

# ECOLOGY OF THE CARMEN MOUNTAINS WHITE-TAILED DEER



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*To Carol, Curtis, and Julie*

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PAUL R. KRAUSMAN  
ERNEST D. ABLES

# Summary

The ecology of Carmen Mountains white-tailed deer (*Odocoileus virginianus carminis*) in Big Bend National Park, Texas, was examined between June 1972 and April 1974. Distribution, habitat, food habits, competition with mule deer (*O. hemionus crooki*), and predator-prey relationships are discussed.

Approximately 580 Carmen deer inhabit the Chisos Mountains in the park. Their range extends to isolated mountains outside of the park and into Mexico but the Chisos Mountains provide the main habitat in the United States. Carmen deer were found most often in pine-juniper-oak (*Pinus* spp.-*Juniperus* spp.-*Quercus* spp.) associations above 4,500 feet (1,373 m). Two components of whitetail habitat were found on all ranges: free-standing water and dense vegetation.

Based on the contents of 25 rumens, forage consumption included browse (35%), succulents (28%), forbs (14%), and grasses (4%). Unidentified food items made up 19% of rumen contents. Lecheguilla (*Agave lecheguilla*) and pricklypear (*Opuntia engelmannii*) were used the most, comprising 17% and 11% of the diet, respectively. Succulents provide a source of moisture and are important throughout the year, especially during dry months.

Mule deer inhabit the Chihuahuan Desert surrounding the Chisos Range and overlap with Carmen deer on lower foothills. An important habitat-separating mechanism between the two species appeared to be topography. Forage competition was precluded due to an abundance of commonly used food items but interference between opposite species may influence habitat selection.

Of whitetail deaths recorded, 24 were of undetermined causes or related to accidents, and 25 were killed by mountain lions (*Felis concolor*). Analysis of 161 lion droppings indicated that 70% of their diet was deer. Other predators of Carmen deer include bobcats (*Lynx rufus*) and coyotes (*Canis latrans*).

A single factor could not be isolated which regulated deer distribution and population levels, but interspecific behavior, habitat preference and topography, water availability, and predation combined were the most likely influences.

# 1

## Introduction

Information on unexploited white-tailed deer (*Odocoileus virginianus*) populations is rare due to their popularity as game animals and to the lack of pristine ranges. Data from such populations would be of value because they serve as a base with which to compare exploited populations.

Big Bend National Park, Texas, is one of the few undisturbed ecosystems remaining in the Southwest and is unique in that it contains the only mountain range entirely within the boundaries of a national park. The Chisos Mountains rise abruptly from the Chihuahuan Desert floor to nearly 8,000 feet (2,440 m) and are the southernmost mountain mass in the United States. This range supports the main population of the Carmen Mountains white-tailed deer (*O. v. carminis* Goldman and Kellogg) in the United States.

Data on Carmen deer were collected for 3 years. During the first year of the study, beginning May 1971, Don E. Atkinson (1975) of Texas A&M University examined population numbers. The remaining 2 years of field work were conducted by me between June 1972 and April 1974.

Research reported herein was conducted to (1) evaluate specific aspects of the Carmen deer's ecology, including distribution, habitat, food habits, mortality, predation, and relationships with other ungulates, especially the desert mule deer (*O. hemionus crooki* Mearns); (2) provide knowledge as a basis for possible management; and (3) make available a source of interpretive information for visitors to Big Bend National Park.

### *Study Area*

Big Bend National Park (Fig. 1) is a preserve representing the rugged northern Chihuahuan Desert. Dominated by expanses of Chihuahuan Desert interspersed with wooded peaks and river-swept floodplains, the Big Bend area provides some of the finest desert and mountain scenery in the United States.

The Chisos Mountains lie between 103 and 104° longitude, and 29 and 30° latitude, and constitute the major locale for the present study. The entire park contains 708,221 acres (286,830 ha) but less than 2% constitutes the woodland community of the Chisos Mountains which lie



Fig. 1. Location of Big Bend National Park, Texas.

above 4,500 feet (1,373 m) (Fig. 2). Higher elevations provide exclusive whitetail habitat but lower areas are shared with mule deer. The sympatric range is a band from approximately 4,000 feet (1,220 m) to 4,800 feet (1,464 m) lying along the face of sheer cliffs, canyons, and drainages.

### *Physiography*

#### **Geology**

The igneous masses of the Chisos Mountains, Rosillos Mountains, and the cretaceous limestone formations of the Christmas Mountains break up the vast basin aspect of southern Brewster County. The Chisos Range, formed from differing volcanic origin, is an uplift of igneous and metamorphic material forming a circle of peaks roughly 5 miles (8 km) across (Lonsdale et al. 1955; Maxwell 1971). Rugged rock outcrops, vertical cliffs, deep canyons, and talus slopes are characteristic (Fig. 3).



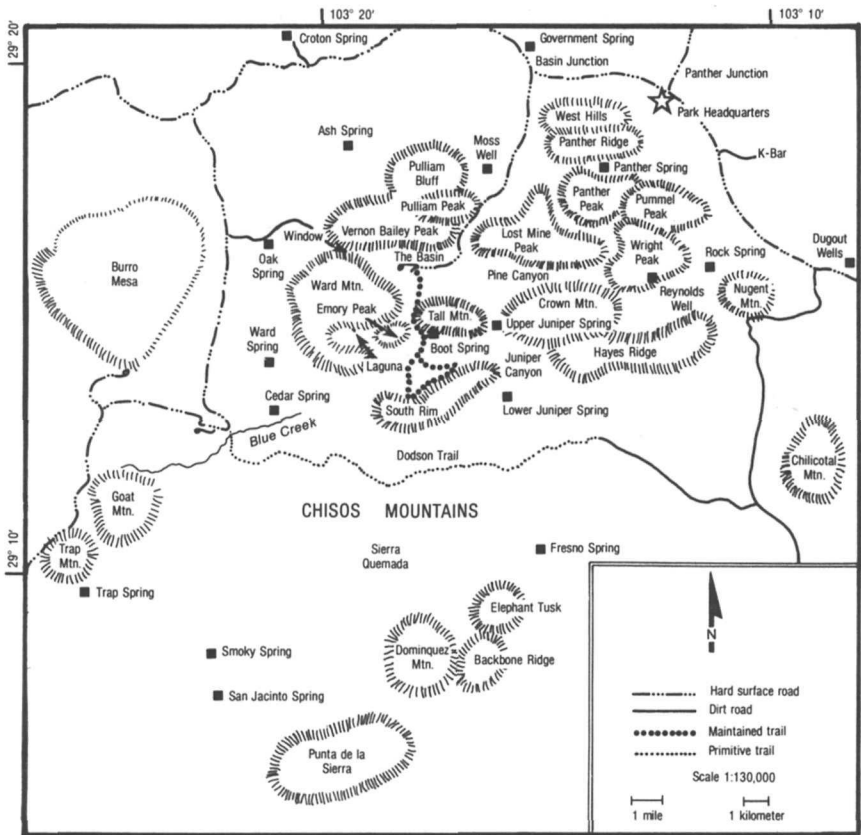
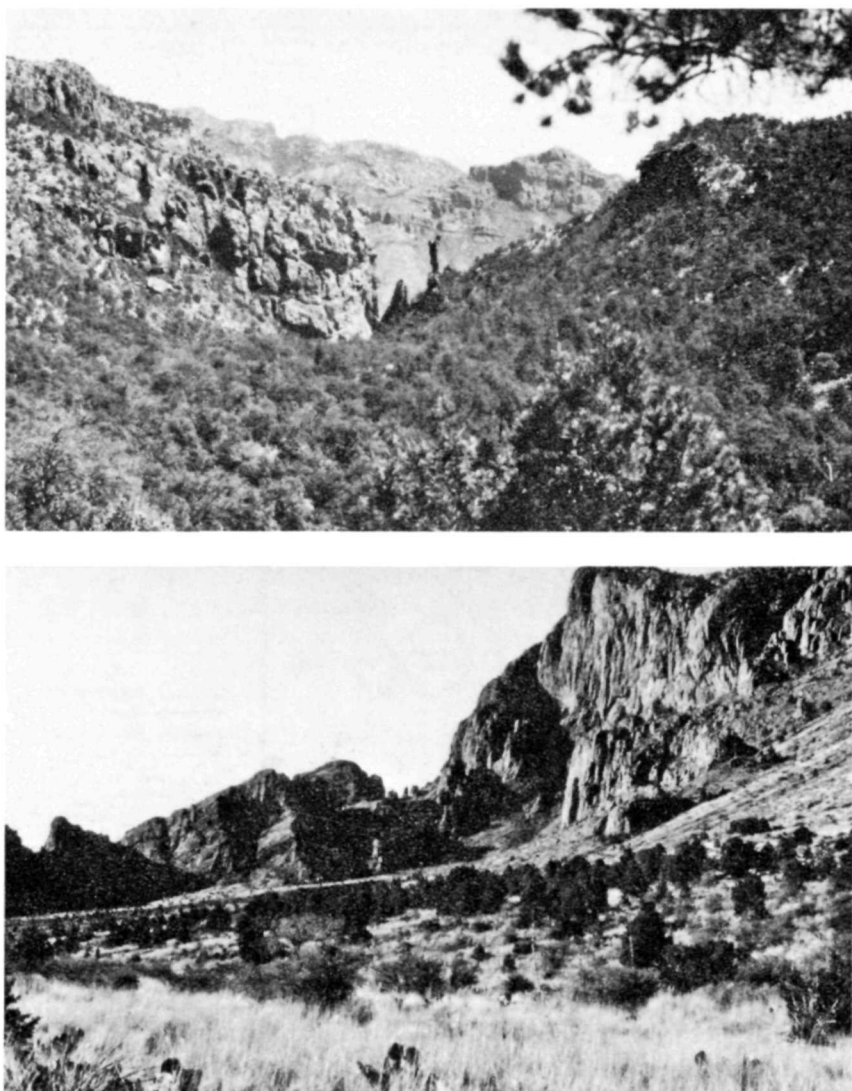


Fig. 2. Area locations in and around the Chisos Mountains.

The Chisos Mountains are the highest features in the park, rising from the 2,000-foot (610 m) desert plain to a maximum altitude of 7,825 feet (2,387 m) at Emory Peak (Fig. 2). The oldest rocks are volcanic ash, ash and clay, sandstone, and conglomerates. These are overlain by thick massive lava penetrated and deformed by intrusions. Both intrusive rocks and lava caps form the high elevations (Maxwell et al. 1967). The geology of the Big Bend Area is discussed in detail by Baker (1935), Kelly et al. (1940), and Maxwell et al. (1967).

### Soils

Soils of the Chisos Mountains are primarily of the Ector, Brewster, and Reagan series. The Ector series are light brown, calcareous, friable, strong, and fine sandy loams, silt loams, and clay loams. This series supports sotol-lecheguilla (*Dasyllirion leiophyllum*-*Agave lecheguilla*) and creosotebush-lecheguilla (*Larrea divaricata*-*Agave lecheguilla*) as-



**Fig. 3.** Characteristic rock outcrops, vertical cliffs, deep canyons, and talus slopes of the Chisos Mountains. *Top.* Boot Canyon. *Bottom.* West of Pulliam Bluff along Green Gulch.

sociations as well as several stands of pine (*Pinus* spp.) in the Chisos proper (Denyes 1956).

The forest communities of the higher life belts are found on fine sandy loams, silt loams, clay loams, and loams of the Brewster series. This series is brown or red, noncalcareous, and friable (Denyes 1956).

Reagan gravelly loam containing a 6- to 10-inch (15–25 cm) topsoil with abundant gravel is characteristic of the basal areas of the Chisos Mountains (Denyes 1956).

### Climate

Hot summers, mild winters, and low rainfall are characteristics of the Chisos Mountains and surrounding foothills. Rains occur throughout the year, with the highest precipitation from May through October and with the greatest amounts recorded in August and September. Annual rainfall is about 13 inches (33 cm) in the higher mountains but occasionally exceeds 20 inches (51 cm). On the surrounding foothills, the annual rainfall averages 11 inches (28 cm).

During the study period, the average maximum monthly temperatures during the hot months fluctuated around 80°F (27°C) in the mountains and 90°F (32°C) in the foothills (Figs. 4, 5). During the cooler months, frost and freezing were rare on the lowlands, while mountain temperatures dropped below freezing 20–30 times during winter (Wauer 1971).

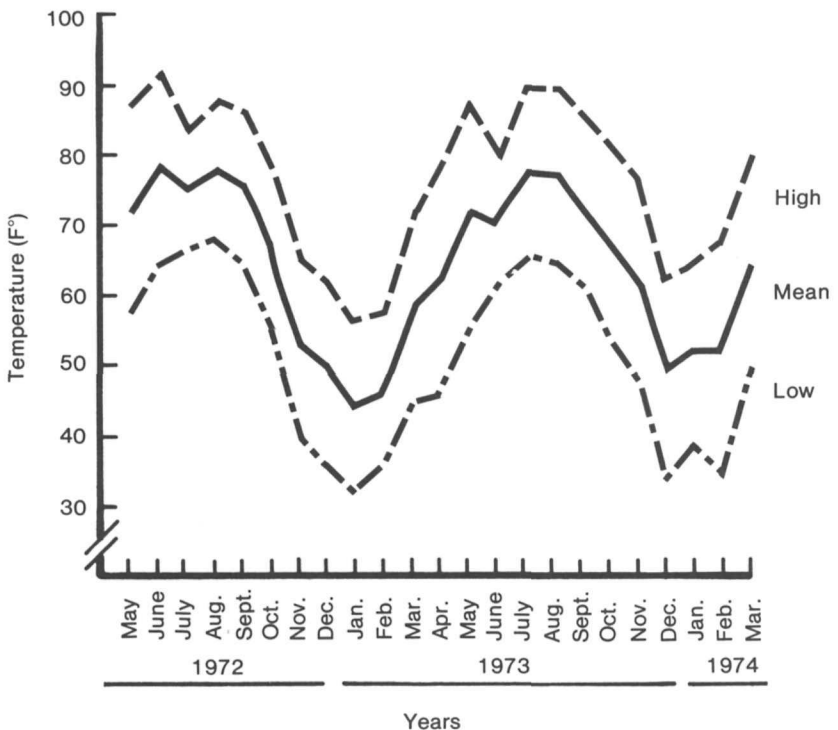


Fig. 4. High, mean, and low temperatures for each month during the study period at Panther Junction.

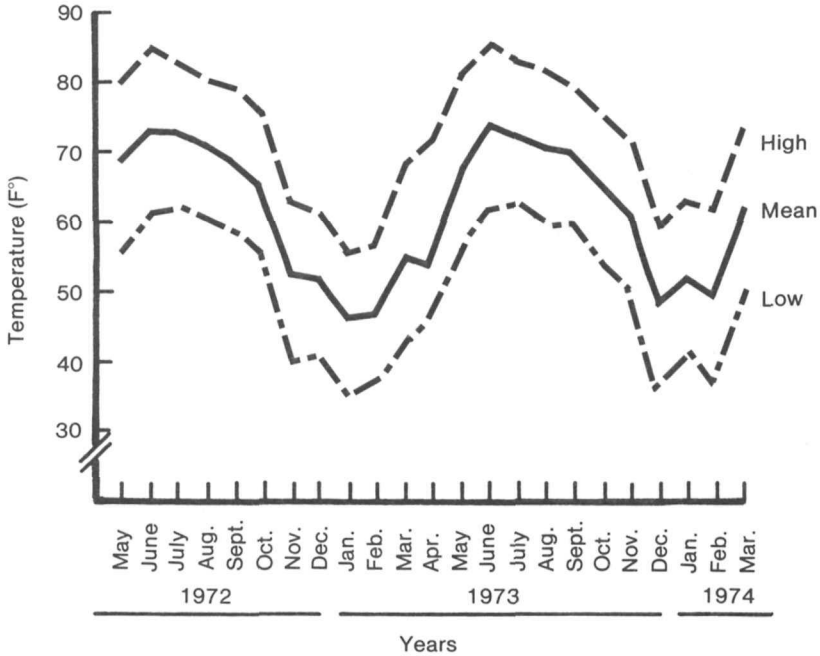


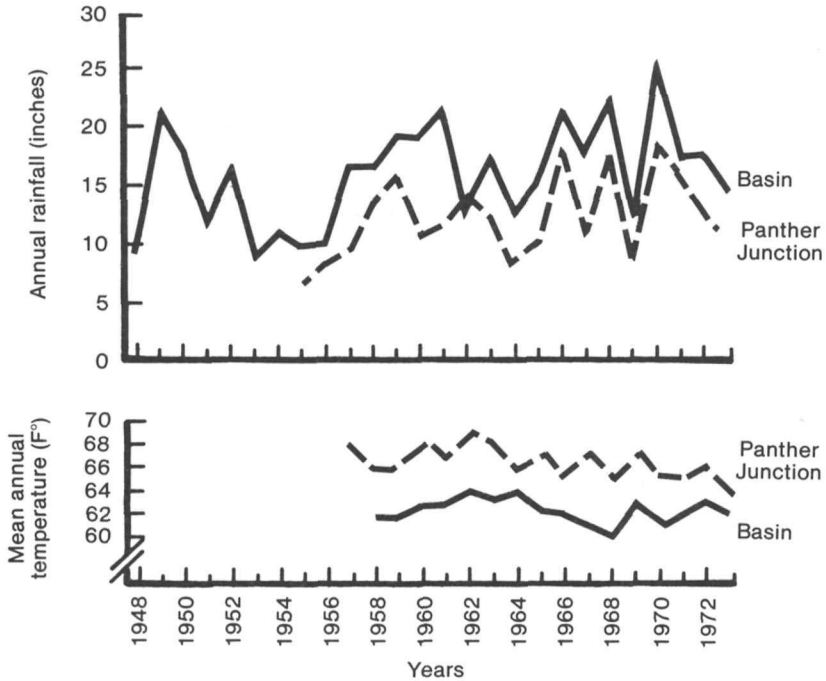
Fig. 5. High, mean, and low temperatures for each month during the study period at the Chisos Mountains.

Snow is uncommon. Between 1948 and 1973, the mean annual temperature was about 66°F (19°C) in the foothills and 63°F (17°C) at higher elevations (Fig. 6) (Anon. 1948–74).

The upper mountains are watered by rain-fed springs in summer. Foothills obtain water from the spring runoff which is high due to torrential precipitation, scant vegetation, and nature of the soil (Muller 1937).

### *History of Land Use*

Man's historic use of Big Bend is poorly understood but some information is available. Uncovered relics suggest that man entered the Big Bend Country before Christ and Indian civilizations existed but then vanished (Madison and Stillwell 1968; Wauer 1973). Spaniards entered the area as early as 1534, found it inhospitable, and bypassed the Big Bend on their westward expeditions (Taylor et al. 1944; Davis 1957). Relatively uninfluenced by man's activities, the area lay in a natural state until late in the 19th century. Even then, settlement in the Big Bend area was delayed as it became a haven for raiding Indians. In the 1880s



**Fig. 6.** Annual rainfall and mean annual temperature for the Basin and Panther Junction from 1948 to 1973.

the Indian threat passed and ranching activities began (Davis 1957). Livestock operations encircled the Chisos Mountains in the sotol-grasslands of the lower foothills by 1920 but the inaccessible mountains received little use. Overgrazing prevailed in the foothills, and by the late 1920s the livestock had advanced into the higher elevations (Wauer 1973). Overgrazing may have been the most destructive influence to hit Big Bend. Cattle destroyed lecheguilla; and grasses were placed in jeopardy by horses, sheep, and goats. Drought created a cattle die-off from 1916 through 1919 and ranchers realized that forage was adjusted to precarious climatic conditions. Grasses disappeared and desert vegetation invaded rapidly (Davis 1957).

As the economic value of the land decreased, the people of Texas decided to preserve this portion of the Chihuahuan Desert. Most of the ranches were purchased by Texas in 1942 but grazing privileges were maintained until 1944. During this 2-year period, excess livestock placed on the area augmented the detrimental effects already operating. From the time the land was purchased until ranching finally ended, cattle increased from 3,880 to about 22,000 head, and the number of horses



increased from 310 to 1,000. Other livestock abuse was caused by 25,700 goats and 9,000 sheep (Prewitt 1947; Wauer 1973).

As early as 1934, the Chisos Mountains were protected when established as a State Park. Hunting was illegal but not completely eliminated until 1944 (Maxwell 1956; Davis 1957; Madison and Stillwell 1968). When land acquisition was completed, the area was presented to the Federal Government. Big Bend National Park was established on 5 July 1944.

## *Flora*

Assigned to the Chihuahuan biotic province, the Big Bend region of Texas can be separated into two biotic districts (Dice 1943; Blair 1950): the Davis Mountains biotic district and the Chisos biotic district which includes Big Bend National Park.

Localized climate and rainfall, weathering and erosion of the mountains and lower slopes, and geological processes that formed the mountains all have had direct effects on the vegetation in the arid and semi-arid land of Big Bend (Maxwell 1971). Burnt pine stumps scattered in high areas of the Chisos indicate that fire also has affected vegetation. Characteristic associations are found in irregular belts related to altitudes and local air currents (Muller 1937; Maxwell 1971). Parts of the Chisos are barren, but forests prevail in areas that receive sufficient moisture, while the lowlands are eroded plains with the most severe temperatures, lowest rainfall, and sparsest vegetation.

Dominant plants in the foothills include pricklypear (*Opuntia engelmannii*) and related species, lecheguilla, century plant (*Agave scabra*), spreading fleabane (*Erigeron divergens*), spurge (*Euphorbia serrula*), gramagrass (*Bouteloua* spp.), sotol, silverleaf (*Leucophyllum* spp.), evergreen sumac (*Rhus virens*), acacia (*Acacia* spp.), yucca (*Yucca* spp.), mimosa (*Mimosa* spp.), basketgrass (*Nolina erumpens*), snakeweed (*Xanthocephalum* spp.), goldeneye (*Viguiera* spp.), mariola (*Parthenium incanum*), guayacan (*Porlieria angustifolia*), and mesquite (*Prosopis glandulosa*). In the higher mountains and extending to the lower slopes, oak (*Quercus* spp.) is abundant along washes, and three species of juniper (*Juniperus flaccida*, *J. monosperma*, and *J. pachyphloea*) are common with pinyon pine (*Pinus cembroides*).

The vegetation in Big Bend National Park has been divided into six vegetational formations by Wauer (1971): River Floodplain-Arroyo Formation, consisting of the arroyo-mesquite-acacia associations; Shrub Desert Formation, consisting of the lecheguilla–creosote–cactus associations; the Sotol–Grassland Formation; the Woodland Formation, containing deciduous woods and pinyon–juniper and oak associations; and the Moist Chisos Woodland Formation, which is composed of the cypress (*Cupressus arizonica*)–pine–oak association. The last three formations are in the main study area of this project.

