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# TECHNICAL REPORTS

## ASSESSMENT OF A DESERT BIGHORN SHEEP REINTRODUCTION IN ARCHES NATIONAL PARK, UTAH

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*Desert Bighorn Counc. Trans.* 35:1-4.

**Abstract:** We conducted a 2-year study to assess the transplant of 25 desert bighorn sheep (*Ovis canadensis nelsoni*) into historical habitat in Arches National Park (ANP) in 1985 and 1986. We investigated the status of the population, focusing on mortality, population dynamics, health status, and movements. The population increased in 3 years since release to approximately 40 animals at the end of 1989. Observed lamb:ewe ratios were 62 and 50 lambs: 100 ewes in 1988 and 1989, respectively. Diseases suspected of decimating other populations in southeastern Utah do not appear to have plagued the sheep in Arches. Movements of the desert bighorn in and near the park indicate interchange with the Potash Unit herd to the southwest, and observations outside the park suggest geographic expansion of ranges. The transplanted population appears to have adapted well to their new environment.

**Key words:** Arches National Park, desert bighorn sheep, disease, movements, population dynamics, predation, reintroduction.

Past efforts to reestablish desert bighorn sheep in historical habitats have ranged from failures to successes. As transplant procedures and techniques have improved since initial efforts in the 1950s, the likelihood a transplant will be successful has increased substantially (Wilson and Douglas 1982). Conforming to accepted capture, handling, and release guidelines, however, does not necessarily insure a successful transplant. A major factor that must receive consideration prior to transplant is whether elements responsible for extirpation, such as disease or predation, still prevail. Suitability of release sites and potential habitat is also a vital consideration (Wilson et al. 1980).

Comprehensive follow-up studies of transplanted desert bighorn sheep populations are seldom conducted (Rowland and Schmidt 1981), leaving gaps in our understanding of why transplants succeed or fail. The question remains, however: what constitutes a successful desert bighorn sheep transplant? A reintroduction that results in a self-sustaining population is considered a success by some authors (Griffith et al. 1989). Factors that contribute to a self-sustaining desert bighorn population and seem reasonable by which to judge a transplant a success or a failure include: low mortality rates, high lamb natality and survival, population growth, fidelity to selected habitats, ability to explore and exploit new

habitats, interchange with neighboring herds to diversify gene pools, and perhaps others.

To assess a transplant's success and address these questions, we conducted a 2-year study on a reintroduced population of desert bighorn sheep in ANP, Utah. A portion of the study focused on rates and causes of mortality, disease incidence and health status, population dynamics, and movements that would facilitate genetic interchange.

Funding was provided by the National Park Service and Utah State University, with cooperation from the Utah Division of Wildlife Resources. We also thank J. A. Bissonette, Utah State University, for reviewing this manuscript.

### STUDY AREA

Arches National Park is located 8 km north of Moab in southeastern Utah and encompasses approximately 295 km<sup>2</sup> (Fig. 1). The park is characterized by high elevations (1,200–1,700 m), sparse vegetation, a semiarid climate, and pronounced angular topography with large expanses of slickrock and massive cliffs.

The park is dominated by the Salt Valley that runs through its northern half for about 18 km and consists primarily of alluvial deposits. The southern portion of the park is predominately Navajo and Entrada sandstone and sand deposits. The geology and topography of the area is discussed in detail by Lohman (1975), Doelling (1985), and Hoffman (1985).

Arches National Park has a semiarid climate with temperatures ranging from <18 C in winter to >44 C in summer, with an mean annual temperature of about 12 C. Precipitation is variable and averages approximately 22 cm annually. Most precipitation occurs in the form of sporadic thunderstorms in the late summer and fall, and as snowfall during the winter ( $\bar{x}$  = 27 cm annually).

The vegetation of ANP is representative of semiarid shrub-steppe vegetation types. The 3 major community types are pinyon- (*Pinus edulis*) juniper (*Juniperus osteosperma*) woodland, desert scrub, and grassland, with each community covering 45, 25, and 11% of the park, respectively. The principle species of the desert scrub community is blackbrush (*Coleogyne ramosissima*), and the grassland community is dominated by purple threeawn (*Aristida purpurea*), galleta grass (*Hilaria jamesii*), dropseed grasses (*Sporobolus* spp.), and Indian ricegrass (*Stipa hymenoides*). Allen (1977) presents a comprehensive analysis and discussion of the vegetation communities of the park.

### METHODS

Six sheep (3 rams, 3 ewes) were captured by net gun from the Island-in-the-Sky District of Canyonlands National Park and released into ANP near the Colorado River in 1985. In 1986, an additional 19 animals (5 rams, 10 ewes, 4 lambs) were released in Anderson Gulch to supplement the previous year's transplant.

Field research was conducted from July to September 1987, from May to December 1988, and from March to June 1989. Results were based on 119 aerial and ground relocations of 5 radio-collared animals (1 ram, 4 ewes) located on a semimonthly to monthly basis, and uncollared sheep that were located by hiking throughout the study area in a systematic manner.

### RESULTS

Desert bighorn sheep locations were concentrated primarily on the steep talus slopes below the cliffs of the Colorado River comdor. We made numerous observations on the rugged slopes across Highway 191 from Atlas Minerals, and to a lesser extent, in association with a topographic feature called the Great Wall.

Two mature rams died shortly after release in 1986 of capture myopathy near the release site. A radio-collared ewe was killed 6 months after release (1986) when struck by an automobile on Highway 191 west of the park. In 1987, a mature ewe was found dead 5 m from the Colorado River. Also in 1987, a radio-collared ram was found dead on

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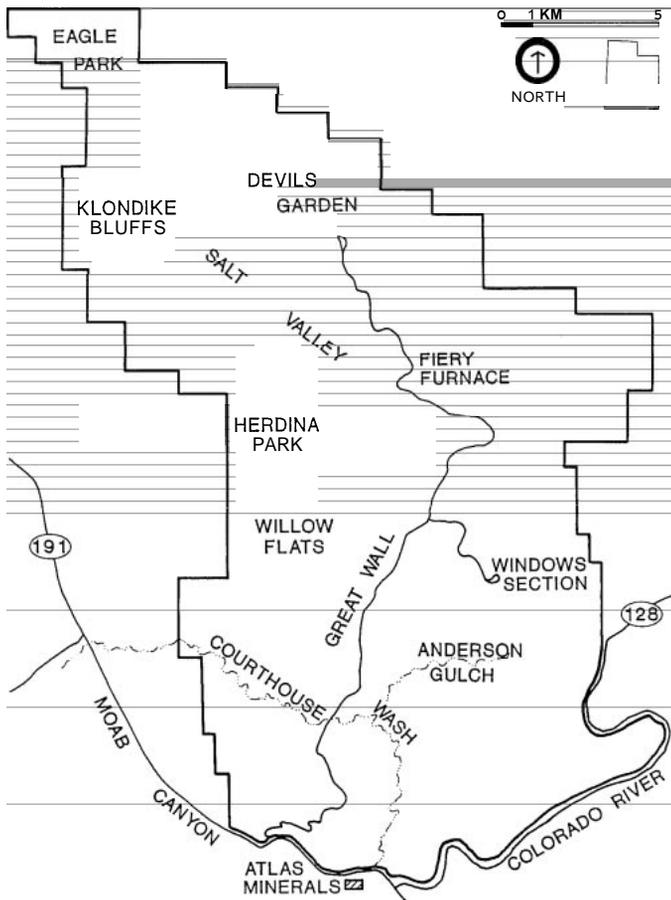


Fig. 1. Desert bighorn sheep study area, Arches National Park, Utah.

the mesa-top near the Colorado River corridor. No field necropsies were performed or causes of death determined due to the advanced state of decomposition of the latter 2 animals.

Results of analyses of blood samples collected ( $n = 10$ ) at the time of capture indicated the majority were negative for infectious bovine rhinotracheitis, bovine virus diarrhea, brucellosis, parainfluenza type 3 (PI3), epizootic hemorrhagic disease (EHD), leptospirosis, and blue tongue. Two ewes tested positive for leptospirosis, 2 ewes and 1 ram tested positive for blue tongue, and 2 ewes were positive for EHD. Only 1 ewe tested positive for all 3 titers.

We did not observe symptoms of illness or disease during the study, with the exception of the ewe that was later found dead near the Colorado River in 1987. Coughing or nasal discharge, typical of PI3 and blue tongue viruses, was not observed in any other animals. Body condition was classified as good (McCutchen 1985) for all individuals observed within reasonable visual range.

Potential predators known to occur in ANP include bobcat (*Felis rufus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), and mountain lion (*Felis concolor*). Bobcat and coyote sign were commonly observed in the study area, but sign of mountain lion (scat, tracks) was rarely encountered. Two mountain lion observations were reported in the park during the course of the study; 1 in the area frequented by desert bighorn near Atlas Minerals.

No instances of predation on desert bighorn were observed or reported. The carcasses of the 2 dead sheep found during the summer of 1987 showed no signs of predation and little evidence of scavenging. Predation does not appear to be a significant factor affecting the desert bighorn population in ANP.

We derived a population estimate of 44 animals (16 rams, 20 ewes, 8 lambs) at the end of 1989 based on the sex ratio and age classes of sheep released into ANP (Table 1), and known mortalities. This estimate

was based upon several assumptions: (1) 100% potential productivity of mature ewes (Turner and Hanson 1980); (2) ewe sexual maturation at 2 years of age (Turner and Hanson 1980); (3) 50% lamb survival; (4) 50% ram and 50% ewe lambs (Geist 1971); and (5) very little unknown adult mortality (Geist 1971).

Thirty-seven individual sheep (9 rams, 16 ewes, 8 lambs, and 4 unclassified) were observed in and near the park in 1989, based upon sex and age classifications, radio-collars, and dates and locations of observations. The number of sheep observed in 1989 agrees closely with the population estimate, indicating that 40 animals is a reasonable estimate of the number of desert bighorn in ANP at the end of 1989.

The sex classification of bighorn sheep observed during late summer 1987 was a ram : ewe : lamb ratio of 33:100:42 ( $n = 12$  ewes); in late summer-early autumn 1988, the observed ratio was 38:100:62 ( $n = 13$  ewes). Three rams died subsequent to transplant, leaving a ram : ewe ratio of 29:100 in 1987 for surviving transplanted rams. Of eight lambs observed in autumn 1988, 7 were ram lambs. This type of ram natality has contributed to an increased proportion of rams in the population as observed in summer 1989 (56 rams: 100 ewes: 50 lambs,  $n = 14$  ewes, excluding 4 unclassified animals).

Post-release exploratory behavior was exhibited to a small degree by the desert bighorn transplanted into ANP. Relocations indicate maximum distances moved from the release site for 4 radio-collared ewes ranged from 5–12 km; 2 collared rams moved 7 and 21 km from the release site.

## DISCUSSION

The threat of disease transmission from livestock to bighorn sheep is well documented (Jessup 1985), and the potential for interaction between desert bighorn in ANP and cattle is substantial. Arches National Park is surrounded by public lands for which grazing permits are issued for at least part of the year. All allotments, however, have been converted to cattle only since the 1988–89 winter grazing season. This change has decreased the threat of disease transmission substantially, since domestic sheep are commonly considered to pose a greater threat of disease transmission than cattle.

Contact with livestock on allotments west of the park increases the possibility that diseases or parasites may be transmitted to the desert bighorn sheep. Cattle are present on allotments from November to May, which includes the breeding season when rams are most likely to engage in movements to seek receptive ewes; these movements further increase the probability of intermingling and potential for disease transmission.

Movements of desert bighorn and domestic livestock across park boundaries provide increased opportunities for contact and disease transmission. Trespass of cattle from surrounding lands into the park, especially to the north of the park and west of the Willow Flats area, is a significant enough problem for the National Park Service to consider erecting a fence at the park boundary.

Observed lamb ratios are considered to be high, particularly when compared to ratios reported for other populations in southern Utah (Anonymous 1990). Such high rates of natality and survival should contribute to continued population growth.

When transplanted into an unfamiliar environment, desert bighorn exhibit exploratory behavior to varying degrees (McQuivey and Pulliam 1980, deVos et al. 1981, Ravey and Schmidt 1981, Dodd 1983) before establishing relatively sedentary home ranges similar to those of established populations (Simmons 1980). Exploratory behavior is a desirable trait in transplanted desert bighorn, as it allows the animals to learn the extent and location of suitable habitat. Exploration can be potentially detrimental, however, through mortality caused by crossing highways, fences (Elenowitz 1983), and flat terrain (Geist 1971). The death of a radio-collared ewe after being struck by a vehicle on the highway west of the park, and the fence entanglement of 2 rams during this study vividly illustrates this point.

Movements observed in and near ANP, and the establishment of a home range proximal to Highway 191 by a radio-collared ewe, suggest the population does not regard roads or traffic as potential danger. Crossing of roads and highways by desert bighorn (Witham and Smith

Table 1. Sex and age classes of desert bighorn sheep released into Arches National Park, Utah, 1985 and 1986.

