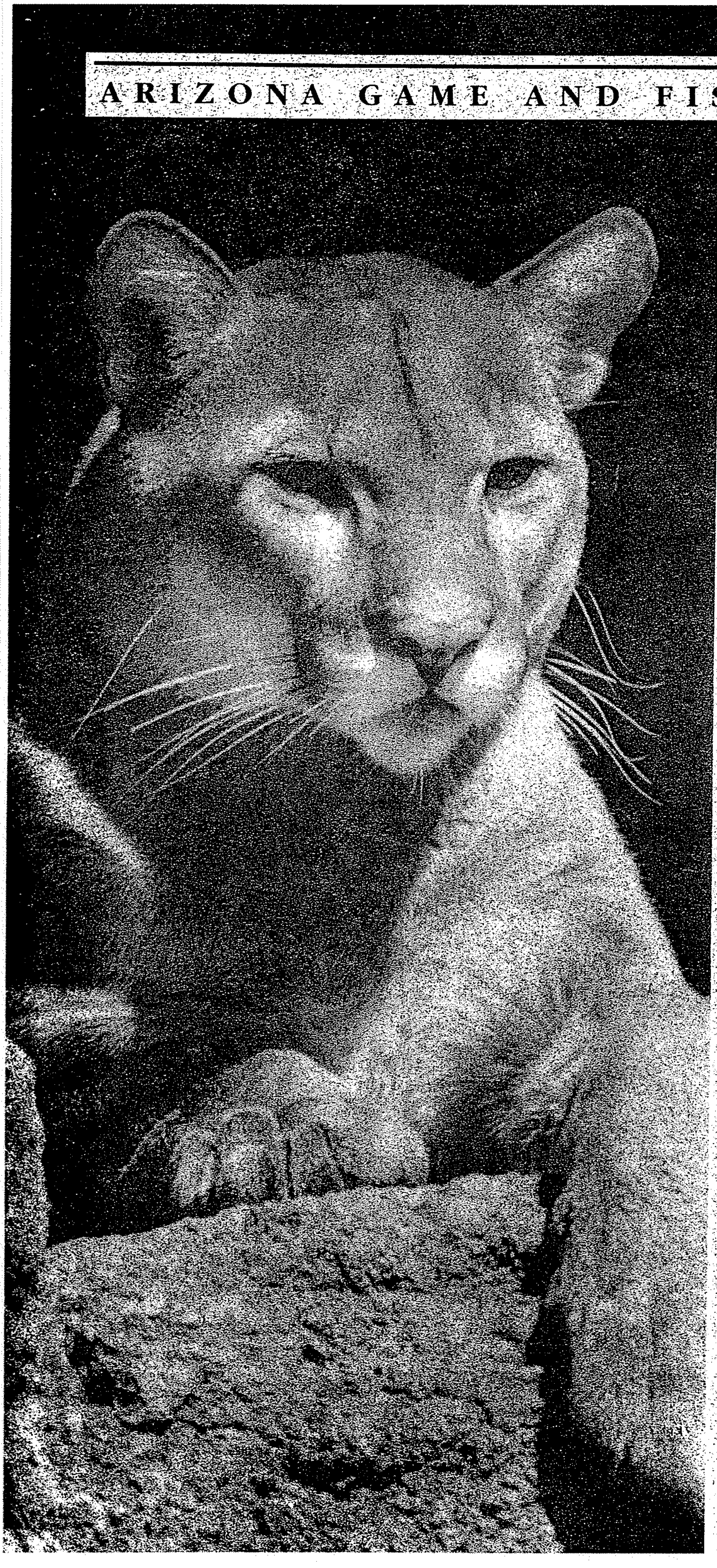
ARIZONA GAME AND FISH DEPARTMENT



RESEARCH BRANCH
TECHNICAL REPORT #17

EVALUATION OF THE INTERACTION BETWEEN MOUNTAIN LIONS AND CATTLE IN THE ARAVAIPA-KLONDYKE AREA OF SOUTHEAST ARIZONA

A Final Report

STANLEY C. CUNNINGHAM
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CARL GUSTAVSON
DENNIS D. HAYWOOD

November 1995

FEDERAL AID IN WILDLIFE RESTORATION PROJECT

Arizona Game and Fish Department Mission
To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

Arizona Game and Fish Department
Research Branch

Technical Report Number 17

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Suggested Citation:

Cunningham, S. C., L. A. Haynes, C. Gustavson, and D. D. Haywood. 1995. Evaluation of the interaction between mountain lions and cattle in the Aravaipa-Klondyke area of southeast Arizona. Ariz. Game and Fish Dep. Tech. Rep. 17, Phoenix. 64pp.

ISSN 1052-7621
ISBN 0-917563-23-9

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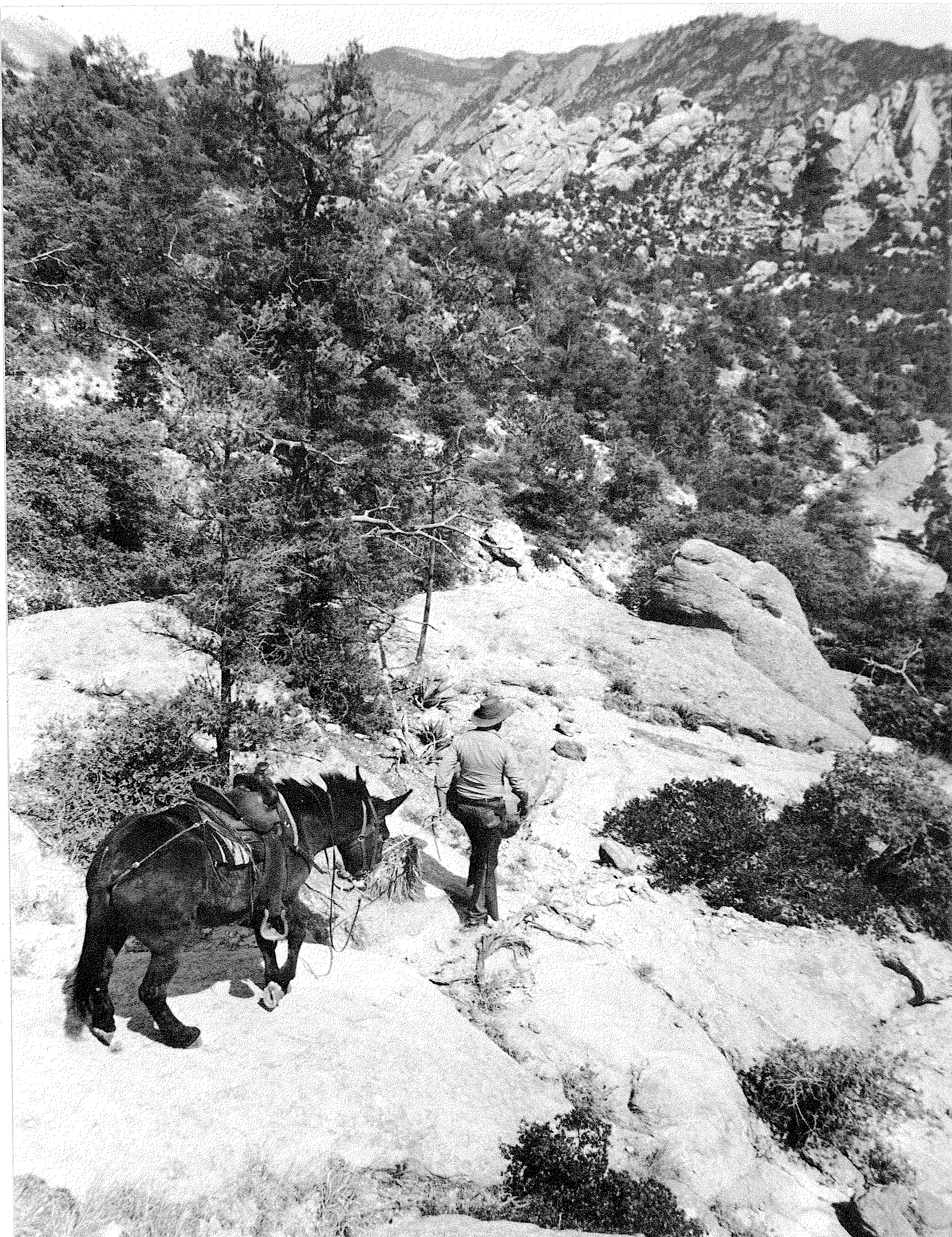
ACKNOWLEDGEMENTS

As with most research projects, this study could not have been completed without the help of many individuals. Al LeCount was the original Principal Investigator on the project. Al, Joe Yarchin, Dennis Haywood, and Cary Chevalier developed the original study plan. Kathy Sergent was a Wildlife Assistant I during the course of the study and collected, excuse my pun, the "lion's share" of the data. Joe Yarchin was another key assistant during the initial phase of the project, and ended up "running the project" temporarily after Al left the Research Branch. Joe's efforts were critical in developing the track survey and food habits protocols. Ron Thompson, Matt Peirce, and Tom Waddell all provided critical field assistance at the beginning of the project. They and John Phelps also provided advice and counsel numerous times during the project. Summer interns Eric Bates, Mellisa Gilbert, and, in particular, Jimmy Simmons (a 2-year man) helped collect valuable information. Larry Hendrix was the contract lion hunter during the project, and his excellent dogs, knowledgeable comments, and critiques helped improve the study quality. Ron Thompson, Matt Peirce, Bill Carrel, Richard Ockenfels, Vanessa Dickinson, Sue Trachy, Brian Wakeling, Richard Brown, John Phelps, Ray Schweinsburg, Jim Heffelfinger, Jim Wegge, Larry Hendrix, Craig Heath, and Tim Rogers all helped gather data on track surveys. Bill Carrel helped with aerial radio telemetry. Scott Woods and Jenny Wennerlund digitized much of the GIS database, and conducted the GIS analysis. Richard Ockenfels and Steve Rosenstock provided statistical counsel and suggestions. Jim deVos, Ray Schweinsburg, Steve Rosenstock, Brian Wakeling, Harley Shaw, Ken Logan, Linda Sweanor, Fred Lindzey, and Paul Beier all reviewed drafts of this manuscript and its contents were improved because of their efforts. Dr. Joe Truett took the lead as key editor and his efforts were appreciated and resulted in a more timely report. The talent and efforts of Vicki Webb during typesetting and layout were greatly appreciated.

Logistical help in the form of a place to stay and congenial company was provided by Kenny Calloway and Gordon Whiting. Kenny also provided much-needed support in the form of horseshoeing, fixing electricity and water, and, most importantly, taking care of our animals when Aravaipa Creek flood conditions prevented us from getting to camp.

Finally, the senior author would like to take the liberty of thanking his wife, Lori, and daughter, Addie, for minimal complaining during his sometimes long absences, and most importantly, making "home" such a nice place to come back to.

This publication is a result of studies undertaken with financial support provided by the Federal Aid in Wildlife Restoration Act Project W-78-R of the Arizona Game and Fish Department. The Act is popularly known as the Pittman-Robertson Act after its Congressional sponsors. The Act provides for a manufacturers' tax on sporting arms, pistols, ammunition, and certain archery items. The collected tax monies are apportioned to the states on a formula basis by the U. S. Fish and Wildlife Service for the conservation and management of wild game birds and mammals. Thus, sport hunters, target shooters, and archers contribute to a program that benefits everyone.



Evaluation of the Interaction between Mountain Lions and Cattle in the Aravaipa-Klondyke Area of Southeast Arizona

Stanley C. Cunningham, Lisa A. Haynes, Carl Gustavson, and Dennis D. Haywood

Abstract: We investigated the ecology of mountain lions (*Felis concolor*) from February 1991 to September 1993 near Klondyke, Arizona, with respect to prey selection and the effects of predation on commercial cattle operations. We found that mountain lion track surveys have value for comparing mountain lion density among areas despite some inherent biases. Mountain lion track survey indices from our study area were higher than any recorded elsewhere in the state. During our study, mountain lions selected deer (*Odocoileus* spp.) less frequently than their availability would suggest, selected calves slightly more than their availability, and took javelina (*Tayassu tajacu*) as expected. We speculate that lions selected calves because they were more vulnerable to predation than deer. Radio-collared mountain lions in our study experienced the lowest overall annual survival rate (0.55) found in any lion study; depredation control was the leading cause of mortality. Male mountain lions were more likely to be killed in depredation cases than females. Mountain lion density and predation on calves remained high despite losses of substantial numbers of mountain lions to depredation control. The sex ratio within our study population was almost even; the age structure was similar to that reported in unexploited populations.

Key words: Age ratio, cattle, depredation control, diet, emigration, home range, immigration, mortality, mountain lion, sex ratio, southeastern Arizona, track survey

INTRODUCTION

The mountain lion or cougar ranges from Yukon Territory, Canada, to the southern tip of South America. Once found from coast to coast in North America, mountain lions occupy approximately 45% of their former range there. Except for a small (<50) population in Florida, they now occur mainly in western mountain ranges (Lindzey 1987).

In North America, efforts to eradicate mountain lions began with the arrival of European settlers and their livestock. Nearly all mountain lion populations east of the Mississippi River were extirpated by 1900 (Hanson 1992). Mountain lions persisted in the western states despite persecution.

Arizona's mountain lions have sustained large harvests throughout the 20th century. Between 1913 and 1947, 2,400 mountain lions, or about 70/year, were reported killed (Anderson 1983). Between 1947 and 1969, the Arizona state government offered a bounty on mountain lions and 5,400 ($\bar{x}$ = 245/yr) were taken (Phelps 1989). Legislative controls enacted in Arizona in 1970, including the classification of mountain lions as game animals, did not reduce the harvest appreciably; an average of about 240/year were killed in the following 2 decades (Phelps 1989).

The historical exploitation of mountain lions in the Aravaipa-Klondyke area paralleled that which occurred elsewhere. Between 1917 and 1937, the region's Cochise-Graham Cattlegrower's Association paid $25 to members for mountain lions killed on their ranges. State records show that bounties were paid on 184 mountain lions ($\bar{x}$ = 8.5/yr) killed in Graham County from 1949 to 1970. During this latter period, mountain lion hunting was a popular sport and some ranchers guided hunters, even advertising in sports magazines such as *Outdoor Life* and *Field and Stream* (Calder 1990). Some goat and cattle ranchers also used poisons (primarily strychnine) in fresh carcasses of livestock killed by predators to control mountain lions and other predators.

After the state bounty was rescinded in 1970, residents of Aravaipa Valley formed the Arizona Varmint Group and offered a $200 bounty for mountain lions. The bounty was reduced to $120 in 1977 and discontinued in 1985. According to members of the group, bounties were paid on 10 to 15 mountain lions/year.

A reported 115 mountain lions were killed in the Aravaipa-Klondyke area from 1988 to the end of 1993. Fifty-seven of these were killed in depredation control cases from late 1988 through 1990 and, following additional stockkiller legislation in 1990 (ARS-117-302), 26 were killed in depredation control cases from 1991 to 1993. Another 32 mountain lions were killed during this 1988-93 period ≤10 km of the Aravaipa-Klondyke area by sport hunters.

With the exception of Texas, other western states, like Arizona, have elevated the status of the mountain lion from pest to big game, and with this change has come the need to devise scientific management strategies. Early studies to this end in Idaho (Hornocker 1969, 1970; Seidensticker et al. 1973) were followed by studies in most other western states. The current body of technical literature on mountain lions includes transactions of 4 technical symposia on mountain lions and studies of mountain lion social behavior, habitat use, food habits, demographics, census techniques, morphology, taxonomy, and genetics. Comprehensive literature reviews were compiled by Dixon (1982), Anderson (1983), Currier (1983), and Lindzey (1987).

The most comprehensive mountain lion investigations in Arizona to date have focused on mountain lion-cattle-wildlife interactions in central Arizona (Shaw 1977, 1981), mountain lion-mule deer (*Odocoileus hemionus*) interactions on the Kaibab Plateau (Shaw 1980), and an analysis of factors affecting mountain lion density and depredation on cattle (Shaw et al. 1988). In addition to these studies, Cashman et al. (1992) described food habits of desert-dwelling mountain lions in southwestern Arizona, and Peirce and Cashman (1994) delineated inter-mountain movements and home range sizes of 3 radio-collared males in the same area.

Mountain lions have preyed on livestock since the first stock introductions from Europe (Barnes 1960), and livestock predation remains a major rationale for controlling mountain lions. Arizona reportedly has some of the highest mountain lion predation rates on cattle in the western United States (Christensen and Fischer 1976, Nowak 1976, Anderson 1983). The killing of mountain lions that have preyed on livestock (i.e., depredation control) remains a legal, though controversial, practice, accounting for a substantial portion of the human-caused mortalities in Arizona mountain lions.

In 1987, ranchers in the Aravaipa-Klondyke area reported an unusually high number of calves killed by mountain lions. As a result, the Klondyke-Bonita Cattle Grower's Association contracted with the Animal and Plant Health Inspection Service (APHIS), a branch of the U.S. Department of Agriculture, for help in controlling mountain lions. A control effort ensued, and 57 mountain lions were removed from an area of 1,000 km² in the first 3 years of effort. Reports in a Phoenix newspaper of the control operation (B. Burkhart: Rancher, U.S. hunters kill wildlife without rein by State. *Arizona Republic*, June 15, 1989) and in several national magazines and newspapers resulted in a strong negative reaction from the public.

Consequently, the Arizona Game and Fish Commission, at its June 1990 meeting, directed the Research Branch of the Arizona Game and Fish Department (AGFD) to initiate investigations of desert-dwelling mountain lions to include a study of mountain lion-livestock interactions in the Aravaipa-Klondyke area. As the result of a study plan subsequently developed by A. L. LeCount, 6 objectives were outlined:

- Test the use of mountain lion track surveys as a population index estimator,
- Compare the density of mountain lions in the Aravaipa-Klondyke area with that in other areas of Arizona,
- Compare trends in prey species abundance in the Aravaipa-Klondyke area with those in other areas of Arizona,
- Determine if mountain lions in the Aravaipa-Klondyke area select livestock out of proportion to their availability,
- Determine the impact of mountain lion predation on livestock in the Aravaipa-Klondyke area, and
- Determine the impact of control efforts on the mountain lion population.

STUDY AREA

We investigated the density of mountain lions in a 4,035 km² area surrounding Aravaipa Canyon and Klondyke, Arizona (Fig. 1). This Aravaipa-Klondyke Study Area (AKSA) included the Aravaipa Canyon and Valley, most of the Aravaipa Creek watershed, much of the Galiuro Mountains, portions of the San Carlos Indian Reservation, the Turnbull-Santa Teresa Mountain complex, and a small portion of the western Pinaleño Mountains. It was bordered by the Gila River to the north and the San Pedro River to the west. About 57% of the AKSA was State Trust or Federal land (State Trust, 28%; Bureau of Land

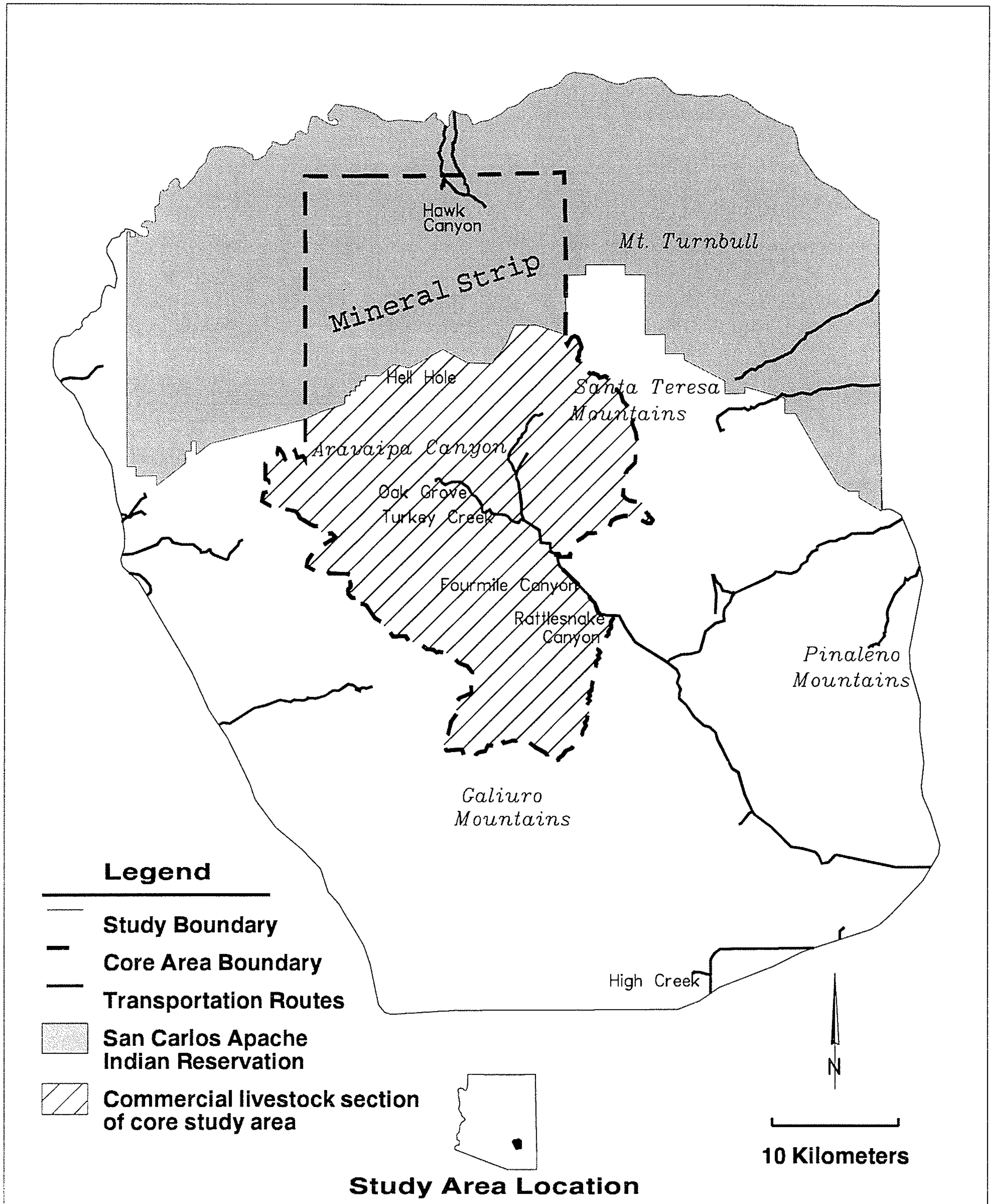


Figure 1. Location and key features of the Aravaipa-Klondyke Study Area, Arizona.

