PREDATION

CHAIR: TOM RYDER, WYOMING GAME AND FISH DEPARTMENT

ERIC M. ROMINGER - BIOLOGICAL EXTINCTION AND A TEST OF THE "CONSPICUOUS INDIVIDUAL HYPOTHESIS" IN THE SAN ANDRES MOUNTAINS, NEW MEXICO.

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Abstract: The desert bighorn sheep (*Ovis canadensis mexicana*) population in the San Andres Mountains (SAM) was once the largest herd of desert bighorn in the Chihuahuan desert ecosystem. This herd has apparently declined from an estimate of >200 individuals in 1978, to a single known ewe. The decline occurred in 2 distinct phases separated by 18 years. The initial decline to <40 bighorn occurred between 1978 and 1980, and was associated with a psoroptic mite (*Psoroptes ovis*) epizootic and a series of capture and treatment operations. Between 1996 and 1997, the herd declined from a minimum known population of 25 to a minimum known population of 1 ewe. During a 15-month period, 90% (9 of 10) of the radiocollared bighorn died and 6 were killed by mountain lions (*Puma concolor*). Associated with this increased lion predation was an extended drought, continued infestation of bighorn by psoroptic mites, and a rapid decrease in the number of mule deer (*Odocoileus hemionus crooki*), the principal prey of mountain lions in the SAM. Despite intensive search effort, no uncollared bighorn sheep have been documented since 1997. Our inability to document any uncollared bighorn suggests that the mortality rate of this portion of the population was at least equivalent to that of radiocollared bighorn. These data are a single, within-population-scale test of the hypothesis that higher mortality occurs on radiocollared ungulates because they are "conspicuous individuals." We also present data that suggest this hypothesis is untrue at a multi-population scale. Additionally, we review high mountain lion predation in other New Mexico desert bighorn sheep herds unaffected by scabies.

In New Mexico, all native bighorn sheep (*Ovis canadensis*), with the exception of two remnant populations in the San Andres and Big Hatchet Mountains, were extirpated by 1955 (NMDGF 1995). However, the exact causes of extirpation in >20 other herds known to occur were never documented. These extirpations were largely attributed to factors that are thought to have caused declines of bighorn sheep throughout western North America including disease, market hunting, and competition with large numbers of domestic livestock (Buechner 1960).

Desert bighorn (*O. c. mexicana*) in New Mexico were state-listed as an endangered species in 1980 (NMDGF 1995). The statewide population estimate, excluding the SAM, has increased from <15 in 1979 (Watts 1979) to 220 in 1998 (Rominger 1999). The desert bighorn sheep herd in the SAM was, until 1978, the largest herd in New Mexico and the largest in the Chihuahuan desert ecosystem (Sandoval 1979). The highest number of bighorn observed in the SAM was 119 in 1976 (Sandoval 1979) and the largest population estimates, although conjecture, were 200-400 (Buechner 1960).

The SAM population declined from an estimated 200 bighorn to <40 subsequent to a virulent

scabies epizootic in 1978 (Sandoval 1980) and a series of treatment operations from 1979-1983 (Lange et al. 1980, Sandoval 1981, Wright et al. 1981, Kinzer et al. 1983). Hoban (1990) reviewed the initial phase of this decline. Although the population remained relatively stable for 15 years following the decline, a sudden increase in adult mortality beginning in the winter of 1996 apparently has resulted in the biological extinction of this herd.

Predator/prey theory suggests that large populations of ungulates are relatively unaffected by pre-dation, even in ecosystems with a full complement of predators (Mech 1970). However, small or isolated populations of ungulates can be vulnerable to predation resulting in population decline or extinction (Murie 1944, Bergerud 1971, Mech and Karns 1977, Seip 1992, Wehausen 1996, Hurd and Bunnell 1999, Harrington et al. 1999). This phenomenon is more common where predators are able to switch to alternate ungulate species as numbers of the more rare species decline (Seip 1992, Hurd and Bunnell 1999, Harrington et al. 1999). This has been documented in numerous predator/prey systems including the caribou (*Rangifer tarandus*)-moose (*Alces alces*)-wolf (*Canis lupus*) system in British Columbia (Seip 1992), the moose-elk (*Cervus elaphus*)-wolf system in Alberta (Hurd and Bunnell 1999), the roan antelope (*Hippotragus equinus*)-zebra (*Equus zebra*)/wildebeest (*Connochaetes taurinus*)-lion (*Panthera leo*) system in South Africa (Harrington et al. 1999) and the bighorn sheep-mule deer-mountain lion system in California (Wehausen pers. commun.). Recent research suggests that individual mountain lions may have impacts on bighorn populations that are independent of mountain lion population density (Hoban 1990, Chow 1991, Logan et al. 1996, Ross et al. 1997).

Small populations of bighorn sheep have higher probabilities of extinction due to greater influences of inbreeding and stochastic events including predation, disease, weather, and variable nutrition (Berger 1990, Wehausen 1999, Berger 1999). These data, for the SAM desert bighorn sheep population, document a rare instance where cause of mortality was determined for ~40% of the population during the extinction phase.

It is hypothesized that radiocollared bighorn sheep are subject to higher rates of mortality, particularly predation, because they are "conspicuous individuals" (*sensu* Curio 1976:117) and therefore more visible. Without intensive monitoring of all predators, to determine the presence or absence of radiocollars on all animals that are preyed upon, or comparison of mortality rates on animals with inconspicuous radio-devices to those on radiocollared animals (*sensu* Garrott et al. 1985) this is nearly an untestable hypothesis. However, the extinction, or in this case the apparent biological extinction, of a bighorn population with a proportion of radiocollared animals enables a comparison of mortality rates between radiocollared and uncollared animals. The apparent biological extinction in the SAM is a single population-scale test of the "conspicuous individual" hypothesis. In addition, population trend data from annual helicopter surveys in desert bighorn herds where a high percentage of the population was radiocollared are compared to trends in populations with few or no radiocollars as a multi-population-scale test of this hypothesis.

