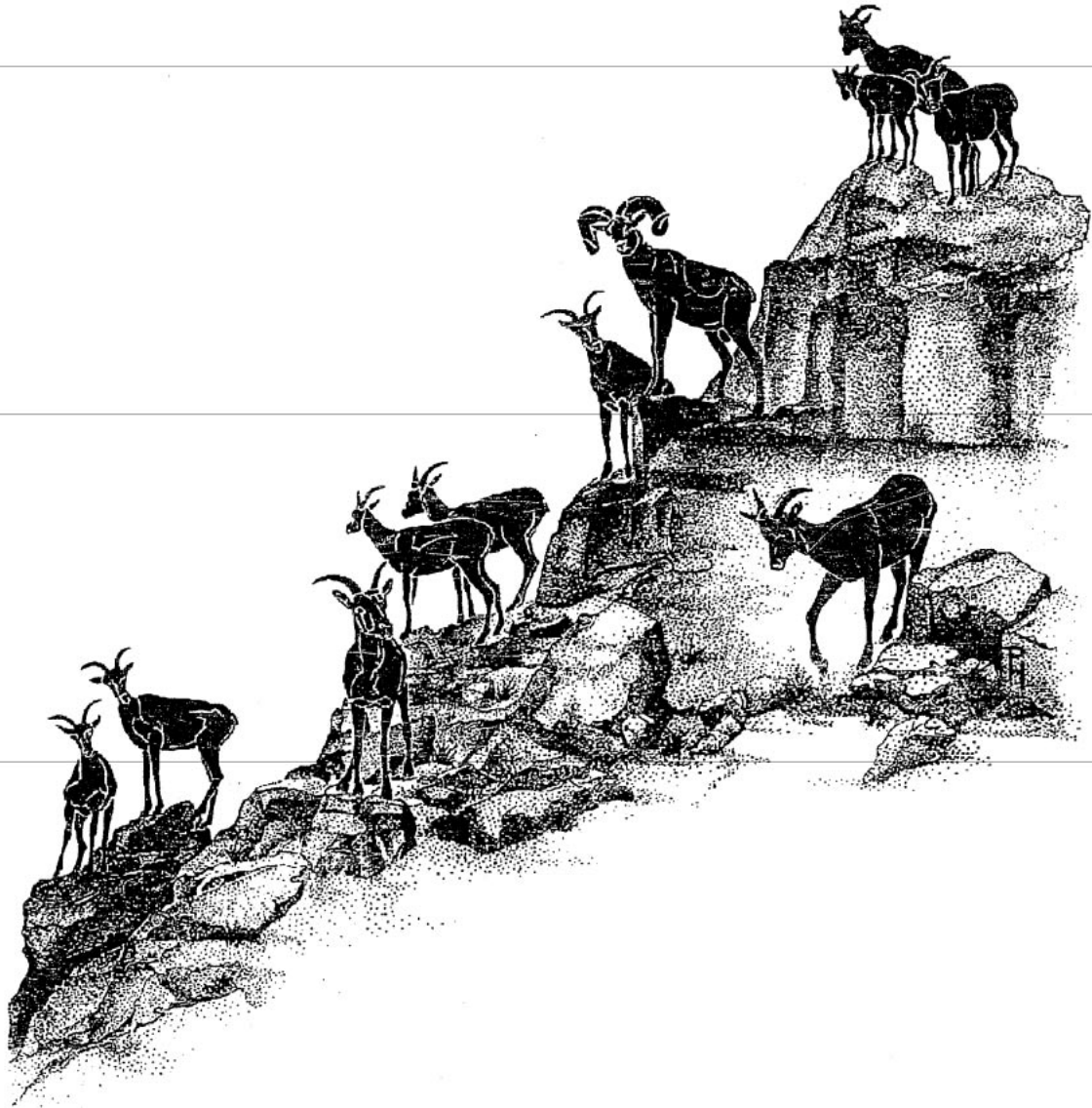

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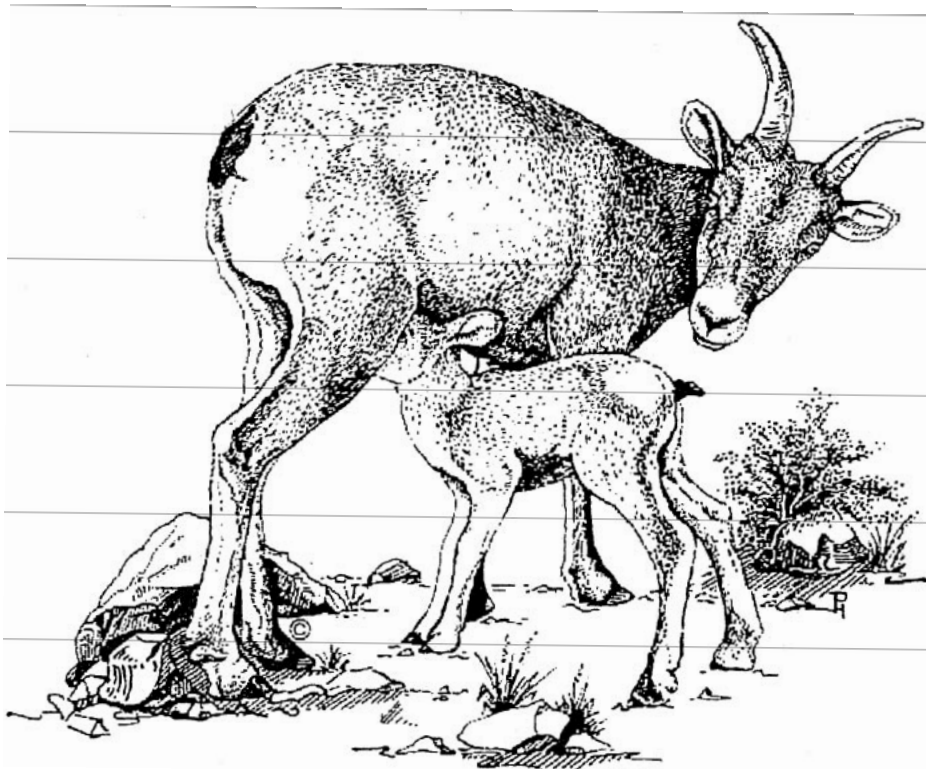
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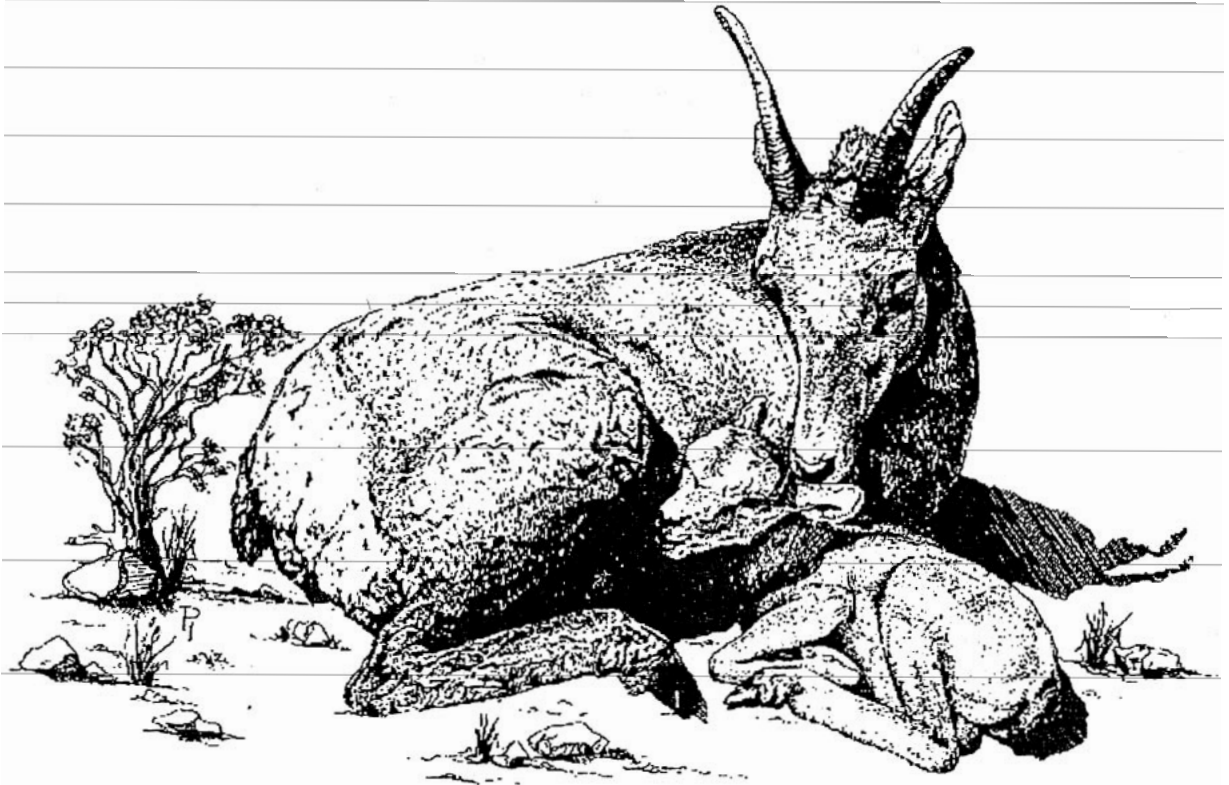
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TECHNICAL REPORTS



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PREDATION RISK IN DESERT BIGHORN SHEEP

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Knowledge of how predation risk factors faced by wild animals translates into population survivorship is important both for understanding predator-prey evolution and effective conservation strategies. Mountain lion (*Felis concolor*) predation is a major mortality factor contributing to the decline of many populations of desert bighorn sheep (*Ovis canadensis*) in the American Southwest. Desert bighorn sheep (*O. c. mexicana*) were studied at the Red Rock Wildlife Area, New Mexico during summer 2000 in order to assess predation risk in different group types (ram, ewe, mixed) and age/sex classes. Individual vigilance increased with increasing predation risk for all sheep; mature males in ram groups experienced greater predation risk than other group types. Males were found in the smallest groups, were more likely to be solitary, were spaced farther apart from conspecifics, and inhabited less rugged terrain compared with ewe and mixed groups. The 'Group Vigilance Index' also indicated that collective alertness was least for ram groups. The oldest and largest males, Class 3/4 rams, spent twice as much time vigilant as other classes, therefore indicating that they perceived themselves at greater risk. The conclusion that the largest rams are most at risk from predation is supported by the recent predation history of the population and previous studies in which mountain lion kills were biased towards rams. Other studies give conflicting evidence. We suggest that future studies of predation risk must take into consideration the process of prey selection by individual predators, as well as factors influencing predation vulnerability in different seasons of the year.

SEXUAL SEGREGATION IN DESERT BIGHORN SHEEP (*OVIS CANADENSIS MEXICANA*)

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Recent interest in behavioral ecology has focused on why males and females of polygynous, sexually dimorphic species form separate herds during most of the year. Bighorn sheep (*Ovis canadensis*) are polygynous ungulates that exhibit extreme sexual dimorphism and segregate into ram and ewe herds outside of the rutting season. Six major hypotheses for sexual segregation were tested in a population of desert bighorn (*O. c. mexicana*) at the Red Rock Wildlife Area, New Mexico, from 1999-2001. We collected data on the size, composition, and location of ram and ewe groups during the summer period of segregation. Activity budgets were recorded for males in ram herds and females in ewe herds, and foraging selectivity was measured for males and females in mixed groups during early rut. Habitat was evaluated by measuring forage availability, ruggedness, and visibility at sites utilized by ram and ewe groups. Ram herds utilized areas with more available forage than sites used by ewe groups, while ewe groups preferred more rugged terrain than that used by ram groups. Ram and ewe groups did not differ in time spent foraging, moving, reclining, or ruminating, nor did they differ in foraging selectivity, but rams were twice as vigilant as ewes. Ewe groups and mixed groups occurred much closer to free water sources than did ram groups. The results support the predictions of the reproductive strategy and predator vulnerability hypotheses, which propose that males seek superior forage in order to build up body condition needed to maximize mating success (even while exposing themselves to greater predation risk), while females choose rugged terrain that minimizes predation risk to themselves and their offspring (even while sacrificing forage abundance). The water requirement hypothesis was also supported, indicating that lactation-related water requirements constrain the movements of ewe groups and may contribute to patterns of sexual segregation in desert bighorn.

A FOUR-YEAR STUDY OF CAUSE-SPECIFIC MORTALITY OF DESERT BIGHORN LAMBS NEAR AN URBAN INTERFACE AND A COMMUNITY RESPONSE

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Between 1985-1997, annual recruitment of desert bighorn sheep (*Ovis canadensis*) in the northern Santa Rosa Mountains (NSRM) of California varied from 0-27 lambs/100 ewes and averaged 9 lambs/100 ewes. In the spring of 1998-2001 we radio collared 34 desert bighorn lambs in the NSRM as part of a 4-year study of cause-specific lamb mortality. Lambs were captured using a hand-held net gun fired from a helicopter and were sampled, radio collared, and released at the capture site. Body weights for the 18-70 day-old lambs ranged from 5.9 to 22.3 kg and neck girths ranged from 18.3 to 24 cm. All lambs rejoined their dams shortly after release and no capture-related mortalities occurred. Through daily monitoring we recorded a total of 14 cause-specific mortalities. Deaths were attributed to urbanization (43%), bobcat (*Lynx rufus*) predation (21%), coyote (*Canis latrans*) predation (29%), and mountain lion (*Puma concolor*) predation (7%). Thirteen mortalities occurred within 300 m of an urban interface. Respiratory disease may have predisposed some lambs to predation. Our data indicates that direct and indirect effects of urbanization (including altered habitat use) are a primary cause of chronic low recruitment in this population. In response, the City of Rancho Mirage has approved a 3.5-mile bighorn-proof fence around the urban area.

PENINSULAR BIGHORN SHEEP RECOVERY THE ROLE OF THE U. S. FISH & WILDLIFE SERVICE

PETE SORENSEN, U.S. Fish & Wildlife Service, Carlsbad Field Office, Carlsbad, CA

GUY WAGNER, U.S. Fish & Wildlife Service, Carlsbad Field Office, Carlsbad, CA

Desert bighorn sheep in the Peninsular Mountain Ranges of southern California were estimated at 1,171 individuals in 1974. Subsequent declines in the 1980's caused the Service to designate Peninsular bighorn sheep as a species potentially needing protection under the Endangered Species Act. The population declined to an estimated 276 individuals in 1996, and the species was listed as endangered in March 1998. Listing led to the formation of the Recovery Team, development of a Recovery Plan, and designation of critical habitat. Listing protects individual bighorns from harm and harassment, reduces habitat loss, and ensures federal actions do not jeopardize the continued existence and survival of the species.

PROGRESS REPORT: CEMEX DESERT BIGHORN SHEEP REESTABLISHMENT PROGRAM

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Desert bighorn sheep (*Ovis canadensis mexicana*) in Mexico were extirpated in the states of Nuevo Leon, Coahuila, and Chihuahua. In an effort to reestablish desert bighorn in northeastern Mexico, thirty-three desert bighorn sheep (*O. c. mexicana*) were transplanted from Sonora, Mexico to the Sierra Pilares breeding enclosure in Coahuila, northeastern Mexico. A 6,000-ha, game-proof fence enclosure, which encompasses the southern two-thirds of the Sierra Pilares, was constructed to provide a protected breeding site. The first transplant into the breeding enclosure in 2000 consisted of 5 sheep (3 females and 2 rams), which produced 1 lamb in 2001. A second introduction in 2001 consisted of 28 sheep (18 females, 10 males). Eleven lambs have been born in 2002. When the population increases to about 200 animals, sheep will be released in surrounding sheep habitat of the Sierra del Carmen. The ultimate aim of the project is to reestablish bighorns throughout northeastern Mexico.

HOW RELIABLE IS TOOTH CEMENTUM RING AGING FOR BIGHORN SHEEP?

JOHN D. WEHAUSEN, U.C. White Mountain Research Station

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DALE R. MCCULLOUGH, Dept. of Environmental Science, Policy, and Management, U.C. Berkeley

Accurate information on ages of bighorn sheep and other species is desirable relative to a variety of questions. Ages determined from tooth cementum annuli are often considered to be very reliable. However, cementum ages received from Matson's Lab for some desert bighorn sheep gave the first author reason to question the reliability of this method. Subsequently, that method was tested using a set of skulls of known aged females sheep from ranges in the eastern Mojave Desert of California and a set of males skulls from California for which the annual horn rings were very distinct and provided reliable ages. Three different methods of cementum aging were used on each specimen and those doing the cementum analysis either did not know they were being tested (Matson's Lab) or did not know the ages of the sheep (second and third authors). The results have confirmed that cementum aging of bighorn sheep is not as reliable as some might think.

