TEXAS PARKS AND WILDLIFE

Ecology of the Mountain Lion on Big Bend Ranch State Park in Trans-Pecos Texas

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Ecology of the **Mountain Lion** on Big Bend Ranch State Park in the Trans-Pecos Region of Texas

FINAL REPORT

Wildlife Division Research Study
Project Number 86

By

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TEXAS PARKS & WILDLIFE

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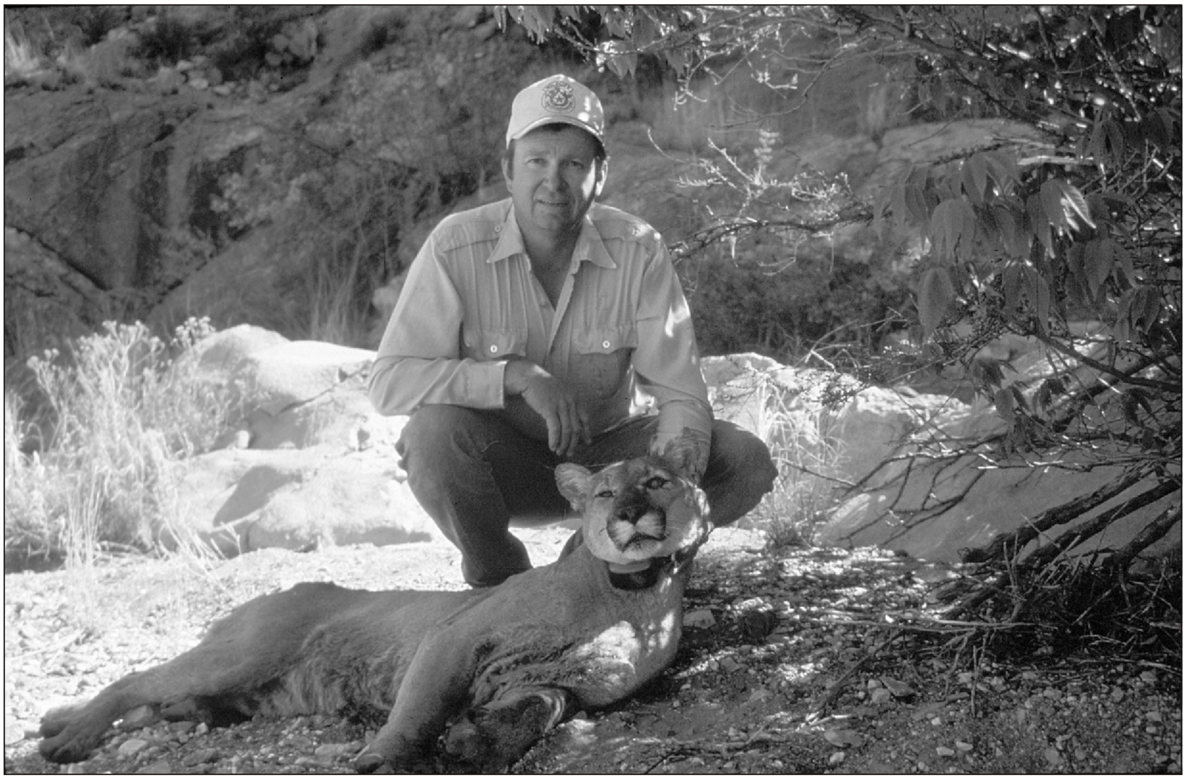


Billy Pat McKinney with large male mountain lion that has been immobilized and radio collared. Photo by Gilbert Guzman.

Abstract

Twenty-one mountain lions (*Puma concolor*) were captured on Big Bend Ranch State Park (BBRSP), 18 December 1992 - 31 August 1997, using leghold snares or trained hounds. Captured lions were examined and aged, and morphological measurements were recorded. Sixteen lions were fitted with radio transmitters operating on individual frequencies. Collared lions were monitored from the ground and fixed-wing aircraft. One radio failed to work, but a total of 711 locations was recorded for 10 male and 5 female radio-collared mountain lions. Home ranges were delineated for 6 male and 5 female lions. Average annual ranges (100% minimum convex polygon) for adult male lions (348.6 km^2 or 86,140 acres) were 59.1% larger ($P<0.05$) than for adult female mountain lions (205.9 km^2 or 50,878.8 acres). Average percent overlap (100% minimum convex polygon) of annual female-female, male-male, and female-male lion ranges were 26.1, 22.9, and 28.9, respectively. Annual shifts were apparent ($P<0.05$) for female lions and for the cumulative male mountain lion ranges. Analysis of fecal scats ($n=135$) indicated collared peccary (*Tayassu tajacu*) and mule deer (*Odocoileus hemionus*) were preferred prey and were consumed almost equally. Genetic analysis, comparing lions from this study to individuals from South Texas, defined two distinct groups of mountain lions with evidence of reduced gene flow between the groups and indicated the effective number of breeding individuals in the West Texas population may be greater than for South Texas. Mountain lion density (#/100 km^2 or 24,710.4 acres) ranged from 0.26-0.59. Observed and deduced lion litters ($n=13$) indicated minimum mean litter size was 1.54. A total of 19 mountain lions was killed, 17 during and 2 after the study. Causes of mortalities included predator control practices on private lands near BBRSP ($n=15$), capture activities ($n=3$), and shooting by a concerned citizen ($n=1$). The mountain lion population on BBRSP was limited by high mortality rates of female and male mountain lions. A follow up survey conducted 2 years after completion of this study indicated a moderate replacement of resident lions on BBRSP.

I. OBJECTIVES

1. Determine home ranges of male and female adult lions on Big Bend Ranch State Park (BBRSP), and estimate population density.

2. Determine reproductive potential of female lions and monitor mortality rates, survival, and dispersal of young lions after they become independent from their mothers.

3. Evaluate the genetics and health of the mountain lion population at BBRSP by collecting blood samples for DNA and disease analysis.

4. Evaluate diets of mountain lions by analyzing fecal samples.

5. Improve the department's knowledge of the technical requirements and support needed to conduct mountain lion research.

II. BACKGROUND

Since 1983, Texas Parks and Wildlife (TPW) has collected mountain lion sightings and mortality data statewide (Job No. 69, Federal Aid Project W-125-R). These data seem to indicate increasing populations in the west, central, and southern portions of Texas with isolated occurrences in North and East Texas (Russ 1992). However, this information alone does not produce accurate estimates of lion population densities for the state and must be supported by research on lion ecology in the respective regions. This study is the first attempt by TPW to supplement mountain lion status information with field research.

Research on mountain lions in Texas has been limited primarily to the Chihuahuan Desert Region and includes studies by McBride (1976), Smith et al. (1986), Pence et al. (1986), Leopold and Krausman (1986), Waid (1990), Packard (1991), and Ruth (1991). The only studies conducted outside Big Bend National Park were Smith et al. (1986) in the Guadalupe Mountains, and McBride (1976) who did some of his work in South Texas and Mexico. The only other long-term comprehensive study of lion ecology in the Chihuahuan Desert was conducted in New Mexico by the Hornocker Wildlife Research Institute (Logan et al. 1996).

This study was conducted in mid-elevation desert scrub and desert grassland habitats in a locale with an unusually large number of perennial water sources for the region. The widely distributed and abundant perennial water of the study area made the site unique within the Trans-Pecos Region. Despite their geographic proximity, the BBRSP habitats stand in sharp contrast to the low desert scrub and isolated montane habitats of Big Bend National Park. BBRSP was considered an ideal site for obtaining data comparative to most of the other Texas studies because BBRSP and Big Bend National Park were of similar size.

In this study, research emphasis was placed on the basic factors affecting mountain lion populations: reproductive rate, mortality rates of different age groups, and juvenile dispersal rate. Juvenile dispersal rate is an important factor because it may act as a population regulating mechanism that results in the colonization of previously unoccupied habitat and also contributes to gene flow (Greenwood 1980). Knowledge of dispersal characteristics of Texas mountain lion populations should contribute substantially to management decisions within the state.

Following the initiation of this study, a similar TPW-funded study was conducted in South Texas from 1994 to 1997 (Harveson 1997).

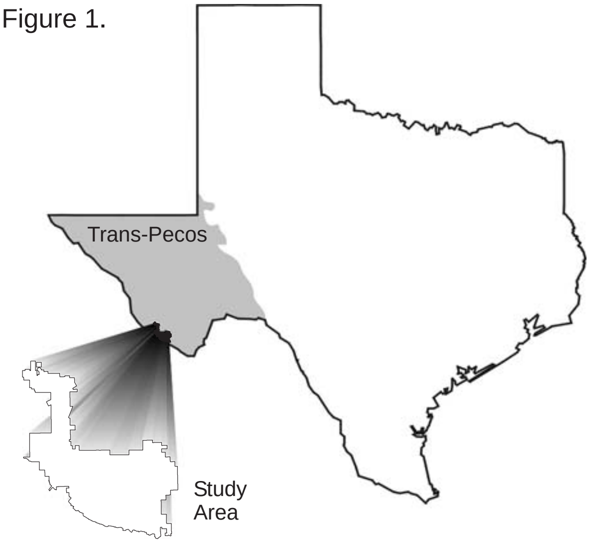
III. STUDY AREA

Big Bend Ranch State Park, which is owned by Texas Parks and Wildlife, contains approximately 1,100 km^2 (271,814.8 acres) located within the Chihuahuan Desert in southwestern Brewster and southeastern Presidio Counties (Fig. 1). BBRSP is situated north of the Mexican State of Chihuahua and is separated from it by the Rio Grande. Big Bend National Park and the town of Lajitas, Texas are located to the east and the city of Presidio to the west.

The most distinctive feature of BBRSP is its topography. The terrain is rugged, ranging from broad mesa tops to steep canyons draining into the Rio Grande. Elevations range from 700 m (2,296 ft.) at Lajitas, Texas along the Rio Grande to 1,565 m (5,135 ft.) at the peak of Oso Mountain (Deal 1976a,b). Approximately 100 perennial springs and associated riparian areas are scattered throughout the park.

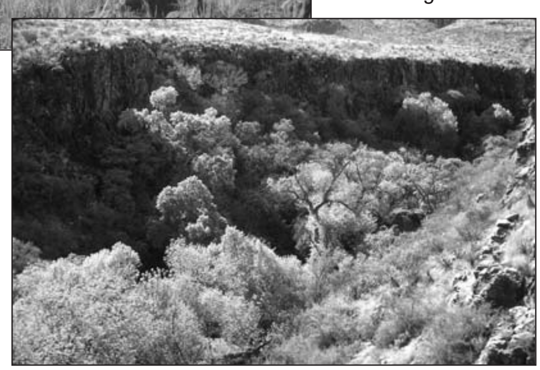
The climate of BBRSP is characterized as semiarid to arid. Average rainfall is approximately

Figure 1.



28 cm (11.0 inches) per year with most falling from July through October in the form of torrential thunderstorms. Occasional winter snowfalls contribute to the annual precipitation.

Average annual temperature is 19°C (66°F) and the frost-free season is 230-245 days long (Butterwick and Strong 1976a,b,c). The average



Big Bend Ranch State Park is characterized by rugged terrain, desert grasslands, and perennial springs. Photos by Ron George.

daily maximum temperature during the summer is approximately 40°C (104°F) with moderate to strong winds common throughout the year (Hanselka 1976a,b,c).

The BBRSP is divided into 6 physiographic zones: the Cienega Mountains, Alamito and Terneros Creek lowlands, the Bofecillos Mountains, the Rio Grande-Colorado Canyon corridor, the Fresno Canyon-Contrabando lowlands, and the Solitario (Carrico 1994). Soil types vary according to location within the physiographic zones on BBRSP. Fine to medium sand, silt, and mud are deposited along the Rio Grande floodplain and associated drainages and are characteristic of sand or sandy gravel deposits (Deal 1976b). As elevation increases, soils become shallower and are associated with igneous rocks and boulders (Hanselka 1976a). Shallow, gravelly loam soil types are typical of areas below mesas and peaks, and soils in shallow draws are deep and rich, with good soil-air-moisture-plant properties (Hanselka 1976c).

Draw, gravelly, igneous hill and mountain, and limestone hill and mountain are the major range sites within BBRSP (Hanselka 1976a,b,c). The park is dominated by species typical of northern Chihuahuan Desert flora that can be grouped into 4 major vegetation types: desert scrub, desert grassland, riparian, and juniper roughlands (Powell 1988). The study area is a mosaic of mid-elevation grasslands and scrublands.

Chihuahuan desert scrub is the most widespread and abundant vegetation type in the park, having replaced much of the former desert grassland (Powell, 1988). The desert scrub community is dominated by a mosaic of woody shrubs such as creosotebush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*), mesquite (*Prosopis glandulosa*), mariola (*Parthenium incanum*), lechuguilla (*Agave lechuquilla*), feather dalea (*Dalea formosa*), catclaw (*Acacia greggii*), and white-thorned acacia (*Acacia constricta*).

Grasslands on BBRSP consist of short and mid grasses, numerous shrubs, and perennial forbs. The grasses include blue grama (*Bouteloua gracilis*), side-oats grama (*B. curtipendula*), chino grama (*B. ramosa*), black grama (*B. eriopoda*), tobosa grass (*Hilaria mutica*), needlegrass (*Stipa* spp.), and bluestem (*Andropogon* spp.). Other plants frequently associated with the desert grassland vegetative type include skeletonleaf goldeneye (V*iguera stenoloba*), sotol (*Dasylirion* spp.), prickly pear cactus (*Opuntia* spp.), and yucca (*Yucca* spp.). Annual forbs are common in the spring and summer following substantial precipitation.

A total of 364 vertebrate species has been documented on BBRSP. These include 10 amphibians. Some of the more common species include the Texas toad (Bufo speciosus), red spotted toad (B. punctatus), couch's (*Scaphiopus couchi*), and western (*S. hammondi*) spadefoots (Scudday 1976a,b,c).

Thirty-three species of reptiles are known to inhabit the park. Lizards such as the collared lizard (*Crotaphytus collaris*), greater earless lizard (*Cophosaurus texana*), and the Texas horned lizard (*Phyrnosoma cornutum*) are the more commonly seen vertebrates (Scudday 1976a,b,c). At least 20 different species of snakes are listed for BBRSP including 4 species of rattlesnakes: the western diamond back (*Crotalus atrox*), rock (C. lepidus), black-tailed (*C. molossus*), and mojave (*C. scutelatus*) (Scudday 1976a,b,c).