Management [BLM], 11%; and the Coronado National Forest [USFS], 18%). Approximately 11% of the Federal Land was designated as wilderness. Thirty-two percent of the AKSA was on the San Carlos Indian Reservation and 11% was deeded as private.

We investigated mountain lion food habits, prey abundance, population demography, and movements in a smaller (951 km^2) subset of the above area, hereafter referred to as the core area (Figs. 1 and 2). The core area included portions of the Mineral Strip on the San Carlos Indian Reservation, the Santa Teresa Mountains, Aravaipa Canyon and much of Aravaipa Valley, and the northernmost portion of the Galiuro Mountains.

Physiography and Geology

Elevations on the AKSA ranged from 750 to 2,300 m. Topography in all of the mountain ranges was steep and broken, with stone pinnacles, narrow, deep canyons, and rugged cliffs all common at higher elevations (Fig. 2). These formations merged downslope to comparatively level terraces near the bajadas of the Aravaipa Valley to the east, the Gila River Basin to the north, and the San Pedro River to the west.

The varied topography was best described by Bell (1869:62):

> "The country seemed to consist of a succession of mesas, piled up one above the other, like terraced mountains, presenting from five to a dozen parapets. Volcanic force considerably assisted in producing the wild confusion which surround us: for many of the summits were formed of pointed masses of plutonic rocks which had been formed up from below, while considerable areas of surface had been covered with a thick coating of lava, the broken edges of which shone out smoothe and black in the sunlight."

The northern portion of the Galiuro Mountains was principally rugged talus slopes bisected by steep (>60% slope), large, narrow canyons. Aravaipa Canyon was narrow; the floodplain was <100 m wide over most of its course, and had steep walls, many of which were sheer cliffs with vertical rises of 200 m or more. Numerous large side canyons had similar topography. Turkey Creek and Oak Grove Creek were the only 2 tributaries of Aravaipa Canyon that had perennial streams. Large boulders (1-10 m in diameter) dotted the landscape of the Santa Teresa Mountains. The Mineral Strip and Mount Turnbull were similar to the Galiuros in having large, steep, talus-sloped mountains separated by steep canyons.

Many of the canyons in AKSA had running water for much of the year. These and numerous permanent springs and water developments maintained by ranchers provided water sources throughout the AKSA.

The AKSA climate typified that of southeastern Arizona (Lowe 1964). Temperatures were mild. An annual spring drought was followed by late summer thunderstorms (monsoons) produced by moisture from the Gulf of Mexico. Winter rains were less episodic and more widespread, originating mostly from Pacific fronts. Snowfall in the area was infrequent at higher elevations and rare in the lower valley areas. The Galiuro Mountains intercept much of the cool-season moisture as it moves northeastward from the Pacific, making the Aravaipa Valley somewhat drier in winter than might be expected for its elevation (Minckley 1981) (Fig. 3).

Vegetation

The AKSA had a wide diversity of vegetation types, as expected given the wide range in elevation and the spatial variation in precipitation (Minckley 1981). Seven of Brown and Lowe's (1974) biotic communities were present (Fig. 4), including strips of riparian areas along streams.

Semidesert Grassland. This grassland was dominated by perennial bunchgrasses (*Aristida* spp., *Bouteloua* spp., and *Trichachne* spp.) and shrubs including mesquite (*Prosopis juliflora*), whitethorn acacia (*Acacia constricta*), prickly pear cactus (*Opuntia phaecantha* var. *discata*), and soaptree yucca (*Yucca elata*). This vegetation type primarily occurred in moderately sloped areas and valley floors and was the most common vegetation type (40% of the total area).

Arizona Upland Sonoran Desertscrub. This open, shrubby vegetation was dominated by foothills palo-verde (*Cercidium microphyllum*) and saguaro (*Carnegia gigantea*). Other common species included whitethorn acacia, ocotillo (*Fouquieria splendens*), jojoba (*Simmondsia chinensis*), desert hackberry (*Celtis pallida*), and fairy-duster (*Calliandra eriophylla*). Various cacti (*Opuntia* spp.) were dominated by Englemann prickly pear (*O. englemannii*) and several cholla

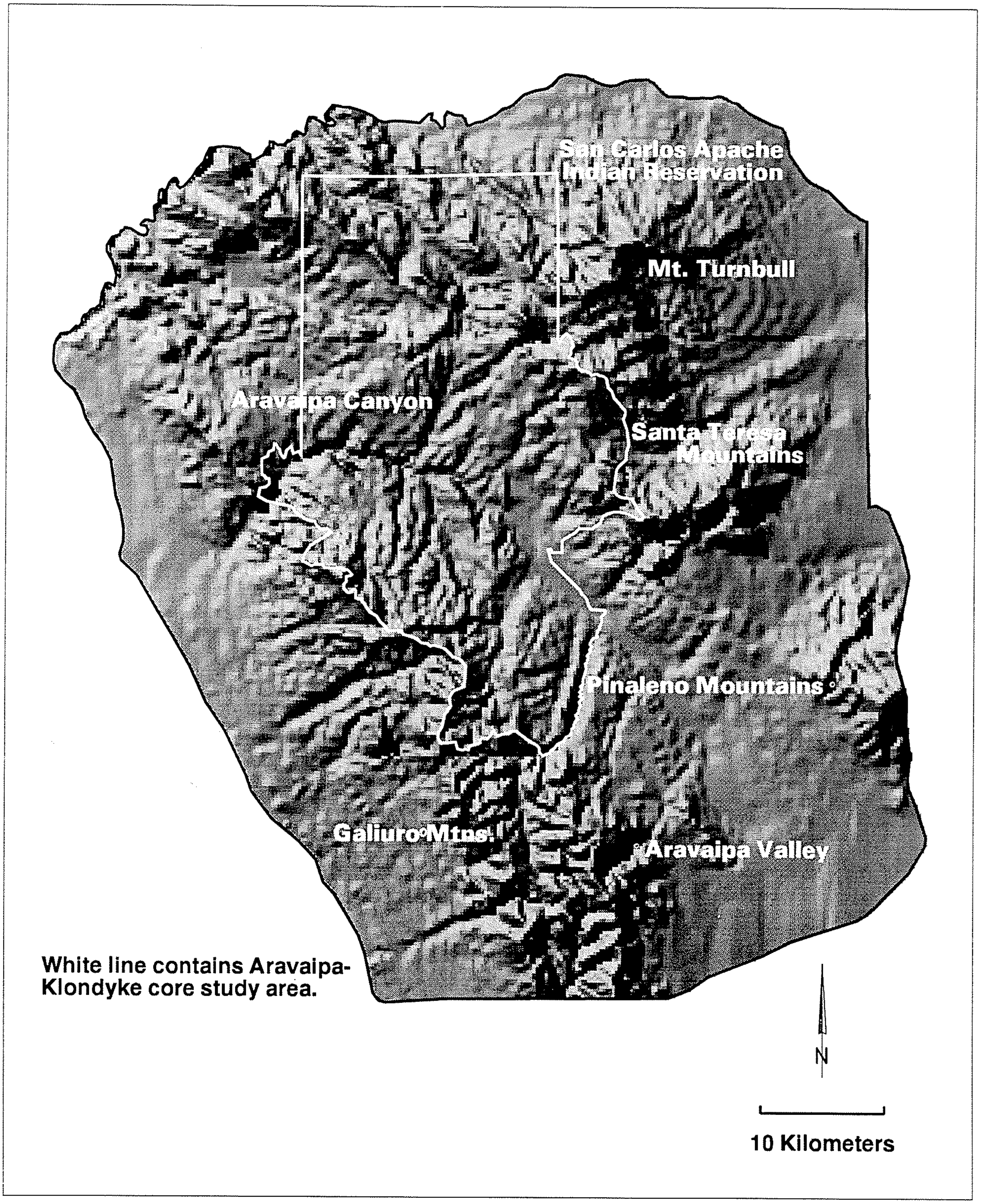


Figure 2. Topographic relief (Digital Elevation Model) on the Aravaipa-Klondyke Study Area, Arizona.

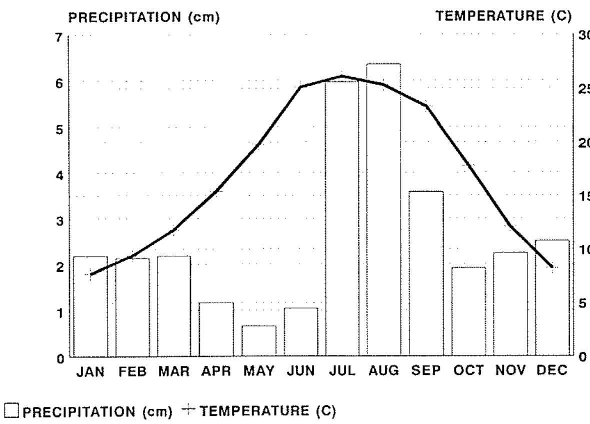


Figure 3. Mean seasonal precipitation and temperatures at Ft. Grant, Arizona, near the eastern boundary of the Aravaipa-Klondyke Study Area, Arizona.

species. This type occurred in the lowest elevations on our study area and was bordered primarily by semidesert grassland. It covered 30% of the AKSA and was the second most common type.

Interior Chaparral. The dense, shrubby vegetation of this type was dominated by shrub live oak (*Quercus turbinella*), desert ceanothus (*Ceanothus greggii*), manzanita (*Arctostaphylos pungens*), mountain mahogany (*Cercocarpus* spp.), skunkbush sumac (*Rhus trilobata*), and silktassel (*Garrya* spp.). Any of the above species may have been locally dominant. The drier, rockier, more open sites occasionally contained "thornscrub" elements such as wait-a-bit (*Mimosa biuncifera*) or catclaw (*Acacia greggii*), or Sonoran desert flora including jojoba, agaves (*Agave* spp.), and fairy-duster. At higher, wetter elevations, this type merged with madrean evergreen woodland or Great Basin conifer woodland. Interior chaparral covered 14% of the AKSA and was generally found on steeper areas (>40% slope). It occurred on most canyon slopes.

Madrean Evergreen Woodland. This woodland primarily was found on the western edge of the Pinaleño Mountains, in most parts of the Galiuro Mountains, and at higher elevations in the Santa Teresa Mountains. It was dominated by Emory oak (*Quercus emoryi*), Mexican blue oak (*Q. oblongifolia*), pinyon pine (*Pinus cembroides*), and some junipers (*Juniperus* spp.). In many places, interior chaparral species occurred within this type. Madrean evergreen woodland was the most common forest type occurring in the AKSA, comprising 13% of the area.

Great Basin Conifer Woodland. This woodland was dominated in about equal proportions by 2 kinds of conifers—juniper and pinyon pine. The most common junipers were alligator juniper (*J. deppeana*) and one-seed juniper (*J. monosperma*). The most common pinyon was the Rocky Mountain pinyon (*Pinus edulis*). This type was not common in our study area and occurred only in the very northern Galiuro Mountains and near the mouth of Aravaipa Canyon. It occupied 2% of the AKSA.

Petran Montane Conifer Forest. This forest type was found only at the highest elevations in the Santa Teresa and Galiuro Mountains and on Mount Turnbull. The overstory was dominated by ponderosa pine (*P. ponderosa*). In some of the highest elevations on the north-facing slopes, some Douglas fir (*Pseudotsuga menziesii*) existed. Gambel oak (*Quercus gambelii*) and New Mexican locust (*Robinia neomexicana*) were locally common and dominated some of the lower, rockier areas.

Riparian Areas. Riparian areas included 2 major communities—mixed broadleaf and cottonwood-willow. The mixed broadleaf community occurred along rubble-bottomed perennial and semi-perennial streams and was dominated by cottonwood (*Populus fremontii*), willow (*Salix* spp.), sycamore (*Platanus wrightii*), velvet ash (*Fraxinus pennsylvanica* var. *velutina*), walnut (*Juglans major*), and box elder (*Acer negundo*). This community had a thick understory. The cottonwood-willow community occurred in relatively narrow canyons. Willows, principally *S. goodingii*, outnumbered cottonwoods, and seep-willow (*Baccharis solicifolia*) was the principal understory plant (Minckley 1981). Floodplains near the Gila and San Pedro rivers and along upper Aravaipa Creek were dominated by mesquite, catclaw, and the non-native salt cedar (*Tamarix chinensis*).

Livestock and Range Condition

Both the nature of livestock operations and the range condition on the AKSA potentially affect the vulnerability of cattle to mountain lions. These factors, in turn, have been influenced strongly by the history of grazing.

Prior to 1870, only small numbers of cattle grazed the AKSA. Beginning in the late 1870s, Anglo-American settlers imported large herds of

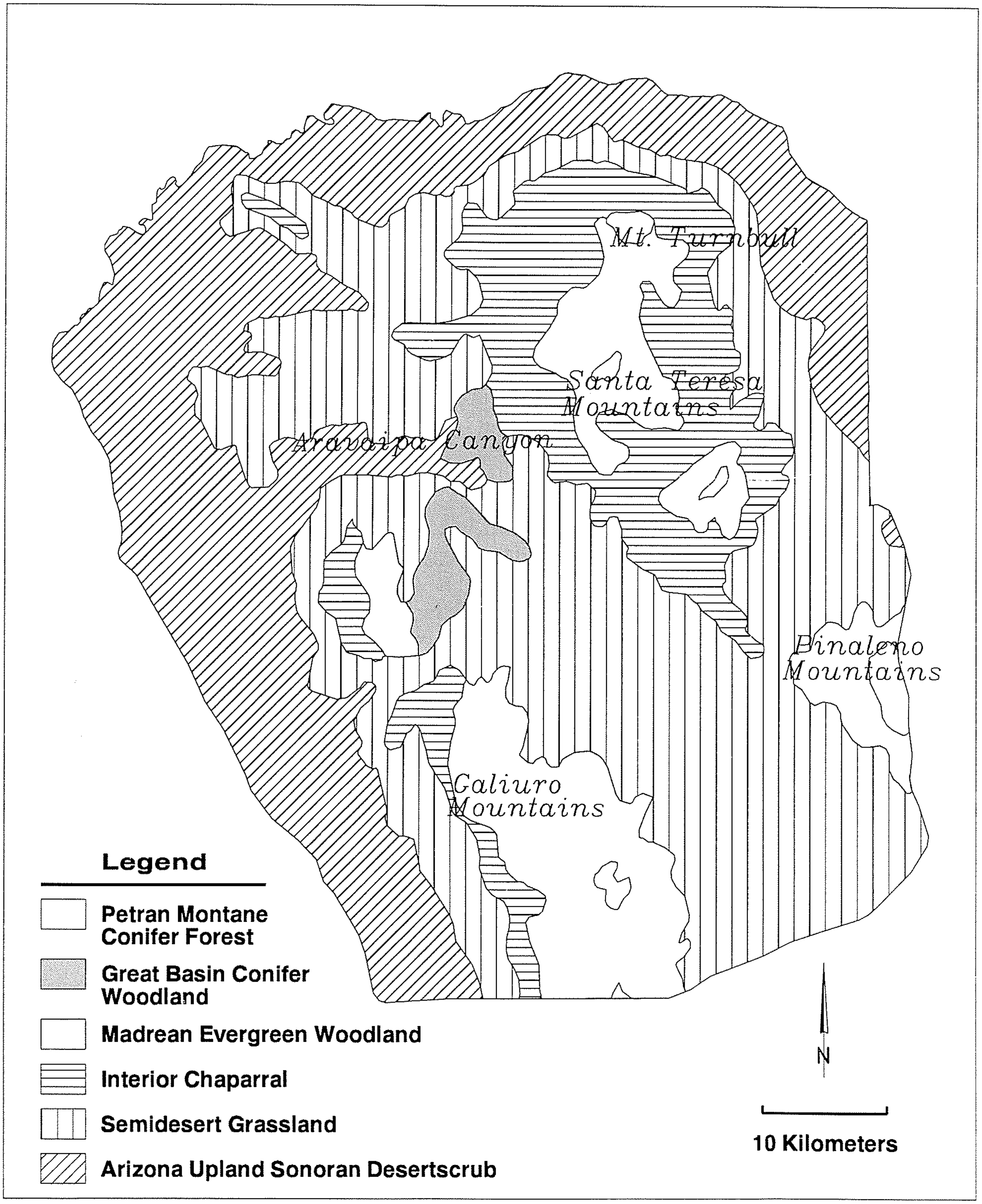


Figure 4. Vegetation cover types on the Aravaipa-Klondyke Study Area, Arizona. (After Brown and Lowe 1974.)

cattle into the area, and cattle in high densities grazed unrestricted until 1934 (Hadley et al. 1991). During this period, probably over 50,000 cattle (>130/km²) annually occupied the Aravaipa Valley. These cattle, known as *corrientes*, were adapted to rough terrain and grazed the range heavily even on steep slopes.

Three droughts occurred between 1870 and 1934 that, together with overgrazing, greatly diminished the range condition. Early Arizona operators used the range to fatten cattle for market, but sharply declining range condition during the drought of 1891-93 brought an end to many steer-fattening operations in the state. Many operators eventually switched to cow-calf breeding operations because of the grassland conversion to shrublands that began around the turn of the century (Hadley et al. 1991).

During the early part of the 20th century, ranchers started replacing *corrientes* with English breeds of cattle because of their greater market value. English breeds were not well adapted to the steep, rugged terrain, and so many ranchers began to run herds of mohair-producing Angora goats as well to graze the steeper areas. By the 1920s, as many as 40,000 goats grazed the rougher parts of the Aravaipa watershed. Further, as many as 2,000 burros and 1,800 horses ran free on the area.

The 1930s saw declines in the grazing pressure. The value of mohair decreased, leading to removal of most of the goats by 1940. The Federal government passed the Taylor Grazing Act in 1934, which called for removal of wild horses, fencing of public lands, and reductions (as much as 50% in some areas) in the number of cattle grazed. The creation and upkeep of water sources helped distribute grazing more uniformly (Hadley et al. 1991).

Presently on the AKSA, range controls exist on public lands but not on Indian lands. During our study, there were 22 allotments grazing cattle by strict controls on public lands. But on the San Carlos Indian Reservation part of the AKSA, wild cattle remained unmanaged and unrestricted.

Wildlife Prey Base and Potential Competitors

Similarly to cattle, wildlife has varied in abundance during the last century. In the late 1800s, native wildlife populations decreased as settlement, local mining, and the introduction of livestock increased. Hadley et al. (1991) reported that Apaches were complaining about the scarcity of game shortly after 1900. Large wild mammals remained scarce for another 2-3 decades, then began to increase.

By mid-century deer were abundant. Both local residents and natural resource managers agreed that deer populations were larger during the period from the 1940s to the late 1960s than they were afterward. The reasons for the post-1960s decline are unclear. Many local ranchers insist that the decline was due to overharvesting. However, various studies (Smith and LeCount 1979, Brown 1984, Haywood et al. 1987) have shown a significant relationship between Arizona deer production and precipitation, and precipitation possibly has influenced deer populations on the AKSA.

Arizona Game and Fish Department survey data indicate that mule deer declined during the period 1980-93 in AGFD game management units (GMUs) 31 and 32, which include the AKSA. (The AKSA comprises 38%, and our core area 8.7%, of GMUs 31 and 32 combined.) As mule deer declined, the AGFD tightened mule deer harvest controls to reduce hunter kill. Years of low precipitation (1980-83 and 1988-90) coincided with lows in number of mule deer surveyed, hunter success, total harvest, and fawn survival. Survey and harvest data indicate that mule deer numbers increased from 1984-87, and more recent surveys indicate that mule deer numbers may be increasing again (Table 1).

Survey and hunt data from GMUs 31 and 32 indicate that white-tailed deer (*Odocoileus virginianus*) numbers may have increased since 1980 (Table 2). Although there was considerable annual variation in the total number observed during surveys, the total harvested and the harvest success both generally increased. The mean fawn:doe ratio (44.5:100) indicates a healthy population according to AGFD species management guidelines.

Local residents and former wildlife managers reported that, prior to 1960, most of the Aravaipa watershed was inhabited by white-tailed deer, and mule deer were rare. According to these reports, mule deer numbers increased in the lower elevations in the 1950s and started moving into the higher elevations in the 1960s.

Javelina populations declined statewide in the early 1900s, partly because of unregulated harvests (Day 1985). However, Aravaipa watershed

Table 1. Mule deer survey and harvest data for Game Management Units 31 and 32, Arizona, 1980-93.