## Mammals

Big Bend National Park supports more mammals than the casual observer would expect. Seventy-five species of mammals have been recorded within the park, including 28 rodent species, 19 species of bats, 17 carnivores, 5 even-toed ungulates, 3 rabbit species, 1 opossum, and 1 shrew (Easterla 1973).

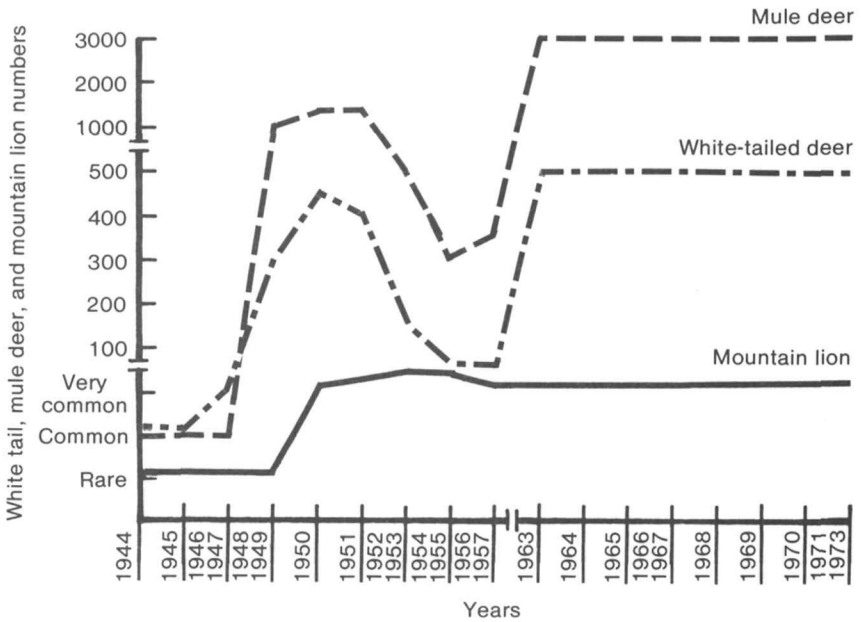
Little was known about deer in the Big Bend area prior to settlement. Bone fragments, Pre-Spanish in age, found in caves in Coahuila, indicate the utilization of Carmen deer by early Indians (Gilmore 1947). Other historical information relating to Big Bend's deer are sparse. Limited data have been recorded in an unpublished ecological survey of the park (Davis 1957). Most of the following information is from that report as discussed by Ross Maxwell, the first Park Superintendent of Big Bend National Park from 1936 to 1952, and George H. Sholly, Chief Park Ranger from 1946 to 1955. The comments of these men were supported by local ranchers and other persons consulted by the ecological personnel at the time.

From 1912 to 1934, the Carmen deer and desert mule deer were fairly common. Their numbers were sufficient to allow ranchers to make as much or more money from selling hunting rights as they did from ranching activities. Mule deer were preferred by hunters, and less than 10 whitetails were harvested each season due to the habitat whitetails occupied. Inaccessible areas, rough terrain, and plenty of mule deer precluded heavy hunting pressure on whitetails (Borell and Bryant 1942).

In 1941 and 1942, acquisition of the remainder of the present park area was accomplished and previous landowners were given until the end of 1944 to cease ranching and hunting. Apparently, deer numbers were stable around 1936 but showed signs of increase from 1947 to 1952 (Murie 1954; Davis 1957) (Fig. 7). During the period from 1944 to 1957, Maxwell claimed the deer population was high. Counts of 70 whitetails and 50 mule deer during drives from the Basin down through Green Gulch, a distance of 13 miles (21 km), were common in the mid-1940s.

Several outbreaks of disease were described, the first in 1942, followed by an apparent decrease in whitetail numbers. Disease of unknown origin was again reported in 1944 and 1948. Ulcers in the mouth, stomach, and intestines were prominent symptoms. In August and September 1948, over 100 whitetail carcasses were noted in the Basin and adjacent areas. National Park Service records (Anon. 1945–present) indicated that stomach worms (*Haemonchus* spp.) may have killed deer in 1944 and undetermined poisonous weeds may have caused the die-off in 1945.

In the early 1950s, it was apparent that deer populations were decreasing. The decrease was blamed on mountain lion (*Felis concolor*) predation, as the number of lions supposedly increased from 1949 to 1953 (Fig. 7).



**Fig. 7.** Population fluctuations of mule deer, white-tailed deer, and mountain lions from 1944–73 (based on NPS Annual Wildlife Reports).

Ranchers killed lions at every opportunity, and considerable time and effort was spent in lion control prior to the park’s establishment; over 100 lions reportedly were killed in the Chisos Range between 1929 and 1942. Ranchers in the Rosillos Mountains north of the park reported killing 75–80 lions between 1947 and 1952. U.S. Fish and Wildlife Service trappers took around 17 lions annually in the same area from 1954 to 1957. Random observations of lions at the time were numerous suggesting a considerable lion population.

Local residents were convinced that lion predation was the major factor for the decline of deer. This may have been an important factor, but other influences were working as well. Grazing pressure was intense prior to 1945 in the areas of high deer concentrations. The pressure was released in 1945 and was accompanied by abundant rainfall. Both range vegetation and deer numbers improved.

In 1944, whitetails were confined to the Chisos Mountains but were occasionally seen on Burro Mesa, Chilicotal Mountain, and Grapevine Hills (Borell and Bryant 1942; Anon. 1945–present). Numbers of deer in these areas were unknown but were probably low. Livestock operations established free-standing water in the form of earthen livestock water tanks and dug-out springs. New water sources may have allowed the deer to extend their range from the Chisos into surrounding hills and

mesas. It is not known if deer occurred in these adjacent areas prior to water establishment. As the ranching years ended and water dried up, whitetails were no longer observed. Concurrent with the decline in ranching were the disease years of 1944 and 1948, which reduced the number of whitetails in the Chisos Mountains and probably added to the reduction on surrounding hills and mesas. A more important factor reducing whitetails in marginal habitat of the park may have been grazing pressure applied by introduced livestock.

In 1947, whitetails were observed on lower mountain bases, areas that had been grazed by goats and formerly unoccupied by deer. The whitetail increase through 1950 (Fig. 7) may have been due to range extension to lower foothills and high elevations.

The reduction of whitetails through 1957 (Fig. 7) was attributed to drought, lion increases, and reduction of free-standing water when ranch operators pulled out water tanks (Anon. 1944–73).

The reader should keep in mind that all census figures prior to 1955 were based on individual opinion, and quantitative measures were not considered in establishing numbers. An attempt was made to quantify measurements when pellet plot transects were established in 1955 and first read in 1956 (Davis 1957). The results of this attempt suggested that numbers of deer were not as low as previously believed. Figure 7 indicates the abrupt increase in numbers from 1957 to 1963. Historic observations of mammals and the 1950 transect work done in Big Bend have been the bases for deer estimates reported in National Park Service Wildlife Inventories and Fish and Wildlife Big Game Inventories from 1963 to the present.

Park rangers read pellet plot transects from 1968 through 1972 but did not analyze the results. Atkinson (1975) established new transects for estimation of deer in the park in 1971. The results of these studies will be presented later.

Park records indicate that ungulate and predator numbers increased when ranching and hunting ended. Table 1 summarizes the historic accounts of Big Bend's javelina and larger predators. Status estimates and numbers in this table sometimes conflict. Such inconsistencies are due to differing yearly assessments without a standard quantification method.

TABLE 1. Status of javelina and large predators from 1944 to 1973 in Big Bend National Park.

Year	Bobcat		Mountain lion		Coyote		Javelina	
	Numbers	Status	Numbers	Status	Numbers	Status	Numbers	Status
1944	C	↑	R	↑	C	↑	—	—
1945	C	—	R	↑	C	↑	R	↑
1946	—	—	—	—	—	—	—	—
1947	C	—	R	↑	C	↑	R	↑
1948	—	—	—	—	—	—	—	—
1949	C	—	U	—	C	—	300	—
1950	C	—	15	S	C	↑	300	—
1951	C	S	20–25	S	C	↓ <sup>a</sup>	500	—
1952	R	S	40	—	C	—	200	—
1953	R	S	40	—	C	—	200	—
1954	U	S	30 <sup>b</sup>	—	C	S	200	—
1955	U	S	30 <sup>c</sup>	—	C	S	200	—
1956	U	S	10–15	S	C	S	250	↑
1957	U	S	10–15	S	C	S	250	↑
1958	—	—	—	—	—	—	—	—
1959	—	—	—	—	—	—	—	—
1960	—	—	—	—	—	—	—	—
1961	—	—	—	—	—	—	—	—
1962	—	—	—	—	—	—	—	—
1963	—	—	17	S	400	S	3,500	S
1964	—	—	17	S	400	S	3,500	S
1965	—	—	17	S	400	S	3,500	S
1966	—	—	15	S	400	S	3,500	S
1967	—	—	10–20	S	400	S	3,500	S
1968	—	—	10–20	S	400	S	3,500	S
1969	—	—	—	—	400	S	3,500	S
1970	—	—	—	—	400	S	—	—
1971	—	—	—	—	400	S	—	—
1972	—	—	—	—	400	S	—	—
1973	—	—	8–12 <sup>d</sup>	S	400	S	—	—

<sup>a</sup>Reduction from illegal poisoning; <sup>b</sup>29 lions were also killed along park boundaries; <sup>c</sup>24 lions were also killed along park boundaries; <sup>d</sup>from Wauer (1973).

C = common; U = uncommon; R = rare; — = no data; ↑ = increasing; ↓ = decreasing; S = stable.



## 2

# Methods

The study was conducted in the Chisos Mountains and surrounding foothills and mesas, an area of approximately 20 square miles (52 km<sup>2</sup>), in Big Bend National Park (Fig. 1). Headquarters were maintained at the Naturalist Workshop in Panther Junction (Fig. 2). Paved roads to the north of the Chisos and up Green Gulch and dirt roads into Pine and Juniper canyons (Fig. 2) served as access routes to the mountains via pickup trucks and a trailbike; travel on the study area itself was by foot. Field observations and collections were the basic methods of obtaining data, but National Park Service records and museum specimens served as additional information sources.

### *Climate*

Weather information was collected from U.S. Weather Bureau stations, maintained by the National Park Service at Panther Junction and in the Basin. These data were supplemented with readings from rain gauges set up over the study area.

### *Deer Description and Distribution*

Descriptions of Carmen deer were based on field observations made with 8×35 binoculars and a 20× spotting scope, and on examinations of collected animals. All collections were by authority of a U.S. Department of the Interior, National Park Service, Class B, Collecting Permit.

Weights and measurements were taken whenever deer were collected. Measurements taken with a flexible steel tape to the nearest millimeter were as follows:

**Body length:** The distance from the tip of the nose to the base of the tail when the tail is held 90° to the dorsal side. The animal was straightened on its side as much as possible and the tape was passed along the curvatures of the dorsal side.

**Tail length:** The distance from the base of the tail held 90° to the dorsal side to the end of the last caudal vertebra.

**Total length:** Body length plus tail length.

**Heart girth:** The circumference of the chest cavity taken behind the forelegs.

**Rear leg:** From the top of the right tibia to the tip of the hoof.

**Height at withers:** The vertical distance from the tip of the hoof of a foreleg to the top of the scapula.

**Neck circumference:** The circumference of the midpoint along the extended neck.

**Outside ear:** The length of the ear from the base to the tip.

Supplemental cranial material used in describing Carmen deer were obtained from the Museum of Vertebrate Zoology, University of California at Berkeley, and the Bird and Mammal Laboratories of the National Museum of Natural History in Washington, D.C. Skulls collected during this study are deposited in the Texas Cooperative Wildlife Collections, Texas A & M University, College Station.

Distribution of Carmen deer was established by examination of potential habitat and confirmation of deer presence in these areas.

### *Population Estimates*

Prior to the start of the present study, Atkinson (1975) established pellet plot transects (Eberhardt and Van Etten 1956) throughout the Chisos Mountains. Transects consisted of 20 pellet plots, for a total of 0.2 acres (0.08 ha) per transect. Each of 12 transects was this size; the upper Juniper Canyon transect consisted of only 10 pellet plots comprising 0.1 acre (0.04 ha). Transects were composed of two parallel lines of plots 72 feet (22 m) apart, with paired plots along each line located at 289 foot (88 m) intervals.

The plots were read in August, November, February, and June of each year. Pellet groups were removed after each reading. Additional information was obtained from 10 pellet plot transects established by the National Park Service in whitetail habitat.

### *Sex and Age Classification*

A total of 1,218 individual observations of whitetails was made. Deer observed in the field were classified as fawns, adult females, adult males, and yearling males or females when possible. Tooth wear (Taber 1969) served as an aging criterion when jaws were available.

### *Group Size and Activity*

Group size and activity were recorded for each field observation. Field work was concentrated during crepuscular hours. An indication of early nocturnal activity was obtained by spotlighting both sides of Green Gulch from Campground Junction to Basin Junction (Fig. 2). Spotlights were handled by two observers, in the bed of a pickup truck, each working one side of the road, as a third member drove 5 miles per hour (8 km per hr). Spotlighting was conducted monthly between June 1972 and January 1973.

### *Reproductive Activity and the Fawning Season*

Development of secondary sex characteristics and male rutting behavior were dated as observed. Several embryos were backdated to determine conception dates and observations of newborn fawns and pregnant females were recorded. When collected, testicles were examined for active spermatogenesis.

### *Mortality*

Deaths were placed into three categories: predation, accidents, and undetermined. Predator-related and undetermined deaths were discovered in the field, while most accidents (i.e., road-kills) were reported by the park staff.

### *Parasites, Disease, and Deer Condition*

All animals collected were examined for external parasites; concentrated searches were made on and in the ears, around the head, between the hooves, neck, back, flanks, genitals, and anus. External parasites were preserved in 70% ethyl alcohol, labeled, and sent to the Department of Veterinary Parasitology, Texas A & M University for identification.

Lung, liver, spleen, kidney, heart, testicle, ovary, and muscle samples from collected deer were labeled and preserved in 10% formalin. Tissues were examined at the Washington Animal Disease Diagnostic Laboratory, Washington State University, Pullman.

An indication of the condition of deer was provided by visual examination of marrow color and consistency, and omental, kidney, and heart fat. Classification was good, fair, or poor (Hornocker 1970).

### *Predator Scat Analysis*

Fecal droppings (scats) from mountain lions, coyotes, and bobcats were collected throughout the study period. One hundred and sixty-one lion scats, 128 bobcat scats, and 245 coyote scats were analyzed. Lion and bobcat scats were found in the field, while most coyote scats were picked up along paved or dirt roads. Upon collection, droppings were identified, labeled, placed in bags, and preserved with mothballs until analyzed.

A reference collection of hair-scale impressions from prey species was made in fingernail polish (Williamson 1951). Drawings of medulla characteristics of hairs, compound microscope hair prints prepared by D. E. Atkinson, and scale photographs (Adorjan and Kolenosky 1969) also were referred to for identification. Teeth, claws, hooves, and cranial material of prey species were sometimes used in determining scat contents.

Individual scats were broken apart and different hairs sorted into isolated piles. Hair mounts were then made of representative hairs from each isolate, studied microscopically, compared to the reference series, identified, and recorded. Volumetric makeup of each hair group was ocularly estimated.

### *Food Habits*

Twenty-five whitetail rumens were analyzed for forage content. One was collected by a hunter outside the park, while all others were obtained in the park. Table 2 lists the sex, age class, and number of animals collected. Collections by special permission were random. In addition, observations of browsing deer were used to determine other plants consumed.

Rumen contents were washed in water, labeled, placed in plastic bags, and frozen. Sampling was performed following the technique of Chamrad and Box (1964). Foods observed in the rumen but not sampled are listed as trace items in the diet.

Food samples from rumens were viewed under a binocular microscope and compared to reference collections of seeds and plants for identification. A complete, verified herbarium of study-area vegetation was also available. Scientific names of plants follow Correll and Johnston (1970).

Seasons are based on plant phenology, climate, and deer activity. Summer includes May, June, and July; late summer is August, September, and October; winter extends from November through January; and February, March, and April are spring months.

### *Competitive Interactions*

Measurements of association between mule deer and whitetails were determined from coefficients of association (Dice 1945) and were subjected to a chi-square examination for determining statistical significance. Competition was also evaluated through habitat and forage use between the two deer species.

TABLE 2. Sex, age, and numbers of Carmen deer collected for analysis of rumen content in Big Bend National Park.

Sex and age class	No. of deer
Adult male	7
Adult female	9
Yearling male	1
Yearling female	2
Fawn male	1
Fawn female	5
Total	25

### *Vegetation*

Vegetative sampling was done between July and November 1973. The sampling technique followed Dix (1969). Several habitat comparisons were made, with a similarity index as described by Curtis (1959:83).

Utilization of various areas by the two species of deer was determined by differences in pH values of pellets deposited by mule and white-tailed deer (Krausman et al. 1974).

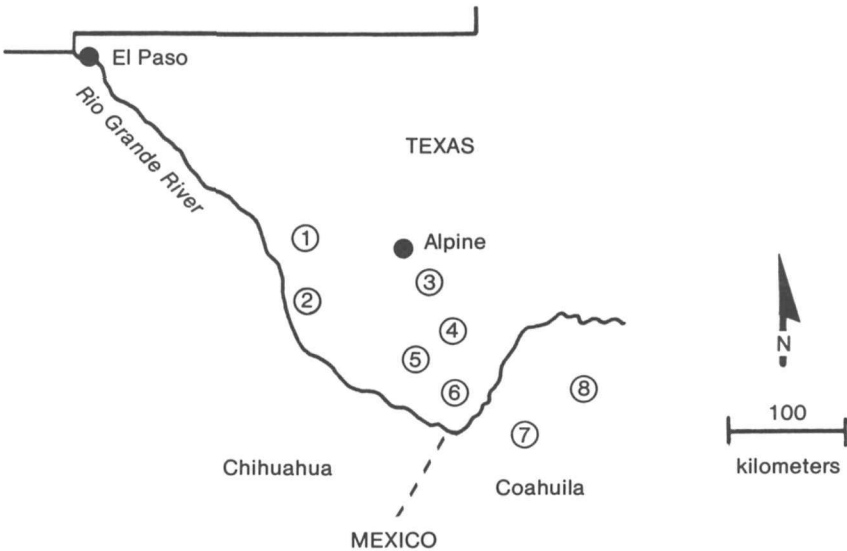
### 3

## Results and Discussion

### *Description of Carmen Mountains White-Tailed Deer*

Carmen Mountains white-tailed deer were described first by Goldman and Kellogg in 1940. The type specimen, an adult male, was collected by J. M. Dealey on 27 October 1939 in Botellas Canyon, Sierra del Carmen, Coahuila, Mexico (Fig. 8).

The Carmen deer is small in size, with moderately spreading antlers which vary considerably in length and form. Many antlers form small baskets, with the main beams curving tightly inward, but sweeping beams forming wider arched antlers also are common. The Carmen deer approaches the color of the Texas white-tailed deer (*O. v. texanus*) and is described by Kellogg (1956).



**Fig. 8.** Distribution of the Carmen Mountains white-tailed deer: (1) Sierra Vieja\*; (2) Chinati Mountains; (3) Del Norte Mountains\*; (4) Rosillos Mountains; (5) Christmas Mountains; (6) Chisos Mountains, (7) Sierra del Carmen; (8) Sierranias del Burro. \*Whitetails may inhabit these ranges.

Goldman and Kellogg (1940) and Kellogg (1956) reported skulls of Carmen deer to be characteristically smaller than Texas white-tailed deer. In relation to the Coues white-tailed deer (*O. v. couesi*), Carmen deer reportedly had smaller ears and antlers and a narrower and more slender rostrum. However, data collected during the present investigation revealed that Carmen deer have a broader rostrum than the Coues deer (Table 3), with longer tines and larger antlers than the Coues deer (Table 4). Additional measurements are compared in Table 5. The data presented by Goldman and Kellogg (1940) are from the type specimen, whereas others represent the largest male examined in the series.

Of the four subspecies of whitetails in Texas, Carmen deer are the smallest and may be smaller than any subspecies on the mainland of the United States. Teer et al. (1965) reported on the field-dressed weights of whitetails from the Llano Basin and Edwards Plateau of Texas. The whitetails in these Texas areas are small, but Carmen deer are smaller.

Ten adults were measured for the present whitetail examination. Adult males averaged 104 pounds (47 kg), and females in the 2.5- to 3.5-year

TABLE 3. The mean skull size of adult males from 13 *O. v. carminis* and 11 *O. v. couesi* collected from their respective ranges.

Skull character	<i>O. v. carminis</i>	<i>O. v. couesi</i>
	Mean size (mm)	Mean size (mm)
Condylobasal length	238.7	230.3
Greatest length	252.3	238.9
Postorbital constriction	75.2	64.1
Rostral breadth	74.3	71.9
Maxillary diastema	78.3	73.2
Palatal length	154.2	146.7
Nasal width	27.4	25.6
Nasal suture length	73.5	67.4
Mandibular length	195.3	188.7

TABLE 4. Mean comparisons of eight antler measurements from *O. v. carminis* and *O. v. couesi* collected in their respective ranges.<sup>a</sup>

Parameter	<i>O. v. couesi</i>	<i>O. v. carminis</i>
Maximum inside spread	258.3 (6)	346.0 (21)
Length of antlers	254.6 (6)	336.7 (27)
Length of brow tine	49.3 (6)	57.6 (25)
Length of tine #1	95.5 (6)	122.7 (26)
Length of tine #2	69.0 (6)	112.0 (22)
Diameter 2.5 cm above brow tine	67.5 (6)	79.5 (31)
Diameter 2.5 cm above base	71.5 (6)	88.6 (31)
Number of points	7.3 (6)	8.2 (29)

<sup>a</sup>Numbers in parentheses are sample sizes.

TABLE 5. Comparative measurements between *O. v. carminis*, *O. v. couesi*, and *O. v. texanus*.<sup>a</sup>

Subspecies	Total length	Tail length	Hind foot	Height at shoulders	Condylbasal length of skull	Maxillary tooth row	Source of data
<i>O. v. carminis</i>	1512	213	403	–	242.3	69.7	Goldman and Kellogg (1940)
<i>O. v. carminis</i>	1520	220	490	793	246.0	–	Kellogg (1956)
<i>O. v. carminis</i>	1516	176	420	870	246.0	71.0	Krausman et al. (1978)
<i>O. v. couesi</i>	1530	270	415	890	241.0	–	Kellogg (1956)
<i>O. v. texanus</i>	1829	254	420	1048	287.5	–	Kellogg (1956)

<sup>a</sup>Measurements are in millimeters.



class averaged 66 pounds (30 kg). The average weights of all sex and age classes sampled for Carmen deer are 67 pounds (30 kg) (Table 6).

