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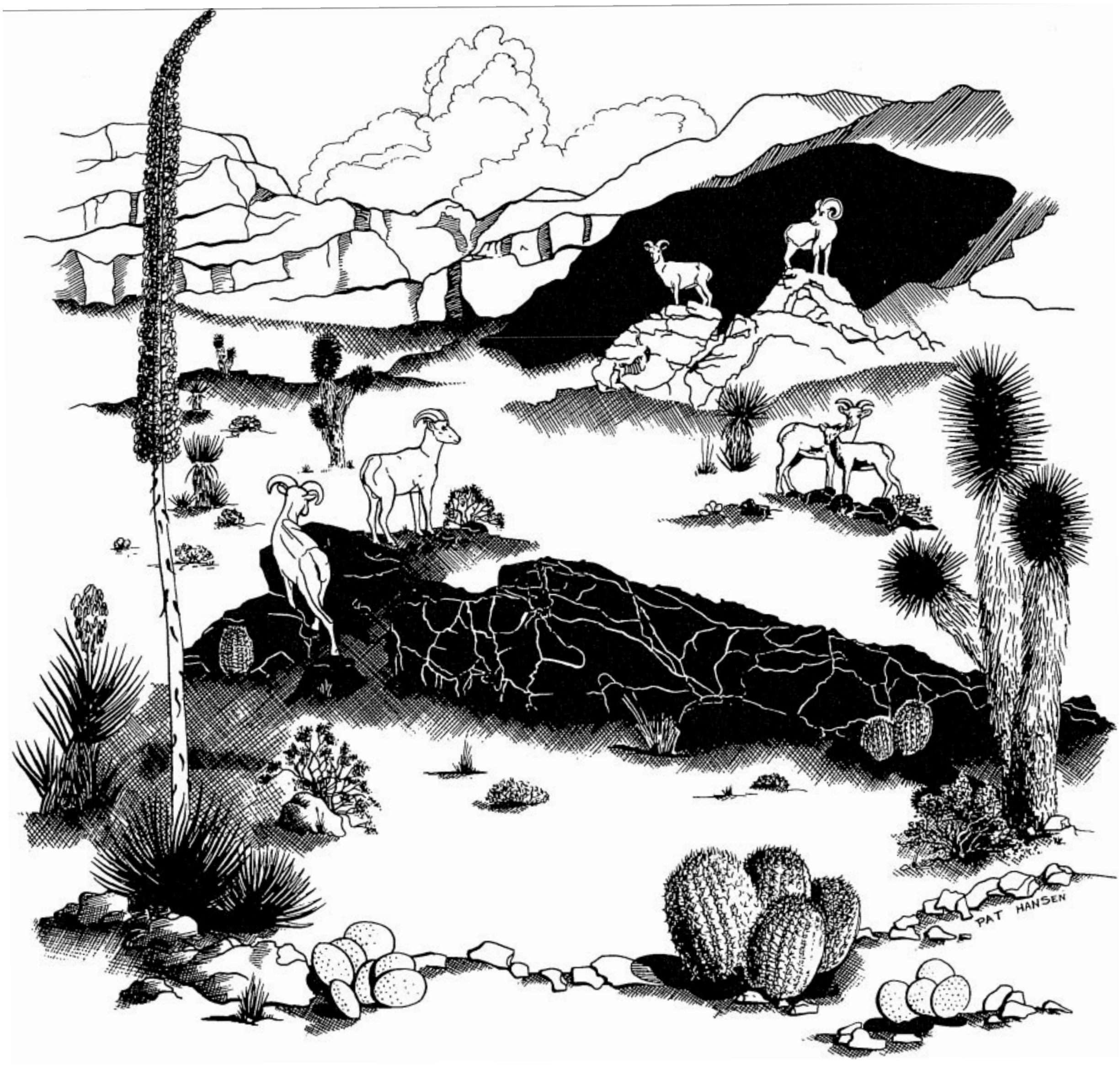
TABLE OF CONTENTS

TECHNICAL REPORTS

STATUS REPORTS AND COMMENTS


PAT HANSEN

INFLUENCE OF FORAGE QUANTITY ON MICROHABITAT USE BY DESERT BIGHORN SHEEP

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Desert Bighorn Counc. Trans. 34:1–5.

Abstract: We examined microhabitat use related to forage availability for desert bighorn sheep (Ovis canadensis nelsoni). Forage availability was examined in 370 random plots throughout the composite home ranges of 5 radio-collared ewes. Each plot was classified as used or unused. No differences were found between used and unused plots in terms of percent cover of shrubs, grasses, forbs and forage species. We found 7 of 24 forage species in greater or lesser quantity in high sheep use areas. We conclude that forage quantity does not influence micro-habitat use.

Key words: habitat, microhabitat, Utah.

A knowledge of habitat use patterns of bighorn sheep is essential to understanding their ecology. Habitat is a template for ecological strategies (Southwood 1977). These strategies may be appropriately analyzed only in the context of a specific habitat. Analysis of habitat variables can provide insight into the animal's life requisites and behavioral strategies (Partridge 1978). Although habitat use patterns of desert bighorn sheep are extensively documented in the literature, and have been quantified recently in a variety of locations (Bates 1982, Elenowitz 1983, Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986, Krausman and Leopold 1986), these patterns are still not adequately understood. Characteristic desert bighorn habitat has often been described as areas with ample forage, water, security, and thermal cover. There are, however, discrepancies in the literature as to the interactions and importance of these components. At a time when management agencies are developing predictive habitat models, these discrepancies may prevent the formulation of predictive models beyond the most general sense.

Habitat use of a specific site is based upon real or perceived needs of the animal. These needs vary with the condition of the range, population, and individuals. Factors affecting habitat use patterns include the size and density of the population (Fowler 1981), the degree of sociality and traditional occupation (Geist 1971:176, Festa-Bianchet 1986), and the present and past level of disturbance to the population and its individuals (King 1984). Thus, when interpreting the results of habitat studies, it may be important to examine the behavior of the population with respect to the above factors before drawing generalized conclusions.

Forage availability is considered 1 of the most important habitat requirements for bighorn sheep (Wilson et al. 1980, Van Dyke et al. 1983). Bates (1982) showed that for a resident population in Canyonlands National Park, sheep preferred areas with high forage availability. Krausman and Leopold (1986) demonstrated that vegetational parameters account in part for macrohabitat use. Other studies also infer that forage availability is important in influencing habitat use patterns (Ferrier and Bradley 1970, McQuivey 1978, Holl 1982). Thus, forage availability is generally accepted as an important habitat requisite.

We examined microhabitat use of a recently reintroduced population of desert bighorn. A statistical model was formulated using 4 forage factors and 13 other habitat components (Steel and Workman, unpubl. rep., Utah State University, Logan, Utah, 1987). Our model was developed using a nonparametric discrimination technique that accounted for interaction between bighorn components (CART, Breiman et al. 1984). The final results of the model will not be presented here due to ongoing tests of the model's predictive ability. Preliminary tests indicate that forage factors are unimportant variables in our model of microhabitat use. This forms the basis of the hypotheses proposed herein.

Funding was provided by Capitol Reef National Park and Utah State University. The Utah Division of Wildlife Resources assisted in radio collaring and aerial telemetry flights. The logistic and technical assistance by John Bissonette, Norm Henderson, and Penny Hoge is greatly appreciated.

STUDY AREA

Desert bighorn sheep were reintroduced into Capitol Reef National Park in 1984 and 1985. Habitat use patterns were examined from April to October 1987. The study area (182 km^2) is part of the Canyonland complex located in Garfield County, Utah, and is comprised of 2 distinct regions: the canyons and cliffs of the Moody Creeks in Glen Canyon National Recreational Area, and the massive monocline of the Waterpocket Fold in Capitol Reef National Park (Fig. 1). Elevations range from 1,300 to 2,100 m. Temperatures range from −13 to 36 C. Mean annual precipitation is 18 cm, predominantly occurring from mid-July through October.

The study area contains 6 geologic formations and 7 vegetation communities that are highly mosaic in distribution. The 6 geologic formations are composed of mudstones, siltstones, and sandstones that vary in thickness and erodability, greatly affecting the topography and vegetation. Dominant vegetation in areas of lower elevation include sagebrush (Artemisia bigelovii), blackbrush (*Coleogyne* ramosissima), Mormon tea (Ephedra spp.), and hilaria (*Hilaria* jamesii). In areas of higher elevation the overstory is dominated by pinyon pine (*Pinus edulis*), Utah juniper (Juniperus osteosperma), and littleleaf mountain mahogany (Cercocarpus intricatus), while the understory is dominated by stipa (Stipa spp.) and Indian ricegrass (Oryzopsis *hymenoides*). Natural water catchments provide year-round water sources.

METHODS

Forage availability, estimated by relative percent coverage, was sampled on 16 randomly chosen units (2.5 km^2) located within the composite home ranges of 2 bighorn sheep herds. In each unit, 15 to 30 systematically located plots were sampled. Microhabitat was examined by restricting sampling to areas within the composite home ranges (Johnson 1980, Morris 1987). Composite home ranges were defined using the convex polygon method (Southwood 1966) based on 120 aerial relocations of 5 radio-collared ewes.

Coverage of perennial vegetation (shrubs, forbs, and grasses) and potential forage species was measured on each plot using 4 randomly placed 25 m intercept transect lines (Canfield 1941). Potential forage species are those plant species that have been reported in the diet of bighorn sheep in southern Utah (Bates 1982). The reliability of applying the line-intercept method to estimate coverage in the study area was

Deceased.

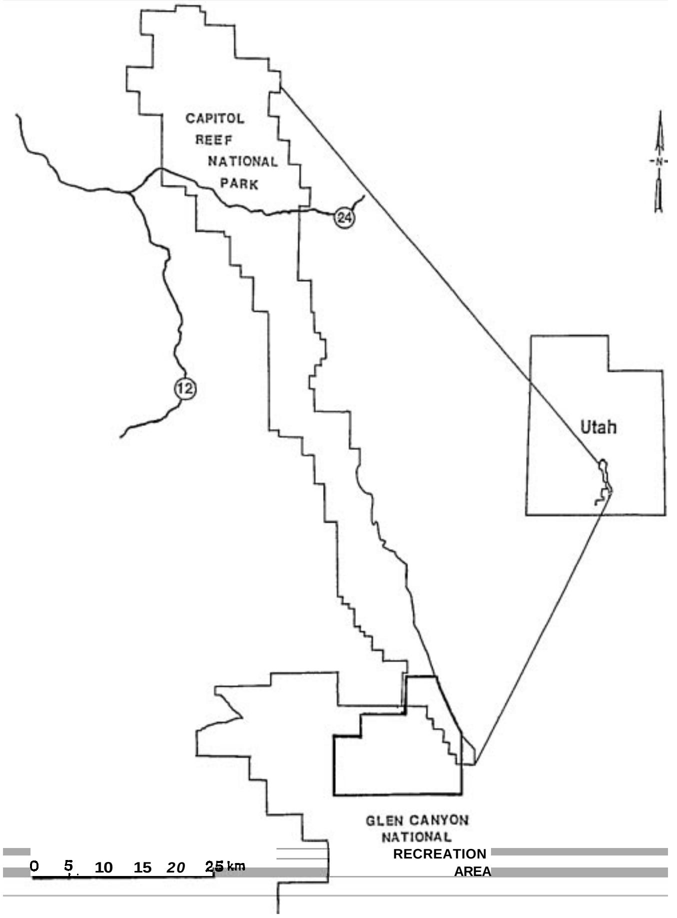

Fig. 1. ***Study area in Capitol Reef National Park and Glen Canyon National Recreation Area, Utah, 1987.***

examined before application. The Student's t-test (Sokal and Rohlf 1969) was conducted on data obtained from 20 plots in 4 vegetation communities to compare the effectiveness of using 4 intercept lines/plot versus 8 intercept lines/plot. No significant difference was found ($P < 0.05$). Method precision was also tested on the 20 plots. Tests (t-tests) showed that any 2 sets of 4 intercept lines were not significantly different ($P < 0.05$).

Each plot sampled was classified as used or unused. Plot classification within each unit was based on a predefined criterion: if the plot contained ≥2 pellet groups the plot was classified as used, otherwise the plot was classified as unused. Pellet groups as indicators of microhabitat use have been satisfactorily used in studies of desert bighorn (Breyen 1971, Merritt 1974), elk (Cewus elaphus) and mule deer (Odocoileus hemionus) (Wambolt and McNeal 1987). There is the possibility that a plot classified as unused may have been used in the past or may be used in the future, leading to misclassification. However, preliminary results of our statistical model show a 75% probability of correct identification based on 2 habitat components: distance to escape terrain and degrees of unobstructed visibility. This indicates that our plot classification criterion is valid.

A "sheep use" class was assigned to all 16 sampling units. Assignment of the use class was based on the percentage of used plots found in the unit. Sheep use classes included minimal (0–10%), low (11–20%), moderate (21–40%) and high (41+%).

Differences between forage and availability on used and unused sites were evaluated. Data were analyzed without interaction between components. Used and unused plots were compared using Student's unpaired t-test (Sokal and Rohlf 1969) to assess statistical significance of the differences. Differences between used and unused plots were also assessed using 95% confidence intervals to examine the potential biological differences (Booth 1987). Percent similarity between used and unused plots (Whittaker 1972:40) were also calculated using percent similarity $= 1 - \sqrt{\Sigma(a - b)^2}$, where a and b equal relative coverage.

To analyze differences in the mean coverage of individual potential forage species among sheep use classes, percent cover of each forage species was averaged over the sampling unit. One-way ANOVA (Sokal and Rohlf 1969) was used to test for differences among the classes; if significant differences were found, Duncan's multiple range test was used to detect which classes differed. All statistical tests were conducted at the $P < 0.05$ significance level.

Table 1. ***Mean cover (%) by site class for shrubs, grasses, forbs, and potential forage species, Capitol Reef National Park, Utah, 1987.***

Vegetation cover	Mean cover (%) Unused	Mean cover (%) Used	95% Confidence interval level	% Similarity
Shrubs	9.4 ± 4.9	9.5 ± 6.0	−1.4–1.3	
Grasses	4.8 ± 3.2	4.4 ± 1.2	0.3–0.5	
Forbs	0.9 ± 1.0	1.1 ± 1.5	0.0–0.6	
Total	15.1 ± 6.5	15.0 ± 7.2	−4.8–5.0	85
Forage species	12.2 ± 5.6	12.5 ± 2.9	−1.0–1.3	96

RESULTS

Forage availability does not statistically differ with plot class (Table 1) or sheep use class (Table 2). No biologically significant differences are detected. Based on the 95% confidence interval testing there are maximums of 1.3%, 0.5%, 0.6%, and 1.3% differences between used and unused plots for shrubs, grasses, forbs, and potential forage species, respectively (Table 1). There is no indication from the literature that these small differences are biologically significant. For 50% of the forage species, significant differences between sheep use classes were found. Duncan's multiple range test indicated that 7 of 12 species shows an increasing or decreasing trend in coverage with a corresponding increase of sheep use in the area. Four-wing salt bush (Atriplex canescens), buckwheats (Eriogonum spp.), and snakeweed (Gutierrezia sarothrae) are found in significantly higher quantities on minimal to low sheep use areas than on moderate to high sheep use areas. Conversely, shadscale (Atriplex *confertifolia*), short saltbush (Atriplex cuneata), littleleaf mountain mahogany, and blackbrush are found in greater quantity on high sheep use areas.

DISCUSSION

Our results do not support the generally accepted views of desert bighorn habitat use. In general, microhabitat use does not differ with respect to forage availability. If forage quantity is characteristically selected at the microhabitat level, as inferred by other habitat use studies (Ferrier and Bradley 1970, McQuivey 1978, Holl 1982, Van Dyke et al. 1983, Bates 1982), our results indicate 3 possible scenarios to explain why this population does not select forage at the microhabitat level: the forage base is homogeneous, therefore site selection cannot occur; plots with low forage quantity supply adequate nutrition for individual growth and reproduction; or the need for security factors is large due to reintroduction stress, and has priority in dictating microhabitat use.

A basic premise in site selection is that the resources that are the basis for selection will vary in degree of acceptability from patch to patch (Fagen 1988). If heterogeneity in resource dispersion does not occur in an area, selection of the resource(s) cannot occur. Homogeneity of forage throughout our study area is not likely, given the mosaic of substrate types (e.g., talus slope, slickrock, bare ground), geologic formations and vegetation communities. Forage availability on the various vegetation communities and geologic formations is extremely variable. For individual forage species coverage ranges from 0–3.8% and 0–2.7%, respectively (T. L. Steel and G. W. Workman 1987). The standard

Table 2. Mean cover (%) for each potential forage species by desert bighorn sheep use classes (minimal, low, moderate and high), Capitol Reef National Park, Utah, 1987.

		Mean cover (%)				
		Degree of sheep use				
Plant species	**Relative cover**	**Minimal**	**Low**	**Moderate**	**High**	**F**
Artemisia utahensis	1.5	0.0	0.0	0.3	0.0	1.90
Artemisia bigelovii	3.7	0.1	0.4	0.5	0.4	1.26
Atriplex canescens	1.4	0.6	0.1	0.1	0.1	5.44**
Atriplex confertifolia	1.7	0.0	0.2	0.1	0.4	3.78**
Atriplex cuneata	1.4	0.0	0.0	0.1	0.4	5.26**
Aristida fendleriana	0.7	0.1	0.0	0.1	0.1	0.89
Cercocarpus intricatus	6.3	0.0	0.2	0.9	0.8	2.84*
Chrysothamnus nauseosus	3.9	0.5	0.7	0.3	0.5	4.11** NT[a]
Coleogyne ramosissima	3.6	0.0	0.0	0.2	1.3	6.94**
Cowania mexicana	3.2	0.2	0.1	0.5	0.3	2.04
Ephedra spp.	10.3	0.8	1.4	1.1	1.4	1.51
Eriogonum spp.	1.6	0.7	0.3	0.1	0.1	6.43**
Fallugia paradoxa	~~1.9~~	~~0.8~~	~~0.0~~	~~7.3~~	~~0.5~~	~~4.81** NT~~
Fraxinus anomala	3.7	1.8	0.0	0.3	0.5	18.02** NT
Grayia spinosa	1.0	0.0	0.0	0.2	0.0	1.78
Gutierrezia sarothrae	12.2	2.2	1.5	1.2	1.5	2.97*
Hilaria jamesii	5.7	1.0	0.5	0.6	0.8	1.74
Machaeranthera spp.	0.9	0.0	0.2	0.1	0.0	0.79
Oryzopsis hymenoides	10.0	0.8	1.3	1.1	1.3	0.88
Poa spp.	4.6	0.1	1.8	0.4	0.4	13.68** NT
Rhus trilobata	4.5	1.8	0.2	0.5	0.4	7.64** NT
Sphaeralcea spp.	0.0	0.0	0.0	0.0	0.1	0.90
Stipa spp.	15.7	0.6	1.6	2.1	1.6	2.47
Symphoricarpus longifolius	1.1	0.0	0.1	0.1	0.1	0.58
TOTAL	100.6	11.7	13.1	11.9	13.0	0.41

* $P \leq 0.05$.
** $P \leq 0.01$.
[a]NT indicates that there is no trend from high to minimal, or visa versa.

deviations associated with each mean (Table 1) indicate the variability of forage at each plot.

The possibility of the second scenario, that plots with low forage quantity contain enough for growth and reproduction, is difficult to grasp given our knowledge of bighorn sheep energetics and nutritional needs. The hypothesis may be plausible because we studied a low density population. We assume that since the population is recently reintroduced the population level is below that which can be supported in the area. With low population density, there is a tendency for group size to be small (Caughley 1977, Elenowitz 1983) and smaller group sizes require less forage per site to meet the needs of their members. Given this, we do not expect to find forage availability affecting site use. We do expect that as the population size and density increases, group sizes will increase, and so will the need for greater forage abundance on microhabitat sites. This would result in forage availability influencing site selection. Also, the forage base and the sheep may be linked in a negative feedback system: as sheep increase, forage will decrease (Caughley 1977). These density-dependent effects might then increase the impact forage availability has on microhabitat use.

Previous stressful experiences, such as those resulting from capture, transport, and placement into a foreign environment, may influence the present behavior of a population. Such effects on the behavior may be exhibited in the observed bighorn use patterns. In an attempt to reduce or adapt to stress resulting from disturbance (Miller and Gunn 1979), a population may change habitat use patterns. Such changes in habitat use by bighorn sheep have occurred as a response to disturbance (Leslie and Douglas 1979, Campbell and Remington 1981) and differences in habitat use patterns between disturbed and undisturbed populations are documented (King 1984). Holl and Bleich (1983), and Wehausen (1983), note that response to disturbance can be affected by habitat characteristics; areas affording greater security will reduce the intensity of the disturbance response. Risenhoover and Bailey (1985) show that sites close to escape terrain with high visibility enable sheep to forage more efficiently. A population that has been captured and transported to a new environment, such as the Capitol Reef population, would likely be placed under a great deal of stress and would respond to reduce this stress. Perhaps the habitat use patterns observed in this study reflect this response. Forage availability may not have priority in selection of microhabitat sites; the need for security may be of ovemding importance. If this is the case, with time we expect a reduction in the role of security factors and an increase in the role of forage factors in influencing site selection.

If forage quantity is not characteristically a basis for microhabitat use, 2 other explanations may account for the results of our study. First, forage availability, as evaluated in terms of percent coverage, may not adequately represent the basis of selection by sheep. Forage nutrition (Hull 1984), edible forage biomass, or variability in forage abundance (Regelmann 1986) may be better indicators of the forage component being selected. Secondly, selection for forage may not be occurring at the microhabitat level, but at the macrohabitat level; i.e., by placement of an animal's home range. Johnson (1980), Peek et al. (1983), and Morris (1987) contend that selection of forage and other life requisites may be at this higher level. If this hypothesis is true, we expect those areas containing vegetation communities with the highest forage abundance to be selected. Several use versus availability studies (Bates 1982, Elenowitz 1983, Gionfriddo and Krausman 1986), examining macrohabitat use, show that desert bighorn do "prefer" certain habitat types over others. Perhaps this preference is due to greater forage abundance in certain habitat types than others.

MANAGEMENT IMPLICATIONS

Rarely are biological systems easily understood making it difficult to draw conclusions about an animal population and its habitat use. To increase our understanding of a system, specific hypotheses need to be formulated and tested. Hypotheses about the nature of forage availability and habitat use have been formulated for desert bighorn sheep in this study and are in need of testing. Conclusions such as ours serve as a reminder of the problems associated with the interpretation of habitat use studies. In considering habitat use studies as a basis for predictive model development, site and population specific conditions need to be examined. This may be laboring an obvious point; certainly it is no surprise that individual populations will use the habitat according to their real and perceived needs and that these needs will vary under differing conditions. While habitat is a template for ecological strategies, this template is flexible (Southwood 1977), allowing for individual and population variation in the expression of their strategies (Fagen 1987). Phenotypic responses of an animal to changing environmental conditions result in tradeoffs between life requisites. The level at which these tradeoffs occur are impossible to predict given present knowledge of bighorn sheep habitat use patterns. We believe that no matter how intuitively obvious this point may be, it has not always been taken into consideration in management of desert bighorn sheep. Region-wide management plans and habitat models may not adequately address the needs of all populations.