Date	Sex	Age class	Comments
1985			
Jan	Ram	2.5 years	
Jan	Ram	2.5 years	
Jan	Ewe	Mature	
Jan	Ewe	Mature	
Jan	Ram	9-10 years	
Jan	Ewe	Mature	
1986			
Jan	Ewe	Lamb	
Jan	Ram	5.5 years	
Jan	Ewe	>4 years	Ultrasound for pregnancy positive, mortality Jul 1986.
Jan	Ram	>8 years	Mortality Jul 1987.
Jan	Ewe	Lamb	
Feb	Ewe	Lamb	
Feb	Ewe	>4 years	
Feb	Ewe	Lamb	
Feb	Ram	5.5 years	
Feb	Ewe	>4 years	Ultrasound for pregnancy positive.
Feb	Ewe	>4 years	
Feb	Ram	4.5 years	
Feb	Ewe	>4 years	Ultrasound for pregnancy positive.
Feb	Ewe	2 years	
Feb	Ram	1.5 years	Mortality Feb 1986.
Feb	Ewe	>4 years	Ultrasound for pregnancy positive.
Feb	Ewe	>4 years	
Feb	Ewe	>4 years	
Feb	Ewe	>4 years	

1979, Elenowitz 1983, King and Workman 1983), and tolerance to traffic and highway noises (Miller and Smith 1985) have been reported for other populations, although some authors suggest highways may act as artificial barriers to bighorn movements (Graham 1980).

Movements by a radio-collared ram and other bighorn west of the park involved crossing large expanses of relatively flat terrain. The area also offers reduced visibility due to the prevalence of juniper woodland in many portions of the area. Movements through such areas increase vulnerability to predation for an animal adapted for evading predators in precipitous terrain, but not for running at sustained speed (Geist 1971).

The establishment of home ranges near the release site by 2 radio-collared ewes, and frequent movements by a third collared ewe from her home range to the release site, reflect a fidelity to release points as observed in other transplanted populations of desert bighorn (deVos et al. 1981, Dodd 1983, Elenowitz 1983).

Based upon several observations of sheep (primarily rams) in the vicinity of Moab Canyon, it is theorized that considerable interchange occurs with the Potash herd to the southwest. These movements introduce the positive aspect of genetic interchange between the 2 populations, an important factor in maintaining the integrity, fitness, and genetic variability of a small population such as that present in ANP (Krausman and Leopold 1986).

Many transplanted populations have failed to expand geographically (Geist 1974, Hanna and Rath 1976). Several observations of the transplanted animals have been made along the Colorado River corridor up stream from ANP, approximately 17 km from the 1985 release site and 13 km from the 1986 release site. These observations, of both rams and ewes, indicate exploratory behavior and geographic expansion of distribution away from the release sites.

The transplant of desert bighorn into Professor Valley, northeast of ANP on the Colorado River by the Utah Division of Wildlife Resources in January 1991, together with movements by the ANP sheep up river

towards Professor Valley, will facilitate genetic interchange and benefit both the Arches population and the newly transplanted herd.

#### TRANSPLANT ASSESSMENT AND CONCLUSIONS

Based on information gathered during the course of this study, desert bighorn sheep transplanted into ANP have adapted to the new environment relatively well. Few known mortalities, lack of predation, low incidence of disease symptoms, and high reproductive rates have contributed to population growth since reintroduction. Movements indicate the possibility of a significant amount of interchange with neighboring populations and geographic expansion of ranges. According to criteria suggested as factors contributing to a successful transplant, the reintroduction of desert bighorn sheep into ANP may be considered a success to date.

Although there have been no guidelines established regarding the minimum number of desert bighorn sheep required to maintain a viable, self-sustaining population, it has been suggested that populations of  $\geq 100$  animals do not suffer from problems associated with inbreeding (Krausman and Leopold 1986). Furthermore, a minimum population size of 50 animals is suggested to preserve fitness, and 500 to maintain genetic variance and adaptability in mammals (Frankel 1983). Perhaps a reintroduction of desert bighorn sheep should not be considered a success until a population size of  $\geq 100$  animals is attained, provided the population is managed to allow genetic interchange to occur (Krausman and Leopold 1986).

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# EVALUATION OF TIME-LAPSE PHOTOGRAPHY TO ESTIMATE POPULATION PARAMETERS

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**Abstract:** We investigated the utility of time-lapse photography to provide population estimates and lamb:ewe ratios of mountain sheep populations. We compared 2 methods of time-lapse data analysis: group sampling and frame sampling. We failed to reject the null hypothesis that population estimates and lamb:ewe ratios from time-lapse and direct observation sampling were the same.

**Key words:** mark-recapture, Mojave Desert, mountain sheep, *Ovis canadensis*, population estimation, techniques, time-lapse photography.

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Time-lapse cameras have been considered an effective tool to determine whether a particular water source is being used by mountain sheep (Davis and Bleich 1980), classify the age and sex of mountain sheep (Helvie 1972, Constantino 1973), and determine mountain sheep drinking times (Constantino 1973, Campbell and Remington 1979). In 1972, Constantino (1973) conducted a census of mountain sheep on the Desert National Wildlife Range, Nevada, using time-lapse cameras. The time-lapse cameras recorded "at least 85%" of the population as determined by estimates made from field observations, lamb counts, helicopter counts, and "other" census methods. However, his methodology was not detailed. Wehausen and Hansen (1986) attempted to use time-lapse cameras to aid in mark-recapture (mark-and-sample; MS) population estimates of desert-dwelling mountain sheep. Various problems precluded this intended use; however, they were able to clearly identify marked individuals. Our objective was to compare time-lapse camera and direct observational sampling for generating MS population estimates and lamb:ewe ratios.

In 1986, the California Department of Fish and Game (CDFG) began field studies of the mountain sheep population in the vicinity of Old Dad Mountain and the Kelso and Marl mountains. Between September 1986 and September 1989, 17 ewes and 22 rams were marked with collars. Ground surveys and helicopter censuses were conducted prior to and during the study period to obtain MS estimates of the population and to determine recruitment rates (Wehausen 1990). These estimates provided the background information against which the time-lapse camera estimates for this study were evaluated.

Inherent to time-lapse camera sampling (TLS) is the potential prob-

lem of time-gaps between photographs. In a standard analysis of sheep groups visiting water, only the minimum group size and composition based on maximum numbers of identified individuals in each age and sex class can be determined. Because ewes were more numerous in most groups and more homomorphic, they were potentially more difficult to identify individually than were other sex and age classes. This could lead to over estimates in ratios of lambs to ewes. Collared ewes and rams were always identifiable as such; therefore, the same problem might occur in ratios of collared to uncollared animals. Because of these potential problems, a second analytical approach also was pursued wherein individual photographs (i.e., frames) were used as sampling units. This approach had a problem of non-independence of successive frames sampled, because the same individuals were sampled multiple times during each visit to water. Nevertheless, it was pursued to investigate potential relative bias in methods of analysis.

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## STUDY AREA

The study area was located in the eastern Mojave Desert approximately 30 km southeast of Baker, San Bernardino County, California. Old Dad Mountain is a steep, limestone massif, while the other ranges are predominately granitic in origin and much less precipitous (Bleich et al. 1990a). Elevations vary from 550 to 1,450 m. Vegetation is typical of the Mojave Desert at these elevations (Martens and Baldwin 1983).

Six water sources in the study area were considered for TLS. Of the 2 springs located in the Marl Mountains, sheep sign was found only at Jackass Spring in the summer of 1988; consequently, we monitored this spring during the 1989 study period. The other water sources monitored are artificial water catchments used by sheep. One of these catchments (Kelso Peak Guzzler) is located near Kelso Peak in a rolling hills area of the mountain complex. The other 3 catchments (Kerr Guzzler, Main Peak Guzzler, North Guzzler) occur at Old Dad Mountain and are located in steep, rocky terrain.

## METHODS

Time-lapse cameras similar to those described by Montalbano et al. (1985) were used to monitor the water sources used by sheep. The units varied in manufacturer, optics, circuitry, and power source. Each camera had a photocell that turned the unit off at night and back on at daybreak. The cameras were set to expose 1 frame of super-8mm color film (Kodak Ektachrome 160) every 60 seconds. Cameras were positioned as described by Constantino (1974).

We conducted TLS from 20 July to 7 September 1988 and 22 June to 27 September 1989. Films were changed every 3-7 days. During 1988, the field of view (or area photographed) for each camera was determined to be too wide for ideal classification of sheep. The field of view was decreased in 1989 and set so that only sheep within a few meters of the water sources were photographed.

The 1988 study period was preliminary, and monitoring was attempted only at the 4 artificial water catchments. The theft of a camera unit from the North Guzzler precluded any useful monitoring of that water source during 1988. This was a major impediment to sampling, because this guzzler received substantial use by ewe groups that summer;

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consequently, the 1988 data were analyzed using only the group sampling method described below.

The number of water sources monitored was increased by the addition of Jackass Spring in 1989. However, the North Guzzler dried-up shortly after 26 June, and monitoring of that water source was discontinued. This was not considered a problem, because sheep distributed around the North Guzzler subsequently shifted to the 2 southern guzzlers. One of these (Kerr Guzzler) dried-up about 6 July, and monitoring was suspended until 21 July, after a local rain shower recharged the guzzler.

Each film was analyzed with a variable speed projector and run through the projector twice. In the first viewing, films were projected at 6 frames/second. Those frames in which objects could be clearly distinguished were timed by stop watch. Using the projection rate, the number of usable frames (uf) per film was calculated. We recorded 60,680 uf for 1988 and 131,897 uf for 1989. In the second viewing, slower projection speeds (often only 1 frame/several minutes) were used to identify the mountain sheep photographed. Sheep were classified by sex and age as: adult and yearling females; lambs; and rams by horn size (class 1 [yearling], class 2, and classes 3 and 4 combined [Geist 1971]). Unidentified sheep also were recorded, but were discarded in the final analysis. Sheep in each category were tallied by water source and used to note differential use of water sources. Days could be determined by changes in lighting on the films, and data were recorded on a daily basis.

We used 2 analytical approaches: group sampling and frame sampling. Group sampling was an analysis of the identity and minimum size of the sheep groups photographed. Sheep groups generally were defined by separation in time, but this determination was subjective. If the viewer recognized that the same individuals were coming into water repeatedly over an extended period, possibly separated by many minutes, then those animals were classified as a single group (thus a single visit). Similarly, if the viewer clearly determined that 1 group of sheep had left and that a different group had come to water within minutes of the first group's dispersal, those were classified as 2 separate groups. Classified sheep were used to determine summer lamb : ewe ratios. Collared sheep were recorded to provide proportions of ewes and rams collared, from which MS population estimates were obtained.

Frame sampling used frames as sampling units and produced 2 data sets: sheep/frame and necks/frame. Sheep/frame was comprised of classified mountain sheep/uf. Each uf containing mountain sheep was carefully analyzed and all sheep photographed on the frame were classified. As discussed previously, each frame was treated as an independent sample; thus, information from preceding frames was not used to identify sheep in the succeeding frames. In this analysis, each identifiable individual photographed/frame was tallied, by sex and age class, as 1 sheep-frame. This produced ratios of lamb frames to adult and yearling ewe frames that were substituted for whole sheep when calculating lamb : ewe ratios using this method.

Necks/frame also treated each frame as an independent sample. Each adult and yearling ewe having a clearly photographed neck was classified as collared or non-collared/frame. The same was done for the adult ram population. Neck frames were used to obtain the proportion of necks collared from which a MS estimate of both the ewe and ram populations could be determined.

Population estimates were calculated using the Lincoln-Peterson MS estimator (Overton 1971). Because sampling was conducted with replacement, we adopted a cumulative sample estimator approach based on the binomial probability distribution as described by Wehausen (1990), in which a large random sample was accumulated over time. Rather than interpolate from published tables of binomial confidence limits, we calculated exact 95% confidence intervals for proportions collared as described by Wenstøp (1988). These were then directly substituted to generate confidence intervals for population estimates; and, differences between population estimates were considered significant if their 95% confidence intervals did not overlap (Overton 1971). No confidence intervals were generated for the frame sampling methods due to the lack of independence of samples. For these methods, statistical inference about differences between estimates was possible only when the frame sampling estimate fell within the confidence intervals of the other estimate, in which case it was clear that no difference could be

detected. The number of collared animals in the population varied during some sampling periods, and a mean number of collared animals weighted by sample size was used for those MS population estimates.

The population estimates used for comparisons were from a combination of helicopter and ground direct samplings of the population (Wehausen 1990), referred to as multiple direct sampling (MDS). The death of a collared ewe in 1989 was used to separate the sampling periods for MDS population estimates of ewes for 1988 and 1989. The sampling for the 1988 estimate was extended to 15 July 1989 by excluding from the sample ewes born in 1988. The ewe population increase for 1989 was the result of including that cohort in the sampling. The estimate of the 1989 ram population from MDS was based on samplings made between successive December hunting seasons.