Year	Total surveyed	Bucks: 100 does	Fawns: 100 does	Permits issued	Total harvest	% hunter success
1980	649	16.7	34.3	3,400	645	21.1
1981	419	13.7	41.6	3,100	528	19.0
1982	624	12.4	53.7	3,500	626	19.5
1983	532	12.0	52.9	3,700	708	23.4
1984	703	13.8	65.0	3,400	947	30.0
1985	1,133	19.6	46.8	3,400	937	28.3
1986	1,173	10.1	40.9	3,400	1,050	31.4
1987	832	11.0	33.4	3,200	925	28.6
1988	1,053	13.0	30.9	2,800	611	22.2
1989	541	11.6	24.5	2,600	568	17.8
1990	645	12.2	39.6	2,100	527	25.8
1991	658	10.0	35.5	2,400	799	32.6
1992	768	7.8	40.3	2,200	637	28.9
1993	787	14.2	43.4	2,200	631	29.7
$\bar{x}$	751.4	12.7	41.6	2,957	724.2	25.6

Table 2. White-tailed deer survey and harvest data for Game Management Units 31 and 32, Arizona, 1980-93.

Year	Total surveyed	Bucks: 100 does	Fawns: 100 does	Permits issued	Total harvest	% hunter success
1980	90		38.7	3,400	256	14.4
1981	95	48.1	40.2	3,100	176	16.3
1982	118	38.2	47.1	3,500		
1983	189	33.2	58.3	3,700	259	27.8
1984	43	56.1	53.0	3,400	567	21.3
1985	337	32.8	60.7	3,400	554	45.0
1986	173	31.0	43.1	3,400	626	38.0
1987	365	39.8	42.6	3,400	566	33.4
1988	182	50.3	40.3	3,400	592	28.5
1989	135	34.1	26.1	3,400	520	27.2
1990	337	45.1	50.0	3,400	571	26.4
1991	344	27.0	47.3	3,400	668	27.3
1992	216	17.0	39.0	3,400	663	24.4
1993	275	24.9	36.0	3,400	763	27.4
$\bar{x}$	207	36.7	44.5	3,407	521.6	27.4

residents did not believe javelina in their region declined as dramatically as in the rest of the state (Hadley et al. 1991). Numbers gradually increased over the next several decades. Arizona Game and Fish Department survey results in GMUs 31 and 32 during 1980-93 showed a slight increase in javelina numbers in the early 1980s followed by a slow decrease from mid-decade through 1993 (Table 3). The largest decline occurred during 1988-89. Some local residents said they believed the population decline during the last 15 years on the AKSA was even greater than indicated by the survey data, and R. Olding (Ariz. Game and Fish Dep., pers. commun.) concurred that the AKSA

Table 3. Javelina survey and harvest data for Game Management Units 31 and 32, Arizona, 1980-93.

Year	Total surveyed	Avg. herd size	Juv: 100 adults	Total permits	Total hunters	Total harvest	Hunt success (%)
1980	307	8.5	22.4	2,200	2,251	678	30.1
1981	344	7.2	35.1	2,400	2,829	864	30.5
1982	286	10.6	31.8	2,400	2,389	640	26.8
1983	309	11.0	26.1	2,900	2,998	801	26.7
1984	298	9.9	22.9	3,000	2,330	621	26.7
1985	526	9.9	25.6	3,100	2,886	862	29.9
1986	343	8.8	24.7	3,100	3,483	857	24.6
1987	483	8.6	17.0	3,100	3,398	991	29.2
1988	510	9.3	26.9	3,100	3,556	926	26.0
1989	409	7.6	14.6	2,600	3,126	611	19.5
1990	183	7.3	22.8	2,600	3,149	779	24.7
1991	310	8.2	25.5	2,300	3,308	649	19.6
1992	237	8.2	31.7	2,100	2,521	606	24.0
1993				2,100	2,353	584	24.8
$\bar{x}$	349.6	8.8	25.2	2,643	3,898	747	25.9

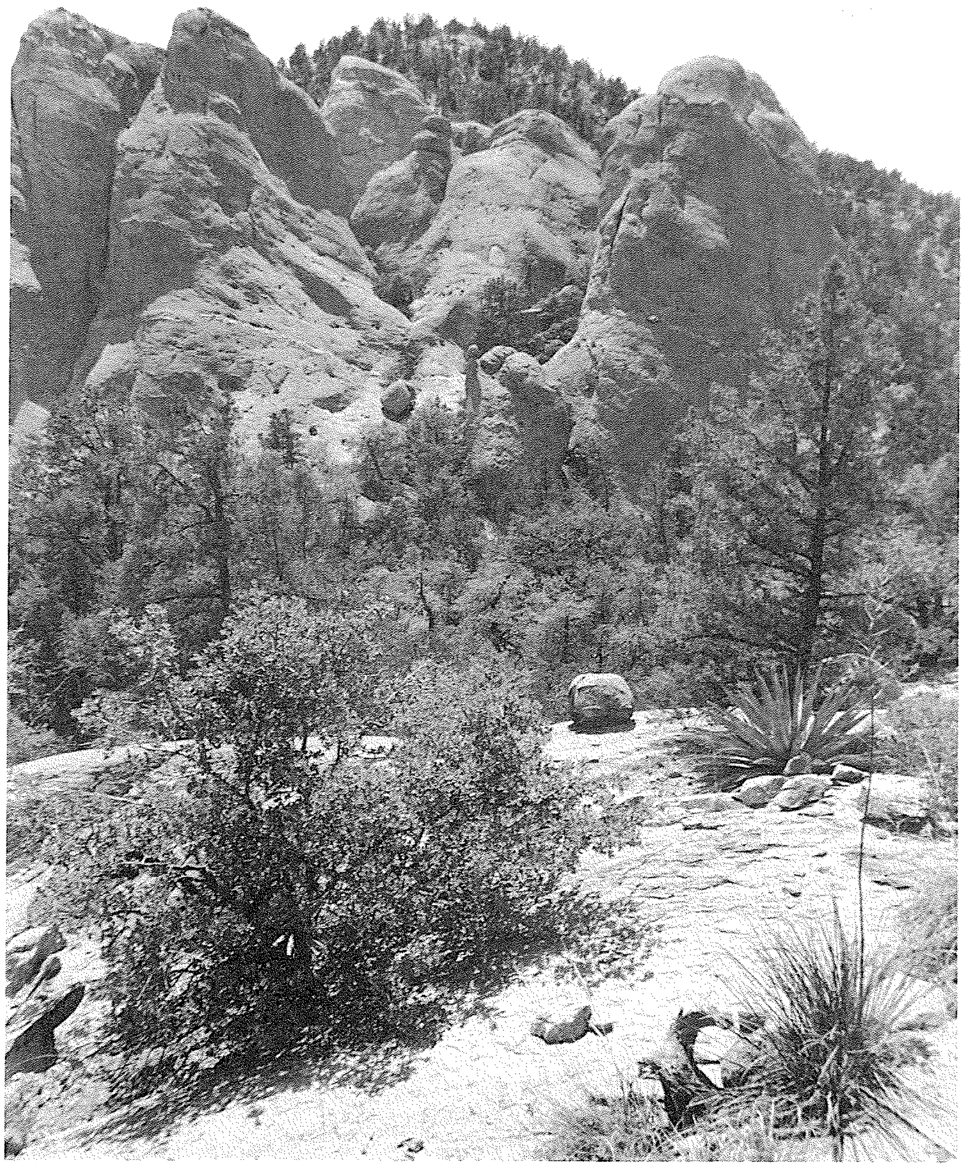
javelina population might have declined over the last 15 years more than the unit-wide population. Causes for the decline are speculative, but canine distemper may be implicated (R. Olding, Ariz. Game and Fish Dep., pers. commun.).

Desert bighorn sheep (*Ovis canadensis mexicana*) in the Aravaipa area were extirpated in the 1930s. Then in 1973, 22 bighorn sheep—15 adults and 7 lambs—were released from an enclosure on the edge of Aravaipa Canyon. The population grew quickly and by 1982 was estimated to contain over 100 animals (Cunningham et al. 1993). Initially, distribution was limited to the north side of the canyon and a few nearby tributaries, and lambing occurred only near the original enclosure site, but by 1984 bighorn sheep had begun to increase their range and establish new lambing areas.

Sheep surveys by the AGFD revealed a 52% decline between 1988 and 1989 in the number of bighorn sheep observed, and 26 carcasses were found after the summer of 1989 (Mouton et al. 1991). Because of the condition of the carcasses, mountain lion predation was not suspected as a cause. Since then, sheep surveyors have reported increased numbers, and the general health of the herd seems good (R. Lee, Ariz. Game and Fish Dep., pers. commun.). Mountain lion predation has been infrequently documented in studies of bighorn sheep in Aravaipa Canyon (Dodd 1982, Mouton et al. 1991).

The Aravaipa area contains a variety of other mammals potentially useful as mountain lion prey. Raccoons (*Procyon lotor*) live near perennial streams and around some of the homes in the area. Desert cottontails (*Sylvilagus audubonii*) and black-tailed jackrabbits (*Lepus californicus*) are common in all habitat types on AKSA. Black bears (*Ursus americanus*) are fairly abundant in the Galiuro and Santa Teresa Mountains. Coyotes (*Canis latrans*); bobcats (*Felis rufus*); gray foxes (*Urocyon cinereoargenteus*); ringtails (*Bassariscus astutus*); badgers (*Taxidea taxus*); and striped (*Mephitis mephitis*), hooded (*M. macroura*), hognosed (*Conepatus mesoleucus*), and spotted (*Spilogale putorius*) skunks were all fairly common in most habitats on AKSA. Coatimundis (*Nasua nasua*) were not seen in the area until after the 1920s (Hadley et al. 1991), but they are now fairly common. Early accounts by Bell (1869) indicated that beavers were once quite numerous in Aravaipa Canyon, but they were extirpated, probably sometime early in the century.

Mountain lions on the AKSA currently have no major wild competitors, but 2 mammals historically may have competed with or even preyed on mountain lions. Mexican wolves (*Canis lupis*) and grizzly bears (*Ursus horribilis*) were once found in the Aravaipa watershed but have been extirpated. The major reduction in the wolf population occurred between the mid-1920s and 1950, principally because of government trapping. In 1976, a lone male wolf, probably the last wild wolf in the southwestern United States (Brown 1983), was trapped and killed between Haby Spring and Rattlesnake Canyon in the middle of AKSA. By 1900, grizzlies were extirpated in the Aravaipa Canyon area, but a few may have persisted for some time afterward on the San Carlos Indian Reservation.



Madrean evergreen woodland vegetation type in the Aravaipa-Klondyke Study Area, Arizona.

METHODS

Track Surveys and Density Estimation

We used track surveys to examine mountain lion density in 3 subareas of the AKSA: (1) that portion in which mountain lion depredation control and hunting existed (DH) (1,150 km^2); (2) the San Carlos Indian Reservation portion, which received no depredation control or mountain lion hunting (NDH) (1,272 km^2); and (3) that portion in which only sport hunting existed (HO) (1,627 km^2) (Fig. 5). Our track survey methods followed those described by Shaw et al. (1988), with some modifications. Survey routes were 8 km in length and separated by ≥16 km. We established routes solely in washes and drainages because tracks were identifiable only in dust, mud, or sand, which seldom occurred in uplands. We required a minimum of 5 precipitation-free days for track accumulation prior to each survey; most surveys were conducted 5-21 days following a major region-wide rain. Surveys were begun at first light, and were usually completed within 4 hours. Each survey was conducted by 1 person on foot. Personnel recorded tracks seen in the drainage bottom, and also were encouraged to search for sign within 100 m of the route by walking side washes and checking saddles, water sources, benches, and other landforms.

We conducted track surveys in all 3 subareas in October 1991, April and October 1992, and April 1993. Nine routes in DH were surveyed on 3-4 occasions each ($\bar{x}$ = 3.8), 10 routes in NDH were surveyed on 2-4 occasions each ($\bar{x}$ = 2.9), and 6 routes in HO were surveyed on 1-4 occasions each ($\bar{x}$ = 2.6). At least 6 months elapsed between surveys on each route.

Data collected from track surveys included estimates of trackable route length (the portion of a route on which tracks could be detected), total mountain lion track sets (a track set was a continuous trail judged to have been made by the same animal) (Fitzhugh and Gorenzel 1985), and total scrapes, scats, and kills. When possible, we measured length and width of all track pads (Fjelline and Mansfield 1989) and determined sex by heel and pad size (Shaw 1989). Because tracks in sand often were not clearly outlined, we could not make the measurements necessary to identify individuals as suggested by Smallwood and Fitzhugh (1993). Observers were asked to estimate the number of mountain lions detected on their routes based on the numbers of track sets, scrapes, scats, and kills observed.

Prior to each survey, inexperienced observers, i.e., those having had <6 months of field experience searching for mountain lion sign, were trained for 2 days. Trainees ran practice routes to view sign while accompanied by skilled observers who taught methodology and procedures. We compared observations from experienced and inexperienced observers using analysis of variance (ANOVA); we used correlation analysis to determine the factors (track sets, scrapes, or all sign) that most influenced estimates of the number of mountain lions detected on the survey route.

To examine the vegetative and topographic (slope) characteristics of each route, we used ARC-INFO GIS. We overlaid each route with a vegetation cover map created by Brown and Lowe (1974) to determine the proportion of each vegetation type within a strip that extended 1 km on each side of the route. The cover map did not discriminate riparian habitats. Using GIS and Digital Elevation Models (DEMs), we determined the proportion of each strip in each of 4 slope classes—0-20%, 21-40%, 41-60%, and >60%. We then determined diversity indices (N1 and N2—Hill 1973) and an evenness index (Hill's modified ratio) (see also Ludwig and Reynolds 1988) for vegetation and slope-topography for each strip. Two independent multiple regression analyses were conducted to examine the relationships between slope and vegetation classes and track count indices.

We overlaid individual Minimum Convex Polygon (MCP) home ranges (Ackerman et al. 1990) that had been generated by >15 locations of each radio-tagged mountain lion over maps of survey routes to determine number of survey routes possibly encountered by each mountain lion. For individuals with >35 locations we also overlaid core area. Using GIS, we determined the mean distance to the closest survey route of each location of a radio-collared mountain lion, and the number of times any radio-collared mountain lion was located <1.6 km from any survey route. ANOVA and a Student's t-test were used to examine the relationship between the gender and social status of mountain lions and their proximity to survey routes.

We estimated mountain lion density within the AKSA and within subareas using a Lincoln index (Davis and Winstead 1980) procedure. The

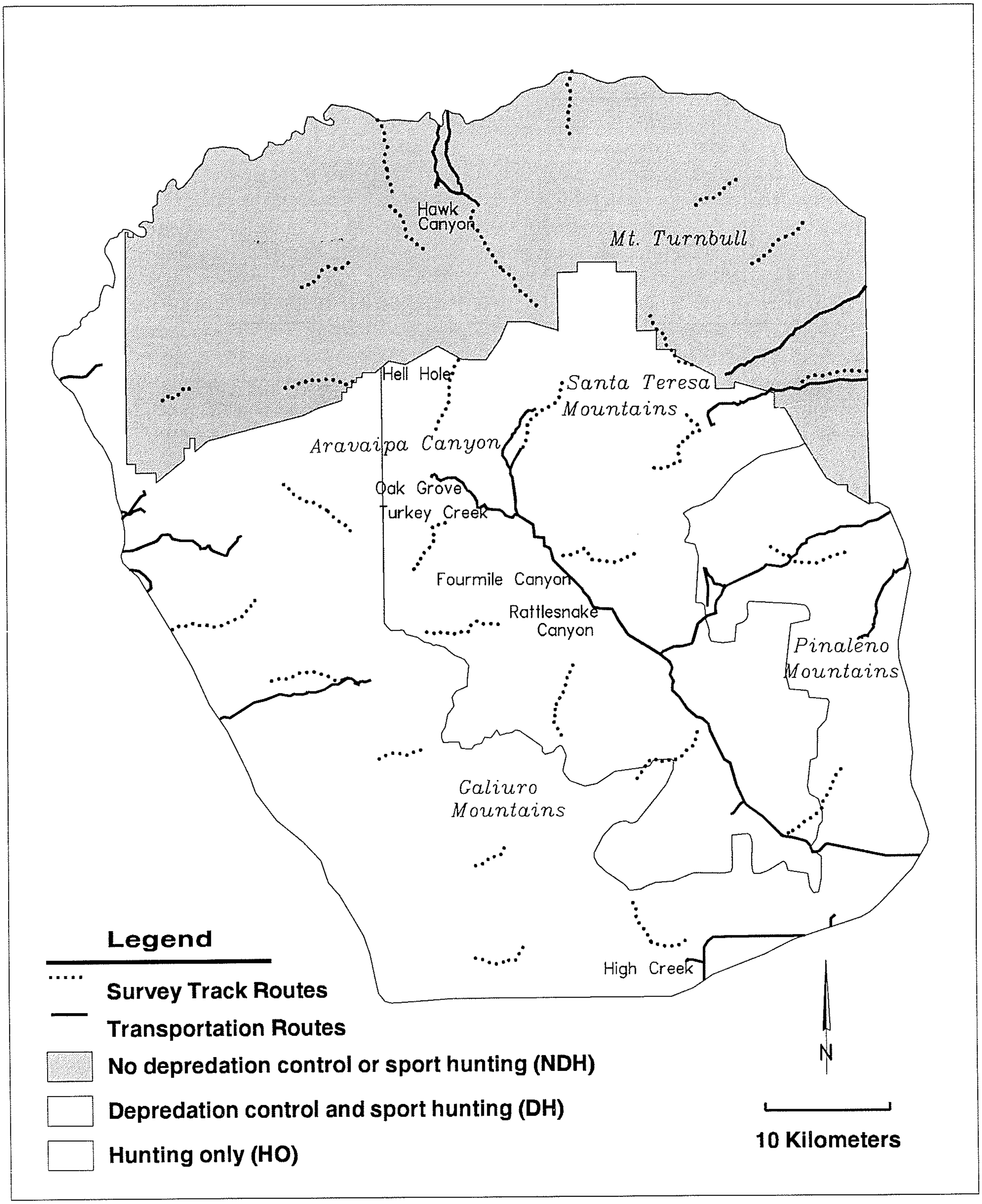


Figure 5. Distribution of mountain lion track survey routes among subareas with different mountain lion management on the Aravaipa-Klondyke Study Area, Arizona.

number of mountain lions that observers estimated to have left sign on each survey route represented the total "captured," and the number of telemetered mountain lions possibly detected by sign on each route represented the number of marked individuals captured. A possible detection on a survey route occurred when we found sign of a mountain lion of the approximate size of a radio-collared mountain lion located <1.6 km from the route since the last rain.

We considered problems encountered by other investigators who used counts of mountain lion tracks and sign to establish indices to mountain lion density (Kutilek et al. 1983, Fitzhugh and Gorenzel 1986, Van Dyke et al. 1986). Smallwood and Fitzhugh (1991) noted that an important assumption—that a track-count index is linearly related to the true population—is often invalid. These authors identified some inherent biases in track count methodologies and noted the low precision and potentially large errors associated with the application of track counts to density estimation. Potential sources of bias include: mountain lions may select travel routes by different criteria than biologists use to select track-count routes, and mountain lions in different populations may leave different amounts of tracks per mountain lion. Because each of our survey periods was <1 week, we believe migration and mortality assumptions of the procedure were not violated.

Capturing mountain lions with hounds.

Home Ranges and Movements

We radio-collared mountain lions and periodically located them to estimate home ranges. To capture mountain lions for radio-tagging, we used hounds to track and tree them (except for 1 captured with an Aldrich foot snare). We captured mountain lions only in the core area, and we attempted to hunt all sections of the core area equally.

Mountain lions were immobilized with drugs delivered by darts from a Cap-Chur pistol at the capture site. We used tiletamine (Telazol) at a dosage of 1.8 mg/kg of mountain lion body weight to immobilize 28 mountain lions. An additional animal died from an overdose of phenocyclidine hydrochloride (Sernylan).

All mountain lions fitted with radio collars were subsequently located with Telonics equipment (Telonics, Inc., Mesa, Ariz.). We located radio-collared mountain lions almost exclusively with an aerial radio-tracking system that included 3 antennae. We used 2 forward-phased, Yagi antennae, each mounted on the wing strut of the survey plane (usually a Cessna 182) for general locations. We then pinpointed the locations using a belly-mounted, rotatable, 2-element "H" antenna (Carrel 1972 *a,b*).

We located radio-collared mountain lions once per week from February 1991 to October 1992 and then every other week until December 1993. Thereafter, for the first 4 months in 1994, flights were made once per month to check for mortalities. Radio locations were plotted on United States Geological Survey (USGS) maps (7.5' and 15'), and Universal Transverse Mercator (UTM) coordinates were recorded.

We used HOME RANGE software (Ackerman et al. 1990) to calculate home range sizes and GIS programs (ARC/INFO) to plot home ranges. We adopted Sweanor's (1990) guidelines (a minimum of 10 months of monitoring and 34 locations) to select mountain

Aging mountain lions by teeth wear and coloration.

lions for home range size estimation. We had sufficient data on 7 of our mountain lions to meet these criteria. We analyzed the spatial relationships among radio-collared mountain lions 1 time each year—the time at which the most radio-collared mountain lions occupied the AKSA.

Prey Availability and Selection

Prey Availability. We equated prey availability with prey density. To calculate the density of each species, we surveyed the core area from a Bell Jet-Ranger helicopter 4 times: October 1991, April and October 1992, and April 1993.

During surveys, we used a line transect approach to enumerate prey animals along flight lines (Anderson et al. 1979, Burnham et al. 1980). Transects were approximately 10 km in length, except where the study area would not accommodate a transect that long. Transects traversed drainages at right angles to maximize the ability of the observers to accurately estimate distance intervals from the flight path. All transects were flown at a velocity of 48 km/hour at an altitude approximately 30 m above ground level (Shupe and Beasom 1987, White et al. 1989). Elevation was visually estimated during the first survey but maintained on the remaining 3 surveys with the aid of downward-looking radar. The pilot located and followed transects with the aid of LORAN and GPS flight navigation systems. Pitch and roll were recorded. Prey observed during aerial surveys were classified as to distance from the transect centerline; we used 8 distance increments of approximately 22-m each in a 185-m-wide transect.