Evaluation of the success of bighorn sheep reintroductions requires long-term studies. Short-term survival and population expansion does not necessarily imply long-term population success. A successful population is one that can reproduce and maintain itself through self-regulation without intensive population management, such as culling or supplemental restocking. Initial population growth is most likely assuming low disturbance, predation and disease, due to the abundance of available habitat and forage relative to the population density. Most reintroduction efforts are judged successful after only 5 to 10 years (Rowland and Schmidt 1981, Dodd 1983) and are usually based on ewe-lamb ratios in the first several years and/or fidelity to an area. Elenowitz (1983) considered short-term sheep use of specific habitat components to evaluate transplant success, which may be a better indicator of long-term success than current population characteristics. Annual ewe-lamb ratios have been found to be highly correlated with weather conditions (Douglas and Leslie 1986, Wehausen et al. 1987); thus, annual population characteristics may be extremely variable, and may not accurately reflect the state of the population and its ability for success. The study of the habitat use patterns after initial population expansion and behavioral acclimation to the reintroduction, can provide valuable insight into the likelihood of population success.

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RADIOTELEMETRY COLLARS AND MOUNTAIN SHEEP: A CAUTIONARY NOTE

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Desert Bighorn Counc. Trans. 34:6–8.

Abstract: We describe several types of injuries associated with loose-fitting telemetry collars in male and female mountain sheep (Ovis *canadensis* ssp.), and 1 injury incurred by a male from an overly tight telemetry collar. The potential proximate and ultimate effects of poorly fitting collars include serious injuries to osseous and dermal tissues, altered foraging behavior, and decreases in the fitness of otherwise dominant males. Researchers are encouraged to use extreme caution when marking mountain sheep, and other species, with telemetry collars, because of the potential ramifications for the animals and for future research.

Key words: collars, injuries, Ovis canadensis, radiotelemetry, techniques, telemetry.

The use of collars for marking large, wild mammals has a long history, beginning with the use of "bells" (Taylor 1947) and made more popular by Progulske (1957). Indeed, the advent of reliable telemetry packages and increased funding for research have resulted in large numbers of collars being placed on wildlife. Researchers have developed expandable collars or breakaway collars (Jordan 1958, Hamilton 1962, Kolz and Johnson 1980, Steigers and Hinders 1980, Keister et al. 1988, Hellgren et al. 1988), to allow for neck-swelling during the rut by male cervids, or expansion for growth if young animals are collared. Historically, the intent has been to minimize the effects of collars and/or telemetry packages on animals being studied, and recent guidelines (Committee on Acceptable Field Methods 1987) suggest that methods used to mark wild animals not abrade or restrict body parts.

Cochrane (1980) noted that researchers may be faced with difficult choices when collaring wild animals. For example, should one use a tight-fitting collar, placed near the head, or a loose-fitting collar, that may slide back and forth, placed lower on the neck? He emphasized that trial and error, coupled with a knowledge of anatomy and behavior, are factors that, ultimately, result in optimal attachment methods. Practical and ethical considerations make it imperative that safe and humane methods are used in field investigations. We describe injuries to mountain sheep in California that were associated with poorly fitted collars.

We thank R. T. Bowyer for comments on an early version of the manuscript, and T. Manning for preparing Figure 3. Preparation of this paper was supported in part by grants from the Society for the Conservation of Bighorn Sheep, Sacramento Safari Club, California Association of Professional Scientists, and M. P. Northam, while the senior author, on a leave of absence from the California Department of Fish and Game, was at the Institute of Arctic Biology, University of Alaska Fairbanks.

The first translocation of telemetered mountain sheep in California occurred in 1979. By 1983, opportunities to handle and mark animals increased markedly (Wehausen et al. 1987). Because of an aggressive translocation program (Bleich et al. 1990), approximately 30 sheep have been collared each year from 1983 through 1989.

Initially, telemetry collars were placed very loosely on the study animals, because of concern that snug collars might be life-threatening. Collars were so loose that they continually slid up and down the necks of the animals as they fed. In 1983, it was noticed that such loose-fitting collars resulted in substantial hair loss on necks. At that time, we raised the issue of (1) heat loss associated with decreased insulation on sheep wintering high in the Sierra Nevada, and (2) potential injuries to the lower jaws of clashing rams from loose collars. Subsequently, we detected dermal lesions on the dorsal neck surfaces of rams and ewes fitted with loose collars, and swelling under the lower jaws of some rams.

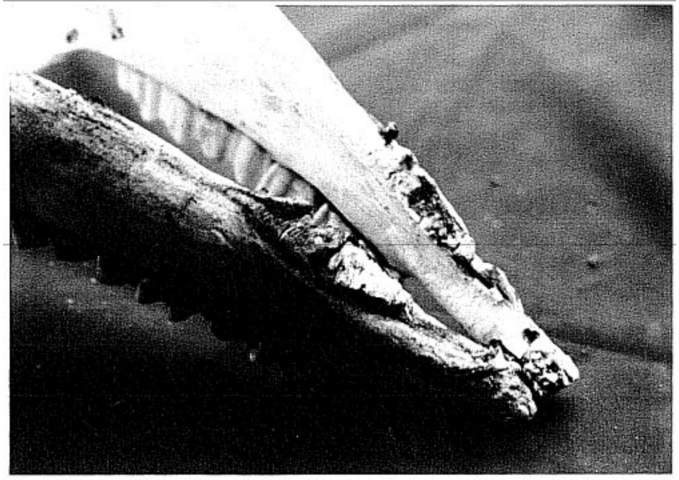

Fig. 1. Ventro-lateral view of the mandible of a 7-year-old mountain sheep ram, originally collared as a 5-year-old. The ram wore a loose-fitting radio collar from November 1984 through August 1986. Note the osteophytes along the ventral surfaces of the rami.

Table 1. Collar circumferences (cm) for female mountain sheep (O. c. nelsoni and O. c. californiana) collared from 1983 to 1988 in California.

		Collar circumference (cm)			
Years	n	$\bar{x}$	SD	Range	CV
1983	2	50.3	10.0	43.2–57.3	19.6
1984	8	48.1	3.0	44.5–53.5	6.2
1985	8	38.8	3.6	33.7–43.5	9.2
1988	9	35.8	1.6	33.0–38.1	4.3
1983–88	27	41.4	6.6	33.0–57.3	15.9

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[2] Present address: U.S. National Park Service, P.O. Box 9, Denali Park, AK 99755.

[3] Present address: Department of Forestry and Resource Management, University of California, Berkeley, CA 94720.

*Table 2. Differences (cm) between collar circumferences and neck circumferences for male and female mountain sheep (*O. c. nelsoni *and* O. c. californiana) *collared from 1984 to 1988 in California.*

		Collar circumference-neck circumference (cm)			
Year	*n*	$\bar{x}$	SD	Range	CV
1984	10	14.3	3.5	8.4–20.0	24.3
1985	2	4.2	1.3	3.2–5.1	30.1
1988	10	3.1	1.4	1.3–5.1	45.2
1984–88	22	8.3	6.1	1.3–20.0	73.8

Several ram carcasses were recovered shortly thereafter, 3 of which exhibited significant injuries that we attributed to loose-fitting telemetry collars. The 3 rams discussed here ranged in age (at time of collaring) from 3 to 5. Two wore telemetry collars for 2 years, and one for 4 years, prior to their deaths. Mandibles from these animals exhibited substantial proliferation of bone along the ventral, lateral, and medial surfaces of the rami (Fig. 1). Numerous small osteophytes were present on the lateral and ventral surfaces, with the lesions up to 1 cm long. Such lesions are consistent with those that would be expected to result from chronic irritation of bone in the areas of their occurrence. We believe these injuries were caused by a loose-fitting transmitter hitting the lower jaw (where it is covered by only a thin layer of tissue) during episodes of feeding, running, and horn clashing. The extreme forces associated with the latter activity (Schaffer 1968, Schaffer and Reed 1972, Kitchener 1988) may explain the absence of similar lesions in female sheep.

Between 1983 and 1988, the incidence of such injuries decreased markedly. We observed no such lesions on animals collared after 1985; trial and error (Cochrane 1980) had caused us to place collars on more tightly. There is a significant decrease (Kruskall-Wallace One-way Analysis of Variance, $\chi^2 = 19.0813$, 3 df, $P = 0.0003$) in circumferences of collars installed between 1983 and 1988, for which we have measurements (Table 1). Similarly, the difference between collar circumference and neck circumference decreased significantly (Kruskall-Wallace One-Way Analysis of Variance, $\chi^2 = 15.9403$, 2 df, $P = 0.0003$) between 1984 and 1988 (Table 2). We surmise that snug-fitting collars greatly reduce the risk of injuries associated with radio collars. Similarly, Fancy et al. (1988) noted a decrease in injuries to caribou (*Rangifer tarandus*) when collars were placed more tightly around necks.

In our experience, most sheep researchers tend to install collars loosely. We believe that injuries are more likely to occur when that is the case, and recommend that the collars be installed as high up on the neck as possible, and as tightly as possible, without constricting the neck. However, in 1989 we documented injuries associated with an overly tight collar. That collar had been placed on a 2-year-old ram in 1987, at a circumference appropriate for an adult ewe. As the ram grew, severe lesions developed on the neck under the collar (Fig. 2). These lesions were not visible, however, without removing the collar; they were discovered only when the animal was captured to replace its non-functional telemetry collar. This problem occurred because future neck growth was not considered when the original collar was installed.

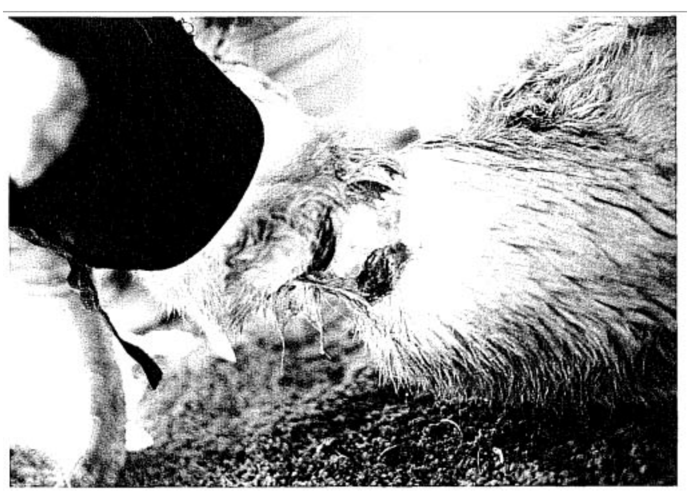

Fig. 2. Ventral view of the neck of a 4-year-old mountain sheep ram that had worn an overly-tight radio collar from September 1987 through December 1989. Note the severe dermal lesions associated with the collar.

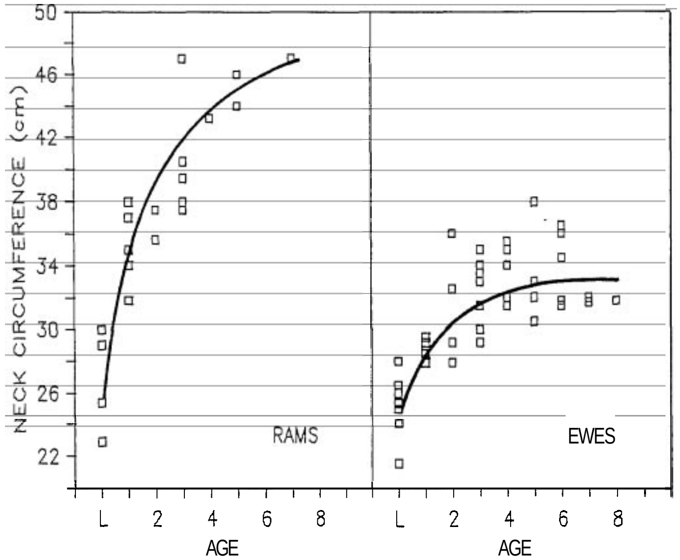

Fig. 3. Neck circumference, as a function of age, for 20 mountain sheep rams and 40 ewes for which neck measurements are available. Neck circumferences in females become asymptotic at an earlier age than in rams.

Because of the extended growth period of rams compared to ewes, the 2 sexes attain maximum neck circumferences at different ages (Fig. 3). For 23 ewes >3 years of age, minimum neck circumference varied from 30.5 to 38 cm, with an average of 33.4 cm. For the same populations, the asymptotic neck circumference for rams was 47 cm. We now use these values as guidelines when collaring sheep that have significant body growth to complete.

Aside from the obvious potential for loose-fitting collars to cause injuries, other ramifications exist. Loose-fitting collars frequently strike sheep under the chin during feeding bouts (Berbach 1987). Such events may alter feeding behavior and nutrient intake, and may cause researchers to record nonrepresentative foraging data. Alteration of male dominance behavior also is likely. Further, an otherwise dominant male, debilitated by an improperly fitting telemetry collar, may not fully realize his evolutionary fitness because of painful jaw injuries incurred during horn clashes.

Finally, the ramifications of injuries associated with wildlife research must be considered in the context of their potential effects on future research projects. Animal rights proponents, and others associated with the humane movement, will be quick to seize upon any opportunity to discredit the wildlife management profession. The Committee on Acceptable Field Methods of the American Society of Mammalogists (1987) has addressed the question of properly-fitted telemetry packages; careful adherence to that policy is urged because of the potential for impacting future research opportunities should concerned individuals take issue with the problems created by ill-fitting collars.

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NUMBERS, MOVEMENTS, AND DISEASE STATUS OF BIGHORN IN SOUTHWESTERN ARIZONA

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Abstract: We studied population size, movements, and presence of disease in desert bighorn sheep (Ovis canadensis mexicana) on the Cabeza Prieta National Wildlife Refuge (CPNWR) and the Barry M. Goldwater Air Force Range (BMGAFR) in southwestern Arizona. We estimated the population size by aerial survey to be 462 in 1986 and 504 in 1987. Mean home range of radio-collared bighorn was 22.0 $\pm$ 4.1 km^2 (range = 7.3–48.3 km^2) for 10 ewes and 115.1 $\pm$ 70.1 km^2 (range = 14.9–319.7 km^2) for 4 rams. Although 1 ram (3.5-yr-old) was documented to make an intermountain movement, bighorn did not move regularly between mountain ranges or between Arizona and Mexico. Disease exposure was low in 7 bighorn examined. Only 1 bighorn was seropositive to any known bighorn pathogen; she had a 1:320 titer to contagious ecthyma virus.

Key words: Arizona, desert bighorn sheep, disease, movements, Ovis canadensis mexicana.

In fall 1986 the Arizona Game and Fish Department (AGFD) began a study of desert bighorn sheep in southwestern Arizona. The study area encompassed the land that is under the management of the CPNWR and the BMGAFR. This study area is virtually without roads and development and has few human visitors because of military operations, extreme summer temperatures, and lack of water. As a result, little was known about the bighorn population here.

Management agencies needed accurate population estimates to ensure the stability of bighorn herds while providing hunts in viable populations. Previous population estimates for the study area were mainly based on waterhole counts, random observations, and insufficient survey data. No systematic surveys had been conducted here to derive reliable population estimates. The AGFD estimated the bighorn population of the study area at 178 animals in 1985 (Ariz. Big Game Investigations, 1984–85, AGFD). The CPNWR estimated that 250 bighorn inhabited the refuge portion of the study area (U.S. Fish and Wildl. Serv., CPNWR Master Plan, 1970). Annually from 1985 to 1987, 7 bighorn hunting permits were allotted in the study area.

Additionally, we did not know much about the movements of these herds. Ecologists have speculated that desert bighorn sheep historically ranged over larger areas before travel corridors through valleys were blocked by roads and developments (DeForge et al. 1979). Early reports on the Cabeza Prieta area, northern Sonora, and Arizona in general allude to the bighorn moving great distances: from 1 mountain range to another, crossing in and out of Mexico, and regularly moving back and forth from the Cabeza Prieta area to the Pinacate region of Mexico (Nichol 1937:7–9, ~~1938:3;~~ CPNWR Narrative Reports 1939, 1943, 1944, 1946 [unpubl.]; Buechner 1960:50, 52, 145, 147; Simmons 1969:70–74; O'Connor 1974, 1977:74, 90–91; Tinker 1978). This reported movement was often attributed to a need for water.

The Cabeza Prieta and Goldwater herds provided an opportunity to study bighorn movements under conditions similar to those before man's intervention. With lack of roads and development blocking corridors between mountain ranges, we expected to see migrations similar to those reported in the early literature. Not only would we get information on present day movements of these herds, but the data could be compared to other areas where intermountain movements are now blocked by man's developments.

In addition to information of population numbers and movements, we desired some information on the disease status of the bighorn here. Contact with bighorn and livestock from Mexico could expose these herds to diseases.

The objectives of this study were to estimate the bighorn population size, study bighorn movements, and analyze the disease status of the population. This project was jointly funded by AGFD, the Arizona Desert Bighorn Sheep Society, the U.S. Fish and Wildlife Service, and the U.S. Air Force.

STUDY AREA

The study area encompasses the CPNWR and that portion of the BMGAFR west of Highway 85. The Goldwater Range overlaps most of the Cabeza Prieta Refuge. The study area is bound on the north by the northern boundary of BMGAFR just south of Interstate 8; on the northeast by Highway 85; on the southeast by Organ Pipe Cactus National Monument; on the south by the Mexican border; and on the west by the western boundary of the BMGAFR, running south from approximately Yuma to the Mexican border (Fig. 1).

This land was generally unsettled because of extreme summer temperatures and aridity. Cattle were grazed on the land in the 1800s and the early ~~1900s,~~ with livestock numbering several thousand at the peak. The range was always marginal for grazing, and degradation of the vegetational resources occurred during this period. The establishment of the CPNWR in 1939 and the Air Force range in 1942 progressively curtailed mining, mineral leasing, and livestock grazing, resulting in eventual protection of the entire area.

The study area is characterized by northwest–southeast trending mountain ranges separated by broad alluvial valleys. Valleys range in elevation from 150 to 350 m, and some mountain peaks rise to 800–900 m. The vegetation of the alluvial valleys is characteristic of the Lower Colorado River Valley Subdivision, and that in the mountains and bajadas is characteristic of the Arizona Upland Subdivision, both of the Sonoran Desertscrub Biome (Turner and Brown 1982).

The study area has high summer temperatures, moderate winter temperatures, and low rainfall. From mid-May to mid-September, afternoon temperatures are normally >37 C and daily maximums are commonly >43 C. Annual precipitation varies from 10 cm on the western portions of the study area to 22 cm on the eastern portions (Sellers and Hill 1974). Two distinct rainy seasons occur. The summer monsoons of July–August contribute $\geq 50\%$ of the total precipitation in the eastern portions of the range. Winter storms of December–mid-March supply $\leqq 100\%$ of the precipitation in the western portions of the study area.

The study area has no permanent or intermittent streams, but is drained by a number of ephemeral desert washes. Only 2 intermittent springs occur in the study area. Most water available to bighorn is in tinajas. Natural tinajas are scattered throughout each mountain range, some so small as to hold water for only a few days after a rain, others large enough to last through long droughts. Throughout history, man has enhanced these natural tinajas and built other catchments to hold rain and runoff water. With the establishment of the wildlife refuge, catchment development increased. Currently, AGFD and CPNWR maintain 70 developed surface waters on the refuge and military range (Nat. Resourc. Planning Team 1986).

Military use of the area has caused some range degradation, but compared to other bighorn habitat, the study area is virtually pristine. Some military debris remains on the range, and a few isolated areas show

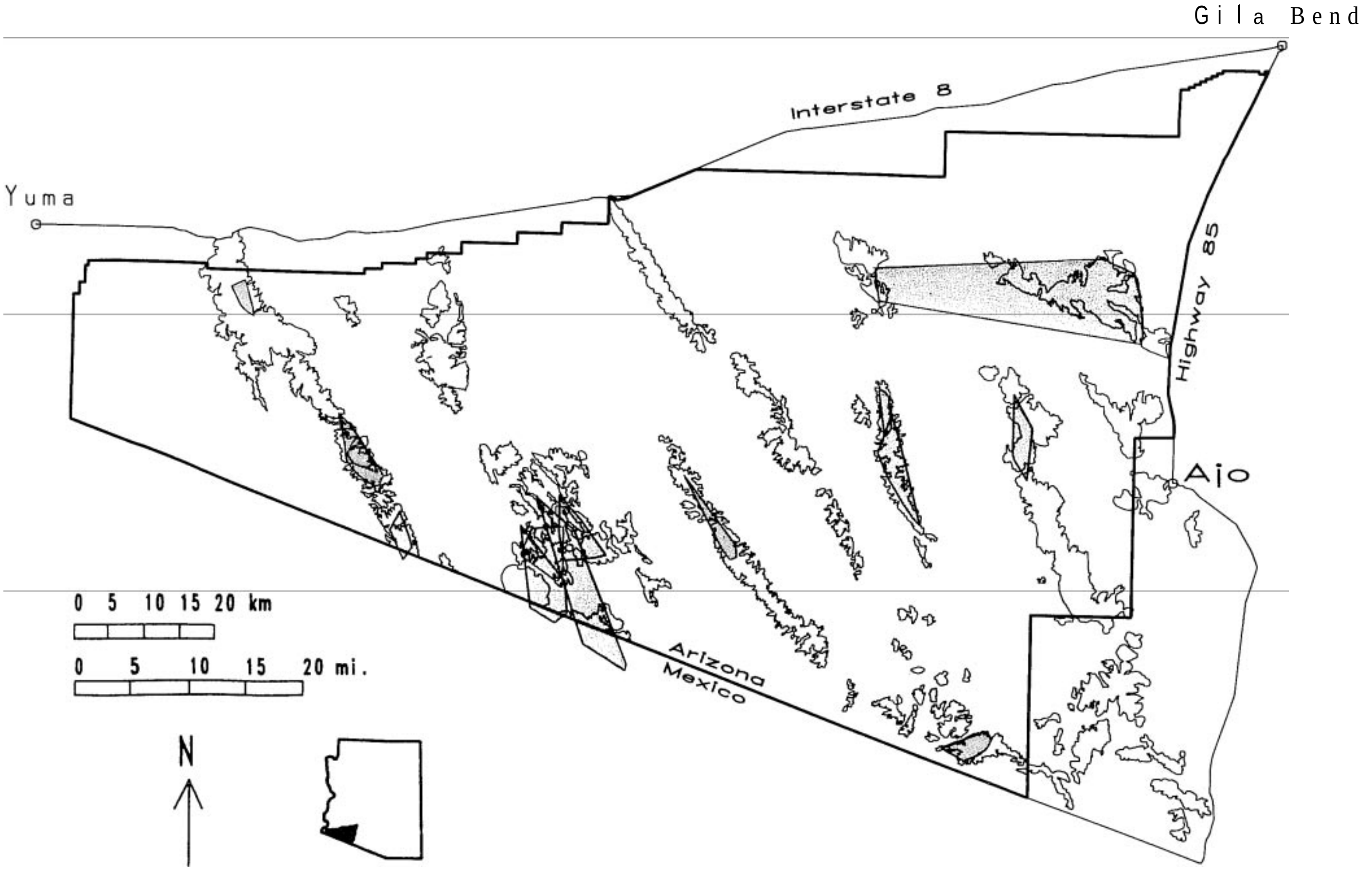

Fig. 1. Home ranges (shaded areas) of 14 radio-collared desert bighorn on the Cabeza Prieta National Wildlife Refuge and the Barry M. Goldwater Air Force Range based on aerial locations from November 1986 to March 1988. Mountain ranges are outlined with narrow lines. The study area is outlined with a wider line.

excessive abuse from military vehicle tracks, but virtually all development and most visitation has been eliminated. A few dirt roads traverse the study area; these are generally ungraded or rarely graded.