### *Distribution and Status*

According to Goldman and Kellogg (1940), the Chisos Mountains are the only North American habitat for Carmen deer. Kellogg (1956) included the adjacent Serranias del Burro, the Sierra del Carmen (Fig. 8), and other northern Coahuila mountain ranges as containing Carmen deer but still restricted (Kellogg 1956; Wauer 1973) their distribution in the United States to ranges in Big Bend National Park.

Diagnostic features important to whitetail distribution seem to be free-standing water and areas of dense vegetation such as oak stands. In each instance where deer were located, within and outside of the park, these two habitat components have been present.

In the Chisos Mountains, whitetails are plentiful above 4,500 feet (1,373 m). Outside of the main Chisos complex, whitetails are common in the Panther Spring, Rock Spring, Cedar Spring, Ward Spring, and West Hills Spring areas (Fig. 2). These locations also are occupied by the desert mule deer. The lowest elevations Carmen deer were observed in this study were 2,970 feet (906 m) and 4,000 feet (1,220 m). A yearling male was observed at Dugout Wells which is 3 miles (5 km) from Rock Spring, the nearest locale where whitetails are common. The other low-elevation sighting occurred in Panther Canyon. An adult male was alerted at 4,400 feet (1,342 m) and ran down to 4,000 feet (1,220 m) before retreating to higher areas.

Chilicotal Mountain and Burro Mesa (Fig. 2) do not support Carmen deer although both areas are occupied by mule deer. These foothill mesas support vegetation associated with the Sotol-Grassland Formation on higher elevations, and Desert Shrub Formation plants on the lower slopes. Each range slightly exceeds 4,000 feet (1,220 m). Atkinson (1975) also investigated these ranges without observing whitetails.

The Sierra Quemada (Fig. 2) forms the southern portion of the entire Chisos Range and provides marginal habitat for the Carmen deer. Borell and Bryant (1942) reported whitetails above Smoky Spring (Fig. 2) at about 4,500 feet (1,373 m) elevation. Atkinson (1975) observed whitetails northeast of Punta de la Sierra and between Punta de la Sierra and the Dodson trail (Fig. 2). During the 12 days Atkinson spent in the Sierra Quemada, only six whitetails were observed. During the present study, Goat Mountain, Blue Creek, Trap Spring, Mule-Ear Spring, Smoky Spring, San Jacinto Spring, Fresno Spring (Fig. 2), and the east end of the Dodson trail were visited. Two whitetails were observed along Blue Creek at 4,100 feet (1,251 m). The occurrence of whitetails in the Sierra Quemada probably always has been, and will continue to be, marginal.

TABLE 6. Body measurements of whitetails collected in Big Bend National Park between July 1972 and April 1974.

Sex and age	Live weight (kg)	Body length (mm)	Tail length (mm)	Total length (mm)	Heart girth (mm)	Rear leg (mm)	Height at withers (mm)	Neck circumference (mm)	Outside ear (mm)
Males									
5 mos	22.2	950	140	1090	680	350	680	250	140
20 mos	38.6	1140	145	1285	800	390	740	290	178
2.00 yrs	41.3	1270	195	1465	746	404	820	306	188
3.50 yrs	62.2	1340	176	1516	974	420	870	470	178
3.50 yrs	40.9	1257	203	1461	711	406	794	356	165
5.00 yrs	44.9	1240	155	1395	790	408	840	360	175
Mean ( $\bar{x}$ )									
≥ 2.00 yrs	47.2	1277	182	1459	805	410	831	373	177
Females									
3 mos	8.2	765	164	929	487	294	553	210	144
3 mos	9.1	830	145	975	474	294	554	210	131
4 mos	15.9	—	—	—	—	318	584	—	—
7 mos	15.4	930	160	1090	530	332	640	220	160
10 mos	26.8	1135	156	1291	650	380	705	240	180
18 mos	38.1	1210	170	1380	764	380	760	305	170
21 mos	31.8	1210	170	1380	702	372	748	250	188
2.25 yrs	34.1	1237	210	1447	732	376	772	280	173
2.25 yrs	27.2	1122	200	1322	675	372	710	250	188
2.25 yrs	21.3	1120	170	1290	730	371	760	250	170
2.50 yrs	39.5	1256	199	1455	795	400	787	297	172
2.50 yrs	29.5	1200	180	1380	775	371	847	263	154
3.50 yrs	29.1	1139	190	1329	700	370	680	230	186
Mean ( $\bar{x}$ )									
≥ 2.00 yrs	30.0	1179	192	1371	735	377	759	262	174

Harsh environments, limited water and cover, and the presence of mule deer probably contribute to low whitetail numbers in this area.

The northern end of the Sierra del Carmen in Coahuila, Mexico, extends into the park and forms the eastern boundary. This portion of the massive del Carmens is called the Sierra del Caballo Muerto or Dead Horse Mountains (Fig. 8), and has elevations approaching 6,000 feet (1,830 m). Kellogg (1956) and Davis (1957) reported whitetails at the higher elevations of this range, but recent observations have been rare. McBride (1973 pers. comm.) reported their occurrence there in the late 1960s but only in small numbers.

Soon after the present study began, it became apparent that whitetails on some mountain ranges outside the park in Texas and Mexico closely resembled Carmen deer. Further, some of these inhabited areas approached the geographic range of the Coues whitetail in Chihuahua, Mexico, and the Texas whitetail in the Davis Mountains, Texas. Proper identification of members of this deer complex is essential for a description of the geographic range and numerical status of the subspecies in southwestern Texas.

Several mountain ranges outside the park were examined for the occurrence of Carmen deer. Carmen deer habitats were found in the Rosillos and Christmas mountains, and in the Chinati Mountains in Presidio County, Texas (Fig. 8). Although other isolated desert mountain ranges such as the Sierra Vieja, Del Norte, and Dead Horse Mountains (Fig. 8) may contain Carmen deer, the three ranges mentioned earlier were those examined. Mexican ranges examined included the Sierra del Carmen Range.

The Rosillos Mountains lie approximately 15 miles (24 km) north of the Chisos and attain a height of over 5,000 feet (1,525 m). The surveyed area was a 35° north slope dissected with deep washes. Vegetation is similar to the foothill vegetation of the Chisos, with ash (*Fraxinus* spp.) and oak providing the bulk of heavier vegetation.

Twelve miles (19 km) northwest of the Chisos Range are the Christmas Mountains (Fig. 9). The third range observed within the United States was the Chinati Mountains, which are approximately 90 miles (145 km) northwest of the Chisos. Chinati Peak is over 7,230 feet (2,205 m) (Fig. 10). The area is dissected with heavy oak washes with equally exposed east and west slopes of 25–35°. The north side of Chinati Peak was examined. This area contained several small basins surrounded by hogbacks inclining to the larger mass of the range. Vegetation was similar to that of the Chisos, with pinyon pine and oak present.

The Rosillos and Chinati ranges contained free-standing water. Small springs were permanent and flowing during the dry part of the year.

Whitetails were observed on all ranges examined. Two adult females and an adult 8-point male were observed on the Rosillos Range; adult



**Fig. 9.** The Christmas Mountains. This range lies 12 miles (19 km) northwest of the Chisos Range.

females, males, yearlings, and fawns were seen in the Christmas Mountains; and six adult females, five fawns, and one yearling were observed in the Chinati Range. Approximately 160 man-hours were spent examining these areas for whitetails.

Cranial and antler measurements were taken from adult Carmen, Coues, and Texas white-tailed deer by Krausman et al. (1978). These authors determined that there was sufficient justification for retaining Carmen deer as a separate subspecies apart from the Coues and Texas whitetail. Most cranial measurements revealed a gradual clinal increase, beginning in north-



**Fig. 10.** The Chinati Mountains, Presidio County, Texas.

ern Coahuila and continuing northward into the Davis Mountains north of Big Bend National Park, and led Krausman et al. (1978) to conclude that white-tailed deer occupying the mountain ranges north and northwest of the park are best referred to as Carmen deer, although they show evidence of intergradation between Carmen Mountains white-tailed deer and Texas white-tailed deer. Size (Table 7), coloration, and antler configuration were also similar to the Carmen deer, and the habitat of whitetails in the areas examined was similar to whitetail habitat in the park.

The pattern of variation in antler measurements is somewhat different from that exhibited by cranial measurements. The antlers of Carmen deer in the park are intermediate in size between Coues deer and Texas white-tailed deer (Krausman et al. 1978). However, antlers of deer from the Rosillos (Table 8), Christmas, Chinati, and Davis mountains average smaller in most measurements than those of Carmen deer in the park; antlers of these deer are intermediate in size between Carmen deer and Coues deer although they are more similar to the former than the latter. Antler measurements are much more variable than are measurements of the skull. Furthermore, the size and configuration of antlers in deer is known to be markedly affected by nutritional factors (French et al. 1955) which relate to range conditions. These two factors make antler measurements of less value than cranial measurements in making geographic comparisons.

Classification of whitetails in the Chinati, Rosillos, and Christmas Mountains, and perhaps other scattered ranges such as the Del Norte, Sierra Vieja, and Dead Horse should be framed around the concept that Texas, Coues, and Carmen deer are valid subspecies and that the isolated populations between the ranges of these subspecies are intergrades between Carmen deer and Texas white-tailed deer. Geographical isolates thus occur between the ranges of the recognized subspecies and are characteristically small, with low populations. The assignment of whitetails from the Davis, Chinati, Christmas, and Rosillos mountains to Carmen Mountains white-tailed deer extends the range of this subspecies about 124 miles (200 km) northward into Jeff Davis County and northward about 118 miles (190 km) into Presidio County.

Cases of primary intergradation are often caused by related fluctuations of environmental conditions. Suitable habitat of Carmen deer on isolated mountain ranges may be the result of such changes. Wells (1966) has produced evidence that pluvial climate of Wisconsin time allowed for extensive growth of the present montane pinyon-juniper-oak woodland zone over much of the available span of elevation in regional lowlands of the Chihuahuan Desert. Over time, the invasion of desert vegetation may have pushed back the pinyon-juniper-oak woodlands to their present relic populations with deer following, resulting in their scattered distribution.

Environmental conditions are a most important factor in the development of new forms. Some animals such as members of the family

TABLE 7. Range, mean, standard deviation, and standard error of the mean of body measurements for deer collected in the Chisos and Christmas mountains.

	Live weight (kg)	Body length (mm)	Tail length (mm)	Total length (mm)	Heart girth circumference (mm)	Rear leg length (mm)	Height at withers (mm)	Neck circumference (mm)	Outside ear (mm)
<b>Chisos Mountains</b>									
<b>Adult male (N=4)</b>									
Range	40.9–62.2	1,240–1,340	155–203	1,395–1,516	711–974	404–420	794–870	306–470	165–188
$\bar{x}$	47.3	1,277	182	1,459	805	410	831	373	177
Standard deviation	10.1	43.9	21.4	49.6	117.1	7.2	32.1	69.2	9.5
Standard error	5.1	22.0	10.7	24.8	58.5	3.6	16.1	34.6	4.7
<b>Adult female (N=6)</b>									
Range	21.3–39.5	1,120–1,256	170–210	1,290–1,455	675–795	370–400	680–847	230–297	154–188
$\bar{x}$	30.1	1,179	192	1,371	735	377	759	262	174
Standard deviation	6.2	60.1	14.6	68.8	44.8	11.6	58.9	23.9	12.3
Standard error	2.5	24.5	6.0	28.1	18.3	4.7	24.0	9.8	5.0
<b>Christmas Mountains</b>									
<b>Adult male (N=2)</b>									
Deer #1	35.4 <sup>a</sup>	1,232	203	1,435	–	413	–	351	178
Deer #2	33.1 <sup>a</sup>	1,428	273	1,701	711 <sup>a</sup>	–	724	–	–
$\bar{x}$	34.3 <sup>a</sup>	1,330	238	1,568	711 <sup>a</sup>	413	724	351	178

<sup>a</sup>Field-dressed weight.

TABLE 8. Mean comparisons of 8 antler measurements from whitetails in known *O. v. couesi* and *O. v. carminis* ranges, and the Rosillos Mountains.<sup>a</sup>

Parameter	<i>O. v. couesi</i>	Rosillos	<i>O. v. carminis</i>
Maximum inside spread	284.8 (5)	296.7 (6)	353.6 (19)
Length of antlers	270.0 (5)	288.3 (9)	313.9 (39)
Length of tine #1	110.6 (5)	83.3 (7)	128.8 (36)
Diameter 2.5 cm above brow tine	71.8 (5)	72.4 (10)	79.3 (55)
Diameter 2.5 cm above base	75.6 (5)	81.4 (10)	85.5 (57)
Number of points	7.6 (5)	7.1 (10)	5.6 (56)

<sup>a</sup>Sample sizes are in parentheses.

Didelphidae have remained morphologically unchanged over millions of years (Doutt 1955), while some rodents take less than 300 years for subspecific differences to develop (Simpson 1944). For some microgeographic races, the differences may show up in relatively few years.

According to Mayr (1963), populations separated from the parent population can form either another subspecies, reestablish with the parent group, or die out. The possibility of new subspecies formation in the isolated ranges is remote and the desert separating them prohibits reestablishment with the parent populations. Environmental and man-caused impositions placed on Burro Mesa, Chilicotal Mountain, and other hills and mesas close to the Chisos Range have caused vegetational changes and water reduction, resulting in the disappearance of former whitetail populations inhabiting this area. This may also be the fate of small, isolated whitetail populations in the Rosillos, Christmas, and Chinati mountains, and other small ranges in southwest Texas which contain Carmen deer.

White-tailed deer populations in Coahuila may be stable at higher elevations. Deer are hunted heavily by local inhabitants and venison is a main food item when available. Hunting in Mexico is common for sustenance and is a definite part of the residents' living (Taylor et al. 1945; Baker 1956; Davis 1957; Leopold 1959). While in the Sierra del Carmen in August 1973, discussions with local residents revealed that the situation has not changed.

The entire area sampled in the Chinati Mountains was heavily overgrazed by sheep, especially on the lower foothills and slopes. Mule deer also occur in this range. All whitetails seen were close to water and few signs of deer were observed in drier areas. These factors along with lower population levels and hunting pressure place the future of this deer in an uncertain position.

Adequate habitat on the Rosillos Range is limited to north slopes, with oak and ash in the washes. Only one free-running spring was found which apparently runs all year. Deer were observed, and deer remains were collected in the vicinity of this spring only. Again, free-standing water appears to be important. Population numbers are low in this range and it would not be surprising for the few remaining whitetails to die out.

The real-estate interests presently active around the Christmas Mountains include free hunting as a privilege for landowners. Most hunting has been for mule deer in the past 4 years, resulting in an extremely heavy over-harvest. During the 1973 season, very few adult males were taken, but there was a heavy hunter harvest of yearlings. With fewer mule deer, excessive harvests of whitetails may result.

Because of hunting pressure, competition with livestock, natural decimating factors, limited water supply, low population levels, and small



range size, whitetails in the small, isolated habitats have a very uncertain future. Ranching activities encourage water production and, as all the whitetails were observed in areas of free-standing water, it appears that this has enhanced their survival. If the water is not maintained, their status will become more vulnerable.

Big Bend National Park provides the most stable environment for the Carmen deer. Hunting and livestock grazing are eliminated. The deer's habitat is stable and human impact on the area is limited at present. Recent decisions by park administrators are aimed at limiting human use of the main wooded Chisos area even further, and excessive use by man of free-standing water has been discouraged since the park's creation. Big Bend is probably the only area remaining where the Carmen deer may continue to maintain a healthy, reproducing population in a natural state.

### *Deer Numbers*

During the late 1950s, O. C. Wallmo made the first quantitative estimate of deer in Big Bend (Davis 1957). The estimated numbers of whitetails and mule deer on exclusive range were 25 per square mile (2.59 km<sup>2</sup>) and 7 per square mile, respectively. With a 20 square mile (52 km<sup>2</sup>) exclusive whitetail range, Wallmo's estimation was 500 whitetails in exclusive habitat.

More recently, the park staff of Big Bend established new transect lines for both deer species in the latter part of 1968 and continued to read them until the middle of 1972. One 0.10-acre (0.04-ha) plot and eight 0.2-acre (0.08-ha) plots were established in exclusive mule deer habitat. Six were in the River Floodplain-Arroyo Formation, and three were in the Sotol-Grassland Formation. Whitetail numbers were estimated by nine 0.10-acre (0.04-ha) pellet plot series and two 0.20-acre (0.08-ha) pellet plot series in the Woodland Formation of the Chisos.

The estimates derived in this study were from pellet plot transects established by Atkinson (1975) (Table 9). Figures 11 and 12 show the Sotol-Grassland and Woodland formations in which some transects were located.

Transect number 1 was the only exclusive mule deer transect. Other transects located in the Sotol-Grassland Formation contained both mule deer and whitetails but sightings of whitetails were infrequent.

Distinct pH qualities of mule deer and whitetail pellets (Krausman et al. 1974) assisted in determining species occurrence in this formation. A sample of 10 pellet groups was collected on overlapping range transects in February and May 1974, providing 100 pellet groups for analysis. All were from mule deer so transects in the Sotol-Grassland Formation were eliminated in establishing whitetail numbers. Other areas in this formation, such as Panther and Rock springs, had higher mule deer: whitetail ratios where pellet plots were not established.

TABLE 9. Pellet plot locations utilized to estimate numbers of deer in Big Bend National Park between 1971 and 1974.

Transect no.	Direction of transect	Location	Approximate elevation (ft)	Vegetative formation	Deer species present
1	E-W	0.2 mi above Basin Junction on Green Gulch Road	4,080	S-G	MD
2	E-W	1.2 mi above Basin Junction on Green Gulch Road	4,320-4,500	S-G	MD-WT
3	E-W	2.4 mi above Basin Junction on Green Gulch Road	4,740	S-G	MD-WT
4	NE-SW	3.25 mi above Basin Junction on Green Gulch Road	5,000-5,200	W	WT
5	NE-SW	4.25 mi above Basin Junction on Green Gulch Road	5,200-5,500	W	WT
7	N-S	0.2 mi south of Basin warehouse through Juniper Flat	5,300-5,740	W	WT
8	N-S	Starts at west-central side of Laguna Meadow	6,680	W	WT
9	NW-SE	Begins at 7,000 ft elevation on Boot Spring trail	7,000-7,300	W-MCW	WT
10	NE-SW	Lower Pine Canyon	5,100	S-G	MD-WT
11	N-S	Upper Pine Canyon	5,500	W	WT
12	NE-SW	1.2 mi above Dodson trail on Juniper Canyon Road	4,380	S-G	MD-WT
13	NW-SE	Upper Juniper Canyon	5,500-6,000	W	WT

S-G = Sotol-Grassland; W = Woodland; W-MCW = Woodland-Moist Chisos Woodland; MD = Mule deer; WT = Whitetail.



**Fig. 11.** Sotol-Grassland Formation. When the upper limits of this zone are approached, pine, oak, and juniper become more common. This formation is common in transects 1, 2, 3, 10, and 11.

Deer estimates from National Park Service data and pellet plots read during this study are presented in Tables 10 and 11. Estimates of mule deer were not attempted over their entire range; the results (Table 11) may be misleading without population estimates that include the rest of their range.

When the whitetail pellet plot transects were established by Atkinson (1975), a minimum number of reasonably accessible areas were sampled. The areas also were visited frequently by deer, and I suspect that the mean density estimates were too high. Numbers of transects were too low for precise estimates, as reflected in the wide confidence intervals given for the deer estimates (Tables 10 and 11). Many parts of the range not utilized as heavily by deer were not sampled. However, I do feel that the lower limits of the 90% confidence intervals (Table 10) are representative of whitetail numbers in Big Bend. An average whitetail density between 1972 and 1974 of 29 deer per square mile would yield 580 whitetails with a biomass of 1,930 pounds (868 kg) on the 20 square mile (52 km<sup>2</sup>) exclusive whitetail range.

Although the mean densities may be high, other Texas areas support higher whitetail numbers. Teer et al. (1965) estimated 92 whitetails per square mile between 1954 and 1961 in the Llano Basin and 44 whitetails per square mile during the same period in surrounding areas. Whitetail density on the King Ranch, Texas, of 38 per square mile (Beasom 1974) and of 35 per square mile on the Rio Grande Plain of South Texas



**Fig. 12.** *Top.* Dense pines, oaks, and juniper common on the South Rim. *Bottom.* *Stipa* spp. common in Chisos Mountains meadows.

(Harwell and Kierce 1972) are more similar to Big Bend's whitetail densities.

Estimates of mule deer around the foothills of the Chisos are higher than in similar areas. Wood et al. (1970) reported 13 deer per square mile for the Fort Sinton mule deer herd in New Mexico, and Truett (1972) found 13 and 11 desert mule deer per square mile on two mountain ranges in southeastern Arizona.

TABLE 10. Estimates of white-tailed deer in Big Bend National Park between 1968<sup>a</sup> and 1974.

Year	No. of plots	Population estimates	
		Mean	90% confidence interval
1968 <sup>b</sup>	5	1,244	652–1,835
1969	38	937	803–1,072
1970	38	790	627–953
1971	40	661	498–824
1972 <sup>c</sup>	36	870	686–1,055
1973	28	649	538–759
1974 <sup>d</sup>	7	702	515–890

<sup>a</sup>1968–71 plots read by National Park Service personnel; <sup>b</sup>Only represents November and December; <sup>c</sup>1972 plots read by National Park Service personnel and the authors; <sup>d</sup>only represents February, March, and April.

TABLE 11. Estimates of mule deer on the Chisos Mountains foothills between 1968<sup>a</sup> and 1974.

Year	No. of plots read	Mean	90% confidence interval
		(deer/mi <sup>2</sup> ) ( $\bar{x}$ )	(deer/mi <sup>2</sup> )
1968 <sup>b</sup>	7	16.07	7–27
1969	38	21.49	16–27
1970	36	26.49	20–33
1971	34	18.35	13–23
1972 <sup>c</sup>	22	36.20	26–46
1973	20	34.50	24–45
1974 <sup>d</sup>	5	40.20	14–66

<sup>a</sup>1968–71 plots read by National Park Service; <sup>b</sup>only represents November and December; <sup>c</sup>1972 plots read by National Park Service personnel and the authors; <sup>d</sup>only represents February, March, and April.

Both mule and white-tailed deer numbers appear to be stable in Big Bend National Park. The apparent population increase in 1972 (Tables 10 and 11) may be related to improved range conditions provided by high rainfall in 1970, 1971, and 1972 (Fig. 6). The importance of environmental factors to the breeding potential of white-tailed deer has been documented by Morton and Cheatum (1946), Ransom (1967), Roseberry and Klimstra (1970), Verme (1969), and Klein (1970). Both deer species may have responded to range conditions enhanced by rainfall.