POPULATION HISTORY OF BIGHORN SHEEP IN THE SIERRA NEVADA

JOHN D. WEHAUSEN, U.C. White Mountain Research Station

Despite a reintroduction program that re-established bighorn sheep in three areas during 1979-88, the total Sierra Nevada bighorn sheep population reached a known low point in 1995 of about 100 sheep. Most herds have grown steadily since then, resulting in about 250 total sheep in 2001 -- the same number that existed when the reintroduction program began. This talk will first trace what is known about the history of herd losses and will conclude with a review of recent conservation efforts and population dynamics during the past quarter century and potential factors involved.

A SIMULATION MODEL FOR EXPLORING DEMOGRAPHIC PROCESSES IN AN ENDANGERED POPULATION OF BIGHORN SHEEP

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We developed a demographic simulation model to explore how population vital rates, initial size, and the addition of animals influenced the viability of an endangered population of bighorn sheep (*Ovis canadensis*) consisting of 8 subpopulations. Our analyses suggested that quasi extinction risk was more sensitive to changes in adult female survival than to changes in reproduction or survival of young animals, and this pattern remained consistent for all 8 subpopulations although they had different initial sizes, survival rates, and recruitment rates. Subpopulation viability was related to the initial number of females and to adult female survival, but not reproduction. Management actions that increase adult survival may be most effective when implemented in the largest subpopulations, while actions involving the addition of animals may be most effective if implemented in subpopulations with high survival rates. Subpopulation augmentation in yearly increments was more effective at reducing quasi extinction risk than was adding the same total number of animals at the beginning of the simulation.

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DETAILED MOLECULAR GENETICS INVESTIGATIONS OF BIGHORN SHEEP IN THE OWENS VALLEY REGION

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JOHN D. WEHAUSEN, U.C. White Mountain Research Station

With the long-term loss of most bighorn sheep herds in the Sierra Nevada, the reestablishment of a few herds during 1979-88 from one herd, and the subsequent decline of all herds to a low of about 100 total sheep in 1995, the potential for significant loss of genetic variation is a concern. In 1997 we embarked on a research project to look at this question in detail using skulls, feces, and archived DNA from blood as sources of DNA. This project involves the development of multiple data sets to address different questions. These include a benchmark data set from the 1970s and 1980s for both sides of Owens Valley and detailed data for each existing herd. We are developing data on 13 micro satellite loci in addition of mitochondrial DNA sequences. These data allow us to further pursue phylogeographic questions in addition to the question of potential changes in genetic diversity. We will provide a progress report on this work.

EFFECTS OF CLIMATE CHANGE ON POPULATION PERSISTENCE OF DESERT-DWELLING MOUNTAIN SHEEP IN CALIFORNIA.

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Species inhabiting isolated desert mountains may be very sensitive to rapid global climate change. About 50 populations of desert bighorn sheep *Ovis canadensis nelsoni* remain in isolated desert mountain ranges in southern California, while at least 27 populations of desert bighorn went extinct in the twentieth century. A GIS map of extant and extinct desert bighorn populations in California was overlaid on raster-based precipitation, elevation, and geologic maps to score each population for variables describing climate, metapopulation dynamics, and other environmental factors. Logistic regression was used to assess the relationship between these variables and population extinction. Populations inhabiting lower-elevation, drier mountain ranges were more likely to go extinct. Native

and reintroduced populations were then assessed for vulnerability to climate-related extinction under current climate change models.

COACHELLA VALLEY RESIDENT SURVEY OF TRAIL USE AND ATTITUDE TOWARDS BIGHORN CONSERVATION

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WALTER BOYCE, Wildlife Health Center, School of Veterinary Medicine, University of California—Davis

JONNA A.K. MAZET, Wildlife Health Center, School of Veterinary Medicine, University of California—Davis

DAVID HIRD, Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California—Davis

Recreational use of bighorn sheep habitat may affect bighorn seasonal usage of areas necessary for lambing, rut, and accessing waterholes. An understanding of the community's attitude towards bighorn conservation and trail usage needs is essential for the development of recreational policies that balance the needs of the bighorn sheep and the community. In order to understand the issues associated with the recreational needs and attitudes of the residents of Palm Desert, California near the habitat of the endangered Peninsular Bighorn Sheep, a mail survey was conducted in August 2000. With 42% of the 700 surveyed responding, the data reflected that the majority of trail use was by hikers, mostly on weekends and in the winter and spring. Most of the trail users were on the trails less than 12 times during the past year. Of the 16 dog-walkers, over half do not use leashes to control the dogs. Though respondents were all voters in Palm Desert, 36% of them hike near other cities and they traveled an average of 22 minutes to reach the trailhead. Most of the trail users stated they would avoid trail use during voluntary closures and seek an alternative trail. Though over half of the respondents knew that the Peninsular bighorn were endangered or threatened and were at least familiar with conservation efforts to aid the sheep, a quarter did not know the sheep were endangered and were unfamiliar with conservation efforts. The overwhelming majority stated that bighorn conservation efforts would either not impact their lives or impact their lives in a positive way. These respondents supported conservation in general, hindering development, state that sheep have aesthetic values, and hope that future generations will be able to enjoy the sheep in the area. The majority stated that it is important or very important to keep bighorn sheep in the Coachella Valley Area. Most of the respondents receive information about bighorn conservation efforts from the media and chose the Living Desert Museum as the most reliable provider of information.

GENETIC CONSIDERATIONS FOR REINTRODUCING BIGHORN SHEEP TO THE SAN ANDRES MOUNTAINS, NEW MEXICO

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We examined genetic variation at 22 microsatellite loci for bighorn sheep from the Red Rock Wildlife Area, NM, and the Kofa National Wildlife Refuge, AZ, to address the following questions: What are the levels of genetic variability among bighorn sheep at Red Rock and Kofa? How do levels of heterozygosity at Red Rock and Kofa compare to other desert bighorn populations in the southwest? Is there evidence of inbreeding at Red Rock? What is an appropriate genetic management strategy for reintroducing bighorn sheep to the San Andres Mountains? We concluded that the Red Rock herd has low genetic variability relative to the Kofa and other desert bighorn sheep populations. Based on genetic considerations from this analysis, bighorn sheep from the Kofa's are preferred to Red Rock bighorn as candidates for reintroduction into the San Andres Mountains.



NOTE: THE FOLLOWING TECHNICAL REPORTS WERE PEER REVIEWED.

USE OF GPS/SATELLITE TELEMETRY SYSTEMS IN MOUNTAIN SHEEP RESEARCH

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Abstract: Researchers conducting studies of bighorn sheep often rely on aircraft equipped with very high frequency (VHF) telemetry systems to locate animals. In the 1990's, satellite telemetry with platform transmitter terminals (PTTs) and radio collars equipped with a Global Positioning System (GPS) became available. We fit three female mountain sheep (*Ovis canadensis mexicana*) on Cabeza Prieta National Wildlife Refuge, Arizona with collars containing GPS units and PTTs to test the performance of these systems on this species. Our objectives were to evaluate the performance of the GPS receivers and PTTs, and compare the cost per location of the GPS/satellite telemetry system versus VHF aerial telemetry. Collars obtained an average of 287 out of 393 possible GPS locations; 67% of these locations were transmitted through the Argos satellite system. The cost/location was lower using the GPS/satellite system versus aerial telemetry. The GPS/satellite telemetry systems result in smaller location error than those obtained by triangulation from aircraft, can collect locations 24 hours a day and during inclement weather, and have the capacity to collect more locations than commonly achieved using VHF telemetry. A potential disadvantage of GPS/satellite telemetry systems is that animal behavior, topography, and vegetation may influence location error and fix rates of GPS receivers and may interfere with PTT transmission. Field-testing these systems prior to deployment may allow researchers to account for and correct these biases. Despite potential limitations, the advantages of GPS/satellite telemetry systems are great enough to warrant assessing the feasibility of using these systems in studies of bighorn sheep.

Key words: Argos, Arizona, GPS telemetry, Global Positioning System, mountain sheep, *Ovis canadensis mexicana*, platform transmitter terminal, radio telemetry, satellite telemetry.

INTRODUCTION

Radio telemetry has become a standard tool for researchers studying ungulates and has been used in studies of many aspects of mountain sheep ecology, including mortality, recruitment, behavior, habitat use, and movement (Krausman et al. 1989, Scott et al. 1990, Wehausen 1996, Bleich et al. 1997, Etchberger and Krausman 1999). Researchers working with mountain sheep have often successfully relied on the use of aerial telemetry to obtain animal locations (Krausman et al. 1989, Wehausen 1996, Bleich et al. 1997, Etchberger and Krausman 1999). The use of radio telemetry from aircraft is not without limitations, however. Triangulation of telemetry signals from aircraft can result in a significant location error that may range ≥ 4 ha (Krausman et al. 1984, White and Garrott 1990). Telemetry flights are often restricted by aircraft availability, light and weather conditions, and airspace restrictions (e.g. military range) (Rodgers et al. 1996). The amount of data tends to be limited when using aerial telemetry to obtain animal locations and many studies using these systems obtain only one to two locations/animal each week (Krausman et al. 1989, Bleich et al. 1997). Furthermore, the use of aircraft for wildlife research poses additional safety risks to the researchers involved.

A recent tool for studying mountain sheep is satellite telemetry. With satellite telemetry, animals are fitted with a radio collar equipped with a platform transmitter terminal (PTT) (Kenward 2001, Rodgers 2001) that emits an ultra high frequency signal that is received by

the Argos satellite system; the location of the animal is calculated using the Doppler shift in the signal that occurs as a satellite passes over the animal (White and Garrott 1990, Kenward 2001). At least two uplinks between the PTT and Argos satellite are required during a satellite pass to estimate the location of an animal, and four uplinks are required for the most accurate estimates (Kenward 2001, Rodgers 2001). Location data is transferred to an Argos ground station for processing where the user can retrieve it. Major benefits of using satellite telemetry to track animals are that it is possible to increase the number of locations compared to VHF aerial telemetry and locations can be obtained 24 hrs a day and during inclement weather. The major limitation of satellite telemetry is the location error, which may range from 150 to $>1,000$ m, and topography or dense vegetation may interfere with signal transmission and influence location error (Fancy et al. 1988, Keating et al. 1991, Ballard et al. 1998, Kenward 2001).

In addition to the advantages of using aerial and satellite telemetry, GPS telemetry has the added benefit of increased accuracy. Since the end of selective availability in May 2000, the GPS receivers used in wildlife research have been tested to be accurate to <40 m and have the potential for accuracy of ≤ 10 meters (Wells 1986, Lawler 2000, Hulbert and French 2001, D'Eon et al. 2002). However, GPS collars can also be influenced by topography and dense vegetation (Kenward 2001).

The major limitation in the use of GPS telemetry is data retrieval. Researchers have three options for data recovery:

store data in the collar, recover the data periodically using a direct radio link, or use PTTs to transmit the data from the GPS collars to the Argos satellite system (Rodgers et al. 1996, Schwartz and Arthur 1999). When using "store-on-board" GPS collars, researchers risk the loss of data if the collars are not retrieved. When using a direct radio link to periodically recover data, researchers must purchase an additional receiver designed for this purpose and must be within range of the collared animal at a predetermined time. The use of PTTs to transmit GPS positions may provide a more efficient and reliable method of data recovery.

When using PTTs to transmit GPS positions via the Argos satellites, the GPS receiver calculates the animal's position, location data are stored in the GPS collar until the programmed transmission time and contact with an Argos satellite is made, then data are transferred to the Argos satellite. The Argos satellite transfers data to a ground station for processing where it can be obtained by researchers.

Our objectives were to test the feasibility of using the combined GPS/satellite telemetry system in a study of mountain sheep. Specifically, we wanted to test the performance of the GPS receivers and platform transmitter terminals, and compare the relative per location cost of using the GPS/satellite telemetry system versus VHF aerial telemetry.

STUDY AREA

We conducted the study in the Growler, Sierra Pinta, and Cabeza Prieta

mountains, Cabeza Prieta National Wildlife Refuge (CPNWR) in southwestern Arizona (Figure 1). Topography of CPNWR is a series of rugged northwest-southeast trending mountain ranges surrounded by large bajadas and separated by wide alluvial valleys, elevations range from approximately 200 to 1,100 m (Simmons 1966). The CPNWR is an ideal area for the use of the GPS/satellite telemetry because the mountain sheep on the refuge inhabit very rugged and inaccessible mountain ranges. Further limiting accessibility is a wilderness designation and a lack of roads; approximately 93% of the refuge is wilderness. Also, approximately 95% of the airspace of the refuge is under the Barry M. Goldwater Air Force Range, which restricts use of aerial telemetry.

METHODS

In March 2001, we used a handheld net gun fired from a helicopter to capture one female desert bighorn sheep in each mountain range (Krausman et al. 1985). All animals were fitted with a radio collar (Model TGW-200, Telonics Inc., Mesa Arizona, USA) at the point of capture and released. Radio collars were equipped with a GPS receiver, a PTT, a VHF beacon, and a programmable collar release mechanism. The GPS receivers were programmed to collect one position every 13 hours. The PTTs were programmed to transmit the GPS positions to the Argos satellites for a period of four hours every two days. The VHF beacons were used to locate animals from the ground while in the field and programmable collar release mechanisms

were to be used in the event that we are unable to recapture the study animals.

RESULTS

The study animal in the Sierra Pinta Mountains died November 2001 and the collar retrieved. We recaptured the animal in the Cabeza Prieta Mountains in February 2002 and recovered the collar. We were unable to recapture the female in the Growler Mountains, and the collar release mechanism failed to release the collar on the scheduled release date. The following results are based on collar performance over a seven-month period from 1 April to 31 October 2001.

We should have obtained 393 GPS locations with the program of one location every 13 hrs. After retrieving the collars from the Sierra Pinta and Cabeza Prieta mountains, we found that the GPS receivers recorded an average of 287 locations ($SD = 19.8$, $n = 2$, range 273-301); the units collected 74% of the programmed locations.

We also wanted to assess the performance of the data transfer component of the system. Based on the two recovered collars, an average of 228 locations ($SD = 64.4$, $n = 2$, range 182-273) were transmitted through the Argos satellite system; 79% of the locations collected were transmitted. Based on all three collars, an average of 192 ($SD = 76.5$, $n = 3$, range 121 to 273) locations were transmitted through the Argos system, 67% of the locations collected were transmitted.

We compared the cost of using the GPS/satellite system compared to VHF

aerial telemetry. The cost/location is based on the average number of locations we obtained in the recovered collars. The collars that we used cost approximately \$4,500 each and the Argos data transfer service cost approximately \$500/year for each animal. The cost of capture is the same regardless of which telemetry system is used. To obtain 492 locations per year it costs \$10.16/location (including collar costs and satellite downloading).

The VHF collars cost approximately \$450 and flight time is \$100/hour. The price/location using aerial telemetry with VHF collars is based on a ten-minute location time. To obtain the 492 locations using aerial telemetry would cost a minimum of \$10.92/location (including collar costs and flight time). Both of these estimates for VHF locations are conservative because neither includes flight time between the study area and the airport. Depending on the distance this could significantly increase the per location cost.

DISCUSSION

Overall, the GPS/satellite telemetry system provided eight times more locations than would have been possible with weekly telemetry flights using VHF telemetry. In our study, the cost/location was slightly less for the GPS/satellite systems than for VHF aerial telemetry. However, the new models (Generation III) of these collars that are currently in production have almost twice the battery life. If we have the same GPS receiver performance with the new collars we can expect to obtain 946 GPS locations in 23

months of operation at a cost of \$5.28/location.

Approximately 74% of the programmed GPS locations were obtained and at least 67% of these locations were transmitted through the Argos satellites. However, the failure of the GPS receivers to obtain 25% of the programmed GPS positions, and the failure of the PTTs to transmit 33% of the GPS positions that were obtained may indicate that there are factors that influence the functioning of the GPS receiver and or the PTT. Animal behavior, topography, and vegetation may influence GPS positional accuracy, the probability of obtaining a GPS position, and may interfere with the transmission of signals from PTTs (Rempel et al. 1995, Rodgers et al. 1996, Moen et al. 1997, Kenward 2001, D'Eon et al. 2002). If the location of animals in areas with certain topographic or vegetation conditions are systematically not obtained, the resulting data will not be representative of the areas actually used by the animals and may influence study results. However, by field-testing these systems prior to deployment, researchers may be able to account for and correct these potential biases. The GPS/satellite telemetry systems result in smaller location error than those obtained by triangulation from aircraft. Since this study was completed, Cain and Krausman (unpubl. data) have located seven sheep mortalities, all of which were <15 m from the location transmitted through the GPS/satellite system. Potential disadvantage of the GPS/satellite telemetry system is location bias due to GPS error caused by topography or dense vegetation. Despite these potential limitations the advantages of

GPS/satellite telemetry systems warrant their use in studies of ungulates and other highly mobile species that inhabit areas that are difficult to access.