Two hundred sixty-two avian species have been documented from BBRSP (Bryan 1999). The more common bird species include white-winged dove (*Zenaida asiatica*), mourning dove (*Z. macroura*), scaled quail (*Callipepla squamata*), killdeer (*Charadrius vociferus*), turkey vulture (*Cathartes aura*), swainson's hawk (*Buteo swainsoni*), and great-horned owl (*Bubo virginianus*).

A total of 59 indigenous mammalian species has been documented for the park (Yancey 1996), including mule deer (*Odocoileus hemionus*), collared peccary (Tayassu tajacu), bobcat (*Felis rufus*), coyote (*Canis latrans*), kit fox (*Vulpes velox*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), ringtail (*Bassariscus astutus*), kangaroo rats (*Dipodomys* spp.), cottontail rabbit (*Sylvilagus* spp.), jack rabbit (*Lepus* spp.), and mountain lion (Yancey 1996).

IV. PROCEDURES

a. Male and female mountain lions within the study site were captured using trained lion hounds or spring-activated leg-hold snares, immobilized with a 10:1 mixture of Ketamine and Rompun, and fitted with radio collars operating on specific frequencies. Kittens were captured by hand and fitted with expandable collars to allow growth without injury. Approximately one year after initial capture, each young lion was recaptured and fitted with an adult collar.

b. Age (from dental characteristics as described by Ashman et al. 1983), sex, and body measurements were recorded for each individual.

c. Blood samples were collected for DNA and disease analysis according to established protocols (Mike Tewes 1993, pers. commun.).

d. Collared lions were monitored every 2 weeks by ground and aerial telemetry to determine movements, home range characteristics, habitat utilization, location of den sites, and survival and dispersal of kittens after they became independent. Telemetry locations were recorded as Universal Transverse Mercator grid coordinates (UTM's) to the nearest 0.01 km (33 ft.) on USGS 7.5-minute topographic maps.

e. All lion fecal scats were collected as encountered and analyzed using micro and macroscopic characteristics of hair, feathers, and skeletal remains to determine diet.

f. Lion kills were verified and locations recorded on 1:24,000 topographic maps.

g. Mule deer, hare (*Lepus californicus*), rabbit (*Sylvilagus* spp.) and furbearer census data from fall spotlight surveys were used to estimate prey population numbers during the study period.

A detailed narrative of procedures and materials used in this study is as follows.

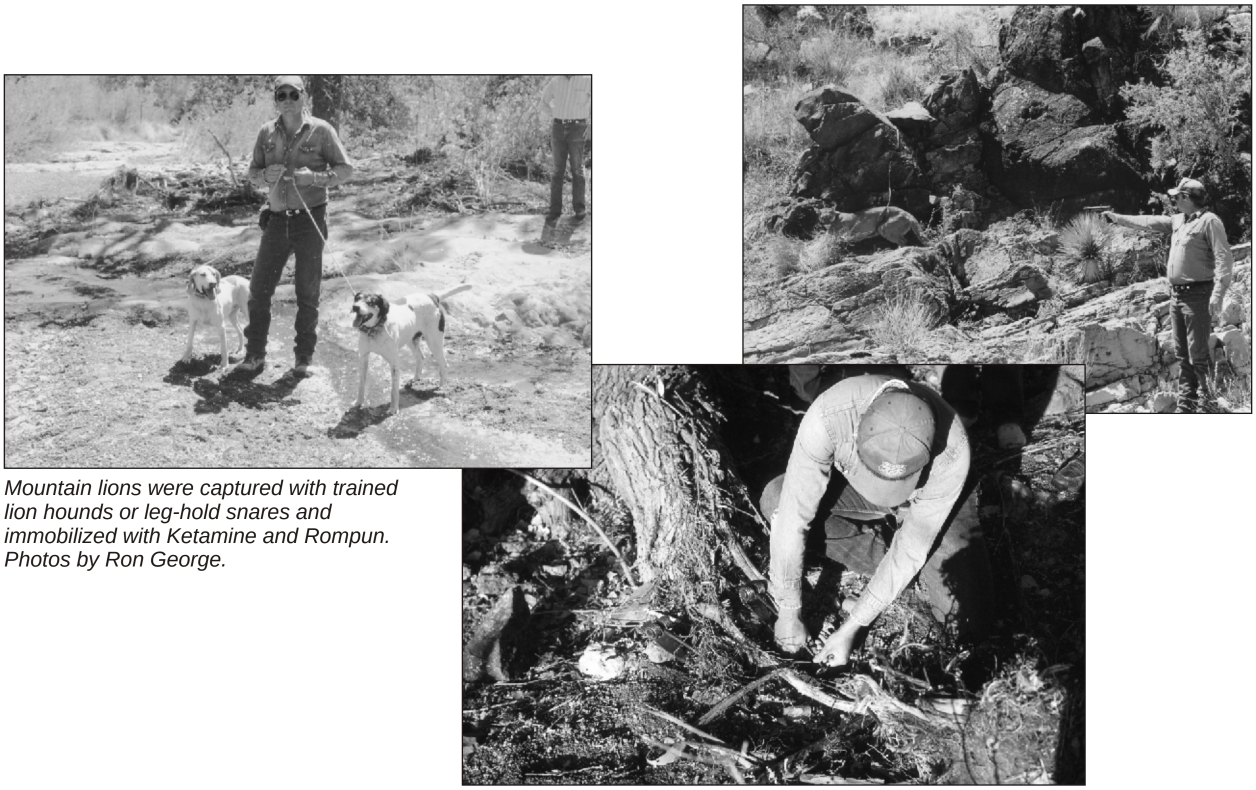
Capture Activities

Field work on BBRSP was initiated 18 December 1992. Initial efforts consisted of searching for mountain lion sign (tracks, scat, scrapes, and kills) in locations thought to be travel routes. Search activities were conducted on foot, and from muleback and vehicles.

Spring activated leg-hold snares (Arizona E-Z Catch, Jerico Ind., Silver City, New Mexico) were set along active lion travel routes (roads, creeks, arroyos, draws, canyons) where recent tracks, scrapes, or kills were observed. Snare sites were chosen to minimize capture-related stress or mortality. Leghold snares were modified with snare stops and shock absorbing rubber bungee cords to minimize injuries and to avoid capturing non-target species (Logan et al. 1996).

A snare site consisted of 1 or 2 snares in blind or baited sets. Blind sets were used where the natural topography forced or funneled lions through a snare site. Bait sets were employed primarily during periods of cool weather using road-killed mule deer, white-tailed deer (*Odocoileus virginianus*), pronghorn antelope (*Antilocapra americana*), and collared peccary. All snares were checked each day by 1200 hours (noon) to prevent unnecessary stress to captures.

The locations of lion sign and snare sites were recorded with a global positioning system (GPS; Trimble Navigation Ltd., Sunnyvale, California) and plotted on 1:24,000 topographic maps

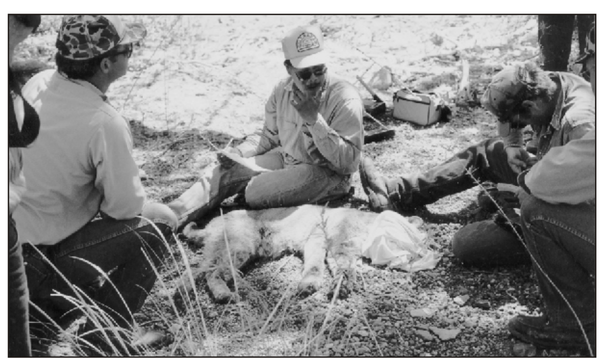


Mountain lions were captured with trained lion hounds or leg-hold snares and immobilized with Ketamine and Rompun. Photos by Ron George.

(7.5-minute quadrangle, United States Geological Survey, Denver, Colorado).

Trained hounds were utilized when fresh lion sign was observed. Once a trail was struck, the lion was pursued until bayed or treed. Hounds were used primarily to recapture radio-collared lions and to capture family members of radio-collared lions.

Body mass of mountain lions, captured by snare or bay, was visually estimated to determine immobilization dosage. Captives were immobilized with a 1.0:0.1 mg mixture of ketamine hydrochloride [Ketaset (ketamine hydrochloride 100 mg/ml), Fort Dodge Laboratories, Inc. for Aveco Co., Inc., Fort Dodge, Iowa 50501] and xylazine hydrochloride [Rompun (xylazine hydrochloride 20 mg/ml), Miles Inc., Shawnee Mission, Kansas 66201] (R. Allen, D.V.M., Alpine Veterinary Clinic, pers. commun.). Dosages approximated 1 ml/10 kg of body weight. Obviously stressed animals were given lower dosages. The drug was injected into heavy muscle by syringe dart fired from a short range CO_2 pistol (Palmer Chemical and Equipment Co., Douglasville, Georgia 30134).



Once immobilized, lions were moved to shade and data were collected. Photo by Ron George.

Once immobilized, lions were removed from snares and placed in the shade. Water was used to cool animals when the possibility of hyperthermia existed. An ophthalmic ointment containing chloramphenicol [Bemacol (chloramphenicol 1%), SmithKline Beecham, West Chester, PA. 19380] was put in both eyes to prevent drying and infection. The head was covered to further protect the eyes and to calm the animal. A long acting antibiotic/cortisone [Azimycin (penicillin G procaine in dihydrostreptomycin sulfate solution with dexamethasone and chlorpheniramine maleate) Schering-Plough Animal Health Corp., Kenilworth, NJ 07033] injection was given to prevent infection and reduce swelling that may have resulted from capture and immobilization. Injections were given intramuscularly (I.M.) by hand syringe at a dosage rate approximating 1 ml/10 kg of estimated body weight.

Lions were aged according to canine length, wear, and coloration as described by Ashman et al. 1983. Each individual was classified as adult (A; >1.5 years with an affinity for a particular range), subadult (S; >1 years, independent with/without an affinity for a particular range), or kitten (K; <1 year or dependent young) (Hemker et al. 1984, Sweanor 1990). Morphological measurements including neck circumference, ear length, chest girth, shoulder height, head length, tail length, total body length, pad dimensions, and body weight were recorded on each captive. Distinguishing physical characteristics such as scars, pelage patterns, and condition of teats or testes were recorded.

Three groups: adult males, females and subadults, and kittens were fitted with radio collars (Models 500, 400, and 205, respectively – Telonics, Inc., Mesa, Arizona 85204) operating on individual frequencies. All transmitters were equipped with mortality sensors that activated after a transmitter remained motionless for more than 5.5 hours.

Lions were aged according to canine length.
Photo by Ron George.

Once radio transmitters were attached and data collection completed, anesthetized lions were administered yohimbine [Yobine (yohimbine 2 mg/ml), Lloyd Laboratories, Shenandoah, Iowa 51601], a reversal agent and antidote for xylazine, to terminate anesthesia. Injections were given I.M. at a dosage rate approximating .5 ml/10 kg body weight.

Radio Telemetry

Collared lions were monitored from the ground and fixed-wing aircraft to determine movements, home area characteristics, habitat utilization, approximate location of den sites, and survival and dispersal of kittens. Ground telemetry locations were obtained using hand-held directional H-antennas attached to portable radio scanner/receivers (TR-2 receiver with TS-1 scanner/programmer, RA-2A antenna, Telonics, Inc., Mesa, Arizona 85204) and from the air using directional antennas mounted to wing struts on fixed-wing aircraft (Cessna 172, 182, or 206).

Mountain lions were monitored 2-4 times/month by triangulation from fixed-wing aircraft. Ground locations were made by listening for signals at elevated sites, and general directional information could often be detected. Triangulation and signal strength were then used to determine the lion's actual position. Aerial telemetry flights were conducted in the early mornings and late afternoons. When a radio-collared lion was detected, a minimum of 3 passes were made (at an average altitude of 303 m or 994 ft.) to determine peak signal strength and to triangulate the lion's actual position.

Periodic ground telemetry checks were made to verify the accuracy of aerial telemetry locations. Error associated with ground and aerial locations was determined by placing test collars in a variety of habitats, by field searches for radio-collared mountain lions, and by locating mountain lion mortalities. Telemetry locations were recorded as Universal Transverse Mercator grid coordinates (UTM's) to the nearest 0.01-km (33 ft.) on USGS 7.5-minute topographic maps. Ground and aerial locations were used to determine home areas and the movements of collared lions.

Ranges

Mountain lions have large home ranges.
Photo by Gilbert Guzman.

Home ranges (Seidensticker et al. 1973) were determined for each collared resident lion by connecting the distant location points to form a convex polygon. A resident lion was defined as a self-sufficient animal whose locations and activities demonstrated its preference for a predictable area (Waid 1990). Ranges (100, 50% minimum convex polygon; 100, 50% adaptive kernel with 30-x-30 m grid) were estimated with CALHOME software (Kie et al. 1994). Annual ranges for adult male and female lions were estimated on 31 December for 1993, 1994, 1995, 1996, and 1997. Perimeter points for the minimum convex polygons were imported into ARCVIEW (Environmental Systems Research Institute, Inc., Redlands, California 92373) to estimate overlap between mountain lion ranges. Home range overlap was defined as 100 x ((overlap area x 2) / (home range A + home range B)). Descriptive statistics were used to determine overlap indices.

Median annual shifts in ranges (100% minimum convex polygon) were tested using a nonparametric ANOVA on the ranks of x- and y-coordinates (UTM coordinates) (Zar 1984). The nonparametric two sample Wilcoxon-Mann-Whitney rank test was used to analyze for differences in total average male and female lion home range areas in both the adaptive kernel and minimum convex polygon at the 50 and 100% contour levels (Zar 1984). Insufficient data were collected to analyze seasonal home ranges of mountain lions.

Density

The minimum number of mountain lions on BBRSP was determined by counting the number of active radio-collared lions within the study site and surrounding areas to incorporate ranges outside the study site. Uncollared lions were also included and their presence determined by the location of recent tracks (size, number, and direction) in areas void of radio-collared lions within the study site.

In February 1999, two years after the completion of the study, a follow up survey was conducted on BBRSP and immediately adjacent lands to determine the current status of the local mountain lion population.