All observations were made by 2 observers looking out the right-hand side of the aircraft. One observer sat in the right front seat and another sat in the right rear seat. Prey species counted were mule deer, white-tailed deer, javelina, bighorn sheep, and cattle. A prey group was defined to be 1 or more individuals apparently associated with others of its kind (Anderson et al. 1979, Burnham et al. 1980). Data were collected on group size and sex and age of individuals. Cattle were classified into 2 groups: calves (<180 kg) and adults (>180 kg). Transects were surveyed during 5-hour periods prior to noon and all surveys were completed within 1 week.

Population density estimates were calculated using TRANSECT II software (Laake et al. 1979) as recommended by Burnham et al. (1980). MANOVA was used to compare prey numbers and proportions among surveys and between the commercial livestock and San Carlos Indian Reservation portions of the core area. To compare relative abundance of prey we assumed that all species were equally visible during surveys.

Prey Consumption and Selection. We analyzed mountain lion scats to estimate the composition of mountain lion diets (i.e., prey consumption). We usually collected 2 scats (occasionally fewer were found) each month in each of 8 equal-sized subdivisions of the core area. We identified mountain lion scats by their size and shape (Murie 1954); only scats >30 mm in diameter were collected which excluded most coyote and bobcat scats (Danner and Dodd 1982). Scats judged to be <1 month old (i.e., those that were dark and moist) were labeled as fresh; those >1 month old were labeled as old. We assumed each fresh scat indicated a separate kill because we thought a mountain lion feeding on 1 kill was unlikely to travel between subdivisions.

We identified prey items in mountain lion diets by examining hair and skeletal remains in the scats. Scats were soaked in water and washed through 1- and 3-mm sieves. Skeletal material in scats was compared with reference collections of prey bones. Hair was identified microscopically using reference slides and photomicrographs from Moore et al. (1974). Because we were unable to differentiate between white-tailed and mule deer hair, we classified both simply as deer. We made no attempt to separate rodent species or to distinguish between cottontail and jackrabbit. Food items were analyzed by frequency of occurrence, i.e., the percent of time they occurred in the scats collected.

Based on the relative frequency of occurrence of each prey species in the scats collected, we calculated relative numbers of each species consumed by mountain lions in the AKSA. To make these calculations, we first estimated the relative biomass consumed of each prey species, based on Ackerman et al.'s (1984) formula that converts remains in a scat to biomass eaten, species by species. We then converted relative biomass eaten to relative numbers of prey animals killed, based on average weight of each prey species. The weights of white-tailed and mule deer were estimated from average live weights measured at deer hunt check stations in Arizona Game and Fish Region V (which includes the AKSA) (R. Olding, Ariz. Game and Fish Dep., pers. commun.). Weights of other species were taken from estimates given by Burt and Grossenheider (1964).

These estimates of relative numbers consumed were divided into 2 seasons—March-August (spring-summer) and September-February (fall-winter). Scats collected during each season were pooled across years to increase sample sizes.

We compared the relative numbers of deer, calves, and javelina estimated to have been eaten by mountain lions (i.e., prey "use") with the relative numbers of the same species estimated to inhabit AKSA, as indicated by our aerial survey data (i.e., "availability"). We used Chi-square contingency tables to test for differences between prey use and prey availability during the spring-summer and fall-winter seasons, and overall. If differences ($P < 0.05$) occurred between use and availability, Bonferroni confidence intervals were used to indicate in which instances use did not equal availability (Neu et al. 1974, Byers et al. 1984). For significant Bonferroni confidence intervals we used Jacobs' D selectivity index (Jacobs 1974) to indicate direction and magnitude of selection or avoidance of prey.

Age Structure and Mortality

Age Structure. Mountain lions were aged according to tooth replacement, wear, and coloration (Ashman et al. 1983, Shaw 1989). We aged mountain lions we captured. The APHIS Animal Damage Control officer aged those taken in mountain lion depredation cases. We used a Chi-square contingency table to test for differences in age structure between mountain lions aged in our study and those described in other published studies.

Survival and Mortality. Survival and mortality rates of radio-collared mountain lions were calculated using MICROMORT as developed by Heisey and Fuller (1985). In the analysis, we included only those mountain lions that remained in the study area >3 months after being radio-collared, but not young kittens equipped with temporary drop collars. If a radio-collared animal left the study area, or if an animal's radio collar stopped functioning, we excluded these animals from analysis beginning with the interval of departure or malfunction.

Equipment used for radio-collaring mountain lions.

RESULTS

Track Surveys and Density Estimates

Track surveys pointed to a relatively high density of mountain lions in the DH subarea of the AKSA (Table 4), despite the depredation control and hunting that occurred there. Several indices of abundance—track sets, all sign, and estimated number of mountain lions per survey route—were not different between the DH subarea and the subarea with no depredation control or hunting (NDH). Both the DH and NDH subareas had more track sets, all sign, and estimated mountain lions per route than did the subarea subjected to hunting only (HO).

The proportion of track routes that contained mountain lion sign was greatest in the DH subarea. Eighty-five percent of the DH routes surveyed contained sign, compared with 69% of the NDH routes and 19% of the HO routes. In most cases, there were no large seasonal fluctuations within subareas in the proportion of routes that contained sign.

As would be expected from the relative amounts of sign among subareas, mountain lion population estimates were higher for DH than for the other subareas (Table 5). Summed across seasons, the data indicate there to have been a mountain lion/61 km^2 in the entire AKSA, 1/37 km^2 in the DH, and 1/65 km^2 in the NDH.

Track count values for the DH and NDH subareas of our study area were greater than those reported in other locations in Arizona (Table 6). Values for subarea HO were in the lower ranges of those reported statewide.

Statistical tests suggested no correlation between mountain lion abundance and vegetation or topographic (slope) variables on the AKSA. Multiple regression analysis did not indicate a relationship between vegetation or slope categories and track survey indices. Examination of a complete correlation matrix involving all vegetation and slope measures failed to reveal relationships with track survey indices.

Mountain lion mortalities in subarea DH, although substantial (Table 7), seemed to have little influence on the results of subsequent track surveys. For example, sign and tracks changed little from October 1991 to April 1992, although a minimum of 10 mountain lions (approximately a third of the estimated population) died during the period. Sign and track values between October 1992 and April 1993 remained stable, although at least 11 mountain lions died during that period. In contrast, track count indices in subarea NDH declined substantially between October 1992 and April 1993, during which time 3 mountain lions resident in the subarea died.

Experienced observers found more sign than inexperienced observers. The difference was attributable to experienced observers finding more scrapes. Both groups of observers found similar numbers of track sets and estimated similar numbers of mountain lions/route (Table 8). Both also found more male sign than female based on track width and the presence of scrapes—81% of the sign inexperienced observers found was male sign, as was 76% of that found by experienced observers.

Correlation coefficients indicated that inexperienced observers estimated the number of mountain lions using survey routes primarily based on the number of track sets found (r = 0.88). The amount of variation in estimates of mountain lion numbers by experienced observers was best explained by the amount of all sign found (r = 0.71), with the number of track sets and the number of scrapes contributing almost equally (r = 0.47 and 0.53, respectively).

Scrapes were found in more variable numbers than track sets. Scrapes averaged 1.45/route (range = 0-11) (Fig. 6). Mean track sets/route for all areas was 1.18 and ranged from 0-5. But track sets were found on more routes (53%) than scrapes (37%).

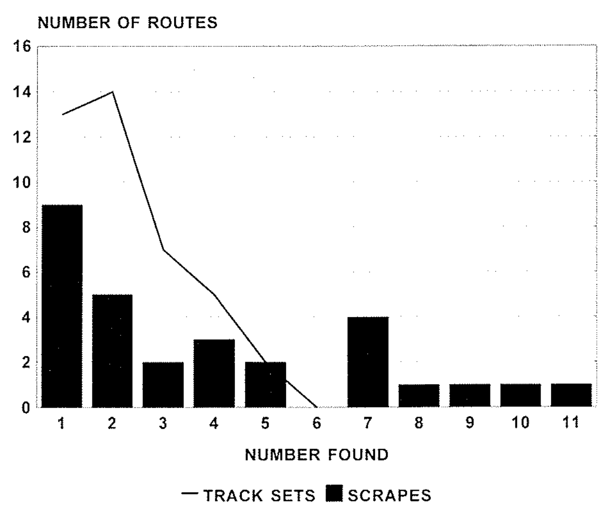


Figure 6. Number of routes on which different numbers of mountain lion track sets and scrapes were found, Aravaipa-Klondyke Study Area, Arizona.

Table 4. Mountain lion track survey values among treatment areas by survey period, and ANOVA probabilities of differences, on the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Survey Area	n	Sign[a]/ route	Sign/ km	Track sets/ route	Track sets/ km	Estimated lions[b]/ route	Estimated lions/ km
Overall							
DH[c]	33	3.5[f]	0.45[f]	1.5[f]	0.18[f]	1.3[f]	0.17[f]
NDH[d]	29	2.7[f]	0.40[f]	1.4[f]	0.21[f]	1.0[f]	0.15[f]
HO[e]	16	0.56[g]	0.08[g]	0.19[g]	0.03[g]	0.19[g]	0.03[g]
P		(0.004)	(0.01)	(0.006)	(0.008)	(0.000)	(0.0001)
October 1991							
DH	9	3.5	0.47	2.0	0.26	1.3	0.17
NDH	7	3.1	0.52	2.1	0.36	1.0	0.17
HO	3	0.33	0.05	0.33	0.05	0.33	0.05
P		(0.28)	(0.26)	(0.3)	(0.26)	(0.09)	(0.13)
April 1992							
DH	9	3.4	0.45	1.1	0.13	1.4[f]	0.19[f]
NDH	10	2.9	0.40	0.9	0.14	1.1[f]	0.15[f]
HO	6	0.0	0.0	0.0	0.0	0.0[g]	0.0[g]
P		(.07)	(0.09)	(0.19)	(0.10)	(0.01)	(0.01)
October 1992							
DH	7	2.4[g]	0.31	1.3[g]	0.16[f]	1.4[f]	0.18[f]
NDH	5	4.4[f]	0.62	2.6[f]	0.37[f]	1.4[f]	0.2[f]
HO	6	0.33[g]	0.05	0.33[g]	0.05[g]	0.17[g]	0.02[g]
P		(.03)	(0.1)	(0.02)	(0.02)	(0.01)	(0.009)
April 1993							
DH	8	4.4	0.56	1.4	0.18	1.1	0.14
NDH	7	0.86	0.12	0.6	0.08	0.6	0.08
HO	1	6.0	0.88	0.0	0.0	1	0.15

[a] Sign = track sets, scrapes, scats, and kills.
[b] Est. mountain lions = number of mountain lions that left sign (estimated by observers).
[c] Subarea with depredation control and sport hunting.
[d] Subarea with no depredation control or sport hunting.
[e] Subarea with sport hunting only.
[f, g] Means with the same letter do not differ ($P < 0.05$).

Table 5. Mountain lion density estimates based on track surveys for the Aravaipa-Klondyke Study Area and subareas, Arizona, 1991-93.

Area or subarea Survey	Estimated No.[a] of lions (n)	Total collared lions in area (M)	Total collared lions possibly detected (x)	Lincoln-Petersen estimate N=nM/x	SE	Density (km²/lion)
Total Study Area						
October 1991	20	3	1	60	58	68
April 1992	24	9	2	108	73	37
October 1992	18	5	2	45	30	90
April 1993	14	12	2	84	21	48
$\bar{x}$	19	7.25	1.75	74.3		61
DH[b]						
October 1991	12	3	1	36	34	32
April 1992	13	3	1	39	37	30
October 1992	10	2	1	20	19	58
April 1993	9	6	2	27	17	43
$\bar{x}$	11	3.5	1.25	31		37
NDH[c]						
October 1991	7	0				
April 1992	11	3	1	33	31	39
October 1992	7	2	1	14	13	91
April 1993	4	2	0			
$\bar{x}$	7.25	1.75	0.66	23.5		65

[a] Estimated number of lions = number of mountain lions that left sign (estimated by observer).
[b] Subarea with depredation control and sport hunting.
[c] Subarea with no depredation control or sport hunting.

Table 6. Mountain lion track survey results by study subarea and Game Management Unit in Arizona, 1986-93. Data for 1986 are from Shaw et al. (1988) and remaining data are from Arizona Game and Fish Department records.

Study subarea or Game Management Unit	Year(s)	No. routes	Sign/km	Track sets/km
Aravaipa-Klondyke Lion Study Area	1991-93			
DH[a]		33	0.44	0.19
NDH[b]		29	0.46	0.22
HO[c]		16	0.08	0.02
27	1990-93	18	0.17	0.07
21	1986, 1993	12	0.08	0.11
44A	1986	8		0.13
13B	1986, 1990, 1992	39		0.09
22	1993	11	0.16	0.09
20B	1993	5		0.09
32	1986, 1993	9		0.06
36A, B, C	1986	18		0.05
14	1986	7		0.04
8	1986	4		0.04
18B	1986	7		0.03
4A, B	1986	11		0.01
23	1986	9		0.01
5A, B, C	1986	16		0.01
3B	1986	3		0
9	1986	2		0
43	1986	3		0
45	1986	9		0
40, 41, 46	1986	9		0

[a] Subarea with depredation control and sport hunting.
[b] Subarea with no depredation control or sport hunting.
[c] Subarea with sport hunting only.

Table 7. Mountain lion track survey values for subareas, Aravaipa-Klondyke Study Area, Arizona, 1991-93. Known mountain lion mortalities between survey periods are indicated.

Area	Survey	Sign/km	Track sets/km	Estimated no. of lions/km
DH[a]				
	Oct 1991	0.47	0.26	0.17
No. known mortalities - 10				
	Apr 1992	0.45	0.13	0.19
No. known mortalities - 6				
	Oct 1992	0.31	0.16	0.18
No. known mortalities - 11				
	Apr 1993	0.56	0.18	0.14
NDH[b]				
	Oct 1992	0.62	0.37	0.2
No. known mortalities - 3				
	Apr 1993	0.12	0.08	0.08

[a] Subarea with depredation control and sport hunting.
[b] Subarea with no depredation control or sport hunting.

Table 8. Comparison of data collected by experienced and inexperienced observers on mountain lion track surveys, Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Surveys Observers	No. routes	Estimated no. of lions	M	F	Unknown	No. tracks	No. scrapes	All sign
Total counts								
Inexperienced	38	33	9	2	22	41	28	69
Experienced	40	43	19	6	18	51	85	141
$\bar{x}$ values/route[a]								
Inexperienced		0.87				1.3	.74	1.6
Experienced		1.07				1.1	2.1	3.5
Scheffe's P		(0.28)				(0.54)	(0.02)	(0.004)

[a] Comparison with ANOVA was significant at $P < 0.003$.

Radio-collared males classed as transients had on average more than twice as many survey routes within their home ranges as did resident males ($P < 0.001$) (Table 9). Transient males also were found on average farther from survey routes than resident males ($P < 0.009$). Interestingly, we never detected sign of a transient radio-collared male on a transect, but 4 of 7 (57%) of the resident radio-collared males were probably detected by sign.

Thirty-nine percent of the mountain lions we radiocollared were located at least once within 1.6 km of a survey route since the last rain prior to a track count survey. We probably detected 28% of our radio-collared animals during track surveys.

Resident male home ranges covered more routes than did those of resident females ($t = 2.47$, $P < 0.029$) (Table 9). We detected sign of only 1 of 7 (14%) of the radio-collared resident females, although this individual was detected on a track survey route during all 3 surveys in which she was being monitored by radio. We never detected sign of a radio-collared kitten on a survey route.

Table 9. Characteristics of radio-collared mountain lion locations with respect to mountain lion track survey routes, Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Sex Status	Animal ID	Age class	No. locations	Days monitored	No. transects within home range	$\bar{x}$ distance from a route (km)	% locations ≤1.6 km from route	No. routes ≤ 1.6 km from locations
M								
residents	M1	1-4 yrs	43	361	2	2.6	16.3	2
	M2[a]	> 4 yrs	44	350	2	2.4	22.7	2
	M3	> 4 yrs	52	463	2	3.2	15.4	2
	M4[a]	> 4 yrs	36	336	2	2.9	22.2	3
	M5[a]	> 4 yrs	34	303	4	4.1	11.7	4
	M6[a]	> 4 yrs	16	380	1	3.1	12.5	1
	M7	> 4 yrs	17	305	3	3.9	23.5	2
	$\bar{x}$				2.3	3.2	17.7	2.3
M								
transients	DM1	1-4 yrs	36	313	5	3.8	13.8	2
	DM3	1-4 yrs	21	367	9	4.1	14.3	1
	DM4	1-4 yrs	14	336	4	5.1	28.6	1
	$\bar{x}$				6.0	4.3	18.9	1.8
F								
residents	F1	> 4 yrs	31	237	2	2.7	16.1	1
	F2	> 4 yrs	59	542	2	3.5	8.5	3
	F4[a]	> 4 yrs	52	524	1	1.7	57.6	1
	F6	1-4 yrs	23	375	1	3.2	13.0	2
	F7	> 4 yrs	22	361	1	3.2	13.6	1
	F8	> 4 yrs	19	326	1	2.1	31.6	1
	F9	> 4 yrs	18	284	1	1.8	50.0	2
	$\bar{x}$				1.3	2.6	27.2	1.6

[a] Mountain lions that were possibly detected during a track survey.

Home Ranges and Movements

We obtained enough locations (34) during a sufficiently long period (10 months) on 7 adult mountain lions (Appendix 1) to meet accepted criteria for calculating home ranges (Sweanor 1990). The average MCP home range size for the 7 mountain lions was 171.3 km². Mean male home range size was nearly twice the mean female home range size (Table 10). The 2 males occupying the NDH subarea had mean home ranges ($\bar{x}$ = 294 km²) more than double the size of those of the 3 males in the HO and DH subareas ($\bar{x}$ = 131 km²). Of the 7 mountain lions for which home range sizes were calculated, only the 2 male mountain lions on NDH overlapped ranges when both were alive. Overlap was 13% of the home range of 1 and 17% of the home range of the other (Fig. 7). Female home ranges commonly overlapped (Fig. 8).

Five young (<2 yr) mountain lions (4 M, 1 F) were radiocollared and monitored on the AKSA. Three of the males (TM2, TM3, and TM4) left the AKSA (Figs. 9 and 10). Their approximate dispersal distances were: 110 km for TM2, 80 km for TM3, and 70 km for TM4. One young female (F7) remained within her natal area after her mother was killed in a depredation control case and 1 young male (TM1) was killed within a year after collaring.

Table 10. Home range sizes (km²) of male and female mountain lions with ≥34 locations and monitored ≥10 months on the Aravaipa-Klondyke Study Area, 1991-93.

Sex Animal ID	No. of locations	Months monitored	100% MCP[a]	90% HM[b]	Grid size for HM[c]
M					
M1[d]	43	12	113.1	137.1	2,175
M2[d]	44	12	115.9	125.5	2,175
M3[d]	52	17	164.5	268.6	2,500
M4[e]	36	13	256.7	385.2	3,150
M5[e]	34	12	331.9	329.9	2,500
$\bar{x}$	42	13.2	196.4	249.3	
F					
F3[d]	59	23	106.6	145.7	2,175
F5[d]	52	22	110.5	182.7	2,175
$\bar{x}$	55	22.5	108.6	164.2	

[a] Minimum convex polygon.
[b] Harmonic mean.
[c] Grid size used in HOME RANGE program (Ackerman et al. 1990).
[d] Monitored primarily in area of depredation control and sport hunting.
[e] Monitored primarily in area of no depredation control or sport hunting.

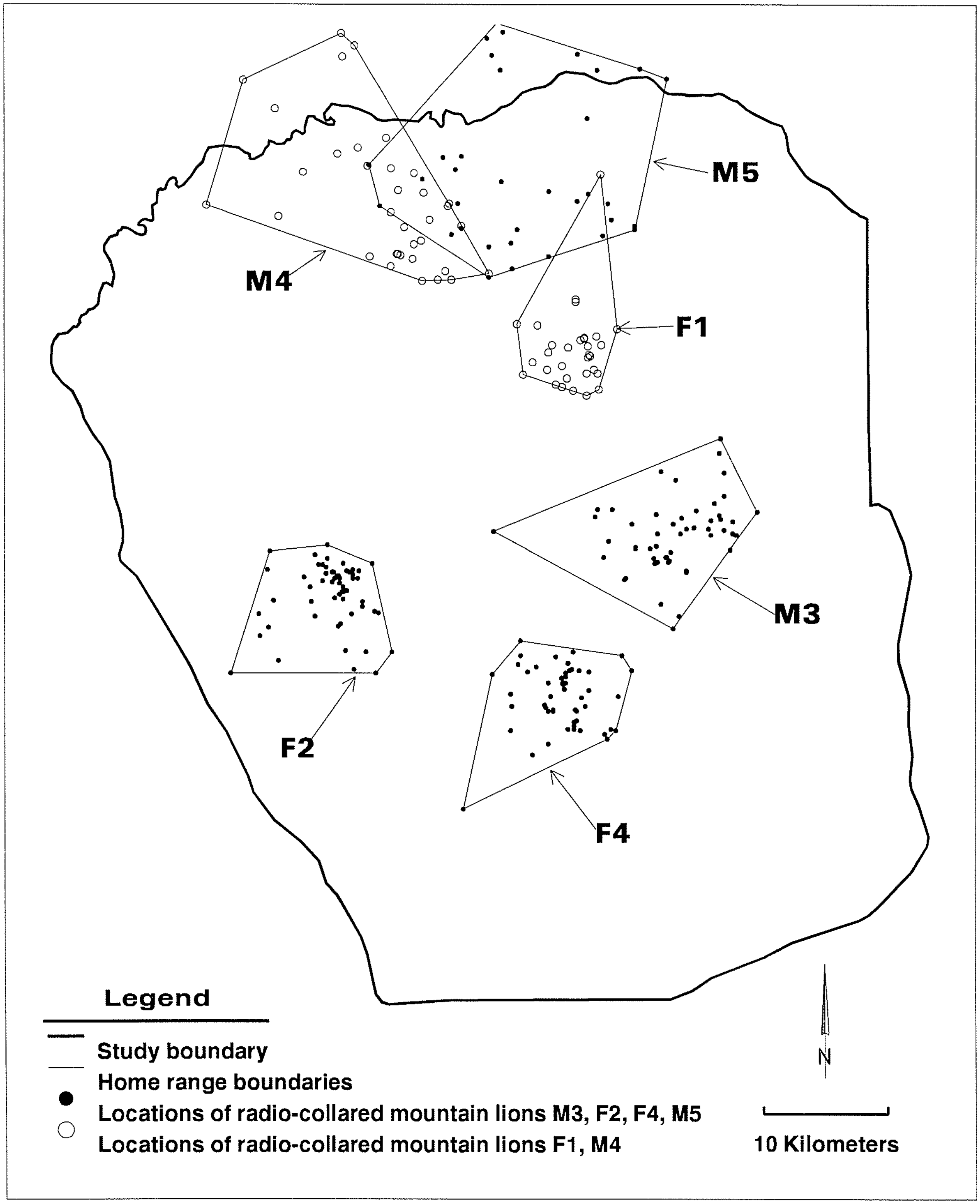


Figure 7. Minimum convex polygons of home ranges of radio-collared mountain lions alive as of July 1992, Aravaipa-Klondyke Study Area, Arizona.