The objectives of this manuscript are to (1) document the extinction phase of the SAM desert bighorn population and (2) compare mortality rates of bighorn sheep with radiocollars to apparent mortality rates of bighorn without radiocollars within the SAM population and population trends of desert bighorn herds with different percentages of radiocollared individuals in New Mexico.

Study Area: The SAM, in southcentral New Mexico, are 130 km in length and the largest contiguous bighorn sheep habitat in New Mexico. Elevations range from 1,280 m at the base of the mountains in the Journada del Muerto to 2,733 m at Salinas Peak. The SAM lie entirely within White Sands Missile Range (WSMR) which is managed by the U.S. Army. Within the SAM is the 232 km^2 San Andres National Wildlife Refuge (SANWR) managed by the U.S. Fish and Wildlife Service

(USFWS). Plant communities are dominated by grass-shrublands at lower elevations and pinyon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) at higher elevations (USFWS 1998).

Population trends for desert bighorn sheep herds in the Peloncillo and Hatchet mountains in southwest New Mexico, the Ladron Mountains 70 km southwest of Albuquerque, and Fra Cristobal Mountains in central New Mexico are also reported during 1996-1997.

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Methods: In 1993, 11 bighorn sheep (3 males and 8 females) were captured and radiocollared (Telonics, Mesa, AZ) using a helicopter and net-gun. In April 1997, the only 2 known bighorn in the SAM were recaptured using a helicopter and net-gun and fitted with new radiocollars to maintain telemetric contact.

For 1995-1997, population estimates for SAM bighorn sheep were derived from annual helicopter and ground surveys. In 1996, 3 helicopters were used simultaneously to survey the entire mountain range from San Agustin Pass north to Capitol Peak. Helicopter surveys were initially flown without the use of telemetry and then reflown using telemetry to attempt to obtain a visual observation of radiocollared bighorn and any associated bighorn. Observation rates of bighorn sheep are based on the number of bighorn observed/hr of search time without telemetry. Numbers of mule deer were recorded during bighorn surveys and are reported as deer/hr as an index of deer numbers seen in bighorn sheep habitat.

Remote census 8 mm video cameras were placed at 3 water sources most likely to be visited by bighorn sheep during summer (Upper Ash Spring, Five Rams Spring, and an unnamed spring on Bennett Mountain). Since the apparent decline of the SAM population to 1 ewe, visual monitoring of this radiocollared ewe was conducted in an attempt to document the presence of a lamb or associated bighorn sheep.

Monitoring of radiocollared desert bighorn sheep in the SAM was conducted at least weekly and mortalities were investigated between 2 and 4 weeks after death. In the other mountain ranges, radiocollars were monitored in monthly fixed wing flights, annual helicopter surveys, and at least weekly in the Peloncillo Mountains. A combination of methods or observations were used to determine lion kills and included: lion tracks scrapes and/or scat at the cache site, multiple cache sites, sticks and rocks covering the carcass, drag marks, canine punctures on the radiocollar, neck/throat or head, the size of lion dental arcades, uneaten rumen, rumen removed from the carcass, blood patterns indicative of arterial pressure at time of death, cracked brain cases in ewes, and the rostrum eaten >10 cm. We recognize that the possibility of a lion scavenging on a dead bighorn would have resulted in some of the above listed variables.

The mortality rate documented for radiocollared bighorn was compared with the assumed mortality in the uncollared portion of the population as a single within-population test of the hypothesis that radiocollared bighorn are subjected to higher rates of mortality than are uncollared bighorn. A multi-population-scale test of this hypothesis was conducted by monitoring population trends in other bighorn populations with different proportions of radiocollared bighorn sheep. These include bighorn in the Ladron and Fra Cristobal mountains, where 100% of transplanted bighorn were radio-collared (n=60) or collared with

neckbands (n=8), and the Peloncillo (n=2) and Hatchet mountains (n=0) where <5% and 0% of bighorn, respectively, were radiocollared during 1996-1997.

Results - San Andres Herd: Desert bighorn sheep numbers in the SAM were at historic highs between 1960 and 1978, prior to declining to fewer than 40 individuals as a result of the psoroptic scabies epizootic and subsequent salvage operation (Fig. 1). From 1980-1995, the causes of mortalities of 52 radiocollared bighorn were determined (Fig. 2), and although mountain lion predation was the principal mortality factor the bighorn population remained relatively stable.

During the second phase of this apparent biological extinction (1996-1997), an increase in mountain lion predation resulted in at least 6 of 9 radiocollared bighorn sheep mortalities in a 15 month period (Fig 3). The remaining radiocollared ewe is the only bighorn sheep known in the SAM since August 1997. Four bighorn sheep kills occurred within the potential home-range of 1 mountain lion and the other 2 kills were within the potential home-range of a second mountain lion. However, because of the relatively high degree of home range overlap by mountain lions in the San Andres Mountains (Logan et al. 1996) more than 2 lions may have killed these bighorn sheep.

As of April 1999, the 3 remote video cameras had not recorded any bighorn sheep, nor has the ewe been observed with other bighorn or a lamb through 3 lambing seasons (1997-1999). Observation rates of bighorn sheep during helicopter censuses have declined from 70.1/hr (Sandoval 1979) prior to the scabies epizootic, to <0.2/hr in 1997.