Food Habits

Numerous researchers have examined the food habits of lions in the United States (Arizona: Cunningham et al. 1995, Cashman et al. 1992, Shaw 1977; Colorado: Anderson et al. 1992; Florida: Maehr et al. 1990; Idaho: Hornocker 1970; Utah: Ackerman et al. 1984; Utah and Nevada: Robinette et al. 1959; Texas: Leopold and Krausman 1986, Waid 1990, Harveson 1997). Mountain lions are opportunists and prey on a wide variety of animals but generally prefer large species of ungulates (McKinney 1996). Lions, and sub-adult lions in particular, often rely heavily on small prey when it is abundant (McKinney 1996).

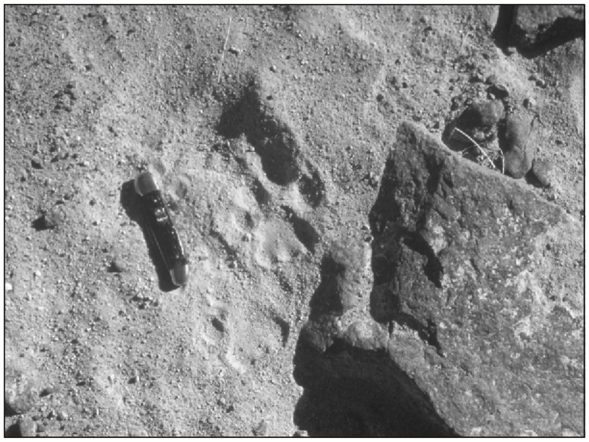
In this study, all lion kills were verified and recorded on base maps, and fecal scats were collected as they were encountered during field activities. Only those scats positively identified as lion were collected. Scats were cleaned of debris, labeled by date and location, and stored in individual plastic bags. Fecal samples were submitted to Sul Ross State University, Alpine, Texas for analysis (McClinton, unpubl. data, 1997). Scats were softened in tap water for approximately 12-24 hours and then washed with tap water through a series of screens (sieve mesh diameter: 0.074 to 1.682). Food items were segregated into individual food items for identification. Contents were macroscopically and microscopically identified to the lowest taxon possible. Hair, teeth, bones, skin, exoskeletons, hooves, and claws were identified by comparison with specimens housed at the Sul Ross State University vertebrate collection.

Frequency of occurrence was calculated by dividing the number of scats examined into the number of scats in which a food item appeared.

Prey Estimates

Surveys were conducted to determine population densities of prey species. Four spotlight survey transects, representing a total of 96 km (60 miles) and 2,979 ha (7,448 acres) of visibility, were established on the study area. Fall spotlight surveys were conducted each year to determine mule deer, rabbit, hare, and furbearer population numbers.

V. RESULTS



Snares were set near tracks and scrapes. Photos by Gilbert Guzman (left) and Mike Pittman (right).

Capture Activities

Capture activities on BBRSP were conducted annually, December through April, 1992-1997. Seventy-five trap sites, set with leghold snares, resulted in 4,756 trap-days (Table 1). Snares accounted for the capture of 13 mountain lions (6 F, 7 M), plus 4 recaptures (1 M(2x) and 2 F). Total snare capture success (capture/trap days) including recaptures was 1/280. Non-target species captured in leghold snares and released included 9 coyotes (*Canis latrans*), 1 skunk (*Mephitis mephitis*), 2 bobcats (*Lynx rufus*), 6 collared peccary, 1 mule deer, and 1 bovine.

Trained hounds were used from December through April during the period 1992-97, and 8 lion captures (2 F, 6 M) made. Also, hounds were used to recapture 6 lions (3 F, 3 M). Two of the 8 were kittens (1 M, 1 F) taken together at a den site on 4 February 1993. They were estimated to be 2 to 4 weeks old, and in poor condition. They were not radio-collared.

A total of 21 lions (8 F (Table 2), 13 M (Table 3)) was captured on BBRSP. Sixteen of the 21 (6 F, 10 M) were fitted with radio collars and released at the capture sites. Collared lions were identified by the letter M or F indicating the sex of each animal. General information on capture date, sex, weight, condition, capture method, capture location, and status was recorded for female and male lions (Tables 2 and 3). Morphological measurements were recorded (Table 4).

Telemetry Activities

Ground and aerial radio tracking was conducted 10 March 1993 - 1 August 1997. A total of 711 aerial locations was recorded for 15 lions (5 F, 10 M). Tracking periods, number of locations, total home range (100% minimum convex polygon, km^2), and percent relocations documented on the study area were recorded for individual lions (Table 5). The rugged topography of BBRSP did not lend itself to collecting teleme-

Radio telemetry equipment was used to monitor lion movements. Photo by Ron George.

try locations from the ground other than general position, direction, and type of signal. Frequency of flights from May through December was 2-4 flights/month with more intense monitoring (4-7 flights/month) January through April. Mean, SD, and range of error radii for aerial locations (n=711) was 44.4, 35.7, and 264 m ±54 m (145.7, 117.0, and 866.0 ±177.2 ft., respectively).

Ranges

Individual home ranges were estimated by 2 commonly used methods called the minimum convex polygon and the adaptive kernel. The minimum convex polygon method simply connects the outermost locations collected from the radio-collared mountain lions to form a polygon. Generally, the area within the polygon increases with an increase in telemetry locations.

The adaptive kernel method determines an animal's distribution and home range with the use of a grid cell system. Mountain lion radio-telemetry locations depict an area of travel that is dissected by a grid of cells. Travel distances that represent different centers of activity create different levels of contours. Home range configurations can be irregular with multiple disjoint centers of activity. All the telemetry locations collected (100%), and half of the locations collected (50%) were analyzed using both of the home range estimators mentioned above for each individual radio-collared mountain lion to determine home range areas, shifts and overlap.

Annual ranges were determined for a single male and 2 female lions in 1993 (Fig. 2), 4 male and 5 female lions in 1994 (Fig. 3), 4 male and 4 female lions in 1995 (Fig. 4),1 male and 4 female lions in 1996 (Fig. 5), and 1 male and 1 female in 1997 (Fig. 6). Mean annual adult female adaptive kernel (100%) ranges (x=369.3 km^2 or 91.26 acres, SD=150.1 km^2 or 37.09 acres) were 1.79x larger than mean minimum convex polygons (100%) (x=205.9 km^2 or 20,559.1 acres, SD=83.2 km^2 or 50,978.8 acres). Annual adult female lion minimum convex polygon (100%) and adaptive kernel (100%) ranges varied from 46.0 km^2 (11,366.8 acres) - 325.9 km^2 (80,531.3 acres) and 92.6 km^2 (22,881.9 acres) - 581.6 km^2 (143,715.9 acres), respectively (Table 6).

Annual adult male mountain lion adaptive kernel (100%) ranges (x=586.9 km^2 or 145,025.6 acres, SD=410.2 km^2 or 101,362.2 acres) were 1.77x larger than minimum convex polygons (100%) and adaptive kernel (100%) ranges (x=348.6 km^2 or 86,140.6 acres, SD=156.1 km^2 or 38,573.0 acres). Annual adult male lion minimum convex polygon (100%) and adaptive kernel (100%) ranges varied from 26.7 km^2 (6,597.7 acres) - 656.9 km^2 (162,322.9 acres) and 41.7 km^2 (10,304.3 acres) - 1,406.0 km^2 (347,428.9 acres), respectively (Table 7).

Annual minimum convex polygons (100%) are shown in Figure 7 for M1 (1993-1995, Figure 8 for M5 (1994-1995), Figure 9 for M6 (1995-1997), Figure 10 for F1 (1993-1997), Figure 11 for F3 (1993-1994), Figure 12 for F4 (1994-1996), Figure 13 for F5 (1994-1996), and Figure 14 for F6 (1994-1996). Annual adult male ranges were different than annual adult female ranges for the 100% adaptive kernel (U=23; P<0.05); 50% adaptive kernel (U=19; P<0.05); 100% minimum convex polygon (U=24; P<0.05); and 50% minimum convex polygon (U=26; P<0.05).

Home Range Shifts

The median annual location of 4 adult radio-collared mountain lions in 1994-95 was different for F1 (P=0.0001), F4 (P=0.0011), F5 (P=0.0022), and M1(P=0.0009). However, median annual location was not different for F3 (P=0.6889), M5

(P=0.3012), and M6 (P=0.1381). A cumulative home range shift was exhibited by F6 (P=0.0129). Adult individuals M2, M4, and M8 were not tested because of insufficient sample size due to removal from the population.

Home Range Overlap

Seventeen annual female-female lion ranges (minimum convex polygon) overlapped at the 100% level of sample points, and 3 female-female ranges overlapped at the 50% level (Table 8). Average percent overlap of annual female-female ranges at the 100% level of sample points was 26.1 (n=17, range=2.4-51.1). Average percent overlap of annual female-female ranges at the 50% level was 14.2 (n=3, range=10.2-20.5).

Six annual male-male lion ranges (minimum convex polygon) overlapped at the 100% level of sample points, and a single male-male range overlapped at the 50% level (Table 9). Average percent overlap of annual male-male ranges at the 100% level of sample points was 22.9 (n=6, range=1.7-60.1). The percent overlap of the annual male-male range at the 50% level was 3.6.

Twenty-six annual female-male lion ranges (minimum convex polygon) overlapped at the 100% level of sample points, and 9 female-male ranges overlapped at the 50% level (Table 10). Average percent overlap of annual female-male ranges at the 100% level was 28.9 (n=26, range=0.03-82.7). Average percent overlap of annual female-male ranges at the 50% level was 18.6 (n=9, range=1.4-40.8).

Density

A density estimate of 0.37, 0.44, 0.59, 0.51, and 0.26/100 km^2 (24,710.4 acres) was determined for BBRSP in 1993, 1994, 1995, 1996, and 1997, respectively (range=0.26 - 0.59, x=0.43, SD=0.13) (Table 11). Radio-collared lions comprised 60, 92, 75, 43, and 43% of the total estimated population, and adults were 50, 83, 81, 71, and 85% of the total population for 1993, 1994, 1995, 1996, and 1997, respectively.

Food Habits

Of the 19 kills verified, 12 were collared peccary (2 boars, 3 sows, 7 unknown) and 7 mule deer (4 bucks, 3 does) killed by lions between January 1993 and March 1997.

A total of 135 fecal scats was collected between January 1993 and March 1997, and only scats positively identified as lion were evaluated. The relative frequency of occurrence percentage (rfp) of food items collected, 1993-97, is presented in Figure 15. Peccary were the most important prey appearing in 46 percent of the scats. Deer and hare were the second and third most important with frequencies of 44 and 13 percent, respectively. Unidentified material amounted to only 4 percent. Mountain lion, badger, and other (grass, rocks, leaves and other debris), each had a frequency of .7 percent.

This buck mule deer was killed, partially eaten, and covered with vegetation by a mountain lion. Photo by Billy Pat McKinney.

Spotlight surveys, conducted from September through November of 1992-1996, indicated mule deer densities of 5.7, 5.0, 3.3, 2.9, and 4.0 deer/400 ha (1,000 acres), for the respective years. The spotlight survey effort yielded lower numbers of furbearers, rabbits, and hares (Table 12), but this may not be an appropriate survey method for some of these small mammals. Although peccaries are common on the study area, none were observed on spotlight surveys, probably due to behavioral characteristics and the lack of reflectiveness in their eyes.

Reproduction

Thirteen litters were recorded from a combination of tracking collared females with offspring, harvest data of collared lions from adjacent private property, captured subadults and kittens, visual observation, and interpretation of track sign (Table 13). Mean litter size for these litters was 1.54 (n=13, SD=0.52).

Genetics

Blood and tissue samples were collected from 9 lions on BBRSP during the initial study period and submitted to Texas A&M University, College Station, Texas for genetic analysis. Sixteen blood and tissue samples from a companion mountain lion study in South Texas (Harveson 1997) were submitted at the same time for comparison. G.W. Walker et al. (2000) concluded that Texas mountain lions had less genetic variation than previously reported for the species in other parts of its range. Analysis of these two samples indicated that the West and South Texas populations were distinct genetically which suggests low gene flow between the two. The data also suggested that the effective number of breeding individuals in the West Texas population might be greater than in the South Texas population.

Mortalities

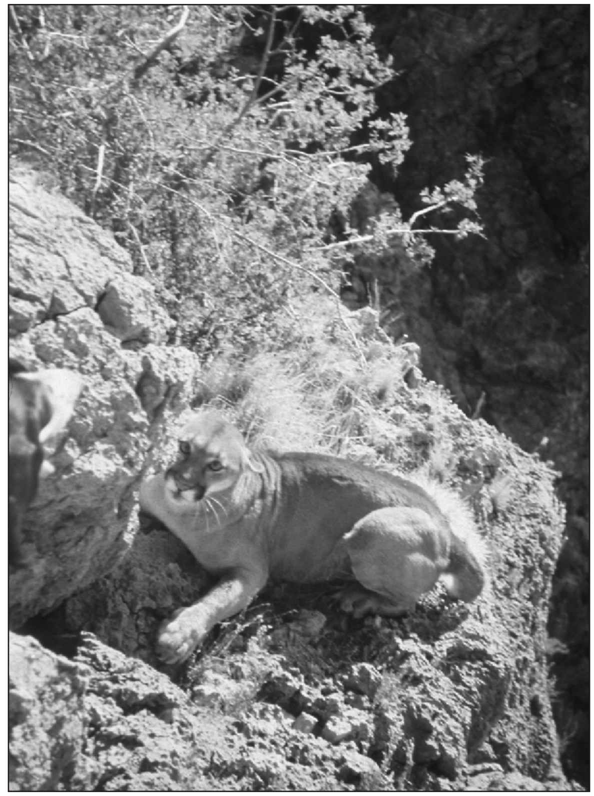
Nineteen mountain lion mortalities occurred on or adjacent to BBRSP, 17 during and 2 after the study. Three of the 19 mortalities occurred on the study site as the result of researcher actions. An adult female, captured in a leghold snare, climbed a small tree and became entangled in the snare cable. A male kitten (M3), approximately 2 months old, was captured at the same snare site 4 days after the female mortality occurred. Because the female had been lactating, it was assumed that the kitten belonged to her. Dogs were used to search for other littermates, but none were found. The kitten was taken to Central Texas Wildlife Institute, Inc., Hamilton, Texas for rehabilitation. A juvenile male, approximately 15 months of age, was treed by hounds on 25 March 1993 and was accidentally overdosed. This juvenile male was determined to be the littermate of M10 and the offspring of F3. A male kitten, approximately 2 months of age, was killed on 28 March 1996 while using hounds to recapture his dam (F4).