LITERATURE CITED

- Ballard, W.B., M. Edwards, S.G. Fancy, S. Roe, and P.R. Krausman. 1998. Comparison of VHF and satellite telemetry for estimating sizes of wolf territories in northwest Alaska. *Wildlife Society Bulletin* 26:823-829.
- Bleich, V.C., R.T. Bowyer, and J.D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? *Wildlife Monograph* 134:1-50.
- D'Eon, R.G., R. Serrouya, G. Smith, and C.O. Kochanny. 2002. GPS radio telemetry error and bias in mountainous terrain. *Wildlife Society Bulletin* 30:430-439.
- Etchberger, E.C. and P.R. Krausman. 1999. Frequency of birth and lambing sites of a small population of mountain sheep. *Southwestern Naturalist* 44:354-360.
- Fancy, S.G., L.F. Pank, D.C. Douglas, C.H. Curby, G.W. Garner, S.C. Amstrup, and W.L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. Resource Publication 172. 'U.S. Fish and Wildlife Service, Washington D.C., USA.
- Hulbert, I.A.R. and J. French. 2001. The

- accuracy of GPS for wildlife telemetry and habitat mapping. *Journal of Applied Ecology* 38:869-878.
- Keating, K.A., W.G. Brewster, and C.H. Key. 1991. Satellite telemetry: performance of animal-tracking systems. *Journal of Wildlife Management* 55:160-171.
- Kenward, R.E. 2001. A manual for wildlife radio tagging. Academic Press, London, UK.
- Krausman, P.R., J.J. Hervert, and L.L. Ordway. 1984. Radio tracking desert mule deer and bighorn sheep with light aircraft. Pages 115-118 in Paul R. Krausman and Norman S. Smith, editors *Deer in the Southwest: a workshop*.
- _____, _____, and _____. 1985. Capturing deer and mountain sheep with a net-gun. *Wildlife Society Bulletin* 13:71-73.
- _____, B. D. Leopold, R. F. Seegmiller, and S. G. Torres. 1989. Relationships between desert bighorn sheep and habitat in western Arizona. *Wildlife Monograph* 102:1-66.
- Lawler, A. 2000. Scientists gain access to sharper GPS signal. *Science* 288:783.
- Moen, R., J. Pastor, and Y. Cohen. 1997. Accuracy of GPS telemetry locations with differential correction. *Journal of Wildlife Management* 61:530-539.
- Rempel, R.S., A.R. Rodgers, and K.F. Abraham. 1995. Performance of a GPS animal location system under boreal forest conditions. *Journal of Wildlife Management* 59:543-551.
- Rodgers, A.R., R.S. Rempel, and K.F. Abraham. 1996. A GPS-based telemetry system. *Wildlife Society Bulletin* 24:559-566.
- _____. 2001. Recent telemetry technology. Pages 79-121 in J.J. Millspaugh and J.M. Marzluff, editors. *Radio tracking and animal populations*. Academic Press, San Diego, California, USA.
- Schwartz, C.C. and S.M. Arthur. 1999. Radio tracking large wilderness mammals: integration of GPS and ARGOS technology. *Ursus* 11:261-274.
- Scott, J.E., R.R. Rernington, and J.C. deVos Jr. 1990. Numbers, movement, and disease status of bighorn in southwestern Arizona. *Desert Bighorn Council Transactions* 34:9-13.
- Simmons, H. L. 1966. The geology of the Cabeza Prieta Game Range. *Arizona Geological Society Digest* 8:147-157.

Wehausen, J.D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. Wildlife Society Bulletin 24:471-479.

Wells, D.E. 1986. Guide to GPS positioning. Canada GPS Association, Fredericton, New Brunswick, Canada

White, G. C. and R. A. Garrott. 1990. Analysis of Wildlife Radio-tracking Data. Academic Press, San Diego, California, USA.



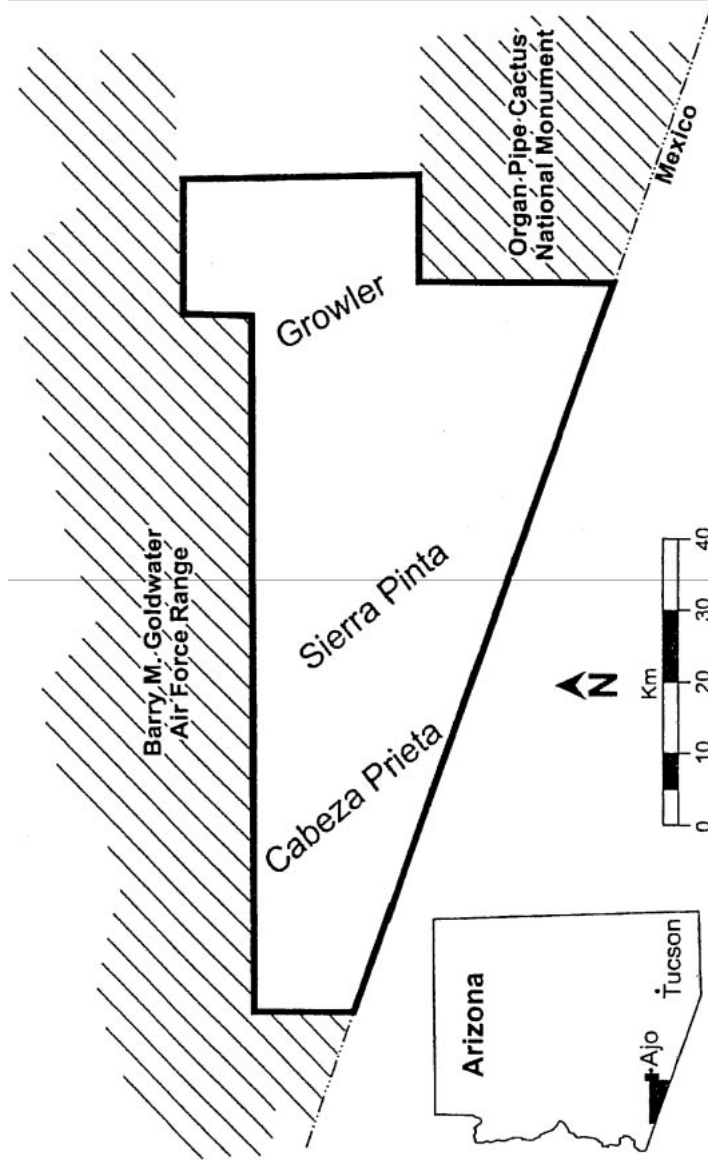


Figure 1. Location of three mountain ranges in the Cabeza Prieta National Wildlife Refuge, Arizona.

SURVIVAL RATES AND CAUSES OF MORTALITY IN A DESERT BIGHORN SHEEP POPULATION ON THE NAVAJO NATION

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Abstract: Reliable information on survival rates and causes of mortality for bighorn sheep are difficult to obtain. Survival rates and causes of mortality differ among populations, and among years, and sex and age classes of bighorn within a population. During the course of a five-year study of population dynamics of a small, indigenous desert bighorn sheep population on the Navajo Nation, we collected data on survival rates of adults and lambs and on causes of mortality. The mean annual mortality rate of rams from natural causes was over four times the mean annual mortality rate of ewes for the same five-year period. Survivorship of lambs from birth to six months of age declined with increasing population density. Causes of death for adults were variable but suggested reasons for differences in mortality rates between sexes. Causes of death were difficult to determine for lambs, however, our observations suggest that weak bonding between mothers and lambs contributed to early lamb mortality.

Key Words: Survival, Mortality, desert bighorn sheep, *Ovis canadensis nelsoni*, Navajo Nation

INTRODUCTION

Marked animals, intensive monitoring and long-term studies are needed to produce reliable data on survival rates of adult bighorn sheep and lambs. Data on survival rates of desert bighorn sheep are particularly rare. A recent review of population dynamics of bighorn sheep cited seven studies of yearly survival of adults and seven studies of survival rates of lambs; all studies were of Rocky Mountain or thin horn sheep (McCarty and Miller 1998). Since 1995,

several studies have yielded quantitative data on survival rates of desert bighorn (Creeden and Graham 1997, Bristow and Olding 1998, Hayes et al. 2000, Kamler et al. 2002) however; these studies focused on herds with alarming mortality rates due largely to lion predation.

In the course of a broad study of a native desert bighorn sheep population (*Ovis canadensis nelsoni*) we recorded information on mortality of rams, ewes and lambs. The Navajo Nation Department of Fish and

Wildlife initiated the study to discover information necessary to conserve and enhance a native desert bighorn sheep population inhabiting the San Juan River Canyon on the Navajo Nation in southeastern Utah. In addition to population dynamics, we are collecting data on distribution, habitat utilization, range productivity, diet selection, and nutrition of the bighorn. We are also investigating impacts of river recreation, and livestock grazing on the bighorn sheep population (Goodson et al. 1999).

We compared survival rates of rams and ewes for the first five years of the study and compared survival of lambs from birth to six months of age from the first two years and last two years of the study. We found higher mortality rates for rams than ewes and evidence of density dependent survivorship for lambs. The Navajo Nation funded the study. The Arizona Desert Bighorn Sheep Society and the Foundation for North American Wild Sheep aided the study by auctioning hunting permits for trophy elk, deer and bighorn sheep.

STUDY AREA

Our study area is located on the San Juan River in southeastern Utah. Bighorn sheep are native to the San Juan River Canyon. The herd we are studying inhabits the upper canyon, and is isolated from other bighorn sheep populations. The study area includes 12.5 km of the river canyon and a valley that extends about three km south from the river. The total study area is approximately 35 km².

Topography is rugged and dominated by horizontal rock formations that form rim cliffs and walls that break down into talus, rock fields, and alluvial fans. Above the canyon rim is an extensive mesa.

The area is a cold desert and summers are hot. From late spring through summer, maximum daily temperatures range from 90 to 110 degrees F. During winter, conditions are often mild, but temperatures can drop below 0 F. and snow cover can persist for weeks. Average annual precipitation is 18 cm (7 in). Precipitation varies from month to month and from year to year. Late spring and early summer are typically very dry.

METHODS

Eleven of fifteen ewes and seven of eight rams age two or older were radio-collared during the fall-winter of 1996-1997. Four additional ewes and one ram were radio-collared in December 1997 prior to the second year of the study. Ages of radio-collared bighorn were estimated from counts of horn annuli and tooth wear at the time of capture.

Radio-collared bighorn were visually located approximately once per week year-round during 1997 and 1998. During 1999, 2000 and 2001, intensive fieldwork was conducted during spring (mid or late March through the end of June) and for six weeks to three months during fall (September through mid-December). During other periods, radio-collars were monitored for mortality signals at least once per month.

For each visual observation we recorded location, group size and sex-age composition, marked bighorn present, and maternal behavior of marked and unmarked individuals. Lactation status was recorded for marked and unmarked ewes. Ages of lambs of unmarked ewes were estimated based on size, coordination, behavior, and comparison with known-aged lambs of marked ewes. Radio-collars were equipped with mortality sensors with a four-hour time delay. When

we received a mortality signal we attempted to locate the carcass and determine the cause of death as quickly as possible. Causes of death were assigned based on observations of marked bighorn prior to death and by ~~examination of the carcass and mortality site.~~

When carcasses were found in good condition, the head and portions of the lungs and liver were submitted for examination to Scott Bender DVM, Navajo Nation Veterinary Program. We found bones or complete carcasses of several unmarked bighorn that provided additional information on causes of mortality.

Because lambs did not necessarily stay with their mothers through October, the lamb survival rate from birth through October was determined from the estimated number of lambs born and the maximum unduplicated count of lambs in late October. The number of lambs born was known for marked ewes. The number of lambs produced by unmarked ewes was the higher of either the maximum unduplicated count of lactating unmarked ewes, or the maximum unduplicated count of unmarked ewes with lambs less than one week of age. Causes of death for lambs were inferred based on observations of lambs and their mothers prior to the lamb's death. No remains of dead lambs were found.

RESULTS

Survival of Adults

During the five years of the study, 13 bighorn ewes (aged two years-old or older) were radio-collared and monitored. Two ewes died of natural causes, resulting in a mean annual survival rate of 0.97 (90% CI 0.93,1.01). During the same period, eight rams (aged two years-old or older) were radio-collared and tracked for a total of 28 ram-years. Four rams died of natural causes

resulting in a mean annual survival rate of 0.86 (90% CI 0.75,0.97) for the five-year period. Thus, mean annual mortality rate, excluding human-induced mortalities, was 0.03 for ewes and 0.14 for rams

Poachers unlawfully killed one radio-collared ram and one radio-collared ewe. This additional human-caused mortality reduced mean annual survival rates to ~~0.95~~(CI 0.90,1.00) for ewes and 0.82 (CI 0.68, 0.96) for rams during the five-year period. Mean annual mortality rate including human-induced mortality was 0.05 for ewes and 0.18 for rams.

Natural causes of mortality for radio-collared ewes were due to lamb birth in one ewe estimated to be five years old, and age-related for an ewe estimated to be over ten years old. The latter ewe was in poor condition for over a year prior to her death.

Natural causes of mortality for radio-collared rams were: an infection possibly related to injury in a two-year-old ram, a fall off a cliff by a nine year-old ram, lion predation for a six year-old ram, and probable lion predation for a ten year-old ram. The two-year-old ram died after an injury and/or infection destroyed his testicles. Two dominant rams of the same age were observed kicking him in the testicles shortly before he withdrew from other sheep. The nine-year-old ram died from a fall in early February after a successful, but energy-consuming, rut. The carcass of the six-year-old ram that was killed by a lion was found close to the top rim of the canyon, and tracks at the scene indicated that the lion had come over the top of the canyon rim from the mesa top and leaped down onto the ram

The gut pile of the ram that was poached was discovered on top of its radio collar within two days of the ram's death. We assumed the

ewe was poached when only the radio collar, one leg bone, and a small piece of hide were found after receiving a mortality signal.

We obtained data on causes of mortality for two unmarked adult ewes that died during the study period. One of these ewes had an infected horn core when she was captured in February of 1997. She lost her right horn, including the core, and gradually became thinner and weaker over the next eighteen months. Her skeleton was near the location where she was last seen alive. We discovered the skull and partial skeleton of another adult ewe. The orbits around the eyes and bases of the horn cores were eroded. We concluded that both these ewes died from sinusitis (Bunch et al. 1978).

A boating guide from Wild Rivers Expeditions in Bluff reported the carcass of a 4-year-old ram near the head of the San Juan River Canyon during summer 2001. The ram had a lump between his horns where an infection had occurred subsequent to a skull injury that was likely a result of fighting. It did not, however, cause his death. A second infection resulted in a swelling that blocked his throat and caused death. Based on examination of the head by Scott Bender, DVM, Navajo Veterinary Program, the fatal infection was likely precipitated by a grass awn penetrating the ram's throat, followed by invasion of *Actinomyces pyogenes*, a common environmental bacteria.

Survival of Lambs

Lamb survival declined during the five years of the study as the population more than doubled in size (Goodson and Stevens unpublished data). Lamb survival estimates for the entire herd from birth to six months of age declined from ~~0.80, 90%~~ CI 0.67, 0.93 (1997, 1998) to 52% 90% CI 0.40,

0.64(2000,2001).

In six (12%) of 49 births by radio-marked bighorn ewes, lambs died before reaching one week of age. In half of those cases (6%), poor mothering was observed. In one case the ewe abandoned her lamb. In the other two cases, the ewes did not attend to their lamb's needs and left them for extended periods or ignored their need for shade. Each of these ewes was observed without a lamb within a week, indicating that the lamb died. In one case, good mothering was observed. In two cases, ewes were observed without a lamb within a few days of the onset of lactation, and no observations of ewe-lamb behavior were obtained.

We suspect that some lambs died due to separation from their mothers. In June 2001, we watched a group of 17 bighorn, including nine ewes and seven lambs, split into two groups, one of which left the area. The remaining group included only marked ewes, their known-age lambs, and an extra lamb less than one week old that may have been separated from its mother. The same group was observed two days later in the same area with one less young lamb indicating that this lamb died. The lamb that was separated from its mother appeared to be weak. Its ears were droopy, and it avoided the sun by remaining in the shade while the other lambs moved out to forage with the ewes.