Other factors that may have influenced the rapid extinction of this herd include 3 years (1994-1996) with below average precipitation (Fig. 4). In addition, there is evidence that the mule deer population also decreased substantially during this period of drought. The observation rate of deer during bighorn helicopter surveys declined from 17.0/hr in 1995 to 2.7/hr in 1997 (Fig. 5). In the 1982 (15.6 hrs count time) and 1996 (15.0 hrs count time) the entire SAM was censused for desert bighorn by helicopter. Deer observation rates were 8.7/hr in 1982 and 3.2 /hr in 1996 (NMDGF, files). Other recent contributors to the overall population decline of desert bighorn have been a small, senescent population, the ongoing effects of the scabies epizootic, and poor reproduction. There was no known recruitment into the SAM bighorn population from 1995-1999. Radiocollared bighorn comprised approximately 42% (11/25) of the estimated population in 1995.

During the 15-month period of rapid decline between 1996-1997, 90% of the radiocollared bighorn sheep died. Because no uncollared bighorn sheep have been observed in more than 3 years using multiple means of detection, i.e., helicopter surveys, remote video cameras, and observation of the extant ewe, it is assumed that 100% mortality has occurred on the uncollared portion of the population. Mean age of the last 9 bighorn sheep that died was 9.9 years (SD=2.7) and the mean age of lion killed bighorn was 8.8 years (SD=2.0).

Mortality in other herds: All bighorn sheep transplanted to the Fra Cristobal Mountains (n=37) were radiocollared and 23 of 31 (74%) bighorn transplanted to the Ladron Mountains were radiocollared, with the other 8 fitted with neckbands (Fig. 6). Between 1996 and 1997 the number of adults decreased slightly in both populations (Fig. 6). In the Peloncillo Mountains population, with 2 radiocollared bighorn, and the Hatchet Mountains population with no radiocollared bighorn (Fig. 6), the estimated number of adults also declined slightly.

All New Mexico populations with radiocollared desert bighorn have been affected by mountain lion predation. Between 1992 and 1997, 106 radiocollared bighorn sheep were transplanted from the Red Rock breeding facility into 4 populations. As of June 1999, the fates of 101 of these 106 bighorn sheep were known. Of 49 known mortalities, 36 (74%) have been due to mountain lion predation (Fig. 7). In addition, 3 of

8 mortalities in the 'unknown cause of death' category are suspected to be mountain lion predation because of the location of radiocollars within areas of high lion predation, or reanalysis of mortality reports. Lion predation accounts for 88% of the known-cause mortality of these transplanted desert bighorn sheep. Eight of 12 ewes transplanted in November 1997, in an attempt to extend range use into unoccupied habitat in the southern Peloncillo Mountains, were killed by mountain lions in <18 months, despite successful efforts to take the offending lion at the carcass of 3 of these ewes. In addition, no lambs born to these transplanted ewes in 1998 were recruited and at least 1 was killed by a mountain lion. Mean age of the 36 bighorn sheep killed by lions has been 6.0 years (2.6 SD).

Discussion: Evidence from video footage, helicopter surveys, visual observation of the sole remaining ewe, including no observation of a lamb, combined with the mathematical prediction based on the 90% mortality rate on radiocollared bighorn suggest that our conclusion of a biological extinction is probable. It is assumed that the remaining ewe continues to ovulate and therefore if a ram or rams were present in the SAM it is likely that they would have encountered her. However, we cannot be sure that there are no other bighorn because of the vastness of this habitat and the difficulty in surveying all areas.

This apparent biological extinction of the SAM population is a partial test of the hypothesis that collared animals suffer higher mortality rates particularly due to predation because they are "conspicuous individuals." Although the cause of mortality is unknown for any uncollared bighorn sheep in the SAM, it appears that an equal or greater rate of mortality has occurred than on the radiocollared portion of the SAM population. Survival rates of mule deer fawns with radiocollars did not differ from those with smaller eartag radio devices (Garrott et al. 1985) nor did adult mortality of mountain goats (*Oreamnos americanus*) differ due to radiocollaring (Cote et al. 1998). Population trends in other desert bighorn sheep herds in New Mexico with high and low percentages of radiocollared individuals are virtually identical, with mountain lion predation being the principal cause of adult mortality on radiocollared bighorn sheep. Neither the within-population test nor the multi-population test supports the hypothesis that mountain lions select for "conspicuous individuals"; i.e., radiocollared bighorn sheep.

During the period 1985-95 a mountain lion study on the SAM documented a mean annual mortality rate of 5% on adult radiocollared bighorn sheep (Logan et al. 1996). This moderate rate of adult mortality was not determined to be a factor limiting population growth. No correlation between mountain lion density and kill rates on desert bighorn sheep was found (Logan et al. 1996). However, the Logan et al. (1996) study was completed just as the final phase of this biological extinction event began and the conclusions presumably would have been different if the study had continued throughout the extinction phase of the bighorn sheep decline. The removal of a mountain lion that had killed 3 radiocollared bighorn in 11.5 weeks in 1989 (Hoban 1990) may have biased the measure of lion predation on desert bighorn in the SAM (Logan et al. 1996). The removal of a mountain lion in 1981 after it killed 5 radiocollared bighorn sheep is evidence that the predicted extinction may have been delayed by the selective removal of individual mountain lions that developed a predilection for killing bighorn (Hoban 1990). These data and the work of others (Chow 1991, Ross et al. 1997) suggest that individual behavior of predators can influence population dynamics of prey and are independent of predator density.