Fifteen of the 16 radio-collared lions were killed on private land adjacent to the study area as a result of private predator control activities. Thirteen of the 15 were killed during the study and 2 after the study had ended. The former group consisted of 8 males (6 adults, 1 subadult, 1 juvenile) and 5 females (4 adults, 1 juvenile); the latter were both adults, a male and female. One additional radio-collared subadult lion (the orphaned male, M3, which had been taken to the Wildlife Institute for rehabilitation) was also killed outside the study area. It had been returned to BBRSP in January 1994, fitted with a collar, and released. It was a shot approximately 2 weeks later when it approached 2 concerned citizens at a boat ramp on the Rio Grande.

Mortality and life span data are presented in Table 14 and Figure 16, respectively.

Technical Support and Education

One study objective was to improve the department's knowledge of the technical expertise and support needed to conduct mountain lion research. This study was the first attempt by TPW to supplement current mountain lion status information with field research. Although this study was designed primarily to answer specific questions about mountain lions in West Texas, and on BBRSP in particular, it also served to increase the technical expertise of TPW personnel and provided a unique educational opportunity for university students. A total of 66 persons visited the study site and assisted with research activities, including 28 TPW Wildlife Division employees, 6 TPW State Parks Division employees, 5 media representatives, and 23 Texas and 4 Mexican university students.



Mountain lion on Big Bend Ranch State Park.
Photo by Billy Pat McKinney.

VI. DISCUSSION

Mean range for adult male lions was greater than for adult females in most of the annual comparisons. This is consistent with Seton's (1909) conclusion that the size of the home range is related to the size of the animal. Since males are 1.5-2x larger than females, they normally exhibit larger home ranges (Harestad and Bunnell 1979). Average adult male ranges in this study ranked within the span of ranges delineated in previous studies conducted within the Chihuahuan Desert (Pence et al. 1986, Smith et al. 1986, Logan et al. 1996).

The average adult female home range size reported in this study was one of the largest recorded to date south of 42^o latitude (Sweanor 1990, Cunningham et al. 1995, Logan et al. 1996, Harveson 1997). However, there was substantial variation in individual figures (46.0-325.9 km^2 or 11,366.0-80,531.3 acres). Female home range size is affected by reproductive status (Sweanor 1990). In this study, it generally increased as kittens grew older, and solitary females exhibited the largest ranges. Average female and male home ranges (minimum convex polygon), as determined by previous researchers, are presented in Table 15.

A low prey density may contribute to an increase in home range size in both males and females. Mule deer spotlight surveys conducted on the study site indicated a low deer population during the period 1992-96 (Table 12). Logan et al. (1996) determined that larger ranges are needed when prey densities are low, and home range size tends to increase when the habitat of the lion's prey becomes fragmented.

In addition, the removal of mountain lions, both males and females, created unoccupied habitat and left voids available for home range shifts to occur. This finding is consistent with other mountain lion studies where home range size varied by sex and age, season of the year, spatial pattern and prey density (Seidensticker et al. 1973).

Male home range size estimates may have been more affected by topography than female estimates. Males generally inhabited more irregular terrain than females on BBRSP, and the increased difficulty that this caused in obtaining positions (McBride 1976) may have made the estimate of male ranges less accurate than for females. This may be the reason that the locations of females were more predictable. Sweanor (1990) found that the home range sizes of most male and female mountain lions with established home ranges leveled off after 35 telemetry locations collected over a 10 month period. All of the adult females in this study (n=6) met this criteria, but 3 of the 6 adult males (M4, M6, and M8) did not.

A home range is the numerical estimate of tracking data over a period of time for an area used by an animal and is calculated by estimating the area within the polygon (White and Garrett 1990). All home range estimators have limitations, but the oldest and most common method used is the minimum area polygon, which connects the outer locations to form a convex polygon (Mohr 1947 and White and Garrett 1990). The 100% minimum convex polygon was used to analyze radio-telemetry data from 10 of 18 mountain lion studies conducted since 1973 (Anderson et al. 1992). In this study, home ranges estimated by the adaptive kernel and the minimum convex polygon methods were affected by the number of telemetry locations (sample size). The adaptive kernel method overestimated home range areas because disjointed grid cells, used to determine a polygon, tend to be added together to form the home range estimate

(Worton 1989). After deleting outliers, the minimum convex polygon method produced a more conservative estimate of range size and shape when compared to the home range area produced by the adaptive kernel method.

The Wilcoxon-Mann-Whitney rank sum test was used to test for differences between adult male and female annual home range sizes. A non-normal distribution occurred in the home ranges of our radio-collared mountain lion population because the annual ranges of the adult males (26.7-656.9 km^2 or 6,597.7-162,322.9 acres) encompassed the ranges of the adult females (46.0-325.9 km^2 or 11,366.8-80,531.3 acres).

Considerable overlap of females occurred between 1993-96. This is consistent with previous studies (Smith et al. 1986, Sweanor 1990, and Logan 1996). Female lions commonly overlapped in the study conducted by Cunningham et al., (1995), and home ranges of resident females sometimes overlapped completely (Seidensticker et al. 1973).

After the first year of the study, F1 and F3 overlapped or shared home ranges by approximately 30% (Fig. 2). In 1994, considerable overlap occurred between all females, especially between F3 and F5, who exhibited an overlap > 50% (Fig. 3). During 1994, F1 and F3 overlapped all other female mountain lion ranges, including each other. In 1995, overlap between females had been reduced by 2/3 compared to the previous year and as a result of the removal of F3 from the population (Fig. 4). In 1996, female mountain lions shifted their ranges to fill F3's abandoned home range. Apparently, F1 moved to the north, and F4 moved to the east, and this increased their overlap from 17.5% to 42.3% (Fig. 5). F1, F4, F5 and F6 experienced decreases in home range overlap because F5 moved north and F6 moved to the east in 1996 (Fig. 5). By the end of the first quarter of 1997, only F1 remained on BBRSP to represent the female segment of the radio-collared lions on the study area (Fig. 6).

Overlap of male ranges was highest in 1995, with M5 and M6 overlapping by 60% (Fig. 8, 9). During this same period, M6 also overlapped M8 by 42% (Fig. 4). This extent of overlap may have been tolerated because males were trying to breed with the remaining females (F1, F4, F5, F6; Fig. 4). After the death of M8 and M5 in 1995, only M6 remained to represent the male segment of the radio-collared lions on BBRSP (Fig. 6).

Overlapping female and male ranges occurred throughout the study, and this is consistent with other studies (Smith et al. 1986, Sweanor 1990, Harveson 1997). Resident lion F4 overlapped with as many as 5 male mountain lions over a three-year period (Fig. 12). In 1995, the adult male group had been reduced to M5, M6, and M8 (Fig. 4). This may have contributed to the high degree of overlap between M5, M6, and M8 as they tried to mate with available females (F1, F4, F5, and F6). Males had to cover large geographic areas and cross the borders of other males' home ranges to breed with more than 1 female. Sweanor (1990) observed similar behavior.

The adult male segment of the lion population on BBRSP exhibited the most dramatic range shifts. Home ranges had been stable until F3, M2 and M4 were removed from the population in 1994.

In 1995, M6 was radio-collared in what had been the exclusive range of M1; M1 was subsequently displaced to the north onto property outside BBRSP. The approximate age of M1 in 1995 was 8, and his home range was reduced to 26.7 km^2

(6,597.7 acres) shortly before his death (Fig. 4). Telemetry data indicated that M6 had occupied M1's lower home range and taken up residence (Fig. 4). Home range shifts of this type are common within mountain lion populations. Sweanor (1990) also documented range shifts attributed to the arrival of new males and pressure exerted by younger more aggressive males.

Telemetry locations recorded off the study site for M2 and M4 were 45.7 and 58.8%, respectively. Within the period 1994-95, 92.7% of the telemetry locations recorded for M5 were off the study site to the east of BBRSP (Fig 8). Shortly after the death of M1 in 1995, M5 shifted into the upper half of M1's home range. The mortality location of M5 was in the general area of M1's mortality.

In 1995, M8 was radio-collared approximately 3.2 km (1.9 miles) from the Rio Grande, and he expanded his range to the north and west. M8 continued to travel north into home ranges previously held by M2 and M4 (Fig. 4). He continued to travel north off the study site and sustained trap wounds which led to his death. Telemetry locations indicated that M8 was returning south to his initial home range when a mortality signal was received. Despite the limited amount of telemetry data collected for M8, (9 months) he still exhibited a home range shift and demonstrated the land tenure system proposed by Seidensticker et al. (1973), which may have caused him to move further north than he had ever done before the removal of M2 and M4.

Home range shifts were documented for adult females (F1, F4, F5, F6) during 1996 (Figs. 10, 12-14). F4 shifted its range to the east while F5 shifted to the north encompassing the range previously held by F3. F6, M5, and M6 did not display annual shifts. However, cumulative home range size figures covering more than a year consistently exceeded the annual home range sizes for the same group of individuals. This suggests that home range shifts probably occur over longer time periods (Sweanor 1990).

The only 2 radio-collared lions monitored during the last year of the study (1997) were F1 and M6 (Fig 6). The last telemetry flight recorded their locations to be on BBRSP. The percent locations on the BBRSP for F1 and M6 were 99.2 and 93.9, respectively. Apparently F1 and M6 continued to shift to the north off the study site because they too were reported as mortalities in November 1997 after the completion of the study.

The degree of mountain lion home range overlap and ultimately the density of a breeding population are affected by the diversity of the habitat (Seidensticker et al. 1973). Habitat diversity promotes an increase in carrying capacity of lion prey species. An increase in lion density can be attributed to an increase in prey species.

In this study, it was noted from both telemetry and sign that male lions preferred to travel along dry canyon bottoms while females with kittens traversed them, but spent most of their time along ridges and in side canyons. Thus, it would appear that one group was actively avoiding the other, and it was assumed that females were avoiding males.

Determining mountain lion population density with confidence has met with difficulty in previous studies conducted in Texas (McBride 1976, Pence et al. 1986, Smith et al. 1986). Several census techniques have been employed. Currier et al. (1977), and Shaw (1977) used the capture-mark-recapture method. Van Dyke et al. (1986) used track characteristics and counts to estimate mountain lion numbers. Tracks provide more information about the size, age, and individual identity of mountain lions than do scrapes (Cunningham et al. 1995).

Mountain lion density on BBRSP and surrounding areas for the period of the 5-year study was determined to be 0.43 mountain lions/100 km^2 (24,710.4 acres). Our density estimate is comparable to densities computed for previous studies (Shaw 1977), and 3 out of the 5 years fall within the range of densities estimated in South-central Utah (Hemker et al. 1984). Densities on BBRSP are also consistent with density figures computed for South Texas where the 3-year average was 0.56 lions/100 km^2 (24,710.4 acres) (Harveson 1997).

Several methods have been used in determining mountain lion food habitats including fecal analysis, stomach contents, and kills identified in the field. Analysis of mountain lion fecal scats on BBRSP indicated mule deer and collared peccary were the most important prey species and were consumed almost equally. It is well documented that mountain lions supplement their diet with a variety of small animals, but fecal analysis from BBRSP scats indicated only two small prey species, hare and badger. Researchers from previous Texas studies reported deer species occurrence in diets ranging from 43-70%, peccary from 0-31%, livestock from 0-14%, porcupine (*Erethizon epixanthum*) from 2-16%, and other small species form 1-24% (McBride 1976, Leopold and Krausman 1986, Smith et al. 1986). Harveson's (1997) ability to use scats in South Texas was hindered by the subtropical climate and the presence of dung beetles (*Scarabidae* spp.). He reported a percent frequency of 28, 12, 28, 20, and 12 for deer, peccary, feral hog (*Sus scrofa*), mountain lion, and rodents, respectively, from 25 scats. The frequency of deer in scats analyzed from BBRSP is within the range reported by other researchers, but the frequency percentage of peccary (46) is the highest reported for all the studies reviewed. Leopold and Krausman (1986) and Waid (1990) had a combined total of 979 scats with a percent frequency of 31 for peccary in Big Bend National Park, Texas.

The number of mountain lion kills (n=19) found during the study was small. The rough topography and dense shrubby vegetation of the study area hindered personnel in locating kills. The absence of vultures during the capture periods, December through April, also hindered the effort.

VII. CONCLUSIONS AND MANAGEMENT

The intense predator control program that operated on private lands adjacent to BBRSP during this study, combined with the large home ranges of the radio-collared mountain lions, had a marked negative impact on the study population. Data collected during this study indicated that the mountain lion population on BBRSP was limited by high mortality of both males and females of all age classes due principally to the private predator control activities. However, based on personal knowledge, this level of intense predator control was practiced by only a small number of landowners in West Texas during the 1990s. Generally, the purpose was to minimize losses to other wildlife, primarily mule deer, and occasionally livestock.

A follow up survey to determine the status of the BBRSP lion population 2 years following the completion of the study was conducted on the park and immediately adjacent lands in February 1999. That survey indicated 8 mountain lions (4M, 3F, and 1U), thus, a moderate level of replacement. The region has experienced a drought and a substantial drop in the mule deer population in the interval between the end of the study and the follow up survey. It is not known what role this factor may have played in determining the rate of recovery of the mountain lion population.

Stability within mountain lion populations is likely influenced by a number of factors, including intraspecific mortality. Males seeking new territories sometimes kill females and kittens within home ranges they are attempting to claim. Increase in kitten mortality may be related to the removal of a large portion of the adult male component (Ross and Jalkotzy 1992). Loss of adult resident females would most likely have the greatest impact on the local population because not only will they need to be replaced, but also their removal will reduce the number of young available to replace losses (Lindzey et al. 1992). Under such circumstances, the rate of population increase will depend on the rate of immigration (Lindzey et al. 1992).

The combination of reduced mountain lion control programs and large, relatively undisturbed tracts of rugged lion habitat should secure the future of relatively stable mountain lion populations in the Trans-Pecos. To ensure the value of these large tracts of land, e.g. BBRSP, Big Bend National Park, and Black Gap Wildlife Management Area, corridors that connect them must be maintained to allow the dispersal of subadults.