DISCUSSION

Survival of Adult Rams and Ewes

McCarty and Miller (1998, Table 2) reviewed data from seven studies of adult survival in rocky mountain bighorn sheep and thin horn sheep. Ewe survival rates were consistently higher than ram survival rates comparing within and between different studies. Pooling

data from all studies resulted in annual survival rates of 0.87 (95% CI 0.83,0.90) for adult rams and 0.94 (95% CI 0.92,0.95) for ewes. Results for prime-aged rams and ewes from a long-term (1971-1996) study at Ram Mountain Alberta were very like our results: mean annual survival rates of rams and ewes were 0.84 (95% CI 0.79, 0.89), and 0.94 (95% CI 0.92, 0.96), respectively (Jorgenson et al. 1997). Ram Mountain rocky mountain bighorn were free of disease epizootics and experienced relatively low predation losses. As in our study, Jorgenson et al. (1997) excluded hunting mortality.

There are biological reasons to expect higher mortality in adult rams. Rams are active during the rut and lose condition, entering the winter with depleted energy reserves. One of our mortalities was a dominant ram that died from a fall in early February following the rut. Rams may also be injured in dominance fights. We found the carcass of an unmarked ram that had an infection resulting from a skull injury likely received in a fight. We agree with Jorgenson et al. (1997) that injuries from dominance fights and exhaustion following the rut are probable causes for higher mortality rates in adult rams compared with ewes.

Differences in habitat use between ewes and rams may also contribute to higher mortality rates in rams. We observed that adult rams are solitary more often than adult ewes, and that rams use less secure terrain (e.g. the mesa top adjacent to the canyon) more often than ewe-juvenile groups (Goodson and Stevens, unpublished data). These differences in behavior may cause rams to be more vulnerable to predation. Two of our adult ram mortalities were likely due to lion predation. One carcass was found close to the canyon rim.

Known losses to poaching are the same for rams and ewes (one each). It is likely, however, that poachers take more rams than ewes over an extended period of time. Both Navajos and non-Navajos value the horns of rams more than those of ewes. Non-Navajos value horns as trophies, and Navajos consider them to be powerful symbols that are used in religious ceremonies.

High annual survival rates of adult ewes, similar to rates observed in this study, are characteristic of stable and expanding bighorn herds (0.92, Jorgenson and Wishart 1986, 0.94, 0.95, Stevens and Goodson 1988, 0.94, Cook et al. 1990). Lower survival rates among adult ewes were found in herds where disease (0.76, during pneumonia epizootic, Jorgenson et al. 1997) or predation (0.625, Wehausen 1996; 0.875, Creeden and Graham 1997; 0.40-0.44, Kamler et al. 2002) was causing population declines.

Lamb Survival

Lamb survival varies widely within and among bighorn sheep populations (Geist 1971, McCarty and Miller 1998). Geist (1971) expected desert bighorn to have consistently high lamb production (>50%) because little neonatal mortality would occur in warm climates. Thus recruitment and trend in desert bighorn should be strongly related to lamb survival. Geist (1971) associated lamb survival greater than 50% with expanding herds. Based on Geist's (1971) analysis, we expect stabilization of our increasing population if lamb survival remains near 50%.

Lamb survival was density-related in a population that increased rapidly after introduction to vacant habitat (Woodgerd 1964). Lamb survival also declined (from 0.72 to 0.29) in a transplant herd that increased from about 40 to 70 animals;

however, an increase in lion predation was the likely cause (Creeden and Graham 1997). Lamb survival was strongly correlated to precipitation variables and disease than to density during a long-term study of bighorn sheep in southern California (Wehausen et al. 1987). Lamb survival was unrelated to density in a Rocky Mountain bighorn herd in Alberta that increased 31% during a long-term study (Jorgenson and Wishart 1986). There was no evidence that reduction of density in a high elevation Rocky Mountain herd was compensated by increases in lamb survival (Stevens and Goodson 1993).

Wehausen et al. (1987), Stevens and Goodson (1993), and Creeden and Graham (1997) concluded that density-independent factors were important influences on lamb survival. Density-independent limiting factors such as harsh winters for northern sheep, drought for desert bighorn, and disease may obscure or mask a relationship between density and lamb survival. On our study area, it is likely that the number of lambs surviving through the hot, dry summer is dependent on milk production by their mothers. Milk production is a function of forage quality and availability per ewe, which are in turn influenced by precipitation, bighorn density, and livestock competition.

LITERATURE CITED

Bristow, K. D. and R. J. Olding. 1998. Status and future of a native desert bighorn sheep population in southeastern Arizona. *Desert Bighorn Council Transactions* 42: 27-42.

Bunch, T.D., S. R. Paul, and H. McCutchen. 1978. Chronic sinusitis in the desert bighorn

(*Ovis canadensis nelsoni*). *Desert Bighorn Council Transactions* 22:16-20.

Creeden, P. J. and V. K. Graham. 1997. Reproduction, survival, and lion predation in the Black Ridge/Colorado National Monument desert bighorn sheep herd. *Desert Bighorn Council Transactions* 41:37-50.

DeForge, J. R., S. D. Ostermann, C. W. Willmott, K. B. Brennan, and S. G. Torres. 1995. Population dynamics of peninsular bighorn sheep in the Santa Rosa Mountains, California 1983-1994. *Desert Bighorn Council Transactions* 39:50-67.

Geist, V. 1971. *Mountain sheep: a study in behavior and evolution*. U. Chicago Press, Chicago, Ill. 383 pp.

Goodson, N. J., D. R. Stevens, 1999. Effects of river-based recreation and livestock grazing on desert bighorn sheep on the Navajo Nation. *North American Wild Sheep Conference Transactions* 2: 123-132.

Hayes, C. L., E.S. Rubin, M. C. Jorgensen, R. A. Botta, and W. M. Boyce. 2000. Mountain lion predation of bighorn sheep in the Peninsula Ranges, California. *Journal of Wildlife Management* 64:954-959.

Jorgenson, J. T and W. D. Wishart. 1986. Preliminary observations on population responses to an expanding bighorn sheep herd in Alberta. *Proceedings Northern*

Wild Sheep and Goat Council 5:
348-365.

Jorgenson, J. T., M. Festa-Bianchet, J.
Gaillard and W. D. Wishart. 1997.
Effects of age, sex, disease, and
density on survival of bighorn
sheep. *Ecology* 78: 1019-1032

Kamler, J. F., R. M. Lee, J. C. deVos. Jr.,
W. B. Ballard, H. A. Whitlaw.
2002. Survival and cougar
predation of translocated bighorn
sheep in Arizona. *Journal of
Wildlife Management* 66(4): 1267-
1272.

McCarty, C. W. and M. W. Miller. 1998.
Modeling the population dynamics
of bighorn sheep. Colorado
Division of Wildlife Special Report
No.73.

Stevens, D. R. and N. J. Goodson. 1993.
Assessing effects of removals for
transplanting on a high-elevation
bighorn sheep population.
Conservation Biology 7(4): 908-
915

Wehausen, J. D., V.C. Bleich, B. Blong,
and T. L. Russi. 1987.
Recruitment dynamics in a southern
California mountain sheep
population. *Journal of Wildlife
Management* 51:86-98.

Wehausen, J. D. 1996. Effects of mountain
lion predation on bighorn sheep in
the Sierra Nevada and Granite
Mountains of California. *Wildlife
Society Bulletin* 24(3): 471-479.

Woodgerd, W. 1964. Population dynamics
of bighorn sheep on Wildhorse
Island. *Journal of Wildlife
Management*. 28:381-391.



MINERAL CONCENTRATIONS OF DESERT BIGHORN SHEEP FORAGES IN THE MAZATZAL MOUNTAINS, ARIZONA

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Abstract: Knowledge of mineral content of forages and environmental variables affecting concentrations is useful to resource managers for evaluating ruminant nutritional status and habitat quality. We measured mineral concentrations in desert bighorn sheep forages collected from July 1999 to June 2000 during drought in the Sonoran Desert of central Arizona. Research is needed to determine mineral requirements of desert bighorn sheep and evaluate environmental variables that may influence forage mineral availability and nutritional status of the ungulate. Knowledge of mineral composition of forages may enhance desert bighorn sheep habitat evaluations and management programs such as reintroductions and supplemental transplants.

Key words: Arizona, desert bighorn sheep, forage minerals, Mazatzal Mountains

Diets of desert bighorn sheep (*Ovis canadensis*) have been widely studied, and browse generally dominates diets of this ungulate in the southwest, followed by forbs, then grass (Seegmiller and Ohmart 1982, Dodd 1989, Krausman et al. 1989, Miller and Gaud 1989). Forage quality has been suggested as a key factor influencing dietary intake and selection by desert bighorn sheep and other free-ranging ungulates (Dodd 1989, Hanley 1997). Protein and energy generally are considered major limiting nutrients for ruminants, but mineral content of forages also is important when considering nutritional status (Robbins 1993, Van Soest 1994).

Among domestic ungulates, simple deficiencies or interactions among minerals may affect animal health and production (Sprinkle et al. 2000, Mayland and Shewmaker 2001). Numerous studies of free-ranging and

captive wild ungulates have addressed questions of mineral deficiencies and requirements, particularly relating to calcium, copper, phosphorus, and selenium (Umess et al. 1971, Ullrey et al. 1975, Weeks and Kirkpatrick 1976, Brady et al. 1978, Scrivner et al. 1988, Flueck 1994, O'Hara et al. 2001, Alldredge et al. 2002). However, clear linkages between mineral deficiencies and population productivity of wild ungulates have not been documented.

Irvine (1969) postulated that selected browse plants on desert bighorn sheep range in southeastern Utah might be deficient in phosphorus, but we are unaware of other studies addressing mineral content of desert bighorn sheep forages. Seegmiller et al. (1990) provided reference data for composition of other nutrients in desert bighorn sheep forages in southern Arizona. However, little is known regarding spatial and

temporal differences of habitats and effects of rainfall on mineral concentrations in vegetation of Southwest deserts (Urness et al. 1971, Umess 1973, Umess and McCulloch 1973, Fox et al. 2000, Sprinkle et al. 2000).

Along with assessment of other nutritional parameters (Seegmiller et al. 1990), data for mineral content of forages are useful to resource managers in evaluating habitat quality. Our objectives were to determine mineral concentrations of desert bighorn forages during drought (McKinney et al. 2001) in the Mazatzal Mountains, Arizona, and to provide baseline data for evaluating habitat quality and nutritional status of desert bighorn.

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STUDY AREA

We conducted the study in the Mazatzal Mountains 65-km northeast of Phoenix, where desert bighorn sheep range within an 87-km² area of Sonoran Desert scrub vegetation adjacent to the Salt River chain of reservoirs (McKinney et al. 2001), between elevations of ca. 457 m to 1,067 m. Average temperatures are about 10° C in winter and 30° C in summer. Drought conditions prevailed between 1994 and 1999, when average annual rainfall was 25 cm, compared to long-term (1975-1993) average of 41 cm (Salt River Project, unpublished data).

Mule and white-tailed deer (*Odocoileus* spp.), javelina (*Pecan' tajacu*), and domestic livestock occurred within the study area.

METHODS

We hand-clipped samples between July 1999 to June 2000 from 18 forage species used by desert bighorn sheep, based on literature review. We collected at least 100 g fresh weight of plants around mid-month from each species and at least 10 individual plants, and composited samples for analyses by quarterly periods (July-September, October-December, January-March, April-June). We collected leaves, stems, flowers, and new growth within 1.5 m of the ground, stored samples in paper bags, and allowed them to air dry at ambient temperatures. We collected only leaves of ocotillo (*Fouquieria splendens*), and only samples from internal portions of barrel cactus (*Ferrocactus* spp.) that bighorn recently had fed on.

Forage samples were analyzed for mineral concentrations (calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, sulfur, zinc) by the Michigan State University Animal Health and Diagnostic Laboratory using inductively coupled plasma emission spectroscopy (ICP-AES). Selenium analyses were performed by the University of Arizona Veterinary Diagnostic Laboratory following Fox et al. (2000). Rainfall data were recorded at Monnon Flat and Horse Mesa dams (Salt River Project, unpublished data), located at the study area's southern boundary.

RESULTS AND DISCUSSION

Forages analyzed for mineral content during our study have been identified in diet of desert bighorn sheep in the Arizona Sonoran Desert (Seegmiller and Ohmart 1982, Dodd and Brady 1988, Dodd 1989, Krausman et al. 1989). Desert bighorn are recognized as opportunistic feeders, and diet selection may not be related to some nutritional indices of forages (Krausman et al. 1989).

Among forage classes annually in our study, browse had higher concentrations of Mg and lower concentrations of Na, compared to forbs, and more Ca, Cu, K, Mg, P, and Zn than grasses. Grasses had higher concentrations of Fe than either browse or forbs, but generally had lower concentrations of most minerals than these categories (Table 1). Barrel cactus had higher concentrations of several minerals, particularly Na, and high availability of this mineral might explain, at least partly, consumption of barrel cactus by desert bighorn (Warrick and Krausman 1989). Ocotillo also contained more K, P, and Se than browse, forbs, and grasses (Tables 1, 2).

Drought and winter rainfall may affect dynamics of desert bighorn sheep and other ungulate populations in desert systems (Smith and LeCount 1979, McKinney et al. 2001), but possible mineral-related mechanisms are poorly understood. Total rainfall during the study was 24.5 cm, and monthly rainfall varied from 0 to ca. 9 cm (Figure 1), but monthly precipitation had no clear correspondence with patterns of forage mineral concentrations among forage categories, although seasonal differences were apparent for forage groups and

species (Tables 1, 2). In general, mineral concentrations particularly of forbs tended to be higher during the spring-summer growing season. However, dead and live plant tissues may differ in mineral content, and several authors reported seasonal differences in mineral concentrations in vegetation (Reynolds 1967, Umess 1973, Urness and McCulloch 1973, Greene et al. 1987, Grings et al. 1996, Sprinkle et al. 2000), suggesting linkages between precipitation levels, seasonal vegetative growth and senescence, and mineral content.'

Hand-collection is widely utilized to determine mineral content of ungulate forages (Greene et al. 1987, Fox et al. 2000, Sprinkle et al. 2000) but may provide conservative results for determining quality of mineral nutrition available to or eaten by desert bighorn sheep. Desert bighorn sheep may select for more nutritious plant components (Provenza 1995, Hanley 1997) than those selected by hand. Efficiency of metabolism also may increase at lower dietary mineral intakes, offsetting apparent deficiencies in forages (Grasman and Hellgren 1993, Robbins 1993). For example, serum P levels in free-ranging desert bighorn sheep generally indicate adequate nutritional levels of the mineral (Bunch et al. 1980, McDonald et al. 1981, Borjesson et al. 2000), even though phosphorus, as well as Cu and Se, is often in short supply in forages on western ranges (Dietz and Nagy 1976, Sprinkle et al. 2000). Weeks and Kirkpatrick (1976) also concluded that behavioral and physiological mechanisms in white-tailed deer generally provided positive sodium balance.

In general, linkages between apparent mineral deficiencies and productivity of wild ungulate populations remain uncertain. Selenium supplementation may increase pre-weaning fawn survival in deer (Flueck 1994), but Brady et al. (1978) suggested that Se requirement of white-tailed deer is low. Trace mineral supplementation to cattle deficient in Se may improve reproductive performance (Sprinkle et al. 2000), but high lamb production persisted in a population of Rocky Mountain bighorn sheep despite apparent Se deficiencies, and research suggests that dietary mineral needs differ between wild and domestic animals (Robbins et al. 1985, Samson et al. 1989). Geophagy and use of mineral licks by wildlife also may offset possible mineral deficiencies in forages (Weeks and Kirkpatrick 1976, Jones and Weeks 1985, Arthur and Gates 1988).

Recent studies indicate that mineral nutrition may influence spatial distribution and carrying capacity of large herbivores in some areas of the world (Grasman and Hellgren 1993). We suggest that research is needed to determine mineral requirements of desert bighorn sheep and evaluate environmental variables that may influence forage mineral availability and nutritional status of the ungulate. Knowledge of minerals in forage may enhance habitat evaluations and programs such as translocation of desert bighorn sheep to supplement existing populations or into vacant areas that were occupied historically (Cunningham et al. 1989).

LITERATURE CITED

Allredge, M. W., J. M. Peek, and W. A. Wall. 2002. Nutritional quality

of forages used by elk in northern Idaho. *Journal of Range Management* 55:253-259.