It is not known whether noise disturbance from low-flying military aircraft has significant negative effects on bighorn. There is evidence showing that bighorn move and change behavior in response to aircraft noise (Krausman and Hervert 1983).

METHODS

From 31 October to 2 November 1986, we captured, sampled, radio-collared, and released 10 female and 4 male bighorn sheep in 9 mountain ranges in the study area. From November 1986 to March 1988, these 14 radio-collared bighorn were located every 2-4 weeks from fixed wing aircraft to monitor movements and document home range size.

Home-range size was determined by the minimum convex polygon method (Mohr 1947). This method is simple and gives a relative figure for comparison to other bighorn studies that used this method. Only 14–25 locations for each bighorn were documented during the 17 months of this study, so more complex analysis of the data was not justified. The minimum convex polygon method gave an estimated figure of home range size and provided a visual outline of the area used by the bighorn, which met our purpose of determining if the herds moved between mountain ranges and between Arizona and Mexico.

During the capture operation, we collected blood samples from 7 bighorn for disease testing at the National Veterinary Services Laboratory in Ames, Iowa. These samples were serologically tested for infectious bovine rhinotracheitis (IBR), parainfluenza-I11 (PI3), contagious ecthyma (CE), bluetongue (BT), respiratory syncytial virus (RSV), epizootic hemorrhagic disease (EHD), and leptospirosis.

From 31 October to 2 November 1986 and 30 October to 2 November 1987, helicopter surveys were conducted to estimate population size. Thirty-three and 36 hours of flight time were used for the 1986 and 1987 surveys, respectively. Bighorn habitat in each mountain range was mapped and divided into blocks, and blocks to be surveyed were determined randomly. Approximately 66% of mountainous sheep habitat was surveyed.

Population estimates were derived by a method developed by AGFD on the Kofa National Wildlife Refuge (R. Miller et al., Ariz. Game and Fish Dep., unpubl. data). The Kofa study used 2 consecutive helicopter flights to determine the percentage of bighorn that are sighted under various survey conditions. That study determined that survey intensity, time of day, bighorn group size, and terrain type had the most effect on the ability of surveyors to sight bighorn, and they calculated "sighting rates" under various survey conditions.

Surveys on the Cabeza Prieta and Goldwater ranges were only flown over mountainous terrain. Mountainous terrain sighting rates were applied from the Kofa study for rams, ewes, lambs, and mixed groups, depending on time of day, group size, and survey intensity. Survey intensity was classed as either "high grade" (emphasizing survey effort over areas most likely to contain bighorn, covering approximately 26 km^2/hr) or "complete" (surveying all ground in the survey block completely, covering 15–23 km^2/hr). The sighting rate for groups of ≥ 5 bighorn is always 1.000. Sighting rates for groups of <5 bighorn are listed in Table 1.

Table 1. Sighting rates for groups of 1-4 bighorn sheep used to estimate desert bighorn sheep population numbers, as determined from a study in the Kofa National Wildlife Refuge (R. Miller et al., Ariz. Game and Fish Dep., unpubl. data). The sighting rate for groups of ≥5 bighorn is always 1.000.

	Morning[a]		Afternoon	
	High grade[b]	Complete	High grade	Complete
Mixed groups	0.353	0.459	0.349	0.841
Rams	0.373	0.424	0.467	0.900
Ewes	0.341	0.493	0.297	0.824
Lambs	0.444	0.571	0.444	

[a]Morning = 0900–1200. Afternoon = 1300–1600.
[b]High grade = emphasizing survey effort over areas most likely to contain bighorn, covering approximately 26 km²/hr. Complete = surveying all areas in the survey block completely, covering 15–23 km²/hr.

Table 2. Estimates of the desert bighorn population size on the Cabeza Prieta National Wildlife Refuge and Barry M. Goldwater Air Force Range from surveys by helicopter on 31 October–2 November 1986 and 30 October–2 November 1987.

	1986	1987
Estimate for mountain ranges surveyed	397	409
Estimate for ranges not surveyed[a]	65	79
Total	462	488
Adjustment for Class III and IV rams[b]	0	16
Total	462	504

[a]In 1986 add Gila Mountains estimate from 1987 survey (Gilas not surveyed in 1986). In 1987 add Tinajas Altas Mountains and Mohawk Mountains estimates from 1986 survey (Tinajas Altas and Mohawks not surveyed in 1987).
[b]In 1987, few older rams were counted, probably because the survey missed the height of the rut. Adjustment is based on ram age ratios in 1986 survey.

The population was estimated as:

$$N = \sum \left(\frac{n}{r}\right) \cdot \frac{a_t}{a_s}$$

where

N = population estimate,
n = number of bighorn sighted in each group,
r = corresponding sighting rate for that group,
a_t = total area of bighorn habitat in a mountain range, and
a_s = area surveyed.

RESULTS

Population Estimate

During the 1986 survey, mechanical problems with 1 helicopter prevented us from surveying the Gila Mountains, and during 1987 inclement weather prevented us from surveying the Mohawk and Tinajas Atlas Mountains. Therefore, population estimates for both years excluded some areas. We estimated the population size to be 397 and 409 in 1986 and 1987, respectively (Table 2). If population estimates for those mountain ranges not surveyed each year are added from the other year's count, the population estimate for the study area would be 462 and 488 for 1986 and 1987, respectively.

In 1987, very few Class III and IV rams were counted. There is no evidence of large numbers of older rams dying. The survey period probably missed the height of the rut; older rams that were not with ewe groups were not as likely to be seen. If the 1987 ram population is adjusted to reflect an age ratio representative of that found in 1986, 16 more animals would be added, resulting in a population estimate for the study area in 1987 of 504.

Movements

Of 14 collared bighorn, only 1 3-year-old ram crossed a major valley, traversing a 10 km valley from the Crater Range to the Aguila Mountains (Fig. 1). This ram crossed the valley in August–September 1987, then was legally taken by a hunter in December 1987. We can only speculate on whether this move would have been repeated. With this 1 exception, no other collared bighorn crossed a major valley during the 17 months of the study. There was some movement between ranges that are nominally different (between the Tinajas Altas and the Gilas and between the Cabeza Prietas and the Tules), but these mountains are really continuum where sheep cross <1 km of flats between mountains.

We recorded some movements between Mexico and Arizona, but they were not intermountain movements, only movements within a mountain complex that spans the Mexico–Arizona border. Of the 14 collared bighorn, 3 moved in and out of Mexico.

Home range sizes varied from 7.3 to 48.3 km² for 10 collared ewes and from 14.9 to 319.7 km² for 4 collared rams. Mean home range for ewes was 22.0 ± 4.1 km² (n = 10) and for rams was 115.1 ± 70.1 km² (n = 4). Home range was based on 14–25 locations for each bighorn over the 17 month period. Mean home range of rams was large due to the inclusion of the 1 ram that crossed a valley. His home range, as calculated by the minimum convex polygon method, includes a large area of valley floor that was not likely used by the animal. If this ram is deleted from calculations, mean home range of 3 rams was 46.8 ± 22.9 km² (range = 14.9–91.2 km²).

Disease Studies

Of 7 bighorn tested, only 1 ewe had a titer to any virus known to be a pathogen in bighorn. This bighorn, a 5-year-old ewe from the Tinajas Altas Mountains, was seropositive to CE at a 1:320 dilution. Contagious ecthyma is an infectious dermatitis that has been documented in other bighorn populations (Connell 1954, Samuel et al. 1975, Lance et al. 1981, King and Workman 1983*a*, Jessup 1985). No disease symptoms were observed on the seropositive ewe, and the titer alone is not an indication of a disease state. Nevertheless, a 1:320 titer is relatively high, probably indicative of a recent or active infection.

The same ewe with the CE titer was also seropositive to Leptospira *interrogans* serovar hardjo at a 1:100 titer. Leptospirosis is a contagious bacterial disease (Siegmund 1973). Positive titers to Leptospira have been found in other desert bighorn populations where no pathologic evidence was present (DeForge 1980, Chilelli et al. 1982, DeForge et al. 1982, Turner and Payson 1982). A 1:100 titer to leptospirosis is not relatively high. This 1 titer cannot be interpreted that leptospirosis is a significant disease factor of the bighorn in this area.

Two ewes (1 in the Tinajas Altas Mountains and 1 in the Gila Mountains) were seropositive to RSV at a 1:20 dilution by indirect fluorescent antibody (IFA) tests, but negative by serum neutralization (SN) tests. All other Cabeza Prieta and Goldwater bighorn were negative to RSV by both SN and IFA. These data would best be interpreted that this herd may have had exposure to this potential respiratory pathogen. Serum neutralization titers to RSV are often found in bighorn serum, but the significance is not known (D. A. Jessup, Calif. Fish and Game Dep., pers. commun.). All of the bighorn tested were seronegative to IBR, P13, BT, and EHD.

DISCUSSION

Population Estimate

The population estimates for the study area were similar for the 2 years. These estimates can be used as a basis for establishing and supporting management goals and hunt recommendations for the study area.

Although >30 hours of flight time were used during each year's survey, this level of survey intensity did not result in sample sizes that gave reliable population estimates for individual mountain ranges. Funds will not likely be available in the near future to survey these ranges at a greater intensity, so reliable population estimates by mountain range may not be a reasonable goal.

Movements

Our movement studies do not support the theory that bighorn commonly make intermountain movements, nor that they range between the Cabeza Prieta and Pinacate areas. Our study confirms data from other bighorn studies (Witham and Smith 1979, Elenowitz 1982, Cochran and Smith 1983, Ough and deVos 1984) that bighorn can, and sometimes do, make intermountain movements, but it is not common for the majority of animals. Home range size was similar to that documented for most desert bighorn (Leslie 1977, Leslie and Douglas 1979, Witham and Smith 1979, Seegmiller and Ohmart 1981, King and Workman 1983*b,* Ough and deVos 1984, Elenowitz 1984), but here it is notable because intermountain movements are not blocked by man's developments.

There are several hypothetical explanations of why movement data from this study might conflict with historical reports.

1. It is possible that bighorn never moved between mountain ranges or to Mexico. Because early observers did not see bighorn during some times of year, they may have mistakenly thought they moved to another area. Early observers did not have the advantage of modern telemetry and biweekly aerial locations.
2. Animals that early observers saw moving across valleys may have only been a few young or very old rams, those same animals we find most likely to wander today.
3. Intermountain movements may be related to long-term cycles that will only be recorded with extended studies of radio-collared animals. Movement cycles could be responses to changes in climatic conditions, such as atypically dry or wet periods.
4. Water development may have eliminated the need to search for water and thus the motivation for moving between ranges.
5. Some management or land-use activity in the study area may be limiting bighorn movements. Some researchers have speculated that noise disturbance from military aircraft may be creating "noise corridors" that are restricting intermountain movements (J. E. Scott, Tyndall Air Force Base, pers. commun.). It is also possible that Highway 2 in Mexico or the intermittent fence along the Mexico/Arizona border has restricted movement.
6. Movements may be related to density-dependent factors. Continued monitoring of these populations may provide documentation of changes in movements related to changes in bighorn density.

Data collected from this study can neither eliminate nor substantiate any of these hypotheses. We cannot determine if bighorn really did migrate in earlier times, if more intermountain movement will be documented by studying this population for a longer period of time, or if bighorn have actually decreased their intermountain movements in recent times.

Any management or land-use action (e.g., water development, military use) that might decrease intermountain movements in the Cabeza Prieta and Goldwater bighorn populations should be evaluated as to its ultimate effect on bighorn. Positive aspects of decreasing intermountain movements in these herds might include (1) less disease exposure in Mexico, (2) less loss to hunting in Mexico, (3) less chance of predation while crossing valleys, and (4) a possible increase in the carrying capacity if forage and space is available but water was a limiting factor in a range. Negative aspects of decreasing intermountain movements might include less mixing of the gene pool.

Our movement studies give support to using these population estimates for managment plans and actions. We know that large fluctuations in population size do not occur because of hypothetical migrations between mountain ranges or to Mexico.

Disease Studies

We theorized that disease exposure would be high in the Cabeza Prieta and Goldwater bighorn population because of potential for contact with domestic livestock in Mexico and contact in the United States with trespass livestock from Mexico. However, serology on samples collected during the radio-collaring operation showed disease exposure to be low.

Disease data from our study contrast considerably with other desert bighorn serological surveys. No bighorn tested in this study were seropositive to BT or PI3, 2 major mortality-causing diseases of bighorn (Hailey et al. 1972, Parks et al. 1972, Blaisdell 1975, DeForge et al. 1982, Jessup 1985, Sandoval et al. 1987). Twenty-five blood samples from bighorn at the Kofa National Wildlife Refuge were processed concurrently with these 7 Cabeza Prieta and Goldwater samples. In contrast to the Cabeza Prieta and Goldwater study, 14/20 of the Kofa samples were seropositive for PI3, 19/25 were seropositive for RSV, and 11/25 were seropositive for leptospirosis, indicating in general a greater disease exposure in the Kofa bighorn populations (R. Remington and J. C. deVos, unpubl. data).

With a sample size of only 7, we cannot conclude that those diseases to which we found no reactors do not exist here, but these data indicate <35% of the population has been exposed to those disease organisms (Wehausen 1987).

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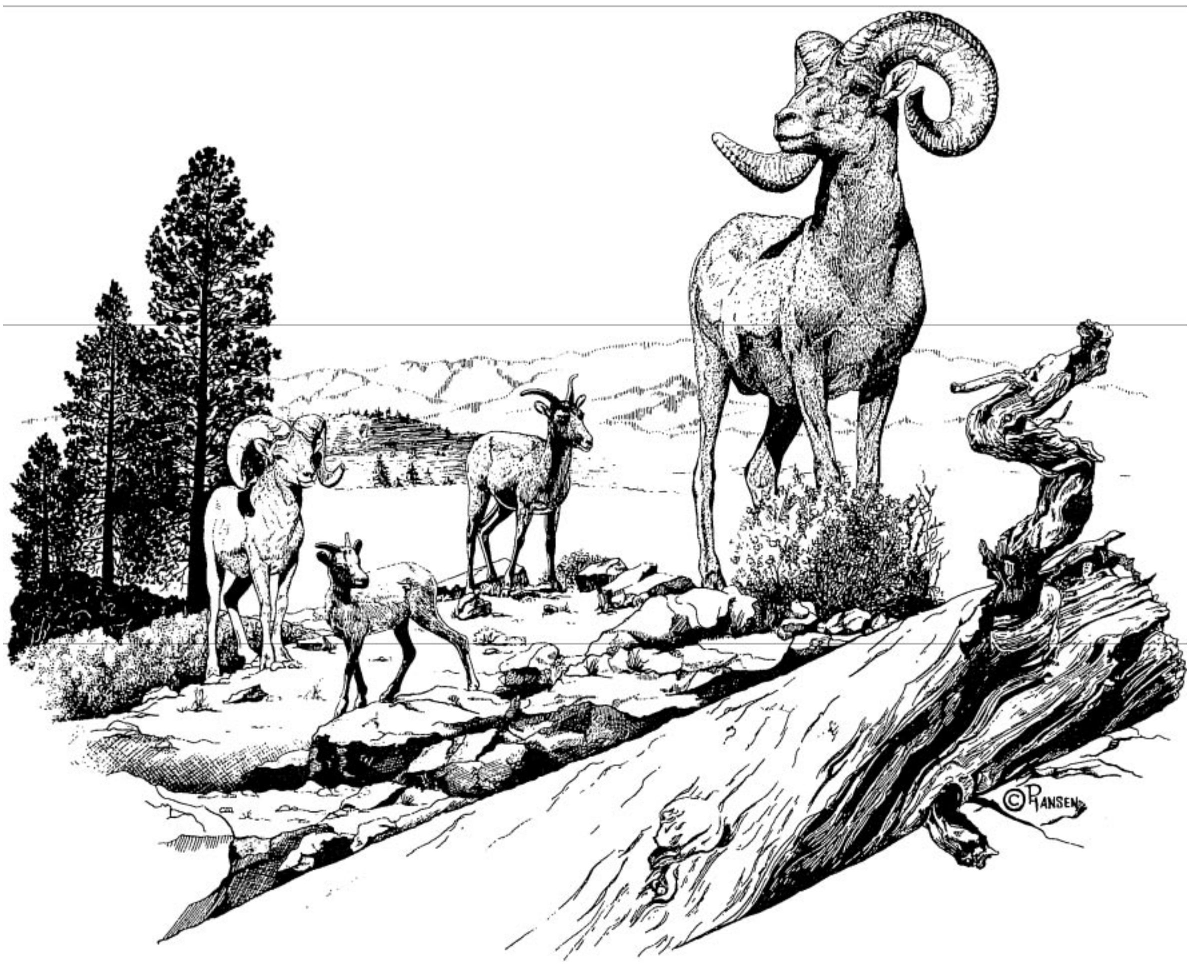

A REVIEW OF DESERT BIGHORN SHEEP IN THE SAN ANDRES MOUNTAINS, NEW MEXICO

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Desert Bighorn Counc. Trans. 34:14–22.

Abstract: Management of desert bighorn sheep (Ovis canadensis *mexicana*) in the San Andres Mountains has been primarily directed toward control or eradication of the scabies mite (Psoroptes ovis) since the 1978–79 scabies-related die-off. Sheep have not responded to management and the population has not increased ($n = 25 \pm 5$) since 1979. Scabies were directly responsible for 2 of all known radio-collared mortalities ($n = 43$) since 1980. Other causes of mortality included accidental falls ($n = 4$), capture ($n = 2$), disease ($n = 3$), lambing ($n = 1$), mountain lion predation ($n = 22$), old age ($n = 2$), and undetermined natural causes ($n = 7$). Based on recent information regarding minimum viable population size, extinction is the anticipated outcome for San Andres sheep at their current population level. Transplants are a feasible alternative to re-establish a viable, self-sustaining population of desert bighorn sheep in the San Andres Mountains.

Key *words:* desert bighorn sheep, New Mexico, Psoroptes, San Andres, scabies.

The San Andres National Wildlife Refuge (SANWR) was established in 1941 for the conservation and development of natural wildlife resources with emphasis on restoring a remnant population of desert bighorn sheep. This subspecies is a New Mexico-listed endangered species. Current state distribution of the 130 free-ranging desert bighorn sheep include populations in the Hatchet, Peloncillo, Alamo Hueco, and San Andres Mountains of southern New Mexico. A major scabies-related die-off occurred in the bighorn sheep herd in 1978–79 in the San Andres Mountains resulting in an estimated loss of >50% of the population (Sandoval 1980). Despite various management strategies directed at controlling or eradicating scabies, the bighorn sheep population has not increased. Whether or not scabies has contributed as a direct or indirect factor in bighorn sheep mortalities in the San Andres Mountains (SAM) since the 1978–79 die-off remains a primary management concern. My objective is to review the status of desert bighorn sheep in the SAM in terms of disease history, past management, mortality, reproduction, and recruitment. Other factors affecting population increase since the 1978–79 scabies-related die-off are also discussed.

HISTORY

In 1941, 33 sheep inhabited SANWR. By 1967, the population increased to 270, the highest number of sheep ever recorded in SANWR. There have been 2 documented desert bighorn sheep declines in the SAM since 1941. In 1955, the population estimate was 70, following a peak of 140 individuals in 1950. The decline was attributed to severe drought, an overpopulation of desert mule deer (Odocoileus *hemionus* crooki) on the refuge, overgrazing by domestic livestock, and human disturbance during the annual deer hunts (Lang 1956). Livestock grazing was completely eliminated in 1951 with the establishment of White Sands Missile Range (WMSR). At that time, all lands fell under the primary jurisdiction of the Department of Army and all forms of appropriation including mining, mineral leasing, and grazing were prohibited.

The other significant population decline occurred in 1978–79 and was attributed to a widespread scabies epizootic (Lange et al. 1980). Prior to the disease outbreak, the bighorn sheep population had stabilized at an estimated 200 ± 18 individuals (Sandoval 1979). The actual number of sheep observed in aerial and ground surveys in 1976 was 180. The October 1978 sheep hunt revealed the presence of scabies mites in the ears of 5 rams harvested. Mites from these lesions were identified as Psoroptes ovis (Hering) (Lange et al. 1980). The population was monitored over the next several months and it was apparent the infestation was widespread. Attempts to treat the sheep with dust bags containing 5% coumaphos were not effective and in November 1979 the U.S. Fish and Wildlife Service (USFWS), New Mexico Department of Game and Fish (NMDGF) and WSMR initiated a salvage and treatment operation. The population estimate in November 1979 was 80 individuals (Sandoval 1980). During the salvage operation 49 sheep were tranquilized and transported to a central treatment facility. Each animal was dipped twice in a 0.5% toxaphene solution at 14 day intervals. Thirty-five sheep survived the capture and subsequent treatment. Seven rams were sent to New Mexico State University for experimental control of P. ovis and cross-transmission studies. The remaining 28 sheep (23 F, 5 M) were relocated to the New Mexico Department of Game and Fish bighorn sheep captive breeding facility at Red Rock, New Mexico, where they remained for 13 months. While in captivity, sheep from the SAM experienced a second disease-related die-off that resulted in a loss of 60% of the remaining population (Sandoval 1981). Serological tests confirmed the presence of viral blue-tongue in the adult population, while contagious ecthyma (CE) was implicated in the deaths of 5 of 7 lambs that had been born at Red Rock (Sandoval 1981). Resident, captive-bred desert bighorn sheep at Red Rock did not experience a similar decline. Survivors ($n = 14$) of the blue-tongue epidemic were captured, inoculated, radio-collared, and transported back to the SAM on 23 January 1981. Two rams died in transport. The population estimate in 1981, following reintroduction, was 40 sheep. As of March 1990, the population estimate was 23 individuals (6 M, 10 F, 4 yearlings and 3 lambs).

The origin of scabies in desert bighorn sheep in the SAM remains unanswered. No records exist to indicate prior evidence of scabies infestation in the population. Speculation on origin includes transmission by domestic livestock co-inhabiting ranges with the sheep, the existence of other wildlife reservoir hosts, or the possibility that mites are endemic in bighorn sheep populations and manifest themselves in varying degrees of virulence when conditions of either the host or environment are optimal for mite reproduction and survival (Lange et al. 1980, Welsh and Bunch 1983).

The ecology of the mite and its involvement as a proximal and/or predisposing mortality factor in bighorn sheep is also unknown. There are ≥3 factors that may have contributed to the severity of the 1978 outbreak: adverse weather conditions preceding the San Andres epizootic (Sandoval 1980), evolution of a more virulent strain of mite (Roberts and Meleney 1971, Kinzer et al. 1983), and the presence of CE in the population (Lange 1980). Blood sera collected from captured sheep in November 1979 revealed the presence of antibodies against CE (a disease that has been associated with mortality in B.C., Mont., and Calif.) (Lange 1980). Twenty-eight percent of the captured sheep ($n = 49$) in 1979 exhibited epidermal lesions of the muzzle and lips. Lange (1980) posed 2 vital questions, neither of which were answered: 1) Is CE the actual cause of mortality in the San Andres? and 2) was mortality the result of a synergistic relationships between scabies and the virus of CE?