Based on personal observations, as well as statewide mountain lion sighting and mortality reports (Russ 1992), we believe the mountain lion population in the Trans-Pecos Region, as a whole, is stable and not in danger of depletion. Therefore, we do not recommend a change in their legal status, which is a non-game animal with no closed season and no bag limit.

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X. TABLES AND FIGURES

Table 1. Summary of mountain lion trapping efforts by TPW researchers on Big Bend Ranch State Park, Texas, January 1993 - August 1997.

	Number count					Rate	Nontarget
Year	trap sites	trap days	trap captures	lion 1st capture	lion recaptured	(capture/ trap day)	animals captured
1993	28	2,355	6	5	1	1 / 393	3[a]
1994	13	762	5	5	0	1 / 152	2[b]
1995	16	514	3	3	0	1 / 171	4[c]
1996	10	581	2	0	2	1 / 291	5[d]
1997	8	544	1	0	1	1 / 544	6[e]
Total	75	4,756	17	13	4	1 / 280	20

[a] 2 coyotes, 1 skunk
[b] 1 coyote, 1 peccary
[c] 1 bobcat, 3 peccary
[d] 1 bobcat, 2 coyotes, 2 peccary
[e] 1 mule deer, 4 coyotes, 1 bovine

Table 2. Capture dates and status of female (F) mountain lions captured on Big Bend Ranch State Park, Texas, January 1993 - August 1997.

Lion ID	Capture date	Age[a] (months)	Weight (kg.)	Weight (lb.)	Condition class	Capture location	Capture method	Status in study
F1	22 Jan 93	36	32.7	72.0	Fair	Panther Mtn.	Snare	Resident
F	04 Feb 93	1	4.5	10.0	Poor	Arroyo Segundo	Hounds	Unknown[b]
F	20 Feb 93	48	29.0	64.0	Good	Fresno Canyon	Snare	Mortality[c]
F3	25 Mar 93	48	34.5	76.0	Fair	Arroyo Secundo	Snare	Mortality[d]
F4	14 Jan 94	48	29.5	65.0	Good	Las Burras Canyon	Snare	Mortality[e]
F5	03 Feb 94	72	28.1	62.0	Poor	Lefthand Draw	Snare	Mortality[f]
F6	03 Mar 94	48	34.0	75.0	Good	Lefthand Shutup	Snare	Mortality[g]
F7	21 Apr 95	6	15.9	35.0	Good	SE La Mota Mtn.	Hounds	Mortality[h]

[a] According to Ashman et al. (1983).
[b] Kitten captured at den site but not radio-collared.
[c] Capture mortality.
[d] Killed outside the study area on 16 Nov 94.
[e] Killed outside the study area on 08 Jan 97.
[f] Killed outside the study area on 15 Mar 97.
[g] Killed outside the study area on 08 Oct 96.
[h] Killed outside the study area on 24 Oct 95.

Table 3. Capture dates and status of male (M) mountain lions captured on Big Bend Ranch State Park, Texas, January 1993 - August 1997.

Lion ID	Capture date	Age[a] (months)	Weight (kg.)	Weight (lb.)	Condition class	Capture location	Capture method	Status in study
M	04 Feb 93	1	3.9	8.5	Poor	Arroyo Secundo	Hounds	Unknown[b]
M3	24 Feb 93	2	6.8	15.0	Good	Fresno Canyon	Snare	Mortality[c]
M1	25 Feb 93	60	63.5	140.0	Good	Arroyo Secundo	Snare	Mortality[d]
M	25 Mar 93	15	24.9	55.0	Good	Arroyo Secundo	Hounds	Mortality[e]
M2	28 Dec 93	36	54.4	120.0	Good	Panther Mountain	Hounds	Mortality[f]
M4	27 Jan 94	48	56.7	125.0	Good	Botella Spring	Snare	Mortality[g]
M5	06 Apr 94	60	56.2	124.0	Good	Lefthand Shutup	Snare	Mortality[h]
M6	07 Feb 95	48	52.2	115.0	Good	Fresno Canyon	Snare	Resident
M7	11 Feb 95	48	62.6	138.0	Good	Las Cuevas	Snare	Mortality[i]
M8	09 Mar 95	60	61.2	135.0	Good	Madera Canyon	Snare	Mortality[j]
M9	23 Feb 95	4	12.7	28.0	Good	Alazan Hills	Hounds	Mortality[k]
M	28 Mar 96	2	6.8	15.0	Good	Manzanillo Mesa	Hounds	Mortality[l]
M10	16 Feb 93	14	24.9	55.0	Good	Los Alamos Spring	Hounds	Mortality[m]

[a] According to Ashman et al. (1983).
[b] Kitten captured at den site but not collared.
[c] Orphan male kitten taken to Central Texas Wildlife Institute, Inc., Hamilton, Texas. Released 8 Jan 94 on BBRSP and killed 27 Jan 94 outside the study area.
[d] Killed outside the study area on 24 Oct 95.
[e] Capture mortality.
[f] Killed outside the study area on 19 Feb 95.
[g] Killed outside the study area on 25 Feb 95.
[h] Killed outside the study area on 17 Apr 96.
[i] Killed outside the study area on 04 Jun 95.
[j] Mortality signal on 09 Jan 96, died of wounds sustained outside the study area.
[k] Killed outside the study area on 21 May 95.
[l] Capture mortality.
[m] Killed outside the study area on 09 Aug 94.

Table 4. Morphological measurements from mountain lions captured on Big Bend Ranch State Park, Texas, 1993-1997.

					Length (cm)							Length (mm)				
													Front Paw		Rear Paw	
ID#	Sex	Date	Age (mo)	Mass (kg)	Total	Body	Tail	Head	Neck	Girth	Shoulder	Ear	L	W	L	W
1	F	22 Jan 93	36	32.7	190	119	71	40	32	60	68	76	41	70	38	57
-	F	04 Feb 93	1	4.5	94	65	29	25	17	31	34	88	25	31	29	32
-	F	20 Feb 93	48	29.0	178	115	63	39	32	57	42	76	45	45	38	38
3	F	25 Mar 93	48	34.5	191	122	69	41	35	64	60	89	45	54	38	51
4	F	14 Jan 94	48	29.5	193	124	69	42	38	57	61	83	44	54	38	48
5	F	03 Feb 94	72	28.1	183	122	69	38	39	66	60	80	40	50	39	40
6	F	03 Mar 94	48	34.0	203	127	76	41	34	64	64	90	41	40	39	40
7	F	21 Apr 95	6	15.9	163	99	64	33	33	56	48	80	40	50	30	39
-	M	04 Feb 93	1	3.9	84	57	27	22	14	25	26	64	19	32	19	25
3	M	24 Feb 93	2	6.8	106	71	35	28	18	34	37	57	32	38	32	32
1	M	25 Feb 93	60	63.5	235	172	64	47	43	79	74	83	54	64	51	57
-	M	25 Mar 93	15	15.0	168	105	62	37	30	56	66	102	41	57	41	51
2	M	28 Dec 93	36	36.0	208	132	76	48	43	76	67	95	54	57	45	51
4	M	27 Jan 94	48	56.7	208	131	77	49	41	81	67	108	48	60	51	54
5	M	06 Apr 94	60	56.2	211	127	81	52	46	81	70	90	40	60	50	60
6	M	07 Feb 95	48	52.2	193	124	69	50	42	71	66	90	40	80	40	60
7	M	11 Feb 95	48	62.6	206	132	74	55	49	84	67	100	80	90	50	60
8	M	09 Mar 95	60	60.0	216	140	76	50	48	79	66	90	50	60	50	50
9	M	23 Feb 95	4	12.7	-	-	-	-	25	50	34	80	10	40	40	30
-	M	28 Mar 96	2	6.8	107	70	37	28	20	41	39	81	30	70	31	40
10	M	16 Feb 93	14	24.9	147	102	46	37	29	61	51	76	38	51	38	45

Table 5. Tracking period and total home ranges (100% minimum convex polygon) as determined from aerial radio telemetry locations for female (F) and male (M) mountain lions on Big Bend Ranch State Park, Texas, March 1993 - August 1997.

Lion ID	Tracking period	No. of relocations	Home range km^2	Percent relocations found within BBRSP
F1	10 Mar 93-01 Aug 97	127	400.0	99.2
F3	25 Mar 93-08 Nov 94	72	386.4	75.0
F4	19 Jan 94-14 Feb 97	69	446.7	62.3
F5	03 Feb 94-14 Feb 97	73	538.1	79.5
F6	03 Mar 94-08 Aug 96	58	128.3	100.0
F7	09 May 95-20 Jul 95	0	[a]	0
M1	10 Mar 93-23 Oct 95	87	697.5	61.6
M2	06 Jan 94-02 Feb 95	35	315.4	54.3
M3	12 Jan 94-26 Jan 94	3	[a]	33.3
M4	01 Feb 94-10 Dec 94	26	347.9	46.2
M5	06 Apr 94-20 Dec 95	40	1,175.0	7.3
M6	07 Feb 95-14 Jul 97	33	895.8	93.9
M7	11 Feb 95-02 Jun 95	8	[a]	87.5
M8	09 Mar 95-09 Jan 96	15	390.2	93.3
M9	23 Feb 95-09 May 95	6	[a]	33.3
M10	10 Mar 93-03 Jun 94	59	390.8	84.5
	Total	711	Mean	74.7

[a] Insufficient number of locations to determine home range.

Table 6. Annual[a] ranges (km^2) for adult female (F) mountain lions on Big Bend Ranch State Park, Texas, 1993-1997.

Animal	Year	n[b]	ADK[c] 100%	ADK[c] 50%	MCP[d] 100%	MCP[d] 50%	Median shift F	Median shift df	Median shift P
F1									
	1993	39A[e]	259.3	44.5	156.3	30.9			
	1994	35B	391.4	32.5	192.9	28.2			
	1995	18B	143.4	18.9	59.9	10.0			
	1996	22A	376.9	60.1	191.0	27.6			
	1997	13A	581.6	117.9	252.1	30.9			
$\bar{x}$			350.5	54.8	170.4	25.5	8.89	4	0.0001
F3									
	1993	37A	452.3	65.1	231.8	45.3			
	1994	35A	481.6[f]	46.7	294.4	17.6			
$\bar{x}$			466.9	55.9	263.1	31.5	0.16	1	0.6889
F4									
	1994	32B	510.6	101.2	325.9	36.6			
	1995	18B	466.4	58.8	228.5	18.2			
	1996	19A	384.8	78.1	243.2	49.5			
$\bar{x}$			453.9	79.4	265.9	34.8	7.60	2	0.0011
F5									
	1994	33B	546.9	48.7	325.0	29.9			
	1995	18B	368.2	49.6	163.6	23.5			
	1996	21A	466.2	110.0	276.7	31.8			
$\bar{x}$			460.4	69.4	255.1	28.4	6.68	2	0.0022
F6									
	1994	27A	144.2	11.8	77.8	19.9			
	1995	18A	107.3[g]	24.6	100.9	8.7			
	1996	14A	92.6	18.8	46.0	6.6			
$\bar{x}$			114.7	18.4	74.9	11.7	4.71	2	0.0129
$\bar{x}$ of $\bar{x}$			369.3	55.6	205.9	26.4			

[a] Annual = 1 Jan-31 Dec.
[b] n = number of telemetry locations
[c] = adaptive kernal
[d] = minimum convex polygon
[e] Years with different letters had different median locations ($P \leq 0.05$).
[f] 99% contour used
[g] 90% contour used

Table 7. Annual[a] ranges (km^2) for adult male (M) mountain lions on Big Bend Ranch State Park, Texas, 1993-1997.

Animal			ADK[c]		MCP[d]		Median shift		
	Year	n[b]	100%	50%	100%	50%	F	df	P
M1									
	1993	36A[e]	532.3	62.6	223.5	44.9			
	1994	37B	559.1[f]	112.2	466.1	63.9			
	1995	13B	41.7	4.4	26.7	2.7			
$\bar{x}$			377.7	59.7	238.8	37.2	7.66	2	0.0009
M2									
	1994	35A	501.5	71.6	315.4	43.5	-	0[g]	-
M4									
	1994	26A	510.1	91.1	347.9	54.1	-	0[g]	-
M5									
	1994	22A	1,406.0	115.6	593.4	127.6			
	1995	18A	1,368.0	183.6	656.9	57.1			
$\bar{x}$			1,387.0	149.6	625.2	92.4	1.10	1	0.3012
M6									
	1995	10A	379.7[h]	84.8	380.3	30.4			
	1996	14A	187.0	35.8	90.4	17.7			
	1997	8A	66.2[i]	14.1	52.0	1.3			
$\bar{x}$			210.9	44.9	174.2	16.5	2.12	2	0.1381
M8									
	1995	15A	534.6[j]	49.6	390.2	36.4	-	0[g]	-
	$\bar{x}$ of $\bar{x}$		586.9	77.8	348.6	46.7			

[a] Annual = 1 Jan-31 Dec.

[b] n = number of telemetry locations
[c] = adaptive kernal
[d] = minimum convex polygon
[e] Years with different letters had different median locations ($P < 0.05$).
[f] 95% contour used
[g] = insufficient sample size
[h] 79% contour used
[i] 68% contour used
[j] 95% contour used

Table 8. Area and percent overlap of annual ranges (minimum convex polygon) for adult female (F-F) mountain lions on Big Bend Ranch State Park, Texas, 1993-1997.

	1993				1994				1995				1996				1997			
	100%		50%		100%		50%		100%		50%		100%		50%		100%		50%	
F - F	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
1-3	57.3	29.5	3.9	10.2	72.7	29.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	-	-	-	-	45.4	17.5	-	-	-	-	-	-	91.9	42.3	-	-	-	-	-	-
1-5	-	-	-	-	112.1	43.3	-	-	2.7	2.4	-	-	20.3	8.7	-	-	-	-	-	-
1-6	-	-	-	-	14.9	11.0	-	-	12.6	15.7	-	-	-	-	-	-	-	-	-	-
3-4	-	-	-	-	25.9	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-5	-	-	-	-	158.3	51.1	2.8	11.8	-	-	-	-	-	-	-	-	-	-	-	-
3-6	-	-	-	-	57.0	30.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-5	-	-	-	-	109.1	33.5	-	-	-	-	-	-	40.6	15.6	-	-	-	-	-	-
5-6	-	-	-	-	77.6	38.5	5.1	20.5	64.0	48.4	-	-	42.9	26.6	-	-	-	-	-	-
$\bar{x}$	57.3	29.5	3.9	10.2	74.8	29.3	4.0	16.2	26.4	22.2	-	-	48.9	23.3	-	-	-	-	-	-

[a] 1 Jan-31 Dec

Table 9. Area and percent overlap of annual ranges (minimum convex polygon) for adult male (M-M) mountain lions on Big Bend Ranch State Park, Texas, 1993-1997.