The potential for misidentifying a mountain lion kill for a scavenging event existed in both the SAM and other mountain ranges. However, at the 9% rate of scavenging documented by Logan et al. (1996) it is unlikely that even 1 of the 6 mountain kills was a scavenged animal. Additionally, all 6 bighorn determined to have been killed by mountain lions had multiple indicators of having been preyed upon by mountain lions rather than scavenged. Because no other New Mexico desert

bighorn herds have mortalities associated with scabies, a lower probability of scavenging is predicted. The rate is likely to be more similar to the 2.4% observed on mule deer in the SAM (Logan et al. 1996) and therefore it is unlikely that even 1 bighorn outside the SAM was scavenged.

A complex of ecological factors have combined to result in this apparent biological extinction and mountain lion predation is perhaps only the proximate cause of the final phase of extinction. The ultimate cause may be related to changes in the landscape induced by succession of overstory canopy cover (Stelfox 1976, Etchberger et al. 1989, Etchberger et al. 1990, Archer 1994), particularly pinyon-juniper trees and shrubs, which make bighorn sheep more vulnerable to predation by ambush predators due to decreased visibility (Risenhoover and Bailey 1985, Wakelyn 1987). For more than 50 years prior to the establishment of WSMR in 1952, the SAM were heavily grazed, resulting in the reduction of the fine fuels required to carry fire. During the latter half of this century, the SAM were managed with a strong fire suppression regime. The USFWS began a prescribed burning program in 1999 to restore desert bighorn sheep habitat on the SANWR. Psoroptic mites may have affected the vulnerability of bighorn sheep due to induced deafness (Norrix et al. 1995) and other decreases in fitness of individual bighorn sheep. Additionally, the drought that may have affected population levels of both bighorn sheep and mule deer, may have influenced the necessity for greater hunting effort by mountain lions resulting in more chance encounters with bighorn sheep which occur at low density due to the small population size.

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Figure 1. Observed and estimated numbers of desert bighorn sheep in the San Andres Mountains, 1941-1999.

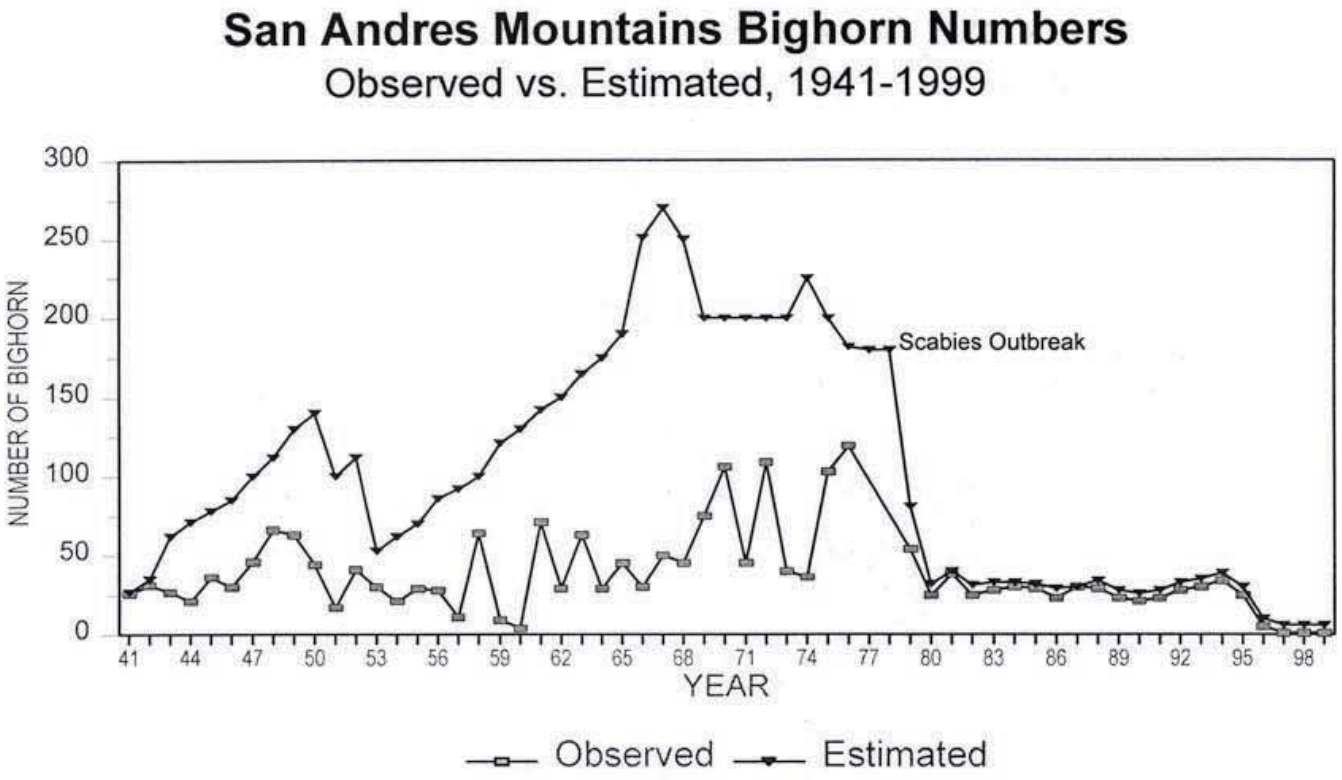


Figure 2. Causes of mortality in radio-collared desert bighorn sheep in the San Andres Mountains, 1980-1995.