STUDY AREA

The SAM are located approximately 32 km northeast of Las Cruces, New Mexico, and are situated within the boundaries of White Sands Missile Range (Fig. 1). The San Andres National Wildlife Refuge includes approximately 230 km² of the southern portion of the SAM and encompasses 23,172 ha. Desert bighorn sheep range throughout the southern half of the mountain range.

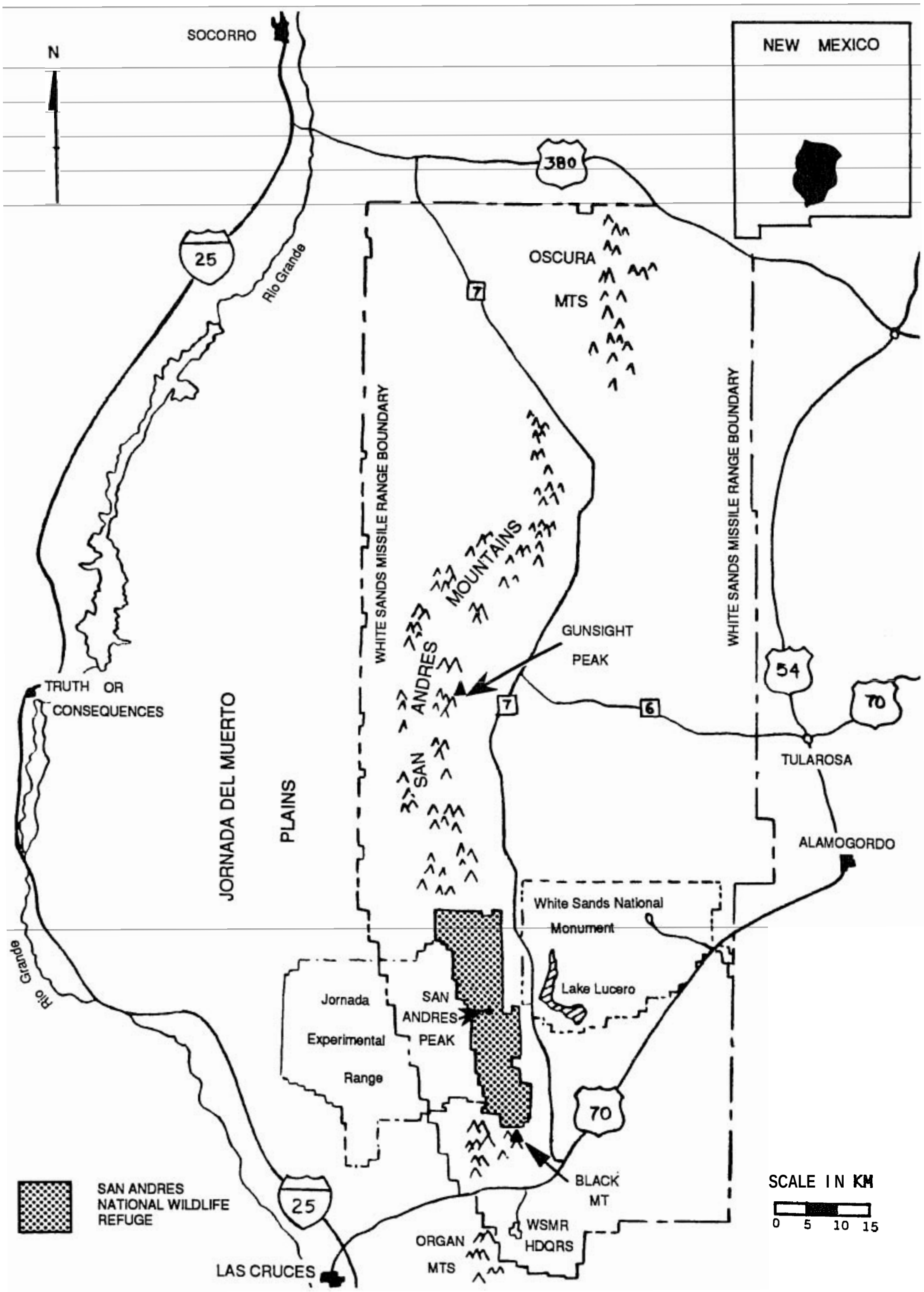

Fig. 1 San Andres National Wildlife Refuge and vicinity, New Mexico.

METHODS

From 1985 to 1989 I collected and summarized data on movements, mortalities, and distribution of desert bighorn sheep in the SAM through the use of radio telemetry and actual observation. During 5 years, I documented 353 observations of desert bighorn sheep. These observations were made primarily from the ground using a portable receiver and hand-held, directional H-antenna. Information summarized for each observation included: date, time, weather, location, habitat, percent slope, aspect, elevation, group size, group composition, physical condition, behavior, food habits, reaction to observer, and distance to escape terrain. Additional information for population analysis was gathered by D. Munoz from 1980–84 and included data from 127 observations. Nine captures of 64 sheep (16 ad M, 33 ad F, 8 F lambs, and 7 M lambs) have been conducted since 1980. Chemical immobi-

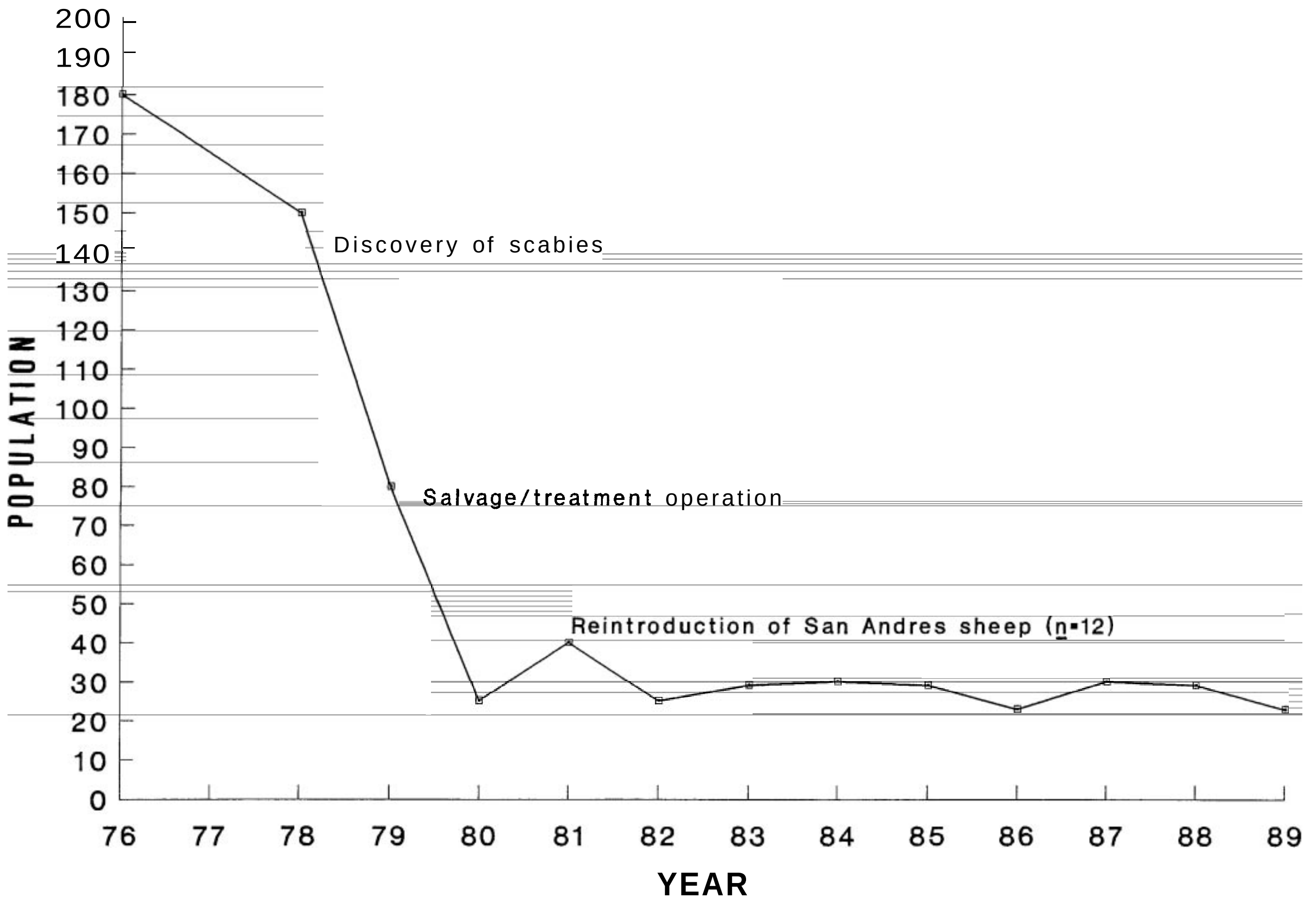

Fig. 2. Number of desert bighorn sheep in the San Andres Mountains, New Mexico.

lization and net gun were the principal means of capture. Each animal was instrumented with a radio telemetry collar containing a 2-hour time delay mortality sensor (Telonics, Inc., Mesa, Ariz.). Blood samples were collected from 44 sheep for serologic and electrophoretic analysis.

SCABIES

Prevalence

Until attention was drawn to the 1978 San Andres scabies epizootic, little effort was made to regularly survey for the presence of mites in bighorn sheep populations. Historically, scabies epizootics have been documented in Rocky Mountain *(Ovis canadensis canadensis)* and desert bighorn sheep in California, Colorado, Idaho, Montana, Nevada, Oregon, and Wyoming (Hornaday 1901, Seton 1929, Wright et al. 1933, Honess and Frost 1942, Packard 1946, Hansen 1967, Cater 1968, Decker 1970, Lange et al. 1980). Effects of scabies within a population have ranged from coexistence between the mite and host (Cater 1968, Decker 1970) to widespread population mortality and decline (Hornaday 1901, Honess and Frost 1942, Packard 1946, Lange et al. 1980, Welsh and Bunch 1982). Recent outbreaks have been documented in Idaho, California, Washington, and Oregon in 1984, 1987, 1988, and 1988, respectively (Foreyt 1985, Clark et al. 1988). Prior to 1987, scabies had not been documented in California since 1950. It had been 15 years since the last documented incidence in Idaho and 50 years since previous reported cases in Washington and California. Although it is possible that recent outbreaks are due to newly introduced parasites, it is more likely, based on recent evidence and lack of contact with domestic livestock, that scabies is endemic in bighorn sheep populations (Clark et al. 1988). Because manifestation of clinical signs is not always apparent, perfection of serological tests for mite antibody levels will be the most reliable method in the future to determine the prevalence of subclinical scabies in various herds (DeVos 1980, Clark et al. 1988).

Taxonomy

Although specific taxonomic identification of mites within the genus *Psoroptes* is inconclusive, the work of Sweatman (1958) is still considered as the most recent and comprehensive study of the problem. According to Sweatman (1958), all stages of *Psoroptes* are morphologically indistinguishable except for the adult males that are separated primarily on the' length of the outer opisthosomal seta. Mites of bighorn sheep have been identified as *P. ovis, P. cervinae, P. cervinus, P. communis* var. *cervinae, P. equi* var. *ovis* and more recently as *P. cuniculi* (Lange 1980; W. M. Boyce, Univ. California at Davis, pers. commun.). Sweatman (1958) further differentiates between species of mites based on their location on the host's body. *P. cervinus* and *P. cuniculi* are classified as ear mites, while *P. ovis* is classified as a body mite. Mites collected from bighorn sheep in the SAM have been classified as *P. ovis* and *P. cuniculi* (Lange 1980; W. M. Boyce, pers. commun.). Identification of mites isolated from bighorn sheep in Wyoming indicate similar taxonomic inconsistencies; 1 laboratory identified the mite as *P. cervinus,* while another laboratory identified the same mite as *P. equi* (Muschenheim 1988). It appears that mite taxonomy, based only on morphological characteristics, is inadequate. To further complicate the issue, Wright et al. (1983) found that cross-matings between *P. ovis* and *P. cuniculi* produced viable hybrid offspring, questioning the validity of 2 separate species. More sensitive techniques such as deoxyribonucleicacid (DNA) analysis, should be used to differentiate between species. Cross-trans-

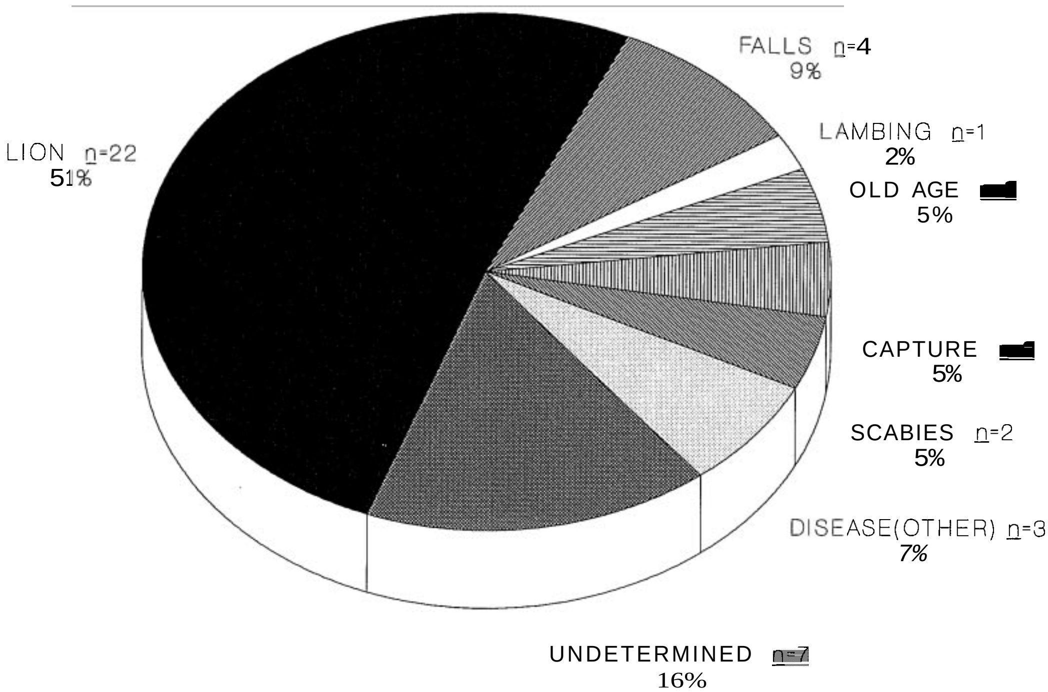

Fig. 3. Mortalities recorded for 43 radio-collared desert bighorn sheep in the San Andres Mountains, New Mexico, 1980–89.

mission studies will be another important test in determining whether or not mites of a particular species are capable of infesting >1 host.

Alternate Hosts

The existence or probability of alternate hosts in the San Andres Mountains was not documented until 1989. Results of preliminary cross-transmission studies, conducted by Kinzer et al. (1983), suggested mites were host-specific based on the difficulty or failure to successfully transfer mites from bighorn sheep to cattle, domestic sheep, mule deer, Barbary sheep (Ammotragus lervia), or oryx (Oryx gazella). During the fall and winter of 1989–90, scabies was discovered on 5 mule deer, 3 from within the San Andres Mountains and 2 from within the Oscura Mountains (a range located approximately 12.8 km northeast of the San Andres Mountains) (Fig. 1). Two mule deer, captured and sampled in conjunction with a mountain lion (Felis concolor) study in the SAM in October 1989, tested positive for scabies, based upon examination of deep ear canal swabs. Neither animal, however, exhibited clinical signs. Two other mule deer, harvested in the November 1989 Oscura Mountain deer hunt, had visible scabies lesions in the ears. In January 1990, mountain lion researchers found a lion-killed mule deer male (>10 yr) on the west slope of San Andres Peak. Scabies lesions were apparent in both ear canals, at the base of each antler, and on the tops of both shoulders. Live mites from both mule deer and bighorn sheep were identified as Psoroptes and both had opisthosomal setae lengths within the range of P. ovis and P. cuniculi according to Sweatman's 1958 classification (W. M. Boyce, pers. commun.). Based on morphometric comparisons, Boyce et al. (1990) concluded bighorn sheep and mule deer mites were not significantly different, suggesting the possibility of a single interbreeding population. Additional studies, including DNA analysis and cross-transmission studies, have been proposed for 1991 to provide further insight into the relationship between these 2 mite populations.

Treatment

Management of desert bighorn sheep following the 1978–79 epizootic has focused on efforts to eradicate scabies in the population. These efforts were based on assumptions that attainment of a mite-free environment was a realistic long-term goal and that no known alternate hosts existed. Since the die-off, the degree and severity of scabies infestation has varied widely among individuals within the population, ranging from total absence of clinical signs in some to infestation of $>50\%$ of the body in others. The ability of certain individuals to recover has also been documented through the subsequent absence of previously observed lesions. Lange et al. (1980) and DeVos (1980) found that yearling or older males suffer a higher incidence of scabies and a greater pathogenicity than females; however, there is little evidence to suggest females are capable of passing on acquired immunity to their offspring.

Over the years, sheep in the SAM have been experimentally treated (both on-site and remotely) with various formulations of Ivermectin. Although treatment has been successful in temporarily reducing clinical symptoms, it has not succeeded in eradicating the mite, nor has it had a positive effect on increasing population size. Kinzer et al. (1983) concluded that the primary objective of treatment should be management of the mite only during critical periods rather than complete eradication. In his opinion, bighorn sheep need to support low level, endemic populations of mites to maintain a level of resistance. When virulent strains emerge, they must then develop resistance to the new strain.

POPULATION CHARACTERISTICS

Following the 1978–79 die-off, the desert bighorn sheep population in the SAM has not increased. Instead, the resident herd has remained relatively stable at approximately 25 ± 5 individuals (Fig. 2). In 1981, following the reintroduction of 12 sheep (9 F, 3 M) from the 1979 salvage operation, the population estimate was 40 individuals; however, after experiencing high mortalities, the herd again stabilized at 25 ± 5 sheep in 1982 and remained within that range for the next 8 years. Mortality, longevity, reproduction, lamb survival, health status, and population size are all significant factors influencing long-term population growth and viability.

Mortality

Twenty to 86% (n = 6–25) of the remaining population has been radio-collared and monitored on a regular basis. Sixty-four desert bighorn sheep have been radio-collared since 1981. Forty-three radio-collared sheep mortalities have been documented. These mortalities have been attributed to a variety of causes including accidental falls, capture, disease, lambing, mountain lion predation, old age, and undetermined natural causes (Figs. 3, 4).

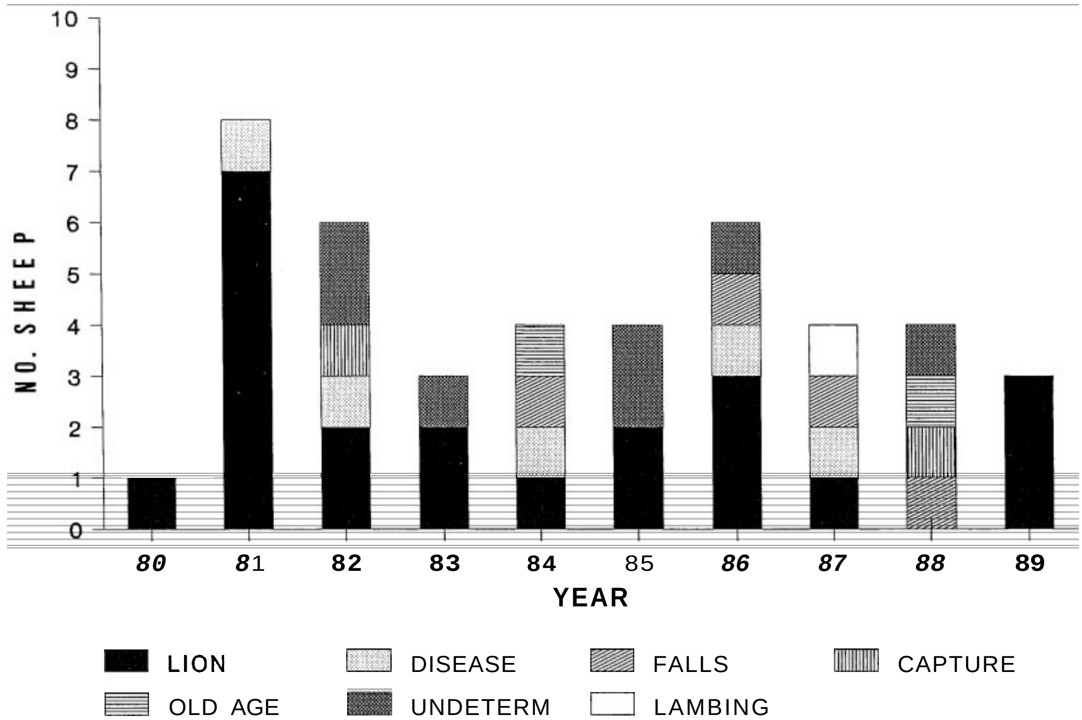

Fig. 4. Annual mortality of 43 radio-collared desert bighorn sheep in the San Andres Mountains, New Mexico.

Scabies was attributed as the primary cause of death in 2 of the 43 documented radio-collared sheep mortalities (SANWR files). Although it has been argued that scabies has contributed indirectly to high population mortality by predisposing sheep (through impaired hearing and balance) to death by other causes (i.e., accidental falls and mountain lion predation) observations obtained from the San Andres herd and available literature do not coincide with this theory. Falls have accounted for 9% of all known mortalities in the San Andres population, while mountain lion predation has accounted for 51%. Fatal falls of bighorn sheep with no associated physical impairment have been documented and attributed to other causes including fleeing from aircraft (R. Kearns, Kofa NWR, Arizona, pers. commun.) and lost footing by lambs or adults in precipitous terrain (Festa-Bianchet 1987, Brundige 1987). Loss of balance and accidental falls may also result from sheep attempting to flee from predators, dogs or people, rams pursuing estrous ewes, and aggressive interactions among rams during the rut (Festa-Bianchet 1987).