Recommendations for statistical analysis of lamb : ewe ratio data have been based on normal approximations under the assumption of sampling without replacement (Otis and Bowden 1979, Czaplewski et al. 1983). Because both our TLS and MDS data approximated sampling with replacement, we instead treated these ratios as proportions and used an analysis based on binomial probabilities identical to that used for the proportion of ewes collared. This amounts to treating the lamb : ewe ratios as the proportion of ewes with surviving lambs. This is reasonable, as lambs are found essentially entirely within ewe groups in the hot season, and most are probably with their mothers.

## RESULTS

Mountain sheep used Kerr and Main Peak guzzlers more than Jackass Spring and the Kelso Peak Guzzler (Fig. 1). Jackass Spring in the Marl Mountains showed no sheep use in 1989, even though this spring is located within an area used by ewes and rams. Only 477 uf were recorded at the North Guzzler during 1989 prior to drying up; 9 mountain sheep were recorded during this limited sampling period. The Kelso Peak Guzzler was only used by adult rams. Consequently, TLS data were derived primarily from the Kerr and Main Peak guzzlers.

### Comparison of TLS Analysis Methods

The group sampling and necks/frame methods produced essentially identical estimates of the ewe population for the 1989 TLS data (Table 1). Our hypothesis that the group sampling method would produce an overestimate in the proportion collared that would lead to an underestimate for the population size was not supported. The estimates of the ram population did demonstrate the expected relative bias. The group sampling method produced a ram estimate that was lower than that from the necks/frame method. However, the latter estimate fell within the 95% confidence interval of the former (Table 1), and the 2 estimates were not significantly different. Furthermore, the low group sampling estimate may have been a function of the small number of rams sampled.

The group sampling method produced a lamb : ewe ratio that was slightly higher than that estimated by the sheep/frame method (Table 2). This was consistent with our hypothesis if ewes were being underestimated by the group sampling method. However, the difference between the 2 estimates was not significant.

The major difference between the 2 analysis methods was that the frame sampling methods produced inflated sample sizes from which misleadingly narrow confidence intervals for population estimates would result. The sample unit of individual sheep/visit used in the group sampling analysis mitigated much of the problem of non-independence. Therefore, this method provided a more valid measure of confidence intervals. Furthermore, the group sampling method took considerably less analysis time than the frame sampling methods. For these reasons, the group sampling method for time-lapse data analysis is recommended for future studies.

### Comparison of TLS with MDS

Substantial overlap in confidence intervals resulted in a failure to detect differences in ewe population estimates from TLS and MDS (Table 1). The 1989 TLS estimate for ewes was lower than the corresponding MDS estimate, which would be expected if time-lapse methods

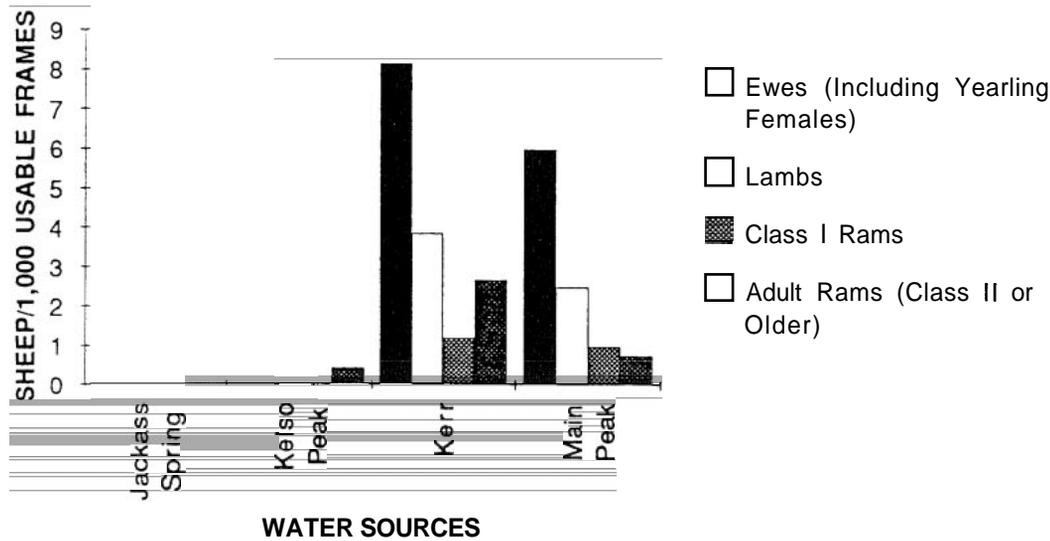


Fig. 1. Mountain sheep use of 4 water sources in the Kelso and Marl mountains and at Old Dad Mountain, California. Data are from group sampling analysis of time-lapse data.

produced higher estimates of the proportions collared. However, the 1988 TLS produced a higher ewe estimate than MDS. Thus, we see no general bias towards underestimation by time-lapse sampling. However, we must temper this conclusion, because the 1988 TLS data were limited by the failure to sample an important water source.

The 1989 TLS estimate of the ram population was notably lower than that produced by MDS; however, due to the small sample size for the TLS data, these estimates also were not significantly different (Table 1). An even smaller sample size precluded a TLS estimate of the ram population for 1988. The small ram sample produced by TLS may be a function of the limited use of the monitored water sources by adult rams. The 1989 MDS estimate of 205 rams, which excluded yearling males, was larger than the estimated ewe population, which included yearling females. The CDFG mountain sheep relocation efforts between 1983 and 1987 removed 87 females and 40 males from this population (Bleich et al. 1990b), and the skewed sex ratio may have resulted from these removals. As measured in sheep/1,000 uf (Fig. 1), ram use of water sources was considerably less than ewe use. If rams and ewes were using these water sources in a similar fashion, ram use should be proportionately greater than ewe use, because of the larger ram population.

The small difference between summer lamb : ewe ratios produced by TLS and MDS was not significant. A substantial decrease in the lamb : ewe ratio between summer and fall of 1989 was documented by MDS (Wehausen 1990). Similarly, we noted a decrease in the proportion of ewes with lambs by separating the TLS data into early summer and late summer samples. This decrease in the lamb : ewe ratio from TLS was consistent with the decline observed by MDS; however, statistical comparisons between the sampling methods were not possible because of differences in the sampling periods.

#### DISCUSSION

We failed to find differences between TLS and MDS population estimates and lamb : ewe ratios. Barring Type II error, this suggests TLS is a valid sampling method for MS estimation of ewe populations in desert mountain ranges with appropriate water distribution. However, we are aware of populations in which the majority of ewes rarely use the available water sources.

We recorded high numbers of ewes at water sources prior to mid-summer rains, suggesting that early summer may be the best period for MS estimates of ewe populations in the Mojave Desert. An adequate

Table 1. Sampling results for mark-recapture population estimation in the Old Dad Mountain and the Kelso and Marl mountains, California. Ewe samplings and estimates include adults and yearlings. Ram samplings and estimates include only adults (> class 1). Time-lapse samplings and estimates are presented for group sampling and necks/frame. Estimates of proportion collared are rounded to 3 decimal places, and the population estimates presented were calculated prior to rounding. Confidence limits are not presented for necks/frame data due to the non-independence of samples.

Year	Sex	No. sampled	Proportion collared	95% C.L.	<i>n</i> collars <sup>a</sup>	<i>n</i>	95% C.L.
Group sampling							
1988	Ewe	195	0.123	0.080-0.177	17.00	138.1	95.8-211.2
1989	Ewe	510	0.118	0.091-0.149	16.50	140.2	110.7-181.3
1989	Ram	125	0.120	0.069-0.190	16.88	140.7	88.8-245.7
Necks/frame							
1989	Ewe	3,781	0.118		16.55	140.3	
1989	Ram	819	0.107		16.98	158.0	
Multiple direct sampling							
1988	Ewe	414	0.135	0.104-0.171	17.00	125.6	99.4-163.9
1989	Ewe	274	0.098	0.069-0.136	16.00	162.4	117.7-231.9
1989	Ram	216	0.079	0.047-0.123	16.10	204.6	130.9-346.2

<sup>a</sup> Weighted mean.

**Table 2.** Summer lamb:ewe ratios for mountain sheep in 1989 at Old Dad Mountain and the Kelso and Marl mountains, California. Sample sizes are the number of ewes or ewe-frames in the denominator. Confidence limits are not presented for the sheep/frame data due to the non-independence of samples.

Sampling	Lambs : 100		No. ewes
	Ewes	95% C.L.	
Time-lapse sampling			
Group sampling	44.5	40.1–48.9	510
Sheep/frame	43.0		5,360
Multiple direct sampling	42.3	35.5–49.3	208

sample of some desert ewe populations may be possible with as few as 3–4 film changes during the early summer period. For ram population estimates, TLS did not provide an adequate sample size. This small sample size may be a function of the apparently limited use of the water sources by rams.

The close correspondence of lamb:ewe ratios from TLS and MDS suggests TLS also can be useful in monitoring recruitment rates of some populations of desert-dwelling mountain sheep. Lamb:ewe ratios determined by TLS may more accurately reflect recruitment rates if Sampling can be conducted in the early fall, after summer lamb mortality. The sampling success during this time period may vary as a function of summer precipitation and fall temperatures, and the difficulty associated with identifying large lambs in fall.

Adequate sample size to estimate population parameters is often a problem with desert-dwelling mountain sheep. For MS estimates derived from a sampling-with-replacement approach, TLS analyzed using the group sampling method appears to produce data that are compatible with those from MDS. Thus, combining TLS data with direct observations to significantly increase sample sizes is a useful approach.

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# STATUS REPORTS and COMMENTS

## STATUS OF BIGHORN SHEEP IN ARIZONA, 1990

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### CURRENT STATUS

Arizona's desert bighorn sheep (*Ovis canadensis mexicana* and *O. c. nelsoni*) population is approximately 4,500 animals. The 1990 winter helicopter survey produced 2,027 observations in 216 hours (9.3 sheep/hour). The 1990 survey was significantly affected by drought conditions; while the observation rate was 4.5% higher than last year, it was still 16.5% lower than in 1988. Survey results yield ratios of 69 rams, 34 lambs, and 19 yearlings: 100 ewes.

The Rocky Mountain bighorn sheep (*O. c. canadensis*) population, estimated at nearly 350 animals, is steadily expanding in numbers and range. Rocky Mountain bighorn sheep are currently residing near the release sites in the San Francisco River drainage but are moving southward into areas generally considered representative of desert bighorn sheep habitat. Winter surveys resulted in 241 observations. These survey results produced ratios of 47 rams, 38 lambs, and 27 yearlings: 100 ewes.

### HUNTING

Bighorn sheep permits remain the most sought after hunting permits in Arizona. There were 3,734 applicants (2,704 resident and 1,030 non-resident) for the 76 regular season permits. This application rate represents over 49 people applying for each permit, with individual unit odds varying from 14:1 to 144:1. As a result of this year's survey, permits for the 1991 season were increased from 76 to 83. Two additional permits will be issued to raise funds for bighorn sheep management programs. During the 1990 hunting season, 77 of the 78 potential hunters participated, harvesting 68 rams. Despite the harvest success of only 88%, this was only the second time in the last 8 years that the hunter

Table 2. Bighorn sheep transplant history in Arizona.

Years	Captured	Released	Mortalities	Radio-collared
1956-1960	45	23	14	0
1961-1965	0	0	0	0
1966-1970	11	3	3	0
1971-1975	11	10	1	0
1976-1980	105	97	8	33
1981-1985	415	392	21	154
1986-1990	408	383	6	147
Totals	995	908	53	334

success fell below 90%. This decrease in success can be attributed to the drought-induced difficulty in finding rams. The average success rate during this period remains above 92% (Table 1).

The 1990 season produced 28 animals (41% of the harvest) qualifying for the Arizona Trophy Book (min. score of 162 Boone and Crockett points). Of these rams, 11 (16%) scored >170 points.

### ALTERNATIVE FUNDING

For the eighth consecutive year, the Arizona Game and Fish Department and the Arizona Desert Bighorn Sheep Society (ADBSS) have entered into an agreement whereby the ADBSS auctions 1 permit (at the Foundation for North American Wild Sheep convention) and raffles another to raise funds for bighorn sheep management in Arizona. In 1990, these permits produced over \$140,000. To date, these permits have produced over \$900,000. Arizona's bighorn sheep management program is dependent upon the funds derived from these permits.

As predicted, the total revenue generated by the special permit program has decreased from its 1987 high (Fig. 1). Consideration should be given to the individual states' and the Bighorn Council's role in promoting this program.

Table 1. Bighorn sheep harvest history in Arizona.

Year	No. rams	%	Boone and Crockett scores		
			≥162	≥170	≥180
1953-					
1980 <sup>a</sup>	29	48	<4	<2	<1
1981	39	80	9	8	1
1982	41	85	6	7	2
1983	44	94	11	5	1
1984	51	93	17	6	2
1985	52	93	15	5	0
1986	56	88	22	7	1
1987	68	96	25	7	2
1988	76	97	21	5	4 <sup>b</sup>
1989	74	91	15	9	0
1990	68	88	17	8	3
Totals	1,431	61	300	116	27

<sup>a</sup> ƒ values for this period.