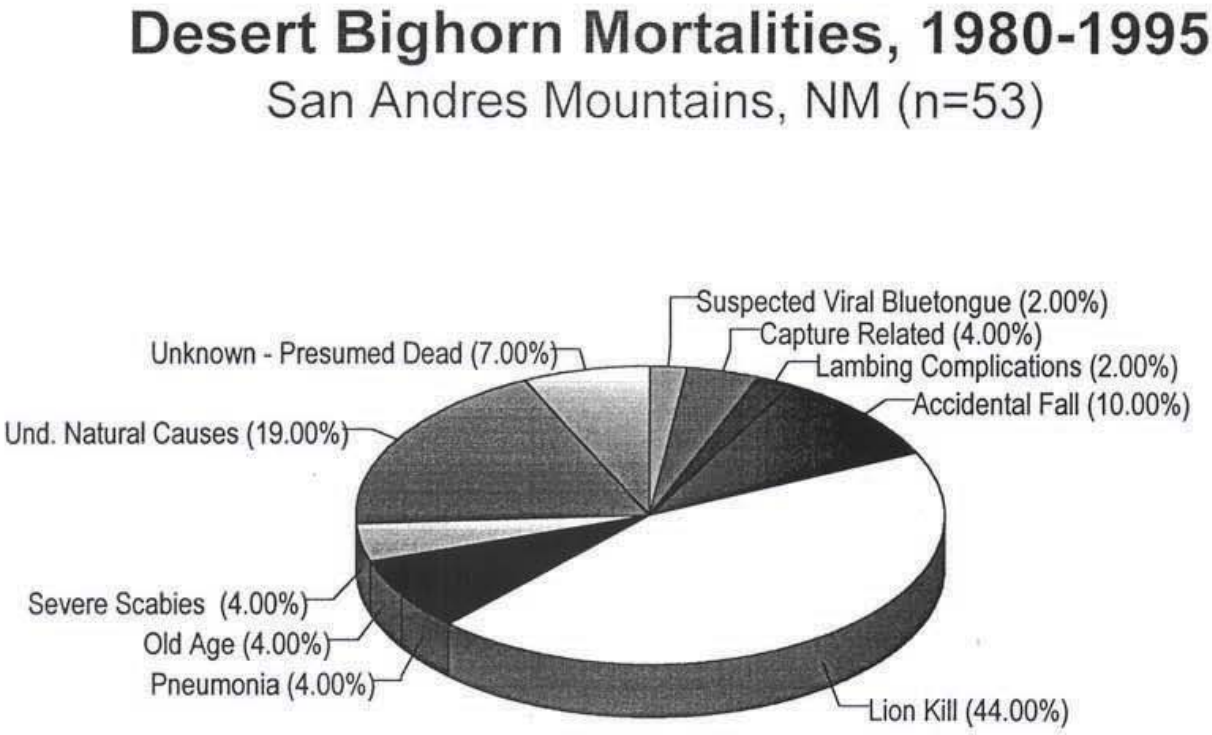


Figure 3. Cause of mortality for last 9 radio-collared mortalities of desert bighorn sheep in the San Andres Mountains 1996-1997.

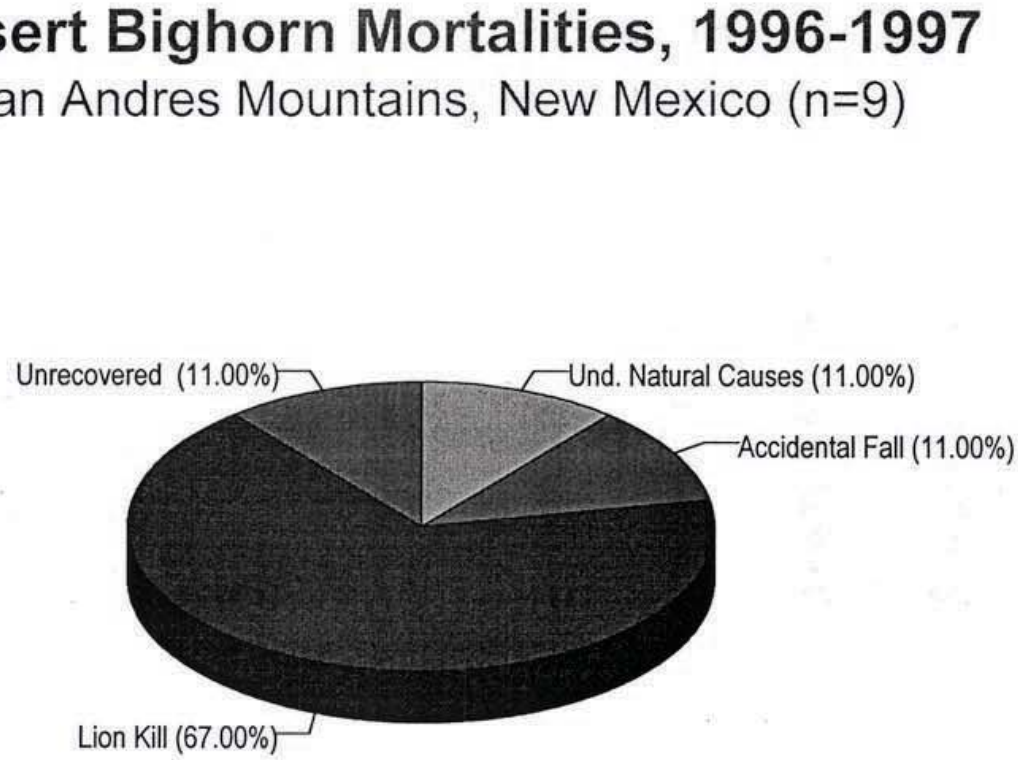


Figure 4. Amount of precipitation recorded in the San Andres Mountains from 1990-1998. Horizontal red line is the long term average.