- Arthur, W. J., and R. J. Gates. 1988. Trace element intake via soil ingestion in pronghorns and in black-tailed jackrabbits. *Journal of Range Management* 41:162-166.
- Borjesson, D. I., M. M. Christopher, and W. M. Boyce. 2000. Biochemical and hematologic reference intervals for free-ranging desert bighorn sheep. *Journal of Wildlife Diseases* 36:294-300.
- Brady, P. S., L. J. Brady, P. A. Whetter, D. E. Ullrey, and L. D. Fay. 1978. The effect of dietary selenium and vitamin E on biochemical parameters and survival of young among white-tailed deer (*Odocoileus virginianus*). *Journal of Nutrition* 108:1439-1448.
- Bunch, T. D., J. W. Bates, P. M. Webb, and E. L. Smith. 1980. Baseline physiologic values in the desert bighorn (*Ovis canadensis mexicana* and *O. c. nelsoni*). *Desert Bighorn Council Transactions* 24:46-49.
- Cunningham, S., N. Dodd, and R. Olding. 1989. Arizona's bighorn sheep reintroduction program. Pages 203-239 *In*: R. M. Lee, editor. *The desert bighorn sheep in Arizona*. Arizona Game and Fish Department, Phoenix, Arizona.

- Dietz, D. R., and J. G. Nagy. 1976. Mule deer nutrition and plant utilization. Pp. 71-78 *In*: G. W. Workman, and J. B. Low, editors. Mule deer decline in the West: a symposium. Utah State University, Logan, Utah.
- Dodd, N. L., and W. W. Brady. 1988. Dietary relationships of sympatric desert bighorn sheep and cattle. *Desert Bighorn Council Transactions* 32:1-6.
- Dodd, N. 1989. Dietary considerations. Pp. 109-134 *In*: R. M. Lee, editor. The desert bighorn sheep in Arizona. Arizona Game and Fish Department, Phoenix, Arizona.
- Flueck, W. T. 1994. Effect of trace elements on population dynamics: selenium deficiency in free-ranging black-tailed deer. *Ecology* 75:807-812.
- Fox, L. M., P. R. Krausman, M. L. Morrison, and T. H. Noon. 2000. Mineral content of Sonoran pronghorn forage. *California Fish and Game* 86:159-174.
- Grasman, B. T., and E. C. Hellgren. 1993. Phosphorous nutrition in white-tailed deer: nutrient balance, physiological responses, and antler growth. *Ecology* 74:2279-2296.
- Greene, L. W., W. E. Pinchak, and R. K. Heitschmidt. 1987. Seasonal dynamics of minerals in forages at the Texas experimental ranch. *Journal of Range Management* 40:502-506.
- Grings, E. E., M. R. Haferkamp, R. K. Heitschmidt, and M. G. Karl. 1996. Mineral dynamics in forages of the northern Great Plains. *Journal of Range Management* 49:234-240.
- Hanley, T. A. 1997. A nutritional view of understanding and complexity in the problem of diet selection by deer (Cervidae). *Oikos* 79:209-218.
- Irvine, C. A. 1969. Factors affecting the desert bighorn sheep in southeastern Utah. *Desert Bighorn Council Transactions* 13:6-13.
- Jones, R. L., and H. P. Weeks. 1985. Ca, Mg, and P in the annual diet of deer in south-central Indiana. *Journal of Wildlife Management* 49:129-133.
- Krausman, P. R., B. D. Leopold, R. F. Seegmiller, and S. G. Torres. 1989. Relationships between desert bighorn sheep and habitat in western Arizona. *Wildlife Monographs* 102:1-66.
- Mayland, H. F., and G. E. Shewmaker. 2001. Animal health problems caused by silicon and other mineral imbalances. *Journal of Range Management* 54:441-446.
- McDonald, S. E., S. R. Paul, and T. D. Bunch. 1981. Physiologic and hematologic values in Nelson desert bighorn sheep. *Journal of Wildlife Diseases* 17:131-134.

- McKinney, T., T. W. Smith, and J. D. Hanna. 2001. Precipitation and desert bighorn sheep in the Mazatzal Mountains, Arizona. *Southwestern Naturalist* 46:345-353.
- Miller, G. D., and W. S. Gaud. 1989. Composition and variability of desert bighorn sheep diets. *Journal of Wildlife Management* 53:597-606.
- O'Hara, T. M., G. Carroll, P. Barboza, K. Mueller, J. Blake, V. Woshner, and C. Willetto. 2001. Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. *Journal of Wildlife Diseases* 37:509-522.
- Provenza, F. D. 1995. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management* 48:2-17.
- Reynolds, H. G. 1967. Chemical constituents and deer use of some crown sprouts in Arizona chaparral. *Journal of Forestry* 65:905-908.
- Robbins, C. T., S. M. Parish, and B. L. Robbins. 1985. Selenium and glutathione peroxidase activity in mountain goats. *Canadian Journal of Zoology* 63:1544-1547.
- Robbins, C. T. 1993. *Wildlife feeding and nutrition*. Second edition. Academic Press, New York.
- Samson, J., J. T. Jorgenson, and W. D. Wishart. 1989. Glutathione peroxidase activity and selenium levels in Rocky Mountain bighorn sheep and mountain goats. *Canadian Journal of Zoology* 67:2493-2496.
- Scrivner, J. H., C. E. Vaughn, and M. B. Jones. 1988. Mineral concentrations of black-tailed deer diets in California chaparral. *Journal of Wildlife Management* 52:37-41.
- Seegmiller, R. F., and R. D. Ohmart. 1982. Desert bighorn lamb and adult-yearling diets from western Arizona. *Desert Bighorn Council Transactions* 26:34-38.
- Seegmiller, R. F., P. R. Krausman, W. H. Brown, and F. M. Whiting. 1990. Nutritional composition of desert bighorn sheep forage in the Harquahala Mountains, Arizona. *Desert Plants* 10:87-90.
- Smith, R. H., and A. LeCount. 1979. Some factors affecting survival of desert mule deer fawns. *Journal of Wildlife Management* 43:657-665.
- Sprinkle, J. E., E. J. Bicknell, T. H. Noon, C. Reggiardo, D. F. Perry, and H. M. Frederick. 2000. Variation of trace minerals in forage by season and species and the effects of mineral supplementation upon beef cattle production. *Proceedings of the Western Section of the American Society of Animal Science* 51:276-280.

Ullrey, D. E., W. G. Youatt, H. E. Johnson, A. B. Cowan, L. D. Fay, R. L. Covert, W. T. Magee, and K. K. Keahey. 1975. Phosphorous requirements of weaned white-tailed deer fawns. *Journal of Wildlife Management* 39:590-595.

Urness, P. J., W. Green, and R. K. Watkins. 1971. Nutrient intake of deer in Arizona chaparral and desert habitats. *Journal of Wildlife Management* 35:469-475.

Urness, P. J. 1973. Chemical analyses and *in vitro* digestibility of seasonal deer forages. Pp. 39-51 *In: Deer nutrition in Arizona chaparral and desert habitats.* Arizona Game and Fish Department, and United States Forest Service, Rocky Mountain Range and Experimental Station Special Report 3., Phoenix and Tempe, Arizona.

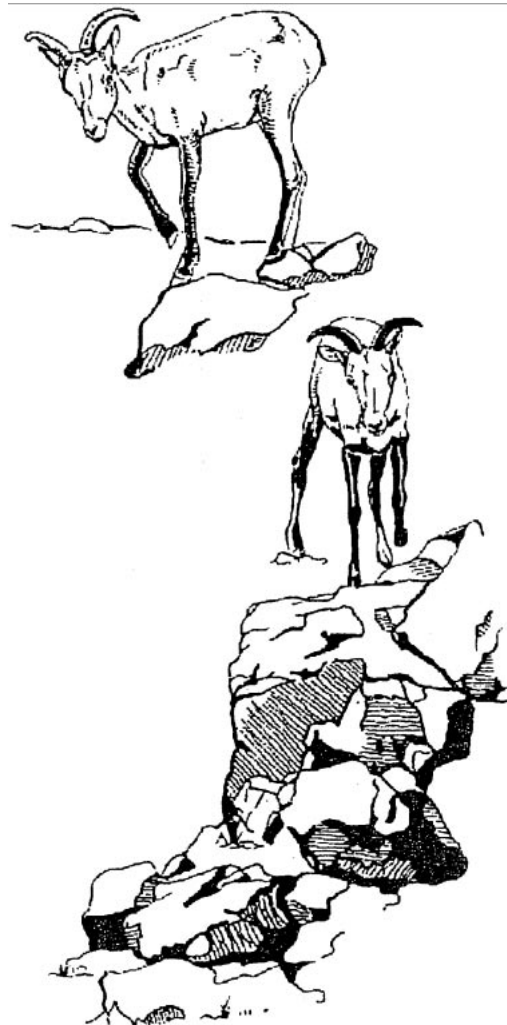
Urness, P. J., and C. Y. McCulloch. 1973. Nutritional value of seasonal deer diets. Pp.53-68 *In: Deer nutrition in Arizona chaparral and desert habitats.* Arizona Game and Fish Department, and United States Forest Service, Rocky Mountain Range and Experimental Station Special Report 3. Phoenix and Tempe, Arizona.

Van Soest, P. J. 1994. Nutritional ecology of the ruminant. Second edition. Comstock Publishing Associates, London, England.

Warrick, G. D., and P. R. Krausman.

1989. Barrel cacti consumption by desert bighorn sheep. *Southwestern Naturalist* 34:483-486.

Weeks, H. P., and C. M. Kirkpatrick. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. *Journal of Wildlife Management* 40:610-625.



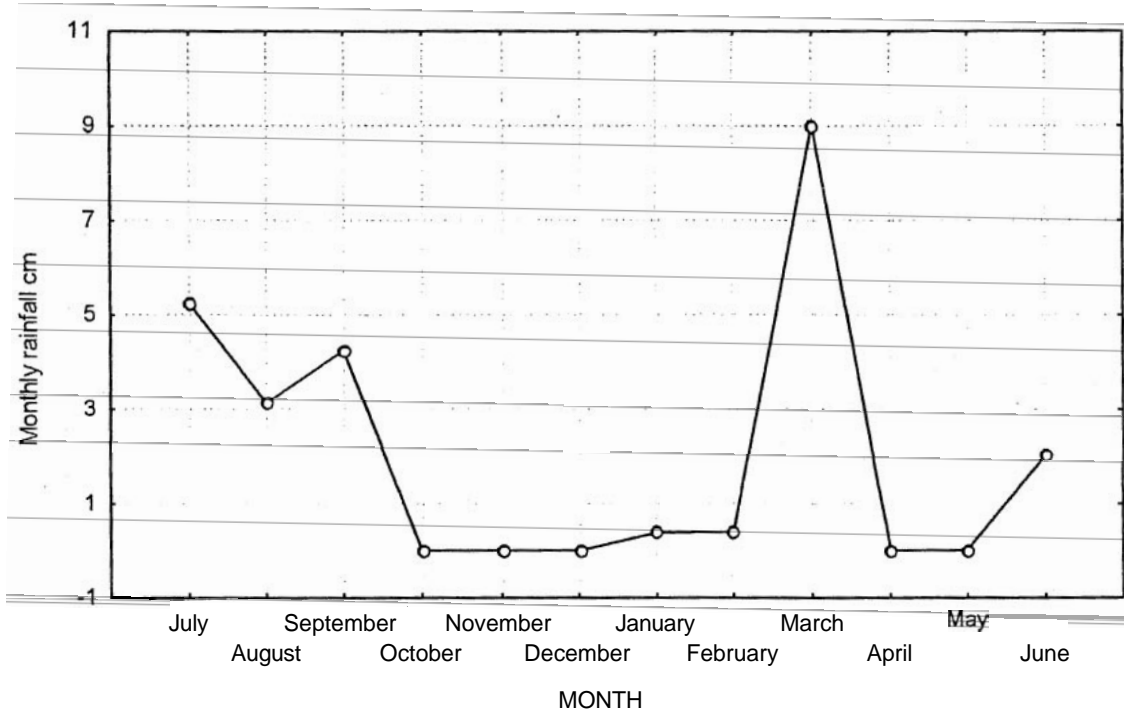


Figure 1. Monthly rainfall (cm), Mazatzal Mountains, Arizona, July 1999-June 2000.

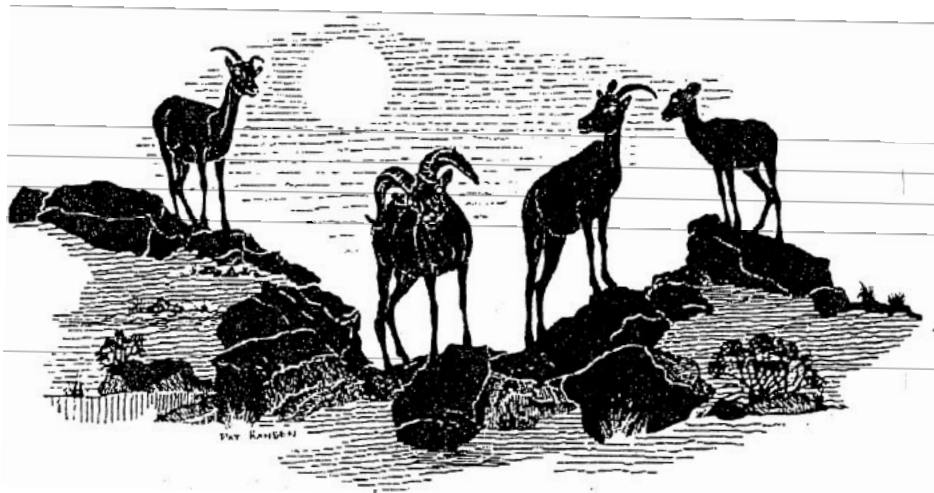


Table 1. Annual (90 % CI in parentheses) and seasonal mean mineral composition (ppm dry w) of desert bighorn sheep forage collected monthly in the Mazatzal Mountains, Arizona 1999-2000.

| Forage | Months | Minerals | | | | | | | | | | |
|---------|---------|---------------------|---------------|---------------|---------------------|-------------------|---------|---------|-------------------|-----------------|-------------|-----------------|
| | | Ca | Cu | Fe | K | Mg | Mn | Na | P | Se | Zn | Ca :P |
| Browse | Jul-Sep | 23,275 | 7.7 | 142 | 11,640 | 3,946 | 54 | 34 | 1,517 | 0.08 | 29 | 15.3:1 |
| | Oct-Dec | 24,950 | 8.2 | 148 | 9,140 | 3,638 | 73 | 47 | 1,108 | 0.10 | 28 | 22.5:1 |
| | Jan-Mas | 18,925 | 6.5 | 127 | 11,948 | 3,488 | 51 | 28 | 1,817 | 0.17 | 27 | 10.4:1 |
| | Apr-Jun | 18,125 | 6.8 | 161 | 13,358 | 2,898 | 58 | 37 | 1,485 | 0.07 | 26 | 12.2:1 |
| | Annual | 21,319 | 7.4 | 144 | 11,521 | 3,491 | 59 | 37 | 1,469 | 0.10 | 28 | 15.1:1 |
| | | (18,913- 23,725) | (6.2- 8.5) | (131- 158) | (9,432- 13,610) | (2,937- 4,046) | (47-71) | (32-41) | (1,152- 1,786) | (0.07- 0.14) | (21- 34) | (8.8-21.4) |
| Forbs | Jul-Sep | 18,250 | 6.6 | 132 | 13,400 | 2,285 | 52 | 65 | 1,217 | 0.10 | 16 | 15:1 |
| | Oct-Dec | 18,800 | 5.0 | 124 | 12,950 | 2,075 | 36 | 53 | 1,132 | 0.06 | 19 | 16.6:1 |
| | Jan-Mar | 18,200 | 5.2 | 133 | 11,575 | 1,625 | 36 | 66 | 981 | 0.08 | 19 | 18.6:1 |
| | Apr-Jun | 19,400 | 6.3 | 111 | 14,975 | 2,440 | 102 | 90 | 1,216 | 0.04 | 20 | 16:1 |
| | Annual | 18,662 | 5.8 | 125 | 13,225 | 2,106 | 44 | 68 | 1,136 | 0.07 | 18 | 16.6:1 |
| | | (15,533- 21,792) | (3.4- 8.1) | (87- 163) | (10,217- 16,233) | (1,862- 2,350) | (34-55) | (45-91) | (851- 1,421) | (0.04- 0.10) | (11- 25) | (14.8- 18.3) |
| Grasses | Jul-Sep | 2,165 | 5.1 | 399 | 4,610 | 604 | 57 | 38 | 557 | 0.10 | 13 | 3.9:1 |
| | Oct-Dec | 2,600 | 4.4 | 202 | 6,970 | 898 | 52 | 22 | 488 | 0.07 | 10 | 5.3:1 |
| | Jan-Mar | 2,740 | 5.3 | 291 | 4,590 | 640 | 47 | 19 | 523 | 0.13 | 13 | 5.2:1 |
| | Apr-Jun | 2,585 | 4.9 | 203 | 5,135 | 702 | 63 | 43 | 591 | 0.10 | 12 | 4.4:1 |
| | Annual | 2,511 | 4.9 | 284 | 5,091 | 684 | 55 | 32 | 547 | 0.10 | 12 | 4.7 |
| | | (2,085- 2,937) | (4.2- 5.5) | (214- 354) | (3,691- 6,492) | (570- 798) | (44-67) | (23-40) | (424- 670) | (0.07- 0.14) | (8-16) | (3.9-5.5) |

