no silver bullet here, so don't expect to sell all of your hunts by simply running a few magazine ads. Each of these outlets offers advantages and disadvantages.

Magazines can reach a large audience and tend to have more shelf life than newspapers. Some magazine ads have to be purchased two or three months ahead of time, which can make it less attractive if you are well into the year when you decide that you need more hunters for that year.

Newspapers tend to be retained for a relatively short period of time, but can be an excellent way to reach a large group overnight. My experience shows that newspapers are a good choice for season leases and inexpensive day hunts but are not effective for pricey package hunts.

Exhibit shows are not as productive as they once were. This is partially explained by the increase in the number of shows in recent years, as well as the increase in advertising outlets in general. The advantage of shows is that you personally get to visit with your prospects which may make for a warmer "sell", but one of the downsides is that they are labor and time intensive, and relatively expensive.

Direct mail can be an excellent means of reaching your audience, but you must first have access to a mailing list, which sometimes takes years to build. Another option for someone who does not already have a database established is purchasing a list through a database service, but you run the risk of a percentage of people on these purchased lists not being current or perhaps having no interest in your product, which means wasted money on printing and postage.

Outdoor writers can provide exposure creating name recognition and credibility, but this can be a speculative venture which will possibly yield no press coverage if you invite a writer to attend a hunt, and they are not successful in harvesting a quality animal. A word to the wise: Make sure that your writer is on staff with a quality publication, as opposed to having to submit their work through an editor on a freelance basis, which makes things even more speculative.

Internet is the big kid on the block these days. It can provide a passive way of reaching a huge audience 24/7. Two major keys to successful internet marketing are: 1) having an attractive and informative website and 2) having a website that is visible to those searching for information through the search engines. The internet is an astronomically huge arena, and people finding your website does not accidentally happen. Type in "Texas deer hunting" and you will get over 50 million matches—that's correct 50,000,000! Type in "pronghorn antelope hunting" and you will get approximately 200,000 matches.

Paying an expert to build your site properly and ensure "optimization" through key words submission, metatags, and various other optimization methods will help create visibility for your site. Another option is bidding on key word phrases through "pay per click" means, which can ensure front page visibility, but you will pay a bidded amount each time someone clicks on your website through your pay per click phrase.

Another common option in promoting your hunting operation is to engage the services of a **booking agent** or **outfitter.** An agent typically works for a 10-15% commission by simply referring customers to you or booking the hunters for you. By industry standard, once they book a client for you that client is considered the agent's customer each time they rebook with you and commissions are still expected.

Relying on an outfitter is essentially wholesaling your product. The landowner will often have to settle on a lower return for their hunting in exchange for the sweat equity that the outfitter provides. In this case, the outfitter typically markets the hunts, as well as doing the majority of the work. This arrangement can work well for a landowner who does not have the time or resources to market and outfit the hunts themselves, or simply is not interested in the hassles and headaches associated therewith.

Deliver The Goods

Over a period of time, even the best marketing plan will not gel properly if it cannot realize the support of repeat and referral business. Satisfied clients not only serve as great ambassadors for your business through spreading your message for you, but they are prone to rebook, which in turn reduces the level of marketing you must do from one year to the next. So, your ability to "deliver the goods" will always serve as a pillar in the success of your hunting operation. You should never underestimate the importance of a satisfied client. That satisfaction begins with good service and is not complete without adequate harvest results. It is cheaper to go to a resort if they are simply interested in fancy facilities and fine cuisine, which means that your hunting clients must consistently harvest what they feel they have paid for or you will be left with a sinking ship.

Client Retention

Delivering the goods is only part of ensuring your rebookings. A complete marketing plan also calls for an adequate job of following up and staying in touch with your clients. If they express interest in rebooking at the hunt's end, diligence in your converting this prime situation into a paid deposit as soon as possible is paramount, as the more time that slips by, the more likely they will find an excuse not to rebook. Furthermore, cultivating your relationship with your existing clients will also help retain their business. Phone calls, letters, and birthday cards, are good ways to maintain or rejuvenate that cozy relationship.

Conclusion

As the economic importance of hunting continues to rise for landowners, and as more hunting operators continue to increase in number, sound marketing efforts become even more important. Generating top dollar for hunting rights or hunting packages often carries a price in itself through the time and expense required to generate this level of interest. For some, striving for top dollar returns from hunting may not make as much sense as simply setting their prices at a reasonable level and letting the operation sell itself. This is especially true for landowners who already have a good group of hunters, particularly if it is a lease type arrangement. Replacing a trusted group with another group who may be willing to pay more can sometimes yield results that are not worth the price increase.

CASE STUDY: SIBLEY'S LAST CHANCE RANCH

BILL SIBLEY, PO Drawer 2048, Carlsbad, New Mexico 88221

I am Bill Sibley of Sibley's Last Chance Ranch. My family has been ranching in the Trans-Pecos for over 130 years. My Great Grandfather, W. D. Casey, began ranching near Balmorrhea in Reeves County in 1879 and began ranching in Culberson County as well in the late 1800's.

We are in the ranching business and have always been interested in caring for the wildlife. Early on we only invited friends and family to hunt on the ranch but for the past 50 years we've been marketing the hunting. By marketing the pronghorn, deer, quail, and dove wisely, we have found that the income generated has made significant contributions to our bottom line and made it possible to improve our operation annually.

We realize the contribution to society that wildlife makes and have been involved with Texas Parks and Wildlife Department programs for 25 to 30 years. During that association we have learned about the needs of wildlife and that the merchandising of wildlife is providing a service to the public by providing hunters opportunities they would not have otherwise.

As landowners / ranchers it is our responsibility to manage our resources and an obligation to share them with others. Our resources are not only the wildlife but also the grass, the trees, the soil, the water, and the cattle. It is extremely important to realize that the wildlife was given to us to protect and to utilize. As a rancher or a landowner if we do not care for the wildlife we are remiss in our duties. Our job is to manage these resources and provide opportunities.

It important to realize that what is good for hunters is good for ranchers as well. Hunters just can't hunt anywhere they please. I am convinced that without marketing our wildlife and all that we have to offer, we would not have been able to make the steady improvement that we have.