<sup>b</sup> 1 > 190 pts.

## BIGHORN SHEEP AUCTION TAGS

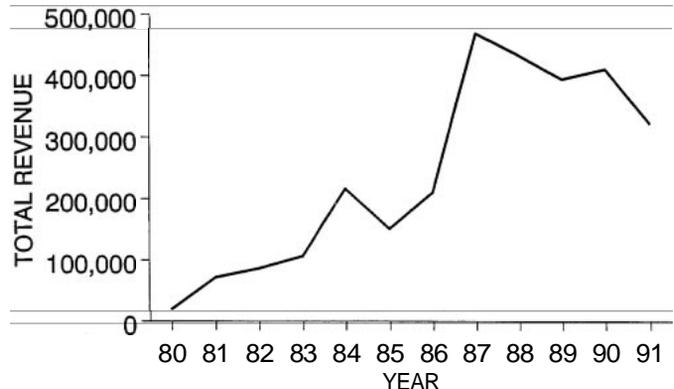
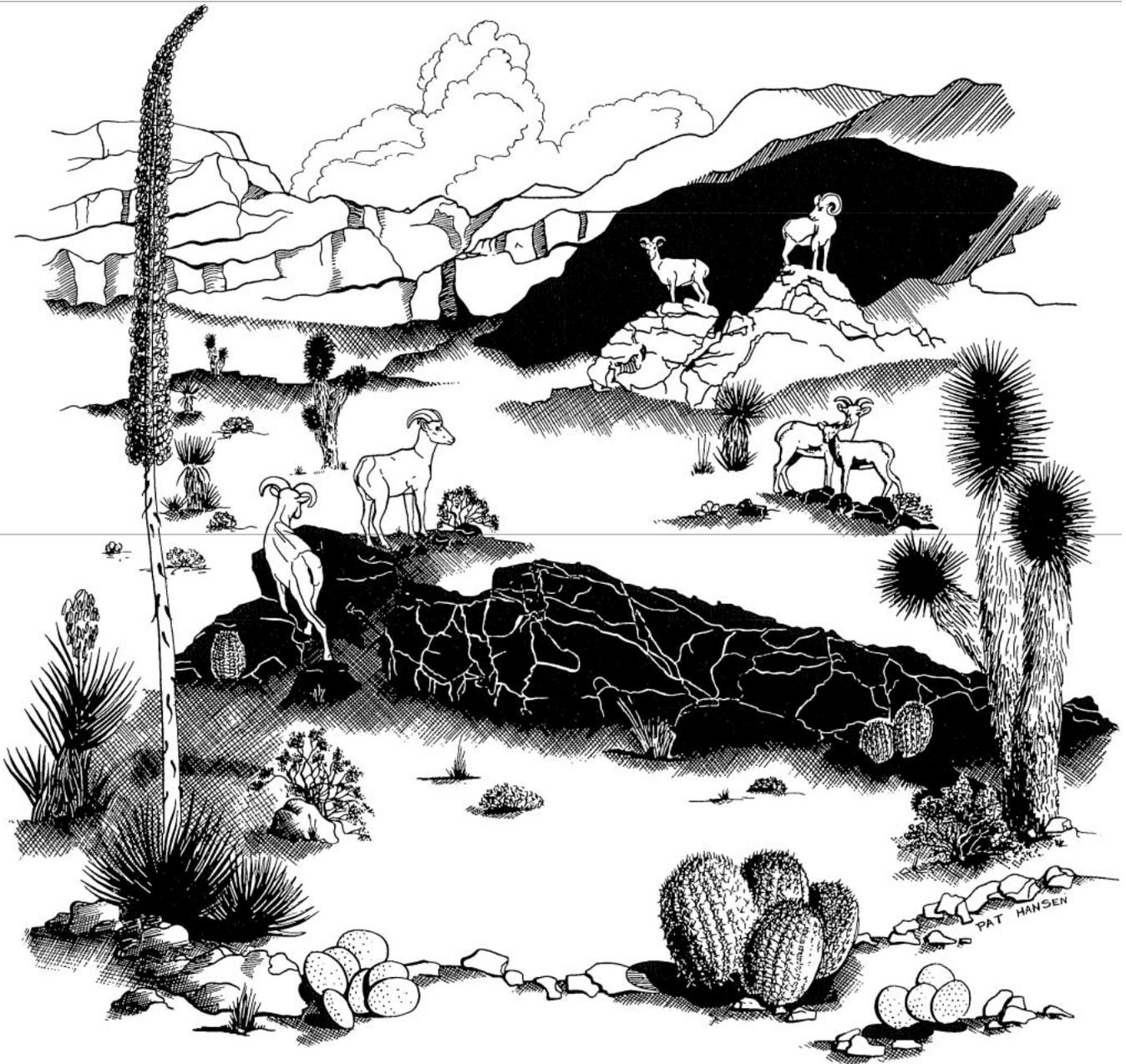


Fig. 1. Total revenue (U.S. dollars) generated from special tags auctioned at the Foundation for North American Wild Sheep annual convention.

**TRANSPLANTING**

Since 1980, a mean of 78 sheep have been transplanted annually, with a mean of  $\leq 3$  mortalities (Table 2). In 1990, using net-guns fired from helicopters, 30 bighorn sheep were successfully captured and released. This apparent slowdown in the transplant program was due to

environmental conditions, the need for increased documentation due to new wilderness designations, and the desire for a more complete analysis of past transplant efforts. Expanded transplant efforts are planned for 1991. In 1990, the 2 largest bighorn sheep harvested were taken from populations transplanted in the 1980s.



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# STATUS OF BIGHORN SHEEP IN CALIFORNIA, 1990

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## POPULATION STATUS

Three subspecies of bighorn sheep occur in California (Cowan 1940): California bighorn (*Ovis canadensis californiana*;  $n = 330$ ) are restricted to the Sierra Nevada of eastern California; Peninsular bighorn (*O. c. cremnobates*;  $n = 600$ ) occur in the western Sonoran Desert of Riverside, Imperial, and San Diego counties; and Nelson bighorn (*O. c. nelsoni*;  $n = 3,900$ ) in the eastern Sonoran Desert, the Mojave Desert, the Transverse ranges, and the Great Basin Desert 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

California's fourth bighorn sheep hunt was held in 1990. Six hunters shot 6 rams: 2 from the Marble Mountains and 4 from the Old Dad/Kelso Mountains. Since 1987, a total of 31 rams have been harvested, and 11 (35.5%) have qualified for the Boone and Crockett Records Book; only 2 hunters have been unsuccessful since the inception of the hunt, yielding an overall success rate of 94.5%.

For the second consecutive year, the California Department of Fish and Game (CDFG) (1991) prepared and circulated an environmental document that fully discloses the anticipated environmental effects of hunting bighorn sheep. The document appears to have complied fully with the mandates of the California Environmental Quality Act, and has not been challenged. In the environmental document, CDFG proposes to issue 8 tags for the 1991 hunting season: 4 at the Old Dad/Kelso Mountains, 3 at the Marble Mountains, and 1 special fundraising (auction) tag to be valid in either hunt zone. The special fundraising tag sold for \$42,000 at the February 1991 convention of the Foundation for North American Wild Sheep (FNAWS), an increase of \$5,000 over the price paid for the 1990 auction tag.

During the 1990 season, hunters again experienced some problems with individuals affiliated with the anti-hunting and animal-rights movements. Tactics of the protesters continued to center around the use of noise-making devices, and hiking ridge-tops in efforts to frighten bighorn sheep away from hunters. No protesters were cited for violations of the California hunter harassment law; however, 3 individuals received citations for possessing parts of fully-protected species, including hawks, owls, and ravens. Protesters identified in the hunt zones came from British Columbia, Washington, Montana, New York, New Jersey, Pennsylvania, and California.

## MONITORING AND RESEARCH

The CDFG currently is cooperating in demographic research in 9 Mojave Desert and Sierra Nevada populations, through a contract with the University of California, White Mountain Research Station; one of these studies centers around the question of blue-tongue (BT) and epizootic hemorrhagic disease (EHD) and their impact on the demography of bighorn sheep in the Old Woman Mountains. Field investigations related to the evolutionary significance of sexual segregation in bighorn

sheep have been completed, and data analyses are proceeding. A detailed demographic investigation of bighorn sheep inhabiting the Kingston, Clark, and Mesquite mountains has been initiated in cooperation with the University of Nevada, Las Vegas.

An investigation of the disease status and demography of bighorn sheep in and around Anza-Borrego Desert State Park is continuing, in cooperation with the California Department of Parks and Recreation, the Zoological Society of San Diego, and the Wildlife Health Program at the University of California, Davis. Additionally, a new investigation began in the Whitewater Drainage of the San Bernardino Mountains, where a *Babesia* species and psoroptic scabies are present; mule deer (*Odocoileus hemionus*), cattle, bighorn sheep, and possibly, some exotic ungulates are sympatric in that area.

The CDFG obtained samples for serology and other ongoing investigations in conjunction with marking and survey efforts in the Orocopa, Avawatz, Old Dad/Kelso, Kingston, Clark, and Turtle mountains. In addition, CDFG personnel are collaborating with personnel from the School of Veterinary Medicine, University of California, Davis in the development of a wildlife health program. The goal of that program is to encourage, facilitate, and coordinate wildlife health instruction, research, and service to improve wildlife health management. Electrophoretic protein separation studies involving 1,000 samples from 10 states, Mexico, and Canada were completed, and a manuscript has been prepared for publication. Additionally, CDFG personnel collaborated on 13 publications with researchers from the University of California, U.S. Forest Service, National Park Service, University of Alaska, and Utah State University.

## MANAGEMENT PLANS

Bureau of Land Management (BLM) personnel completed a management plan for the Kingston Range Area of Critical Environmental Concern, and CDFG personnel assisted BLM personnel by completing a draft of the Bristol Mountains Bighorn Sheep Habitat Management Plan. Personnel from CDFG completed drafts of 6 additional bighorn sheep population management plans, as prescribed by the California Legislature.

## HABITAT IMPROVEMENTS

The Volunteer Desert Water and Wildlife Survey (VDWWS) continues to maintain the 56 big game guzzlers currently within the range of bighorn sheep. Although construction of new guzzlers has slowed considerably, maintenance requirements have increased because existing guzzlers are getting older (Bleich and Pauli 1990). All of these guzzlers are located on public lands, and maintenance is performed within the constraints placed on Wilderness Study Areas, in cooperation with the BLM.

Personnel from the Inyo National Forest conducted a pinyon pine (*Pinus monophylla*) thinning operation on the winter range of the Mt. Langley herd in the Sierra Nevada. The project was funded by FNAWS, in an effort to increase the use of portions of that winter range by California bighorn sheep. National Park Service personnel, in cooperation with the VDWWS, worked to improve flows at Virgin Spring, in the Black Mountains, Death Valley National Monument.

## POTENTIAL MANAGEMENT PROBLEMS

Funding has become a critical issue with state and federal agencies. During 1990, some federal employees were temporarily furloughed, and 72 CDFG biologists received notices of impending layoff. Emergency funding, in the form of legislation requiring new user fees, temporarily halted the need for layoffs of CDFG employees.

Since 1984, CDFG has received an appropriation from the state legislature, specifically for bighorn sheep management and research. Although approximately \$270,000 was appropriated for fiscal year 1990-91, there is no certainty that such appropriations will continue. During fiscal year 1990-1991, approximately one-third of the legislative appropriation was given to the Bighorn Institute. Receipts from the sales of hunt applications, tags, and the special auction permit have averaged approximately \$60,000 annually since 1987; no major changes are anticipated.

**LEGISLATION**

During 1990, the state legislature acted to delete the "sunset clause" that was attached to prior legislation authorizing bighorn sheep hunting in California (Bleich et al. 1990). Bighorn sheep hunting will continue in perpetuity in the open areas, unless special legislation is enacted to eliminate the CDFG authority to authorize hunts. Hunts will continue to be limited to the currently open areas.

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# STATUS OF DESERT BIGHORN SHEEP IN NEVADA, 1990

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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 (*O. 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 1,687 desert bighorns in 22 of 46 mountain ranges surveyed. Each range is counted biennially. Counts included 922 females, 267 lambs, and 498 rams (29 lambs : 100 ewes, 54 rams : 100 ewes). Nevada has been dry for the past several years and lamb production is down. The NDOW estimates the desert bighorn sheep population at 5,200 animals.

### Water Developments

In 1990, water catchments were constructed in the Last Chance (n = 2), McCullough (n = 2), Muddy (n = 2), Specter (n = 1), and Bare (n = 2) mountains in the Las Vegas area. In the northern part of desert bighorn range, 2 catchments were constructed in the Clan Alpine Range east of Fallon and 1 in the Gabbs Valley Range east of Hawthorne. Water storage capacities of the catchments range between 15,000 and 26,000 L. The Fraternity of the Desert Bighorn (Las Vegas), Reno Chapter of Nevada Bighorns Unlimited (NBU) and Fallon Chapter of NBU funded and/or constructed the water projects, in addition to NDOW and Bureau of Land Management (BLM) personnel.