### *Whitetail Habitat*

As the topography ascends from the Rio Grande across the lowlands and desert, washes give way to canyons, and small hills and mesas gradually build up to the Chisos Mountains. Changes in vegetation are

as contrasting as variations in topography. In less than 5 miles (8 km) harsh desert environments are replaced by montane woodland associations. Sparse desert vegetation is replaced by dense stands of mesic types and thick stands of pinyon pine, juniper, and oak are in the higher elevations of the Chisos Mountains (Fig. 11 vs. Fig. 12).

Quantitative measures of whitetail habitat were from several locales. Areas in Sotol-Grassland Formations include Green Gulch, Panther Spring, and Pine Canyon, while the Basin, Boot Spring, and the South Rim (Fig. 2) represent the Woodland Associations.

Changes in vegetation associated with elevation, topography, and climate are seen with increasing altitude along Green Gulch as Chihuahuan Desert plants are replaced by woodland species. The lower canyon at 4,000 feet (1,200 m) is represented with mesquite, acacia, basketgrass, sotol, lecheguilla, and mimosa. As the elevation increases, sotol is still common but juniper (*J. monosperma*) becomes more abundant and scattered clumps of pines and oaks are common.

To the west along Green Gulch at 5,000 feet (1,525 m) elevation is Moss Well where oak is dense and follows the waterways out into the desert (Fig. 13). This area is the lower limit of exclusive whitetail range on the south side of the Chisos.

Panther Spring provides more water than other desert springs in whitetail habitat and the area is the northern extension of whitetail range in the Chisos. Water from the spring runs down the narrow canyon, much



Fig. 13. Moss Well.

of which is rock floored and walled, before breaking out into the desert (Fig. 14).

Pine Canyon is similar to Green Gulch in that vegetational changes are seen as desert shrub plants are gradually replaced by woodlands. Prior to entrance into the narrow canyon, dense stands of sotol are abundant with scattered clumps of oak, juniper, pine, and sumac.

The Basin varies in elevation from 4,500 feet (1,373 m) at the Window to 5,500 feet (1,678 m) behind the lodge (Fig. 2). Abrupt and rolling hills dissected with deep washes draining out through the Window into Oak Creek are characteristic (Fig. 15). The lower areas contain dense stands of whitebrush (*Aloysia wrightii*) and acacia (*Acacia constricta*), but as elevation increases pines, oak, and juniper again become more important (Appendixes, I, II, and III).

Boot Spring vegetation was sampled at 6,300 feet (1,922 m) at the top of Boot Canyon (Fig. 2). Trees form a very dense canopy and grasses and succulents are scattered.

Areas sampled on the South Rim varied from 6,500 feet (1,983 m) to 7,500 feet (2,288 m). Large rolling hills with washes draining into Boot Canyon are common. Grasses, forbs, and woody and succulent plants are scattered and not as important as the dense associations of oak, pine, and juniper.

The Shrub Desert Formation contains a Lecheguilla–Creosotebush–Cactus Association and although it generally extends to 3,500 feet (1,068 m) it does invade mountainous areas where erosion and disturbances have eliminated grass cover, and where south slopes are exposed to higher temperatures. Creosotebush, lecheguilla, ocotillo



**Fig. 14.** Panther Canyon. Notice that as the canyon opens up, the walls decrease until the desert flats prevail. Cain cholla (*Opuntia imbricata*) is in the foreground.



**Fig. 15.** *Top.* The Basin as seen from the top of Boot Spring trail. *Bottom.* West of the Basin, called the Window, serving as a major drainage for the west side of the Chisos Mountains. The central mass is Vernon Bailey Peak.

(*Fouquieria splendens*), cactus, fluffgrass (*Tridens pulchellus*), yucca (*Yucca torreyi*), candelilla (*Euphorbia antisiphilitica*), and leatherstem (*Jatropha* spp.) are characteristic plants (Wauer 1971). Silverleaf, marjola, and guayacan are common, but grass is sparse.

A clear boundary does not exist between the Shrub Desert and Sotol-Grassland Formations. As the open xeric flats approach the Chisos, more grasses, succulents, and brushy vegetation are supported, typical of the Chihuahuan Desert uplands. Sotol forms a belt around the Chisos up to 5,000 feet (1,525 m) and is referred to as the Foothill Life Belt (Denyes 1956:301). Flats gradually increase to rolling hills butting up against the Chisos, where grasses are more abundant and there is a mixture of plants from both shrub desert and foothills.



The flats leading into Pine Canyon are representative of the Sotol-Grassland Association. Grasses and forbs having over 5% relative frequency of occurrence include sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), needle grama (*B. aristidoides*), spreading fleabane, bluestem (*Andropogon* spp.), threeawn (*Aristida* spp.), bristlegrass (*Setaria* spp.), and triadial grass (*Tridens* spp.). Important woody and succulent plants with at least 5% relative frequency of occurrence are mimosa, basketgrass, cactus, sotol, goldeneye, acacia, and evergreen sumac (Appendixes I, II, and III).

As indicated by Wauer (1971), vegetation of the washes and canyons within the Sotol-Grassland Formation is a mixture of plants found in associations both higher and lower in elevation. In Pine Canyon washes the most dominant woody vegetation is oak, which is associated with the Woodland Formations. Again, no clear-cut line separates this association from those below and there is an intergradation of plants.

Relatively heavy growths of sotol, lecheguilla, yucca, mimosa, basketgrass, snakeweed, agave, brickellia (*Brickellia* spp.), whitebrush, and numerous cacti are seen on the foothills and uneven outwash of the Chisos. Waterways support a variety of vegetation, depending on the association they are within, but normally include the more dense stands of mesic plants.

Shrubbery becomes denser in the higher foothills and lower mountain slopes are covered with sumac, ash, mountain mahogany (*Cercocarpus* spp.), with occasional junipers, pines, and oaks. Of the oaks, emory oak (*Quercus emoryi*), graves oak (*Q. gravesii*), and gray oak (*Q. grisea*) are more common.

Vegetational composition of higher elevations is quite simple. Various grasses such as muhly (*Muhlenbergia* spp.), grama, pinyon ricegrass (*Piptochaetium fimbriatum*), and forbs (*Senecio millelobatus*) provide ground cover. Basketgrass, pricklypear, and mountain mahogany provide much of the scattered woody and succulent layer and pines, oaks, and junipers form dense stands of trees. North slopes, in proportion to the degree of slope, become more woody and less grassy, while some south slopes are almost void of trees. Grass is dominant on lower layers, with sumac, sage (*Salvia* spp.), lecheguilla, and basketgrass making up the woody and succulent layer.

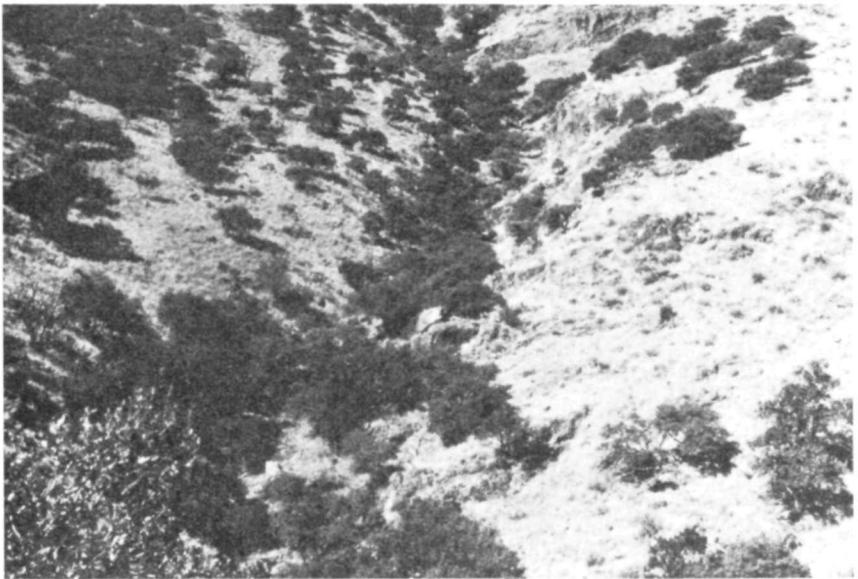
Several microhabitats on the north slopes in the higher canyons support plant species not found elsewhere. Upper Pine Canyon and Boot Spring contain Arizona cypress, Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), oaks, and maple (*Acer grandidentatum*) because of the cooler, more moist north slopes of the Chisos Mountains.

Only the grosser characteristics are presented in the foregoing description, but it emphasizes both the change in vegetation as altitude increases and the variable habitat of the Carmen deer. Although their habitat is diverse, woody cover is found throughout the habitat.

### *Habitat Use*

Based on deer pellet distribution, there were significantly ( $P<0.01$ ) more whitetails in woodlands than in the lower sotol grasslands. The three mountain ranges examined outside the park that support whitetails were not as wooded as the Chisos (Appendixes IV, V, and VI), but two relationships were found. Carmen deer were associated with (1) dense cover and (2) free-standing water. Oak washes with free-flowing water on the north side of Chinati peak (Fig. 16) supported whitetails, whereas terrain lacking oaks and water was void of these deer. The only whitetails seen in the Christmas Mountains were associated with junipers, oaks, and limited water, and in the Rosillos Mountains whitetails were observed only close to water or dense vegetation. More detailed vegetative data for these three areas are presented in Appendixes IV, V, and VI.

Although the exclusive habitat of mule deer and whitetails are quite different (high canyons, bluffs, and slopes with dense vegetation vs. open, rolling, desert foothills and flats), the question arose as to what separated the two species in the areas of range overlap. Vegetation on the exclusive deer ranges bordering the overlap zones were compared by using a similarity index (Curtis 1959:83). The closer to 100% this index is, the closer are the areas in vegetational composition. High vegetational similarity was found in all areas measured. Important plants used in computing the index were those which contributed at least 5%



**Fig. 16.** Typical whitetail habitat in the lower areas of the Chinati Mountains. Notice the dense oak stands in the washes.

to the deer's diet or were significant as cover. The similarity of important vegetation in exclusive mule deer and whitetail habitats along Green Gulch was 31%, and 95% and 75%, respectively, along Panther Ridge and the northwest slopes of Panther Ridge. The important point is that in these areas the two deer species are first separated, but the vegetation changes slightly rather than drastically. This indicates that topographic features probably play a major role in species separation. Those areas supporting Carmen deer outside the park are similar to the foothills of the Chisos and support both mule deer and whitetails. Numbers in these areas are not known, but mule deer outnumber whitetails. Mule deer range from the bottom to the tops of the mountains, but whitetails are restricted to densely covered areas with free-standing water. That whitetails prefer more dense vegetation than mule deer is not surprising and has been documented throughout their ranges (Krämer 1972). In Canada, whitetails are associated more with brushy and wooded river flats, coulees with aspens (*Populus tremuloides*), mixed forests (Soper 1964; Webb 1967), dense thickets of lower valleys, waterways, burned over areas (Cowan and Guiguet 1956), and willow (*Salix* spp.). Mule deer prefer more open forests, prairie, and badlands.

Similar preferences exist in Washington as whitetails occur more frequently in brushy river bottoms than mule deer, which are more common in open forests and other open habitat (Ingles 1965). In other western states whitetails are associated more closely with woody cover than mule deer (Queal and Hlavachick 1965; Hoffmann and Pattii 1968; Martinka 1968; Kamps 1969). In the southwestern states whitetails sometimes are associated with more open hillsides or flats (Ruhl 1956) but generally prefer dense vegetation afforded by mountains, while mule deer are common in open deserts, foothills, and chaparral types (Borell and Bryant 1942; Cowan 1956; Ruhl 1956; Swank 1958; Anthony 1972; Truett 1972).

Although there are significant differences in habitat preferences, either species can occupy many diverse habitats over their ranges. This suggests wider physiological tolerances than might be concluded from studies made in any one locale (Krämer 1972).

In areas where vegetation was sparse, whitetails sought washes for cover. Of 190 bedding sites examined, 119 (63%) were in washes with dense vegetation such as oak, pinyon pine, juniper, mountain mahogany, sumac, ash, Texas persimmon (*Diospyros texana*), and desert willow (*Chilopsis linearis*).

Bedding sites not in washes were associated with the heavier vegetation available, which included pinyon pine, evergreen sumac, oak, single-seeded juniper, mesquite, and cain cholla (*Opuntia imbricata*) (Fig. 17). Other vegetation which provided bedding cover included grass, snakeweed, mountain mahogany, lecheguilla, goldeneye, sotol, acacia, littleleaf sumac (*Rhus microphylla*), skunkbush sumac (*Rhus trilobata*),



**Fig. 17.** Typical, commonly used deer bed. *Rhus microphylla* provides the overhead cover. The grass in the foreground is *Bouteloua* spp.

pricklypear, yucca, algritia (*Mahonia trifoliolata*), silverleaf, mimosa, eysenhardtia (*Eysenhardtia angustifolia*), Mexican buckeye (*Ungnadia speciosa*), Texas persimmon, mariola, and Mormon tea (*Ephedra* spp.).

The substrata of bedding sites varied from hard ground and rocks to plush, sandy-dead vegetation mixtures up to 6 inches (15 cm) in depth. Many sites appeared to have been used repeatedly and others showed little evidence of prolonged visits. Of bedding areas not in washes, only 4 were not associated with any type of cover, and only 10 were on level ground. Table 12 presents the degree of slope related to bedding areas.

**TABLE 12.** Slope of bedding sites of Carmen deer in Big Bend National Park.

Slope (degree)	Percent of bedding sites on respective slopes
0	5
1-5	14
10	15
15	4
20	7
25	1
30	3
35	2
45	2
Undetermined	47

Bedding sites were distributed almost equally between north, east, and west exposures. South slopes were avoided; only 6% of the beds were found on this exposure. South slopes were drier and did not provide as much cover as other exposures.

### *Food Habits*

Major forage classes in this study included browse, forbs, succulents, and grasses. Succulents, which included lecheguilla and cactus, were a major forage class because of the importance to whitetail diets and the high availability on the range. Table 13 lists the volumetric percentages of all forage species obtained from rumens and Table 14 presents food items observed being eaten by deer but not found in stomachs.

The diet of free-ranging deer depends on forage availability of which a broad spectrum is available. From plant phenological data, 351 plants representing 74 families were described for the study area.

Overall, browse comprised 35.1% of the diet, followed by succulents (28.1%), forbs (14.3%), and grass (3.5%); 18.7% of the diet was undetermined (Table 13).

Lecheguilla and pricklypear (Fig. 18) were utilized most by whitetails, comprising 17% and 10.9% of the diet, respectively. Other species that made up more than 5% of the diet were acacia (7.4%) oak (6.7%), euphorbia (*Euphorbia serrula*) (6.6%), and evergreen sumac (5.9%) (Table 13).

Grass utilization was low throughout the year but highest (12%) during developmental stages. Overall, grass was consumed in small quantities by Carmen deer but seasonally may provide significant dietary requirements. Grass consumption was also at a peak during summer months for the Coues whitetail in Arizona (Anthony 1972).

Succulents were utilized more than other forage classes, except in late summer when rainfall was high, and were consumed more on the lower elevations of the range of Carmen deer. At higher elevations more free-standing water was available and plants were more lush than at lower levels. Succulent plants provide a source of moisture and although nutrient content of these plants is important, the water in them may be more significant to the whitetail's ecology when free-standing water is not available. Deer collected near springs in October 1973 utilized succulent plants in less than 6% of their diet. The mean monthly rainfall for the preceding 3 months was high at 2.13 inches (5.4 cm), which provided free-standing water. In December of the same year, succulents comprised 70% of the diet when springs were drying up because of low precipitation during the preceding 3 months. Diets of deer collected prior to March rains in 1974 contained over 50% succulents. In January, February, and the first half of March less than 0.15 inches (0.38 cm) of

TABLE 13. Volumetric percentages of forage in rumens of 25 white-tailed deer collected from June 1972 to April 1974 in Big Bend National Park.<sup>a</sup>

Species	Summer (3)	Late summer (6)	Winter (9)	Spring (7)	Total years (25)
<b>Browse species</b>					
<i>Acacia</i> spp.	2.7	12.2	7.4	5.1	7.4
<i>Quercus</i> spp.	1.3	11.0	4.2	8.4	6.7
<i>Rhus virens</i>	—	0.7	12.1	5.0	5.9
<i>Porlieria angustifolia</i>	0.3	12.5	1.6	—	3.6
<i>Garrya wrightii</i>	—	10.5	—	—	2.5
<i>Rhus microphylla</i>	3.7	—	—	5.1	1.9
<i>Prosopis glandulosa</i>	—	5.8	—	—	1.4
<i>Dalea</i> spp.	2.3	3.2	0.6	—	1.2
<i>Rhus</i> spp.	—	0.5	2.3	—	1.0
<i>Cercocarpus</i> spp.	3.7	1.2	0.6	—	0.9
<i>Rhus trilobata</i>	—	1.5	0.7	—	0.6
<i>Dyssodia</i> spp.	—	0.3	0.9	T <sup>b</sup>	0.4
<i>Fraxinus greggii</i>	—	—	—	1.4	0.4
<i>Nolina erumpens</i>	1.7	—	—	—	0.2
<i>Fallugia paradoxa</i>	—	—	—	0.9	0.2
<i>Diospyros texana</i>	1.3	—	0.4	—	0.3
<i>Forestiera angustifolia</i>	—	—	—	0.4	0.1
<i>Phoradendron</i> spp.	—	—	—	0.1	T
<i>Viguiera</i> spp.	1.0	—	—	0.3	0.2
<i>Juniperus</i> spp.	0.3	—	0.6	—	0.2
<i>Pinus cembroides</i>	—	0.2	—	—	T
<i>Xanthocephalum</i> spp.	—	—	—	—	—
<i>Prunus havardii</i>	—	—	—	—	—
<i>Hoffmanseggia</i> spp.	—	—	—	—	—
<i>Leucophyllum</i> spp.	—	—	—	—	—
Total browse	18.3	59.6	31.4	26.7	35.1
<b>Forb species</b>					
<i>Euphorbia serrula</i>	18.7	3.7	4.4	6.6	6.6
<i>Erigeron divergens</i>	—	1.3	5.4	—	2.3
<i>Lotus oroboides</i>	—	—	5.1	—	1.8
<i>Eriogonum</i> spp.	—	—	—	5.3	1.5
<i>Verbena</i> spp.	1.0	2.5	0.6	—	0.9
<i>Argythamnia humilis</i>	—	—	1.7	—	0.6
<i>Menodora</i> spp.	0.7	—	0.4	—	0.2
<i>Penstemon havardii</i>	—	—	—	0.4	0.1
<i>Hedyotis</i> spp.	—	—	0.2	—	0.1
<i>Artemisia</i> spp.	—	0.2	0.1	—	0.1
<i>Setcreasea</i> spp.	—	0.3	—	—	0.1
<i>Mentha</i> spp.	0.3	—	—	—	T
<i>Croton</i> spp.	—	—	—	T	T
Total forbs	20.7	8.0	17.9	12.3	14.3
<b>Succulent species</b>					
<i>Agave lecheguilla</i>	8.0	3.2	20.9	27.6	17.0

TABLE 13—continued

Species	Summer (3)	Late summer (6)	Winter (9)	Spring (7)	Total years (25)
<i>Opuntia engelmannii</i>	14.3	3.7	6.7	21.1	10.9
<i>Echinocereus</i> spp.	2.0	—	—	—	0.2
Total succulents	24.3	6.9	27.6	48.7	28.1
Grass species					
Gramineae	12.0	3.7	1.3	2.4	3.5
<i>Bouteloua</i> spp.	—	—	0.1	—	T
Total grasses	12.0	3.7	1.4	2.4	3.5
Other (Insect wing)	—	—	—	0.1	T
Unknown	24.7	21.8	21.7	9.8	19.0

<sup>a</sup>Sample sizes are in parentheses; <sup>b</sup>T = Items observed in rumen but not sampled.

TABLE 14. Food items observed to be eaten by white-tailed deer but not found in rumen samples collected between June 1972 and April 1974 in Big Bend National Park.

Food items	
Browse species	Forb species
<i>Acacia greggii</i>	<i>Menodora decemifida</i>
<i>Acacia texensis</i>	<i>Selaginella</i> spp.
<i>Aloysia wrightii</i>	<i>Sphaeralcea</i> spp.
<i>Celtis pallida</i>	Succulent species
<i>Dasyllirion leiophyllum</i>	<i>Agave scabra</i>
<i>Forestiera</i> spp.	<i>Opuntia imbricata</i>
<i>Fouquieria splendens</i>	Grass species
<i>Juniperus monosperma</i>	<i>Aristida</i> spp.
<i>Leucophyllum</i> spp.	<i>Bouteloua breviseta</i>
<i>Mimosa</i> spp.	<i>Bouteloua curtipendula</i>
<i>Mimosa lindheimeri</i>	<i>Panicum</i> spp.
<i>Parthenium incanum</i>	<i>Piptochaetium fimbriatum</i>
<i>Rhamnus</i> spp.	
<i>Viguiera longifolia</i>	

rain was recorded. Occurrence of browse was at a peak in diets during the late summer when available moisture reduced the necessity for deer to obtain water by consuming succulents.

Importance of succulents to whitetails is evident from the analysis but they also may contribute to mule deer-whitetail range separation in Big Bend. Free-standing water in Big Bend, even in wet seasons, is limited. Impressions in rocks, cavities formed by leaves of succulent plants, or washes may hold water for several days, and even the most productive



**Fig. 18.** *Top.* *Agave lecheguilla*. *Bottom.* *Opuntia engelmannii*. Both have been utilized heavily by deer.

springs produce only a trickling stream. Whitetails in the park and other southwestern areas have a remarkable adaptability to hot, arid conditions. In New Mexico whitetails apparently can survive on moisture present in plants alone (Raught 1967). Water sources in whitetail habitat were all utilized even though some greatly increased vulnerability to predation.



Recent examinations (Knox et al. 1969) failed to show that Rocky Mountain mule deer were less dependent on water than whitetails. Krämer (1972) suggested that "differential distribution of the two species [mule and whitetail deer] in regard to moisture may be due to reasons other than the presence or absence of free water." Field evidence in this study may suggest otherwise.

Observations of white-tailed deer around water sources commonly included drinking activity, whereas observations of mule deer involving water consumption were the exception. Areas with free-standing water in the Chisos, Chinati, Rosillos, and Christmas mountains supported whitetails, whereas there was little sign of whitetails in areas without some free-standing water.

Anderson (1949) and Mearns (1907) often observed desert mule deer passing surface water during dry months without drinking and felt that free-standing water was not required because moisture was provided in lecheguilla.