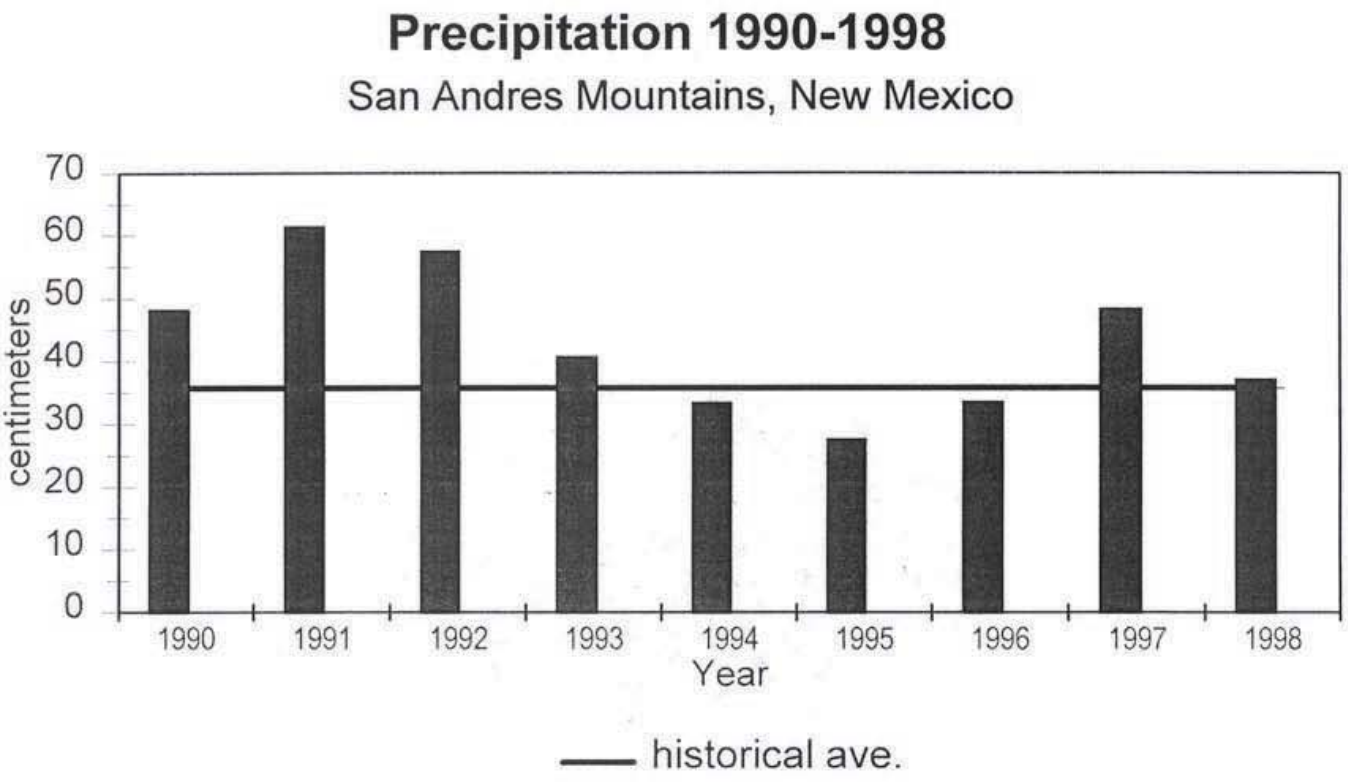


Figure 5. Observation rate of mule deer in the San Andres Mountains seen during bighorn sheep helicopter surveys, 1995-1997.