The NBU Reno and NBU Fallon were presented with national BLM

volunteer awards and BLM Carson City District plaques in recognition of their sustained contributions of money and labor for water developments.

### Trapping and Transplanting

In 1990, 82 desert bighorns were captured in the Black Mountains (n = 12), River Mountains (n = 29), Muddy Mountains (n = 29), and Sheep Range (n = 12). They were released in the Specter Range (n = 19), the Pahranaagats (n = 12), and Gabbs Valley Range (n = 12). Desert bighorns were also sent to Colorado (n = 19) and Utah (n = 20).

### Harvest

During the 1990 season 136 desert bighorn sheep tags were available in Nevada. This included 121 resident, 13 non-resident and 2 special bid tags. Four new sheep units were opened for hunting in 1990. All 4 populations in the new units resulted from transplants. Populations established by transplants accounted for 16 tags or 12% of the desert bighorn tags available in 1990.

In 1990, 93 rams were harvested (a hunter success rate of 68%), a 12% decline from 1989 and below the previous 5-year average (83%). The average age of rams harvested was 6.8 years old, comparable to the previous 5-year average. Ten rams exceeded the Boone and Crockett minimum of 168 points. These 10 were taken in 7 different management units. The largest ram was taken on the Sheep Range north of Las Vegas and scored 174 points.

### FUTURE PLANS

The NDOW has recommended to the Board of Wildlife Commissioners that 128 harvest permits (114 resident, 12 non-resident and 2 auction) be issued on 28 management units for 1991. Any ram could be legally harvested on 11 units while "legal" rams could be taken on 17 units. A "legal" ram in Nevada must be  $\geq 7$  years old or score  $\geq 144$  Boone and Crockett points (doubling the score of the longest horn).

Two harvest permits were auctioned in Nevada in January and February 1991 for the 1991 hunt: 1 at the Foundation for North American Wild Sheep (FNAWS); the second at the Nevada Bighorns Unlimited (Reno Chapter) banquet. Funds raised from these auctions totalled \$81,000.

There are nine water developments planned, all located in the Las Vegas area. The Reno Chapter of NBU is contributing funds to buy the majority of parts needed for these jobs, and the Fraternity of the Desert Bighorn will provide the volunteer labor.



# STATUS OF DESERT BIGHORN SHEEP IN NEW MEXICO, 1990

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In 1990, 209 desert bighorn sheep (*Ovis canadensis mexicana*) occurred in New Mexico based on fall surveys (Table 1). The population trend between 1985–90 indicates that all free-ranging populations are stable and the captive Red Rock herd is increasing. Increased precipitation in 1990 may be responsible for higher lamb survival in the Hatchet herd. Low lamb survival in the Alamo Hueco Mountains may be due to poor forage conditions caused by cattle overgrazing following the 1989 drought. An investigation into disease status of Peloncillo bighorn confirmed that clinical pneumonia is not active in the population. Investigations into the relationship between psoroptic scabies (*Psoroptes ovis*) and bighorn sheep in the San Andres Mountains ceased in 1990 pending a review by the Wildlife Management Institute.

## POPULATION STATUS

### Hatchet Mountains

The 1990 Hatchet population increased to 44 bighorn and the lamb : ewe ratios returned to 50:100, from a low of 20:100 in 1989. Preliminary analysis indicates that weather, measured by Palmer Drought Severity Index (PDSI) (Palmer 1965), may be the driving force in population fluctuation in the Hatchets (Fisher and Humphreys 1990). Low negative PDSI values corresponded with population declines in 1953, 1956, and 1989, whereas high positive PDSI values in 1983–88 and 1990 corresponded with population increases (Fig. 1).

### Alamo Hueco Mountains

The 1990 Alamo Hueco population dropped to an estimated 20 bighorn from 30 bighorn between 1986–89. No lambs were observed in 1989 and 1990 compared with 10–50 lambs: 100 ewes observed between 1986–88.

I believe that poor forage conditions, due to cattle overgrazing following the 1989 drought, limited lamb survival in the Alamo Huecos. The number of cattle tripled to 300 head of cattle in spring 1990 and density in sympatric bighorn areas was 6 cows/km<sup>2</sup>. Repeated aerial and ground surveys confirmed the seriousness of the situation: low grass diversity dominated by three-awn (*Aristida* spp.), few shrubs, heavy trampling, and only a few precipitous slopes without cattle were present. Furthermore, wildlife that was commonly seen in this range and is still seen in the adjacent desert ranges was scarce or absent (e.g., deer, raptors, passerine birds, and lagomorphs).

### Peloncillo Mountains

In 1981–82, all Red Rock bighorn transplanted to the Peloncillo Mountains died of bronchopneumonia following contact with the co-released Arizona bighorn (Elenowitz 1983, Sandoval et al. 1987). Between 1981–90, the population has remained below 30 animals and pneumonia was the suspected limiting agent (Fisher and Humphreys 1989).

To determine whether pneumonia was still active in the population, 6 radio-collared rams from Red Rock were released in the Peloncillo Mountains in January 1991 and ground tracked until 30 June. The primary objective was to assess presence/absence of clinical pneumonia in lambs and introduced rams following contact with extant bighorns from Arizona. Based on death dates in the early 1980s, rams would be expected to die within 4 months if pneumonia was still active; therefore, disease-free status could be assumed if rams survived the 6 month study period.

All but 1 ram contacted the extant population ( $n = 38$ ; lamb : ewe ratio = 35:100). No clinical symptoms of pneumonia were observed in any sheep, including lambs. All of the introduced rams were alive at the end of the study (Mabe 1991). It is impossible to predict whether pneumonia will manifest in the future. Based on this investigation, however, the Peloncillo population is presently considered clinically free of pneumonia. Although pneumonia was not observed in the population, the failure of this population to increase due to low lamb survival in the southern Peloncillos indicates that there may be other problems in this herd.

### San Andres Mountains

Based on a 2-year mite-bighorn interaction study (Inter. Vet. Serv., Status of psoroptic scabies in and health of bighorn sheep in the San

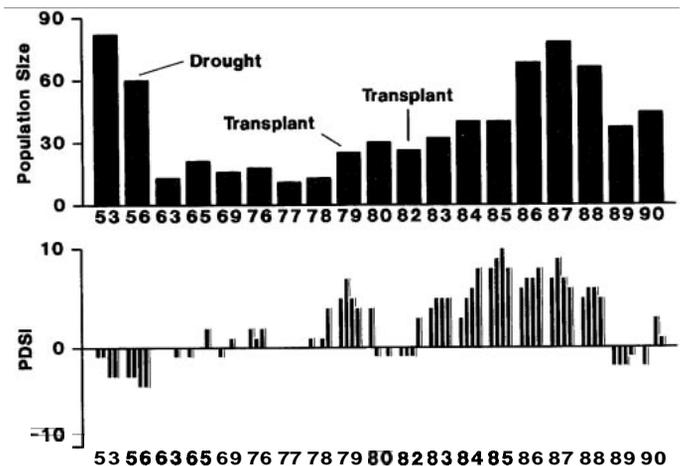


Fig. 1. Relationship between bighorn population and Palmer Drought Severity Index (PDSI) in the Hatchet Mountains, New Mexico, 1953–90.

Table 1. Status of desert bighorn sheep in New Mexico, fall 1990.

Area	Population history	No.		Trend
		Estimated	Actual <sup>a</sup>	
Hatchet Mountains	Indigenous, supplemented 30 in 1979, 1982	55	44	Stable
Alamo Hueco Mountains	Transplanted 21 in 1986	20	12	Stable
Peloncillo Mountains	Transplanted 38 in 1981, 1982	30	14	Stable
San Andres Mountains	Indigenous	22	19	Stable
Red Rock	Propagating facility, supplemented 21 in 1972, 1973, 1975	82	80	Increasing

<sup>a</sup> Actual no. based on aerial or ground surveys fall 1990.

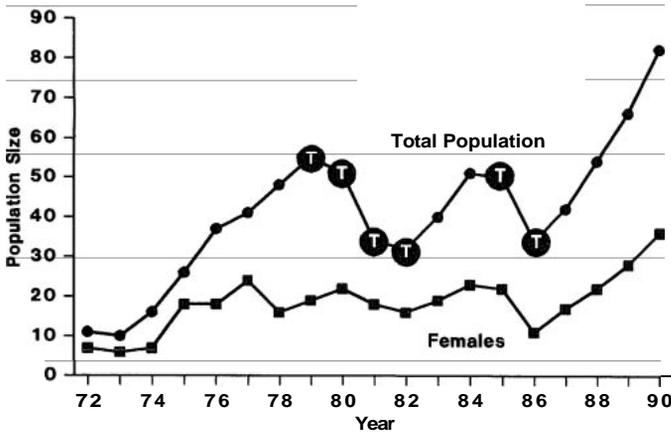


Fig. 2. Population growth of desert bighorn sheep, Red Rock, New Mexico, 1972-90. Circled "T" denotes years in which sheep were removed for transplants.

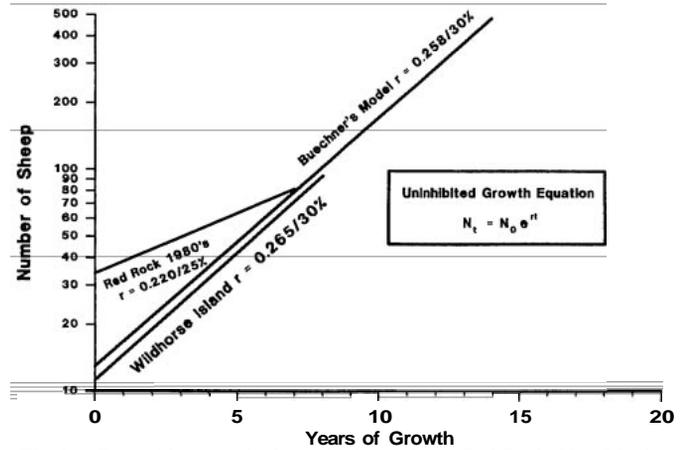


Fig. 3. Rate of increase in desert bighorn sheep, Red Rock, New Mexico, 1986-90.

Andres Mountains of New Mexico, Rep. to USFWS, 1990, 199pp.) in the Andres Mountains, draft Environmental Assessments (EA) were written by New Mexico Department of Game and Fish (NMGF) and the U.S. Fish and Wildlife Service (FWS) in 1990. The proposed action was to remove the existing population (n = 20-25) with their return and supplementation with Red Rock sheep contingent on the eradication of psoroptic mites on the sheep and in the environment. Intensive scabies mite cross-transmission and genetic studies were proposed concurrent with the removal.

Soon after the EA was written, however, FWS diverged from the proposed action and suggested that small population size and not scabies itself was the primary factor limiting the population (Hoban 1990). Red Rock transplants were therefore suggested as the best means to revive the population.

The NMGF rejected this option on the biological and ethical grounds that scabies was the primary predisposing and proximal cause of low population size and, due to the susceptibility of Red Rock sheep to scabies (Kinzer et al. 1983), Red Rock transplants would only temporarily increase numbers in this unhealthy herd. To attempt resolution, the San Andres mite-bighorn problem is being reviewed by the Wildlife Management Institute in 1991.

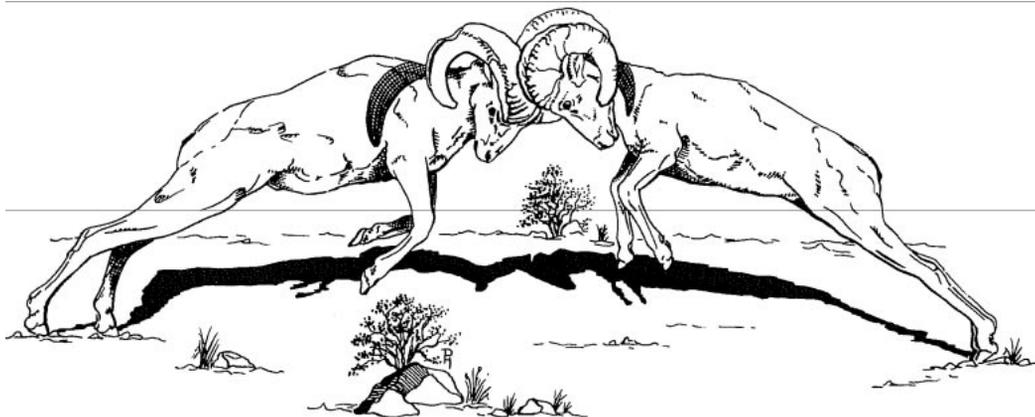
**Red Rock**

The captive Red Rock herd increased to 80 bighorn in 1990. With the exception of years in which sheep were removed for transplants, the population has increased most years since its establishment in 1972 (Fig. 2). For the years 1986-90 (no removals), rate of increase (0.220) represented an annual increase of 25% and was similar to the rate that Buechner (1960) calculated for the Wildhorse Island population (Fig. 3). Red Rock also approximated the theoretical maximum rate of increase (30%) as calculated by Buechner's model.