### *Sex and Age Ratios*

Whitetail sex and age classes are summarized in Table 15. Observer bias is probably the largest limiting factor in calculating accurate ratios since yearlings, does, and sometimes fawns may not be sexed accurately in the field (Leopold 1933:112; Teer et al. 1965). Also, adult males were more conspicuous than other sex and age classes due to their larger size

TABLE 15. Sex and age classification of whitetails from field observations in Big Bend National Park between June 1972 and April 1974.

Sex	Age	June- July	Aug.- Oct.	Nov.- Jan.	Feb.- April	Total period
Undetermined	Undetermined	19	12	17	23	71
Undetermined	Yearling	18	8	3	14	43
Male	Undetermined	1	0	0	3	4
Male	Yearling	12	20	23	9	64
Female	Yearling	23	21	35	17	96
Male	Adult	43	98	90	50	281
Female	Adult	78	87	139	134	438
	Fawns	17	41	79	84	221
Total		211	287	386	334	1218
Observations		97	122	172	119	510
Mean group size		2.18	2.35	2.24	2.81	2.39
% males in adult population		36	53	39	27	39
% females in adult population		64	47	61	73	61
Adult male:adult female		0.6:1	1.1:1	0.7:1	0.4:1	0.6:1
Yearlings:adult		0.4:1	0.3:1	0.4:1	0.2:1	0.3:1
Fawns:adult		0.1:1	0.2:1	0.3:1	0.5:1	0.3:1
Fawns:adult female		0.2:1	0.5:1	0.6:1	0.6:1	0.5:1

and secondary sexual characteristics. Behavior of the deer, density of the vegetation [especially above 5,000 feet (1,525 m)], and nature of the terrain affected visibility.

Only six newborn fawns were observed during the entire study. Observations of fawns increased in the months following birth as they increased in size and abandoned their seclusive habits. Of three gravid females examined, each had one fetus, and only one corpus lutea was present in ovaries which were examined. These data indicate a low incidence of twinning.

### *Group Size*

A total of 1,218 whitetails was recorded in 510 separate observations. The mean group size was 2.4 whitetails per group (Table 15). Small group size is common for whitetails in southwest Texas and southeastern Arizona. Anthony (1972) reported the mean group size of whitetails in southeastern Arizona to be 2.3 in the San Cayetano Mountains and 2.2 in the Dos Cabezas Mountains. Groups consisting of more than seven animals were uncommon in the Chisos Mountains.

### *Home Range*

White-tailed deer are sedentary and occupy the same home range sites throughout the year in the Chisos. Hahn and Taylor (1950) and Thomas et al. (1964) reported the home range of Llano Basin deer in Texas to have a radius of less than 1.5 miles (2.4 km). Adult male whitetails on the Welder Wildlife Refuge occupied up to 800 acres (324 ha) for their home range (Michael 1965). Home range size appears similar for white-tails in the Chisos Mountains.

### *Composition*

The white-tailed deer is the least gregarious species of the genus *Odocoileus* and social groupings are often small (de Vos et al. 1967). However, several group associations of whitetails have been identified. The family group is the core of the social organization and consists of does and yearlings, or does, fawns, and yearlings (Canton 1877; Newsom 1926; Townsend and Smith 1933; Severinghaus and Cheatum 1956; Hawkins and Klimstra 1970). Frequency of family groups for Carmen deer were highest in the summer and constant through the remainder of the year (Table 16). The family groups may be matriarchal, with three generations present (Palmer 1951; Hawkins and Klimstra 1970).

Primary associations involve the sociobiology between the female and fawn or fawns of the year (Hawkins and Klimstra 1970). These bonds were highest following the fawning season but were maintained throughout the year. Montgomery (1959:54) examined the social behavior of whitetails and did not find any unusual disruptions in the primary as-

TABLE 16. Group associations of whitetails in Big Bend National Park between June 1972 and April 1974.

Associations	Summer		Late summer		Winter		Spring		Total	
	Counts	%	Counts	%	Counts	%	Counts	%	Counts	%
Family groups	23	23	13	11	22	14	18	15	76	15
Primary associations	8	8	19	17	34	21	40	33	101	20
Male groups	19	19	32	28	39	24	19	16	109	22
Yearling groups	5	5	10	9	7	4	5	4	27	5
Fawn groups	3	3	3	3	2	1	1	1	9	2
Mixed adult groups	4	4	2	2	7	4	7	6	20	4
Random associations	7	7	6	5	23	14	11	9	47	9
Single females	30	30	30	26	27	17	19	16	106	21
Total	99		115		161		120		495	

sociations during the breeding season. Observations collected in the present study agree with the above conclusion.

Male groups included one or more males without females or fawns. Hawkins and Klimstra (1970) found buck groups less common than family groups, but this association did not appear to be as stable as family groups. Although my observations show male groups to be more common than family groups (Table 16), observer bias may account for the difference because adult males were more conspicuous than other classes. Male groups were variable, but two to three males per group were most common. Thomas et al. (1965) reported small male groups of two to five animals following the rut on the Edwards Plateau of Texas, and Linsdale and Tomich (1953) found similar associations in mule deer. Male social organization is often hierarchical (Severinghaus and Cheatum 1956; Michael 1966). Hierarchical dominance of male groups was obvious during the breeding season in the Chisos Mountains, and the social group system apparently had been established prior to the rut. In the few instances of intraspecific encounters observed, the presence of a larger member was all that was required to establish dominance. An excellent review of ungulate aggressive encounters is provided by Brown (1971).

Yearling groups included those female yearlings that were observed singly or in groups without adults or fawns. Observations of yearlings were constant throughout the study. Brown (1971) believes this association interacts with a variety of other groups, but strong social bonds do not develop, resulting in transitory relationships.

Random associations consisted of various sex and age classes that grouped together out of some social attraction but did not develop bonds or individual recognition (Dasmann and Taber 1956). The higher incidence of random groupings (Table 16) during the breeding season may be in response to males joining family groups during the rut. Hawkins and Klimstra (1970) in their deer studies found this lasted only a few days and data collected during this examination also indicate these groupings to be more dominant during the breeding months.

Unfortunately, most observations were of disturbed deer, and true social interactions probably were masked. However, no data were obtained to indicate that group associations and social interactions of the Carmen deer differed from the whitetail sociobiology reported in other southwestern areas of the United States (Brown 1971; Hirth 1973; Atkinson 1975).

### *Activity Patterns*

Although whitetails are generally considered to be crepuscular, individuals may be active during any hour. Three general daytime activity periods of deer have been reported for whitetails (Halloran 1943; Hahn 1949), mule deer (*O. h. californicus*) (Cronemiller and Bartholomew

1950), and black-tailed deer (*O. h. columbianus*) (Taber and Dasmann 1958): (1) dawn to midmorning feeding and movement; (2) midmorning to midafternoon bedding; and (3) movement and feeding from midafternoon or late afternoon until dark or longer (Montgomery 1963). Gladfelter (1966) and Howard (1969) found whitetails feeding prior to and past sunset, with three nocturnal bedding periods separated by two feeding periods. The fourth feeding began before sunrise and extended into the early daylight hours. Similar activity patterns were observed in Carmen deer (Table 17). Browsing was common in early morning (0500–0800) and late afternoon (1700–2000) hours, with periods of inactivity during the warmer hours (0900–1600). Deer bedded earlier during winter months in response to cooler temperature, which may be an energy conservation measure.

Nocturnal observations were limited to the hours following darkness until midnight, with the majority observed between 2200 and 2300 hours. While spotlighting from September 1971 to April 1972 (Atkinson 1975; this study), 207 whitetails were observed. Forty-five percent were bedded and 12% were browsing. Twenty-five percent were standing and 18% of the observations involved uncertain activity of the deer. Undoubtedly, the spotlight disturbed many deer and those standing or undetermined may have been involved in other activities.

Undisturbed white-tailed deer were difficult to observe in the Chisos Mountains due to topography and alertness of the deer. Of all whitetails observed, 17.6% were not alerted to the presence of an observer. An additional 5.7% of the observations were of deer that were alerted but continued their activities. The remaining 76.6% of whitetail observations were terminated by the alerted animal leaving the area.

### *Reproductive Activity and the Fawning Season*

Calculation of timing and duration of events in the sexual cycle of the Carmen deer are a composite of data collected from June 1972 to April 1974. Antlers began to grow in the latter half of April and the first half of May, during the primary development phase of reproductive activity as described by Robinson et al. (1965). Antler development continued through September when the bucks began shedding velvet. By the first week of October practically all antlers had a polished appearance. This stage of sexual activity is associated with spermatogenesis and has been described as the "full production stage" (Robinson et al. 1965). Testicles collected from three whitetails showed spermatogenesis was occurring during this time period and some males were sexually active in late September. Bucks were often together in October but showed little aggression toward each other and few observations of sexual relationships with females occurred until the latter part of November.

Late in November, sexual activity was more pronounced. Bucks would

TABLE 17. Numbers of whitetails observed in activities in Big Bend National Park between June 1972 and April 1974.

Time	Activity							
	Browsing	Bedded	Drinking	Walking	Standing	Running	Grooming	Mating
Summer								
0500-0800	50	32	5	8	6	3	12	0
0900-1200	4	46	29	7	3	7	0	0
1300-1600	3	13	0	0	0	0	0	0
1700-2000	32	2	0	2	0	0	2	0
Late summer								
0500-0800	38	11	9	2	0	3	0	0
0900-1200	36	61	4	5	0	0	7	0
1300-1600	3	19	0	6	0	0	1	0
1700-2000	29	9	0	5	0	2	0	0
2100-2400	0	1	0	0	0	0	0	0
Winter								
0500-0800	101	20	1	7	3	7	12	2
0900-1200	58	64	16	4	7	14	10	38
1300-1600	28	34	1	8	4	3	3	3
1700-2000	1	2	0	0	0	1	0	0
Spring								
0500-0800	68	8	0	3	0	15	0	12
0900-1200	35	43	10	7	3	18	0	5
1300-1600	2	49	0	4	0	9	0	0
1700-2000	35	7	0	0	0	1	0	0

form "scrapes" (shallow depressions in the ground formed by pawing and into which they urinated), and increase their sparing and thrashing activity. At this time most bucks had swollen necks. Most sexual activity occurred from mid-December to mid-January. Breeding seasons for the Carmen deer peak approximately one month later than recorded for the northern whitetails (Wislocki 1942:645; Cheatum and Morton 1942), which can be expected due to latitude variations (Cheatum and Morton 1942). In southern Texas, Illige (1951) also found the peak of breeding to occur in December.

Pursuit of females was observed commonly in late December but the peak reproductive activity was between 2 and 12 January. Copulation was never observed, but bucks with their noses to the ground trailing does and bucks chasing females were common during this time period. Some sexual behavior was observed as late as 15 February.

Pregnant females were observed in June and July. Fawns less than 24 hours old were observed on six separate occasions: 7, 21, 22, 24, 25 July, and 1 August. A fetus was collected at 106 days of age, two road-killed fawns were aged, and a gravid female was examined in March. Assuming a 201-day gestation period (Severinghaus and Cheatum 1956), these individuals would have been conceived during the peak sexual activity period. Atkinson (1975) reported similar fawning periods in Big Bend during 1971.

Spotted fawns were common until the end of September, but by mid-October most had completely lost their spots. The latest observation of a spotted fawn occurred on 5 November 1973. The animal was extremely small and did not appear to be more than a week old. If this observation is interpreted correctly, conception dates for some whitetails may be as late as April.

Northern whitetails normally drop their antlers in late December or January following the rut (Wislocki 1942). Whitetail populations farther south generally have later breeding seasons which last longer, with antlers being retained longer. The Carmen deer retained antlers until early March. New growth reoccurred during the latter portion of April when the reproductive cycle began once more. Based on testicular examination, there was no spermatogenesis and sexual activity was quiescent during this "rest phase."

### *Competition*

Birch (1957) states that competition occurs when animals of the same or different species utilize a common resource that is in short supply. If the resource is not in short supply, competition occurs when the species seeking that resource harm one another in the process by behavior that is detrimental to survival or reproduction. In this paper competition is as defined by Birch (1957), either through interference or

exploitation. Exploitation is the utilization of a resource in short supply and interference operates when interactions between organisms affect survival or reproductive success of the species (Park 1954).

Population control, interspecific competition, and species isolation may all influence species diversity in natural communities (Miller 1967). Interspecific competition cannot be evaluated without an idea of basic niche intersection in areas where overlap occurs and does not occur. Unless it can be demonstrated that species distribution at any level is less than what would be expected from an unrestricted intersection of the overall niche, evidence for competition as a limiting factor is minimal (Miller 1967).

Coexistence is less likely as ecological requirements of two species become more similar and competition becomes more intense. The less similar the two species' requirements become, potential for competition decreases and chances of coexistence increase (Miller 1967).

Competitive displacement in theory is an all or nothing situation; one species exists and the other dies out since different species with identical ecological niches cannot coexist (Lack 1944; De Bach 1966). When species coexist indefinitely, they must have different niches and not be ecological homologues (De Bach 1966).

Competition for food between large ungulates has been examined by several researchers. Martinka (1968) precluded competitive interactions due to the abundance of commonly utilized resources of mule and white-tailed deer in Montana. Morris and Schwartz (1957) demonstrated high utilization of grass in the diets of mule deer and elk. Hill and Harris (1943) showed differences in foods of mule deer and whitetails. Competition was not evident between whitetails and mule deer due to minor use of the common resource by mule deer (Allen 1968). Competition was not evident between whitetails and elk due to light use of forage plants by elk although the same foods were being eaten (Allen 1968). Research by Thilenius and Hungerford (1967) revealed that signs of inadequate food supply were not evident in deer-cattle areas, indicating that the presence of cattle during the summer did not adversely affect the food supply of the deer.

Competition is not present in the above examples due to the light use of the common resource by one species or an abundance of the common resource. Only a few articles dealing with interspecies relationships conclude that competition has occurred and most of these involve small mammals (Raun and Wilks 1964; Sheppe 1967; Koplín and Hoffman 1968; Morris 1969; Cameron 1971; Grant 1971).

There is little agreement in the literature concerning competition between mule and white-tailed deer. Krämer (1973) stated that whitetails and Rocky Mountain mule deer have coexisted through their evolutionary history and do not competitively exclude each other from sympatric



habitat. Krämer (1973) further suggested that optimum habitat for either deer species is void of the other. In a Montana study, Kamps (1969) concluded that forage competition does not exist between whitetails and mule deer but dual use of the range may be more efficient than utilization by a single species.

Anthony (1972) stated that desert mule deer competitively exclude whitetails in Arizona's San Cayetano Mountains and explained that the deer were competing actively for food, but it was a transient phenomenon. Anthony (1972) believed the mule deer would eventually exclude whitetails in this Arizona range.

Mule and white-tailed deer utilized similar foods in Big Bend but forage preferences did not appear to be a major separating factor between the deer habitats (Krausman 1978). The obvious mechanism separating the species appeared to be topography but behavioral interactions, or interference, could not be ruled out.

On sympatric range 1,180 deer were observed: 551 (47%) whitetails and 629 (53%) mule deer. When either species was able to observe or detect the other, the observation was classified as a "dual species interaction" in which 172 (15% of the total) deer were involved: 96 mule deer (8% of the total) and 76 whitetails (7% of the total).

Table 18 lists the species, their activity, distance apart, and type of interaction. Apparent disregard for each other was involved in 65% of the encounters and was the most common behavioral reaction observed. Mutual disregard was common for distances less than 30 feet (9 m). Disregard is as the word implies, and in interactions so classified no behavioral changes due to the presence of the opposite species were detected. Only four instances of active avoidance were observed; all involved an adult being dominant over submissive subadults. In two instances adult male whitetails were walking to a spring as two yearling mule deer were leaving on the same trail. In each instance the adults stopped and stared at the yearling, which avoided contact by departing from the trail and going around the adults in order to proceed. When the mule deer passed, the bucks discontinued their stare and continued walking.

Aggressive encounters and alerted scattering were each observed twice. One aggressive approach involved a bedded yearling and an adult female whitetail. The whitetails bedded 30 feet (9 m) apart. A mule deer doe approached the yearling and departed. The yearling walked to the whitetail doe. A second mule deer doe approached them both at a trot. At this time the adult whitetail got up and with the yearling retreated a short distance. The approaching mule deer then departed as the whitetails returned to their original bedding sites.

The second aggressive encounter involving yearlings (Table 18) included a whitetail female walking slightly to the right and in back of two immature mule deer. After lagging behind, she trotted toward the mule

TABLE 18. Dual species interactions between whitetails and mule deer observed in Big Bend National Park between June 1972 and April 1974.

<i>O. v. carminis</i>						<i>O. h. crooki</i>						Distance (meters)	Behavior
Sex and Age					Activity	Sex and Age							
Adult		Yearling		Fawn		Adult		Yearling		Fawn	Activity		
M	F	M	F		M	F	M	F					
	1	1	1		Browsing			Herd		Browsing	500	D	
2			1		Unknown		1	1		Unknown	300	D	
	2	2	2		Walking		2	2	2	Walking	150	D	
3					Walking			Herd		Browsing	125	D	
	1		1		Browsing		1	1		Drinking	100	D	
1	1		1		Drinking		1	1	1	Walking	70	D	
2					Drinking			1		Drinking	50	D	
1					Walking	4	1			Walking	50	D	
3					Running	1				Running	50	D	
	1		1	1	Walking		1			2	Walking	50	D
2					Bedded		2		1	1	Bedded	50	D
	1	1	1		Browsing				1		Browsing	30	D
2					Browsing		2			2	Browsing	25	D
1				1	Unknown		1			1	Unknown	20	D
	1			1	Browsing			1	1		Browsing	7	D
1					Browsing			1	1		Browsing	7	D
	1		1		Browsing		1		1		Browsing	5	D
2					Browsing				1		Browsing	5	D
1					Browsing				4		Browsing	5	D
		1	1		Browsing			1			Browsing	5	D
	1			1	Bedded		5		4	6	Bedded	5	D
	1				Walking				1		Walking	1	D
1					Watching			2			Walking	5	A
1					Watching			1			Walking	5	A
				1	Drinking		1			3	Drinking	5	A

TABLE 18—continued

<i>O. v. carminis</i>						<i>O. h. crooki</i>								Distance (meters)	Behavior
Sex and Age					Activity	Sex and Age					Activity				
Adult		Yearling		Fawn		Adult		Yearling		Fawn					
M	F	M	F			M	F	M	F						
1					Watching			2			Walking	3	A		
1	1				Watching		1	1			Walking	200	CW		
	1		1		Watching	1	1				M chasing F	100	CW		
3					Walking	1					Watching	15	CW		
1		1			Browsing			1			Watching	10	CW		
	1		1		Bedded		2				Walking	5	AA		
			1		Walking			1	1		Walking	1	AA		
			2		Running			1	1		Browsing	20	AS		
1					Running	1	1	2	1		Browsing	15	AS		

M = Male; F = Female; D = Disregard; A = Avoidance; CW = Conspicuous Watching; AA = Aggressive Approach; AS = Alerted Scattering.

deer, at which time the male charged her with head low and ears back. The whitetail moved to avoid contact and then remained stationary. As the mule deer left, the whitetail stood for a moment and then ran out of sight.

Alarmed animals that had been alerted by observers ran into groups of the opposite species, resulting in deer running out of sight in several directions. This happened on two occasions when whitetails fled into groups of browsing mule deer.

Dual species interactions between whitetails and javelinas were observed on nine occasions. Two cases involved conspicuous watching and two involved disregard. Alerted scattering occurred five times. Table 19 lists species activity and interaction behavior. The instances of scattering occurred due to disturbances made by the javelina and not by the observer. The cases usually involved deer browsing or bedded in thickly vegetated areas and as the javelina groups moved down through the brush, the whitetails departed.

Due to the possibility of competition between mule deer and whitetails in overlap areas, it is of value to know the extent of dual species associations in these areas. Dice (1945) referred to coefficients of associations and proposed association and coincidence indexes to measure associations between two species. These have been utilized by McMillan (1953) to relate moose and elk associations on feeding grounds. Both authors (Dice 1945; McMillan 1953) explain the derivation of the indexes and provide information for their application.

The coefficient of association measures the difference between the number of times two species occur together and the number of times they are expected to occur together by chance. The association index measures the amount of association between one species, taken as the base for comparison, and a second species being compared. The third method, a coincidence index, has a value intermediate between the first two indexes and is a measure of the amount of association between both species compared.

Values of the latter two indexes range from 1.0, indicating association, to 0.0, which indicated failure to associate. The computed values relate to the proportional amount of association. Values equal to 1.0 in the coefficient of association would indicate occurrence the same as expected by chance, less than 1.0 would indicate occurrence of association less than expected by chance, and greater than 1.0 would indicate an amount of association greater than expected by chance.

Table 20 lists the measures of association and their values for mule deer and whitetail relationships. The coefficient of association indicates that the two species occur together approximately one-third as many times as expected by chance. Association indexes show that 12% of the observations in which whitetails occur they were associated with mule deer, and the association index of mule deer with whitetails reveals that

TABLE 19. Dual species interactions observed between whitetails and javelinas in Big Bend National Park between June 1972 and April 1974.

<i>O. v. carminis</i>					<i>Dicotyles tajacu</i>				
Sex and Age Composition					Composition	Activity	Distance between Species (meters)	Behavior of <i>O. v. carminis</i>	
Adult M	Adult F	Yearling M	Yearling F	Fawn					
	1		1	1	W	Family	WK	10	CW
	2	1	1	2	W	Family	WK	10	CW
	1			2	DR	Family	DR	25	D
1	1	1	1		DR	Family	DR	25	D
	2	2	2		BR	Family	WK	50	AS
1		1			BR	Family	WK	50	AS
3	4	1	1	3	B	Family	WK	30	AS
1					B	Family	WK	10	AS
2	1	1	1	2	B	Family	WK	10	AS

M = Male; F = Female; W = Watching; DR = Drinking; BR = Browsing; B = Bedded; WK = Walking; CW = Conspicuous Watching; D = Disregard; AS = Alerted Scattering.

TABLE 20. Measures of association between whitetails and mule deer in Big Bend National Park.

Measures		Association values
Coefficient of association		0.32
Coincidence index		0.16
Association	whitetail/mule deer	0.12
Index	mule deer/whitetail	0.22

22% of the observations of mule deer were associated with whitetails. The tendency reveals limited association between the two as indicated by the low coincidence index.

All of the index values were combined and subjected to the chi-square analysis. The calculated chi-square was 54.02. With one degree of freedom, this value is far above the 5% level of significance, which suggests that lack of association of whitetails with mule deer is due to factors other than chance errors in random sampling. One species or perhaps both actively but subtly avoid each other.