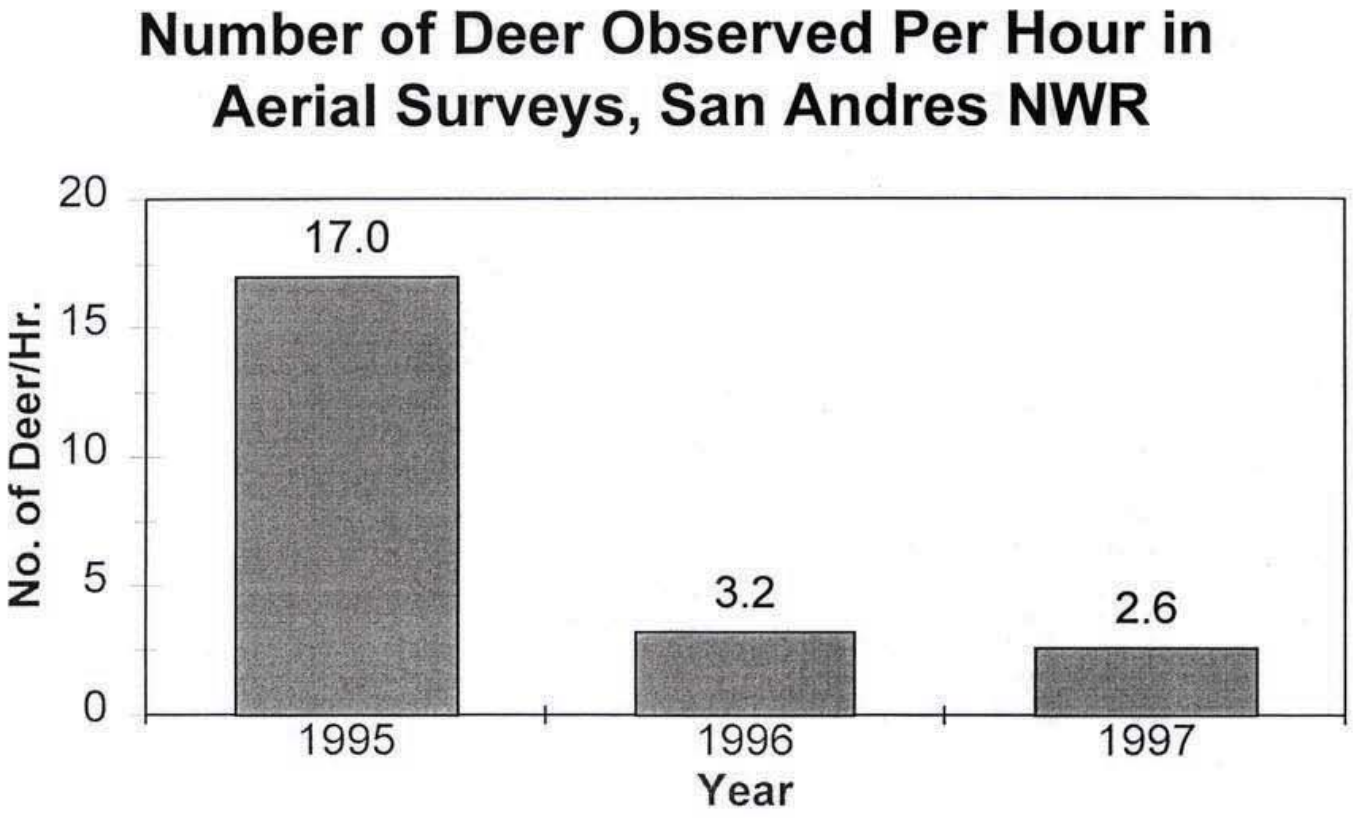


Figure 6. Proportion of radio-collared bighorn sheep and estimated numbers of bighorn sheep in 4 herds in New Mexico. Mountain ranges are described as LA = Ladron, FC = Fra Cristobal, PE = Peloncillo, and HA = Hatchet.

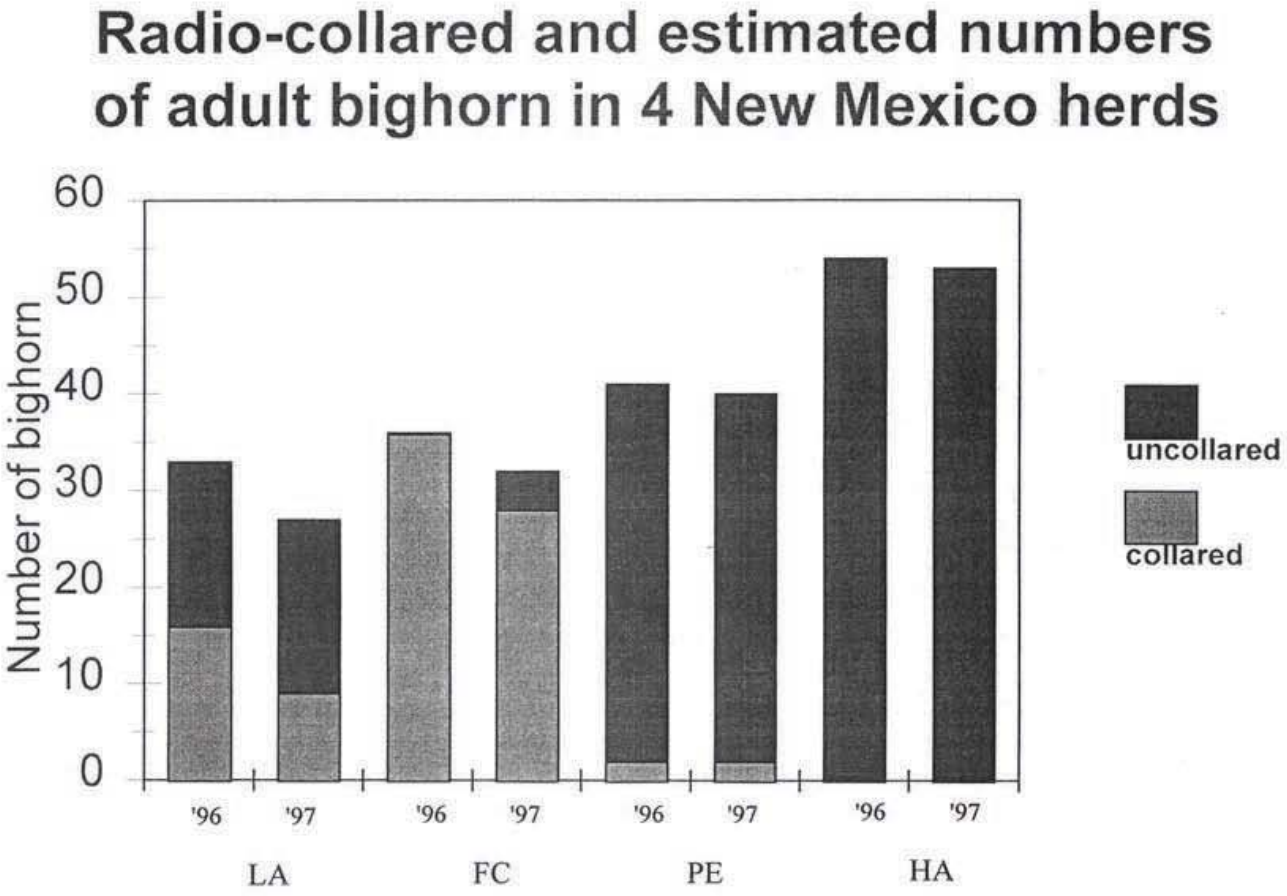
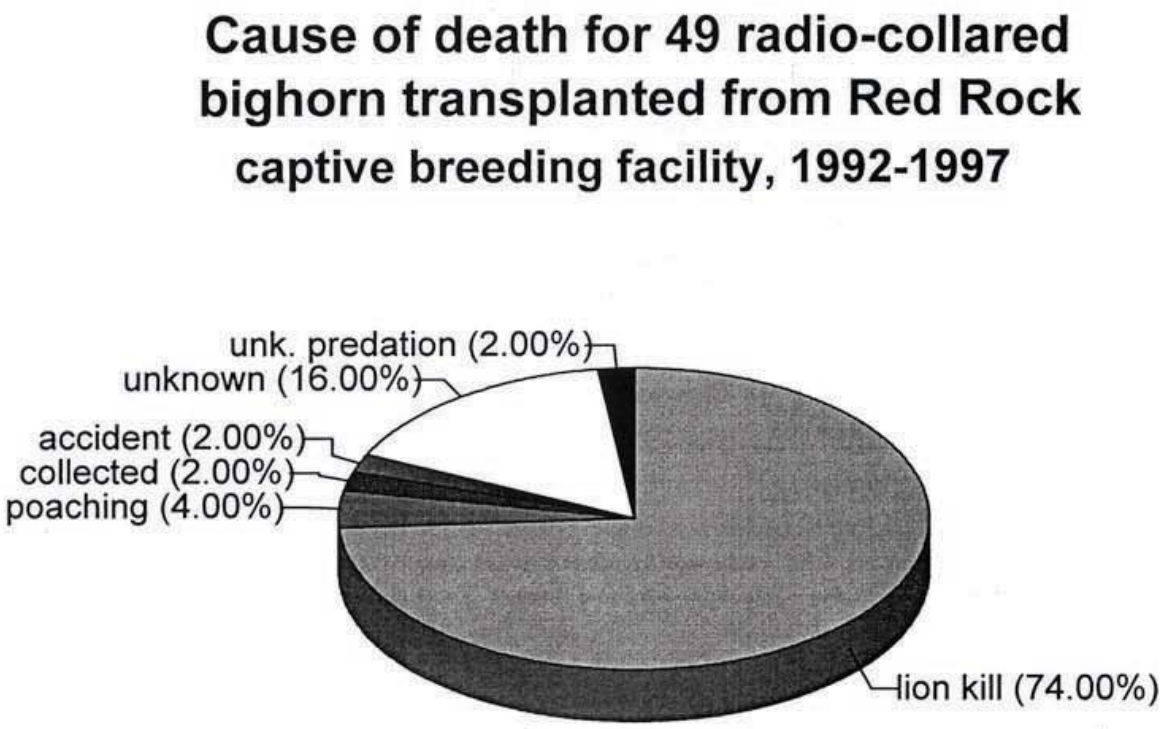