	1993				1994				1995				1996				1997			
	100%		50%		100%		50%		100%		50%		100%		50%		100%		50%	
M-M	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
1-2	-	-	-	-	32.2	8.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-5	-	-	-	-	9.1	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	-	-	-	-	61.4	18.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	-	-	-	-	-	-	-	-	220.6	60.1	-	-	-	-	-	-	-	-	-	-
5-8	-	-	-	-	-	-	-	-	19.5	3.7	-	-	-	-	-	-	-	-	-	-
6-8	-	-	-	-	-	-	-	-	105.8	45.2	1.0	3.6	-	-	-	-	-	-	-	-
$\bar{x}$	-	-	-	-	34.2	9.5	-	-	115.3	36.3	1.0	3.6	-	-	-	-	-	-	-	-

[a] 1 Jan-31 Dec

Table 10. Area and percent overlap of annual ranges (minimum convex polygon) for adult female and male (F-M) mountain lions on Big Bend Ranch State Park, Texas, 1993-1997.

	1993				1994				1995				1996				1997			
	100%		50%		100%		50%		100%		50%		100%		50%		100%		50%	
F - M	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
1-1	62 1	32.7	4.4	11.6	127.5	38.7	1.8	3.9	-	-	-	-	-	-	-	-	-	-	-	-
3-1	113.8	49.9	15.5	34.4	289.9	76.2	12.1	29.7	-	-	-	-	-	-	-	-	-	-	-	-
4-1	-	-	-	-	98.3	24.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-1	-	-	-	-	243.9	61.7	4.7	10.0	0.4	0.4	-	-	-	-	-	-	-	-	-	-
6-**1**	-	-	-	-	68.5	25.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-2	-	-	-	-	13.9	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-2	-	-	-	-	0.1	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-2	-	-	-	-	230.7	71.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-2	-	-	-	-	73.0	22.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-4	-	-	-	-	18.7	5.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-5	-	-	-	-	3.0	0.7	-	-	90.5	22.1	-	-	-	-	-	-	-	-	-	-
6-5	-	-	-	-	-	-	-	-	51.1	13.5	-	-	-	-	-	-	-	-	-	-
1-6	-	-	-	-	-	-	-	-	20.2	29.3	2.0	13.4	79.5	54.5	7.4	40.8	0.6	0.4	-	-
4-6	-	-	-	-	-	-	-	-	-	-	-	-	45.6	26.5	0.4	1.4	-	-	-	-
5-6	-	-	-	-	-	-	-	-	84.2	54.9	-	-	-	-	-	-	-	-	-	-
6-6	-	-	-	-	-	-	-	-	99.8	82.7	3.2	22.4	-	-	-	-	-	-	-	-
1-8	-	-	-	-	-	-	-	-	60.0	26.7	-	-	-	-	-	-	-	-	-	-
4-8	-	-	-	-	-	-	-	-	134.6	43.5	-	-	-	-	-	-	-	-	-	-
5-8	-	-	-	-	-	-	-	-	54.0	19.5	-	-	-	-	-	-	-	-	-	-
6-8	-	-	-	-	-	-	-	-	68.1	27.7	-	-	-	-	-	-	-	-	-	-
$\bar{x}$	88 0	41.3	10.0	23.0	106.1	30.3	6.2	14.5	66.3	32.0	2.6	17.9	62.6	40.5	3.9	21.1	0.6	0.4	-	-

[a] 1 Jan-31 Dec

Table 11. Estimated density (No./100 km^2) of radio-collared and non-radio-collared mountain lions on Big Bend Ranch State Park and adjacent areas (2,720 km^2), Texas, January 1993 - August 1997.

	Adult					Juvenile					Mountain lion	
	Radio		Nonradio			Radio		Nonradio				
Year	F	M	F	M	U[a]	F	M	F	M	U[a]	n[b]	Density
1993	2	2	1	0	-	0	2	1	2	-	10	0.37
1994	5	4	-	1	-	0	2	-	-	-	12	0.44
1995	3	7	1	-	2	1	1	-	-	1	16	0.59
1996	4	2	2	2	-	0	0	1	2	1	14	0.51
1997	2	1	1	1	1	0	0	-	-	1	7	0.26

[a] U = unknown sex
[b] n = total number of mountain lions/year.

Table 12. Mule deer, furbearer, hare, and rabbit census data determined from spotlight surveys on Big Bend Ranch State Park, Texas, November 1992 - September 1996.

Year	Animals/400 ha (1,000 acres)								Animals/1.6 km (mile)	
	Mule Deer	Ringtail	Skunk	Kit Fox	Gray Fox	Coyote	Bobcat	Unknown Furbearer	Hare	Rabbit
1992	5.74	0.00	0.00	0.40	0.29	0.42	0.00	0.43	0.20	0.00
1993	5.04	0.14	0.22	0.00	0.23	0.14	0.14	0.00	0.31	0.10
1994	3.30	0.13	0.00	0.00	0.00	0.00	0.13	0.00	0.11	0.10
1995	2.86	0.13	0.00	0.00	0.13	0.00	0.00	0.42	0.17	0.00
1996	3.96	0.14	0.00	0.00	0.13	0.00	0.14	0.40	0.00	0.00
Mean	4.18	0.11	0.04	0.08	0.16	0.11	0.08	0.25	0.16	0.04

Table 13. Mountain lion reproductive characteristics on Big Bend Ranch State Park, Texas, between January 1993 and August 1997, determined from radio telemetry, visual sightings, and harvest data collected on adjacent private property.

Litter Reference No.	Known Litters	Sex[a]	Year	Method	Maternal ID No.
1	1	M	1993	capture	F3
2	1	M10	1993	capture	F3
3	2	F, M	1993	capture	U[b]
4	1	M3	1993	capture	U[b]
5	2	F, F	1994	harvest	F3
6	1	U	1995	visual	U[b]
7	2	U, U	1995	visual	F1
8	2	F7, M9	1995	capture	F4
9	1	U	1996	tracks	U[b]
10	2	M, U	1996	capture	F4
11	2	M, M	1996	harvest	F6
12	2	F, F	1997	harvest	F4
13	1	F	1997	harvest	F1
Mean	1.54				

[a] Sexes are female (F), male (M), and unknown (U)
Mountain lion ID numbers are listed when possible.

[b] Unknown

Table 14. Life span for collared mountain lions captured on the Big Bend Ranch State Park, Texas, January 1993 - November 1997.

Lion ID	Capture date	Mortality date	Cause of mortality	No. of months with live signal
F1	22 Jan 93	15 Nov 97	Predator control	58
F3	25 Mar 93	16 Nov 94	Predator control	20
F4	14 Jan 94	08 Jan 97	Predator control	36
F5	03 Feb 94	15 Mar 97	Predator control	37
F6	03 Mar 94	08 Oct 96	Predator control	31
F7	21 Apr 95	24 Oct 95	Predator control	6
M1	25 Feb 93	24 Oct 95	Predator control	32
M2	28 Dec 93	19 Feb 95	Predator control	14
M3	24 Feb 93	27 Jan 94	Gun Shot	11[a]
M4	27 Jan 94	25 Feb 95	Predator control	13
M5	06 Apr 94	17 Apr 96	Predator control	24
M6	07 Feb 95	15 Nov 97	Predator control	33
M7	11 Feb 95	04 Jun 95	Predator control	4
M8	09 Mar 95	20 Dec 95	Predator control	9
M9	23 Feb 95	21 May 95	Predator control	3
M10	16 Feb 93	09 Aug 94	Predator control	18

[a] M3 spent 10 months in Central Texas Wildlife Institute, Inc., Hamilton, Texas; was released on BBRSP; and was shot when it approached two people at a boat ramp.

Table 15. Summary of female and male mountain lion mean home ranges (100% minimum convex polygon) from studies in the United States.

	Female		Male		
Area	km^2	n	km^2	n	Reference
Central Idaho	106.6	9	125.5	4	Seidensticker et al. 1973
CCNP[a], GMNP[b]	59.0	4	207.0	4	Smith et al. 1986
BBNP[c]	143.0	5	629.0	1	Pence et al. 1986
South Cal.	84.0	4	179.0	4	Hopkins et al. 1986
South Fla.	191.0	10	558.0	5	Maehr et al. 1991
Cent. Colo.	136.0	7	279.0	3	Anderson et al. 1992
South Ariz.	108.6	2	196.4	5	Cunningham et al. 1995
South N.M.	73.5	29	187.1	23	Logan et al. 1996
South Texas	131.8	4	503.5	6	Harveson 1997
BBRSP[d]	205.9	5	348.6	6	This study

[a] Carlsbad Cavern National Park, New Mexico
[b] Guadalupe Mountains National Park, Texas
[c] Big Bend National Park, Texas
[d] Big Bend Ranch State Park, Texas

Figure 2. Adult male (M) and female (F) mountain lion home ranges (100% minimum convex polygon) on Big Bend Ranch State Park, 1993.

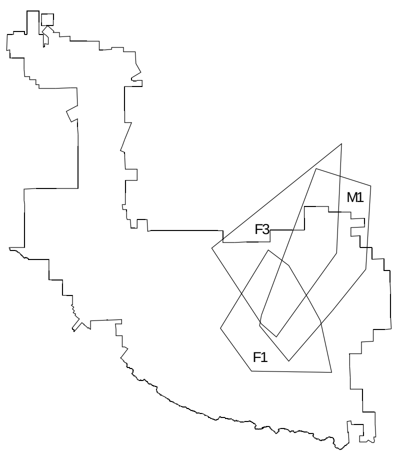


Figure 3. Adult male (M) and female (F) mountain lion home ranges (100% minimum convex polygon) on Big Bend Ranch State Park, 1994.

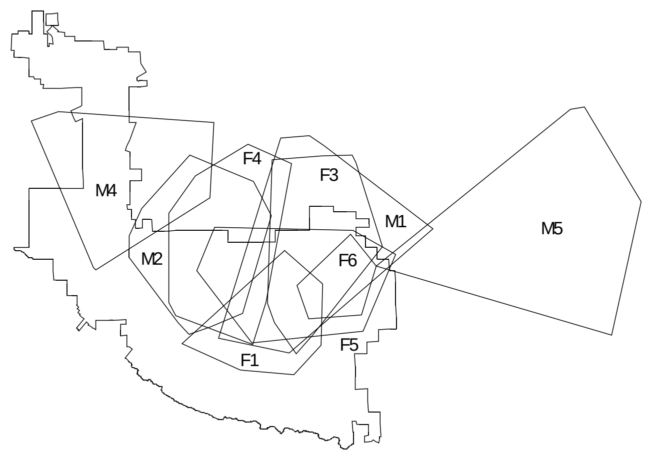


Figure 4. Adult male (M) and female (F) mountain lion home ranges (100% minimum convex polygon) on Big Bend Ranch State Park, 1995.

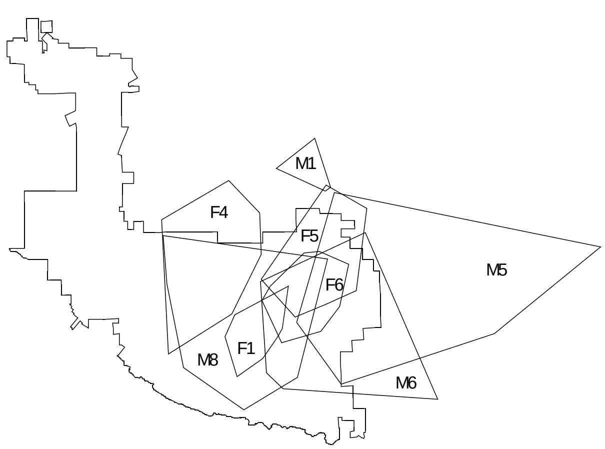


Figure 5. Adult male (M) and female (F) mountain lion home ranges (100% minimum convex polygon) on Big Bend Ranch State Park, 1996.

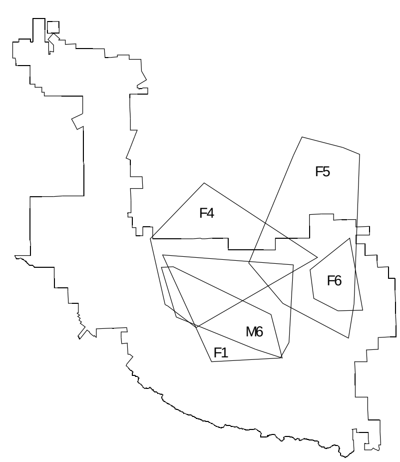


Figure 6. Adult male (M) and female (F) mountain lion home ranges (100% minimum convex polygon) on Big Bend Ranch State Park, 1997.

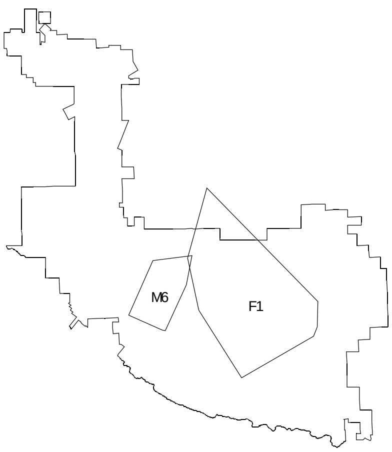


Figure 7. Annual home ranges (100% minimum convex polygon) for Male 1 (M1) on Big Bend Ranch State Park, 1993-1995.