In working with similar species in the Southwest, Anthony (1972) concluded that interference was not of importance. From the behavioral interactions he observed, the infrequent occurrence of interactions and usual nonaggressive nature of both species were not very important in relationships between desert mule deer and whitetails. He did find mule deer to be dominant in all encounters with whitetails when dominance could be determined. Krämer (1973) found that in interspecific encounters between mule and white-tailed deer neither species could be considered socially dominant but rank order of sex and age determined the interspecific hierarchy.

Both authors felt interference did not occur or was not important, but while Krämer (1973) said separation by competitive exclusion was unlikely, Anthony concluded that mule deer would eventually outcompete whitetails in the San Cayetano Mountains in Arizona.

Data collected herein suggest that neither mule deer nor whitetails were socially dominant over the other. More avoidance occurred between species than within, deer occurred more with each other than with other species, and separation by competitive exclusion is unlikely. That the coexistence of whitetails and mule deer, being sympatric over much of North America, rests on habitat difference and preferences (Carter 1951; Martinka 1968; Kamps 1969; Krämer 1973) is also probable in Big Bend National Park.

### *Mortality*

Ninety-one deer deaths were recorded during the study: 42 mule deer and 49 whitetails. Mountain lions accounted for 34 deaths, vehicles hit

and killed 30 deer, and the causes of 26 deaths were undetermined. One death was the result of a whitetail doe breaking her leg when tangled in a fence. Table 21 summarizes sex and age of deer mortality from accidents and undetermined causes. Mortality related to predation will be discussed later.

Sexing and aging vehicle-killed animals was often difficult since only portions of the carcass were found. Scavengers, such as coyotes and turkey vultures (*Cathartes aura*), and high temperatures causing decomposition could reduce an intact carcass to a scattered assemblage of bones in a short period of time. Often, only clues remained as to sex and age if the bodies were not found within a few days. On two separate occasions I received reports of deer killed around 0700 hours and was able to arrive on the scene within 2 hours. Both times all that was found was the backbone and portions of the rear legs. A fawn kill was reported to me one evening, and although I was at the site within 15 minutes, all that remained was a blood spot and part of the hide.

Only two whitetails were reported killed by cars: a 14-month-old female and a 5-month-old fawn of undetermined sex. An adult female died as a result of a broken leg caused when she became tangled in the wire fence surrounding the sewage lagoon located in the Basin. This is one of the few fences in the park. Other fences recently have been installed along the pack trail leading to Laguna Meadow to prevent horses and people from cutting across switchbacks. The effect of fences on the deer will be minimal, however, occasional deaths due to the fences should be expected.

Cause of death of the remaining 24 whitetails was not determined and any reason provided would be speculation only. However, the four dead

TABLE 21. Sex and age of deer killed by cars, undetermined causes, and fences in Big Bend National Park between June 1972 and April 1974.

Age	Whitetails			Mule deer		
	M	F	U	M	F	U
<6 mo	0	0	5	3	1	1
6-12 mos	0	0	0	1	3	0
13-23 mos	2	3	1	3	5	2
2 yrs	0	0	0	1	1	0
2.5 yrs	0	0	0	2	0	0
3.5 yrs	0	1	0	2	0	0
4 yrs	0	0	0	2	0	0
>2 yrs	2	3	4	4	2	0
Undetermined	1	0	2	0	0	0
Total	5	7	12	18	12	3

M = Male; F = Female; U = Undetermined.

fawns found were not killed by predators. Three were intact and a fourth consisted of an unchewed skeleton. Fawns have a higher mortality rate than other age classes (Swank 1958:50).

Two adult females died from causes other than predation. Their carcasses were found intact in bedding sites. Five of the remaining carcasses may have been the result of predation, but evidence was too inconclusive to classify them as known predator-killed deer.

Robinette et al. (1954) reported that sick and debilitated deer move downhill where they die. This behavioral characteristic appeared to be operative with the Carmen deer since 17 carcasses were found at the bottom of washes and canyons. Sick animals at the bottom of a wash have little strength with which to move.

The majority of dead mule deer found were killed by vehicles. Only four deaths were unexplained. The higher incidence of vehicle-killed mule deer than whitetails is easily explained. There are over 80 miles (129 km) of paved and well traveled roads in mule deer habitat and less than 3 miles (5 km) of paved roads in whitetail habitat. Although mule deer were hit by vehicles during all seasons of the year, 62% of the subadults were killed during the fawning and breeding seasons. During these times yearling bonds with adults may break down, resulting in more wandering by yearlings.

On two occasions deer-snake encounters were observed in Big Bend. Taber and Dasmann (1957) listed rattlesnake bites as a cause of deer deaths, but this type of mortality would be difficult to document under natural conditions. The first encounter involved an adult female whitetail and a Western diamondback rattlesnake (*Crotalus atrox*). The deer was walking along a ridgetop and was alerted by the snake. She approached the snake rapidly, struck it with her front hooves, and killed it. The second encounter occurred when several whitetails ran out of Panther Canyon. A nearly dead Texas Lyre snake (*Trimorphodon vilkinsoni*) was found in the tracks of the fleeing deer. As the deer departed, one may have accidentally stepped on the snake but it also may have been crushed deliberately. Although the above observations indicate aggressive behavior of deer toward snakes, it is unlikely that snake bites result in, or contribute to, mortality of deer in Big Bend.

### *Parasites, Disease, and Deer Condition*

#### **External Parasites**

Forty-eight deer were examined for external parasites: 19 whitetails and 29 mule deer. Fawn, yearling, and adult age classes were represented. Most deer examined were free of external parasites. Twelve whitetails (63%) did not have parasites, six (32% had one or more winter ticks (*Dermacentor albipictus*), and a deer nose bot larva (*Cephenemyia* spp.) was located in one animal (5%). Of the 19 mule deer examined,



18 (62%) were free of external parasites, 9 (31%) had winter ticks (one in this category also had a nose bot larva), 1 (3%) had a spinose ear tick (*Otobius megnini*), and 1 (3%) was infested with screwworm (*Cochliomyia hominivorax*).

Winter ticks were the most common for both deer species and were found in and on ears, the neck, shoulder, udder, anus, head, and between the hooves. Only one deer was infested heavily. The shoulders of an adult male mule deer were covered with this parasite. Seventy ticks were removed from a 15.5-square-inch (100-cm<sup>2</sup>) area representing the infestation. Although the deer was killed by a car, the heavy infestation may have altered his behavior, contributing to a lack of awareness. Excessive ticks may result in death, especially on poor range (Krull 1969:457). Evidence collected, however, does not indicate that the winter tick is detrimental to deer in Big Bend.

Nose bot larva infest the nasal sinuses of deer and are commonly referred to as head- or nose-maggots or bots; most deer are infested to some degree. Bots may be more abundant in deer in Big Bend than indicated by visual examination.

Spinose ear ticks may be a source of irritation causing ear cankers, nervous and digestive disturbances, a lowering of animal condition, and decreased milk flow in lactating animals (Krull 1969:436). Low incidence of occurrence in examined deer indicates that they are of little importance to deer health in Big Bend.

Screwworms, true parasites that attack living animals having fresh lesions on which larvae must feed, have been a problem in Texas and the Southwest (Teer et al. 1965; Krull 1969:350–351), but only one case of screwworm infestation was observed during this study period. This parasite attacked the top of an adult male mule deer's head and the flesh was consumed to the skull.

Although this was the only case of screwworms observed, it may play an important role during other periods when favorable climatic factors enhance the success of screwworms. Teer et al. (1965) attributed low deer productivity in 1955 and 1957 to screwworms in the Llano Basin of Texas, and ranchers stated that the navel of every newborn calf was infested with screwworms within a few hours of birth if the calf was not found and preventive measures taken during the same period.

External parasites did not appear to affect deer adversely in Big Bend, although given certain conditions, the effects of parasites, especially screwworms, could be substantial.

### **Internal Parasites and Deer Condition**

Of all tissues examined, only three mule deer samples suggested parasitic infection but none was found. Internal parasites played a minor role in deer condition, especially for the whitetails, during this study.

Inflammation of the myocardium (myocarditis) was found in two mule deer and one whitetail. In each case, the condition was subacute and minimal. Although the etiology of the myocarditis was not determined, minimal lesions in the hearts of four mule deer may be of the same or similar etiology.

Significant lesions were found in only two mule deer: one with myocarditis, the other with biliary proliferation and phylonephritis, inflammation of both the lining of the pelvis and parenchyma of the kidney. In the latter case, the animal was collected in a weakened condition. There was a proliferation of bile ducts in the liver, and the presence of hepatocytes suggests a prior toxic hepatitis. The biliary proliferation was probably secondary to infections from toxin and the phylonephritis.

Omental, kidney, heart fat, and marrow from 16 whitetails and 20 mule deer were examined visually. The results are presented in Table 22.

Laboratory tests, field examinations, and observations of live deer indicated that both mule and white-tailed deer were not affected adversely by parasites or disease and were in good physical condition from 1972 to 1974. Atkinson (1973 pers. comm.) claimed deer were also in good physical condition during 1971.

### *Predators and Deer*

Interest in predation recently has provided a body of knowledge which has enhanced the understanding of predator-prey relationships. Hornocker (1970) and Seidensticker et al. (1973) have published accounts of mountain lion population mechanics in the Idaho Primitive Area, and Knowlton (1964), White (1967), and Beasom (1974) have discussed the effects of coyotes and bobcats on deer populations. That some carnivores are very effective in preying on ungulate young has been demonstrated with coyotes and antelope in Texas (Jones 1949) and Arizona (Arrington and Edwards 1951), and with coyotes, bobcats, and whitetails in south Texas (Knowlton 1964; White 1967; Beasom 1974).

Controversy over predators in the Big Bend region of Texas is legion, with bias against carnivores. Many ranchers and hunters shoot predators on sight, and protected areas are limited. When Big Bend was established as a national park, the area was called a protected breeding ground for "livestock-killing vermin." National Park Service personnel adopted the common philosophy that predators controlled the deer. Murie (1954:120) found several lion-killed whitetails during his visit to Big Bend and felt that the lions were keeping the deer under control. Wauer (1973:93) recently has proposed the same "balance of nature."

Predator-prey relationships are being studied, but little information is available on lions in the Southwest. Atkinson (1975) reported on predator-prey relationships in Big Bend during 1971, and during the time

TABLE 22. Omental, kidney, heart fat, and marrow condition of 16 whitetails and 20 mule deer collected between June 1972 and April 1974 in Big Bend National Park.

Class	Omental fat	Kidney fat	Heart fat	Marrow condition
<b>Whitetails</b>				
Adult males	F	P	P	P
	G	F	F	G
	G	G	G	G
	G	G	G	G
Adult females	F	P	P	G
	F	F	F	F
	F	F	F	G
	F	F	F	G
	G	F	F	G
	G	G	F	G
	G	G	G	G
Yearlings	G	G	F	G
	F	G	G	G
Fawns	F	P	P	G
	F	F	F	F
	F	F	F	G
<b>Mule deer</b>				
Adult males	F	P	F	G
	F	F	F	P
	G	G	F	G
	G	G	F	F
	G	G	G	G
	G	G	G	G
	G	G	G	G
	G	G	G	G
Adult females	F	P	P	F
	F	P	P	G
	F	F	P	F
	G	F	P	F
	G	G	F	G
	G	G	G	G
Yearlings	F	F	F	G
	F	F	G	G
	G	F	F	G
	G	G	G	G
Fawns	F	F	F	F
	F	F	F	G

G = Good; F = Fair; P = Poor.

of the present study, Roy McBride of Sul Ross State University investigated mountain lion movements in the Big Bend region. Examinations of lion populations are taking place in other southwestern states, but

more data are needed, especially in undisturbed areas. Big Bend National Park is such a large, undisturbed area where predators are protected. The following data are presented to better understand the relationships between carnivores and prey in natural habitats.

### **Predators**

The ungulates in Big Bend are affected by lions, coyotes, and bobcats. Although lions are listed as uncommon for the park, they are fairly numerous in the Chisos Mountains and adjoining mountains and hills. As mentioned earlier, numerous lions were killed in the Chisos during the 1920s and 1930s. This suggests that the population has been augmented by individuals coming in from Mexico and the surrounding ranges in Texas. Although the National Park Service records report as many as 40 lions in the park in 1952 and 1953 (Table 1), more widely used figures are between 6 and 12 lions at any one time (Wauer 1973; McBride 1974 pers. comm.). To date, an accurate census has not been made and sufficient data have not been collected to estimate the number of lions in Big Bend. Visitor sightings of lions in the park between 1952 and 1974 have ranged from no observations to a high of 61 observations in 1953 (Anon. 1945–present). In 1956, a government trapper reported killing 40 lions in the Rosillos Mountains in a 14-day period. The reliability of these data is questionable although they indicate an abundance of lions. During the 1973 hunting season, at least seven lions were killed by hunters in the Christmas Mountains, and others may have been killed but not reported.

Data on coyote and bobcat numbers in the park also are scanty. Bobcats are less abundant than coyotes. Coyotes are common and have been estimated at 400 for the entire park (Anon. 1944–73). Without more accurate data on predator numbers, it will be difficult to evaluate the ungulate population dynamics in relation to predation.

### **Mortality of Predators**

No deaths of bobcats were discovered during this study, and the few coyote deaths reported were caused by vehicles. Very few cases of natural mortality of lions have been reported since the park's conception. In 1967, a yearling was drowned in Ernst Tinaja (Anon. 1945–present), and only one natural death was recorded during this study. Cause of death was not determined but tooth wear was excessive, indicating old age.

### **Frequency of Lion Kills**

Turkey vultures often indicated the presence of a kill, but most were discovered during routine field activities. Only when signs were conclusive were kills attributed to lions. Signs included scats (Fig. 19), scrapes (Fig. 20), covered carcasses (Fig. 21), removed stomachs, tracks, and



**Fig. 19.** Mountain lion scat. These were often deposited in scrapes, but it was common to find them in dry wash beds.



**Fig. 20.** Mountain lion scrape, or depression, formed out of ground litter.

drag marks. Most scrapes were found in washes and at wash junctions. Others were made in dead sotol stumps and other plant litter. Of 10 scrapes measured, the average radius was 6 inches (15 cm). Most kills were found in rough canyons and washes and were covered under vegetation such as evergreen sumac, mesquite, pines, juniper, whitebrush.



**Fig. 21.** Mountain lion cache.

and oak branches. Although vegetation normally was used to cover the remains of prey, rocky outcrops forming small caves were sometimes used to cache remains of prey.

Lions normally do not consume viscera of their prey, and on many occasions the entire stomach had been removed and buried 6–15 feet (2–5 m) away from the rest of the carcass.

Kills were found throughout the study, but killing frequency could not be determined. From June to October 1973, four lion kills were found at monthly intervals in Panther Canyon, but this indicates only lion activity since all the kills in the area were not located, and the number of lions involved was not known. Seidensticker et al. (1973) demonstrated that although over a given year kills by resident lions are made randomly in their home ranges, over the years there are areas where kills are made more frequently.

Panther Canyon provided an advantage to lions when pursuing white-tails. Deer use the spring at the canyon's bottom for water, but sheer rock slopes and the canyon floor restrict rapid movement. For a deer to slip and fall when alarmed in the area is common.

Hornocker (1970) found that lions in the Idaho Primitive Area completely utilized each kill, unless disturbed, which maximizes expended energy in hunting and killing and minimizes potential danger in attacking large prey animals. Generally, the same can be applied to lions in Big Bend when warm weather does not cause rapid decomposition of killed prey. On warm days microtemperatures are often lower than ambient temperatures, and canyons are often cooler. A kill found in the hot month of June in a canyon was eaten completely, whereas other kills made on exposed areas were consumed only partially. This kill, an adult female whitetail, was covered after a portion of the shoulder had been eaten and the viscera removed. The carcass was moved 75 yards (69 m) down the canyon from point of attack. On the following night, it was moved 17 yards (16 m) and the heart and left shoulder were eaten. A third meal was obtained the next night when the right shoulder and flank, front leg, neck, and head were consumed. The deer had been moved 50 yards (46 m) down the wash and left uncovered. Remaining flesh was dark red and not rancid. Similar feeding patterns have been reported by Robinette et al. (1959). Movement of the carcass after each feeding may have been in response to disturbance caused by me.

On another occasion an adult male whitetail had been killed and entirely consumed within 12 hours except for the stomach, intestines, and larger bones. A female with two kittens was reported in this area and may have been responsible.

Other lions ate only shoulder portions of their kills, covered them, and failed to return. This type of behavior has also been reported by McBride (1973 pers. comm.). Warmer southwestern climates may increase this type of feeding activity due to decomposition, but would reduce efficient resource utilization. On one occasion three adult female mule deer had been killed in the same area during October. In all cases the stomach was buried away from the carcass, and after portions of the shoulder were consumed, the remainder was covered with available vegetation where the bodies decomposed.

Lions in the Idaho Primitive Area killed deer every 10–14 days. Other mammals supplemented the summer diet thereby reducing ungulate kills (Hornocker 1970). Evidence of predation on small ungulates is difficult to obtain since they are often consumed entirely (Young and Goldman 1946:126; Hornocker 1970). During this study the kill remains of a doe and fawn were discovered. A small portion of hide and hair was all that remained of the fawn.

Robinette et al. (1959) suggested that lions kill a deer per week in the winter in Utah and southwestern researchers (McBride 1973 pers.

comm.) claim lions kill a deer every 7–10 days. McBride (1973 pers. comm.) felt that it was not uncommon for more than one kill to be made during a week; his comments are supported by limited observations reported by Young and Goldman (1946), suggesting that adult lions have killed about every 3 days in the Southwest.

Table 23 is a summary of all lion kills found during the study. One of the javelina known to be killed by a lion was an adult with malformed hooves which affected locomotion. Although only two kills of javelina were found, they did constitute part of the lion's diet. Hornocker (1970) suggested that the tight-knot group behavior of bighorn sheep (*Ovis canadensis*) in Idaho allowed them to cope well with lions. Since javelina are very social, a similar mechanism may reduce their vulnerability to predation. Also, the physical structure of javelinas may assist in survival against lions. Their thick layer of bristly hair and hide, short neck, and thick skull provide protection. Canines of the javelina are well developed and can severely injure an attacker. Energy expenditures of capturing prime adult javelina are probably too great to justify the effort from the standpoint of predators. One pig–lion encounter was noted however. An

TABLE 23. Sex and age of whitetails, mule deer, and javelinas known to have been killed by mountain lions in Big Bend National Park between June 1972 and April 1974.

Age	Total no.	Total kill (%)	Sex		
			M	F	U
Whitetails					
Undetermined	6	24	2	0	4
0–12 mos	1	4	0	0	1
1–1.5 yrs	6	24	3	1	2
2.0 yrs	5	20	3	2	0
3.0 yrs	1	4	1	0	0
3.5 yrs	2	8	1	1	0
5.0 yrs	1	4	1	0	0
6.0 yrs	1	4	1	0	0
8.0 yrs	1	4	0	1	0
9.0 yrs	1	4	1	0	0
Mule Deer					
2.0 yrs	2	22	0	2	0
2.5 yrs	1	11	0	1	0
3.5 yrs	4	44	1	3	0
4.0 yrs	1	11	1	0	0
5.5 yrs	1	11	0	1	0
Javelina					
0–6 mos	1	50	0	0	1
Adult	1	50	0	0	1

M = Male; F = Female; U = Undetermined.



adult javelina in poor physical condition was sacrificed and examined. Claw and puncture marks were on each side of the shoulders, as if attacked from behind, and the rear leg was broken. A lion was responsible for the injury, but the important point is that the pig was not consumed, so the lion's efforts were wasted. Similar encounters with prime adult javelinas may influence lion selection against them.

Nineteen whitetails of known ages were killed by lions. Twelve (63%) were 2-years-old or less, five (26%) were between 3 and 7.5 years, and two (11%) were over 8 years. As found by Hornocker (1970), the majority of deer killed were young or old animals (74%). More males 2 years or older were killed than females of the same age class (5 vs. 2). The higher incidence of males killed by lions (Table 23) may be due to their wandering nature which brings them in contact with lions, and reduced alertness and physical condition during the rut, as suggested by Robinette et al. (1959) and Hornocker (1970).

### Food Habits of Predators

**Lions:** Studies of food habits of cougars in the western United States have been published by Hibben (1939), in Utah and Nevada by Robinette et al. (1959), in Idaho by Hornocker (1970), and in British Columbia by Spalding and Lesowski (1971) (Table 24). There is no published study of food habits of cougars in Texas' Big Bend region.

Table 25 lists all food items found in lion scats. Deer comprised over 70% of the diet throughout the year, and as much as 90% in the late summer of 1972. Next in importance was javelina, followed by a number of less important items. Together, deer and javelina made up 85% of the lion's diet (Fig. 22).

Although grass content was high in several scats, the high frequency of occurrence of vegetation was probably due to accidental consumption.

As in other studies (Dixon 1925; Hibben 1939; Young and Goldman 1946; Robinette et al. 1959; Hornocker 1970; Spalding and Lesowski 1971), deer (or deer and elk as reported by Hornocker) furnished lions with more food than all other prey species combined. Schwartz (Robinette et al. 1959) collected a small sample of scats in Washington and found varying hare (*Lepus americanus*) to be more abundant than deer and Atkinson (1975) reported deer abundance in scats to be less than 20% during 1971 in Big Bend National Park. Small samples in both cases may not have represented preference of cougars.

Hornocker's (1970) data indicated complete prey utilization in Idaho, and Seidensticker et al. (1973) documented lions feeding only once on a kill and then moving on if disturbed. As mentioned earlier, similar instances were recorded in this study. If lions feed on a kill and then move long distances as suggested by McBride (1974 pers. comm.), fecal deposition would not necessarily be in the same locale as a kill. Lion movement in Big Bend is longitudinal from mountain range to mountain

TABLE 24. Major food items of mountain lions as reported in five studies (% frequency of occurrence).

Author	Hibben (1939)	Robinette et al. (1959)	Hornocker (1970)	Spalding and Lesowski (1971)	This study
Data source	>3,000 scats and stomachs	254 stomachs (winter study)	198 scats (winter study)	99 stomachs (winter study)	161 scats
Area	Western U.S.	Utah and Nevada	Idaho	British Columbia	Big Bend National Park
Prey					
Deer	82.0	73.9	—	57.0	72.4
Deer and elk	—	—	70.0	—	—
Porcupine	5.8	13.9	—	10.0	4.0
Lagomorph	6.0	2.9	5.5	11.0	1.5
Moose	—	—	—	4.0	—
Domestic stock	0.5	3.7	—	7.0	—
Javelina	—	—	—	—	12.7

TABLE 25. Food items in 161 mountain lion scats from Big Bend National Park.