Table 2. Mineral composition (ppm dry wt) of selected plant species, Mazatzal Mountains, July 1999-June 2000.

| Species/month | Mineral Concentration (ppm) | | | | | | | | | | |
|-----------------------------|-----------------------------|-------|-----|-------|-------|--------|-------|------|-------|------|------|
| | Ca | Cu | Fe | Mg | Mn | K | P | Na | S | Se | Zn |
| <i>Browse</i> | | | | | | | | | | | |
| <i>Prosopis velutina</i> | | | | | | | | | | | |
| Jul-Sep | 17,200 | 8.40 | 110 | 3,510 | 39.7 | 9,210 | 919 | 32.6 | 4,900 | 0.03 | 38.9 |
| Oct-Dec | 21,900 | 16.0 | 189 | 3,940 | 91.9 | 12,000 | 813 | 50.7 | 4,550 | 0.20 | 44.0 |
| Jan-Mar | 27,100 | 7.23 | 152 | 6,050 | 89.4 | 6,960 | 717 | 32.3 | 4,810 | 0.28 | 13.7 |
| Apr-Jun | 10,600 | 7.91 | 211 | 2,690 | 29.5 | 15,900 | 1,400 | 44.9 | 3,890 | 0.08 | 43.0 |
| <i>Coursetia glandulosa</i> | | | | | | | | | | | |
| Jul-Sep | 23,800 | 8.50 | 163 | 6,400 | 63.0 | 21,200 | 2,250 | 34.9 | 3,090 | 0.09 | 15.6 |
| Oct-Dec | 26,500 | 5.83 | 118 | 4,460 | 72.2 | 11,100 | 1,380 | 44.9 | 1,790 | 0.07 | 19.4 |
| Jan-Mar | 6,700 | 7.88 | 147 | 2,250 | 28.2 | 21,200 | 4,830 | 39.5 | 3,980 | 0.15 | 36.7 |
| Apr-Jun | 24,800 | 7.61 | 155 | 3,900 | 120.0 | 17,100 | 1,680 | 29.7 | 2,220 | 0.12 | 15.6 |
| <i>Encilia farinosa</i> | | | | | | | | | | | |
| Jul-Sep | 33,300 | 12.90 | 219 | 3,980 | 58.6 | 23,300 | 1,710 | 20.5 | 5,280 | 0.19 | 31.3 |
| Oct-Dec | 16,400 | 9.88 | 167 | 2,220 | 41.2 | 21,800 | 1,470 | 38.2 | 3,830 | 0.05 | 28.9 |
| Jan-Mar | 15,500 | 10.30 | 175 | 1,910 | 59.2 | 24,500 | 1,860 | 25.0 | 3,000 | 0.13 | 35.2 |
| Apr-Jun | 35,400 | 12.60 | 230 | 3,800 | 79.3 | 29,400 | 1,780 | 31.6 | 6,720 | 0.18 | 28.3 |
| <i>Acacia greggii</i> | | | | | | | | | | | |
| Jul-Sep | 31,300 | 5.97 | 157 | 3,560 | 55.6 | 6,380 | 1,200 | 35.7 | 1,700 | 0.17 | 9.62 |
| Oct-Dec | 27,100 | 5.10 | 161 | 3,210 | 92.1 | 5,820 | 1,060 | 40.5 | 1,800 | 0.05 | 10.7 |
| Jan-Mar | 16,300 | 5.25 | 114 | 2,820 | 53.2 | 11,500 | 1,750 | 23.9 | 2,050 | 0.23 | 20.6 |
| Apr-Jun | 17,200 | 5.61 | 120 | 2,730 | 52.7 | 12,300 | 1,460 | 20.9 | 1,780 | 0.06 | 13.1 |

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Table 2 (continued).

| Species/month | Mineral Concentration (ppm) | | | | | | | | | | |
|--------------------------------|-----------------------------|------|-----|-------|------|--------|-------|-------|-------|------|------|
| | Ca | Cu | Fe | Mg | Mn | K | P | Na | S | Se | Zn |
| Browse | | | | | | | | | | | |
| <i>Ephedra</i> spp. | | | | | | | | | | | |
| Jul-Sep | 22,200 | 2.71 | 96 | 2,100 | 75.3 | 8,700 | 713 | 91.7 | 1,950 | 0.05 | 6.79 |
| Oct-Dec | 21,400 | 1.96 | 70 | 1,930 | 27.8 | 12,800 | 873 | 64.4 | 2,160 | 0.06 | 7.31 |
| Jan-Mar | 23,200 | 2.03 | 65 | 1,470 | 36.7 | 7,950 | 731 | 103.0 | 1,570 | 0.03 | 6.44 |
| Apr-Jun | 24,700 | 2.61 | 65 | 2,340 | 49.9 | 9,550 | 751 | 124.0 | 1,800 | 0.03 | 7.18 |
| <i>Parkinsonia microphylla</i> | | | | | | | | | | | |
| Jul-Sep | 20,800 | 7.90 | 139 | 2,300 | 57.8 | 9,770 | 1,700 | 31.6 | 1,550 | 0.04 | 53.3 |
| Oct-Dec | 24,300 | 5.69 | 123 | 2,940 | 35.0 | 7,640 | 1,180 | 51.1 | 1,120 | 0.06 | 37.6 |
| Jan-Mar | 17,000 | 5.47 | 98 | 1,860 | 26.8 | 9,130 | 1,090 | 33.2 | 1,170 | 0.07 | 49.2 |
| Apr-Jun | 19,900 | 6.07 | 159 | 2,270 | 28.9 | 8,130 | 1,400 | 52.9 | 1,320 | 0.02 | 34.2 |
| <i>Eriogonum fasciculatum</i> | | | | | | | | | | | |
| Jul-Sep | 16,900 | 7.56 | 345 | 2,480 | 37.7 | 8,920 | 920 | 63.9 | 1,420 | 0.08 | 17.4 |
| Oct-Dec | 11,800 | 5.26 | 235 | 1,990 | 23.6 | 7,400 | 673 | 63.1 | 1,040 | 0.08 | 11.8 |
| Jan-Mar | 12,500 | 6.35 | 243 | 1,720 | 27.4 | 7,190 | 839 | 91.0 | 1,140 | 0.08 | 15.2 |
| Apr-Jun | 16,700 | 5.93 | 325 | 2,850 | 47.2 | 10,500 | 822 | 86.4 | 1,230 | 0.13 | 14.8 |
| <i>Hyoptis emoryi</i> | | | | | | | | | | | |
| Jul-Sep | 17,300 | 14.0 | 656 | 3,920 | 68.6 | 18,400 | 1,320 | 71.6 | 1,850 | 0.18 | 28.8 |
| Oct-Dec | 11,900 | 11.3 | 306 | 2,910 | 82.9 | 16,900 | 1,240 | 109.0 | 1,500 | 0.09 | 25.5 |
| Jan-Mar | 13,000 | 13.7 | 411 | 2,420 | 153 | 14,600 | 1,290 | 62.0 | 1,330 | 0.18 | 22.9 |
| Apr-Jun | 16,400 | 12.3 | 624 | 3,870 | 100 | 19,900 | 1,490 | 115.0 | 1,790 | 0.16 | 23.2 |

2002 DESERT BIGHORN COUNCIL TRANSACTIONS

Table 2 (Continued).

| Species/month | Mineral Concentration (ppm) | | | | | | | | | | |
|------------------------------|-----------------------------|------|-----|-------|-------|--------|-------|-----|-------|------|------|
| | Ca | Cu | Fe | Mg | Mn | K | P | Na | S | Se | Zn |
| Browse | | | | | | | | | | | |
| <i>Krameria grayi</i> | | | | | | | | | | | |
| Jul-Sep | 15,300 | 5.65 | 160 | 2,500 | 30.0 | 17,800 | 1,320 | 732 | 1,830 | 0.10 | 16.0 |
| Oct-Dec | 16,700 | 6.66 | 107 | 1,790 | 18.4 | 14,300 | 1,560 | 183 | 1,510 | 0.08 | 16.0 |
| Jan-Mar | 12,000 | 8.32 | 149 | 1,530 | 23.1 | 18,800 | 1,940 | 203 | 1,510 | 0.09 | 21.3 |
| Apr-Jun | 12,000 | 9.40 | 110 | 1,760 | 26.8 | 26,500 | 2,210 | 102 | 2,100 | 0.16 | 20.3 |
| <i>Larrea divaricataa</i> | | | | | | | | | | | |
| Jul-Sep | 20,300 | 8.84 | 245 | 2,080 | 26.6 | 12,200 | 1,150 | 31 | 3,800 | 0.18 | 15.5 |
| Oct-Dec | 22,000 | 7.63 | 265 | 1,930 | 40.6 | 13,800 | 1,040 | 37 | 4,140 | 0.27 | 15.8 |
| Jan-Mar | 17,000 | 8.54 | 179 | 1,740 | 30.1 | 14,600 | 1,460 | 22 | 4,300 | 0.18 | 20.5 |
| Apr-Jun | 18,700 | 6.78 | 152 | 1,800 | 20.3 | 13,500 | 1,360 | 21 | 3,680 | 0.11 | 7.29 |
| <i>Simmondsia chinensis</i> | | | | | | | | | | | |
| Jul-Sep | 14,500 | 3.51 | 89 | 9,660 | 122.0 | 12,600 | 812 | 283 | 2,550 | 0.04 | 11.6 |
| Oct-Dec | 13,200 | 3.14 | 88 | 9,370 | 130.0 | 14,700 | 527 | 616 | 2,160 | 0.19 | 9.0 |
| Jan-Mar | 11,700 | 2.83 | 87 | 8,520 | 96.5 | 16,600 | 568 | 776 | 1,860 | 0.12 | 8.2 |
| Apr-Jun | 10,500 | 3.90 | 101 | 7,740 | 97.9 | 14,900 | 932 | 294 | 2,500 | 0.06 | 10.1 |
| <i>Calliandra eriophylla</i> | | | | | | | | | | | |
| Jul-Sep | 19,800 | 5.18 | 313 | 2,470 | 66.7 | 6,390 | 1,690 | 39 | 2,030 | 0.09 | 14.1 |
| Oct-Dec | 17,600 | 6.00 | 189 | 3,220 | 73.6 | 4,990 | 864 | 20 | 1,230 | 0.11 | 13.7 |
| Jan-Mar | 12,000 | 7.47 | 153 | 2,660 | 44.6 | 5,990 | 1,510 | 33 | 2,060 | 0.12 | 24.5 |
| Apr-Jun | 16,900 | 5.33 | 160 | 2,490 | 93.7 | 6,400 | 1,240 | 24 | 1,890 | 0.14 | 12.4 |

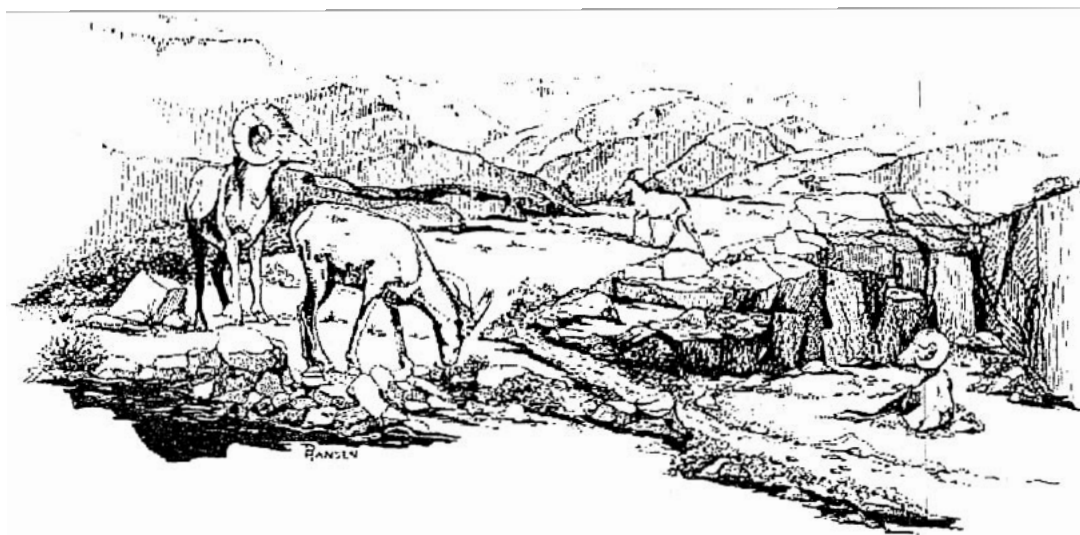
2002 DESERT BIGHORN COUNCIL TRANSACTIONS

Table 2 (Continued).

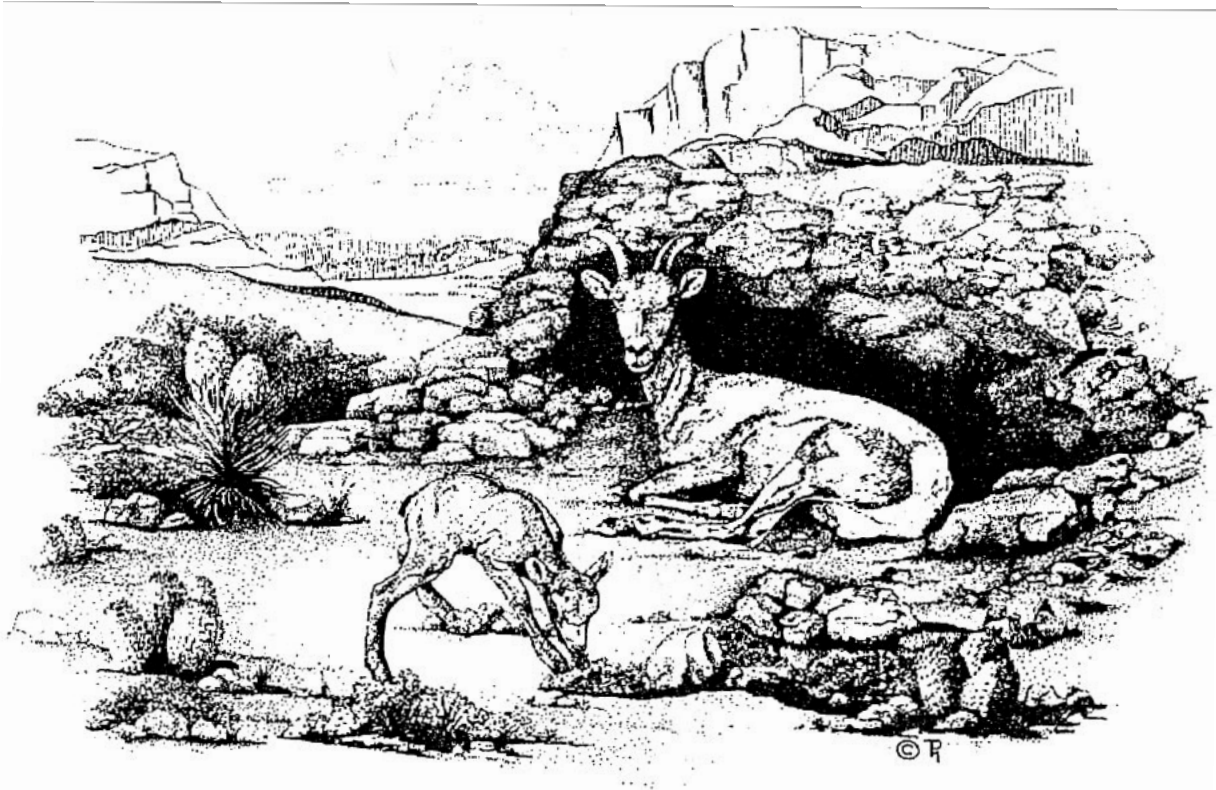
| Species/month | Mineral Concentration (ppm) | | | | | | | | | | |
|-------------------------------|-----------------------------|------|-----|-------|------|--------|-------|-------|-------|------|------|
| | Ca | Cu | Fe | Mg | Mn | K | P | Na | S | Se | Zn |
| Forbs | | | | | | | | | | | |
| <i>Argythamnia lanceolata</i> | | | | | | | | | | | |
| Jul-Sep | 24,400 | 6.50 | 239 | 2,160 | 34.0 | 17,200 | 1,010 | 101.0 | 3,090 | 0.26 | 16.7 |
| Oct-Dec | 24,200 | 5.44 | 175 | 2,050 | 28.7 | 13,800 | 957 | 87.5 | 2,510 | 0.19 | 15.8 |
| Jan-Mar | 24,300 | 5.56 | 202 | 2,230 | 38.5 | 13,000 | 1,030 | 67.4 | 2,380 | 0.31 | 17.7 |
| Apr-Jun | 24,800 | 5.06 | 209 | 2,040 | 32.8 | 18,500 | 1,000 | 115 | 2,830 | 0.11 | 14.2 |
| <i>Sphaeralcea ambigua</i> | | | | | | | | | | | |
| Jul-Sep | 14,300 | 10.4 | 167 | 2,470 | 29.1 | 18,100 | 1,720 | 37.8 | 3,250 | 0.16 | 24.2 |
| Oct-Dec | 16,200 | 7.78 | 178 | 2,220 | 45.1 | 13,100 | 1,390 | 41.5 | 3,050 | 0.06 | 29.7 |
| Jan-Mar | 13,200 | 8.29 | 201 | 1,780 | 36.1 | 15,200 | 1,230 | 28.8 | 2,430 | 0.13 | 31.6 |
| Apr-Jun | 14,100 | 9.86 | 156 | 2,540 | 54.0 | 20,400 | 1,680 | 54.9 | 3,500 | 0.04 | 32.3 |
| Grasses | | | | | | | | | | | |
| <i>Aristida</i> spp. | | | | | | | | | | | |
| Jul-Sep | 1,890 | 4.25 | 440 | 493 | 51.3 | 2,340 | 297 | 36.1 | 697 | 0.07 | 5.1 |
| Oct-Dec | 2,600 | 4.38 | 202 | 898 | 51.6 | 6,970 | 488 | 21.5 | 716 | 0.07 | 9.7 |
| Jan-Mar | 2,100 | 5.38 | 340 | 479 | 34.9 | 2,990 | 416 | 17.0 | 763 | 0.09 | 11.0 |
| Apr-Jun | 2,000 | 5.52 | 204 | 648 | 42.2 | 6,110 | 622 | 38.6 | 994 | 0.16 | 10.2 |
| <i>Bouteloua curtipendula</i> | | | | | | | | | | | |
| Jul-Sep | 2,440 | 5.83 | 357 | 715 | 62.3 | 6,880 | 817 | 39.7 | 923 | 0.09 | 20.5 |
| Oct-Dec | | | | | | | | | | | |
| Jan-Mar | 3,380 | 5.17 | 242 | 800 | 58.8 | 6,190 | 630 | 20.1 | 962 | 0.16 | 14.0 |
| Apr-Jun | 3,170 | 4.18 | 202 | 755 | 84.1 | 4,160 | 559 | 46.8 | 870 | 0.05 | 13.0 |