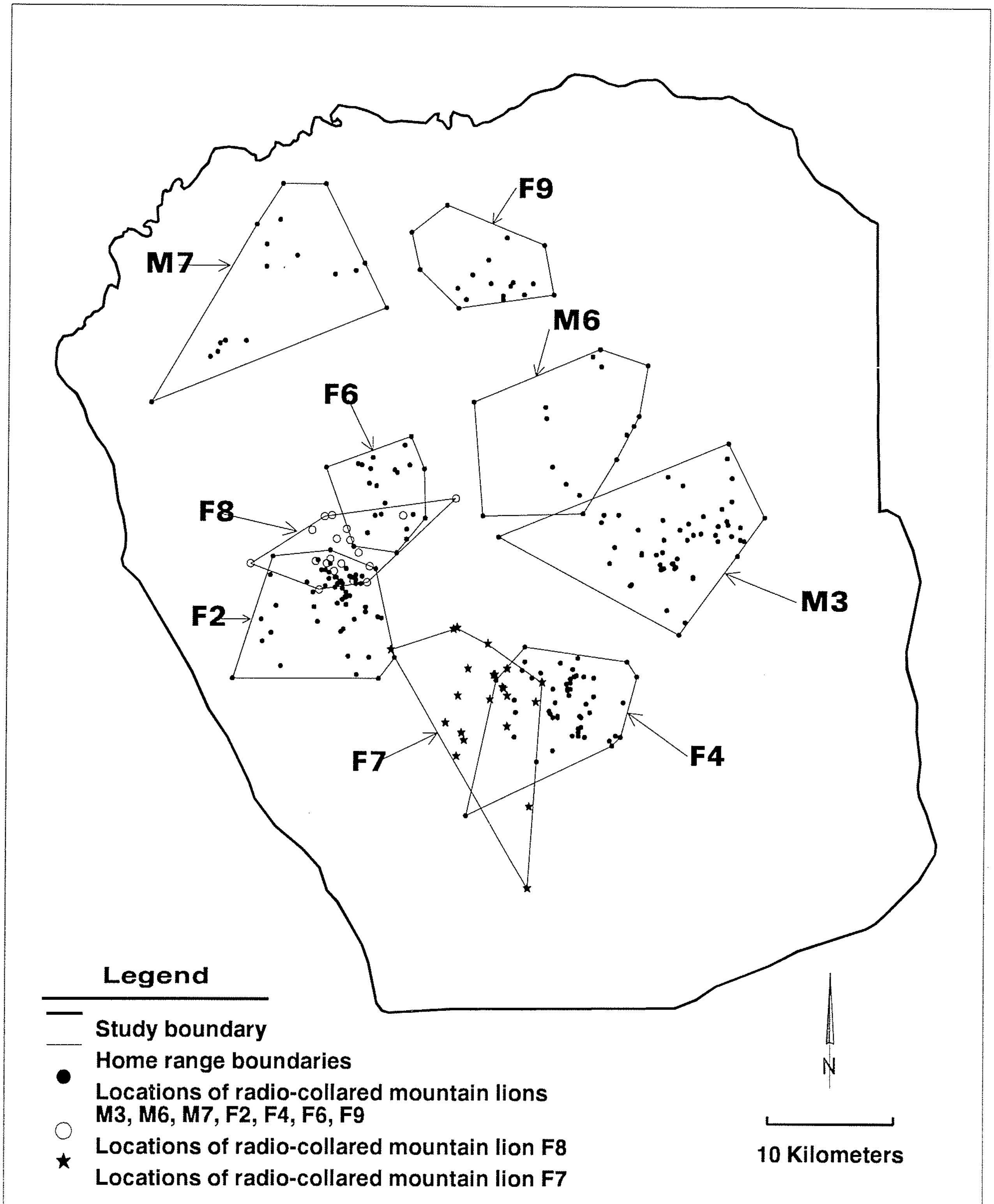


Figure 8. Minimum convex polygons of home ranges of radio-collared mountain lions alive as of April 1993, Aravaipa-Klondyke Study Area, Arizona.

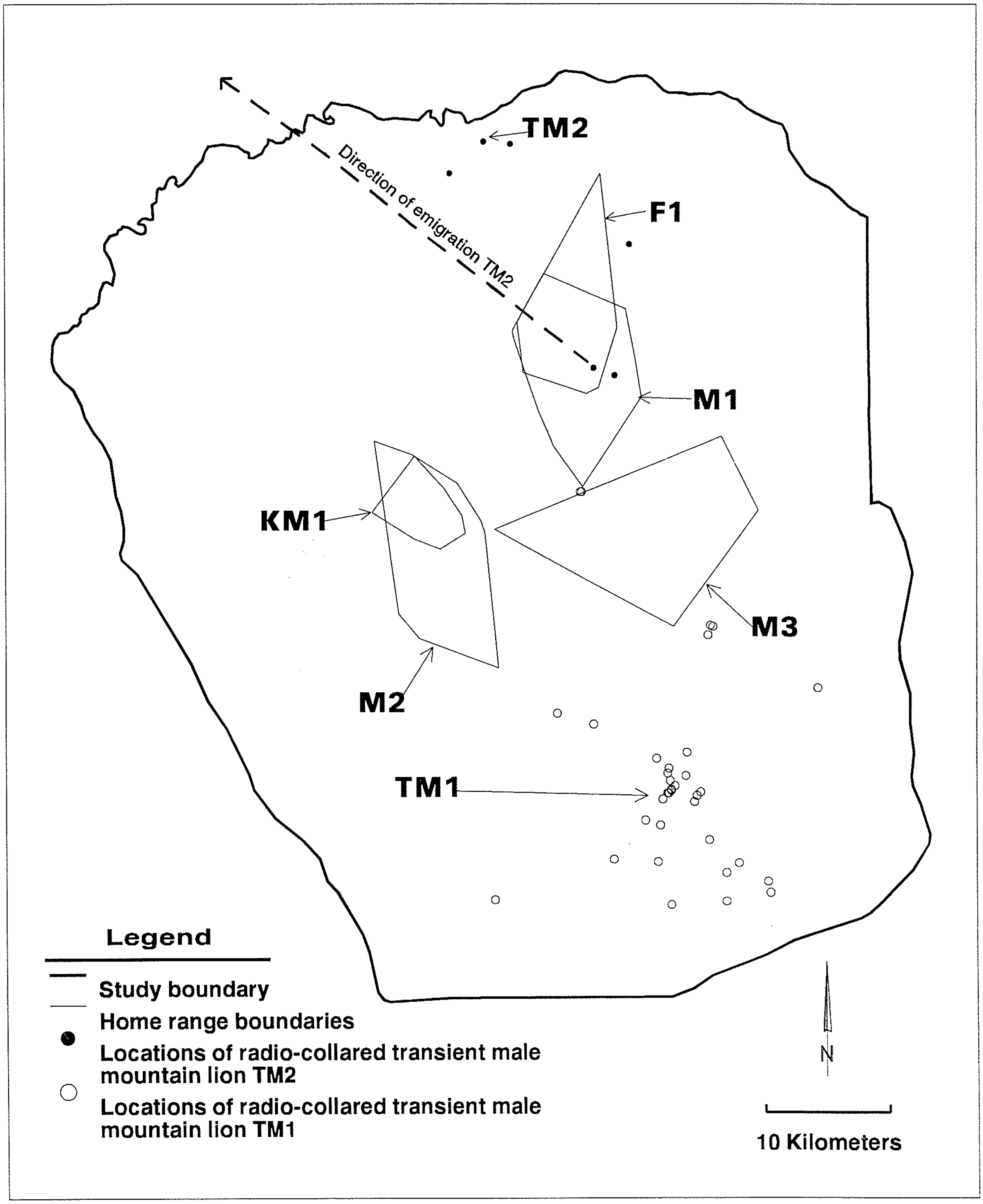


Figure 9. Radio locations of 2 transient mountain lions (TM1 And TM2) and the emigration direction of 1 with respect to home ranges of residents (polygons), Aravaipa-Klondyke Study Area, Arizona.

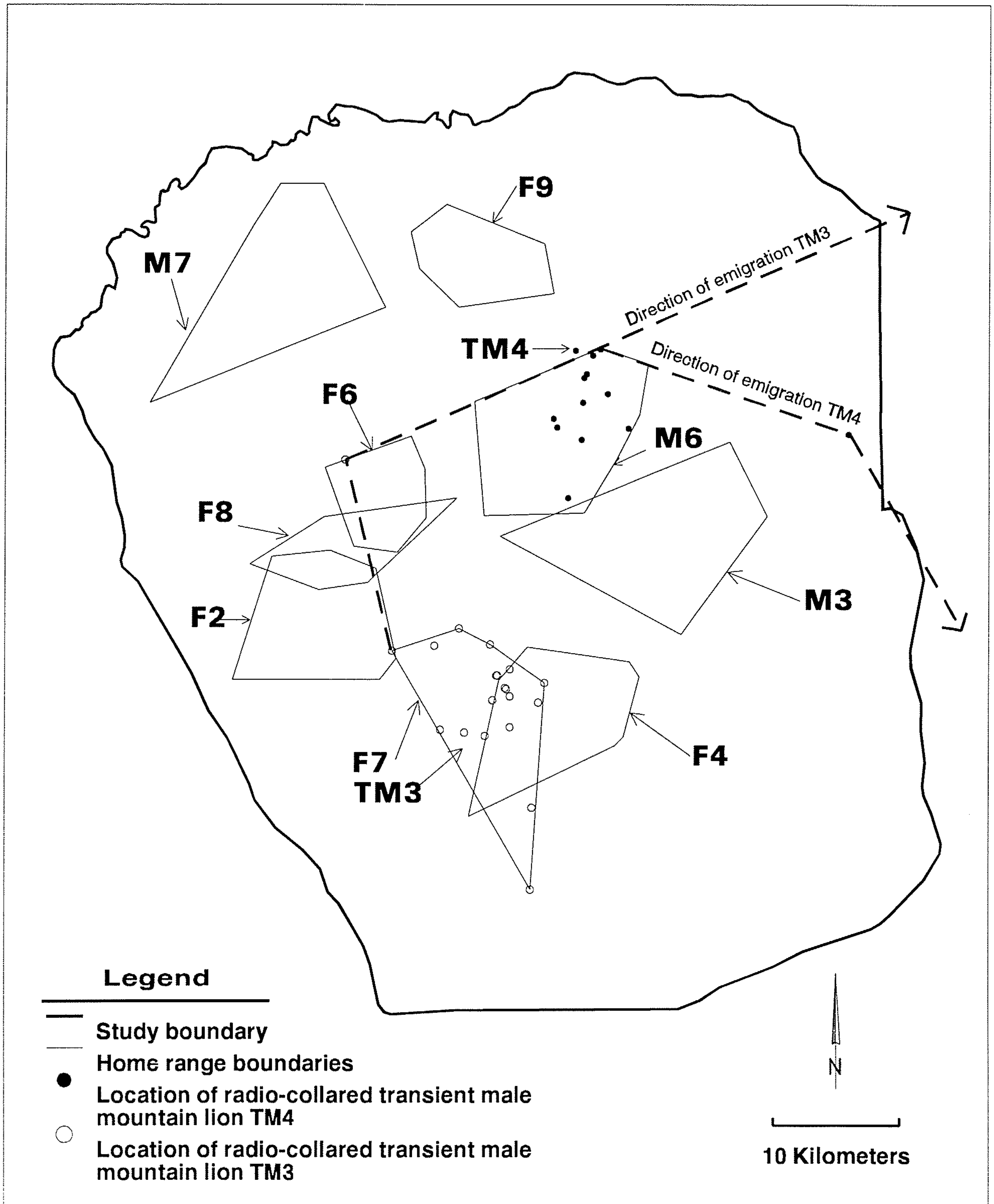


Figure 10. Radio locations of 2 transient mountain lions (TM3 and TM4) and their emigration directions with respect to home ranges of resident (polygons), Aravaipa-Klondyke Study Area, Arizona.

Prey Use

Prey Availability. Deer (mule and white-tailed) were the most abundant of the prey items we surveyed in the commercial livestock portion of the core area (Table 11). As expected, deer numbers were slightly higher in fall (post-fawning) than in spring. Calf numbers were greater in spring than in fall because most calving occurs from December to February. Javelina numbers varied little among the first 3 surveys, but dropped in the last survey.

Deer also were the most abundant prey item on the Reservation portion of the core area (Table 11), but neither deer nor calf numbers on the Reservation showed the seasonal pattern we found on the commercial area. Contrary to expectations, deer numbers on the Reservation in 1993 were estimated to be higher in the spring than in the fall. Calf numbers on the Reservation were highest in the fall 1992 survey, and javelina numbers were extremely variable among surveys.

Greater densities of prey items (all species combined) were found on the commercial livestock portion of the core area than on the Reservation ($P = 0.043$). A MANOVA showed no difference between the 2 parts of the core area in relative proportions of prey species.

Prey Selection. We found 41 mountain lion kills. Deer made up over half of the kills, cattle (mostly calves) a fourth, and javelina and bighorn sheep about a tenth each (Table 12). The buck:doe ratio was almost equal for white-tailed deer kills but all mule deer kills were does. We found no kills of deer fawns or javelina young, but 3 of the 4 bighorn sheep kills were lambs. Nine of 10 of the cattle we found killed were calves, and the other was an adult cow; evidence indicated she was killed at the same time as her calf. The calves we found, and 7 additional ones reported by ranchers, were nearly all less than 185 kg (Fig. 11).

Scat analyses indicated only minor differences in the frequency of occurrence of prey species in mountain lion diet between the Reservation and the commercial livestock area (Fig. 12). The means were not significantly different, thus we pooled data from scats collected from both areas.

Deer remains were found in almost half of the 370 scats analyzed and cattle remains occurred in ⅓ (Table 13). Javelina was the next most commonly-encountered food item in scats, followed by rabbit, rodent, and bighorn sheep.

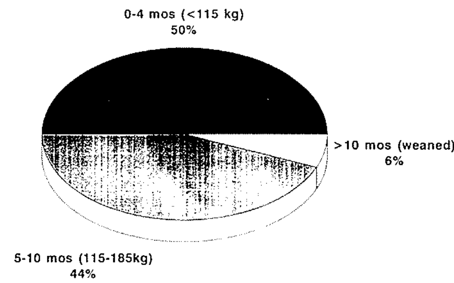


Figure 11. Mountain lion calf kills found (10) and reported by ranchers (7) by age and size range on the Aravaipa-Klondyke Study Area, Arizona.

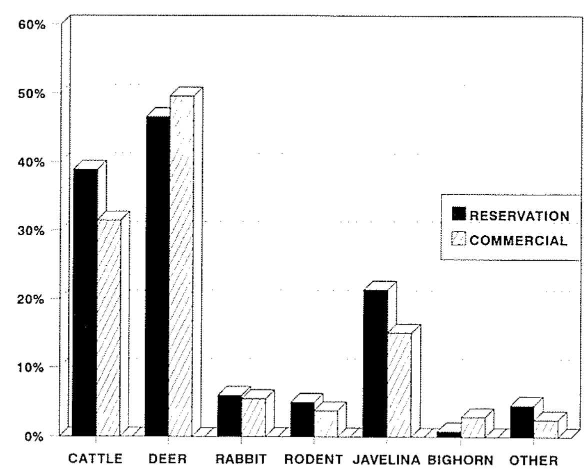


Figure 12. Frequency of occurrence of prey species in mountain lion scats on the San Carlos Indian Reservation and commercial livestock portions of the Aravaipa-Klondyke Study Area, Arizona.

Other prey—birds, badger, black bear, porcupine, and skunk—occurred in very few scats.

On a biomass basis, the diet of mountain lions was dominated by cattle (44%) and deer (40%). Javelina comprised about 11% of the biomass, and rabbits, rodents, and bighorn sheep all comprised less than 3%.

Neither the frequency of prey in scats nor its biomass proportion of the diet accurately reflected how many prey items were eaten. In terms of numbers, rabbits were the most frequently killed prey item, followed by deer, rodents, javelina, cattle, and desert bighorn, in that order (Table 13).

Table 11. Prey densities from surveys of the commercial livestock and San Carlos Indian Reservation portions of the core area, Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Location Survey	Calves (<180 kg)		Adult cattle (>180 kg)		Deer		Javelina	
	No./ km^2	95% CI	No./ km^2	95% CI	No./ km^2	95% CI	No./ km^2	95% CI
Commercial livestock portion								
Oct 1991	0.59	0.37 - 0.97	1.7	1.0 - 2.8	6.1	0.46 - 8.1	2.5	1.7 - 3.7
Apr 1992	1.2	0.85 - 1.75	5.1	4.3 - 6.0	5.5	4.3 - 7.1	2.7	1.9 - 3.7
Oct 1993	0.57	0.0002 - 2.019	1.7	0.00005 - 62.850	6.9	5.4 - 8.8	2.9	0.1 - 77.02
Apr 1993	2.0	1.6 - 2.4	4.8	4.2 - 5.5	2.7	2.1 - 3.5	0.64	0.39 - 1.0
$\bar{x}$	1.09		3.3		5.3		2.2	
San Carlos Indian Reservation								
Oct 1991	0	0 - 0	0.42	0.19 - 0.91	3.6	2.6 - 4.9	0	0 - 0
Apr 1992	2.3	0.009 - 56.5	1.8	1.2 - 2.8	2.5	1.5 - 4.1	27.5	0.28 - 2.679
Oct 1993	0.03	0.005 - 0.25	0.13	0.04 - 0.42	2.5	1.6 - 3.8	0.58	0.32 - 1.0
Apr 1993	0.05	0.027 - 0.92	1.8	1.0 - 3.3	6.3	4.3 - 9.4	0	0 - 0
$\bar{x}$	0.6		1.04		3.7			

Table 12. Mountain lion kills located on the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Species Age Class	No. (% of total)	M	F	Unknown sex	<1 yr old
White-tailed deer	16 (39)	6	8	2	0
1-3 yr		2	6	2	0
3-5 yr		4	2	0	0
5-7 yr		0	0	0	0
7+ yr		0	0	0	0
Mule deer	7 (17)	0	7	0	0
1-3 yr		0	0	0	0
3-5 yr		0	6	0	0
5-7 yr		0	1	0	0
7+ yr		0	0	0	0
Cattle	10 (24)	0	1	0	9
0-4 months (<115 kg)		0	0	0	5
5-10 months (115-200 kg)		0	0	0	4
>10 months (weaned)		0	0	0	0
Javelina	4 (10)	2	2	0	0
Desert bighorn	4 (10)	0	1	0	3

Table 13. Diet of mountain lions, based on the analysis of 370 scats, from the Aravaipa-Klondyke Study Area, Arizona, 1991-93. Percent biomass and relative number of individuals consumed by the mountain lion population are calculated according to Ackerman et al. (1984).

Prey species	(A) Frequency of occurrence (%)	(B) Estimated weight of individuals (kg)	(C) Correction factor (kg/scat)[a]	(D) Percent biomass consumed [b]	(E) Relative number of individuals consumed (%)[c]
Deer	0.48	44	3.52	40.1	16.3
Cattle	0.34	100	5.48	44.2	8.0
Javelina	0.17	20	2.68	10.9	10.0
Rabbit	0.06	1	2.02	2.9	52.7
Rodent	0.04	0.03	0.03	0.02	2.0
Desert bighorn	0.02	50	3.73	1.7	0.5

[a] Estimated weight of prey consumed per collectible scat produced, when such prey is the only item in the scat ($C = 1.98 + 0.035 B$).

[b] $D = (A \times C) / \Sigma (A \times C)$.

[c] $E = (D \div B) / \Sigma (D \div B)$.

During the spring-summer season, deer and calf (in equal frequencies) occurred in mountain lion scats much more commonly than did other items (Table 14). Rabbit and javelina occurred only about a third as frequently as either of these, and rodent and desert bighorn occurred in very few scats. During this season, cattle contributed the greatest biomass to the mountain lion diet, followed by deer, javelina, rabbits, desert bighorn, and rodents, in that order of importance. In terms of numbers, rabbits were consumed more than any other species.