Item	Volumetric %	Frequency of occurrence (%)	95% confidence interval
<i>Odocoileus</i> spp.	72.39	76.40	65.49–79.29
<i>Dicotyles tajacu</i>	12.71	15.53	7.56–17.86
<i>Erethizon dorsatum</i>	3.99	5.59	0.97– 7.01
<i>Mephitis mephitis</i>	2.55	4.35	0.12– 4.98
Unidentified rodent	1.58	3.11	
Lagomorpha	1.52	3.11	
Gramineae	1.30	40.37	
Undetermined	1.24	1.24	
<i>Sigmodon</i> spp.	T	–	
<i>Spermophilus</i> spp.	T	1.86	
<i>Neotoma</i> spp.	T	–	
<i>Mustela frenata</i>	T	–	
<i>Bassariscus astutus</i>	T	–	
<i>Urocyon cinereoargenteus</i>	T	–	
<i>Canis latrans</i>	T	–	
Unidentified insect	T	–	
<i>Diospyros texana</i> seeds	T	4.35	
<i>Mahonia</i> spp.	T	–	
<i>Pinus cembroides</i>	T	1.24	
<i>Agave lecheguilla</i>	T	1.24	
<i>Opuntia</i> spp. seeds	T	1.86	
<i>Quercus</i> spp.	T	7.45	
<i>Rhus virens</i>	T	–	
<i>Acacia romeriana</i>	T	–	
Twigs, roots, and leaves	T	2.28	
Vegetative spine	T	–	
Cotton fiber	T	–	
Unknown vegetation	T	20.50	

T = Trace items  $\leq$  1%.

range, and a lion in the park one day may be 25 miles (40 km) or more removed the following day (McBride 1973 pers. comm; Scudday 1975 pers. comm.). Of particular interest is the fact that no domestic livestock remains were found in any scat even though livestock is consumed outside the park. Most scats were collected deep in the park's interior and remains may have been deposited prior to a lion's arrival in the collection areas.

**Coyotes and bobcats:** The importance of lagomorphs to bobcats and coyotes has been documented (Young 1958:70–77; Knowlton 1964; Bailey 1972). Lagomorphs were the prey most commonly consumed for both bobcats and coyotes during this study (Tables 26 and 27).

Fifty-eight percent of the coyotes' diet consisted of equal parts of rabbits and vegetation (Table 27). Texas persimmon was the most commonly utilized plant. The fruits of this plant were ripe in late May and consumed through December. Their importance to diets of coyotes prob-

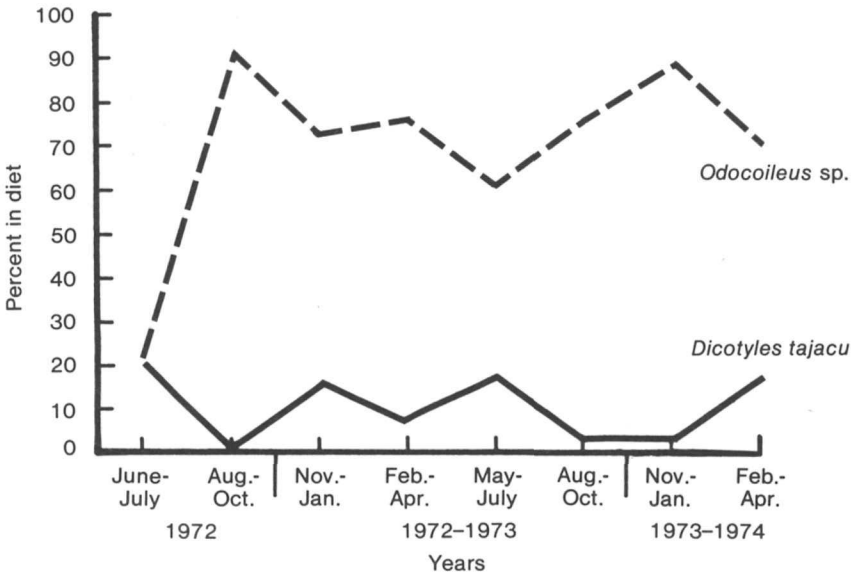


Fig. 22. Two species comprising over 85% of the diet of mountain lions in Big Bend National Park.

ably reduced the impact of coyote predation on small mammals which made up 17% of the diet. Deer made up 15% of the diet, and javelina, 7%.

Various small mammals (Table 26) comprised 28% of the food items found in 128 bobcat scats, and the third most abundant food was deer, making up 22% of the diet. Vegetation and javelina were of minor importance to bobcats.

Similar small mammals were eaten by bobcats and coyotes during this study and the higher incidence in bobcat scats may be correlated to the increased use of Texas persimmon by coyotes. Ecological and behavioral differences permitted these predators to use the same area and food sources in different ways in Idaho (Bailey 1972), and similar mechanisms may be operative in Big Bend.

### *Effects of Predators on Deer*

That the diet of coyotes and bobcats consisted mainly of small mammals, while mountain lions consumed primarily larger ungulates, emphasizes the fact that relative prey size is a factor in predator-prey relationships as suggested by Hornocker (1970). Although Bailey (1972) found no evidence of bobcat predation on deer, the killing of deer by bobcats has been reported (Young 1928, 1958; Marston 1942; Dill 1947). Hamilton and Hunter (1939), Pollack and Sheldon (1951), Rollings (1945), and Knowlton (1964) found deer to comprise 20-30% of the bobcat's

TABLE 26. Food items in 128 bobcat scats from Big Bend National Park.

Item	Volumetric %	Frequency of occurrence (%)	95% confidence interval
Lagomorpha	46.20	50.00	37.56–54.84
<i>Odocoileus</i> spp.	22.19	25.00	14.99–29.39
<i>Neotoma</i> spp.	11.13	14.06	5.68–16.58
<i>Spermophilus</i> spp.	8.63	10.94	3.77–13.49
<i>Sigmodon hispidus</i>	2.31	2.34	
<i>Mephitis mephitis</i>	2.07	2.34	
Unidentified rodent	1.60	5.47	
Bird	1.25	7.81	
<i>Dicotyles tajacu</i>	1.25	5.47	
<i>Thomomys bottae</i>	1.02	1.56	
Gramineae	T	16.41	
<i>Peromyscus</i> spp.	T	T	
Unidentified vegetation	T	14.06	
Rocks	T	T	
<i>Quercus</i> spp.	T	1.56	
<i>Diospyros texana</i>	T	T	
Leaves	T	1.56	
<i>Odocoileus</i> pellets	T	T	
Seeds	T	T	
<i>Pinus cembroides</i>	T	T	
<i>Agave scabra</i>	T	T	
<i>Erethizon dorsatum</i>	T	T	
Stems	T	T	
Grasshopper	T	T	
<i>Opuntia</i> spp. seeds	T	3.91	
Other insects	T	3.91	

T = Trace items  $\leq$  1%.

winter diet, much of which may be carrion. Data collected in this examination approximate this figure, although rabbits comprise the staple food (Fig. 23). Lack of snow and easy access to rodents may lessen the importance of deer to bobcats. Knowlton (1964) found that bobcats were not a source of attrition on deer in south Texas and although data in this study are inconclusive, I do not feel that bobcats are detrimental to deer populations in Big Bend even though they contribute to mortality.

Circumstantial evidence that juvenile mortality among North American deer is high and represents one of the major factors determining population density, especially in unhunted populations, has been compiled by Taber and Dasmann (1957:238–240), Brown (1961:61), Knowlton (1964), and Cook et al. (1971). The latter researchers concluded that coyote predation on fawns was a major factor in the stability of the dense and healthy whitetail population on the Welder Wildlife Refuge, Sinton, Texas. Knowlton (1964) showed that on the same area the amount of deer eaten by coyotes rose sharply during the fawning season in June. Diets of coyotes at this time consisted of more than 75% deer, mainly

TABLE 27. Food items in 245 coyote scats from Big Bend National Park.

Item	Volumetric %	Frequency of occurrence (%)	95% confidence interval
Lagomorpha	28.65	38.78	22.99–34.31
<i>Diospyros texana</i>	24.45	40.82	19.07–29.83
<i>Odocoileus</i> spp.	14.80	21.22	10.35–19.25
<i>Neotoma</i> spp.	8.09	13.06	4.68–11.50
<i>Dicotyles tajacu</i>	7.18	9.80	3.95–10.41
<i>Opuntia</i> spp. seeds	2.94	7.35	0.82– 5.06
<i>Spermophilus</i> spp.	2.80	4.49	
<i>Mephitis mephitis</i>	1.61	1.63	
Unidentified rodent	1.45	5.31	
<i>Erethizon dorsatum</i>	1.39	2.04	
<i>Thomomys bottae</i>	1.12	1.22	
<i>Sigmodon</i> spp.	T	T	
<i>Perognathus</i> spp.	T	T	
<i>Dipodomys</i> spp.	T	T	
<i>Canis latrans</i>	T	T	
Bird	T	T	
Lizard	T	T	
Undetermined insect	T	T	
Gramineae	T	T	
<i>Agave scabra</i>	T	T	
<i>Quercus</i> spp.	T	T	
<i>Setaria</i> spp.	T	T	
<i>Juniperus</i> spp.	T	T	
<i>Jatropha</i> spp.	T	T	
<i>Echinocereus</i> spp.	T	T	
<i>Prunus havardii</i>	T	T	
Twigs	T	T	
Rocks	T	T	
Unknown vegetation	T	T	

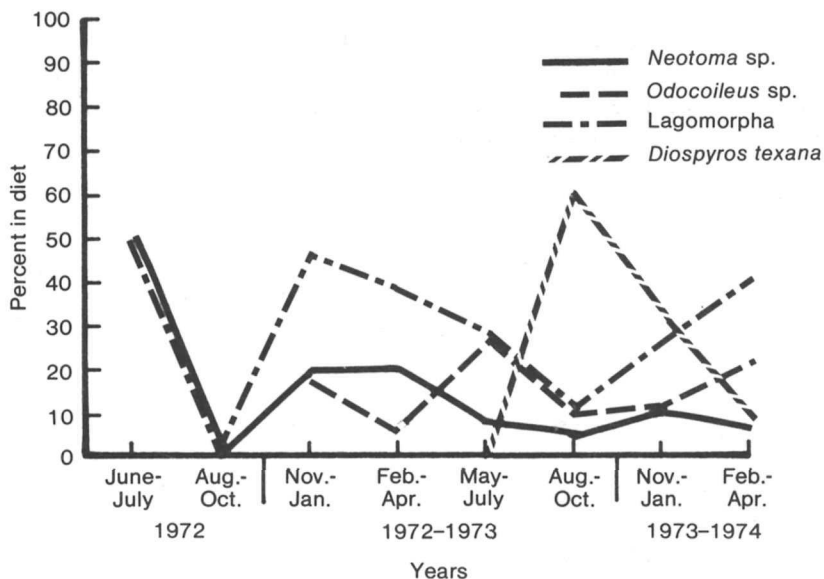
T = Trace items  $\leq$  1%.

fawns. Increases of deer in the diets of coyote during the fawning period were also reported by Salwasser (1974) in central California. Figure 24 shows an increase of deer in coyote scats during the 1973 fawning period, but age of deer consumed is undetermined.

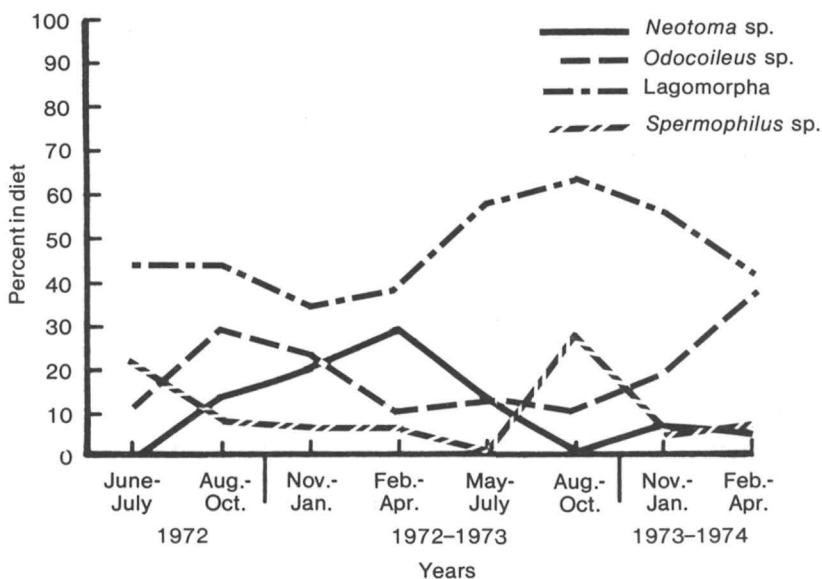
Coyotes and bobcats are responsible for fawn deaths in Big Bend but the impact on the population is probably minimal. Of coyote scats containing deer remains, only 11% had hooves or hair that could be identified conclusively as fawns.

As mentioned earlier, coyotes could reduce a road-killed animal to a pile of bones in less than 2 hours. Most of the deer in coyote scats may have been road-kills or other carrion. It is well known that the coyote is an opportunistic feeder that will eat the most easily obtainable food.

Insects and fruit are of ecological importance to both the coyote and prey (Knowlton 1964). Consumption of these items may relieve predatory



**Fig. 23.** Four species accounting for over 88% of the bobcat's diet in Big Bend National Park.



**Fig. 24.** Four species comprising over 75% of the coyote's diet in Big Bend National Park.

pressure on prey species during periods of greater vulnerability. Since Texas persimmon was consumed more than any other plant material by coyotes, it may play an important ecological role to deer in areas of coyote occurrence. Coyotes were observed, but uncommon, above 5,000 feet (1,525 m) and probably exert a greater influence on mule deer than on whitetails.

The total number of lions preying on the Carmen deer must be considered in order to assess the impact of lion predation on whitetails, but population dynamics of lions in the Chisos is unknown. The park supposedly supports 8–12 lions at any one time (McBride 1973 pers. comm.; Wauer 1973), but this is an opinion not based on quantitative data. With an average adult lion's home range of about 13 square miles (34 km<sup>2</sup>) (Hornocker 1970), it is realistic to assume that at least three resident lions inhabit part of the Chisos in their home ranges which radiate out to the lower hills and desert. Assuming that the adults supported two yearlings which ate the same amount as one adult, and that transient lions were equivalent to one resident adult present at all times, five adult lions would be exerting predatory pressure on the Carmen deer throughout the year. Historically, large lion numbers have been removed from the Chisos, suggesting a large number of transients.

The average live weight of Carmen deer is 67 pounds (30 kg). If large predators consume 70% of their prey as suggested by Schaller (1967) and Hornocker (1970), 47 pounds (21 kg) would be consumed from each deer kill. Assuming a 5 pound (2.3 kg) meat requirement per lion per day (Hornocker 1970), each lion would require at least one Carmen deer every 10 days. Five adult lions exerting predatory pressure on deer throughout the year would remove 183 deer or 8,601 pounds (3,905 kg). If proportions of mule deer to whitetails in lion kills are accurate, then it can be speculated that 126 whitetails are removed from the population by lions each year.

Limitations are obvious in this discussion: Predator numbers and dynamics are poorly understood, all kills were not located, killing frequency was based on studies in other areas, and the percentage of whitetails in the diet of lions was estimated roughly. Data collected provide a starting point for future investigation. Since this is the first examination on the subject in Big Bend National Park, only a base has been established. Additional information on numbers, movements, food habits, habitats, and general behavior patterns of coyote, bobcat, and mountain lion in the park will allow better understanding and evaluation of predator–prey relationships in unexploited areas of the Southwest.



## 4

# Concluding Comments and Management Implications

Carmen deer have a larger geographic range than previously thought. It extends beyond the boundaries of Big Bend National Park in the United States. Population indexes and tissue analyses suggest that, within the park, the herd is healthy and stable. Although the Chinati, Christmas, and Rosillos mountains, and perhaps other ranges in the Big Bend area support Carmen deer, the Chisos Mountains provide conditions that will continue to support a viable herd. Carmen deer in other areas are not as secure due to smallness of ranges, livestock competition, hunting pressure, and marginal habitat. A single factor was not isolated regulating distribution and population levels, but several conditions were operative: interspecific behavior, habitat, water availability, and predation.

Interspecific aggression between mule deer and Carmen deer was minimal. However, 6% of mule deer–white-tailed deer encounters were aggressive, and avoidance was recorded 12% of the time (Table 18). This indicates that behavioral interactions may play a part in separation, but a more important point should be considered. In all encounters, the relationship was terminated by submissive actions of the younger individual, whether mule or white-tailed deer. Interspecific interactions, as described between mule deer and whitetails, at a young age may influence habitat selection as adults.

Whitetail habitat in the Chisos and other ranges has been described and obviously is a factor in distribution and abundance. Although exclusive mule and white-tailed deer habitats are distinctly different, the Sotol–Grassland Formation, which is sympatric range, provides a combination of desert shrub and woodland vegetation. Forage utilization by deer in this area was in response to availability and, although the potential for forage competition existed, it did not appear to be operative during this study.

Perhaps a more important consideration of whitetail distribution in areas of overlap is water availability. In other Carmen deer ranges, distribution was associated with water and relatively heavily vegetated canyons and washes. In the Chisos Mountains, as more xeric conditions

prevailed toward the outlying desert, vegetational density and springs decreased as did the Carmen deer. Whitetail range in Big Bend is bordered by springs: Lower Juniper Spring, Rock Spring, Panther Spring, Moss Wells, Oak Spring, Cattail Flats, and Blue Creek. Even in marginal habitat, distribution is associated with water: Dodson Spring, Fresno Spring, and Smoky Spring (Fig. 2). More xeric areas between the bordering springs were void of whitetails. Historically, whitetails inhabited several mesas which now support only mule deer. Free-standing water had been made available by ranchers, and as their operations ceased, so did inhabitation by whitetails. Competition with livestock and mule deer and hunting were possibly the primary reducing factors, but the influence of water cannot be ruled out. Leopold (1933:135) claimed that, "A range is habitable for a given species when it furnishes places suitable for it to feed [including moisture acquisition], hide, rest, sleep, play, and breed, all within the reach of its cruising radius." Of these factors, water availability cannot be ruled out as an important influence, especially in areas of marginal habitat.

Data presented herein on predation primarily concern food habits and only begin to explore the understanding of predator-prey relationships in the park. Although numbers of deer are estimated, an indication of predator density is not available. Local reports and "gut feeling" estimates have been presented, but without a quantitative base. Without such data, accounts of predator-prey relationships will be as speculative as are estimates of predator populations. That predators, especially cougars, have an effect on the population is probably true. Other influences are those suggested by Hornocker (1970) that lions tend to distribute prey and dampen oscillations. In more xeric areas, lions may serve, in part, to distribute deer among water sources and contribute to limitations in distribution.

Man's direct influence has not been required to maintain a viable population of Carmen deer in the park. The future of this subspecies in other areas is uncertain due to previously discussed reasons. However, increased interest in the National Park System means greater use by man. At present, active management programs are unnecessary to maintain whitetails in Big Bend, but several factors should be kept in mind. Interference with natural water sources by visitors should be discouraged. Fences should be built only when necessary, and as has been proposed, minimal development and maximum reduction of permanent fixtures is warranted in the Basin. More importantly, the deer populations should be kept under surveillance, which need not require more than the simplest of quantifiable population indexes.

"The National Park Service is charged with the responsibility of preserving designated areas, selected samples of primitive America, in their natural condition for the enjoyment and study of present and future Americans. In line with this high purpose, the flora and fauna should

be subjected to a minimum of disturbance. The natural interactions of the members of the fauna and flora and the environment have a place in such a scheme and serve to furnish significance and greater interest in the animal life'' (Murie 1940). The Carmen Mountains white-tailed deer in Big Bend National Park are a desirable member of the assembly of animals and contribute to the interest and variety of this fauna.