Group size, rather than the prevalence of scabies, may have a more

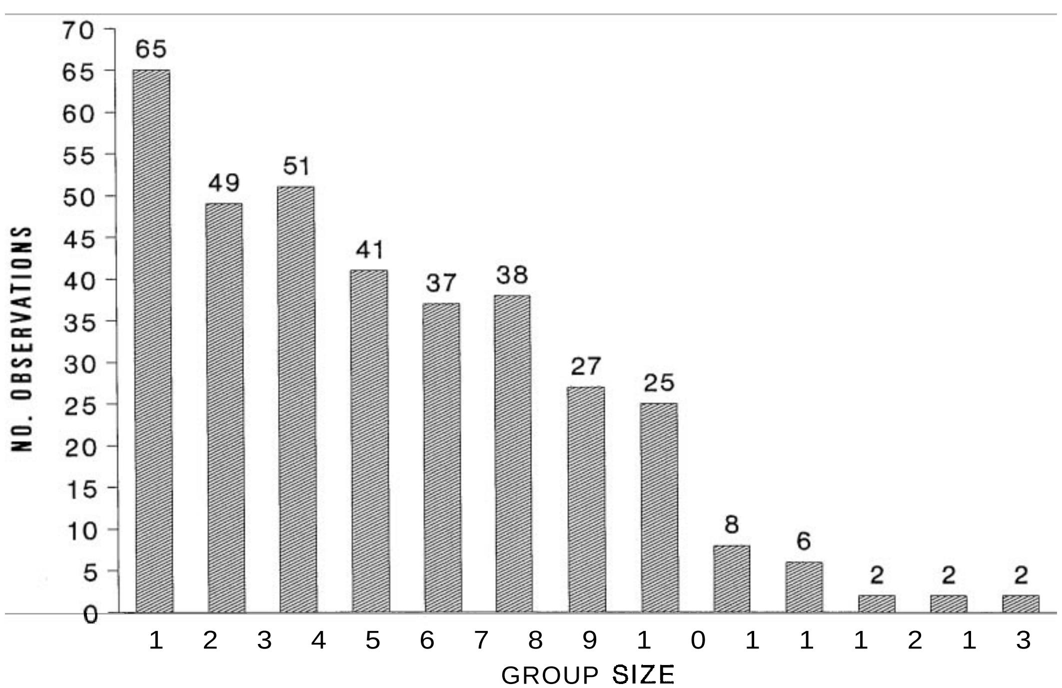

Fig. 5. Group size and number of observations of desert bighorn sheep in the San Andres Mountains, New Mexico, 1985–89.

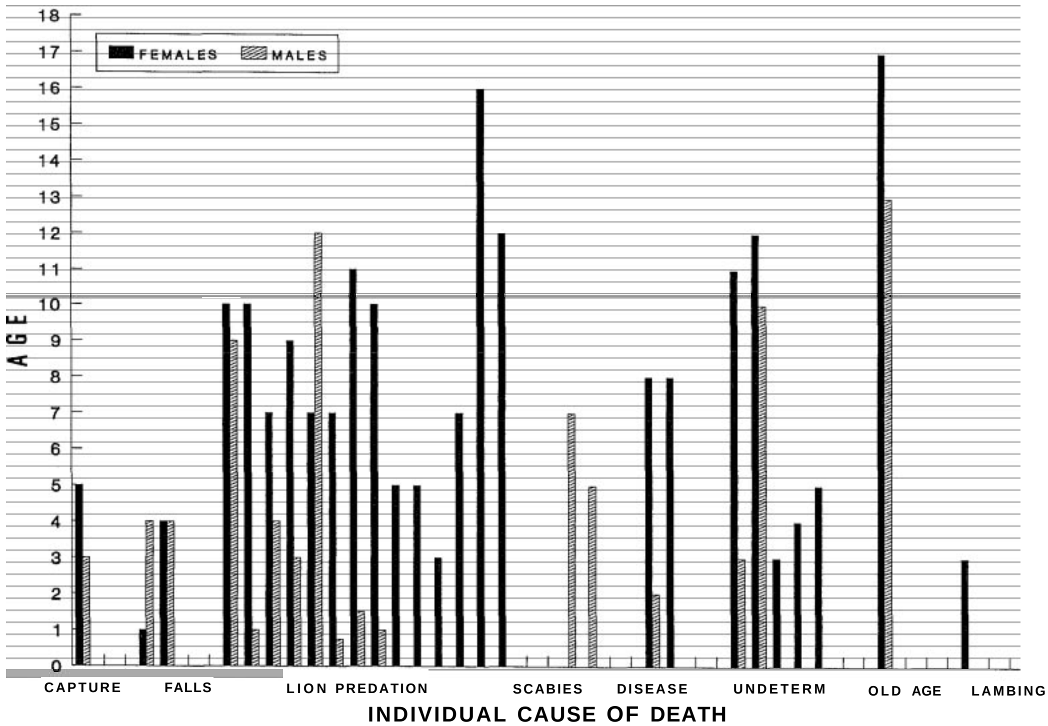

Fig. 6. Age, sex, and individual cause of death for 43 radio-collared desert bighorn sheep in the San Andres Mountains, New Mexico, 1980–89.

significant effect on sheep survival relative to mountain lion predation. Bighorn sheep rely primarily on visual rather than auditory or olfactory senses to detect danger (Monson 1980, Lawson and Johnson 1982). Several studies have shown that foraging in large groups reduces individual risk and enhances detection of predators (Berger 1978, Simmons 1982, Risenhoover and Bailey 1985). Sheep in small groups forage less efficiently and spend more time alert (Berger 1978). Increased individual altertness, however, does not always result in increased ability to detect predators. Simmons (1982) found that sheep foraging efficiency increased with group sizes up to 20 animals. Even though solitary sheep were 3 x more alert than sheep foraging in a group of 20, the combined alertness of sheep foraging in a group of 20 animals provided almost 7 x the number of alert postures/minute. Larger groups, therefore, were more likely to detect approaching predators or other threats than sheep confined to smaller groups. Two studies indicated that a band size of 5 was most efficient with respect to predator avoidance (Berger 1978, Risenhoover and Bailey 1985). Annual mean group size during the past 5 years at San Andres ranged from 4.75 in 1985 to 3.65 in 1989. Fifty-eight percent of all observations from 1985 to 1989 were composed of ≤4 individuals (Fig. 5).

Longevity

Analysis of 43 radio-collared bighorn sheep mortalities from 1980 to 1989 indicate average age at time of death was 6.6 years old (Fig. 6). The number of mortalities in females as compared to males is in proportion to the number of females to males in the radio-collared segment of the population. Individual age at time of death ranged from 0.75 to 17 years. Although sheep may live to be 15–17 years of age, 10–12 years is a more realistic estimate (Hansen 1967, Clark 1970, Bunnell 1978, Monson 1980). Twenty-eight percent (n = 43) of all known radio-collared bighorn sheep mortalities in the SAM were ≥10 years old at the time of death.

Group Composition, Reproduction, and Lamb Survival

Population composition of bighorn sheep in the SAM has remained stable since 1985 and is consistent with population ratios prior to the 1978–79 die-off (Tables 1, 2). Minor fluctuations in herd size and composition since 1985 reflect changes relative to reproductive success in a given year.

Composition estimates in Table 1 (Sandoval 1979) are based on ground surveys and/or aerial surveys. Data in Table 1 should be viewed with caution because population ratios in some years were based on only 1 survey. Since 1985, proportion reproduction among breeding age females has ranged from 0.46 to 0.89, averaging 0.63 (Table 3). Lambing has been documented in both young females (age 2) and older females (≥10 yr). One female, SAE-021, successfully lambed until the age of 15. This particular individual was present on the mountain prior to, during, and for 10 years following the scabies epizootic. According to Monson (1980) average proportion survival of desert bighorn lambs from birth to age 6 months is 0.55. Over the past 5 years, lamb survival to 1 year in the SAM has averaged 0.79 (range = 0.55 to 1.00) (Table 3).

Health

A study was initiated in 1988 to determine whether or not there were underlying health problems in bighorn sheep in the SAM that predisposed them to mite infestation and/or clinical manifestation of the disease. Preliminary results of the first year capture and sampling efforts were categorized as: physical condition, individual health screening, immunology, infectious disease screening, pathogen isolation, and pathology (R. K. Clark, status of psoroptic scabies in and health of bighorn sheep in the San Andres Mountains of New Mexico, Rep. to U.S. Fish Wildl. Serv., 14pp., 1989). Of the 9 live sheep sampled, all but 1 yearling ewe were described as being "in good flesh" and "sturdy." Fecal cortisol levels ranged from 6.3 to 21.4 ng/mg dry matter feces with a mean of 10.8 and standard error of 1.7. In comparison, tame Rocky Mountain bighorn sheep have a mean of 7.0 ng/mg while stressed Rocky Mountain have a mean of 12.0 ng/mg. Immunology testing indicated there were more antibodies and other globulin fractions produced relative to albumin as compared to other sheep populations. Infectious disease findings were negative for antibodies to immunosuppression diseases normally associated with declining bighorn sheep populations such as bovine leukemia virus, bovine lentivirus, and progressive pneumonia-maedi visna virus. Additional serology for epizootic hemorrhagic disease virus,

Table 1. Numbers and composition of desert bighorn sheep in the San Andres Mountains, New Mexico, from 1941 to 1976 (Sandoval 1979).

		Composition					Composition		
Year	No.	Ram : Ewe	Lamb : Ewe	Yearling : Ewe	Year	No.	Ram : Ewe	Lamb : Ewe	Yearling : Ewe
1941	27	50:100	75:100	00:100	1959	121	142:100	92:100	42:100
1942	31	52:100	52:100	22:100	1960	130	175:100	50:100	00:100
1943	62	57:100	63:100	43:100	1961	142	72:100	50:100	25:100
1944	71	82:100	73:100	54:100	1962	150	32:100	37:100	10:100
1945	78	63:100	33:100	47:100	1963	165	70:100	53:100	36:100
1946	85	71:100	33:100	23:100	1964	175	61:100	21:100	00:100
1947	100	51:100	34:100	19:100	1965	190	79:100	49:100	01:100
1948	112	67:100	46:100	35:100	1966	251	88:100	50:100	16:100
1949	130	41:100	91:100	29:100	1967	270	107:100	40:100	32:100
1950	140	100:100	43:100	26:100	1968	250	77:100	55:100	07:100
1951	100	68:100	29:100	10:100	1969	200	90:100	62:100	26:100
1952	112	68:100	31:100	26:100	1970	200	109:100	53:100	23:100
1953	53	48:100	34:100	17:100	1971	200	40:100	88:100	33:100
1954	62	65:100	39:100	35:100	1972	200	106:100	74:100	36:100
1955	70	58:100	42:100	42:100	1973	200	69:100	68:100	53:100
1956	86	60:100	50:100	00:100	1974	225	31:100	29:100	16:100
1957	92	70:100	41:100	30:100	1975	200	82:100	46:100	26:100
1958	100	50:100	59:100	32:100	1976	182	47:100	36:100	34:100

ovine border disease virus, ovine progressive pneumonia virus, and parainfluenza 3 virus were also negative. Pathogen isolation included both bacterial and viral analyses. *Pasteurella haemolytica* (non-hemolytic) was isolated from 1 individual. No virus was isolated from either nasal or whole blood samples. *Psoroptes* mites were isolated from the body and/or ears of 9 of 10 individuals in 1988 and 10 of 10 individuals in 1989. Gastrointestinal parasites included low levels of *Balantidium coli, Trichuris* spp., and *Nematodirus* spp. A pathological study was performed on SAR-053, a ram that died as a result of a fall during the 1988 capture. All pathological abnormalities were attributed to the traumatic death. R. K. Clark (1989) concluded "major deviations from normal were not evident in most areas of investigation based on the animals sampled to date" and suggested further research was needed.

Population Size

From 1980 to 1989 mortalities canceled recruitment in the bighorn sheep population in the SAM, resulting in a stable population (Fig. 7). This suggests that the problem affecting long-term population increase may be associated with population size, rather than current health status or reproductive success of the San Andres herd. The minimum number of desert bighorn sheep necessary to sustain a viable population is debatable. A viable population, as defined by Soul6 (1987:1–2), is "one which maintains its vigor and its potential for evolutionary adaptation . . . without significant demographic or genetic manipulation for the foreseeable ecological future with a certain, agreed upon, degree of certitude, say 95%." Franklin (1980) suggested that the short-term effective population size should not be <50 and the long-term effective population size should be 500 individuals. Soul6 (1987) discounts 50 as a viable number because it does not protect the population against loss of genetic variation. Berger (1990) studied demographic and weather data for 122 bighorn sheep populations in southwestern North America and found that all populations with <50 individuals became extinct within 50 years, those with >100 animals persisted for up to 70 years, and rapid extinctions were not likely to be caused by food shortages, severe weather, predation, or interspecific competition. Berger (1990) concluded that population size is a marker of persistence trajectories and extinction cannot be overcome because 50 individuals, even in the short term do not constitute a minimum viable population size.

Table 2. Group composition of desert bighorn sheep in the San Andres Mountains, New Mexico, based on fall–winter surveys, 1985–89.

	Rams		Ewes		Yearlings		Lambs		Ram : Ewe :
Year	No.	%	No.	%	No.	%	No.	%	Lamb
1985	7	24	13	45	4	14	5	17	54:100:38
1986	6	26	10	44	4	17	3	13	60:100:30
1987	7	23	10	33	5	17	8	27	70:100:80
1988	7	24	9	31	8	28	5	17	78:100:56
1989	6	26	10	44	4	17	3	13	60:100:30

DISCUSSION

Since the 1978 epizootic, scabies has been directly responsible for 2 (5%) of the 43 documented San Andres desert bighorn sheep mortalities. Other causes of mortality have been attributed to accidental falls (9%), capture (5%), disease (7%), lambing (2%), mountain lion predation (51%), old age (5%), and undetermined natural causes (16%). Past management has focused primarily on eradication of the scabies mite, followed by limited efforts to control mountain lions.

Table 3. Reproduction by female bighorn sheep in the San Andres Mountains, New Mexico, and lamb survival to 1 year from 1985 to 1989.

Year	Females ≥3 years of age	No. females[a] reproducing	Proportion reproducing	Proportion of lambs surviving from age 0 to 1 year
1985	13	9	0.69	0.55
1986	13	6	0.46	0.83
1987	9	8	0.89	0.78
1988	8	5	0.62	0.80
1989	6	3	0.50	1.oo

[a] Two additional females, not included in this column, produced a lamb at age 2 in 1987 and 1989.

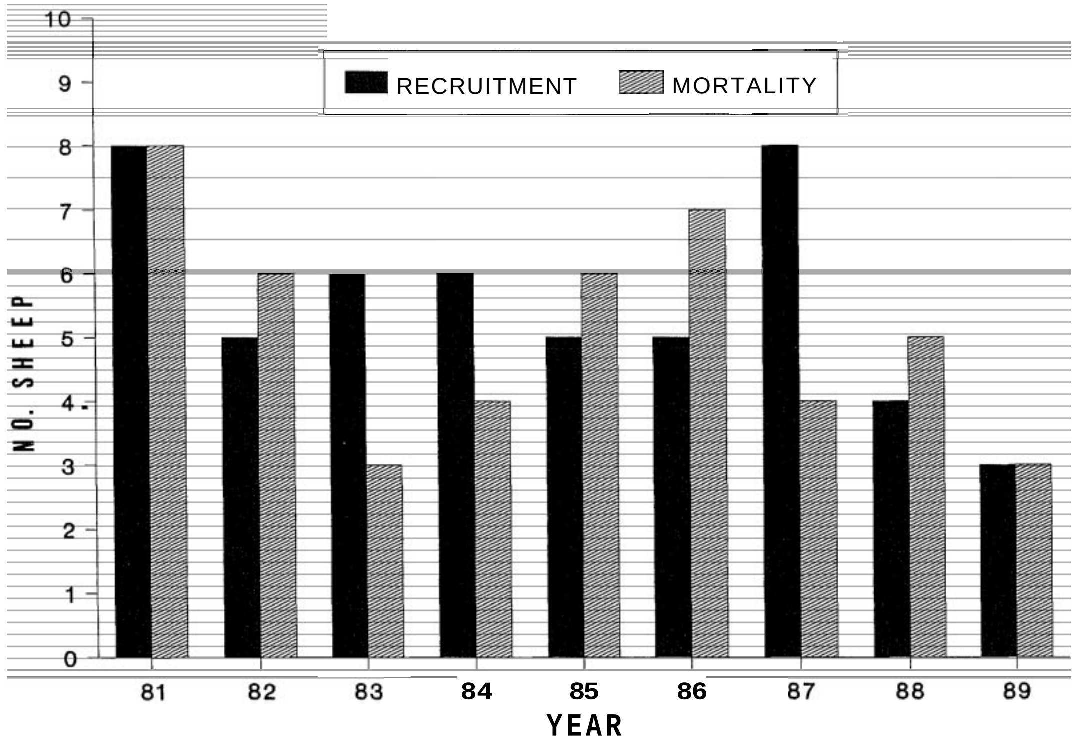

Fig. 7. Annual recruitment and mortality of desert bighorn sheep in the San Andres Mountains, New Mexico, 1981–89.

From 1980 to 1983, 20 lions were trapped and removed from the southern half of the San Andres Mountains in an effort to minimize mountain lion predation on desert bighorn sheep. Such efforts, however, were not successful in reducing the number of lion-related sheep mortalities. In the SAM bighorn sheep mortalities are not simply the result of random encounters between mountain lions and desert bighorn sheep. Individual lions, on 2 separate occasions, have shown a definite preference for desert bighorn sheep. In 1981, 5 radio-collared desert bighorn sheep were killed by 1 female within 4 months. In 1989, 3 desert bighorn sheep were killed by male lion no. 23 in 11.5 weeks, accounting for 100% of all known radio-collared mortalities that year. Because it is unlikely only radio-collared individuals are being selected, it is probable similar losses are also occurring in the uncollared segment of the population. "Problem" lions, therefore, if not controlled can have a significant impact on a small population. The difficulty, obviously, is in identifying and removing these lions before further losses are incurred. This may in part explain why indiscriminate lion control efforts were not successful in reducing the number of lion-related sheep mortalities from 1980 to 1983. Unless "problem" lions are caught and removed simply by random chance, desired results of such operations may never be realized.

Attempts to eradicate scabies were initiated before fully understanding mite and host specificity, mite and host interaction, and mite pathogenicity. Although treatment with Ivermectin was effective in temporarily reducing clinical symptoms, it did not eliminate the infestation and may instead have been detrimental to certain individuals within the population. Nine capture sessions, involving 101 sheep, have been conducted since 1978 in the SAM. Stress-related impacts associated with repeated capture, handling, and treatment of desert bighorn sheep in the SAM have never been evaluated in relation to population welfare and long-term survival. Kock et al. (1987) stated, "Although the net-gun appears to be one of the safest methods of capturing individual bighorn sheep, based on evaluation of capture data and biological parameters, it may not be associated with the best long-term survival in some bighorn sheep."

Sufficient documentation as to whether or not scabies has been a major predisposing factor to other types of mortalities, particularly accidental falls and mountain lion predation, remains to be proven. Recent evidence, however, suggests Psoroptes mites are endemic in other bighorn sheep populations and have co-existed with sheep for several years. The persistence of bighorn sheep in the SAM since the 1978 decline tends to support these findings through the observed absence of a second scabies epizootic. Factors responsible for the sudden virulence of scabies in the San Andres population in 1978–79 may never be completely understood.

MANAGEMENT IMPLICATIONS

The most significant factor affecting a long-term population increase of desert bighorn sheep in the SANWR appears to be population size. Direct effects of small population size range from a reduction in the number of breeding individuals to a loss of genetic variation within the population. Indirect effects may be evident in the number of mortalities attributed to mountain lion predation, based on predator avoidance strategies relative to group size.

Based on recent information regarding minimum viable population size, extinction is the anticipated outcome for desert bighorn sheep in the SAM. Supplemental transplants into the existing herd will be necessary if reestablishing a viable, self-sustaining population is the desired goal. The source for such transplants would likely involve desert bighorn sheep from Red Rock, New Mexico, a state-managed captive bred herd derived from SAM and Sonora, Mexico desert bighorn sheep. The feasibility of such a transplant was viewed with caution until genetic similarity and disease exposure between the 2 populations were adequately researched. Results of genetic tests indicate very little difference between Red Rock and San Andres sheep (Ramey 1989), while disease history also appears similar, with the exception of scabies (Sandoval 1986). Any transplant, however, is contingent upon first establishing a mite-free environment prior to the introduction of sheep from the Red Rock facility (a requirement of the NMDGF). Realistic attainment of this goal will ultimately depend on the existence and/or certainty of alternate hosts.

There are 2 important advantages associated with transplanting bighorn sheep into currently occupied habitat, the first being increased survival among transplants. Native sheep may show naive transplants existing escape routes, feeding areas, migration routes, and waterholes.

The second advantage is in maintaining the existing distribution of sheep through the mountain range. Transplanting bighorn sheep into unoccupied habitat has often resulted in small, isolated, non-migratory herds (Geist 1971, Risenhoover et al. 1988). The inability to colonize new areas results from learned behavior, passed down through generations, which favors traditional use of home ranges (Geist 1971). Every effort, therefore, should be made to maintain sheep in their native habitat to preserve the migratory traditions associated with that herd.

Additional research can adequately answer questions concerning scabies mite and host interactions and alternate hosts; however, persistence of desert bighorn sheep in the SAM since 1982 at a stable population level demonstrates their ability to coexist with the scabies mite. After reviewing past reproduction, lamb survival, adult longevity and health status, it appears that desert bighorn sheep in the SAM are compromised largely from the standpoint of having reached a level below the minimum viable number necessary to sustain themselves.

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STATUS OF BIGHORN SHEEP IN ARIZONA, 1989

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CURRENT STATUS

Arizona's desert bighorn sheep population (Ovis canadensis mexicana and O. c. nelsoni) is estimated to be 4,500 animals. The 1989 winter helicopter surveys produced 2,266 observations of sheep in 254 hours (8.9 sheep/hour). These survey results yield ratios of 53 rams : 100 ewes : 28 lambs : 20 yearlings. The 1989 survey results may have been affected by drought; the observation rate was 21% lower than last year. Calculated sex and age ratios are indicative of a population that is merely capable of maintaining its current level.

The Rocky Mountain bighorn sheep (*O.* c. canadensis) population, estimated to be 250 animals, is steadily increasing in numbers and range. These sheep are residing near the release site in the San Francisco River drainage, but are moving southward into areas generally considered representative of desert bighorn sheep habitat. During the winter surveys 147 sheep were observed, with ratios of 51 rams : 100 ewes : 57 lambs : 80 yearlings. These ratios are indicative of a productive population.

HUNTING

Bighorn sheep permits remain Arizona's most sought after hunting permits. There were 3,693 applicants for the 80 regular season permits. This continues a 13% annual increase in the application rate with over 46 people applying for each permit, with individual unit odds varying from 8:1 to 318:1.

Two special permits were issued to raise funds for bighorn sheep management programs. Only 81 of the 82 potential hunters participated, harvesting 74 rams, 1 fewer than Arizona's record harvest set last year. Despite this harvest success of only 91%, the last 5 years' mean hunter success remains above 93%.

The 1989 season produced 26 animals (35% of the harvest) qualifying for the Arizona Trophy Book (min. score of 162 Boone and Crockett points). Of these rams, 11 scored ≥170 points. During the previous 5 years, 46% of the harvest scored ≥162 points, while 14% of the harvest scored ≥170 points. The slight decrease in mean score can be attributed to the drought-induced difficulty finding trophy rams during this hunting period.

As a result of this year's surveys, and an increase in observed mortalities, permits for the 1990 season were reduced from 80 to 74. Two additional permits will again be issued for alternative funding purposes.

ALTERNATIVE FUNDING

For the seventh consecutive year, the Arizona Game and Fish Department (AGFD) and the Arizona Desert Bighorn Sheep Society have entered into an agreement whereby the Society auctions 1 permit (at the Foundation for North American Wild Sheep convention) and raffles another to raise funds for bighorn sheep management programs in Arizona. In 1989, these 2 permits produced >$140,000. Since 1984, this program has produced over $900,000. Arizona's bighorn sheep management program is dependant upon the funds derived from these permits.