In the fall-winter season, large animals as a whole were even more important than in spring and summer (Table 14). Mountain lions ate deer and javelina more frequently, and rabbits and rodents less frequently, than in spring and summer. The frequency of occurrence of calves in the fall and winter diet was similar to that in spring and summer. The number of individual deer, calves, and javelina consumed in fall and winter all increased more than 10% over that in spring and summer.

On a year-long basis, mountain lions in the commercial livestock portion of the core area ate slightly fewer deer than expected, based on deer availability, slightly more calves than expected, and javelina in proportion to their availability (Table 15). During the fall-winter season, mountain lions in the commercial livestock portion consumed fewer deer than expected but consumed calves and javelina in proportion to their availability. During the spring-summer season, all 3 species were consumed as expected based on their availability.

Based on the Ackerman et al. (1986) caloric needs model, and the prey proportions eaten by mountain lions on the AKSA (Table 15), we estimated the numbers of prey items the mountain lions would theoretically need to survive for 1 year. A resident female with 3 kittens would need 35-40 deer, 17-19 calves, 21-24 javelina, 90-100 rabbits, 20-23 rodents, and 1-2 desert bighorn sheep. A resident female without kittens would need 9-11 deer, 5-6 calves, 8-11 javelina, 7-9 rabbits, 5-7 rodents, and <1 desert bighorn sheep per year. A resident male would need 14-18 deer, 7-9 calves, 9-11 javelina, 36-46 rabbits, 8-11 rodents, and <1 bighorn sheep per year. Ackerman et al. (1986) estimated that young

Table 14. Seasonal diet based on frequency of occurrence, percent biomass, and relative numbers of individuals consumed by mountain lions in the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

	March - August (n = 82)			September - February (n = 54)		
Prey species	Frequency of occurrence (%)	Percent biomass consumed	Relative number of individuals consumed (%)	Frequency of occurrence (%)	Percent biomass consumed	Relative number of individuals consumed (%)
Deer	36.6	33.2	8.6	44.4	37.9	21.0
Cattle	36.6	51.6	5.9	33.3	44.2	10.8
Javelina	11.0	7.5	4.4	22.2	14.3	17.6
Rabbit	12.2	6.4	73.3	3.7	1.7	41.7
Rodent	4.9	0.02	7.5	1.9	0.01	8.0
Desert bighorn	1.2	1.0	0.2	1.9	1.7	0.7

Table 15. Selection of 3 prey species by mountain lions based on frequency of occurrence in mountain lion scats and proportion available as determined from prey surveys, Aravaipa-Klondyke Study Area, Arizona, 1991-93.

Season Species	Frequency of occurrence (%)	Relative number of individuals consumed (%)	Proportion of prey species available (%)	Bonferroni 95% CI	Jacobs' D[a]
Year-long diet					
Deer	48	47.3	58.0	0.41 - 0.54	-0.22
Calves (<180 kg)	34	23.2	17.8	0.18 - 0.28	0.16
Javelina	17	29.5	24.1	0.24 - 0.35	
Fall diet					
Deer	47	42.6	63.1	0.27 - 0.59	-0.40
Calves (<180 kg)	35	21.8	10.7	0.08 - 0.35	
Javelina	24	35.6	26.2	0.2 - 0.51	
Spring diet					
Deer	44	45.8	52.7	0.33 - 0.59	
Calves	44	31.2	25.8	0.19 - 0.43	
Javelina	13	22.9	21.5	0.12 - 0.34	

[a] A positive number means the item was selected for; a negative number means the item was selected against. (Range = -1.0 to +1.0)

female or male transients would consume approximately ½ the prey of a resident female without kittens.

Age Structure and Mortality

Although we captured an equal number of female and male mountain lions in the AKSA, mountain lions killed in depredation control cases were more frequently male than female (Table 16). Statewide, mountain lions killed in cattle depredation control cases since passage of the 1990 stockkiller law were also primarily males (31:15). This male:female ratio was different (X^2 = 5.790; P = 0.0161) from the more nearly equal sex ratio reported in most mountain lion studies (Anderson 1983).

Mountain lions killed in depredation cases on the AKSA also were older on average than those captured (Table 16). The mean age of captured mountain lions was 38 months, and the age of those killed in depredation cases was 54 months. In depredation cases, no lone kittens and only 1 individual ≤2 years old were killed near fresh cattle kills.

Mountain lions on the AKSA suffered high mortality (Table 17). Of the 19 radio-collared mountain lions we monitored in DH, only 4 (21%) were alive in the AKSA at the study's end (June 1, 1994). Eight (42%) were killed in depredation control cases, 1 (5%) was killed by another mountain lion, 2 (11%) were killed by sport hunters, 2 (11%) dropped their radio collars, and 2 (11%) dispersed. In the NDH subarea, of 6 mountain lions monitored, 2 were living in the AKSA as of June 1, 1994. One had emigrated, 1 was killed by another mountain lion, and 2 died in a major flood.

In the DH subarea, all of the radio-collared males that did not emigrate were eventually killed in depredation control cases, but most of the females and juveniles met other fates or survived (Table 17). The 5 radio-collared males lived from 1 to 18 months before being killed. Two of 8 radio-collared females died in depredation control cases, 1 was hunter harvested, 1 was killed by another mountain lion, 1 slipped her collar, and 3 survived as of June 1, 1994. One of 4 radio-collared juveniles was killed by a deer hunter, 1 emigrated from the AKSA, 1 slipped his radio collar, and 1 survived as of June 1, 1994.

Both of the males in the NDH subarea that we presumed to have drowned had crossed the Gila River a minimum of 4 to 10 times within 10 months based on weekly radio locations. During March 1993 a major flood occurred in the Gila River and shortly thereafter transmitters from both mountain lions began emitting mortality signals. Because of their locations it took up to 3 months to retrieve the collars. One of the collars and the partially-eaten carcass were found 1.2 m from the Gila River waterline below Coolidge Dam; the location would have been under water during flood stages. The other collar was not immediately retrievable because it was covered by the raised water in San Carlos Reservoir, but in June, when the water had receded, we found the carcass lodged with debris in trees beside the river channel. The carcass had no major abrasions or wounds that would indicate an external injury.

We originally hypothesized that mountain lions would be most likely to be killed in the spring when young calves were most available and depredation control typically increases. However, we found no clear relationship between the availability of calves and the depredation killing of mountain lions.

The annual average rate of survival of all radio-collared mountain lions on the DH portion of the AKSA was 0.55 (Table 18). Most mortality occurred in spring, and most was caused by depredation control. Sport hunting mortality occurred only during the deer hunting season. The annual average rate of survival of all radio-collared mountain lions on the NDH subarea was 0.53.

The annual average rate of survival of radio-collared male mountain lions on the DH subarea was 0.44 (Table 19). All mortalities were caused by depredation control. Females showed higher survival rates than males except during the first year of study, when the sample size of females was small (n = 2).

Seasonal trends in depredation control of mountain lions on the AKSA (Fig. 13) reflected the statewide pattern (Fig. 14). The most mortalities occurred during spring and early summer, the times we detected the highest mortality rates in radio-collared animals.

At least 3 (10%) of the 29 mountain lions captured died because of capture-related injuries. One died as a result of an overdose of Sernalyn and 1 was injured by the dogs. The third, a female, appeared in good health following capture, but analysis after her death revealed the dogs may

Table 16. Sex and age of lions captured for radio-collaring and those killed in depredation control cases in the area open to depredation control and sport hunting on the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

	Capture			Depredation		
Age	M	F	All	M	F	All
1-24 months	4	4	8	1	0	1
25-48 months	5	2	7	5	4	9
49-72 months	2	3	5	7	2	9
73-96 months	0	1	1	1	0	1
96+ months	0	1	1	2	0	2
Total	11	11	22	16	6	22
$\bar{x}$ (sd)	32.7 (21.9)	49.7 (31.4)	38.3 (29.3)	58.0 (25.4)	46.3 (10.7)	54.4 (20.5)

Table 17. Status of radio-collared mountain lions on 2 subareas of the Aravaipa-Klondyke Study Area, Arizona, as of June 1, 1994.

	Subarea DH[a]				Subarea NDH[b]			
Status or fate	Male (>1.0 yr)	Female (>1.0 yr)	Juvenile (<1.0 yr)	Total	Male (>1.0 yr)	Female (>1.0 yr)	Juvenile (<1.0 yr)	Total
Killed in capture	1	1		2	0	0	1	1
Alive as of 6/1/94	0	3	1	4	1	1		2
Dispersed	1	0	1	2	1			1
Depredation kill	6	2	0	8				
Intraspecific strife		1		1		1		1
Unknown			1	1				
Sport kill		1	1	2				
Dropped collar		1	1	2				
Accidental death					2			2
Total	8	9	5	22	4	2	1	7

[a] Subarea with depredation control and sport hunting.
[b] Subarea with no depredation control or sport hunting.

Table 18. Mean probabilities of survival and mortality by season and annually on the subarea with depredation control and sport hunting on the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

			Mortality (*P*)		
Season	Survival (*P*)	95% CI	Depredation	Intraspecific strife	Sport hunt
Calving peak (Jan-July)	0.63	0.46 - 0.86	0.33	0.05	
Fall (Aug-Oct)	0.93	0.8 - 1.0[a]	0.07		
Deer Hunt (Nov-Dec)	0.95	0.8 - 1.0[a]			0.05
Annual	0.55	0.38 - 0.8	0.35	0.05	0.05

[a] Indicates confidence interval was truncated at 1.0.

Table 19. Probabilities of survival and mortality for male and female mountain lions in the subarea of depredation control and sport hunting on the Aravaipa-Klondyke Study Area, Arizona, 1991-93.

				Mortality (*P*)		
Sex Period	No. lions	Survival (*P*)	95% CI	Depredation	Intraspecific strife	Sport hunt
M						
2/91 - 1/92	4	1.0	1.0 - 1.0			
2/92 - 1/93	4	0.12	0.01 - 0.9	0.88		
2/93 - 1/94	4	0.36	0.08 - 1.0[a]	0.64		
Overall $\bar{x}$	11	0.44	0.22 - 0.85	0.56		
F[b]						
2/91 - 1/92	2	0	0	0.5	0.5	
2/92 - 1/93	5	0.81	0.53 - 1.0[a]			0.19
1/93 - 1/94	5	0.78	0.48 - 1.0	0.22		

[a] Indicates confidence interval was truncated at 1.0.
[b] Overall survival and mortality could not be computed for females because a value of 0 was determined for 1991-92.

have caused serious internal injuries. A fourth mountain lion, a juvenile male, may have died because of capture-related trauma. It was killed by a rancher's dogs the day after we captured it, and the rancher stated that he believed it was hurt and would not have survived in any case.

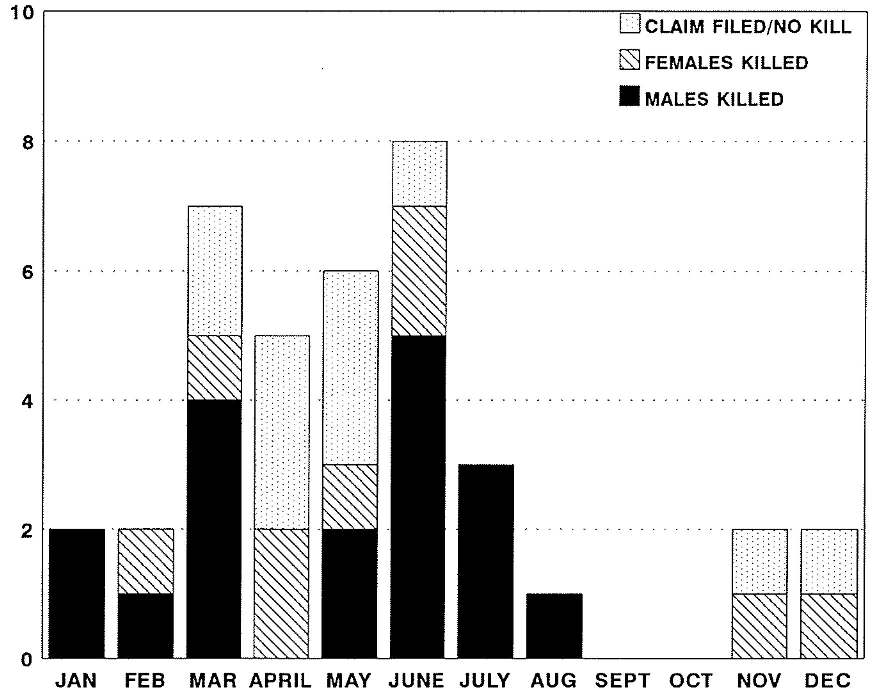


Figure 13. Seasonal trends in depredation control of mountain lions, Aravaipa-Klondyke Study Area, Arizona.

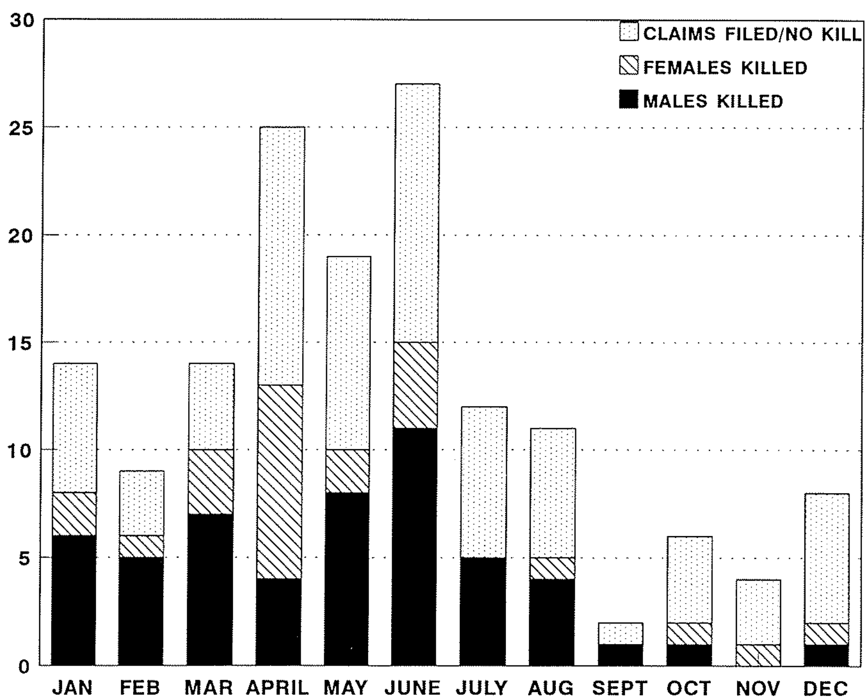


Figure 14. Seasonal trends in depredation control of mountain lions in Arizona, 1991-93.


SCHERR TUMICO

DISCUSSION

Track Surveys and Mountain Lion Density

Van Dyke et al. (1986) established that there was a positive linear relationship between mountain lion sign and density. Use of sign, specifically track counts, to estimate density has been used in California (Kutilek et al. 1983, Fitzhugh and Gorenzel 1986) and Arizona (Van Dyke et al. 1986, Shaw et al. 1988).

Results from our track surveys indicated that track sets provided a more reliable index to mountain lion density than did scrapes. Other researchers (Kutilek et al. 1983, Fitzhugh and Gorenzel 1986, Van Dyke et al. 1986, Shaw et al. 1988, Smallwood and Fitzhugh 1991) likewise used counts of track sets to index mountain lion numbers. Because scrapes are made almost exclusively by males (Shaw 1989), and because the number of scrapes made by individuals may change with mountain lion density and habitat factors (Anderson 1983, Shaw et al. 1988), the abundance of scrapes may be only weakly related to animal density. Our findings also agree with those of others (e.g., Shaw 1989, Smallwood and Fitzhugh 1993) that tracks provide more information than do scrapes about the size, age, and individual identity of mountain lions.

Using track counts to infer mountain lion density had some obvious biases. Variation in observer experience in our study led to differences in the observers' abilities to discriminate the tracks of one mountain lion from those of another. (Fitzhugh and Gorenzel [1985] propose methodologies to help reduce observer differences.) Even though we detected approximately 28% of our radio-collared mountain lions on each survey, population density, sex ratio, and age ratio, as well as different behaviors among individuals, are known to cause differences in rates of detection of individuals by tracks. Differences among survey routes in their attractiveness to mountain lions as travelways may have introduced another bias. Low precision and probable inaccuracies are inherent in the conversion of track counts to individuals per unit area (Smallwood and Fitzhugh 1991).

Results of our track surveys supported the belief of livestock operators that mountain lion densities on the AKSA were high. Our data suggested that mountain lion density was highest in the subareas used by commercial livestock operators, and that depredation control in these areas did little to reduce the annual average abundance of mountain lions. Density estimates for the subarea DH, where large proportions of the population were lost annually to depredation control and hunting, were among the highest reported for the southwestern United States (Table 20).

How a mountain lion population subject to high rates of mortality maintains its density is speculative. Interestingly, the only area in the southwest (Guadalupe Mountains-Carlsbad Caverns) where higher mountain lion densities were reported than we found on the DH subarea also experienced high annual losses to depredation control (Smith et al. 1986). Smallwood and Fitzhugh (1991) theorized that areas of superior habitat will quickly attract mountain lions from surrounding areas to fill vacancies left by the deaths of resident animals. Our data from the DH subarea of the AKSA supported this theory; indications were that immigration quickly filled vacancies left when resident mountain lions died.

Results from track surveys in combination with analyses of vegetation and topography adjacent to track survey routes indicated that mountain lion density on the AKSA was not related to vegetation type or topography. Other authors (e.g., Shaw et al. 1988, Smallwood and Fitzhugh 1991) suggest that mountain lion abundance is influenced to some extent by both vegetation and topography. At least 2 factors may account for our results. First, prey density and species richness on the AKSA may have overshadowed the effects of vegetative and topographic variables as influences on mountain lion abundance. Second, the criteria we used to classify vegetation (i.e., community classes) and topography (i.e., % slope) may have been different from the criteria that influenced mountain lions.

Home Ranges and Movements

Our radio-tracking results indicated that home ranges of adult male mountain lions were larger than those of females. This is common among mountain lions (Lindzey 1987).

Both males and females in our study had, with 1 exception, smaller same-sex home ranges than those reported elsewhere in similar habitats (Table 21). One or more of 3 characteristics of our study may have led to small home range estimates for our mountain lions: (1) high prey

Table 20. Comparison of mountain lion density estimates among several areas in the southwestern United States.

State Location (Source)	Length of study (yr)	Study area size (km^2)	Method of density estimation	km^2/lion		Lions/100 km^2	
				All lions	Resident adults	All lions	Resident adults
ARIZONA							
DH[a]	2.5	1,150	Lincoln index from track counts	37.3		2.7	
NDH[b] (This study)	2.5	1,272	Size of home range	64.7		1.6	
Spider Cross U-Ranch (Shaw 1977)	4	406	Radiotelemetry, mark-recapture		52		1.9
Kaibab Plateau (Shaw 1980)	4	5,260	Mark-recapture		148		.68
NEW MEXICO							
Carlsbad Caverns/ Guadalupe Mountains (Smith et al. 1986)	3	1,036	Size of home range	17.9	43.4	5.6	2.3
San Andres Mountains (Sweanor 1990)	4	1,935	Size of home range, mark-recapture	58.8	100	1.7	1.0
SOUTHERN CALIFORNIA							
Santa Ana Mountains (Beier & Barrett 1993)	5	2,070	Size of home range		95		1.05
NEVADA							
Ruby Mountains (Ashman 1976)	4	1,554	Mark-recapture	60-74		1.49	
UTAH							
South-central Utah (Hemker et al. 1984)	2	4,500	Size of home range		250		.3 -.5
TEXAS							
Big Bend Nat'l Park (McBride 1976)	14	2,865	Tracking, interviews	136.4		.73	
COLORADO							
Uncompahgre Plateau (Anderson et al. 1992)	4	3,120	Size of home range		90.9		1.1

[a] Subarea open to depredation control and hunting, Aravaipa-Klondyke Study Area.
[b] Subarea with no depredation control or hunting, Aravaipa-Klondyke Study Area.

Table 21. Home ranges ($\bar{x}$ MCP[a]) (km^2) of female and male mountain lions in mild, dry climates (<45 cm of precipitation/yr) in the southwestern United States.

	F				M			
Study area (Source)	No. lions	Home range (HM)[b]	$\bar{x}$ No. locations	$\bar{x}$ No. months	No. lions	Home range (HM)[b]	$\bar{x}$ No. locations	$\bar{x}$ No. months
Aravaipa-Klondyke, AZ (This study)	2	109 (164)	55	22	5	196 (249)	42	13
San Andres Mountains, NM (Sweanor 1990)	5	117 (155)	124	20	8	302 (403)	121	25
Guadalupe Mountains, NM (Smith et al. 1986)	4	59	61	16	4	207	30	15
Big Bend, TX (Pence et al. 1986)	5	143	158	14	1	628	14	15
Santa Ana Mountains, CA (Beir and Barrett 1993)	12	218	351	39	2	767	210	27

[a] Minimum convex polygon
[b] Harmonic mean

diversity and vulnerability, (2) a high exploitation rate of mountain lions, and (3) relatively small numbers of radiolocations used to plot home ranges.

A greater diversity of ungulate prey (4 species—mule deer, white-tailed deer, javelina, and cattle) existed on our study area than reported in other areas. We also suspect that the ungulate prey density in our area was high compared with that in other areas. The prey may have been relatively vulnerable because of the abundance of chaparral and other dense vegetation; some investigators (Kruuk 1986) have noted the greater efficiency of felid predation in denser vegetation.