# Appendixes

## Appendix I

## RELATIVE FREQUENCY OF GRASS AND FORBS IN SELECTED WHITETAIL HABITAT, BIG BEND NATIONAL PARK, TEXAS.

Grass and Forb Species	Sotol-Grassland Formations							
	Green Gulch	Green Gulch Washes	Panther Spring	Lower Pine Canyon	Upper Pine Canyon	Upper Pine Canyon Washes	North Slopes Pine Canyon	South Slopes Pine Canyon
<i>Erigeron divergens</i>	14.63	11.90	1.45	22.48	3.20	13.16	7.32	15.78
<i>Aristida</i> spp.	1.22	5.95	13.04	14.73	24.00	8.77	—	2.63
<i>Bouteloua curtipendula</i>	15.85	36.90	24.64	15.50	8.80	23.68	36.57	17.11
<i>Andropogon</i> spp.	8.54	7.14	1.46	10.08	5.60	1.75	7.32	3.95
<i>Eragrostis</i> spp.	—	14.29	1.45	0.78	2.40	5.26	4.88	3.95
<i>Bouteloua eriopoda</i>	1.22	—	21.74	—	20.00	4.39	2.44	1.32
<i>Bouteloua hirsuta</i>	15.85	—	—	13.18	16.00	7.02	2.44	21.05
<i>Euphorbia serrula</i>	1.22	1.19	5.79	6.98	10.40	—	—	9.21
<i>Hedyotis</i> spp.	7.32	1.19	2.89	—	2.40	0.88	2.44	—
<i>Muhlenbergia</i> spp.	17.07	1.19	—	—	—	5.26	19.51	1.32
<i>Croton</i> spp.	—	1.19	1.46	0.78	0.80	2.63	—	—
<i>Lycurus phleoides</i>	7.32	1.19	—	—	0.80	0.88	2.44	—
<i>Thelypodium wrightii</i>	—	—	—	1.55	—	3.51	2.44	—
<i>Heteropogon</i> spp.	1.22	—	—	—	—	1.75	—	9.21
<i>Notholaena</i> spp.	—	—	—	—	—	1.75	—	—
<i>Sida</i> spp.	—	2.39	1.45	—	—	0.88	—	—
<i>Trichachne californica</i>	—	1.19	—	0.78	—	—	—	—
<i>Eriogonum wrightii</i>	—	—	2.89	3.10	—	2.63	—	—
<i>Krameria glandulosa</i>	—	—	—	0.78	2.40	—	—	1.32
<i>Leptochola dubia</i>	—	3.57	—	—	—	—	—	—
<i>Setaria</i> spp.	—	—	—	—	—	5.26	—	—

Undetermined	-	-	-	6.94	3.20	-	-	-
<i>Artemisia</i> spp.	-	1.19	-	-	-	-	-	-
<i>Bahia</i> spp.	3.66	2.39	-	-	-	-	-	-
<i>Bouteloua gracilis</i>	-	-	-	-	-	-	-	-
<i>Galium</i> spp.	-	-	-	-	-	-	-	-
<i>Leptoloma cognatum</i>	1.22	-	-	-	-	-	-	-
<i>Macrosiphonia macrosiphon</i>	-	-	5.79	0.78	-	-	-	-
<i>Mentha</i> spp.	1.22	1.19	-	-	-	-	-	-
<i>Panicum hallii</i>	-	-	1.46	-	-	-	-	-
<i>Piptochaetium fimbriatum</i>	-	-	-	-	-	-	-	-
<i>Sphaeralcea</i> spp.	-	-	-	0.78	-	-	7.32	-
<i>Senecio millelobatus</i>	-	-	-	-	-	-	-	-
<i>Tridens</i> spp.	-	-	-	-	-	5.26	-	-
<i>Verbena</i>	-	-	1.45	-	-	-	-	-
<i>Artemisia ludoviciana</i>	-	-	-	-	-	0.88	-	-
<i>Asclepias</i> spp.	-	-	-	-	-	0.88	-	-
<i>Astragalus mollissimus</i>	-	3.57	-	-	-	-	-	-
<i>Bouteloua breviseta</i>	-	-	1.45	-	-	-	-	-
Cruciferae	-	-	-	-	-	-	2.44	-
<i>Dyschoriste decumbens</i>	1.22	-	-	-	-	-	-	-
<i>Dyschoriste linearis</i>	-	-	-	-	-	2.64	-	-
<i>Erioneuron pullchellum</i>	-	-	2.89	-	-	-	-	-
<i>Eupatorium wrightii</i>	1.22	-	-	-	-	-	-	-
<i>Gnaphalium</i> spp.	-	-	-	-	-	-	-	-
<i>Hedyotis nigricans</i>	-	-	-	-	-	-	2.44	-
<i>Heliopsis parvifolia</i>	-	-	-	-	-	-	-	-
<i>Leucelene ericoides</i>	-	-	-	0.78	-	-	-	-
<i>Lotus oroboides</i>	-	1.19	-	-	-	-	-	-
<i>Melampodium</i> spp.	-	-	-	-	-	-	-	-
<i>Menodora</i> spp.	-	-	-	-	-	0.88	-	-
<i>Poa</i> spp.	-	-	-	-	-	-	-	-
<i>Polygala</i> spp.	-	1.19	-	-	-	-	-	-

Grass and Forb Species	Sotol-Grassland Formations							
	Green Gulch	Green Gulch Washes	Panther Spring	Lower Pine Canyon	Upper Pine Canyon	Upper Pine Canyon Washes	North Slopes Pine Canyon	South Slopes Pine Canyon
<i>Ruellia parryi</i>	—	—	—	—	—	—	—	7.89
<i>Salvia lyciodes</i>	—	—	—	—	—	—	—	—
<i>Selaginella</i> spp.	—	—	—	—	—	—	—	5.26
<i>Stipa</i> spp.	—	—	—	—	—	—	—	—
<i>Tridens muticus</i>	—	—	8.69	—	—	—	—	—
Absolute Density/m <sup>2</sup>	43.43	15.88	49.89	36.09	42.11	18.86	3.60	46.88

Grass and Forb Species	Woodland Formations				
	Upper Basin	Lower Basin	Basin	Boot Spring	South Rim
<i>Erigeron divergens</i>	2.86	21.95	1.54	3.03	—
<i>Aristida</i> spp.	7.14	—	6.15	3.03	3.33
<i>Bouteloua curtipendula</i>	44.29	—	43.03	9.09	—
<i>Andropogon</i> spp.	4.29	—	4.62	—	—
<i>Eragrostis</i> spp.	1.43	2.44	1.54	—	—
<i>Bouteloua eriopoda</i>	1.43	2.44	15.38	—	—
<i>Bouteloua hirsuta</i>	—	12.19	—	5.05	3.33
<i>Euphorbia serrula</i>	—	2.44	6.15	—	—
<i>Hedyotis</i> spp.	—	—	3.08	2.02	—
<i>Muhlenbergia</i> spp.	22.83	—	—	25.25	33.33
<i>Croton</i> spp.	—	—	1.58	—	—
<i>Lycurus phleoides</i>	4.29	—	—	1.01	3.33
<i>Thelypodium wrightii</i>	—	—	—	3.03	1.69
<i>Heteropogon</i> spp.	—	4.88	—	—	—
<i>Notholaena</i> spp.	2.86	—	—	6.06	3.33
<i>Sida</i> spp.	—	2.44	—	—	—

<i>Trichachne californica</i>	-	2.44	3.08	-	-
<i>Eriogonum wrightii</i>	-	-	-	-	-
<i>Krameria glandulosa</i>	-	-	-	-	-
<i>Leptochola dubia</i>	-	2.44	9.23	-	-
<i>Lycurus phleoides</i>	-	-	-	-	-
<i>Setaria</i> spp.	-	14.63	-	1.01	-
Undetermined	-	-	-	11.11	28.33
<i>Artemisia</i> spp.	-	-	-	1.01	-
<i>Bahia</i> spp.	-	-	-	-	-
<i>Bouteloua gracilis</i>	-	31.71	4.62	-	-
<i>Galium</i> spp.	-	-	-	4.04	3.33
<i>Leptoloma cognatum</i>	1.43	-	-	-	-
<i>Macrosiphonia macrosiphon</i>	-	-	-	-	-
<i>Mentha</i> spp.	-	-	-	-	-
<i>Panicum hallii</i>	-	-	-	5.05	-
<i>Piptochaetium fimbriatum</i>	-	-	-	10.10	3.33
<i>Sphaeralcea</i> spp.	-	-	-	-	-
<i>Senecio millelobatus</i>	-	-	-	2.02	13.33
<i>Tridens</i> spp.	1.43	-	-	-	-
<i>Verbena</i>	-	-	-	-	-
<i>Artemisia ludoviciana</i>	-	-	-	-	-
<i>Asclepias</i> spp.	-	-	-	-	-
<i>Astragalus mollissimus</i>	-	-	-	-	-
<i>Bouteloua breviseta</i>	-	-	-	-	-
Cruciferae	-	-	-	-	-
<i>Dyschoriste decumbens</i>	-	-	-	-	-
<i>Dyschoriste linearis</i>	-	-	-	-	-
<i>Erioneuron pulchellum</i>	-	-	-	-	-
<i>Eupatorium wrightii</i>	-	-	-	-	-
<i>Gnaphalium</i> spp.	-	-	-	1.01	-
<i>Hedyotis nigricans</i>	-	-	-	-	-
<i>Heliopsis parvifolia</i>	-	-	-	-	3.33



Grass and Forb Species	Woodland Formations				
	Upper Basin	Lower Basin	Basin	Boot Spring	South Rim
<i>Leucelene ericoides</i>	—	—	—	—	—
<i>Lotus oroboides</i>	—	—	—	—	—
<i>Melampodium</i> spp.	4.29	—	—	—	—
<i>Menodora</i> spp.	—	—	—	—	—
<i>Poa</i> spp.	—	—	—	6.06	—
<i>Polygala</i> spp.	—	—	—	—	—
<i>Ruellia parryi</i>	—	—	—	—	—
<i>Salvia lyciodes</i>	—	—	—	1.01	—
<i>Selaginella</i> spp.	—	—	—	—	—
<i>Stipa</i> spp.	1.43	—	—	—	—
<i>Tridens muticus</i>	—	—	—	—	—
Absolute Density/m <sup>2</sup>	13.53	25.34	24.90	33.79	23.35

# Appendix II

## RELATIVE COVER OF WOODY AND SUCCULENT PLANTS IN SELECTED WHITETAIL HABITAT, BIG BEND NATIONAL PARK, TEXAS.

Woody and Succulent Plants	Sotol-Grassland Formations							
	Green Gulch	Green Gulch Washes	Panther Spring	Lower Pine Canyon	Upper Pine Canyon	Upper Pine Canyon Washes	North Pine Canyon Slopes	South Pine Canyon Slopes
<i>Opuntia engelmannii</i>	12.18	0.80	8.57	5.26	5.17	3.24	1.52	0.83
<i>Xanthocephalum</i> spp.	4.98	23.11	17.07	1.46	1.53	3.15	46.34	6.76
<i>Viguiera</i> spp.	2.62	3.09	11.07	9.29	9.41	11.51	15.32	—
<i>Agave lecheguilla</i>	1.52	—	0.55	0.43	4.36	0.06	—	13.64
<i>Dasyllirion leiophyllum</i>	9.29	1.62	1.78	27.10	22.94	2.23	6.19	61.38
<i>Nolina erumpens</i>	29.98	0.86	—	22.24	25.42	4.94	11.49	5.78
<i>Mimosa</i> spp.	20.98	3.81	—	8.30	0.82	12.44	2.53	0.23
<i>Rhus virens</i>	0.92	12.73	—	20.31	1.75	12.01	3.94	—
<i>Acacia constricta</i>	1.01	2.43	28.96	—	5.54	0.80	—	—
<i>Dalea</i> spp.	4.18	1.84	—	—	0.42	—	11.77	—
<i>Dyssodia</i> spp.	0.16	—	—	0.72	1.09	0.53	—	—
<i>Echinocereus</i> spp.	0.04	—	0.05	0.04	—	0.09	—	—
<i>Agave scabra</i>	0.65	—	—	0.28	—	—	—	0.15
<i>Cercocarpus</i> spp.	1.17	21.41	—	—	—	—	—	—
<i>Acacia greggii</i>	1.89	—	2.02	0.58	13.98	—	—	8.58
<i>Rhus microphylla</i>	0.98	—	2.57	0.73	2.48	—	—	—
<i>Acacia texensis</i>	0.12	—	—	—	3.08	0.10	—	2.65
<i>Bouvardia ternifolia</i>	1.83	0.20	—	—	—	—	—	—
<i>Rhus trilobata</i>	3.90	3.54	—	—	—	1.94	—	—

Woody and Succulent Plants	Sotol-Grassland Formations							
	Green Gulch	Green Gulch Washes	Panther Spring	Lower Pine Canyon	Upper Pine Canyon	Upper Pine Canyon Washes	North Pine Canyon Slopes	South Pine Canyon Slopes
<i>Yucca</i> spp.	1.14	—	0.62	—	0.78	0.29	—	—
<i>Acacia romeriana</i>	—	—	—	0.31	—	0.53	—	—
<i>Hoffmanseggia</i> spp.	1.46	0.40	0.65	—	—	—	—	—
<i>Prosopis glandulosa</i>	—	0.40	9.13	—	—	—	—	—
<i>Prunus minutiflora</i>	—	0.20	—	1.53	—	4.78	—	—
<i>Aloysia wrightii</i>	—	1.12	—	—	—	—	—	—
<i>Ephedra</i> spp.	—	—	—	1.40	0.67	—	—	—
<i>Eysenhardtia</i> spp.	—	8.08	—	—	—	0.96	—	—
<i>Parthenium incanum</i>	—	—	13.81	—	—	—	0.90	—
<i>Allionia</i> spp.	—	—	—	—	—	—	—	—
<i>Brickellia</i> spp.	—	—	—	—	—	3.87	—	—
<i>Chrysactinia mexicana</i>	—	—	—	—	0.57	—	—	—
<i>Diospyros texana</i>	—	—	—	0.01	—	—	—	—
<i>Fallugia paradoxa</i>	—	13.92	—	—	—	—	—	—
<i>Fraxinus greggii</i>	—	—	—	—	—	—	—	—
<i>Mahonia trifoliolata</i>	—	0.44	—	—	—	—	—	—
<i>Mammillaria</i> spp.	—	—	0.17	—	—	—	—	—
<i>Opuntia imbricata</i>	—	—	2.98	—	—	—	—	—
<i>Philadelphus microphyllus</i>	—	—	—	—	—	—	—	—
<i>Pinus cembroides</i> <sup>a</sup>	—	—	—	—	—	1.09	—	—
<i>Ungnadia speciosa</i> <sup>a</sup>	—	—	—	—	—	0.98	—	—
<i>Quercus</i> spp. <sup>a</sup>	—	—	—	—	—	34.47	—	—
<i>Salvia regla</i>	—	—	—	—	—	—	—	—
Absolute Density/m <sup>2</sup>	1.38	0.85	5.67	5.55	4.87	6.96	8.40	11.21

Woody and Succulent Plants	Woodland Formations				
	Lower Basin	Basin	Upper Basin	Boot Spring	South Rim
<i>Opuntia engelmannii</i>	11.58	6.22	24.78	19.99	59.40
<i>Xanthocephalum</i> spp.	–	5.12	7.39	0.40	2.18
<i>Viguiera</i> spp.	4.00	25.72	3.11	1.25	–
<i>Agave lecheguilla</i>	0.14	6.24	5.23	0.08	–
<i>Dasyllirion leiophyllum</i>	–	1.37	0.89	–	–
<i>Nolina erumpens</i>	–	–	7.71	48.07	22.11
<i>Mimosa</i> spp.	4.44	–	1.00	–	–
<i>Rhus virens</i>	–	10.13	13.26	–	–
<i>Acacia constricta</i>	29.59	15.99	–	–	–
<i>Dalea</i> spp.	–	0.03	0.53	0.59	–
<i>Dyssodia</i> spp.	–	3.16	2.89	0.75	–
<i>Echinocereus</i> spp.	0.14	–	–	0.52	0.70
<i>Agave scabra</i>	–	–	4.24	1.65	8.97
<i>Cercocarpus</i> spp.	–	17.49	5.54	13.11	4.94
<i>Acacia greggii</i>	–	–	–	–	–
<i>Rhus microphylla</i>	–	–	3.51	–	–
<i>Acacia texensis</i>	–	–	–	–	–
<i>Bouvardia ternifolia</i>	–	–	0.87	0.26	–
<i>Rhus trilobata</i>	–	–	19.04	–	–
<i>Yucca</i> spp.	–	–	–	–	–
<i>Acacia romeriana</i>	10.95	–	–	–	–
<i>Hoffmanseggia</i> spp.	–	–	–	–	–
<i>Prosopis glandulosa</i>	–	4.76	–	–	–
<i>Prunus minutiflora</i>	–	–	–	–	–
<i>Aloysia wrightii</i>	39.16	–	–	–	–
<i>Ephedra</i> spp.	–	–	–	–	–
<i>Eysenhardtia</i> spp.	–	–	–	–	–

<sup>a</sup>Trees are only in the woody and succulent category when their abundance does not warrant a separate classification.

Woody and Succulent Plants	Woodland Formations				
	Lower Basin	Basin	Upper Basin	Boot Spring	South Rim
<i>Parthenium incanum</i>	-	-	-	-	-
<i>Allionia</i> spp.	-	-	-	1.53	-
<i>Brickellia</i> spp.	-	-	-	-	-
<i>Chrysactinia mexicana</i>	-	-	-	-	-
<i>Diospyros texana</i>	-	-	-	-	-
<i>Fallugia paradoxa</i>	-	-	-	-	-
<i>Fraxinus greggii</i>	-	3.77	-	-	-
<i>Mahonia trifoliolata</i>	-	-	-	-	-
<i>Mammillaria</i> spp.	-	-	-	-	-
<i>Opuntia imbricata</i>	-	-	-	-	-
<i>Philadelphus microphyllus</i>	-	-	-	0.68	-
<i>Pinus cembroides</i> <sup>a</sup>	-	-	-	-	-
<i>Ungnadia speciosa</i> <sup>a</sup>	-	-	-	-	-
<i>Quercus</i> spp. <sup>a</sup>	-	-	-	-	-
<i>Salvia regla</i>	-	-	-	11.11	1.71
Absolute Density/m <sup>2</sup>	5.95	22.46	4.36	0.88	0.39

<sup>a</sup>Trees are only in the woody and succulent category when their abundance does not warrant a separate classification.

Appendix III  
RELATIVE TREE COVER IN WHITETAIL HABITAT, BIG BEND NATIONAL  
PARK, TEXAS.

Trees	Sotol-Grassland Formation		Woodland Formation		
	Green Gulch	Green Gulch Washes	Basin	Boot Spring	South Rim
<i>Juniperus monosperma</i>	27.91	10.95	8.37	1.52	0.21
<i>Pinus cembroides</i>	32.46	11.31	49.84	37.11	50.06
<i>Quercus</i> spp.	22.47	25.69	20.08	33.44	41.36
<i>Juniperus flaccida</i>	—	6.41	6.78	5.72	—
<i>Juniperus pachyphloea</i>	—	—	11.27	17.63	8.37
<i>Quercus emoryi</i>	17.06	37.99	3.66	—	—
<i>Arbutus texana</i>	—	1.50	—	—	—
<i>Celtis reticulata</i>	—	0.62	—	—	—
<i>Cupressus arizonica</i>	—	—	—	2.16	—
<i>Pseudotsuga menziesii</i>	—	—	—	2.42	—
<i>Quercus chesosensis</i>	0.10	—	—	—	—
<i>Ungnadia speciosa</i>	—	5.54	—	—	—
Absolute Density/m <sup>2</sup>	0.14	0.07	0.15	2.09	3.18

Appendix IV

RELATIVE FREQUENCY OF GRASS AND FORBS, AND RELATIVE COVER OF  
WOODY AND SUCCULENT PLANTS ON THE NORTHEAST SIDE OF THE  
CHRISTMAS MOUNTAINS, BREWSTER COUNTY, TEXAS.

Grasses and Forbs	Relative Frequency	Woody and Succulent Plants	Relative Cover
<i>Bouteloua curtipendula</i>	17.59	<i>Dasyliirion leiophyllum</i>	22.58
<i>Aristida</i> spp.	16.67	<i>Acacia constricta</i>	12.70
<i>Bouteloua eriopoda</i>	11.11	<i>Xanthocephalum</i> spp.	10.66
<i>Bouteloua ramosa</i>	11.11	<i>Rhus microphylla</i>	8.59
<i>Euphorbia serrula</i>	9.26	<i>Agave lecheguilla</i>	6.44
<i>Ruellia parryi</i>	7.41	<i>Nolina erumpens</i>	5.38
<i>Hedyotis</i> spp.	6.48	<i>Viguiera</i> spp.	4.97
<i>Polygala</i> spp.	4.63	<i>Parthenium incanum</i>	3.83
<i>Hedyotis nigricans</i>	3.70	<i>Rhus virens</i>	3.40
<i>Croton</i> spp.	1.85	<i>Porlieria angustifolia</i>	3.17
<i>Erigeron divergens</i>	1.85	<i>Acacia romeriana</i>	2.80
<i>Andropogon</i> spp.	0.93	<i>Yucca thompsoniana</i>	2.63
<i>Eragrostis</i> spp.	0.93	<i>Opuntia engelmannii</i>	2.35
<i>Heteropogon</i> spp.	0.93	<i>Dalea</i> spp.	2.20
<i>Krameria glandulosa</i>	0.93	<i>Ephedra</i> spp.	1.59
<i>Lycurus phleoides</i>	0.93	<i>Schaefferia cuneifolia</i>	1.52
<i>Sphaeralcea</i> spp.	0.93	<i>Echinocereus stramineus</i>	1.19
<i>Sporobolus</i> spp.	0.93	<i>Opuntia imbricata</i>	1.02
<i>Thelypodium wrightii</i>	0.93	<i>Juniperus monosperma</i>	0.95
<i>Tridens muticus</i>	0.93	<i>Forestiera angustifolia</i>	0.80
Absolute Density/m <sup>2</sup>	30.23	<i>Echinocereus</i> spp.	0.60
		<i>Dyssodia</i> spp.	0.36
		<i>Zexmenia brevifolia</i>	0.27
		Absolute Density/m <sup>2</sup>	0.22

## Appendix V

RELATIVE FREQUENCY OF GRASS AND FORBS, AND RELATIVE COVER OF  
WOODY AND SUCCULENT PLANTS AND TREES ON NORTH SLOPES OF THE  
CHINATI MOUNTAINS, PRESIDIO COUNTY, TEXAS.

Grasses and Forbs	Relative Frequency
<i>Aristida</i> spp.	43.33
<i>Bouteloua curtipendula</i>	23.33
<i>Bouteloua hirsuta</i>	6.67
<i>Machaeranthera parviflora</i>	6.67
<i>Cassia</i> spp.	3.33
<i>Eragrostis</i> spp.	3.33
<i>Leptochloa dubia</i>	3.33
<i>Setaria</i> spp.	3.33
<i>Sida</i> spp.	3.33
<i>Trichachne californica</i>	3.33
Absolute Density/m <sup>2</sup>	100.00
Woody and Succulent Plants	Relative Cover
<i>Brickellia laciniata</i>	69.48
<i>Opuntia engelmannii</i>	15.91
<i>Opuntia imbricata</i>	11.17
<i>Mimosa borealis</i>	2.27
<i>Koberlinia spinosa</i>	1.18
Absolute Density/m <sup>2</sup>	3.02
Trees	
<i>Quercus gravesii</i>	91.31
<i>Juniperus pachyphloea</i>	4.26
<i>Juniperus monosperma</i>	3.58
<i>Celtis</i> spp.	0.85
Absolute Density/m <sup>2</sup>	0.04



## Appendix VI

RELATIVE FREQUENCY OF GRASS AND FORBS, AND RELATIVE COVER OF  
WOODY AND SUCCULENT PLANTS ON THE NORTH SLOPES OF THE  
ROSILLOS MOUNTAINS, BREWSTER COUNTY, TEXAS.

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Grasses and Forbs	Relative Frequency
<i>Bouteloua curtipendula</i>	22.22
<i>Erigeron divergens</i>	15.28
<i>Aristida</i> spp.	12.50
<i>Selaginella</i> spp.	9.72
<i>Setaria</i> spp.	8.33
<i>Muhlenbergia</i> spp.	6.94
<i>Bouteloua eriopoda</i>	6.94
<i>Leptochloa dubia</i>	5.56
<i>Leptoloma cognatum</i>	4.17
<i>Notholaena</i> spp.	4.17
<i>Lycurus phleoides</i>	2.78
<i>Sphaeralcea</i> spp.	1.39
Absolute Density/m <sup>2</sup>	39.06
Woody and Succulent Plants	Relative Cover
<i>Fraxinus</i> spp.	38.79
<i>Quercus</i> spp.	27.98
<i>Nolina erumpens</i>	7.85
<i>Artemisia</i> spp.	6.47
<i>Xanthocephalum</i> spp.	3.67
<i>Prunus havardii</i>	3.49
<i>Bouvardia ternifolia</i>	3.44
<i>Diospyros texana</i>	3.02
<i>Dasyllirion leiophyllum</i>	1.43
Undetermined	1.20
<i>Opuntia imbricata</i>	1.05
<i>Dalea</i> spp.	0.89
<i>Viguiera</i> spp.	0.70
<i>Echinocereus</i> spp.	0.02
Absolute Density/m <sup>2</sup>	2.63

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