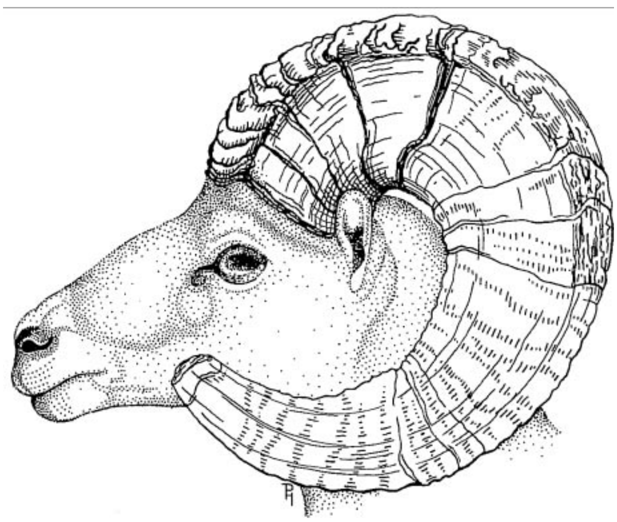
TRANSPLANTING

Since 1980, a mean of 80 bighorn sheep have been transplanted annually, with a mean of only 3 mortalities. In 1989, using drop-nets and net-guns fired from helicopters, 80 bighorn sheep were successfully captured and released. Similar transplant efforts are planned for 1990, with desert bighorn sheep going to Colorado in return for Rocky Mountain bighorn sheep.

Due to the need for increased documentation required to meet environmental concerns and to better coordinate transplant efforts with other agencies, the AGFD recently developed guidelines to facilitate transplant efforts.

RESEARCH

The AGFD has, until recently, been emphasizing research work that provides wildlife managers with more effective management tools. A compendium of these results, coupled with some theories, and even opinions, was recently completed. "The Desert Bighorn Sheep in Arizona" is now available from the AGFD.



STATUS OF BIGHORN SHEEP IN CALIFORNIA, 1989 AND TRANSLOCATIONS FROM 1971 THROUGH 1989

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POPULATION STATUS

Three subspecies of bighorn sheep occur in California: California bighorn (Ovis canadensis *californiana*; n = 300) in the Sierra Nevada of eastern California; Peninsular bighorn (*O.* c. cremnobates; n = 600) in the Peninsular ranges of southwestern California; and Nelson bighorn (*O.* c. nelsoni; n = 3,800) in suitable habitat throughout the eastern Sonoran Desert, the eastern Mojave Desert, the Transverse ranges, and the Great Basin of Mono and Inyo counties. California and Peninsular bighorn are classified as threatened by the California Fish and Game Commission and all populations, except 2 populations of Nelson bighorn, are fully protected by state law.

HUNTING

Since bighorn sheep hunting was authorized by the California Legislature in 1986, 3 hunting seasons have been held. Nine permits were issued in each year from 1987 to 1989. Two hunters in 1988 were unable to complete their hunts, but all others were successful. Hunting is restricted to Old Dad Peak and the Kelso Mountains (30 km SE Baker, San Bernardino Co.), and the Marble Mountains (110 km W Needles, San Bernardino Co.). Animals shot during annual hunts have ranged from 6 to 13 years of age; 8 qualified for the Boone and Crockett Records Book. No difference exists between the ages of sheep taken on an annual basis (Kruskall-Wallis 1-way analysis of variance, $\chi^2 = 3.113$, 2 df, $P = 0.222$) or between the scores of sheep taken on an annual basis (Kruskall-Wallis 1-way analysis of variance, $\chi^2 = 1.234$, 2 df, $P = 0.539$). Similarly, no differences exist between the ages of sheep taken in either hunt zone (Mann-Whitney U-test, $Z = 1.557$, $P = 0.119$). Animals shot in the Marble Mountains were larger than those taken at Old Dad Peak (Mann-Whitney *U*-test, $Z = 2.066$, $P = 0.039$). The harvests in both hunt zones are dominated by large, old rams.

A legal mandate required the California Department of Fish and Game (CDFG) to prepare a comprehensive environmental document to assess the anticipated effects of the proposed 1990 bighorn sheep hunting season. This is the first time that a state wildlife management agency has been required to prepare the equivalent of an environmental impact report for hunting. The CDFG prepared a comprehensive document designed to address and fully disclose the potential impacts of a limited harvest of mature male bighorn sheep on the local (hunted) populations and on the statewide population. The document complied with mandates of the California Environmental Quality Act, and has not been challenged.

State law limits the number of tags to be issued to $\leq 15\%$ of the mature rams (≥ 2 yr old) actually counted in each hunt zone on an annual basis. Because of the variance inherent in aerial survey from year to year, it is anticipated that the number of tags similarly will vary on an annual basis. For hunting purposes, legal rams are those possessing $\geq 3/4$ curl. Six permits have been proposed for the 1990 season: 5 at Old Dad Peak, 1 in the Marble Mountains, and 1 special fundraising (auction) tag, to be valid in either zone. Hunting of bighorn sheep in California will terminate 31 December 1992, unless legislation authorizing the continuation of hunting is passed in 1992.

During each of the past 3 seasons, hunters have experienced some problems with individuals affiliated with the anti-hunting and animal-rights movements. Tactics of those protesters have centered largely around attempting to scare bighorn sheep out of the range of hunters through the use of airhorns or other noise-making devices. Such activities have been largely ineffective and in ≥ 2 cases have facilitated the harvest of large rams that were diverted toward hunters.

In 1988, the California Legislature passed a hunter harassment law that became effective on 1 January 1989. The law makes it an infraction for persons to willfully interfere with the legal take of game species by individuals appropriately authorized to do so. Conviction of such an infraction carries a fine of $\geq \$100 \leq \$500$. Upon conviction of an individual of a first offense, such a violation becomes a misdemeanor, carrying with it a fine of $\geq \$100 \leq \$1{,}000$, and/or imprisonment for ≤ 1 year in county jail. The law was in effect for the bighorn sheep season for the first time during 1989.

During the 1989 season no citations were issued and hunt protestors seemed unwilling to challenge the new law. However, CDFG wardens identified 8 protestors during the 1989 season: 2 were on probation for civil disturbances, and ≥ 3 had been arrested several times for disturbing the peace, interfering with a peace officer, or assault. Seven warnings were issued to protesters. Given the past records of these individuals, the law appears to have been successful in curtailing hunter harassment. Furthermore, there appears to be declining interest on the part of the media in the potential for confrontations to develop between sportsmen and those with hopes of disrupting lawfully sanctioned activities. As media coverage declines or becomes less sensational, we expect a concomitant decline in the illegal activities of animal-rights activists.

MANAGEMENT AND TRANSLOCATIONS FROM 1971 THROUGH 1989

The management objectives of CDFG are to maintain, improve and expand bighorn sheep habitat; reestablish bighorn sheep populations on historic ranges; increase bighorn sheep populations so that all subspecies become numerous enough to no longer require classification as threatened or fully-protected; and provide for aesthetic, educational, and recreational uses of bighorn sheep.

In 1972, approximately 3,700 bighorn sheep occurred in California. In 1989, that estimate is 4,700. In some cases, population increases were realized in areas formerly deficient in water through the implementation of an aggressive and effective water development program (Bleich 1983). Population increases also may have occurred because of good forage production resulting from greater than normal rainfall in some locations (Bleich 1986, Wehausen 1989). At least 4 populations of bighorn sheep not known to exist prior to 1985 have been discovered recently, bringing the total number of populations of bighorn sheep in California to 61. Management direction in California emphasizes the importance of populations of mountain sheep, in lieu of total numbers, to the continued well-being of this species (Schwartz et al. 1986; Wehausen et al. 1987; Bleich et al. 1990).

Table 1. Summary of mountain sheep translocated within California from 1979 through 1989. Numbers in parentheses are additional animals removed from the source populations as mortalities during the capture efforts. Animals translocated from Sand Mountain and Sawmill Canyon are California bighorn; all others are Nelson bighorn.

		Females			Males			
Date	Source[a]	Ad	Yearling	Lamb	Ad	Yearling	Lamb	Moved to[b]
Mar 79	SC	4	0	0	0	1	2	WC
Mar 79	SM	0	0	0	2	0	0	WC
Mar 80	SM	7	0	1	0	1	1	WC
Mar 80	SC + SM	6	0	1	4	0	0	ML
Mar 80	SC + SM	3	1	2	2	0	2	WA
Mar 82	SC	5	0	1	3 (1)	0	0	ML
Apr 82	SM	0	0	0	6	0	0	ML
Apr 82	SM	0	0	0	4	0	0	WC
Jul 83	MM	8 (1)	0	2	1	1	0	WM
Jul 83	OD	2	3	0	1	1	2	WM
Nov 83	LC	11 (1)	6	1	1	2	1	PF
Dec 83	MM	7	1	0	0	0	0	EC
Dec 83	MM	0	0	0	2	0	0	WM
Dec 83	OD	5	0	4	3	1	4	EC
Nov 84	MM	8	0	2	0	2	1	WM
Nov 84	OD	6 (3)	2 (1)	2	4	1	1	WM
Nov 84	OD	7	0	0	3	0	1	SH
Jul 85	MM	11	1	2	2	2	1	WM
Jul 85	OD	4 (1)	1	2	1	1	0	WM
Jul 85	OD	8	1	3	2	0	2	SH
Dec 85	CC	15 (1)	1	0	4	1	0	SR
Mar 86	SM	2	1	0	0	1	0	WC
Mar 86	SM	13 (1)	0	2	3	4	5	LV
Sep 86	OD	16 (2)	3	2	5	0	2	AR
Jan 87	CC	13 (2)	3 (1)	0	6 (1)	0	0	SR
Oct 87	OD	7	2	2	3	1	1	EC
Mar 88	SM	7	1	0	3	0	0	LV
Mar 88	LT	4	1	1	0	2	2	SC
Dec 89	OD	28	9	0	2	4	0	CM
Totals		207 (12)	37 (2)	30	67 (2)	27	27	

[a]SC = Sawmill Canyon, Inyo Co.; SM = Sand Mountain, Inyo Co.; SC + SM = Sawmill Canyon and Sand Mountain combined; MM = Marble Mountains, San Bernardino Co.; OD = Old Dad Peak, San Bernardino Co.; LC = Lytle Creek, San Bernardino Co.; CC = Cattle Canyon, Los Angeles Co.; LT = Lone Tree Canyon, Mono Co.

[b]WC = Wheeler Crest, Inyo Co.; ML = Mt. Langley, Inyo Co.; WA = Warner Mtns., Modoc Co.; WM = Whipple Mtns., San Bernardino Co.; PF = Prairie Fork, Los Angeles Co.; EC = Eagle Crags, San Bernardino Co.; SH = Sheephole Mtns., San Bernardino Co.; SR = San Rafael Peak, Ventura Co.; LV = Lee Vining Canyon, Mono Co.; AR = Argus Range, Inyo Co.; SC = Silver Canyon, Inyo Co.; CM = Chuckwalla Mtns., Riverside Co.

From 1971 through 1989, 11 California bighorn sheep were translocated to California from British Columbia (n = 10) and Nevada (n = 1). Additionally, 411 mountain sheep were captured from 7 native California populations, and 395 of those were translocated to 12 historical ranges; 16 animals died during capture. We summarize the two initial efforts to reestablish mountain sheep (*O. c. californiana*) in northeastern California in an effort to provide a complete translocation history to date.

The first translocation of bighorn sheep in California occurred in 1971, when 8 female and 2 male California bighorn sheep were captured in British Columbia, and released at Lava Beds National Monument, Siskiyou County (Blaisdell 1972, Weaver 1972). In 1972, 1 Lava Beds ram was shot and killed; a second ram was thought to have been shot at the same time, and died several weeks later (Blaisdell 1974, 1975). As a result of the loss of those males, a ram was captured at the Charles Sheldon National Wildlife Refuge, Nevada, and translocated to the Lava Beds (Blaisdell 1974).

Subsequently, in February 1980, 1 male and 3 females from the apparently healthy population at the Lava Beds were translocated to the Warner Mountains, Modoc County, as part of an effort to reestablish bighorn sheep (Sleznick 1980). In March 1980, 10 sheep from the Sand Mountain population in the Sierra Nevada of Inyo County also were translocated to the Warner Mountains to increase the biotic potential of that newly founded population (Camilleri and Thayer 1982).

During summer 1980, all of the sheep at Lava Beds succumbed to pneumonia. Circumstantial evidence implicated domestic sheep as the source of the pathogens involved (Foreyt and Jessup 1982, Weaver 1983). Similarly, the entire Warner Mountains population was extirpated in 1988 by pneumonia attributed to pathogens transferred to the wild sheep from domestic sheep (Weaver and Clark 1988). That incident, thus, eliminated the remaining wild sheep in northeastern California.

Beginning in 1979, the CDFG, in cooperation with the U.S. Forest Service, the National Park Service, the Bureau of Land Management, and the City of Los Angeles, initiated an effort to reestablish California bighorn sheep in historically occupied areas of the Sierra Nevada in Inyo and Mono counties (Wehausen et al. 1987). In 1983, the first translocation of desert-dwelling mountain sheep took place (Clark 1983) and, since that time, the CDFG has carried out an active translocation program with cooperating land management agencies (e.g., the U.S. For. Serv., Bur. Land Manage., and Dep. Defense). The results of these efforts, excluding the initial translocation of mountain sheep to the Lava

Beds and the subsequent translocation of 4 sheep from the Lava Beds to the Warner Mountains in 1980, are presented in Table 1.

The CDFG currently is finalizing plans for 2 additional translocations: bighorn sheep will be reintroduced into the Bullion and Bristol mountains, San Bernardino County in cooperation with the Department of Defense and the Bureau of Land Management, respectively. A third effort, to reestablish bighorn sheep on the Great Western Divide in Sequoia–Kings Canyon National Park will begin when translocation stock are available from the Sierra Nevada.

The CDFG is mandated to complete management plans for each population of bighorn sheep by 31 December 1992. To date, 17 of approximately 60 plans have been completed. All plans should be completed before legislation authorizes the extension of bighorn sheep hunting.

FUNDING

Funding for bighorn sheep management in California has been relatively consistent over the past 6 years. The Legislature has provided approximately $270,000/year from the special automobile license plate fund; those dollars are spent to maintain bighorn sheep populations, to investigate diseases and other limiting factors, and for reintroduction purposes. One-third ($90,000) of the annual $270,000 appropriation is given to the Bighorn Institute.

Additional revenues from the sale of bighorn hunting applications, permits, and the sale of the special fundraising permit are deposited in a special bighorn sheep account established by the Legislature. Those funds have totaled approximately $250,000 since the inception of bighorn sheep hunting in California, and represent a significant portion of the funding available to CDFG on an annual basis.

The public is instrumental in bighorn sheep management projects (Bleich et al. 1982; Bleich 1990). Volunteer programs are a popular facet of California's overall management effort, and are involved primarily with habitat management projects. Since its inception in 1970, participants in the Volunteer Desert Water and Wildlife Survey have donated approximately $2,000,000 worth of labor, materials, and services to the CDFG. These cooperative efforts are helping to achieve the CDFG's goals for bighorn sheep management.

We thank J. A. Keay for providing detailed field notes on several translocation projects in which he participated and, especially, C. Jones, S. McBain, and M. W. Berbach for recording data during translocation projects.

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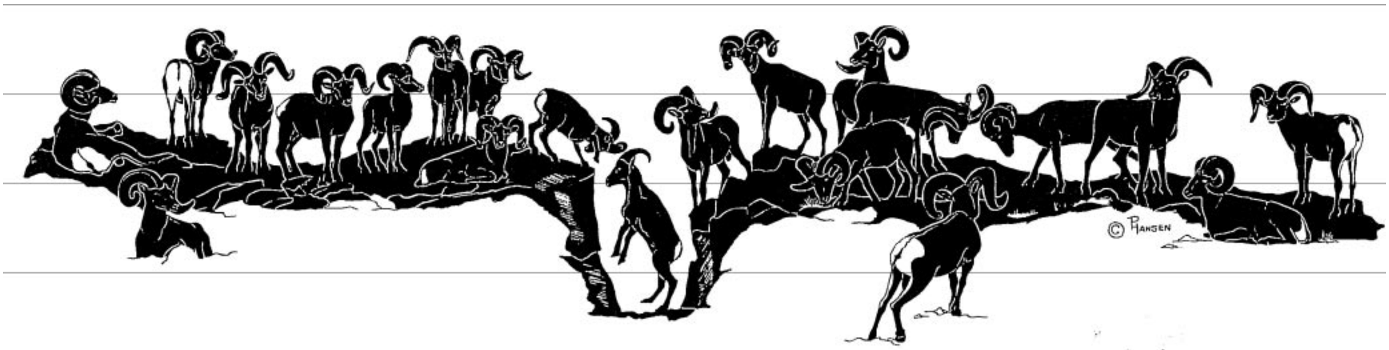

STATUS OF DESERT BIGHORN SHEEP IN COLORADO, 1989

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POPULATION STATUS

The Colorado Division of Wildlife (CDOW) initiated the reintroduction of desert bighorn sheep (Ovis canadensis) in 1979. Since 1979, 133 sheep from Arizona and Nevada have been released in Colorado.

The releases have established 3 populations of desert bighorn sheep in the Colorado National Monument (CNM): Rattlesnake Canyon, west of Grand Junction; Dominguez Canyon, northwest of Delta; and Dolores Canyon, south of Slick Rock. In 1989, approximately 250 sheep inhabited these areas.

The CNM population (n = 110) continues to grow although reproduction appears to be slowing. The Dominguez Canyon population (n = 60) is increasing slowly due to low reproduction. Causes for low reproduction rates are unknown. The Dolores Canyon population (n = 80) is increasing.

TRANSPLANTS

The CDOW is planning to establish herds in 3 additional areas as sheep become available: the Dolores River Canyon from Slick Rock to Bedrock, Roubideau Canyon, southwest of Delta, and the lower Dolores River Canyon near Gateway. Planning has been initiated to trap and translocate sheep from the CNM and Rattlesnake Canyon herd to Mee and Knowles canyons immediately west of Rattlesnake Canyon to expand the range and abundance (from 110 to 400) of the existing herd.

HUNTING

The CDOW recommended, and the Colorado Wildlife Commission approved, Colorado's first desert bighorn sheep hunting season in 1988. The season dates were 18 November through 15 December. A legal animal was defined as a ram with horns ≥½ curl to conform with existing regulations for Rocky Mountain bighorn sheep (*O.* c. canadensis). The 2 permits, for residents only, which were authorized attracted 486 applicants. The successful applicants shot 2 rams. The first ram scored ≥150 Boone and Crockett points. The second ram scored ≥135 points. In 1989, 2 permits were authorized and 236 persons applied. The successful applicants shot 2 rams that scored ≥150 Boone and Crockett points. The Colorado Wildlife Commission authorized 4 permits for desert bighorn sheep in 1990. Colorado also issues permits for Rocky Mountain bighorn sheep. In 1989, 3,221 persons applied for 366 permits available in 42 sheep management units; 366 permits are available in 1990.

The Colorado Wildlife Commission beginning in 1989 authorized the auction of 1 Rocky Mountain bighorn sheep permit and 1 Rocky Mountain goat (Oreamnas americanus) permit. The Commission also authorized a raffle for 1 permit for each species. The proceeds from the auction and raffle were $67,697. The special auction permit for sheep produced a bid of $43,000 and the raffle raised $12,875. Funds derived from the auction and raffle are dedicated to the management of wild sheep and goats.

MONITORING AND RESEARCH

The CDOW is not conducting any research related to desert bighorn sheep. However, a landowner west of CNM has proposed to fund a study of livestock and wild sheep interactions. The CDOW research section and Colorado State University will evaluate the proposal.

Monitoring of existing sheep herds will continue with the use of radio telemetry, ground, and aerial locations. The herd has 4 sheep with active collars. There are no active collars in the Dominguez Canyon herd. Seven collars are active on sheep in the Dolores Canyon.

WATER DEVELOPMENTS

Lack of water is not considered a major limiting factor for distribution of desert bighorn sheep in Colorado. However, 1 water development was installed in 1989 to attract sheep into ranges with available forage not currently being used. The development was a cooperative project between the CDOW and the Bureau of Land Management (BLM). The influence this water source has on the population will be examined in 1990.

POTENTIAL MANAGEMENT PROBLEMS

Landowners controlling BLM grazing allotments in the vicinity of the CNM herd are attempting to convert from cattle to sheep grazing. Contact between domestic and wild sheep are possible.

The CDOW is working with the landowners and BLM to resolve this problem and prevent interaction between domestic and wild sheep.

The introduction of exotic sheep, specifically Barbary sheep (*Ammotragus* lervia), has occurred in the DeBeque area approximately 40 km east of the CNM herd. The exotics were illegally imported and released in 1986. Approximately 25 sheep have been killed in the past year by CDOW personnel and public hunters. The current population is estimated at 65–70 animals. An eradication program has been initiated but success is doubtful. The CDOW will continue to monitor the status of exotics.

STATUS OF DESERT BIGHORN SHEEP IN NEVADA, 1989

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THE DESERT BIGHORN PROGRAM

There are 3 subspecies of bighorn sheep in Nevada: Rocky Mountain (Ovis canadensis canadensis), California (*O.* c. *californiana*) and Nelson's (0. c. nelsoni). Desert bighorn populations are located in the southern half of Nevada. This report summarizes Nevada's desert bighorn sheep program. The program is divided into 4 categories: surveys, water developments, trapping and transplanting, and harvest.

Surveys

Nevada Department of Wildlife (NDOW) personnel counted 1,321 desert bighorns in 18 of 40 mountain ranges surveyed. Each range is counted biennially. Counts included 707 females, 170 lambs, and 444 rams (24 lambs: 100 ewes, 62 rams: 100 ewes). Nevada has been dry for the past several years; lamb production is down, but no lamb losses have been reported. The NDOW estimates the desert bighorn sheep population at 5,200 to 5,300 animals.

Water Developments

In 1989, water catchments were constructed in the Spectre Mountains (n = 3) and the Muddy Mountains (n = 1), in the Las Vegas area. In the northern part of desert bighorn range, 2 catchments were constructed in the Gabbs Valley Range east of Hawthorne. Capacities of the catchment storage range between 11,500 and 23,000 L. The Fraternity of the Desert Bighorn, Reno Chapter of Nevada Bighorns Unlimited, Fallon Chapter of Nevada Bighorns Unlimited, and Foundation for North American Wild Sheep funded the water projects. Each group has an annual fundraiser; i.e., a dinner followed by an auction. Two harvest permits were auctioned off in Nevada in 1989: 1 at the Foundation for North American Wild Sheep convention and 1 at the Nevada Bighorns Unlimited, Reno banquet.