High depredation kills of mountain lions and the resulting disruption of their social dynamics also may have influenced home range size in our study. Heavy exploitation of mountain lion populations typically allows more immigrants and local subadults to occupy an area; this may result in higher mountain lion densities and smaller home ranges (Shaw 1981, Lindzey 1987). In our study, home ranges of males on the unexploited area (NDH) were larger than home ranges of males in the exploited populations (HO and DH). In the Guadalupe Mountains (Smith et al. 1986), which had levels of human-caused mountain lion mortalities that were similar to ours, the female home ranges were smaller and the male home ranges were larger than those in our study. Small sample sizes in some of these studies, including ours, suggest caution in the interpretation of these differences.

The 1 study area (California) where both male and female home ranges were smaller than those in our study (Hopkins et al. 1986) had higher prey (deer) density than existed on AKSA and was unexploited. This suggests that prey abundance may be more influential on home range size than the degree of exploitation of the population. But even in areas with high prey densities, there seems to be a maximum mountain lion density regulated by social factors (Seidensticker et al. 1973).

The duration of radio-tracking and the numbers of radiolocations of our mountain lions were small compared with those in other radio-tracking studies of mountain lions in the Southwest. Our males were tracked the shortest amount of time ($\bar{x}$ = 13 months) of any study, and the females had the fewest locations ($\bar{x}$ = 55). Home range estimates based on radio-tracking often expand over time with changes in mountain lion age, social status, and breeding condition (Seidensticker et al. 1973, Sweanor 1990).

Despite the high kill of adult mountain lions on the AKSA, young males still emigrated. Two crossed through recently-vacated home ranges of adult males that had been killed in predator control. Similarly, Hemker et al. (1984) found that young mountain lions sometimes emigrate even if vacant home ranges are in the vicinity of their natal areas.

Prey Use

Felids are strictly carnivorous and select prey commensurate with their own body size (Kruuk 1986). Deer are the principal prey of mountain lions in many areas; cattle, except for young calves, are larger than most mountain lion prey. Prey selection is influenced by both prey availability and vulnerability (Sunquist and Sunquist 1989, Iriate et al. 1990).

Only in Arizona have mountain lions been reported to prey heavily on cattle (Tully 1991, Table 22). Most reports come from mid-elevation chaparral and pine-oak woodlands in central Arizona; few cases have been documented in high-elevation or low desert areas. In central Arizona, Shaw (1977) found cattle to comprise 37% of the mountain lion kills he found, and cattle remains occurred in 34% of the scats he analyzed; cattle kills peaked in spring.

Our density estimates of prey animals, coupled with the mountain lion dietary analyses, suggested that calves were selected by mountain lions in preference to deer. Deer density in the chaparral and in the forest vegetation types was probably higher than we estimated—the poor visibility may have hid some deer from view during helicopter surveys. If this was so, mountain lion selection for calves over deer was even greater than our calculations showed.

We postulate that mountain lions selected calves because they are more vulnerable to predation than deer. Most calves are easy to see and often are noisy; deer are cryptically colored, generally quiet, and spend most of the day hiding. Deer are more alert and wary than calves. When we followed mountain lion travel routes, we saw calves more commonly than we saw deer or javelina.

Shaw (1981) believed that increasing the deer:calf ratio may alleviate cattle predation by mountain lions. However, we believe the relative

Table 22. Percent frequency of occurrence of mountain lions prey species from studies in the southwestern United States. NA indicates the species was not present in that study area.

Study Area Year Source	Method	n	Deer	Cattle	Domestic Sheep	Javelina	Rabbit	Small Rodent	Bighorn Sheep	Carnivora[a]	Porcupine	Other[b]
ARIZONA												
Aravaipa-Klondyke 1991-93 (This study)	Scats	370	48	34	NA	17	6	4	2	1	1	1
Spider Cross U 1971-75	Scats	82	58	37	NA				NA			3
North Kaibab- winter range 1977-80	Kills	47	57	2	NA	NA	45	21	NA			
North Kaibab- summer range 1977-80 (Shaw 1981)	Scats	49	73	6	NA	NA	10		NA	6	2	
Southwestern AZ 1987-90 (Cashman et al. 1992)	Scats	159	39	13		25	8	8	7	11	2	
NEW MEXICO												
San Andreas Mtns. 1985-90 (Logan et al. 1990)	Kills	234	87.2		NA		0.4		3.9	4.7	2.1	1.7
CarlsbadCaverns/ Guadalupe Mtns. 1982-85 (Smith et al. 1986)	Scats	318	82	2	6	NA	7	3	NA		15	
CALIFORNIA												
Santa Ana Mtn. Range 1988-93	Kills	145	58.6	2.8	2.8	NA	0.7		NA	18.7	NA	13.8
(Beier and Barrett 1993)	Scats	178	53.4	3.1		NA	4.7	7.3	NA	12.9	NA	10.4
TEXAS												
Big Bend Nat. Park 1972-74	Scats	161	76.4	NA	NA	15.5	3.3	4.5	NA		6.5	3.8
1980-81 (Leopold and Krausman 1986)	Scats	272	38.6	NA	NA	38.2	13.8	4.5	NA			2.5
1984-85 (Pence et al. 1987)	Scats	548	43.2	NA	NA	38.1	7.9	0.1	NA	10.5	1.0	1.0
UTAH												
Boulder Escalante 1979-81 (Ackerman et al. 1984)	Scats	239	80.3	0.4	NA	NA	17.2	12.1	NA	4.6	0.8	5.1

[a] Prey species include mountain lion (6), skunk (5), bobcat (4), badger (4), coyote (3), racoons (5), gray fox (2), and black bear (1).

[b] Prey species include avian (3), goat (2), beaver (1), marmot (1), elk (1), opossum (1), pronghorn (1), desert tortoise (1), and gila monster (1).

vulnerability of calves is the major factor influencing predation rates, and that calves grazed within good mountain lion habitat will continue to be killed despite moderate changes in deer relative availability. In any case, changes in deer and javelina populations are probably caused by factors difficult to control by managers. This suggests that attempts to manipulate the prey base may not affect predation on calves.

We believe that mature male mountain lions, rather than females and immatures, caused most of the livestock losses. During our study females were killed in depredation control cases only during the periods when small calves were abundant, and only 1 mountain lion <24 months of age was killed in connection with a depredation case. After analyzing the results of several studies, Anderson (1983) reported that male mountain lions weighed approximately 1.4 times as much as females. Iriate et al. (1990) found that there was a positive correlation (r = 0.875) between mountain lion body size and prey size selected. These relationships support our belief.

If, in fact, mature males did most of the livestock killing in our study, then our estimates of potential livestock losses to females with kittens based on caloric needs are probably unrealistically high. A further bias might have occurred because we restricted our scat collections to scats >30mm in diameter—most of these scats might have been left by larger mountain lions, which might have preyed on a greater proportion of cattle than did smaller mountain lions.

Computations based strictly on the prey selectivity, population levels, and sex and age ratios we estimated, and the caloric needs of mountain lions, indicate that >225 calves might have been killed each year on the core area (including both the commercial livestock and San Carlos Indian Reservation portions). Conversations we had with ranchers suggested they believed livestock losses, though substantial, were not that great. Our estimates clearly indicate the potential for economic losses from mountain lion predation.

In our study area, many of the allottees have nowhere to graze their cattle except in rugged terrain with relatively dense vegetation cover. Those with sufficient flat, open pasture hold their younger calves out of rugged areas as long as possible and generally experience fewer losses to mountain lions. Those without lower pastures experience greater losses of calves to mountain lions.

Sex and Age Structure

Given the high mortality of males in the AKSA and the resulting high influx of new animals, we would have expected a younger age distribution than we found. Hopkins (1989) reported that the average ages of males and females in an unexploited population (37 and 51 months, respectively) were greater than in moderately or heavily exploited populations. Capture records in our heavily exploited population (the DH subarea) showed a similar pattern—the mean age of males was 33 months and that of females was 50 months. Males killed in depredation cases in our study averaged 54 months of age and females averaged 46 months. Capture and depredation records combined for the DH subarea showed 10 males at 25-48 months, 9 at 49-72 months, 1 at 73-96 months, and 2 >96 months. The age distributions of our mountain lions and those in 2 other areas of heavy exploitation (>10 animals killed/year) (Table 23) were not different from the age distributions of mountain lions in 3 unexploited populations (X^2 = 1.107, P = 0.7754).

Most immigrants into DH were, by definition, transients. Some researchers have found the majority of mountain lions classified as transients to be <2 years old (Hemker et al. 1984, Logan et al. 1986); some simply classed them as "young" (Hornocker 1970, Siedensticker et al. 1973). From review of the literature and her own data, Sweanor (1990:138) stated: "It is apparent that most transient behavior occurs between independence and 2 years of age, when mountain lions are dispersing subadults. The length of time a subadult remains a transient may depend on the availability of sufficient space and food resources."

Several researchers have found that vacant territories are quickly filled by young transients (Hornocker 1970, Siedensticker et al. 1973, Sweanor 1990). Although the age distribution of our mountain lions showed that some vacant territories were probably filled by animals that fit the conventional definition of a transient (Sweanor 1990), some were filled by animals older than expected. For example, 9 months after the death of M2, a 5-year-old male we monitored for 12 months, we captured a 6-year-old male within his former home range; he apparently had resided there since shortly after M2's death. This new

Table 23 . Comparison of age distributions[a] reported for exploited and unexploited lion populations in the southwestern United States.

Population status Location and period Data source	Age class (months)				
	0-24	25-48	49-72	73-96	97+
Exploited					
Aravaipa-Klondyke, AZ, 1991-93					
Capture records	10	6	5	1	1
Depredation records	1	11	8	3	0
San Andres Mtns., NM, 1980-84 (A. Fisher, NM Dep. of Game & Fish, pers. commun).	13	7	10	6	2
Guadalupe Mtns. NM, 1982-85 (Smith et al. 1986)	9	5	8	0	0
Total	32	30	31	10	3
Unexploited					
Uncompahgre Plateau, CO, 1981-88 (Anderson et al. 1992)	27	9	2	1	0
Diablo Range, CA, 1985-88 (Hopkins 1989)	10	2	7	3	2
San Andres Mtns., NM, 1985-88 (Logan et al. 1990)	36	11	6	1	0
Total	73	22	15	5	2

[a] Difference in age classes between exploited and unexploited populations as determined from Chi Square Contingency Table: $X^2 = 1.107$ df = 3 $P = 0.7754$. The 0-24 month age class was not used in the analysis due to possible differences in efforts to catch yearlings and/or kittens.

Calves were killed and eaten by mountain lions more than expected based on availability.

male was killed in a depredation control case less than 1 month after his initial capture. Within 2 weeks of his death we noticed sign from yet another new, larger male, which we never captured but believe was the same 7-year-old male killed in a depredation control case within 5 months. Based on previous research, we would have expected 6- and 7-year-old males to have stable territories elsewhere and thus not move into newly-vacated territories.

Some of our mountain lions apparently did not find a permanent home range until >4 years of age. Mountain lion DM2 was captured and aged at 4 years on NDH in January 1992. In March, DM2 left and moved 100 km northeast toward the Sierra Anchas Mountains. One week after he emigrated, we captured M5, an 8-yr-old male with severe fighting injuries, adjacent to where we had captured DM2. We suspected M5 may have fought with DM2 and pushed him out of the territory. DM2 stayed in the Roosevelt Lake area for 1 year, and then was located just north of NDH; his radio collar failed shortly after this movement, but he had failed to establish a permanent territory at >5 years of age. In December 1992 we captured DM4 (a 3-yr-old male) in DH. He resided in the same general area for 9 months before leaving for the Pinaleño Mountains, 70 km away and resided there until monitoring stopped in June 1994. We were unable to speculate why he left an established territory. R. Ockenfels and W. K. Carrel (Ariz. Game and Fish Dep., pers. commun.) observed similar behavior in a Mazatzal Mountains male originally aged 3-4 years that kept shifting his area of residence the following 6 years.

None of the 7 mountain lions captured in the unexploited area (NDH) moved to vacated territories in the adjacent DH during our study. The older average ages and the restricted movements of mountain lions in NDH indicated permanent residency. The source of immigrants to DH could have been the nearby southern Galiuro Mountains, where we radiocollared no mountain lions.

Hornocker (1970), Siedensticker et al. (1973), Logan et al. (1986), Spreadbury (1989), and Sweanor (1990) documented shifting of home ranges of adults that were originally described as residents. Because of the continued exploitation of mountain lions in our DH subarea, shifting of adjacent residents would have had to be historically continuous. We do not believe this explanation accounts for all of the older mountain lions we captured or that were killed in depredation control in the AKSA. For example, many transients could be >2-3 years old before establishing a territory.

Survival and Mortality

Survival for dispersers has been largely unstudied. Probability of survival for mountain lion kittens has been estimated to be between 0.52-0.78 (Anderson 1983, Ashman et al. 1983, Hemker et al. 1986, Beier and Barrett 1993), but only Beier and Barrett (1993) have examined survivability of dispersers. None of the 3 dispersers we monitored died during our study.

In unhunted mountain lion populations, juvenile survival is suppressed because suitable vacant habitat is scarce (Siedensticker et al. 1973). Adult survival rates are high, and thus there often are high proportions of relatively old adults (Hopkins 1989). The large annual mortality of adults on the AKSA, by leaving vacancies, might have contributed to the high survival of dispersers.

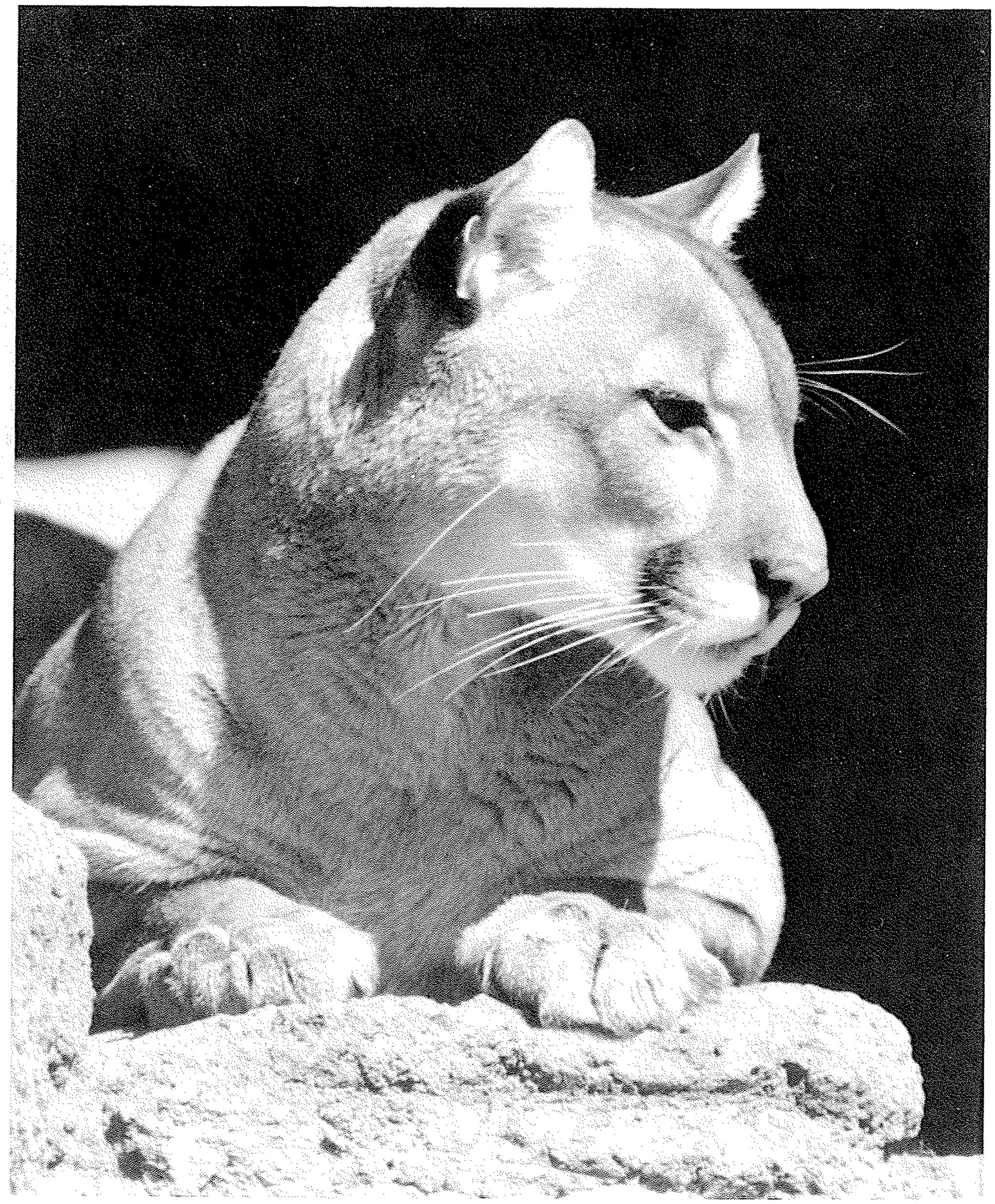
Studies in other places generally found higher rates of mountain lion survival than the 55% annual average we documented. In unhunted populations in southern Utah, Lindzey et al. (1988) reported annual adult survival rates of 52-100% ($\bar{x}$ = 74%). In southern California, Beier and Barrett (1993) estimated annual survival of adults to be 75% and that for juveniles to be 52%. In Colorado, Anderson et al. (1992) reported an adult survival rate of 88%.

Human-caused mortality on the DH subarea was very high compared with human-caused and natural mortalities that other studies have reported. Anderson (1983) reviewed many studies and reported none that found mortality rates higher than ours. Ten of the 11 documented mortalities on the DH subarea in our study were caused by humans. Sweanor (1990) reported that only 6.3% of the mountain lion deaths in a relatively isolated population were human-induced.

Curiously, the mountain lion survival rate in our DH subarea was not much lower than it was in the NDH subarea. Our small sample sizes may have given an inaccurate representation of the true mortality rate in NDH. The 2 NDH individuals that apparently drowned greatly reduced the measured survival rates in NDH, but drowning may be relatively uncommon.

Considerable immigration must occur to sustain the DH population. This area seemed to attract mountain lions of all ages, so much so that continued removal had little or no numerical effect. There are no obvious barriers to immigration of mountain lions within 100 km of the AKSA (Fig. 15), making it accessible to mountain lions from a large area.

What effect intensive mountain lion removal in high-quality habitat has on mountain lion numbers in adjacent, lower-quality habitat is unknown. Because mountain lions reproduce rapidly and young ones may move long distances before setting up residency, it may be impossible to measure the regional effect of locally high exploitation. At present, areas of high mountain lion removal, such as the Aravaipa watershed, are rare and fairly localized. Although mountain lion harvest data suggest no recent statewide declines in mountain lion abundance (J. Phelps, Ariz. Game and Fish Dep., pers. commun.) local declines in areas adjacent to areas of high mountain lion removal (such as HO) seem plausible.



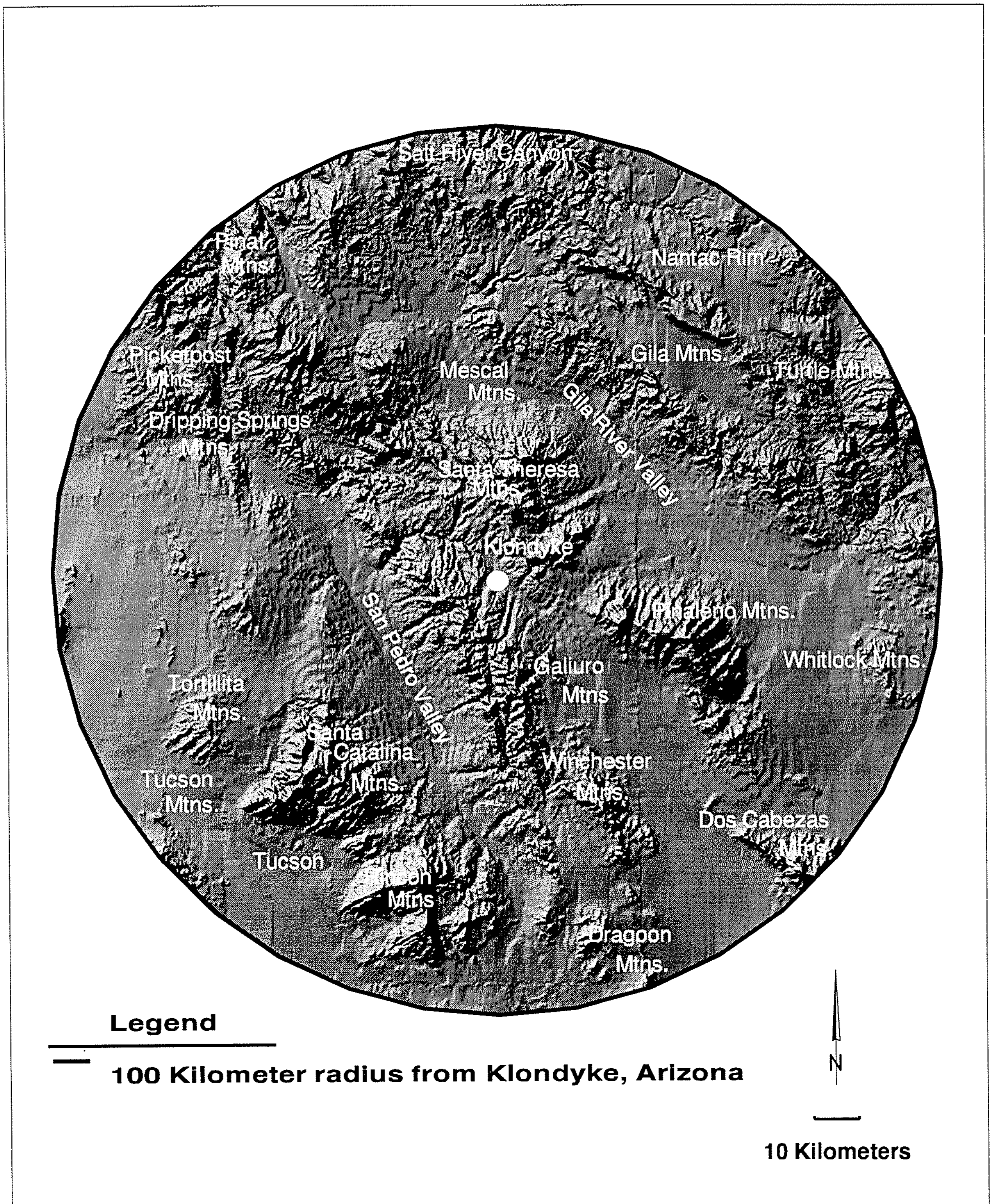


Figure 15. Landscape surface features (Digital Elevation Model) within a 100-km radius of Klondyke, Arizona.