The expansion of Red Rock from 300 to 600 ha encompassing 5 pastures was completed in June 1990. The sheep will be allowed to gradually move into the new pastures. The next transplant of Red Rock bighorn is projected for fall 1992. Transplant sites will be selected based on an evaluation of historic ranges currently being conducted.

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# STATUS OF DESERT BIGHORN SHEEP IN TEXAS, 1990

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## HELICOPTER SURVEYS

In 1990, the first intensive helicopter surveys for desert bighorns were conducted in the Sierra Diablo Mountains of West Texas. Flights were made in August and October using a Jet Ranger. Fifty-two sheep (23 rams, 20 ewes, 7 lambs, and 2 yearling rams) were observed in August. Eighty sheep (44 rams, 24 ewes, 10 lambs, and 2 yearling rams) were observed in October (Table 1).

## POPULATION TRENDS

Five free-ranging populations of bighorn sheep occur in Texas: the Sierra Diablo Mountains in Hudspeth and Culberson counties, Van Horn and Baylor mountains in Culberson County, Sierra Viejo Moun-

tains in Presidio and Jeff Davis counties, and Elephant Mountain Wildlife Management Area in Brewster County. Free-ranging populations are estimated at 212 animals.

Three captive herds are located at the Sierra Diablo Wildlife Management Areas (WMA), Chilicote Ranch, and Beach Mountain Ranch. A temporary holding pen was constructed in November–December 1990 on the Beach Mountain Ranch in Culberson County to facilitate a "soft" release of sheep produced at the Sierra Diablo WMA brood facility. On 17–19 December 1990, 24 sheep were transferred from the Sierra Diablo brood facility to the Beach Mountain pen for a release planned in May. There were 95 captive sheep on 28 February 1991 (Table 2).

Most populations are generally small but the Sierra Diablo free-ranging sheep are considered a growing and viable population. The Sierra Diablo brood facility constructed by the Texas Bighorn Society continued to be the heart of the bighorn sheep restoration program. Sheep populations in the Sierra Diablo Mountains, Elephant Mountain WMA, and the scheduled release in the Beach Mountains are the result of production at this facility. Since 1984 170 lambs were born at Sierra Diablo; 122 survived (71.8% survival) (Table 3).

## HABITAT EVALUATION AND REINTRODUCTIONS

The Texas Parks and Wildlife Department is continuing to evaluate historic and potential bighorn sheep habitat to identify, evaluate, and prioritize areas suitable for future transplants. Some areas of the Sierra Diablo Mountains still lack sheep and additional releases likely will be desirable. A second release is planned for the Beach Mountains. Big Bend National Park personnel have expressed an interest in sheep and initial discussions have occurred with Texas Parks and Wildlife Department personnel about transplants. Currently the Black Gap Wildlife

Table 1. Bighorn sheep observed during August and October helicopter surveys, Sierra Diablo Mountains, Texas.

Date	Ram class				Ewes	Lambs	Yearlings		Total	Flight time (hrs)
	I	II	III	IV			Male	Female		
Aug 1990	2	13	5	3	20	7	2	0	52	35.8
Oct 1990	8	12	21	3	24	10	2	0	80	21.4

Table 2. Summary of bighorn sheep numbers and locations in Texas, 1991.

Area	Rams	Ewes	1990 lambs	1991 lambs	Unknown	Total
Sierra Diablo Mountains					135	135 <sup>a</sup>
Sierra Diablo						
Brood Pens						
Nevada Pen	1	8	4 (F)	2		15
Arizona Pen	1	9	3 (F)	5		18
Utah Pen						0
Texas Pen	1	11		6		18
Old Pen						0
Isolation Pen						0
Elephant Mountain					34	34 <sup>a</sup>
Chilicote Ranch						
Pasture					18	18 <sup>a</sup>
Free-ranging					6	6 <sup>a</sup>
Van Horn Mountains					19	19 <sup>a</sup>
Baylor Mountains					18	18 <sup>a</sup>
Beach Mountains	1	5	17 (13M,4F)	2		25
Glaze Clinic		1				1
Total						307 <sup>a</sup>

<sup>a</sup> Estimated without all 1991 lambs.

**Table 3. Lamb production and survival at the Sierra Diablo Wildlife Management Area brood facility, Texas.**

Year	Lambs born	Lambs surviving	% survival
1984	17	10	58.8
1985	18	11	61.1
1986	29	14	48.3
1987	25	16	64.0
1988	25	25	100.0
1989	27	20	74.0
1990	29	26	89.7
Totals	170	122	71.8

Management Area and adjoining private, state, and national park properties have priority ranking as a transplant site.

### HUNTING

In 1987 the Texas Parks and Wildlife Department provided a desert bighorn sheep hunting permit to the Foundation for North American Wild Sheep for auction. This hunt was allotted for a 7-day period in November 1988. Although 41 sheep (24 rams, 14 ewes, and 3 lambs) were observed, no ram was harvested. Three rams observed were of excellent trophy quality, but were located in terrain inaccessible to the hunter.

In 1988 a public drawing was conducted by Governor Bill Clements from a pool of 1,042 applicants. The hunt was conducted during 8 days in February 1988. Thirty-one sheep (14 rams, 13 ewes, and 4 lambs)

were observed. However, all rams were 5-4 years old and none were harvested.

In 1989 another permit was made available and auctioned by the Foundation for North American Wild Sheep. The successful bidder later requested his money be refunded and no hunt was conducted.

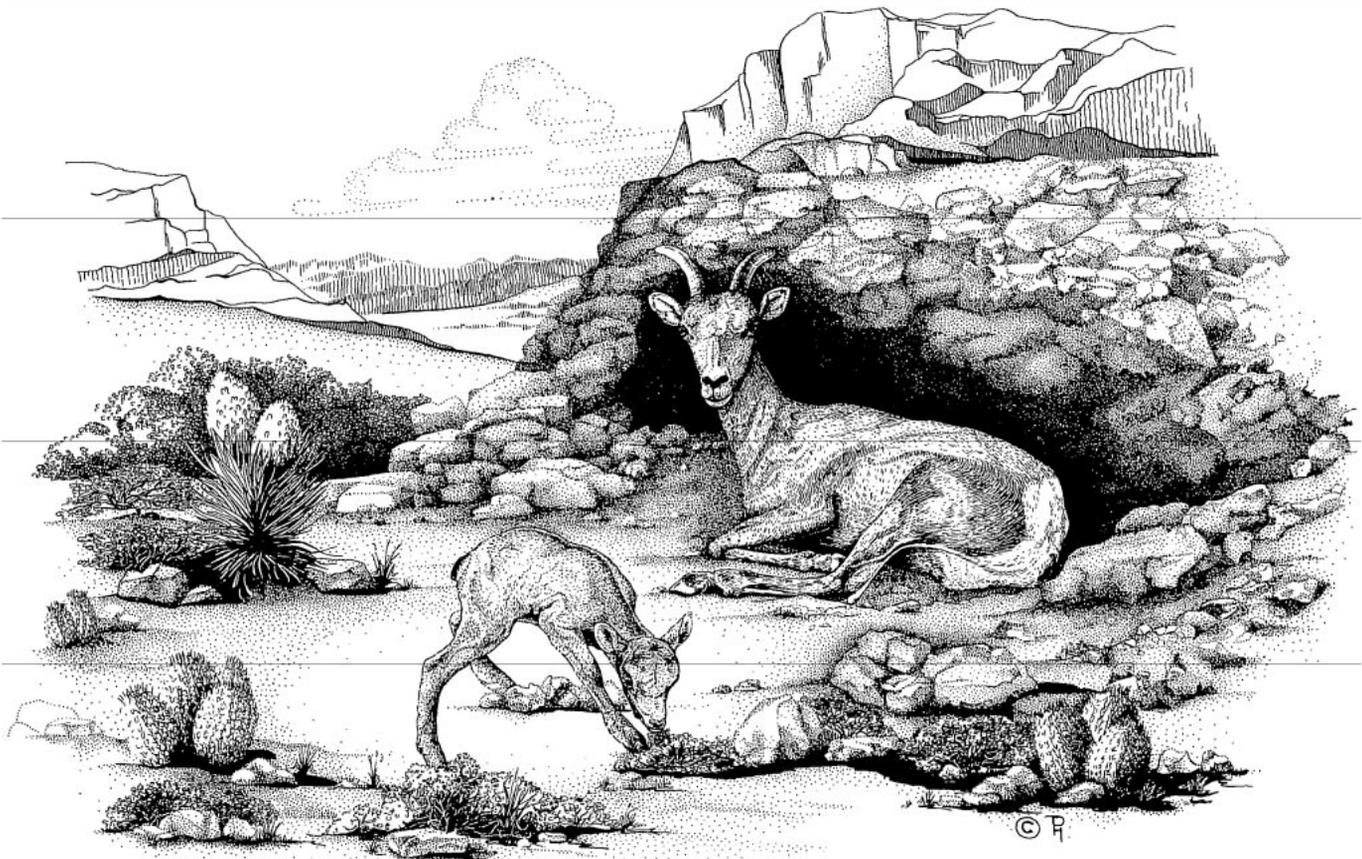
Governor Clements again drew a public permit from a pool of 1,550 applicants in 1990. A hunt was scheduled for 12-23 December 1990 on the Sierra Diablo WMA and 2 adjoining ranches comprising a Desert Bighorn Sheep Cooperative. The hunter successfully harvested a ram in the Victorio Canyon area of the Sierra Diablo WMA on the fourth day of the hunt. The ram was estimated to be 12 years old with heavily broomed horns measuring slightly over 73.66 cm in length and just over 35.56 cm in circumference at the base. Thirty-nine sheep (17 rams, 14 ewes, 5 lambs, and 3 unknown) were observed.

Permits have been issued to the 2 private landowners in the sheep cooperative for the 1991 season. The chances for a successful harvest of 2 trophy class animals are good.

### RESEARCH AND THE FUTURE

Currently no sheep research projects are being conducted in Texas; although, monitoring of radio-collared sheep is continuing at 3 release sites. There is a need for information about the ecology and movement of sheep at all release sites; particularly in the Sierra Diablo Mountains.

Most of the bighorn range in Texas is privately owned. The future of this species hinges on the ability of the Texas Parks and Wildlife Department and private landowners to work together to reintroduce and manage this unique natural heritage. The path has been, and will be, filled with pitfalls. However, the Texas Parks and Wildlife Department, cooperating landowners, the Texas Bighorn Society, and others are committed. The program is succeeding and the outlook is optimistic.



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# A DESERT BIGHORN SHEEP DECLINE IN ARAVAIPA CANYON, ARIZONA

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Aravaipa Canyon was evaluated in the early 1950s as a potential release site to re-establish desert bighorn sheep (*Ovis canadensis mexicana*) in historic range. In 1957 a 45 ha enclosure was constructed at Aravaipa to accommodate sheep transplanted there between 1958 and 1972. A study conducted in 1970 found the carrying capacity of the habitat within the enclosure to be 15 adult bighorns (Weaver 1970). Transplanted sheep and their offspring increased the population to 22 by January 1973 (Weaver 1973, Dodd 1982). Because sheep numbers exceeded the previously determined carrying capacity, a section of the fence was removed in early 1973 to allow free dispersal from the enclosure.

Subsequent surveys revealed that many of the bighorn sheep dispersed into adjacent habitats although there was fidelity to the enclosure for lambing (Hernbrode 1974, Olding 1981). A survey conducted in October 1989 also revealed a 52% decline in sheep observed ( $n = 58$ ) compared to the 1988 survey ( $n = 121$ ). The purpose of our study was to investigate causes for this population decline. Possible causes for the decline included dispersion, displacement, predation, disease, nutritional stress, poaching, and ingestion of noxious plants.

Funding for this study was provided by the Foundation for North American Wild Sheep and the Arizona Desert Bighorn Sheep Society. We acknowledge the San Carlos Apache Indian Reservation, The Nature Conservancy and the Safford District of the Bureau of Land Management for their input.

## POSSIBLE NON-MORTALITY FACTORS

Two helicopter surveys were conducted in April 1990. These flights expanded survey efforts into sheep habitats adjacent to the Aravaipa Creek drainage system in an attempt to determine whether dispersion was a factor. These surveys did not result in additional sightings of sheep.

The presence of livestock on the north rim was investigated as a possible contributory factor to displacement. Dodd and Brady (1986) reported little overlap in bighorn sheep and domestic cattle diets and ranges at Aravaipa. Their study, however, was conducted between 1981 and 1983 when annual rainfalls were at or above long term averages that were in contrast with the drought conditions that prevailed at Aravaipa in 1989 and 1990.