Trapping and Transplanting

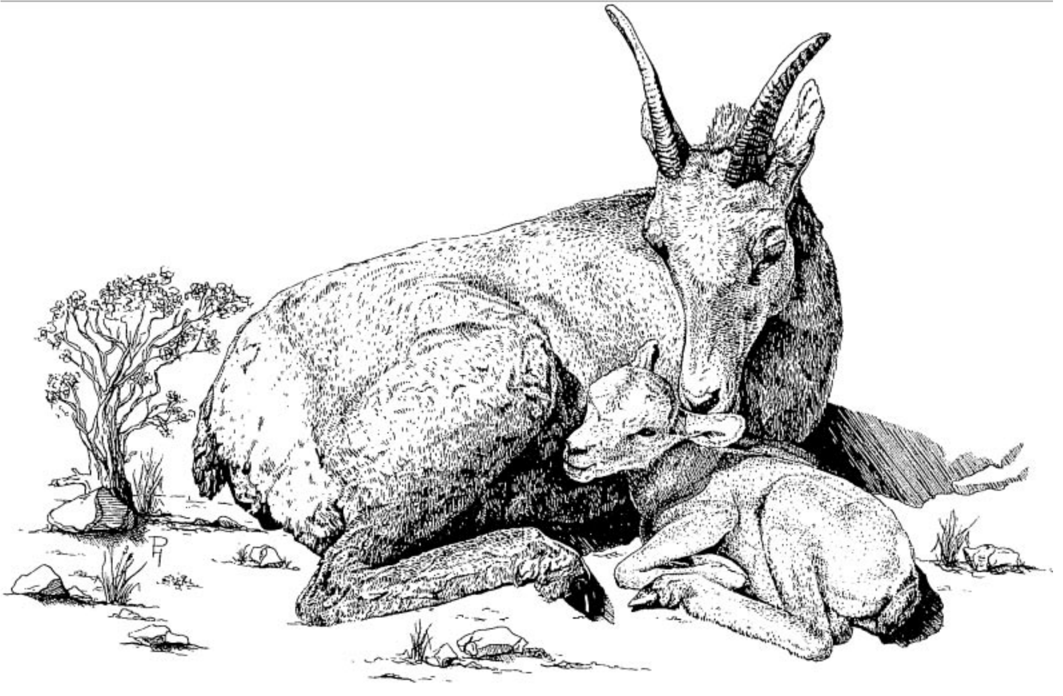
Forty desert bighorns were captured in the River Mountains near Las Vegas and released in the Last Chance Mountains (n = 25) and used to augment existing populations in several mountain ranges (n = 15). Two groups of sheep were captured in the Black Mountains near Las Vegas and released in the Stillwaters (n = 15) and Clan Alpine Mountains (n = 11) in northern Nevada. In the past decade ≤66% of all collared sheep have been killed by mountain lions (Felis concolor). Desert sheep captured in the Las Vegas area are released in habitats that have trees and mountain lions; both are absent from the native habitat of these sheep.

Harvest

In 1989 111 rams were harvested in Nevada (82% hunter success). Fifteen rams had green scores that would qualify them for the Boone and Crockett Record Book.

FUTURE PLANS

In 1990 sheep habitat will be enhanced with the construction of 6 water catchments in the Las Vegas area, and 3 in the northern part of desert bighorn habitat in Churchill and Mineral counties. Sheep trapped in summer 1990 will be released in 3 mountain ranges: 2 near Las Vegas and the Gabbs Valley Range east of Hawthorne. Since 1968, 706 desert bighorns have been trapped and transplanted in Nevada. The NDOW made a concerted effort to have 11 1990 permits be for any ram, as it was felt the trophy requirements in place since legal harvest began in the 1950s had served their purpose but were outdated, but public opposition to the proposal forced them to maintain current trophy requirements. In 1990 131 permits will be issued. Legal rams must be ≥7 years old or score ≧144 Boone and Crockett points (doubling the score of the longest horn) except in the Lone Mountain and Silver Peak management units, where the minimum score is 138 points.



STATUS OF DESERT BIGHORN SHEEP IN NEW MEXICO, 1989

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In 1989,200 desert bighorn sheep (Ovis canadensis mexicana) occur in New Mexico based on fall helicopter surveys (Table 1). The population trend between 1984 and 1989 indicate that the Hatchet population is declining; the Alamo Hueco, Peloncillo, and San Andres populations are stable; and the Red Rock captive herd is increasing. Drought may be responsible for the decline of the Hatchet population and low lamb survival in the Alamo Hueco and Peloncillo mountains. Psoroptic scabies (Psoroptes ovis) is still considered the primary predisposing cause limiting population growth in the San Andres Mountains.

POPULATION STATUS

Hatchet Mountains

The 1989 Hatchet population (n = 37) declined by 50% since 1987 (Fig. 1). The greatest proportion of the decrease was due to the low number of lambs observed (20 lambs: 100 ewes). In the last 5 years, this population generally exhibited high fall ratios (≥50 lambs: 100 ewes).

Weather may be a causative factor in the 1989 decline. When the population was increasing during 1983–88, mean annual precipitation was 36 ± 7 cm (SD). The population decline in 1989 corresponded with a 50% decrease in precipitation. In comparison, the 30 year average for this area was 25 cm. Also, 1989 was the only year between 1983 and 1989 that negative Palmer Drought Severity Index (PDSI) values were recorded (National Oceanic and Atmospheric Administration climatological data, Hachita weather station).

The PDSI is a measure of soil moisture availability relative to normal conditions based on total precipitation, average temperature, and soil moisture-holding capacity (Palmer 1965). Values from -1 to $+1$ describe approximately normal moisture conditions. Lower negative values indicate drier conditions and higher positive values indicate wetter conditions. The PDSI illustrates the possible correlation between weather and population fluctuation in the Hatchets. Low negative PDSI values in 1953 and 1956 corresponded with the decline of the population, high positive values between 1983 and 1988 corresponded with population increase, and negative values in 1989 corresponded with population decline (Fig. 1).

Low and variable precipitation in desert ecosystems affect survival of lambs through its influence on vegetative availability and quality (Douglas and Leslie 1986, Wehausen et al. 1987). Still, the relationship is not well understood. An attempt will be made to model the Hatchet population using 20 years of available data. This may help elucidate the relationship between weather and lamb survival.

Alamo Hueco Mountains

The Alamo Hueco population has remained stable at an estimated 30 bighorn since it was established in 1986. As in past years, bighorn that originated from the Hatchets were identified in the Alamo Huecos in 1989.

No lambs were observed during the 1989 fall survey compared 10, 50, and 23 lambs: 100 ewes in 1986, 1987, and 1988, respectively. Although the Alamo Huecos looked relatively green compared to the desiccated vegetation in the Hatchets, the mountain received little moisture until late summer 1989. As in the Hatchets, there may be a positive relationship between precipitation and lamb survival.

Peloncillo Mountains

The Peloncillo Mountain population has remained stable at an estimated 30 bighorn since it was established in 1981–82. Also, the age and sex composition of the population has remained about the same since the original transplants.

Fall lamb: ewe ratios have been variable (≤14:100 in 1982, 1984, 1985, and 1989 and ≥30:100 in 1981, 1983, 1986, and 1987). It is still unknown if pneumonia is playing a role in low lamb recruitment.

San Andres Mountains

Due to a scabies mite epizootic, the San Andres desert bighorn sheep decreased from 200 in the mid 1970s to an estimated 25 in 1989. The population has remained stable at 25–30 sheep since 1982.

International Wildlife Veterinary Services (IWVS), under contract by the U.S. Fish and Wildlife Service (USFWS), completed 2 years of a mite-bighorn study designed to determine prevalence of scabies, overall herd health, and optimal management strategies. All bighorn captured in fall 1988 (n = 10) and 1989 (n = 9) were clinically and/or serologically positive for scabies (Clark 1989). The degree of infestation ranged from relatively mild, in which scabies was confined to the ears, to severe in which scabies invaded the head, neck, chest, and flanks. Overall, the physical condition of the sheep was poor in 1989, evidenced by low body weights and endurance. A 9-year-old ram, for example, weighed approximately 50 kg (R. Clark, IWVS, pers. commun.).

Results of laboratory analysis of blood and sera were similar in both years. Abnormalities that were detected (e.g., high hematocrits, reversed ratios of neutrophils to lymphocytes, and low globulin levels) suggested immune suppression and/or stress response, possibly due to scabies. The bighorn also lacked antibodies to most common livestock viruses. These results should be interpreted with caution as they are based on 2 years of sampling 19 animals (Clark 1989).

The lamb : ewe ratio in winter 1989 was 30:100 and 3 radio-collared

Table 1. Status of desert bighorn sheep in New Mexico, fall 1989.

Area	Population history	No. Estimated	No. Actual[a]	Trend[b]
Hatchet Mountains	Indigenous, supplemented 30 in 1979, 1982	45	37	Decreasing
Alamo Hueco Mountains	Transplanted 21 in 1986	30	25	Stable
Peloncillo Mountains	Transplanted 38 in 1981, 1982	30	25	Stable
San Andres Mountains	Indigenous	25	20	Stable
Red Rock	Propagating facility, supplemented 21 in 1972, 1973, 1975	70	70	Increasing

[a] Actual no. based on aerial or ground surveys fall 1989.
[b] Trend based on change from previous year's survey.

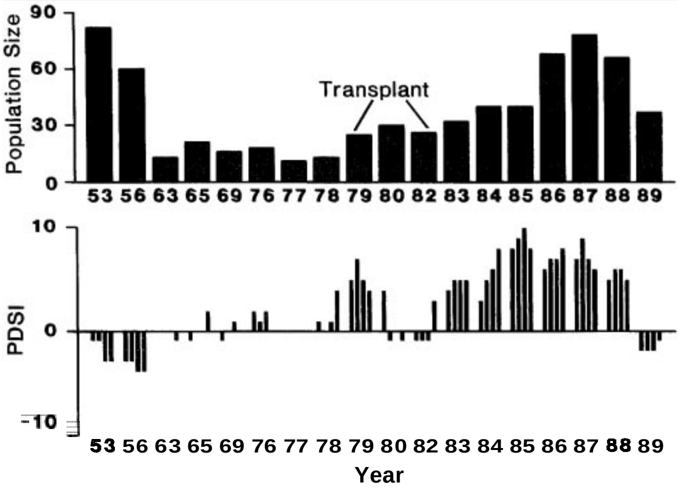

Fig. 1. Relationship between population size and Palmer Drought Severity Index (PDSI) in the Hatchet Mountains, New Mexico, 1953–89.

mortalities (1 male, 2 female) were documented during 1989. The proximate cause of death was mountain lion (*Felis concolor*) predation; however, the 2 females had ears plugged with scabies at death and the male, although totally consumed when found (P. Hoban, USFWS, pers. commun.), was observed with aural scabies plugs when captured 4 months previous to death (Clark 1989). The possible predisposing role of scabies in attributed mortality factors was discussed by Elenowitz and Humphreys (1989).

The cooperators (IWVS, USFWS, New Mexico Department of Game and Fish [NMGF], and the U.S. Army White Sands Missile Range [WSMR]) have concurred that the San Andres population has lost viability and will probably go extinct if left alone. Negotiations are underway to determine if a viable population can be restored to the San Andres Mountains.

Red Rock Propagating Facility

The captive population at Red Rock increased to 70 bighorn in 1989. The ram-segregation project, in which 15 rams were segregated into a 41 ha pasture (Elenowitz and Humphreys 1989), produced the expected result of reducing excessive harassment of ewes by rams during the breeding season (A. Ford, NMGF, pers. commun.). Several more years of monitoring will be needed to determine if early lamb survival improves.

Four rams (3–4 yr) died in 1989 after being segregated, presumably due to fighting during the rut (prior to segregation about 1 ram died each yr during the rut). Infighting may be reduced when rams are removed for experiments. The expansion of Red Rock from 300 to 600 ha, projected to be completed in spring 1990, will also reduce density of rams and ewes.

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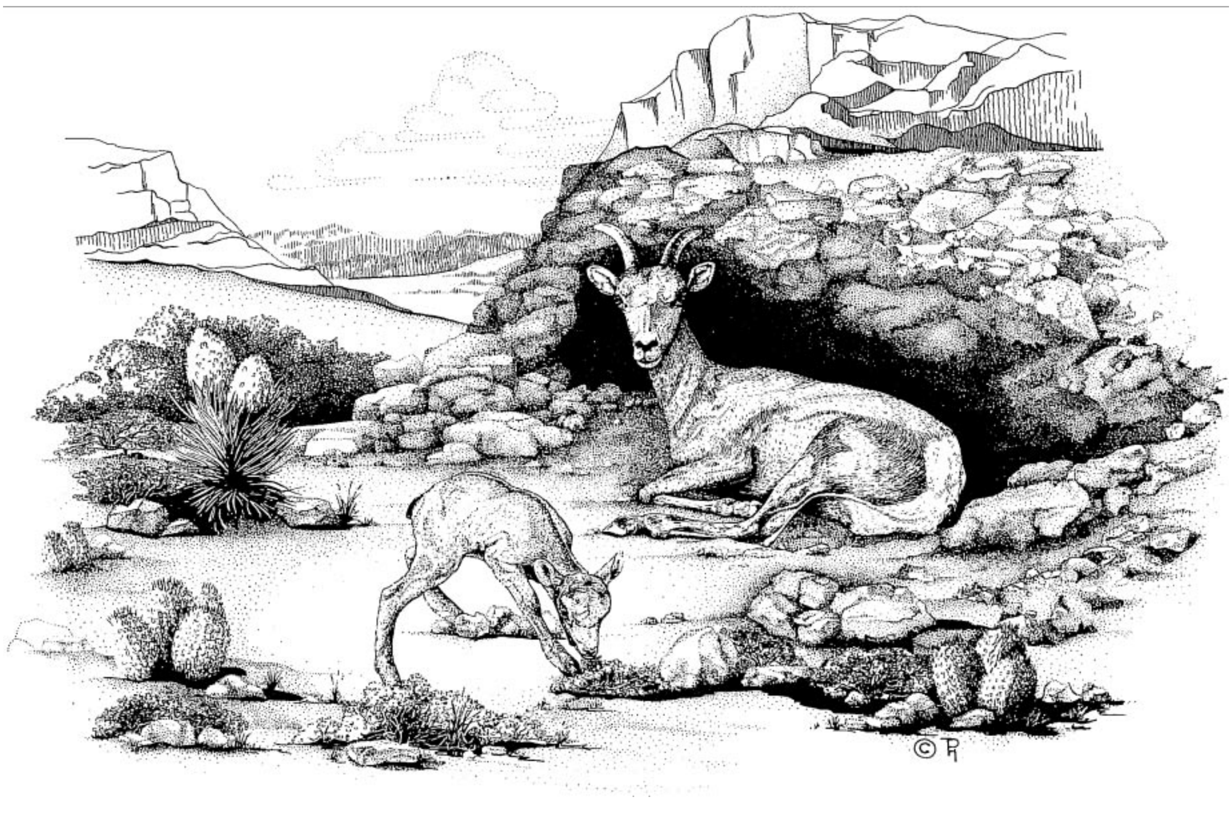

STATUS OF DESERT BIGHORN SHEEP IN UTAH, 1989

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POPULATION TRENDS

Desert bighorn sheep (Ovis canadensis nelsoni) were aerially surveyed from helicopter on 7 geographicareas in 1989; 418 bighorn were counted on 6 areas. An additional 155 bighorns were located in Canyonlands National Park, during helicopter and ground surveys conducted by park personnel (Table 1). The apparent trends of these populations varied by area. Increased numbers of bighorns were documented on some units while decreased numbers were observed in other areas. Increased numbers of bighorn and good lamb: ewe ratios were observed on some of the transplanted herds including the San Rafael, Escalante and Kaiparowits units. The native bighorn herds doing well include the Island in the Sky and the Potash units.

The North San Rafael Unit now has the largest population in the state. An increase of 32 bighorn were observed over the 1988 survey with 66:100 ewes. The South San Rafael Unit was surveyed for the first time. Locating bighorn sheep was difficult because of the terrain and habitat. Surveys were funded by the Bureau of Land Management (BLM).

The survey of the Potash Unit was very encouraging and lamb survival was good (52 lambs : 100 ewes) in 1989 (Table 1). Fourteen more bighorn were observed than in 1988 (Table 2).

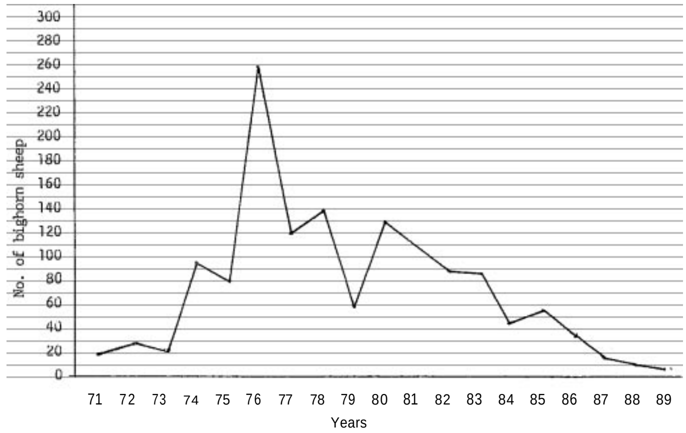

Fig. 1. Trend of desert bighorn sheep surveys on the North San Juan Unit, Utah, 1971–89.

The native bighorn herds east of the Colorado River had 12 lambs: 100 ewes and decreased numbers of sheep. In the South San Juan 15 fewer bighorn were counted than in 1988 (Table 2). This herd is following the trend of the North San Juan Unit and will continue to decline.

The North San Juan herd was not counted because there are too few bighorn to be cost effective. In 1976, 259 bighorn were observed on this same unit but the population has declined (Fig. 1). Population trends increased in other areas since 1988 (Tables 1, 2).

In Canyonlands National Park, Island in the Sky, bighorn sheep were counted (131 lambs: 100 ewes). This is a slight increase from 1988 (Tables 1, 2). The Needles was partly surveyed. Only 10 bighorn were counted (Table 1) as compared to 21 in 1988 (Table 2). Lambs were seen for the first time since 1986. Twenty-three bighorn were counted in the Maze District (42 lambs: 100 ewes). Twenty-two bighorn were counted in Arches National park (Table 1).

The Utah Division of Wildlife Resources (UDWR) surveyed 79 Rocky Mountain bighorn in 1989 on the east side of the Green River. Forty-five bighorn, including 21 rams, were on BLM land between the Ute Indian reservation boundary and Tusher Canyon. Thirty-four bighorn were located on Ute Tribal lands above Coal Creek.

Table 1. Desert bighorn sheep observed in Utah aerial survey, November and December 1989.

Area	Trend	Rams	Ewes	Lambs	Unclassified	Total	Lambs : 100 ewes	Rams : 100 ewes
North San Rafael	Up	38	56	37	2	133	66	68
South San Rafael	Unknown	10	12	5		27	42	83
Potash	Up	27	31	16		74	52	87
South San Juan	Down	17	33	4		54	12	52
Lockhart		6	9	6		21	67	67
Escalante	Up	14	32	16		62	50	44
Kaiparowits	Up	6	23	12		41	52	26
Little Rockies	Unknown							
Total		118	296	96	2	412		
National park								
Island in the Sky	Stable	44	25	12	19	100		
Needles	Down				10	10 (Incomplete survey)		
Maze	Up				23	23 (Incomplete survey)		
Arches	Down	6	14	2		22 (Incomplete survey)		
Total		50	39	14	52	155		

Table 2. Desert bighorn sheep observed in Utah aerial survey, November and December 1988.

Area	Trend	Rams	Ewes	Lambs	Unclassified	Total	Lambs : 100 ewes	Rams : 100 ewes
North San Rafael	Up	35	43	23		101	53	81
Potash	Up	22	22	16		60	73	100
South San Juan	Down	22	41	6		69	14	53
North San Juan	Unknown	3	5	0		8	0	60
Escalante	Up	13	25	13		51	52	52
Kaiparowits	Up	11	14	9		34	64	79
Little Rockies	Unknown	2	7	1		10		
Total		108	157	68		333		
National park								
Island in the Sky	Stable	39	39	12	3	93		
Needles	Down			0	21	21 (Incomplete survey)		
Arches	Stable				27	27 (Incomplete survey)		
Total		39	39	12	51	144		

This herd originated from 9 bighorn obtained from Wyoming in 1970 and 13 bighorn from Canada in 1973. The original release sites were on the Ute Indian Reservation.

HUNTING

Twelve permits were authorized for the 1989 hunt, including 1 non-resident permit and 1 bid permit that sold for $20,000. Ten rams were harvested.

Rams were taken on all 5 hunted units: Escalante (n = 1), Kaiparowits (n = 1), South San Juan (n = 3), Potash (n = 3), San Rafael (n = 2). Thirteen permits will be authorized for the 1990 hunting season.

TRANSPLANTS

Since 1973 the UDWR has had an active transplant program to reintroduce desert bighorn sheep into historic range. In the past 17 years, >250 desert bighorn sheep have been relocated into suitable habitats to begin new herds. The transplant program has been instrumental in maintaining bighorn sheep in Utah.

A meeting was held in January 1990, between UDWR, BLM and agricultural interest groups, to discuss conflicts between bighorn sheep and domestic sheep and potential bighorn release sites. A tentative agreement was reached to drop some proposed bighorn release sites where there are existing domestic sheep permits. It was also tentatively agreed that present bighorn populations should be maintained.

Based on this meeting, UDWR proposes to concentrate its transplant efforts to maintain existing populations. Translocations will be scheduled for Dirty Devil–Happy Canyon, Horseshoe Canyon (West side of Lower Green River), Westwater Canyon–Professor Valley, Lower Lake Powell, Virgin River Mountains, and New Foundland Mountains. A similar list of areas was developed for Rocky Mountain bighorn. Utah's transplant program has been entirely funded by sale of the high bid permit, which has not sold for more than $20,000 over the last 4 years.

LAND USE PLANNING BENEFITTING BIGHORN

A Resource Management Plan (RMP) Amendment was completed for the Elliott Mountain Area (Desolation–Gray Canyons, on the west side of the Green River). This amendment retired livestock grazing privileges on over 40,469 ha and will allow the area to be managed for Rocky Mountain bighorn. The amendment resolved an on-going problem with domestic sheep permits in the area. The permits were purchased by private parties and UDWR. An RMP amendment was also completed in the Grand Resource Area that raised numerical constraints for bighorn sheep to the numbers outlined by the Bureau and District desert bighorn plans. The amendment also identified geographic areas to be managed for desert and Rocky Mountain bighorn, and outlined how these areas would be managed. One of the management constraints deals with domestic sheep. Conversions from cattle permits to sheep permits will not be allowed in those areas.

WATER CATCHMENTS

Two water catchments were installed in the Escalante Unit, and 2 water catchments were placed in the Beaver Dam Mountains to help expand bighorn range northward. This area is near the Utah–Arizona stateline in southwest Utah. All four water developments were completed through a cooperative effort by UDWR and BLM. Three additional catchments were installed with funds provided by Foundation for North American Wild Sheep.

Two catchments were completed by BLM and sportsman volunteers in South San Juan Unit. One catchment was installed in the Potash Unit by BLM and the Canyonlands Wildlife Federation. This sportsman group has accepted the maintenance responsibility for 26 wildlife catchments in the Grand Resource Area.

GUIDELINES FOR MANAGEMENT OF DOMESTIC SHEEP IN THE VICINITY OF DESERT BIGHORN HABITAT

Technical Staff
Desert Bighorn Council

The Bureau of Land Management (BLM) requested that the Technical Staff (Tech Staff) of the Desert Bighorn Council (DBC) prepare management guidelines for domestic sheep in the vicinity of desert bighorn habitat. Desert bighorn habitat includes all geographic areas that would provide for the life requisites of desert bighorn sheep, as defined by state wildlife and/or land management agencies. This request followed a meeting of BLM biologists concerned with problems resulting from interactions between bighorn sheep (Ovis canadensis ssp.) and domestic sheep (0. aries).