Table 2 (continued).

| Species\month | Mineral Concentration (ppm) | | | | | | | | | | |
|-----------------------------|-----------------------------|------|-----|--------|-------|--------|-------|-------|-------|------|------|
| | Ca | Cu | Fe | Mg | Mn | K | P | Na | S | Se | Zn |
| <i>Succulent/Woody</i> | | | | | | | | | | | |
| <i>Ferrocactus</i> spp. | | | | | | | | | | | |
| Jul-Sep | | | | | | | | | | | |
| Oct-Dec | 37,300 | 1.02 | 28 | 20,500 | 202.0 | 37,500 | 291 | 1,620 | 7,140 | 0.07 | 2.5 |
| Jan-Mar | 50,200 | 1.59 | 42 | 16,300 | 124.0 | 24,300 | 423 | 701 | 5,300 | 0.06 | 4.2 |
| Apr-Jun | | | | | | | | | | | |
| <i>Fouquieria splendens</i> | | | | | | | | | | | |
| Jul-Sep | 18,200 | 4.54 | 168 | 3,200 | 34.0 | 19,700 | 1,900 | 35.3 | 3,560 | 0.19 | 21.2 |
| Oct-Dec | | | | | | | | | | | |
| Jan-Mar | | | | | | | | | | | |
| Apr-Jun | 6,700 | 7.88 | 147 | 2,250 | 28.2 | 21,200 | 4,830 | 39.5 | 3,980 | 0.15 | 36.7 |



STATUS REPORTS



ARIZONA'S BIGHORN SHEEP IN 2001

JON HANNA, Arizona Game and Fish Department, 7200 East University, Mesa, AZ 85207

POPULATIONS

Estimates of Arizona's desert bighorn sheep (*Ovis canadensis mexicana* and *O. c. nelsoni*) indicate a relatively stable population of about 6,000 animals. Due to budgetary considerations, much of Arizona's bighorn sheep range is now being surveyed on three-year intervals. Survey results yielded ratios of 50 rams, 25 lambs, and 14 yearlings:100 ewes.

The Rocky Mountain bighorn sheep (*O. c. canadensis*) population, estimated at nearly 600 animals, continues to expand both in numbers and range. Winter survey results produced ratios of 35 rams, 30 lambs, and eight yearlings:100 ewes. These values are well below historic levels.

RESEARCH

The Arizona Game and Fish Department (AGFD) is currently involved in one bighorn sheep management study. This study is an attempt to determine the cause for a decline in bighorn sheep numbers near Saguaro Lake. We are continuing a water development study on the Yuma Proving Grounds, which may have ramifications for bighorn sheep management.

HABITAT IMPROVEMENTS

The AGFD, primarily in cooperation with the Arizona Desert Bighorn Sheep Society, conducts six to ten habitat improvement projects annually. These projects are usually water developments, but also include fencing

modifications and prescribed burns.

TRANSPLANTS

Since 1980, a mean of nearly 70 sheep has been transplanted annually. In 2000, 25 desert bighorn sheep were captured in the Eagletail Mountains and released in the Harquahala Mountains, about 75 miles northwest of Phoenix. One ewe had to have one of her rear legs surgically amputated as a result of a capture injury. That animal is still alive and with the group released in the Harquahala Mountains.

Since 1957, Arizona has translocated 1,399 bighorn sheep - with 99 going to Colorado, 67 to Utah, 29 to Texas, 23 to New Mexico, and nine to various Zoos and Universities. Of the 33 game management units in Arizona, which are open to bighorn sheep hunting, 16 received bighorn sheep transplants. Thirty-five of the 103 permits occur in these populations established from transplants. Arizona is now actively looking for a source of Rocky Mountain bighorn sheep for release near Bear Mountain in Unit 27.

HARVEST

Bighorn sheep permits remain the most sought after hunting permits in Arizona. There were a record 8,767 applicants in 2001 for the 103 regular season permits. This application rate represents over 77 hunters applying for each permit, with individual unit odds varying from as low as 13:1 to 446:1, depending on the unit's

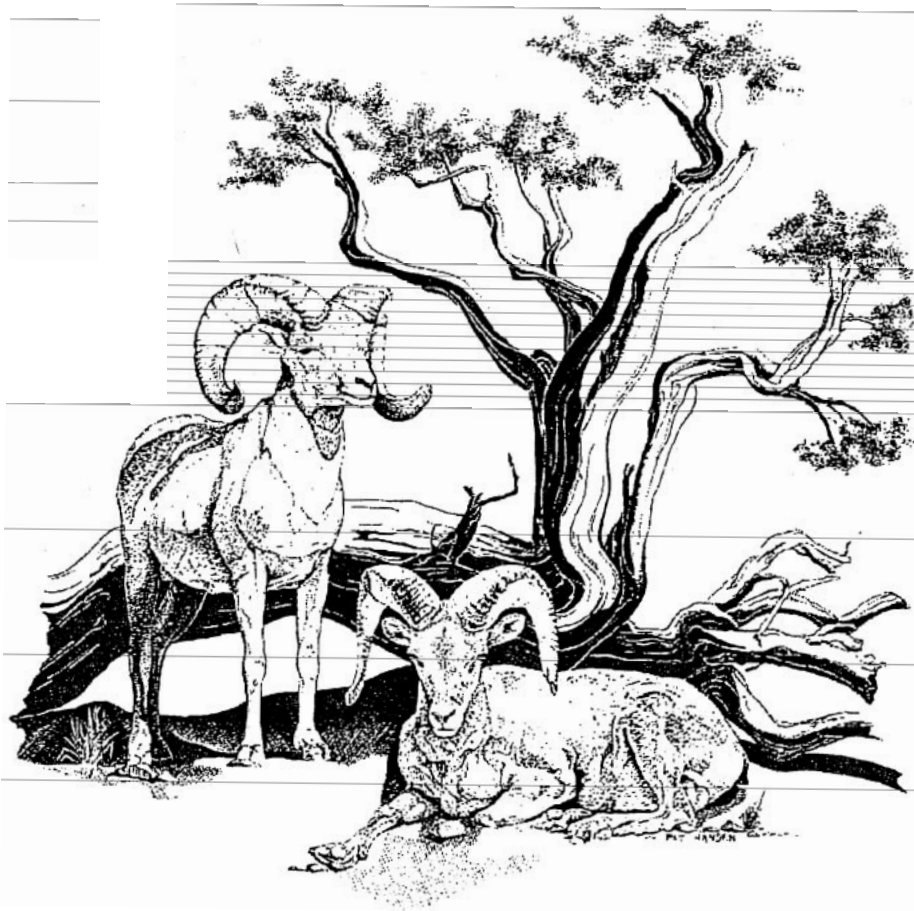
accessibility and harvest history.

As a result of this year's survey, total permits for the 2001 season were unchanged at 103, with the two additional special fund-raising permits remaining.

During the 2000 hunting season, 106 hunters participated, harvesting 101 rams in 691 hunter days for a 95% success rate. The mean age of the harvest was 7.8 years and the mean score was 157 1/8. Ages ranged from 3.5 to 12.5 and scores from 65 6/8 (a one homed ram) to 183 6/8. The 2000 season produced 36 animals (35% of the harvest) qualifying for the Arizona Trophy Book (minimum score of 162 Boone and

Crockett points). Of these rams, 12 (12 %) scored >170 points.

For the 17th consecutive year, the Arizona Game and Fish Department and the Arizona Desert Bighorn Sheep Society entered into an agreement whereby the Society auctions one permit (at the Foundation for North American Wild Sheep convention) and raffles another to raise funds for bighorn sheep management projects. In 2000, these two permits produced \$256,900. To date, these permits have produced over \$3,250,000. Arizona's bighorn sheep management program is dependent upon the funds derived from these permits.



STATUS OF DESERT BIGHORN SHEEP IN TEXAS - 2001

CLAY E. BREWER, Texas Parks and Wildlife Department, Bighorn Sheep Program Leader, 109 South Cockrell, Alpine, Texas 79830

POPULATIONS

The Trans Pecos region of Texas currently supports seven free ranging populations of desert bighorn sheep. These occur within the Baylor, Beach, Sierra Diablo, Sierra Vieja and Van Horn Mountains, and the Texas Parks and Wildlife Department's (TPWD) Black Gap and Elephant Mountain Wildlife Management Areas (WMA). Helicopter surveys conducted August-September of 2001, indicated an increasing bighorn population. A total of 461 bighorns were observed during 45.0 hours of flight time (Table 1.). Survey results yielded ratios of 62 rams:100 ewes: 40 lambs. Restoration efforts have resulted in re-establishing bighorn sheep numbers to population levels of the early 1900s.

The Chilicote Ranch, located in the Sierra Vieja Mountains, is the only remaining captive population in Texas. The facility currently contains three rams, four ewes, and one lamb.

The largest in-state transplant in the history of the Texas restoration program was conducted December of 2000, with 45 bighorns (23 M, 22 F) transplanted from Elephant Mountain WMA to Black Gap WMA. Migration of bighorns between management areas has been observed. As a result, small bands of sheep are currently occupying suitable habitat along the travel corridors between management areas.

RESEARCH

A study concerning the diets of desert bighorn sheep at Elephant Mountain WMA was completed during the reporting period. Two additional research projects are currently in progress including: home ranges, movements, and mortalities of desert bighorns at Elephant Mountain WMA; and guzzler use, habitat selection and movement patterns of desert bighorn sheep at Black Gap WMA.

HABITAT IMPROVEMENTS

In March of 2001, two water catchments were constructed on private land in the Sierra Diablo Mountains. The projects were accomplished through the cooperative efforts of the Texas Bighorn Society (TBS), private landowners, and TPWD. The 2002 project will involve refurbishing eight guzzlers in the Sierra Diablo Mountains including replacement/burying of drinkers and waterlines, and construction of helicopter pads.

A National Fish and Wildlife Foundation grant has been approved for restoring travel corridors in the Baylor, Beach, and Sierra Diablo Mountains. The project will involve eliminating and adapting fences and other barriers to facilitate movement between mountain ranges.

HARVEST

Since reinstated by the Texas Legislature in 1988, a total of 32 desert bighorn hunting

permits have been issued. Among these were nine public hunting permits, six FNAWS permits, and 17 private landowner permits. Four desert bighorn hunting permits were issued during the 2001 hunting season including one Texas Grand Slam Hunt permit and three private landowner permits (one-Beach Mountain and two-Sierra Diablo Mountains).

Bighorn sheep restoration and management in Texas continues to be funded by hunters through the Federal Aid in Wildlife Restoration Program, FNAWS auction permits, and the Texas Grand Slam Hunt Program. The 2001 Texas Grand Slam Hunt permit produced \$97,000 for the program. Approximately \$499,000 has been generated from six permits, since the inception of the Texas Grand Slam Hunt Program in 1996.

PROBLEMS/OPPORTUNITIES

Elephant Mountain will continue to serve as the primary source of brood stock for re-introduction efforts. However, additional out of state brood stock may be needed to facilitate restoration of desert bighorn sheep in areas of suitable habitat.

The private landowner remains the single most important factor in restoring and maintaining viable desert bighorn populations in Texas. Efforts to educate landowners regarding proper management of desert bighorns must continue to be expanded.

Aoudad sheep continue to be observed mixing with desert sheep in Texas. TPWD has the authority, coupled with landowner consent, to eliminate aoudads by lethal means for controlling encroachment in habitat utilized by desert sheep.

Mountain lion predation continues to be one of the limiting factors of desert bighorn sheep populations in Texas. Predator control efforts must be continued in sheep restoration areas to minimize losses to desert bighorn sheep brood stock.

Efforts to educate the public regarding desert bighorn restoration and management in Texas have increased through the installation of a portable solar operated web camera at Elephant Mountain WMA. The motion activated camera downloads still photos via satellite telephone to the Texas Bighorn Society website (www.texasbighornsociety.org). Schools, zoos, and others are currently using the system for educational purposes.

Construction of wind generators within critical desert bighorn sheep habitat areas has recently been proposed. The noise and motion produced by the structures themselves, and increased human disturbances resulting from road construction and other maintenance activities are among the concerns. Information regarding impacts to desert bighorn sheep and other wildlife is presently lacking.

Table 1. Desert bighorn sheep observed (2001 helicopter survey).

| Mountain Range | Sheep Observed | Ratio per 100 ewes Rams/Lambs | Mountain Range |
|-----------------------------|------------------|----------------------------------|----------------|
| Black Gap WMA | 87 | 76/26 | Increasing |
| Chilicote Ranch | 7 | 50/25 | Decreasing |
| Elephant Mountain WMA | 130 ^a | - | Increasing |
| Metapopulation ^b | 225 | 62/49 | Increasing |
| Van Horn Mountains | 12 | 10/10 | Increasing |
| Total | 461 | 62/40 | Increasing |

^a Helicopter survey not flown – estimate reflected

^b Baylor, Beach, and Sierra Diablo Mountains



Table 2. Summary of desert bighorn sheep numbers and locations in Texas (free ranging and captive populations).

| Area | Rams | Ewes | Lambs | Unknown | Total |
|-------------------------|------|------|-------|------------------|-------|
| Black Gap WMA | 3% | 42 | 11 | 2 | 57 |
| Chilicote Ranch | 2 | 4 | 1 | | 7 |
| Elephant Mountain WMA | - | - | - | 130 ^a | 130 |
| Metapopulation | - | - | - | - | - |
| Baylor Mountain | 10 | 19 | 10 | | 39 |
| Beach Mountain | 19 | 36 | 13 | | 68 |
| Sierra Diablo Mountains | 37 | 52 | 29 | | 118 |
| Van Horn Mountains | 1 | 10 | 1 | | 12 |
| Total | 101 | 163 | 65 | 132 | 461 |

^a Helicopter survey not flown – estimate reflected



STATUS OF DESERT BIGHORN SHEEP IN NEW MEXICO, 2001

ELISE J. GOLDSTEIN, New Mexico Department of Game and Fish, 1 Wildlife Way, Santa Fe, NM 87507

ERIC M. ROMINGER, New Mexico Department of Game and Fish, 1 Wildlife Way, Santa Fe, NM 87507

In December 2001, there were an estimated 166 desert bighorn sheep in the wild in New Mexico, and 79 in the Red Rock captive breeding facility. All herds continued to decline in population size during 2001, with the exception of the Fra Cristobal herd, which increased. The Red Rock population increased in size, and after three years of supplemental feeding it appears the sex ratio of lambs is getting closer to parity, and less skewed in favor of males. Mountain lion predation continued to be the primary cause of bighorn mortality in all herds. The mountain lion removal program has succeeded in eliminating a limited number of mountain lions in several desert bighorn herds, which will hopefully allow bighorn herds to start increasing. Implementing controlled burns and obtaining desert bighorn from other sources were primary management objectives.