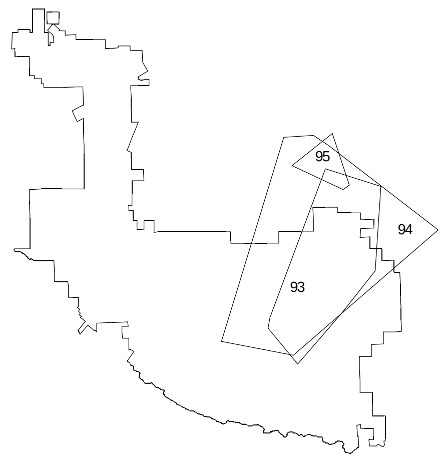


Figure 8. Annual home ranges (100% minimum convex polygon) for Male 5 (M5) on Big Bend Ranch State Park, 1994-1995.

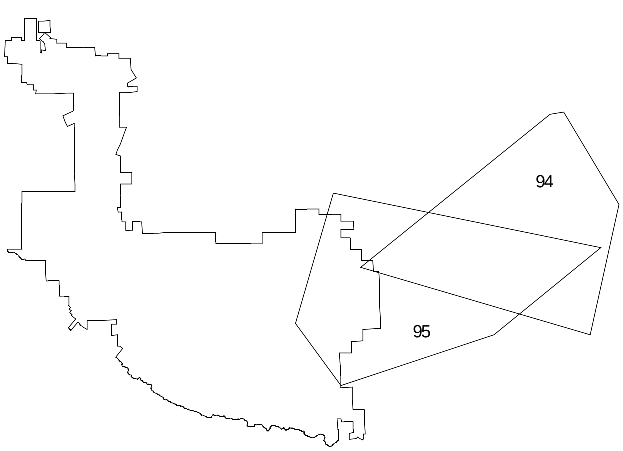


Figure 9. Annual home ranges (100% minimum convex polygon) for Male 6 (M6) on Big Bend Ranch State Park, 1995-1997.

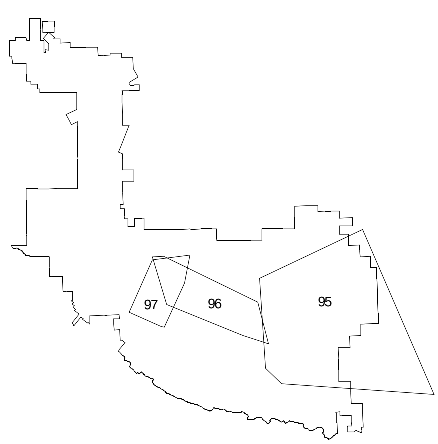


Figure 10. Annual home ranges (100% minimum convex polygon) for Female 1 (F1) on Big Bend Ranch State Park, 1993-1997.

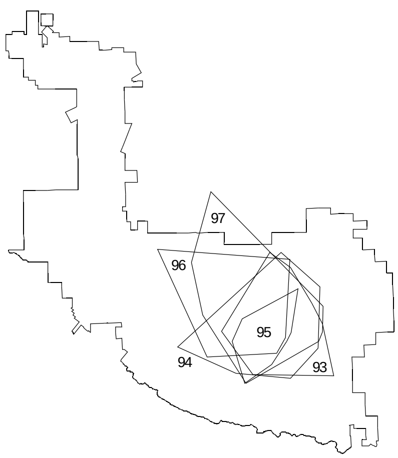


Figure 11. Annual home ranges (100% minimum convex polygon) for Female 3 (F3) on Big Bend Ranch State Park, 1993-1994.

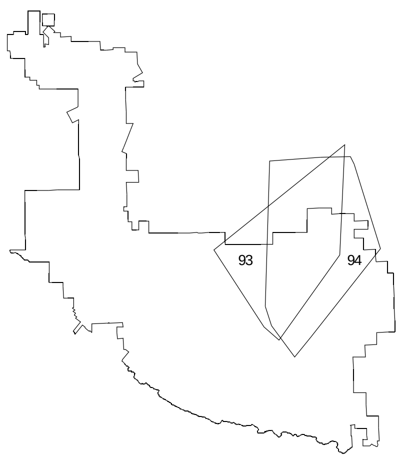


Figure 12. Annual home ranges (100% minimum convex polygon) for Female 4 (F4) on Big Bend Ranch State Park, 1994-1996.

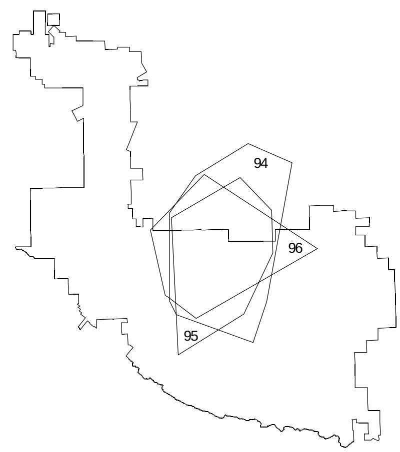


Figure 13. Annual home ranges (100% minimum convex polygon) for Female 5 (F5) on Big Bend Ranch State Park, 1994-1996.

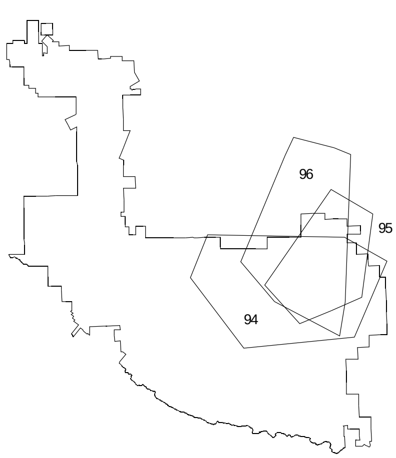


Figure 14. Annual home ranges (100% minimum convex polygon) for Female 6 (F6) on Big Bend Ranch State Park, 1994-1996.

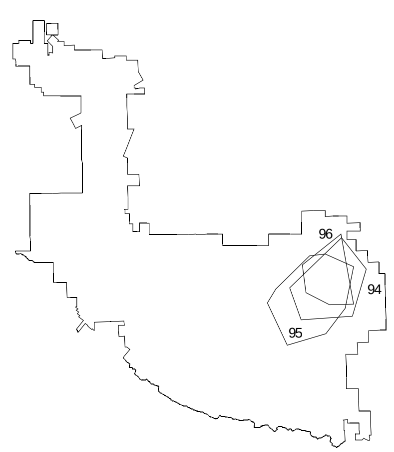


Figure 15. Relative frequency percentage (rfp) of food items determined from mountain lion fecal samples (n=135) collected on Big Bend Ranch State Park (BBRSP), Texas, between 1993 and 1997.

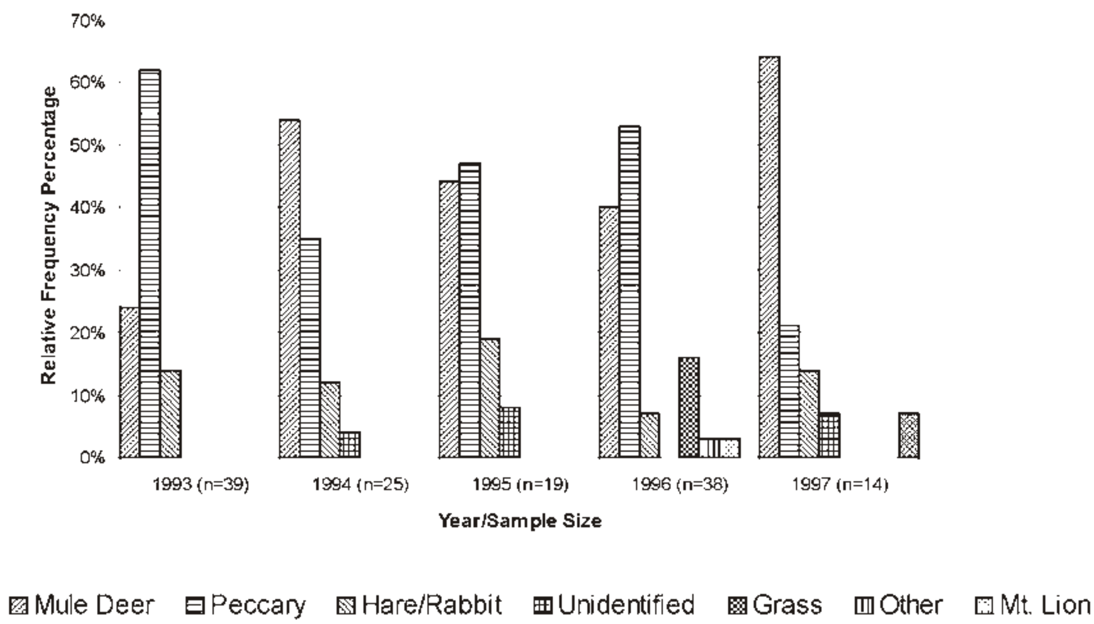


Figure 16. Life span for collared mountain lions captured on the Big Bend Ranch State Park (BBRSP), Texas, between January 1993 and August 1997.

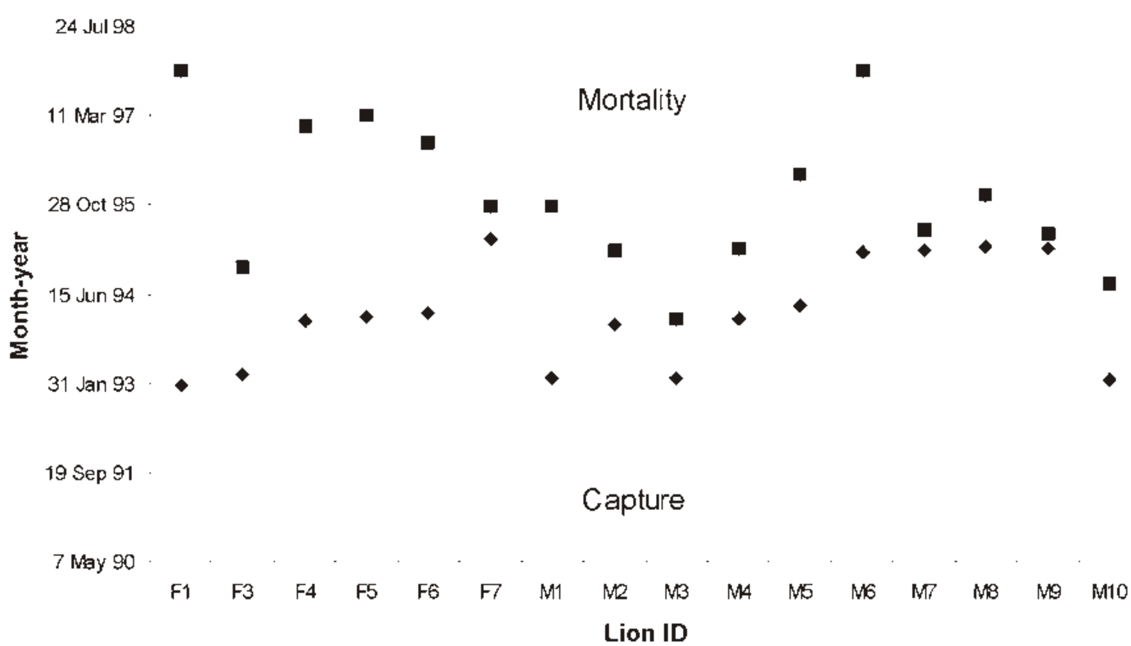
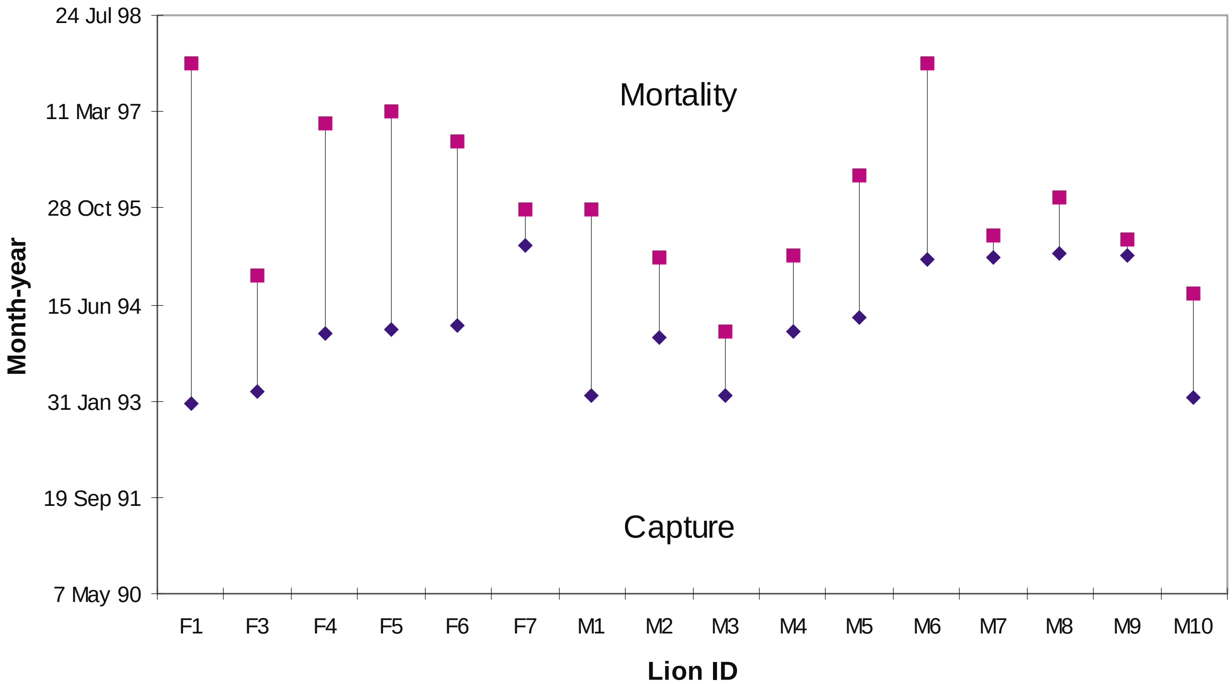


Figure 16. Life span for collared mountain lions captured on the Big Bend Ranch State Park (BBRSP), Texas, between January 1993 and August 1997.



VI. DISCUSSION

Mean range for adult male mountain lions was greater than for adult females in most of the annual comparisons. This is consistent with Seton (1909) who stated that the size of a home range is related to the size of the animal. Since males are 1.5-2x larger than females, they exhibit larger home ranges (Harestad and Bunnell 1979). Average adult male ranges ranked within the span of ranges delineated for previous studies conducted within the Chihuahuan Desert (Pence et al. 1986, Smith et al. 1986, Logan et al. 1996).