The Tech Staff understands that 2 additional factors should be considered. First, the BLM has prepared, or is preparing, land use planning documents in several western states (Nev., Ariz., Colo., and Ut.) that would allow reintroduction of desert bighorns (*O.* c. nelsoni, 0 . c. mexicana, and 0 . c. cremnobates) into suitable historic habitat. Several potential bighorn reintroductions in Nevada have been contested by the livestock industry; e.g., woolgrowers and cattlemen. They contend that bighorn reintroductions will seriously hamper their ability to graze livestock of their choice on public lands. Second, in 1989, the BLM issued a "Rangewide Plan for Managing Habitat of Desert Bighorn Sheep on Public Lands," which states "Livestock grazing on desert bighorn habitats will be managed via land-use or activity plans to mitigate impacts to desert bighorns and their habitats to ensure objectives for desert bighorn are achieved."

The DBC is comprised of state fish and game and federal agency biologists, private research organizations, academia, and the public. The 4 primary objectives of the DBC are to: provide for the exchange of information on the needs and management of desert bighorns; stimulate and coordinate studies in all phases of the life history, ecology, management and protection, recreational, and economic uses of desert bighorns; provide a clearinghouse for information among all agencies, organizations, and individuals professionally engaged in work on the desert bighorn; and function in a professional advisory capacity, where appropriate, on local, national, and international questions involving the management and protection of desert bighorn.

The DBC's Tech Staff is comprised of 7 elected members. One of the functions of the Tech Staff is to answer requests from agencies and organizations such as the BLM, regarding desert bighorn management.

This document describes problems associated with domestic sheep and bighorn interactions, with emphasis on diseases. Recommendations are then provided to minimize interaction, especially physical contact between domestic and bighorn sheep.

The Tech Staff appreciates the opportunity to consider the problems and develop these guidelines, with the underlying goal of eliminating domestic sheep and bighorn conflicts on public lands.

BACKGROUND

Current bighorn numbers are <2% of what they were prior to the coming of European man and his livestock and firearms (Wagner 1978). Following enormous population declines in the late 1800s and early 1900s, bighorn populations did not recover, in contrast to other wildlife species such as mule deer (Odocoileus hemionus) and elk (Cervus elaphus). Bighorns have demonstrated much less tolerance than other native North American ungulates to poor range conditions, interspecific competition, overhunting, and stress caused by loss of habitat. Furthermore, they have shown a much greater susceptibility to diseases (Goodson 1982).

Bighorns have died from a wide variety of diseases that they have contracted from domestic sheep. These include scabies (a major cause of mortality in the 1800s and as late as the 1970s in New Mexico), chronic frontal sinusitis, internal nematode parasites (worms), pneumophilic bacteria, footrot, parainfluenza III, bluetongue, and soremouth (contagious echthyma) (Jessup 1985). Documented bighorn die-offs were recorded as early as the mid-1800s and have continued up to the present (Jessup 1985, Goodson 1982, Foreyt and Jessup 1982, Sandoval 1988, Weaver 1988). Die-off documentation covers not only desert bighorns, but also California bighorns (*O.* c. *californiana*) and Rocky Mountain bighorns (*O.* c. canadensis). Bighorn die-offs have occurred in every state in the western United States.

In broad perspective, when there has been contact between apparently healthy bighorns and domestic sheep, the bighorns die within a few days to a few weeks. While many diseases or stress factors may be involved, bighorns exposed to domestic sheep almost invariably die from pneumonia.

Little is known about the actual mechanism(s) that lead to the demise of bighorns after they have come into contact with domestic sheep. In all of the cases of bighorn die-offs following direct contact with domestic sheep or overlap of grazing in bighorn ranges, 2 things are apparent.

1. There is a preponderance of evidence (Table 1) strongly linking the presence of domestic sheep with the subsequent loss of part or all of the affected bighorn population. Of the 25 documented cases (Table 1) 4 of the situations were in controlled laboratory experiments in 3 states, and 2 were in situations where bighorns were penned in large paddocks.
2. The effects have all been I way—bighorns have died, while domestic sheep never have suffered ill effects because of coming into contact with bighorn. The prevailing theory on why this has occurred can be summed up as follows: New World sheep (bighorns) are so susceptible to diseases of Old World sheep (domestics) because the bighorns did not co-evolve with the above-listed diseases, as did domestic sheep. Bighorns have not developed effective immunity against these diseases. Domestic sheep are inoculated or, through natural selection over hundreds of years, have developed a resistance against some of these diseases, but carry blood titers for most of them. When there is contact between bighorns and domestic sheep, the bighorns have little defense. This theory is analogous to the accepted explanation for the transmission of human diseases carried to the Native Americans by Europeans. The Native American populations had no immunity to Old World diseases and suffered many documented die-offs.

RECOMMENDATIONS

The DBC Tech Staff has reviewed the bighorn sheep problem and developed recommendations for eliminating domestic and bighorn sheep conflicts on public lands. They consist of 1 general recommendation and 4 specific recommendations dealing with buffer strips, livestock supervision, trailing, and reintroductions. Each recommendation is preceded by a statement of the issue, followed by a justification.

General Recommendation

Issue.—Desert bighorn that come into contact with domestic sheep die as a result of the contact.

Recommendation.—Domestic sheep in the vicinity of desert bighorn ranges should be managed so that desert bighorn never come into contact with domestic sheep nor the disease organisms that domestic sheep carry.

Justification.—Evidence (Table 1) indicates that contact with domestic sheep is almost invariably lethal to desert bighorn. The recommendations that follow deal with methods to minimize interaction, especially physical contact between domestic and bighorn sheep.

Table 1. Bighorn declines and die-offs resulting from contracts with domestic sheep.

Location	Cause of die-off	Results	Year(s)	Source
Sun River, Mont.		>70 died	1910–35	Goodson (1982)
Upper Rock Ck., Mont.		All died	1965–70s	Goodson (1982)
Thompson Falls, Mont.		All died	1940–60	Goodson (1982)
Kootenay National Park, B.C., Can.	Pneumonia		1939	Goodson (1982)
Bull River, B.C., Can.	Pneumonia	96% died	1965	Bandy (1968) in Goodson (1982)
MacQuire Creek, B.C., Can.	Pneumonia		1981–82	Davidson in Goodson (1982)
Lava Beds National Monument, Calif.[a]	Pneumonia	All died	1980	Blaisdell (1982)
Mormon Mts., Nev.	Pneumonia	50% died	1980	Jessup (1981)
Dinosaur National Monument, Colo.		All died	1950	Barmore (1962) in Goodson (1982)
Rock Creek, Mont.		8 left	1900–20	Goodson (1982)
Rocky Mtn. National Park, Colo.	Pneumonia	All died	1917–30	Packard (1939*a*, 1939*b*) in Goodson (1982)
Methow Game Range, Wash.[a]	Pneumonia	13 of 14 died	1979–81	Foreyt and Jessup (1982)
Warner Mt., Calif.	Pneumonia	All died	1988	Weaver (1988)
Oregon	Scabies		1936	Lange (1980)
California	Scabies		1870–79, 1898	Jones (1900) in Lange (1980)
Grey Bull River, Wyo.			1881	Honess and Frost (1942) in Lange (1980)
Wyo., Mont.			1885	Hornaday (1901 in Lange (1980)
Colo.	Scabies		1859–31	Packard (1946) in Lange (1980)
Rocky Mtn. National Park, Colo.	Scabies		1878–1903	Lange (1980)
Latir Parks, N.M.	Pneumonia	All died	1978–82	Sandoval (1988)
Utah St. Univ., Utah[b]	Pneumonia	All died	1970s	Spillett in Goodson (1982)
Univ. B.C., Can.[b]	Pneumonia	All died	1970s	Hebert in Goodson (1982)
Colorado St. Univ., Colo.[b]	Pneumonia	All died	1970s	Hibler in Goodson (1982)
Utah St. Univ., Utah[b]	Pneumonia	4 of 5 died	1988	T. D. Bunch (Utah State Univ., pers. commun.)

[a] Large pen or paddock.
[b] University controlled conditions.

Specific Recommendation 1: Buffer Strips

Issue.—Desert bighorn and domestic sheep must be spatially separated to minimize the possibility of these 2 species coming into contact.

No domestic sheep grazing should be authorized or allowed within buffer strips ≥13.5 km wide surrounding desert bighorn habitat, except where topographic features or other barriers prevent any interaction.

Justification.—Armentrout and Brigham (1988) recommended a 13.5-krn-wide separation strip as optimum, based on 9 cited literature sources. Bighorn and domestic sheep separation distances cited in the literature range from 3.2 to 32 km. The California Department of Fish and Game (1983), in its discussion of conflicting land uses, recommended that domestic sheep grazing be eliminated within 3.2 km of bighorn habitat where feasible. The 3.2-km buffer strip also is included in the Mina Habitat Management Plan in Nevada (U.S. Dep. Interior, BLM 1988*a*) in ≥1 land-use plan in the Boise, Idaho BLM District (Goodson 1982); and in the Winnemucca, Nevada BLM 1978 grazing Environmental Impact Statement for the Sonoma-Gerlach Resource Area. A 9.6-km-wide buffer strip was recommended in the Lahontan Resource Management Plan (RMP) and the Stillwater Habitat Management Plan in Nevada (U.S. Dep. Interior, BLM 1985, 1986*b*). The widest recommended buffer (32 km) was used in Arizona. A 32-km buffer was agreed upon in the original Memorandum of Understanding (MOU) between the BLM and Arizona Game and Fish Department. However, when the master MOU was redrafted in 1976, the section relating to domestic sheep grazing in bighorn habitat was not included (Gallizioli 1980). Situations involving potential bighorn and domestic sheep conflicts in Arizona now are handled on a case-by-case basis.

The reason for the 32-km buffer strip was concern over the chronic frontal sinusitis in desert bighorn. This disease occurs when bot fly (*Oestrous* ovis) larvae enter the sinus cavities of bighorns, grow too large to get out, and die, thus infecting the bighorn (Bunch 1978). Sinus cavities in desert bighorns are much larger than those in domestic sheep. The major unanswered question asked by biologists in the 1970s was "what is the range of the bot fly?" Although the U.S. Department of Agriculture has investigated this question, there is no definitive answer, as it depends upon variables such as temperature, precipitation, and wind. The 32-km buffer strip, however, was felt to be adequate (Gallizioli 1980).

Another problem when considering buffer strips is that young (3–4 yr old) desert bighorn, especially rams, tend to travel extensively (≤64 km). Extensive travel by bighorns increases the potential for nose-to-nose contact with domestic sheep. Nose-to-nose contact and resultant transmission of disease(s) was blamed for the catastrophic loss of penned bighorns at the Lava Beds National Monument, California in 1980 (Blaisdell 1982) and in the total population loss of transplanted bighorns in the Warner Mountains, California, in 1988 (Weaver 1988).

Considering all the evidence presented above and cited in Armentrout and Brigham (1988), the Tech Staff feels that buffer strips of ≥13.5-km are needed to minimize the potential of disease transmission, including chronic frontal sinusitis, and to avert nose-to-nose contact between wandering bighorns and domestic sheep.

Specific Recommendation 2: Livestock Supervision

Issue.—Domestic sheep must be closely and carefully herded to prevent them from straying into desert bighorn range.

Recommendation.—Domestic sheep that are trailed or grazed outside the 13.5-km buffer, but in the vicinity of desert bighorn ranges, should be closely supervised by competent, capable, and informed herders.

Justification.—There is virtually no practical way to control movements of young bighorns, but control of domestic sheep is possible. The key to minimizing impacts by domestic sheep upon bighorns is very close supervision of domestic bands by herding, both while trailing and grazing. Both the Warner Mountains and Lava Beds bighorn die-offs were attributed to stray domestic sheep. Had domestic sheep herding been more intensive, neither of these catastrophes probably would have occurred.

Sheep herders and their control of domestic sheep bands vary considerably. Many herders come to the United States from other countries, especially South America. Many have never herded sheep before their amval in the U.S. Permittees who graze domestic sheep on public lands should ensure that their herders are competent and capable and that herders understand the potential problems that may be caused by straying domestic sheep.

The Tech Staff recognizes that the BLM's grazing regulations may need modification to further implement this recommendation. Existing regulations provide that the authorized officer can require herders. The regulations also could be strengthened to allow impoundment of stray domestic sheep, whenever they are found in occupied bighorn habitat. This recommendation could be partially implemented by directives requiring that BLM area managers, range conservationists, and wildlife biologists meet with the permittees and their herders to explain the importance of close supervision by the herders and what could result if domestic sheep are allowed to stray.

Specific Recommendation 3: Trailing

Issue.—Domestic sheep being trailed near desert bighorn range are likely to transmit diseases to bighorns, especially when ewes are in estrus.

Recommendation.—Domestic sheep should be trucked rather than trailed, when trailing would bring sheep closer than 13.5 km to bighorn range. Trailing should never occur when domestic ewes are in estrus.

Justification.—Many domestic sheep are still trailed between grazing allotments. The Tech Staff recommends that domestic sheep be trucked whenever possible to minimize possible contact with bighorns. Close supervision by herders is essential. The time of trailing also is important. When domestic ewes are in estrus, they will attract bighorn rams from distances >3.2 km. The Tech Staff recommends, therefore, that domestic sheep not be trailed closer than 13.5 km to occupied bighorn habitat. Domestic sheep also should not be trailed when ewes are in estrus, to reduce potential for bighorn sheep contact. This prescription should be included in BLM grazing regulations as part of the supervision and husbandry requirements.

Specific Recommendation 4: Reintroduction

Issue.—Ranges formerly occupied by domestic sheep can harbor diseases detrimental to desert bighorn.

Recommendation.—Bighorn sheep should not be reintroduced into areas where domestic sheep have grazed during the previous 4 years.

Justification.—Our concern involves bighorn reintroductions into habitats formerly occupied by domestic sheep. The Tech Staff does not advocate the co-use of bighorn habitat by both bighorn and domestic sheep. Two diseases that could be transmitted to bighorn after domestic sheep have been removed are footrot and soremouth (Jessup 1985, Kistner 1982). Both of these diseases can lie in the soil and, when conditions are right, be transmitted to bighorns. The soremouth virus can remain viable in the soil for 10 to 20 years (Jessup 1985, Lance 1980).

SUMMARY

The DBC Tech Staff herein has identified some of the problems associated with bighorn and domestic sheep interactions, and has recommended procedures that should eliminate or reduce contact between domestic and desert bighorn sheep. These recommendations include: no nose-to-nose contact between bighorn and domestic sheep; a minimum of a 13.5-km-wide buffer strip between ranges used by domestic sheep and bighorns; trucking of domestic sheep in preference to trailing, and no trailing when domestic ewes are in estrus; and no bighorn reintroductions onto areas that have been grazed by domestic sheep during the previous 4 years.

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OBITUARY

LOWELL SUMNER
1907–1989

Lowell Sumner, a long-time member of the Desert Bighorn Council and co-editor of *The Desert Bighorn,* died on 1 October 1989 in Silver City, New Mexico. Lowell was born in New York City on 7 December 1907. He spent his early childhood in North Kingston, Rhode Island, then moved to southern California with his family. He attended Pomona High School and Pomona Junior College. He attended the University of California at Berkeley where he received a Master's degree and also worked toward a doctorate.

Almost his entire working career was spent with the National Park Service (NPS). He accomplished important exploratory work in Alaska while attached to the San Francisco Regional Office, and was the senior author of *Birds and Mammals of the Sierra Nevada.* Later he became Chief Research Biologist for the NPS in Washington, D.C. where he retired in 1967. Then he and his wife, Marietta, lived in Friendship, Maine, and Glenwood, New Mexico. Since 1971 they had made their home in Glenwood.

Besides his wife, Lowell is survived by a daughter, Ruth Crandall of San Dimas, California. Memorial services were held in Glenwood on 21 October where Dick Weaver delivered a eulogy as a representative of the Desert Bighorn Council.

Lowell was deeply interested in desert bighorn and constantly worked for their welfare. He carried out bighorn research, especially in Death Valley and Joshua Tree national monuments. He possessed a deeply held conservation ethic, and was widely known as a man of integrity and idealism. He was well-respected by the Desert Bighorn Council; we will miss him.—G. *Monson, 8831 N. Riviem Drive, Tucson, AZ 85737.*

DESERT BIGHORN COUNCIL 1990-1991

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DESERT BIGHORN COUNCIL MEETINGS AND OFFICERS
1957–1990 ANNUAL MEETINGS

Year	Location	Chairman	Secretary-Treasurer
1957	Las Vegas, Nevada	M. Clair Aldous	
1958	Yuma, Arizona	Gale Monson and Warren Kelly	
1959	Death Valley, California	M. Clair Aldous	Fred Jones
1960	Las Cruces, New Mexico	Warren Kelly	Fred Jones
1961	Hermosillo, Sonora, Mexico	Jon Van Den Akker	Ralph Welles
1962	Grand Canyon, Arizona	James Blaisdell	Charles Hansen
1963	Las Vegas, Nevada	Al Ray Jonez	Charles Hansen
1964	Mexicali, Baja Calif., Mexico	Rudolfo Hernandez Corzo	Charles Hansen
1965	Redlands, California	John D. Goodman	John P. Russo
1966	Silver City, New Mexico	Cecil Kennedy	John P. Russo
1967	Kingman, Arizona	Claud Lard	John P. Russo
1968	Las Vegas, Nevada	Ray Brechbill	John P. Russo
1969	Monticello, Utah	Ralph and Buddy Welles	W. Glen Bradley
1970	Bishop, California	William Graf	W. Glen Bradley
1971	Santa Fe, New Mexico	Richard Weaver	Tillie Barling
1972	Tucson, Arizona	George W. Welsh	Doris Weaver
1973	Hawthorne, Nevada	Warren Kelly	Doris Weaver
1974	Moab, Utah	Carl Mahon	Lanny Wilson
1975	Indio, California	Bonnar Blong	Lanny Wilson
1976	Bahia Kino, Mexico	Mario Luis Cossio	Lanny Wilson
1977	Las Cruces, New Mexico	Jerry Gates	Peter Sanchez
1978	Kingman, Arizona	Kelly Neal	Peter Sanchez
1979	Boulder City, Nevada	Bob McQuivey	Peter Sanchez
1980	St. George, Utah	Carl Mahon	Peter Sanchez
1981	Kerrville, Texas	Jack Kilpatric	Peter Sanchez
1982	Borrego Springs, California	Mark Jorgensen	Rick Brigham
1983	Silver City, New Mexico	Andrew Sandoval	Rick Brigham
1984	Bullhead City, Arizona	Jim de Vos, Jr.	Rick Brigham
1985	Las Vegas, Nevada	David E. Pulliam, Jr.	Rick Brigham
1986	Page, Arizona	Jim Guymon	Bill Dunn
1987	Van Horn, Texas	Jack Kilpatric	Bill Dunn
1988	Needles, California	Vernon C. Bleich	Donald Armentrout
1989	Grand Junction, Colorado	Jerry L. Wolfe	Donald Armentrout
1990	Hermosillo, Sonora, Mexico	Raul Valdez	Donald Armentrout

INSTRUCTIONS FOR CONTRIBUTIONS TO THE DESERT BIGHORN COUNCIL TRANSACTIONS

GENERAL POLICY: Original papers in the field of desert sheep ecology and management are published in the DESERT BIGHORN COUNCIL TRANSACTIONS. All papers presented at the Council's annual meetings are eligible for publication. Additional papers may be published when reviewed and approved by the Editorial Board. Costs for papers ≥ 10 printed pages will be charged to the author at the current cost per page unless authorized by the Editorial Board. Papers must be submitted to the Editor at or before the Council's annual meeting to be considered for the current edition of *The Transactions.*

COPY: Use good quality white paper 215 × 280 mm (8.5 × 11 inches), or size A4. Do not use "erasable," light weight, or mimeo bond paper. Double space throughout, with 3-cm margins. Do not hyphenate at the right margin. Type the name and complete address of the person who is to receive editorial correspondence in the top left corner of page 1. On succeeding pages type the senior author's last name in the top left corner and the page number in the top right corner. The author's name and affiliation at the time the study was performed follows the title. Present address, if different, should be indicated in a footnote on the first page. Keep 1 copy. Submit 4 good xerographic copies. Do not fold any copy.

STYLE: Proceed from a clear statement of purpose through introduction, study area, methods, results, and discussion. Sequence of contents: title, authors, abstract, key words, introduction, study area, methods, results, discussion, literature cited, tables, and figures. Follow the *CBE Style Manual: a guide for authors, editors, and publishers in the biological sciences,* Fifth edition revised and expanded, 1983 (Counc. Biol. Eds., Inc., Bethesda, MD 20814), except for specific style items that differ in recent issues of *The Transactions.* Consult the 1988 TRANSACTIONS and Manuscript guidelines for the Journal of Wildlife Management (J. Wildl. Manage. 52[1, Suppl.]) for example of prevailing style.

TITLE: The title should be concise, descriptive, and ≤ 10 words. Use vernacular names of organisms.

FOOTNOTES: Use only for an author's address if it differs from the byline address, and in tables.

ACKNOWLEDGMENTS: Include acknowledgments at the end of the introduction as an untitled paragraph.

SCIENTIFIC NAMES: Vernacular names of plants and animals should be accompanied by the appropriate scientific names (in parentheses) the first time each is mentioned.

ABSTRACT: An abstract of about 1–2 typed lines per typed page of text should accompany all articles. The abstract should be an informative digest of significant content. It should be able to stand alone as a brief statement of problems examined, the most important findings, and their utility.

KEY WORDS: Place key words below the abstract. Supply 6–12 key words for indexing: vernacular and scientific names of principal organisms, geographic area, phenomena and entities studied, and methods.

REFERENCES: Authors are responsible for accuracy and completeness and must use the style in *The Transactions* since 1986. Avoid unnecessary references. Order multiple references consecutively by date. Show page numbers for quotations, paraphrases, and for citations in books or bulletins unless reference is to the entire publication. Cite unpublished reports only if essential. Include source, paging, type of reproduction, and place unpublished reports are filed parenthetically in the text.

LITERATURE CITED: Use capital and lower case letters for authors' last names, initials for given names. Abbreviate titles of serial publications according to references endorsed in the 1983 *CBE* manual, p. 54. Show issue number or month only if pagination is not consecutive throughout the volume. Consult *The Transactions* since 1986 for examples of correct style.

TABLES: Prepare tables in keeping with the size of the pages. Tables should be self-explanatory and referenced in the text. Short tables with lists of pertinent comments are preferred to long tables. Start each table on a separate page and continue onto 1 or more pages as necessary. Double space throughout. Omit vertical lines. Identify footnotes by roman letters. Do not show percentages within small samples (N or n $\leq$ 26).

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PROOF: All papers will be reviewed for acceptability by the Editorial Board and 2 outside reviewers. Submit papers to Dr. Paul R. Krausman, Desert Bighorn Transactions, 108 Biological Sciences East Building, University of Arizona, Tucson, AZ 85721. When papers are returned to authors for revision, please return corrected manuscripts within 30 days. Galley proofs should be returned within 72 hours.

TRANSMITTAL LETTER: When the manuscript is submitted, send a letter to the Editor, stating the intent to submit the manuscript exclusively for publication in *The Transactions.* Explain any similarities between information in the manuscript and that in other publications or concurrent manuscripts by the same author(s), and furnish a copy of such manuscripts or publications.