Prior to the implementation of a high intensity/short duration grazing system in 1984, 250 head of cattle were grazed continuously on the 31,724 ha allotment. Total livestock numbers were increased to 376 in 1986 and 384 in 1987. The most extreme grazing intensity recorded for the north rim of Aravaipa (392 head) occurred from November 1988 until July 1989 when it was reduced to 322 head due to a lack of forage.

Continued drought through Aravaipa's normal rainy season led to complete removal of livestock on 11 September 1989 (C. Templin, U.S. Bur. Land Manage., pers. commun.).

## POSSIBLE MORTALITY FACTORS

Between October 1989 and July 1990, 26 sheep carcasses and skeletal remains were located in the Aravaipa area. Estimated mortality dates for 24 of these sheep preceded the initiation of this study. Decomposition prevented definite causes of mortality to be determined. The other 2 mortalities were discovered during the course of this study; a 3-year-old ram was determined to be a victim of mountain lion (*Felis concolor*) predation, and a 3-month-old lamb fell and died.

## Predation

Between 1 January and 30 April 1990 13 mountain lions were removed by United States Department of Agriculture Animal Damage Control agents from a 10,400 ha block located 24 km south of Aravaipa Canyon suggesting high mountain lion densities in that area. Dodd (1983) also noted high lion densities during his work at Aravaipa, but found sheep losses due to lion predation to be insignificant. With the exception of the 1 radio-collared ram located on the San Carlos Indian Reservation, the bighorn sheep mortalities discovered in the Aravaipa area appeared to be non-predator related.

## Poaching

Aravaipa Canyon has the reputation for producing some of the highest quality trophy desert bighorn sheep in the Southwest. A new state record (Boone and Crockett score) came from Aravaipa in 1982 followed by the new world record bighorn harvested in 1988, and new archery and muzzleloader records in 1989. Although this could have been an impetus for illegal hunting activities, this probably would not account for the dramatic decline involving all sex and age classes. The mortalities located at Aravaipa in 1989 and 1990 included both ewes and rams, with skulls, horns and hides intact, suggesting non-selective mortality.

## Plant Toxicity

Dodd and Brady (1988) listed 32 forage species from bighorn sheep fecal samples collected at Aravaipa from 1981 to 1983. From this list, they identified 10 as being toxic or potentially toxic, including milk-vetch (*Astragalus* spp.), which they determined to be the second most common constituent (11% relative abundance) in bighorn sheep fecal samples. According to Schmutz et al. (1968), drought has the effect of concentrating toxins in preferred browse species. Plant toxicity could not be investigated due to the resumption of normal rainfall patterns during the initial stages of this study.

## Nutritional Stress

The intense drought coupled with possible overgrazing by livestock could prevent the buildup of energy reserves in the form of adipose tissue prior to the rut and result in a serious energy deficit during the interval of peak rut. The segment of the sheep population expected to be most affected by nutritional stress during peak breeding activities would be the older, more actively breeding rams. Twenty-one of the 36 rams observed during the October 1988 survey (58%) were classified as Class III and IV. Of the 13 rams observed during the October 1989 survey, however, only 3 (23%) were Class III and none were Class IV. These surveys also revealed a decline in the ram:ewe ratio from 67 rams:100 ewes in 1988 to 46:100 in 1989.

## Disease

Physiological stress can invoke a weakening of immunities and bring about a manifestation of clinical disease conditions from casual exposure to pathogens (DeForge 1976). Blood samples from 10 adult and 4 yearling sheep from Aravaipa in 1980 and 1983 were tested for possible disease titers. Results of the serological tests indicated that all 10 of the adults had been exposed to the bluetongue virus and epizootic hemorrhagic disease (EHD). The yearlings tested negative. In April 1990, 2 ewes and 1 ram were captured at Aravaipa and blood samples taken. All 3 sheep tested seropositive for bluetongue, contagious ecthyma and

EHD, indicating previous exposure to these diseases. Positive titers suggest that the sheep either have been previously exposed to or infected by the disease, signifying some level of immunity.

Bluetongue and EHD are most commonly transmitted by midges (*Culicoides* spp.) and mosquitoes (*Aedes lineatobennis*). The population dynamics of these disease vectors for bluetongue and EHD govern the highly characteristic explosive onset and spread of these closely related viral diseases, which almost exclusively occur during the late summer and early fall (Lance 1981). With cattle often grazing in proximity to bighorn sheep ranges at Aravaipa, the potential for these livestock diseases being transmitted to the sheep population is high.

A ground survey in May 1990 revealed a nursery band of 35 to 40 sheep concentrated within an area estimated to be  $<14$  ha in Hell Hole Canyon, creating the potential for high transmittal rates. Dodd (1983) expressed concern regarding the high sheep densities in the area of Horse Camp Canyon and the potential impacts to both habitat and health of the population.

## DISCUSSION

Between 1973, when the sheep were allowed to disperse, and 1988, the desert bighorn sheep population in Aravaipa Canyon expanded in numbers and occupied range. The 1988 population estimate was 195 sheep. Estimates resulting from 7 ground and aerial surveys conducted between October 1989 and April 1991 indicated a 59% decline in sheep numbers compared to 1988. The lack of sheep observations during surveys in habitats peripheral to Aravaipa's traditional sheep ranges suggests that dispersion was not a primary factor in the loss of bighorn sheep.

Increased predator-related mortalities would be expected to occur coincidental with the removal of the domestic livestock. Field evaluations and physical condition of the bighorn carcasses places the mortalities between 1 August and 15 September 1989, suggesting that the loss of sheep had actually occurred prior to the removal of cattle. Neither the ADC nor AGFD received reports of livestock predation in the Horse Camp Canyon.

The location of the sheep carcasses, their intactness and the short time interval in which the mortalities had taken place discount the likelihood of predator-related death. While 1 bighorn mortality on the San Carlos Apache Indian Reservation can definitely be attributed to a mountain lion, the others cannot.

Toxemia from alternate forage plants and water quality were also suspect. The time lapse between mortality dates and investigations, and the resumption of monsoon rains prevented conclusions regarding these factors.

The 1989 and 1990 lamb survival rates (18 lambs/100 ewes and 23 lambs/100 ewes, respectively) were below the average for Aravaipa Canyon's 5 previous survey years of 54 lambs/100 ewes. An April 1991 aerial survey indicated excellent spring lamb production (80 lambs/100 ewes). This figure decreased to 44/100 ewes by October 1991. Results of the blood serum tests in 1970, 1973 and 1990 suggest a possible window of disease vulnerability in young sheep at Aravaipa as all yearlings tested in the past showed no disease antibodies.

Comparisons were made to statewide desert bighorn sheep surveys and to surveys of other game species in Game Management Units 31 and 32 that include Aravaipa Canyon. Of the 21 game management units where 1988 and 1989 data were available, 14 (67%) showed a decrease in the number of desert bighorns surveyed. Statewide totals (excluding units 31 and 32) point to a 20% drop in the number of sheep surveyed. Units 15C and 15D in northwest Arizona showed a decrease in bighorn sheep survey numbers similar to the figures obtained from Aravaipa (approximately 50%).

Surveys of other big game species in the Aravaipa area showed similar trends based on 1988 and 1989 survey data; mule deer (*Odocoileus hemionus crooki*) decreased 49%; whitetail deer (*O. virginianus couesi*) decreased 26%; and javelina (*Tyassu tajacu*) populations decreased 20%.

Rainfall data from the National Oceanic and Atmospheric Administration revealed that 1989 statewide precipitation was about 20% lower than the average annual rainfall for those regions of the state where desert bighorns occur. Arizona's northwest region, which contains units 15C and 15D, received only 47% of its annual average rainfall. Aravaipa rainfall data provided by the BLM revealed that the east side of Aravaipa Canyon received 55% of its 10-year average annual rainfall. The west side, where the greatest discrepancy in sheep survey observations occurred, received only 37% of its average rainfall in 1989. Nutritional stress from a lack of forage can also be compounded by intensive livestock grazing practices.

In conclusion, while few of the factors investigated as possible causes for the decline in observed sheep numbers can be eliminated with certainty, the evidence examined during the course of this study suggests the mortalities that occurred during the late summer of 1989 were probably the result of livestock related viral diseases compounded by nutritional stress. Blood samples from Aravaipa sheep showed that 100% of the adult sheep had been either exposed to or previously infected with the bluetongue and EHD viruses. In contrast, for serum samples from statewide sheep populations (excluding Aravaipa), only 2.4% had detectable titer levels for bluetongue ( $n = 206$ ), and 8.8% had detectable titers for EHD ( $n = 193$ ) (deVos 1989).

Results of an aerial survey on 17 October 1991 indicate that sheep are gradually moving eastward from the 1990 Hell Hole Canyon high usage area. The observed lamb survival rate (44:100 ewes) was higher than the 1989 and 1990 figures, and the 60 sheep observations suggest an 18% increase in estimated population size.

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# ARTIFICIAL INSEMINATION OF WILD SHEEP

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Artificial insemination (AI) has several advantages for breeding mountain sheep (*Ovis canadensis*): (1) increased rate of genetic improvement, (2) easy transport of genetic material, (3) long-term storage of semen, (4) reduction or elimination of the need to maintain males with females, (5) use of synchronized or out-of-season breeding, and (6) reduced spread of disease. The latter advantage is extremely important concerning the transmission of fatal *Pasteurella* pneumonia to mountain sheep following contact with domestic sheep (Onderka and Wishart 1988, Onderka et al. 1988, Foreyt 1989), exotic wild sheep (Callan et al. 1991) and bighorn from other localities (R. L. Glaze, veterinarian, pers. commun.).

A successful AI program requires knowledgeable and skilled operator (~and must be properly planned and organized. The following procedures should be considered when planning an AI program.

## ESTROUS SYNCHRONIZATION

A reliable means of estrous synchronization (i.e., timing of ovulation) is essential. Artificial insemination must be performed at the proper time in relation to ovulation, or the onset of estrus. Synchronization of estrus shortens the time required to breed a group of ewes, facilitates management during pregnancy and lambing and, when used in conjunction with exogenous hormones, makes it possible to stimulate ovarian function, thereby increasing the number of females conceiving (fertility) and the number of offspring/female (fecundity) (Evans and Maxwell 1987). When estrus and ovulation are induced, ewes in good body condition can be bred anytime of the year providing enough good quality semen is available.

There are several methods to synchronize estrus. The more common pharmacologic method is the intravaginal pessary containing either Flugestoneacetate (FGA) or Medroxy-progesteroneacetate (MAP) (Smith et al. 1981). For convenience and simplicity, the intravaginal pessary or sponge is preferable. Unfortunately, the pessary is not sold in the U.S. and must be purchased through vendors in Canada (Tuco Products Co., Orangeville, Ont.) and Holland (Intervet International B.V., Boxmeer, Holland). The sponge is inserted into the vagina with an applicator and comes threaded with a string to aid withdrawal. The sponge is usually removed after 12–14 days, although we have synchronized estrus by leaving the sponge in for 10–21 days.

Upon withdrawal of the sponge, the ewe is treated with 200–500 i.u. Pregnant Mare Serum gonadotrophin (PMSG) intramuscularly. Ewes are artificially bred 52–56 hours after sponge withdrawal.

Subcutaneous ear implants (Ceva Laboratories, Kansas City, Kan.) containing impregnated progestagens are also used to synchronize estrus. They are inserted under the skin of the ear with a special applicator and are removed with a scalpel and a sterile forceps. Ear implants used with cattle have been cut in half and used in sheep. They are as effective as pessaries but are more difficult to use and if not inserted using sterile techniques will result in an infection (Evans and Maxwell 1987).

## SEMEN COLLECTION

Semen quality is highest at the peak of the breeding season and an AI program or the collection of semen for freezing should coincide with the breeding season. Ewes can be bred with frozen semen any time of year.

The preferred method of semen collection is the artificial vagina (AV), which can only be used on trained rams. This requires that the ram be artificially reared as a lamb. The best time for training is during the breeding season when the sex drive is the strongest and when estrous ewes are available as teasers. Once trained, rams quickly relearn the procedure at future semen collections. Training methods are described by Evans and Maxwell (1987). The AV imitates the vagina of the ewe and provides the proper temperature and pressure to initiate an ejaculation. Semen can be collected several times a day with an AV.

Electrical stimulation (i.e., electroejaculator) is used to collect semen from untrained rams. The procedure is simple but causes considerable discomfort to the animal. Semen cannot be collected as frequently as with the AV and the semen may be contaminated with urine. All types of electroejaculators have a bipolar rectal electrode. We prefer the Ruakura ram probe (I.M.V. International Corp., Minneapolis, Minn.) that is commonly used in Australia and New Zealand. The ram is easiest to collect from when restrained in a lateral position during electrical stimulation.

## HANDLING AND EXAMINATION OF SEMEN

Semen must be handled carefully to maintain viability of the spermatozoa. Evans and Maxwell (1987) identify several factors that should be considered. Generally the quantity and quality of an ejaculate is assessed based upon  $\geq 5$  factors.