Figure 7. Cause of death for 49 radio-collared desert bighorn sheep transplanted (n=106) from the Red Rock captive breeding facility, 1992-1997.



QUESTIONS, ANSWERS AND COMMENTS - ERIC ROMINGER PRESENTATION

JON HANNA, ARIZONA: Just to get more of a clarification, you mentioned that mountain lions were the principal cause of the decline or exterpation of the sheep herd there. I wanted a little clarification on your reasons or thoughts on decline of the sheep herd. From what you presented, I would say your herd declined from scabies. I did not know if you were interpreting the decline of the herd to be from lion predation?

ERIC ROMINGER: No, I don't. The initial phase of decline in that population of 40 was certainly scabies. But when you lose six of nine radio-collared sheep due to mountain lion predation, we would say the eventual biological extinction, or at least 66.6 percent of it, was attributed to lion predation.

HANNA: By the time you get to less than 40 sheep, you are pretty much going to lose your population. If you could touch on Kenney Logan's ten-year study from his management recommendations, he felt that removal of lions or management of lions was inconsequential as to any effect on the bighorn sheep population. Do you have any thoughts on that?

ROMINGER: We always hope for long-term data sets. In the case of the Logan study, I think 10 years wasn't quite long enough. If it had had been an 11 1/2 year study, I think the conclusions would have been completely different. We removed a lion in 1989. I believe that was the department's decision; that if a lion was preying heavily on bighorn sheep that lion would be removed. If that individual hadn't been removed, you probably would have seen the extinction or a drastic decline while Logan was in the field. That's an unfortunate imposition on the data. We've seen the raw data from Alberta, and some of the Wehausen data suggesting individual lions may be responsible for significant predation on bighorns.

Of the six mortalities, four would have been easily within the home range of one lion. The other two mortalities would have been in the home range of another lion. We weren't able to fingerprint those, but it looks like it could have well been the work of perhaps just two individual lions.

VERN BLEICH, CALIFORNIA: We've been involved in reasonably intensive work for about nine years in the eastern Sierra Nevada, and have in fact marked 1,480 deer with telemetry collars and reported 450 lions. The deer had declined from 6,000 down to 950, then recovered to 2,400. Long-term studies truly are important, and like you say, Kenney might have come to a different conclusion had it been an 11 1/2 year study.

One thing that has come out of this, with reference to your statement about tom lions killing rams. I think you said something like 42 percent of the animals go for males and 48 percent go for females. Do you think female lions kill big rams?

ROMINGER: We've got a big tom in the Fra Cristobal Mountains that we feel has been responsible for the vast majority of rams killed in this mountain range.

BLEICH: One of the things that has come out of our work is the importance of understanding the demography of the predator population as well as the prey population.

We were able to demonstrate that females traveling with kittens select heavily upon younger mule deer,

actually fawns. Neither lone females or males were selective in what they killed. That's just another thought to put in your back pocket if you're looking at long-term work in the future.

ROMINGER: We're hoping that with this operation on the Fra Cristobal, we'll have all the lions collared, and get a better picture on deer and bighorn sheep predation.