The average adult female range reported in this study was one of the largest recorded to date south of the 42° latitude (Sweanor 1990, Cunningham et al. 1995, Logan et al. 1996, Harveson 1997). This phenomenon may be related to the following; the reproductive status of a female mountain lion, a low density of prey, or the reshuffling of ranges. Annual female ranges at BBRSP varied greatly (46.0 - 325.9 km^2). Female home range size generally increased as kittens grew older, solitary females exhibited the largest ranges (Sweanor 1990). Average female and male mountain lion home ranges (minimum convex polygon), as determined by previous researchers, are presented in Table 15.

A low density of prey may contribute to an increase in home range size. Mule deer spotlight surveys conducted on the study site indicated a low deer population during the period (1992-96) (Table 12). Logan et al. (1996) determined that larger ranges are needed to provide adequate food, and home range size tends to increase with fragmented habitats essential to a mountain lion's prey base.

More importantly, the removal of mountain lions (male and female) left voids available for home range shifts to occur within BBRSP. This is consistent with other mountain lion studies where home range size varied by sex and age of the lion, season of the year, spatial pattern and prey density (Seidensticker et al. 1973).

Male home ranges may have been biased because the irregular topography hindered the locating of male mountain lions in relation to predictable locations of females on BBRSP. Some mountain lions were not located regularly because of the topography of their habitat (McBride 1976). It was determined (Sweanor 1990) that home range sizes of most male and female mountain lions with established home ranges would level off at 35 telemetry locations collected over a 10 month period. All of the adult females (n=6) met this criteria, but 3 of the 6 adult males (M4, M6, and M8) did not.

The home range estimator used when comparing the minimum convex polygon to the adaptive kernel method influenced mountain lion home range size. All home range estimators have limitations, but the oldest and most common method used is the minimum area polygon, which connects the outer locations to form a convex polygon (Mohr 1947 and White and Garrett 1990). The 100% minimum convex polygon was used to analyze radio-telemetry data from 10 of 18 mountain lion studies conducted since 1973 (Anderson et al. 1992).

A home range is the numerical estimate of tracking data over a period of time for an area used by an animal and is calculated by estimating the area within the polygon (White and Garrett 1990). In this study, mountain lion home ranges estimated by the adaptive kernel and the minimum convex polygon methods were both affected by the number of telemetry locations or sample size. The adaptive kernel method overestimated home range areas because disjoint grid cells, used to determine a polygon, tend to be added together to form the home range estimate (Worton 1989). After deleting outliers, the minimum convex polygon method produced a more conservative estimate of the actual range size and shape when compared to the home range area produced by the adaptive kernel method.

The Wilcoxon-Mann-Whitney rank sum test was used to test for significant differences between adult male and female annual home range sizes. A non-normal distribution occurred in the home ranges of our radio-collared mountain lion population because the annual ranges of the adult male mountain lion (26.7-656.9 km^2) encompassed the ranges of the adult female mountain lions (46.0-325.9 km^2).

Intrasexual overlap of female mountain lions occurred between 1993-96. This is consistent with previous studies (Smith et al. 1986, Sweanor 1990, and Logan 1996). Female mountain lions commonly overlapped in the study conducted by Cunningham et al., (1995), and home ranges of resident females overlapped, sometimes completely (Seidensticker et al. 1973).

After the first year of the study, F1 and F3 overlapped or shared home ranges by approximately 30% (Fig. 2). In 1994 considerable overlap occurred between females, especially between F3 and F5 which exhibited an overlap > 50% (Fig. 3). During 1994, F1 and F3 overlapped all other female mountain lion ranges, including each other. In 1995 overlap between females had been reduced by 2/3 the overlap of the previous year as a result of the removal of F3 from the population (Fig. 4). In 1996, female mountain lions shifted their ranges to fill the abandoned home range left by F3 and reshuffled their home areas (Seidensticker et al. 1973). In fact, F1 moved to the north and F4 moved to the east and increased their overlap from 17.5%-42.3% (Fig. 5). F1 and F5, F4 and F5, and F5 and F6 experienced decreases in home range overlap because F5 moved north and F6 moved to the east in 1996 (Fig. 5). By the end of the first quarter in 1997, only mountain lion F1 remained on BBRSP to represent the female segment of the radio-collared mountain lions on BBRSP (Fig. 6).

Intrasexual overlap of male mountain lion ranges was highest in 1995, with M5 and M6 overlapping by 60% (Fig. 8, 9). During this same period, M6 also overlapped M8 to the south and west by 42% (Fig. 4). The extent of overlap may have been tolerated because males were trying to breed with the remaining females (F1, F4, F5, F6; Fig. 4). After the death of M8 and M5 in 1995, M6 remained to represent the male segment of the radio-collared mountain lions on BBRSP (Fig. 6).

Intersexual overlap of ranges of female and male mountain lions were exhibited in 1994-95 and are consistent with other studies (Smith et al. 1986, Sweanor 1990, Harveson 1997). Resident female mountain lion F4 overlapped with as many as 5 male mountain lions over a three-year period (Fig. 12). In 1995 breeding males had been reduced to M5, M6, and M8 (Fig. 4). This may have contributed to the high degree of overlap between males M5, M6, and M8 trying to mate with available females (F1, F4, F5, and F6). Males had to cover large areas and cross the borders of other male's home ranges to potentially breed with more than 1 female (Sweanor 1990).

The adult male segment of the mountain lion population on BBRSP exhibited the most dramatic shifts that occurred throughout the study period. Mountain lion home ranges were stable until F3 was removed from the population in 1994. Also in 1994, M2 and M4 were the first 2 males to be trapped and removed from BBRSP.

In 1995, M6 was radio-collared within M1's home range and displaced M1 to the north off the BBRSP. The approximate age of M1 in 1995 was 8 years old, and his home range had been reduced to 26.7 km^2 shortly before his death (Fig. 4). Telemetry data indicates that M6 now occupied M1's lower home range and took up residence (Fig. 4). Home range shifts of this type are common within mountain lion populations. Sweanor (1990), also documented range shifts attributed to the arrival of new males and the pressure exerted by younger more aggressive males.

Telemetry locations recorded off the study site for M2 and M4 were 45.7 and 58.8%, respectively. Within the same period 1994-95, 92.7% of the telemetry locations recorded for M5 were off the study site to the east of BBRSP (Fig 8). Shortly after the removal of M1 in 1995, M5 shifted into the upper half of M1's home range. This is evident because of the mortality location of M5 was in the general area of M1's mortality.

In 1995, M8 was radio-collared approximately 3.2 km from the Rio Grande and expanded his range to the north and west. Radio-collared mountain lion, M8 continued to travel northward into the home ranges previously held by M2 and M4 (Fig. 4). He continued to travel north off the study site and sustained trap wounds, which attributed to his death. Telemetry locations indicated M8 was returning south to his initial home range when a mortality signal was received. Despite the limited amount of telemetry data collected for M8, (9 months) he still exhibited a home range shift and demonstrated the land tenure system proposed by Seidensticker et al. (1973), which may have caused him to move further north than he had ever been before the removal of M2 and M4.

Home range shifts were documented for adult female mountain lions (F1, F4, F5, F6) during 1996 (Fig. 10, 12-14). Radio-collared mountain lion F4 shifted to the east while F5 shifted to the north to encompass the home range previously held by F3. F6, M5, and M6 did not exhibit consecutive annual shifts. Although, the cumulative home range sizes were calculated for the radio-collared mountain lions (5 F, 3M) monitored for > 12 months were larger than the mean annual home range sizes for the same lions which suggests that home range shifts may occur over longer periods of time (Sweanor 1990).

The only 2 radio-collared mountain lions being monitored were F1 and M6 during the latter part of the study in 1997 (Fig 6). The last telemetry flight recorded their locations to be on BBRSP. The percent locations on the BBRSP for F1 and M6 were 99.2 and 93.9, respectively. Apparently F1 and M6 continued to shift to the north off the study site because they too were reported as mortalities in November 1997 after the completion of the study.

The degree of mountain lion home range overlap and ultimately the density of a breeding population are affected by the diversity of the habitat (Seidensticker et al. 1973). Wildlife diversity begins with habitat diversity that promotes an increase in carrying capacity available to mountain lion prey species. An increase in mountain lion density can be attributed to an increase in prey species.

Mountain lion population density was difficult to estimate (McBride 1976, Pence et al. 1986, Smith et al. 1986) in previous studies conducted in Texas. Several census techniques have been employed to estimate mountain lion density. Currier et al. (1977), and Shaw (1977) used the capture-mark-recapture method. Van Dyke et al. (1986) used track characteristics and counts to estimate mountain lion numbers. Tracks provide more information about the size, age, and individual identity of mountain lions than do scrapes (Cunningham et al. 1995).

Mountain lion density on BBRSP and surrounding areas for the 5-year study was determined to be $\underline{x}$=0.43 mountain lions/100 km^2. Our mountain lion density compares to densities computed for previous studies (Shaw 1977) and 3 out of the 5 years fall within the range of densities estimated in South-central Utah (Hemker et al. 1984). Densities on BBRSP are also consistent with density figures computed for South Texas with a 3-year average of 0.56 lions/100 km^2 (Harveson 1997).

Several methods have been used in determining mountain lion food habitats including fecal analysis, stomach contents, and kills identified in the field. Fecal analysis of mountain lion scats on BBRSP indicated mule deer and collared peccary were the most important prey species and were consumed almost equally. It is well documented that mountain lions supplement their diet with a variety of small animals, but fecal analysis from BBRSP scats indicated only two small prey species, hare and badger. Researchers from previous Texas mountain lion studies reported deer species occurrence in diets ranged from 43-70%, peccary from 0-31%, livestock from 0-14%, porcupine (Erethizon epixanthum) from 2-16%, and other small species form 1-24% (McBride 1976, Leopold and Krausman 1986, Smith et al. 1986). Harveson (1997) was hindered by the subtropical climate and the presence of dung beetles (Scarabidae spp.) from collecting a substantial number of scats (n=25) in the South Texas study. Harveson (1997) did report a percent frequency of 28, 12, 28, 20, and 12 for deer, peccary, feral hog (Sus scrofa), mountain lion, and rodents, respectively. The frequency of deer in scats analyzed from BBRSP is within the range reported by other researchers, but frequency percentage of peccary (46) is the highest reported for all mountain lion studies reviewed. Leopold and Krausman (1986) and Waid (1990) had a combined total of 979 scats with a percent frequency of 31 for peccary in Big Bend National Park, Texas.

The number of mountain lion kills (n=19) recorded throughout the study was low. The rough topography and dense shrubby vegetation of the study area hindered the ability of personnel in locating lion kills. The absence of vultures (Catharidae spp.) during capture periods, December through April of each year, also hindered personnel efforts in locating lion kills.

VII. CONCLUSIONS AND MANAGEMENT

Data collected during this study indicated the mountain lion population on BBRSP was limited by high mortality rates of males, females, and kittens, all attributed to predator control activities outside the study site. The Texas Parks and Wildlife Department collects sighting and mortality reports but a sex ratio of a living population cannot be inferred from these data. In this study, it was notable that male mountain lions travel along dry canyon bottoms and female mountain lions with kittens traversed creek bottoms. A certain amount of bias involved in the methods of capture (trapping) interacting with possible differences in vulnerability among sex and age classes of mountain lions (Logan et al. 1996).

Maintaining stability within the male component of a mountain lion population may enhance kitten survival. Increase in kitten mortality may be related to the removal of a large portion of the male component (Ross and Jalkotzy 1992). An immigrating male mountain lion may kill females or kittens within the home range he is trying to occupy. Loss of adult resident females would most likely have the greatest impact on the population because not only will they need to be replaced, but their removal will reduce the number of female kittens available to replace the lost residents (Lindzey et al. 1992).

Predator control, and intensive predator control in particular, is practiced by a small number of landowners in West Texas. Generally, landowners conduct predator control activities to minimize losses to other wildlife, primarily mule deer, and occasionally for livestock. Mountain lion populations are quite resilient if given the opportunity to be excluded from harvest (Lindzey et al. 1992, Ross and Jalkotzy 1992). The rate of a population increase will depend on the rate of immigration (Lindzey et al. 1992).

A follow up survey was conducted on BBRSP during February 1999, to determine the status of the mountain lion population since the completion of the study. The survey indicated 8 mountain lions including 4M, 3F, and 1U were present on BBRSP or adjacent property during this period indicating there has been some replacement of lions lost to predator control.

Since the number of mountain lion predator control programs has declined and the topography of the Trans-Pecos contains large tracts of rugged habitat, future mountain lion populations should remain stable. In addition to the large tracts of habitat necessary to maintain populations of mountain lions, corridors that connect these large tracts of land, e.g., Big Bend Ranch State Park and Big Bend National Park, are also required in order to promote mountain lion populations by dispersal of subadult mountain lions.

Mountain lion issues should continue to be addressed by TPWD. A mountain lion round table discussion was held in Del Rio, Texas in April 1992 to address such issues. The outcome of that meeting was that additional information on mountain lion ecology was needed to effectively manage this species. As a result of that meeting, two mountain research studies were initiated and completed. The information from this study as well as other Texas mountain lion studies, have provided TPWD with important information concerning Texas mountain lions.

The study on BBRSP yielded important information regarding mountain lion ranges, food habits, genetics, reproduction, and densities in a mid-elevational desert scrub/grassland. Resource and recreation managers should consider the information from this study when: (1) estimating mountain lion populations in West Texas, (2) evaluating the effects of park visitors and high-intensity recreational development on mountain lion populations on public lands in West Texas and (3) considering the effects of predator control on mountain lion populations in West Texas.

The intensive predator control program on private lands adjacent to BBRSP, along with the large home range areas exhibited by the radio-collared mountain lions, severely impacted the mountain lion population on BBRSP. Intense predator control programs do occur in the Trans-Pecos Region, but they are uncommon. At the present time, we believe the mountain lion population in the Trans-Pecos Region, as a whole, is stable and not in danger of depletion. Therefore, we do not recommend a change in the current status of the mountain lion, which is classified as a non-game animal with no closed season and no bag limit.

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Due to their cryptic coloration and secretive nature, mountain lions are seldom seen in the wild even where they are relatively abundant. Photo by Gilbert Guzman.

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