1. Color (normal is milky white or pale cream) and smell (urine is deleterious).
2. Volume (approx. 1–1.5 mL).
3. Motility (proportion of progressively motile spermatozoa in a sample. Score of  $\leq 3$  based on a high of 5 is considered a poor quality ejaculate).
4. Proportion of motile spermatozoa ( $\leq 70\%$  is poor quality).
5. Concentration of spermatozoa (good quality ram semen contains  $3.5\text{--}6.0 \times 10^9$  spermatozoa). Concentration can be determined with a hemocytometer.

Motility may be the best indicator of sperm quality. The wave-like motion of good quality semen is visible in a glass collecting vessel; however, accurate assessment requires a microscope. With microscopic examination, a drop of semen is placed on a clean, warm (37 C) microscope slide with a coverslip, and the wave motion is observed at low power (40 x–100 x).

## DILUTION OF SEMEN

The lower effective limit of semen ranges from 20–300  $\times 10^6$  motile spermatozoa/inseminate, depending on deposition site. Volumes of 0.05–0.20 mL are used for cervical and intrauterine insemination. Higher concentrations are necessary for vaginal deposition with frozen semen. Vaginal deposition is usually not practical due to the low rate of fertilization.

## Fresh Semen

Commonly used diluents for fresh ram semen are egg yolk–tris–fructose and egg yolk–glucose–citrate (Evans and Maxwell 1987). Semen samples of good concentration and motility are never diluted more than 5-fold (1 part semen + 4 parts diluent).

## Frozen Semen

Frozen semen is stored at  $-196\text{ C}$ , which arrests metabolic activity. Frozen semen can be kept for prolonged periods and can easily be transported. The use of frozen/thawed semen can result in lambing rates of 60–75%.

Egg yolk is an essential component of any diluent. It contributes some nutrients, but its principal role apparently involves regulation of the flow of cryoprotectants through the spermatozoa membrane, thus min-

imizing damage (Ruttle 1989). Rodriguez's (Rodriguez et al. 1986) diluent and Salamon's (Evans and Maxwell 1987) diluent differ in the concentration of egg yolk. Rodriguez's diluent contains VPI-40 (an aloe vera extract). This extract (VPI-40) has high amounts of glucose and triglycerides and coats the membrane of the spermatozoa. It is added to the diluent to compensate for the lower concentration of egg yolk in Rodriguez's diluent. Glycerol is the most effective cryoprotectant for freezing ram semen. Semen is frozen in pellet form on carbonic ice (i.e., dry ice) and then stored at  $-196^{\circ}\text{C}$ .

### INSEMINATION

Sheep may be inseminated with non-frozen semen at vaginal, cervical or intrauterine sites. Only intrauterine insemination is acceptable with frozen semen. For mountain sheep the recommended insemination methods (either frozen or non-frozen semen) are transcervical deposition or intrauterine deposition by laparoscopy.

#### Transcervical

Since 1989 Halbert et al. (1990a, 1990b) have modified a transcervical intrauterine A technique for commercial use. The ewe is positioned in dorsal recumbency in a Commodore cradle (Premier, Washington, Ia.). The external cervical os is located, a forceps is fastened to the surrounding cervical tissue, and then the cervix is slightly retracted into the vagina. A specialized insemination instrument (Halbert et al. 1990a) is introduced into the external os and manipulated through the cervical canal into the uterus, where the semen is deposited. We have observed uterine penetration  $\leq 96\%$  in estrous ewes using this procedure. Pregnancy rates with frozen semen are 50–70%.

#### Intrauterine

The method for intrauterine insemination is laparoscopy, which we prefer in mountain sheep using fresh or frozen semen. This allows the inseminator to bypass the cervical barrier and increase the rate of conception. The basic equipment consists of a telescope (approx. 7 mm in diam), 2 trocar-cannula assemblies (1 for the telescope with gas line attachment and the other for the manipulation probe and insemination pipette). The manipulation probe is used to position the uterus. Once the uterine horns are in place, the probe is removed from the cannula and the insemination pipette inserted. Air or carbon dioxide ( $\text{CO}_2$ ) is used to insufflate the abdomen. There are several types of pipettes that can be used for insemination. We use the French (IMV) Cassou pipettor (I.M.V. International Corp., Minneapolis, Minn.) that has been developed for AI in cattle. The Cassou pipettor is readily available at any AI distributor. The plastic sheath that fits over the pipettor is replaced for each animal bred. This allows the inseminator to work under sterile conditions and alleviates potential contamination between ewes. A laparoscope insemination needle tip is placed into the Cassou sheath, the straw with semen is inserted, and the sheath is slipped over the pipettor.

Food and water should be withheld from the ewes 12–24 hours before insemination. Thaw semen just prior to insemination and maintain temperature at  $37^{\circ}\text{C}$ . The animals must be mildly sedated to minimize the stress of handling. We have had good results with small animal Xylazine (to effect). The following procedures are used for Laparoscopy AI:

1. Sedate ewe with Xylazine (IM) (to effect) until the animal is immobilized.
2. Place ewe in cradle, secure legs and shear hair 15–21 cm anterior to the udder.
3. Clean the sheared area with an antiseptic scrub such as Betadine.
4. Rinse the cleaned area with a disinfectant such as Nolvasan.
5. Elevate the cradle with the abdomen in an upright position  $50\text{--}60^{\circ}$  above horizontal.
6. Inject 2 ml of lidocaine approximately 16–18 cm anterior to the udder and 7 cm off the midline.
7. Make a small incision with a scalpel through the skin 3–4 cm on the left and right side of the midline and 16–18 cm anterior to the udder.

8. Push the trocar and cannula into the peritoneal cavity at the left site, withdraw the trocar and insert the telescope with fiber optic light.
9. Inflate the abdominal cavity with either  $\text{CO}_2$  or air.
10. Insert a second trocar assembly into the peritoneal cavity on the right site. Remove the trocar and insert a manipulating rod.
11. Place the uterine horns into position with the rod.
12. Position the Cassou pipettor with the pipette needle about midway on the curve of the uterine horn and eject semen into the uterine cavity.
13. Repeat the procedure on the other uterine horn.
14. Withdraw pipettor, telescope and cannulas.
15. Spray antibacterial agent such as Furacin on wound sites. Sutures are not necessary as wounds will heal quickly. You may, however, want to close the skin with wound clips. Antibiotics are given intramuscularly (e.g., Procaine penicillin—5 cc/45 kg).

Ewes should not be disturbed for 2–3 hours after insemination. Pregnancy rates of 70% are common using this technique. Females that do not become pregnant can be naturally mated with fertile males. For natural mating, ewes are placed with rams 12–14 days after AI.

### SUMMARY

Artificial insemination (AI) is the introduction of semen into the reproductive tract of a female by means of specialized instruments. The success of AI depends on factors that are specific to the ewe, the ram, the semen, and the insemination technique. Although AI has been used with domestic cattle, only recently in the U.S. has it been used commercially with sheep. In the breeding of mountain sheep, AI eliminates direct male-female contact and hence may control or prevent potential disease transmission, particularly fatal *Pasteurella pneumonia*. We describe methods used to artificially inseminate mountain sheep that achieved lambing rates of 70% breeding with frozen semen.

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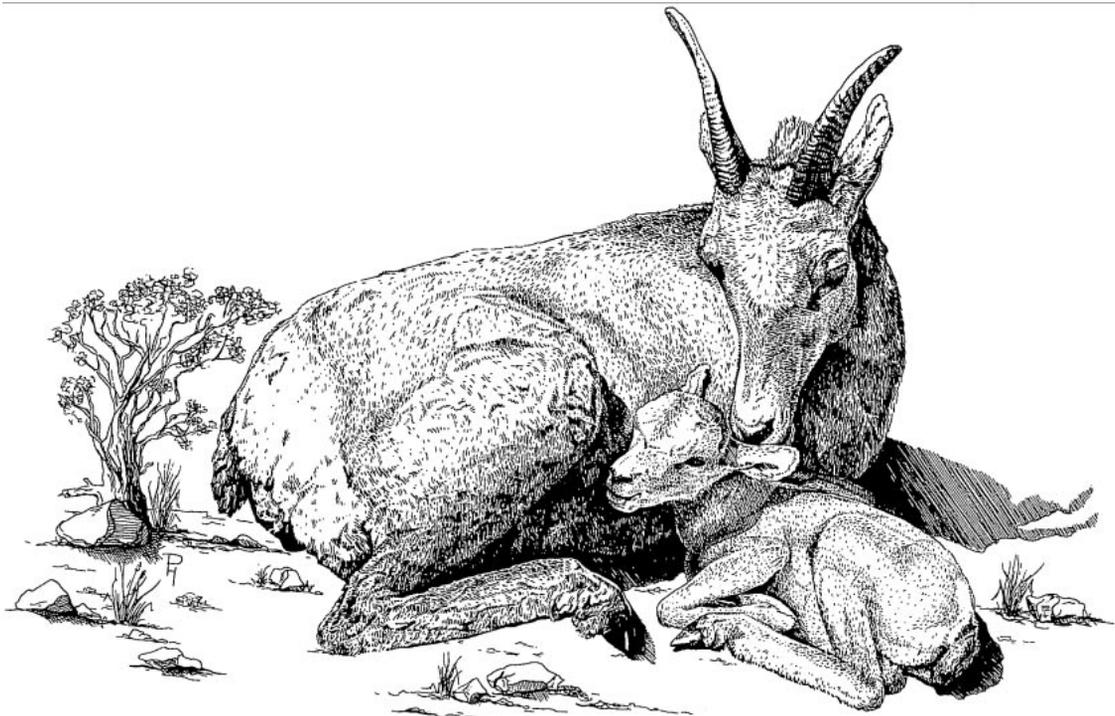
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# DESERT BIGHORN COUNCIL 1991-1992

## OFFICERS:

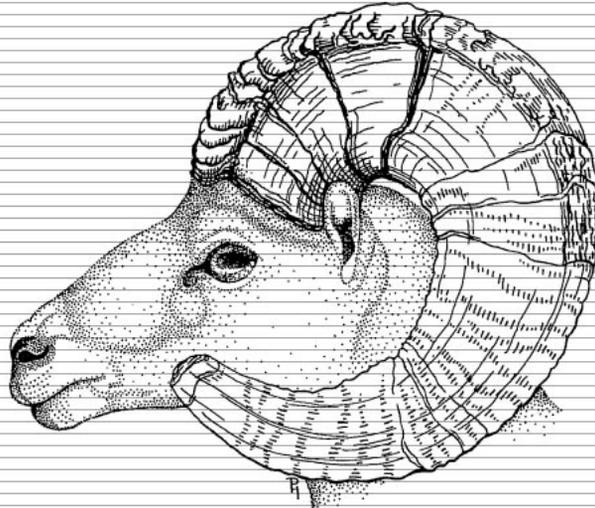
**Chairman:** Doug Humphreys, New Mexico Department of Game and Fish  
**Vice-chairman:** Amy Fisher, New Mexico Department of Game and Fish  
**Past Chairman:** Raul Valdez, New Mexico State University  
**Secretary-Treasurer:** Donald Armentrout, Bureau of Land Management

## TECHNICAL STAFF:

William R. Brigham, James R. DeForge, Mark Jorgensen, Andrew V. Sandoval, J. Juan Spillett, Richard A. Weaver (Chairman), George Welsh

## COMMITTEE CHAIRMEN:

**Nominations:** Raymond Lee  
**Program:** Doug Humphreys and Amy Fisher  
**Arrangements:** Debbie Sandoval  
**Transactions:** Paul R. Krausman  
**Burro:** Michael Coffey  
**Barbary Sheep:** Bruce Morrison  
**Historian:** Warren Kelly  
**Ewes:** Doris Weaver  
**Awards:** William R. Brigham



# DESERT BIGHORN COUNCIL MEETINGS AND OFFICERS 1957-1991 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
1991	Las Cruces, New Mexico	Doug Humphreys	Donald Armentrout

# INSTRUCTIONS FOR CONTRIBUTIONS TO THE DESERT BIGHORN COUNCIL TRANSACTIONS

**GENERAL POLICY.** Original papers relating to desert bighorn 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. There are 3 types of papers published in the TRANSACTIONS: technical papers; state reports; and opinions, comments, and case histories or notes. Technical papers are peer reviewed. State reports are edited for syntax and style. Opinions, comments, case histories and notes provide for philosophical presentations and the presentation of ideas and concepts. Some of these papers are also peer reviewed. Preliminary papers will also be published if they are complete enough to provide new information. Authors will be responsible for all page charges for preliminary papers. 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 < 26).

**ILLUSTRATIONS:** Illustrations and drawings must be in india ink or equivalent on 215 × 280 mm (8.5 × 11 inches) white drafting paper or tracing cloth. Make all letters and numbers large enough to be ≥1.5 mm tall when reduced. Lettering size and style when reduced should be the same in all figures. Only essential photographs for half-tone illustrations will be acceptable. Submit prints of good contrast on glossy paper. Type captions on a separate page in paragraph form. On the back of each illustration, lightly write the senior author's name, figure number, and "Top."

**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.