Using mules to look for mountain lion scat in Aravaipa Canyon, Arizona.

CONCLUSIONS

Results from this study led to several conclusions, as follows:

1. Counts of track sets provided a more reliable index to mountain lion density than did counts of scrapes and other sign. Use of track counts has some inherent biases that partly can be overcome by understanding the sources of bias and designing surveys accordingly.

2. Mountain lion density on the Aravaipa-Klondyke area, as estimated from track surveys, was higher than densities reported elsewhere in Arizona. Density remained high despite annual removal of substantial proportions of the mountain lion population.

3. Mountain lion density estimates based on track counts were not correlated with vegetation type or percent slope of the landscape.

4. Immigration of mountain lions from surrounding areas apparently was the primary mechanism by which high densities were maintained despite attrition. Immigrants were on average older than we anticipated based on the results of other studies.

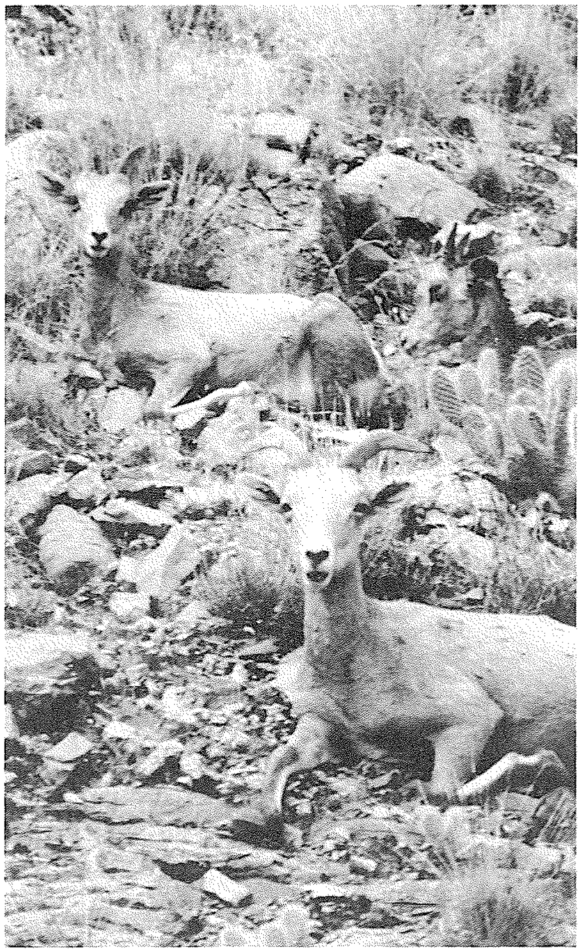
5. Home ranges of adult male mountain lions were larger than those of females. Home ranges of both males and females averaged smaller than those reported in most other localities and similar habitats. Reasons for this are speculative.

6. Mountain lions selected calves over deer as prey in the Aravaipa-Klondyke area, probably because calves were more vulnerable to predation. Moderate increases in the deer population are unlikely to cause appreciable reductions in mountain lion predation on calves.

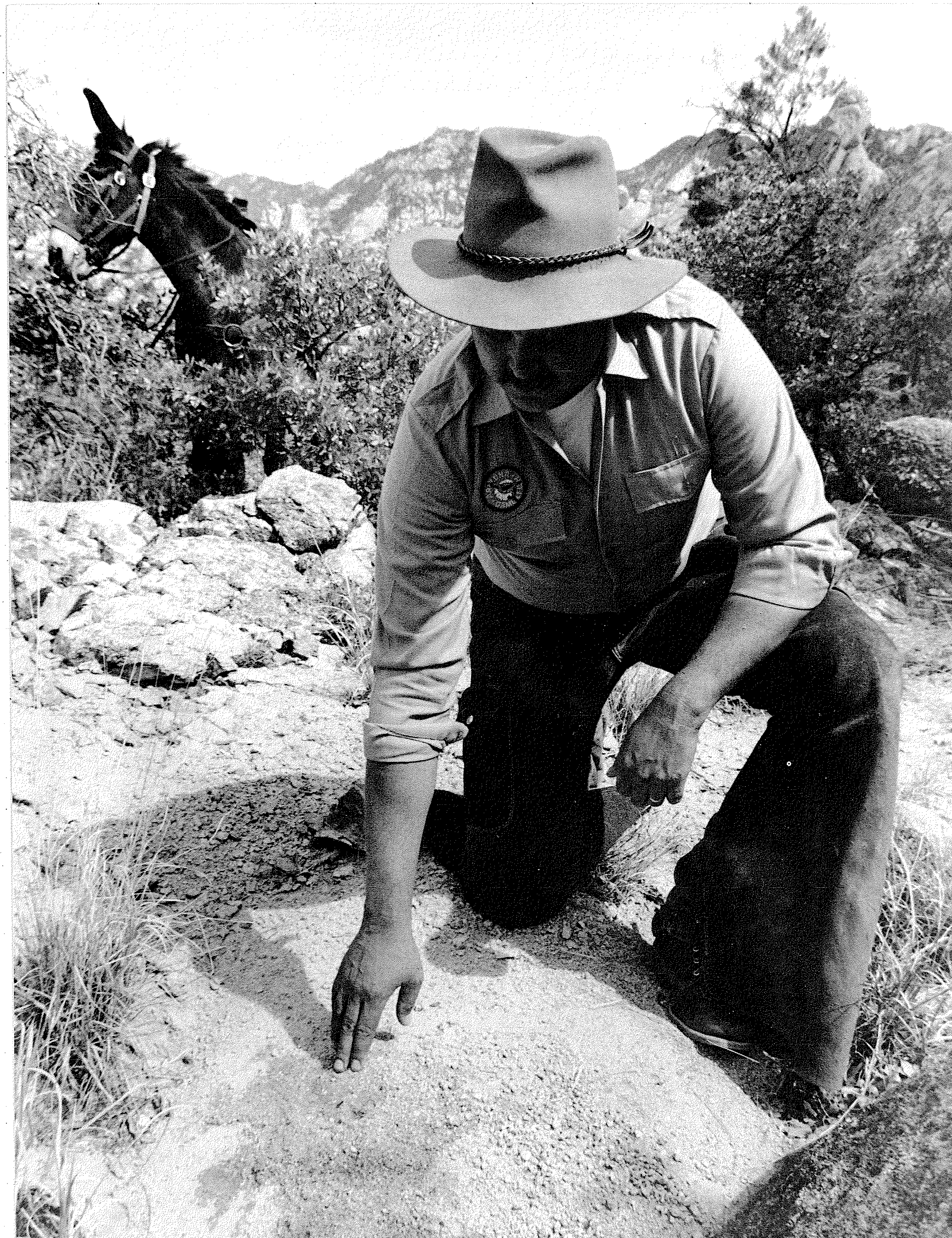
7. The principle wildlife prey of mountain lions has fluctuated considerably during the last century. During the last 13 years in the Aravaipa-Klondyke area, a slight decline in deer and javelina numbers occurred.

8. Mountain lion predation is responsible for the loss of some cattle, mainly calves, in the Aravaipa-Klondyke area. Impacts are greatest on allotments where cows with young calves inhabit steep and densely vegetated terrain.

9. Killing depredating mountain lions in localized areas will reduce calf losses in the short term (months) but probably not in the longer term (years). Immigration of mountain lions into good-quality habitat will ensure continued cattle depredation in these habitats despite control efforts. It may also cause a localized reduction in mountain lion numbers in adjacent habitats.



Desert bighorn sheep were not preyed upon heavily by mountain lions in the Aravaipa-Klondyke Study Area, Arizona.



MANAGEMENT AND RESEARCH IMPLICATIONS

Management Options

Track surveys are the least expensive way to index mountain lion density. If surveys were standardized and biases reduced, they could become an effective management tool. Other studies and ours suggest precautions in setting up track count surveys.

Smallwood and Fitzhugh (1991) described a theoretical source-sink efficiency concept that could affect track survey sampling design. They defined source strata as areas of superior habitat, and postulated that the population in a source area will almost always be constant because as individuals are removed, new individuals will immigrate. Sink strata are areas of inferior habitat, and population levels in such areas may be so low that sampling would be inefficient. They recommend censusing in areas of medium density, because these areas would be optimal for monitoring trends.

Results from our surveys suggest the presence of source and sink strata on the AKSA. In DH, over 33% of the estimated population died in <6 months, but we found no detectable change in survey indices. We would characterize DH as a source area as defined by Smallwood and Fitzhugh (1991). In HO, a possible sink area, our surveys yielded too little sign to estimate population size.

Results of our study suggest that variability in track survey indices is potentially large enough to mask substantial changes in mountain lion populations. To assess the nature of this variability, we recommend repeated surveys on the same routes over several years. Lag autocorrelated procedures, in combination with multiple regression trend predictors, then could be used to help sort normal variability from that caused by population changes.

We recommend the following procedures:

1. Use tracks as the primary sign for comparisons among times or areas. Conduct intensive training programs for inexperienced personnel. Have new trainees trace tracks they encounter to better learn to discriminate individual animals.

2. Estimate numbers of mountain lions per route. A decision matrix would help standardize how these estimates are made.

3. Avoid placing track survey routes only in the best mountain lion habitat. Results of this study suggest that good-quality habitats can be heavily harvested and still exhibit high track count indices.

4. Establish permanent routes and distribute them systematically among mountain lion habitat types. Route lengths and distances between routes should be standardized to the extent possible.

Research Priorities

New research to help reduce livestock losses to mountain lion predation is needed. We discuss the potential for study of 4 topics to this end: (1) test alternative livestock and range management options, (2) develop a mountain lion habitat model, (3) test the effects of altering wildlife prey populations, and (4) evaluate taste aversion.

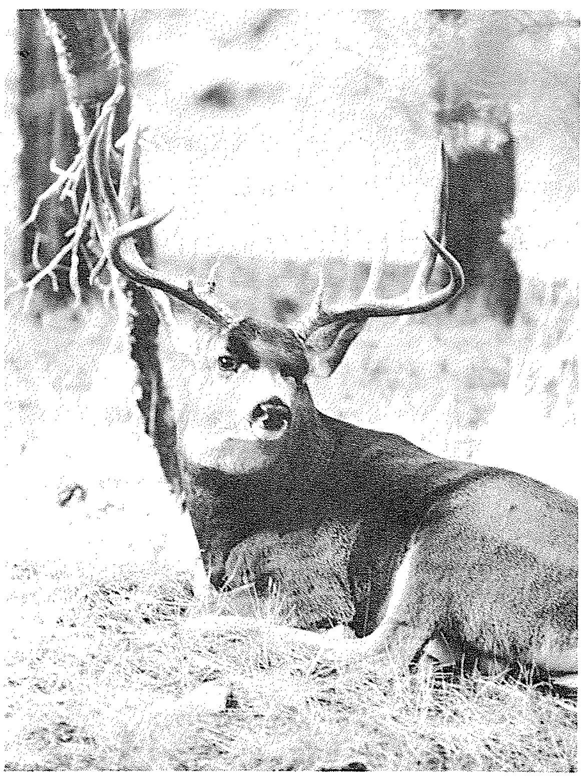
1. *Alternative Livestock and Range Management Options.* Several recommendations for managing cattle to reduce mountain lion predation in Arizona have been made (Shaw 1977, Shaw et al. 1988): (1) minimize the period of the year during which calves are born, (2) time calving to coincide with the deer fawning period, (3) move cows with small calves to poor mountain lion habitat, (4) convert cow-calf operations to steer operations, and/or (5) use cattle breeds less susceptible to predation.

   Testing the effects of some range management options also may be useful. Ranches with little or no open, level range for calving frequently report the highest losses. Most of their grazing area is rocky slopes vegetated by mesquite and/or chaparral. Prescribed burning, chaining, and other ways of removing brush and increasing visibility may improve calf survival and these should be studied. Testing livestock and range management options will require long-term (>10 yr) control of ranch management by the researchers.

2. *Develop a Mountain Lion Habitat Model.* A habitat rating system could be developed to help define areas where young calves are at risk from mountain lion predation. This rating system could be useful to land management agencies as well as ranchers. Information about mountain lion habitat selection among a broad array of habitat types in Arizona would be necessary.

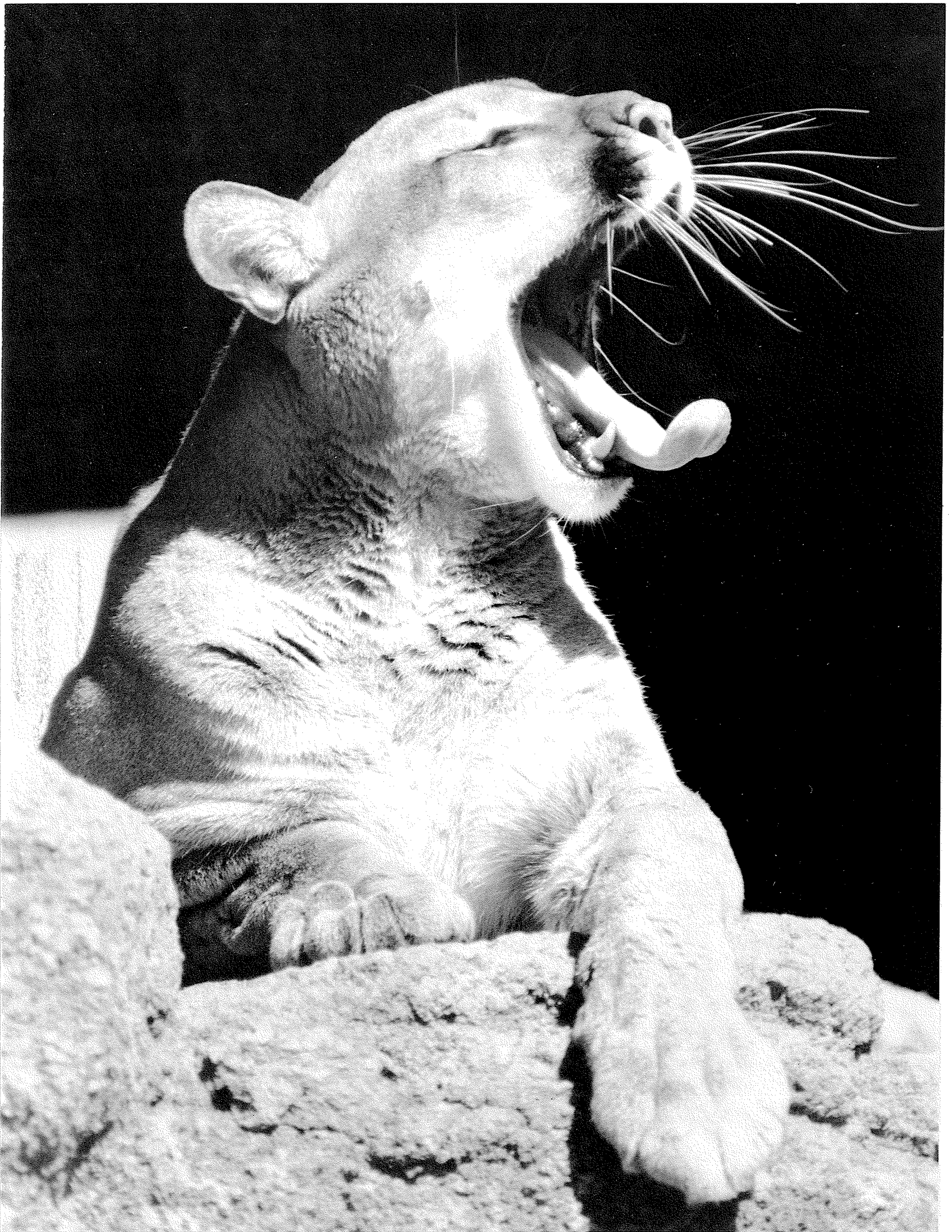
3. *Evaluate the Effectiveness of Altering Prey Availability.* Opportunities to experimentally alter prey abundance within a local area to examine its effect upon cattle predation are limited. Substantial increases in prey numbers would be needed to conduct useful evaluations, and this is probably beyond the current capabilities of wildlife or habitat managers.

4. *Evaluate Taste Aversion.* The scientific literature contains little information on the use of aversive training to reduce predation by felids. Gustavson et al. (1974, 1975, 1976) and Gustavson (1977) reported that aversion compounds may cause bobcats to avoid some foods. Their findings are consistent with observations made on aversive conditioning in coyotes and wolves (Gustavson et al. 1982, Gustavson 1983). The major problem with aversive conditioning in felids is inducing the animals to consume baits containing aversion compounds. We recommend field experimentation to determine (1) the conditions under which mountain lions will take bait and (2) whether aversive conditioning reduces calf predation.



Deer were not killed and eaten by mountain lions as much as expected based on availability.

Javelina were killed and eaten as expected based on availability.



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Appendix 1. Age at capture, number of locations, period of time monitored, and final status of each mountain lion captured on the Aravaipa-Klondyke Lion Study Area, Arizona, 1991-93. A, B, and C refer to lions that were alive and radio-collared on the dates indicated.

Lion No.	Age at capture[a]	No. of locations	Monitored period	12/91 group	7/92 group	4/93 group	Status
M1[b]	2 yr	43	2/91 - 2/92	A			Depredation kill
F10	1 yr	1	2/91 - 3/91				Lion kill
F11	2 yr	11	3/91 - 5/91				Depredation kill
M2[b]	5 yr	44	3/91 - 3/92	A			Depredation kill
KM1	3 mo	23	12/91 - 6/92	A			Dropped collar
KF2	3 mo	17	12/91 - 4/92				Dropped collar
M8	3 yr	1	3/91				Capture mortality
M3[b]	3 yr	52	12/91 - 5/93	A	B	C	Depredation kill
DM1[b]	2.5 yr	36	4/91 - 2/92	A			Depredation kill
F1	4 yr	31	12/91 - 8/92	A	B		Lion kill
DM2	4 yr	26	1/92 - 12/93				Left study area
F12	4 yr	1	1/92				Capture mortality
F2[b]	6 yr	59	1/92 - 12/93		B	C	Alive
F3	5 yr	6	1/92 - 3/92				Dropped collar
F4[b]	9 yr	5	2/92 - 12/93		B	C	Alive
M4[b]	7 yr	36	2/92 - 3/93		B		Drowned
M5	8 yr	34	3/92 - 3/93		B		Drowned
M9	8 mo	1	4/92				Unknown mort.
F5	7 yr	9	11/92 - 4/93				Depredation kill
M6	4 yr	16	11/92 - 8/93			C	Depredation kill
F6	2 yr	23	11/92 - 12/93			C	Alive
DM3	8 mo	22	11/93 - 12/93			C	Left study area
F7	8 mo	21	11/92 - 12/93			C	Alive
M10	6 yr	1	12/92 - 1/93				Depredation kill
DM4	3 yr	14	12/92 - 12/93			C	Left study area
F8	5 yr	19	12/92 - 12/93			C	Alive
M7	6 yr	17	1/93 - 12/93			C	Alive
M11	1 yr	1	2/93				Capture mortality
F9	8 yr	18	2/93 - 12/93			C	Alive

[a] Ages are approximate based on field-aging techniques (Ashman et al. 1983).

[b] Mountain lions whose home range sizes were calculated.

Cunningham, S. C., L. A. Haynes, C. Gustavson, and D. D. Haywood. 1995. **Evaluation of the Interaction between Mountain Lions and Cattle in the Aravaipa-Klondyke Area of Southeast Arizona.** Arizona Game and Fish Dep. Tech. Rep. 17, Phoenix. 64pp.

Abstract: We investigated the ecology of mountain lions (*Felis concolor*) from February 1991 to September 1993 near Klondyke, Arizona, with respect to prey selection and the effects of predation on commercial cattle operations. We found that mountain lion track surveys have value in comparing lion density among areas despite some inherent biases. Mountain lion track survey indices from our study area were higher than any recorded elsewhere in the state. During our study, mountain lions selected deer (*Odocoileus* spp.) less frequently than their availability would suggest, selected calves slightly more than their availability, and took javelina (*Tayassu tajacu*) as expected. We speculate that lions selected calves because they were more vulnerable to predation than deer. Radio-collared mountain lions in our study experienced the lowest overall annual survival rate (0.55) found on any lion study; depredation control was the leading cause of mortality. Male mountain lions were more likely to be killed in depredation cases than females. Mountain lion populations and predation on calves remained high despite losses of substantial numbers of mountain lions to depredation control. The sex ratio within our study population was almost even, and mountain lion age structure was similar to that reported in unexploited populations.

Key words: Age ratio, cattle, depredation control, diet, emigration, home range, immigration, mortality, mountain lion, sex ratio, southeastern Arizona, track survey.

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Layout, design, and typesetting by Vicki L. Webb
Photos by:
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Stan Cunningham (Pages 52, 53)
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ARIZONA
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WILDLIFE RESTORATION

Federal Aid Project
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hunting equipment