Peloncillo Mountains

Since 1997, 36 bighorn sheep (24 rams and 12 ewes) have been released into the Peloncillo population from Red Rock, and an additional six from the existing herd were radio collared. High mountain lion predation resulted in the failure of this effort. Of the radiocollared ewes, 12 were killed by lions within two years, one died from an unknown predator, two died of unknown causes, one dropped her collar, and only two ewes were known to be alive as of December 2001. Mountain lion predation has been the documented cause of

mortality for approximately 85% of all known-cause non-hunter adult bighorn mortalities in the Peloncillos. Currently the population estimate is 30, with less than ten ewes remaining (Table 1, Rominger and Goldstein 2001).

Hatchet Mountains

This herd is distributed in two distinct subpopulations about seven miles apart in the southern Little Hatchet and southern Big Hatchet Mountains. In 1999, three radio-collared rams were released into the Little Hatchet Mountains and eight extant ewes were radiocollared (three in the Big Hatchet Mountains and five in the Little Hatchet Mountains). There have been nine known mortalities including six lion kills, one poaching, one capture related mortality, and one natural death. The Hatchet herd has decreased since 1995, despite transplanting nine rams from Red Rock, and the population estimate in 2001 was 40 bighorn (Table 1, Rominger and Goldstein 2001).

Alamo Hueco Mountains

The Alamo Hueco Mountain population was established in 1986 with 21 bighorn transplanted from the Red Rock Wildlife Area (Axtell 1988). This population was never documented to be >30 individuals (New Mexico Department of Game and Fish (DGF) unpubl. data), and since 1996 no more than seven bighorn have been observed. It is therefore hypothesized that the Alamo Hueco population has been

extirpated and bighorn observed in the Alamo Hueco Mountains, including the one bighorn observed in 2001, are transients from the Big Hatchet population (Table 1, Rominger and Goldstein 2001).

Animas Mountains

This is the only documented self-starting herd in the state. However, in 1996 only 13 bighorn were observed, and numbers have declined every year since. In 1999, two ewes were radiocollared but within 12 months lions killed both ewes. It is hypothesized that the Animas population is now extirpated, as no bighorn sheep have been observed since 2000 (Table 1, Rominger and Goldstein 2001).

San Andres Mountains

A scabies mite (*Psoroptes* spp.) epizootic in 1978 caused the San Andres population to decline from 200 bighorn in the mid-1970's to 75 bighorn within a year (Sandoval 1980). Between 1982 and 1994 population numbers ranged between 25 and 35 animals (DGF Files). Mountain lions began preying heavily on the herd, causing it to decline to three individuals by 1996, only one ewe by 1997 (Rominger and Weisenberger 2000). This ewe was captured in 1997, tested positive for and subsequently treated for scabies. In 1999, a two-year sentinel ram study was initiated by releasing six rams with two primary goals: to determine that bighorn and their habitat were free of scabies; and to learn if there were additional bighorn in the San Andres. After two years of monitoring, capturing, and testing sentinel rams and the remaining ewe, no bighorn tested positive for scabies during any of the five tests and no additional bighorn were located. Of the six rams released, three were killed by mountain lions and one died of unknown causes. In 2001

an additional five rams were released on the Mountain to continue the project in an unofficial capacity (Table 1).

Ladron Mountains

The Ladron Mountain population was established in 1992 with 23 bighorn transplanted from Red Rock (Knadle 1993), and was supplemented the following year with eight bighorn from Red Rock. Despite an augmentation of 11 radiocollared rams in 1997 and 1999, this population declined to 26 individuals by 2001 (Table 1).

Mountain lion predation has been the most common cause of mortality ($n=19$ lion kills out of 31 total mortalities recorded). In 2000, five bighorn were captured and radiocollared in a net-gun operation designed to assist monitoring of this population during a Masters project at New Mexico State University (Arana 2002). Since 1997, one lion per year has been removed from the Ladrons.

Fra Cristobal Mountains

In November 1995, 37 bighorn sheep (13 rams and 24 ewes) were transplanted to the Fra Cristobal Mountains on the privately owned Arrendaris Ranch to establish a population (Krausman et al. 2001). Despite documentation of substantial lion predation ($n=28$) this population increased to an estimated 66 individuals in 2001 (Table 1, Parsons 2001). In 1997, seven radiocollared rams were released from Red Rock, but six of these rams were killed by mountain lions within 18 months. A lamb mortality study was initiated in 2001 and 14 lambs were radiocollared. Causes of mortality included mountain lion predation ($n=three$), golden eagle predation ($n=two$), accident ($n=one$), disease ($n=two$), and an unknown predator ($n=one$).

Red Rock

Red Rock has been negatively impacted over the past few years from a skewed sex ratio and increased predation rates (Figure 1). This has resulted in a stable population at a lower density resulting in no ewes transplanted since 1997. In 1999, a supplemental feeding program was initiated in an attempt to alter the sex ratio at birth to parity. Bighorn were supplementally fed between 1981 and 1992, and the yearling male:female ratio was 80:100 (n=110). Supplemental feeding was terminated and between 1993 and 1999 the yearling male:female ratio changed dramatically to 158:100 (n=155). Ratios went from 267:100 in 2000 to 143:100 in 2001. The program will be continued until we learn if supplemental feeding is effective.

Increased predation has also been a problem and since 1999, seven lions have been killed in or near the facility, three of them during November 2001. In 2000, additional efforts were put into fence repair and predator control, resulting in declining predation. We plan to continue both the supplemental feeding and predator removal program as this year's data suggest that they are returning the sex ratio at birth to parity, and decreasing mortality, respectively.

MANAGEMENT ISSUES

Mountain lion predation

Predation by mountain lions is considered the principal limiting factor in all desert bighorn sheep populations in New Mexico as it has been responsible for 85% of all known-cause radiocollared bighorn mortalities since 1992. Extinction probabilities were calculated for New Mexico populations using VORTEX

modeling (Fisher et al. 1999). All existing populations had a 100% probability of extinction within 65 years with just 5% additive annual mortality due to lion predation. Using MICROMORT, it was calculated that the annual mortality rate due to mountain lion predation from 1992-2000 in the Ladron Mountains was 11%, which is likely, lower than, and minimally representative of, annual mortality rates in other desert bighorn herds in New Mexico. Between 1995 and 2001, 87 desert bighorn sheep were documented to have been killed by mountain lions, including eight at Red Rock. Because only a portion of the desert bighorn sheep population was radiocollared during this period this is hypothesized to be a fraction of the total mortality. Predation by mountain lions was the primary cause of the biological extinction of the remnant San Andres populations (Rominger and Weisenberger 2000).

Despite compelling evidence that proactive mountain lion control is beneficial to desert bighorn herds, only selective control of predators that posed a threat to bighorn in the Red Rock captive facility was allowed. By 1997, after the deployment of 78 radio collars on bighorn in the Sierra Ladron, Fra Cristobal, and San Andres populations, it was documented that mountain lion predation was the primary cause (85%) of known-cause radiocollared adult mortality in desert bighorn sheep in New Mexico (Sandoval 1980, Hoban 1990, Rominger and Weisenberger 2000). In addition, in 1999, 58 desert bighorn sheep were radiocollared (27 rams from Red Rock and 31 extant ewes). Although several offending lions were harvested in the Peloncillo, Fra Cristobal, and Ladron mountains DGF was unable to mitigate the statewide decline in desert bighorn.

A research project was designed to test the effectiveness of increased lion harvest on survival rates of adult radiocollared bighorn in four bighorn sheep ranges (Rorninger and Dunn 2000). An increase in the lion quota in three desert bighorn sheep ranges (Peloncillos, Hatchets, Ladrons) was implemented in an effort to increase sport harvest of mountain lions in these ranges. This liberalized hunting quota resulted in no lions being harvested in these ranges. During the 1999-2000 and 2000-2001 hunting seasons, DGF contracted houndsmen to hunt in these ranges, but no lions were taken during either hunt season. In 2000 and 2001 mountain lions were responsible for 73% and 75% of radiocollared desert bighorn mortality, respectively.

Fire Suppression

Decreased fire frequency has led to increased woody vegetation density in most bighorn sheep ranges in the west (Wakelyn 1987). While the fire suppression policies of the land management agencies over the past 80 years has contributed to the lack of fires, livestock grazing is the primary factor leading to fire suppression. Several prescribed burns have been implemented in desert bighorn range in the past ten years but the majority of these fires were not very successful because weather conditions were often either too cool or too humid. A successful fire in the San Andres in 2001 resulted in reestablishing flowing springs in areas clogged by vegetation before the fire (M. Weisenberger, pers. comm.). There are fires planned in the Ladrons, and Big Hatchets this spring. Tentative fires are planned, in conjunction with BLM, Malpais, and the Grey Ranch

for spring 2003. A Little Hatchets burn is scheduled for 2004.

Transplants

In November 2001, five rams were captured in Red Rock and transplanted to the San Andres Mountains. Relying on Red Rock as the sole transplant stock for the state of New Mexico may not supply us with enough animals to recover the species. We have been working with Arizona on the possibility of exchanging Mexican desert bighorn from Arizona for Rocky Mountain bighorn from New Mexico in an effort to improve herds in both states.

Hunting

The auction hunter paid \$75,000 for a desert bighorn license and shot a 181 2/8 ram in the Peloncillos. The public hunter shot a 172 3/8 ram in the Peloncillos.

LITERATURE CITED

- Arana, M. 2002. Population enumeration and habitat management assessment for desert bighorn in the Ladron Mountains, New Mexico. Research Completion Report. New Mexico Cooperative Fish and Wildlife Research Unit. 56 pp.
- Axtell, J. A. 1988. Post-release movements of desert bighorn sheep in the Alamo Hueco Mountains, New Mexico. M. S. Thesis. New Mexico State Univ., Las Cruces. 57pp.
- Fisher, A., E. Rorninger, P. Miller, O. Byers. 1999. Population and habitat viability

assessment workshop for the desert bighorn sheep of New Mexico (*Ovis canadensis*): Final Report. IUCN/SSC Conservation.

Hoban, P. A. 1990. A review of desert bighorns in the San Andres Mountains, New Mexico. Desert Bighorn Council Transactions. 34:14-22.

Knadle, G. E. and B. Thompson. 1993. Movements and mortality assessment of desert bighorn sheep translocated to the Ladron Mountains, New Mexico. Unpubl. Rpt. New Mexico Dept. Game and Fish. PSC No. 93-516-28. 41pp.

Krausman, P. R., P. Bangs, K. Kunkel, M. K. Phillips, Z. Parsons, and E. Rominger. 2001. Mountain sheep restoration through private/public partnership. Pages 231-242 in Large Mammal Restoration, D.S. Maehr, R. F. Noss, J. L. Larkin (eds.) Island Press.

Parsons, Z. 2001. Desert bighorn sheep recovery project, Fra Cristobal Mountains, report for July and August 2001. 3 pp.

Rominger, E. M., E. J. Goldstein 2001. New Mexico autumn desert bighorn census report. 19pp.

_____. and W. C. Dunn. 2000. Reducing mountain lion predation on bighorn sheep in four New Mexico Mountain ranges: A study design. NMDGF Unpublished Report. 17pp.

_____, and M. E. Weisenberger. 2000. Biological extinction and a test of the "conspicuous individual hypothesis" in the San Andres Mountains, New Mexico. Pages 293-307 in Transactions of the 2nd North American Wild Sheep Conference. April 6-9, 1999, Reno, NV. 470pp.

Sandoval, A. V. 1980. Management of a psoroptic scabies epizootic in bighorn sheep (*Ovis canadensis mexicana*) in New Mexico. Desert Bighorn Council Transactions. 24:21-28.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51:904-912.



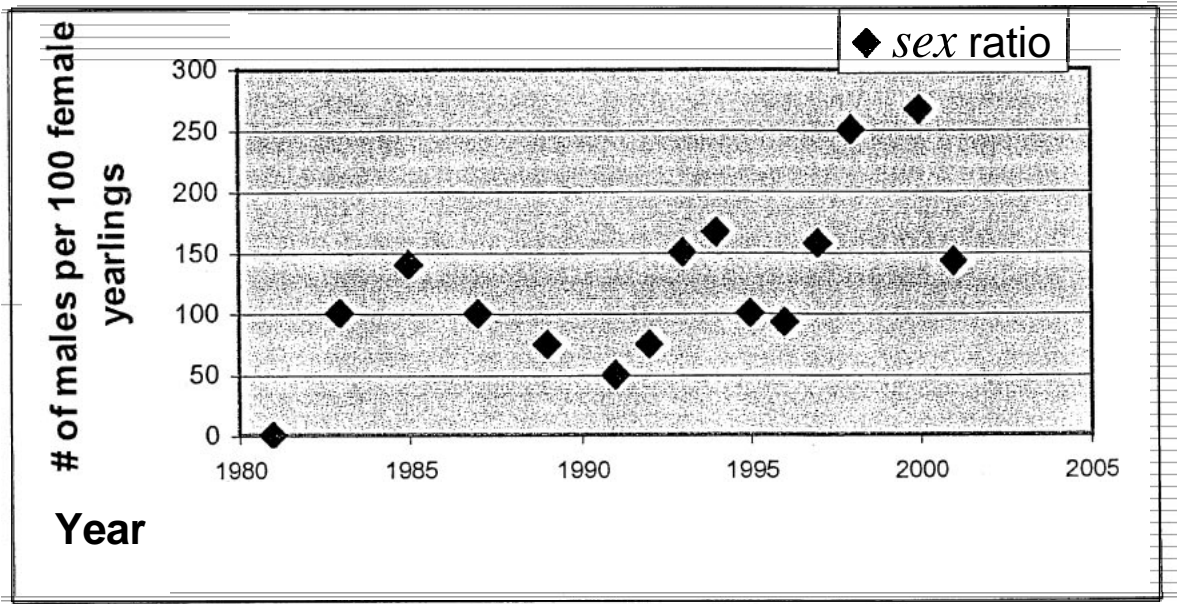


Figure 1. Sex ratio of yearling desert bighorn sheep in the Red Rock captive breeding facility from 1981-2001. Bighorn were provided with supplemental feed from 1981-1992, were not provided with supplemental feed from 1993-1999, and provided with supplemental feed from 2000-2001.

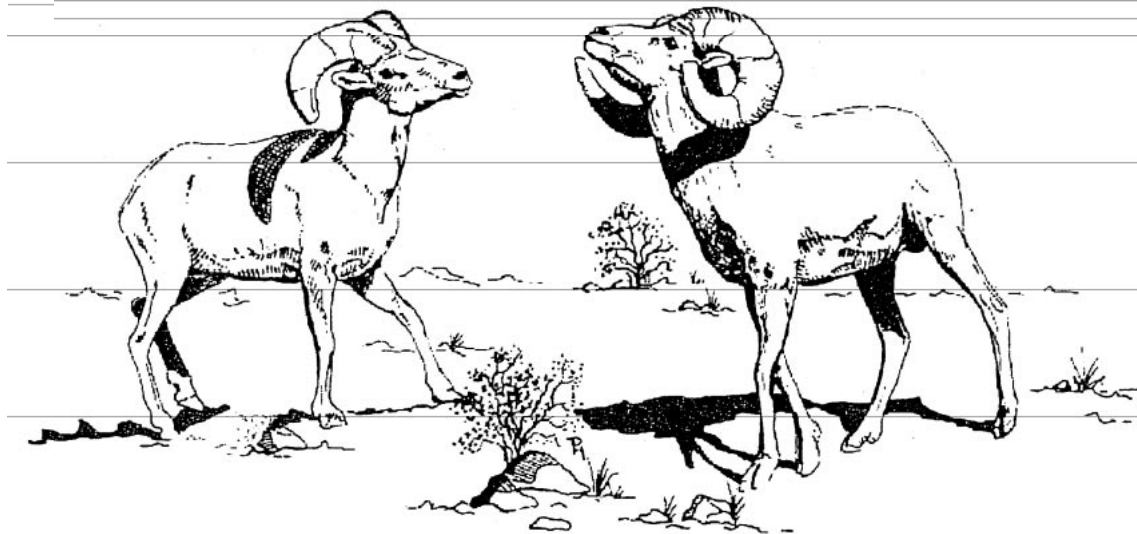
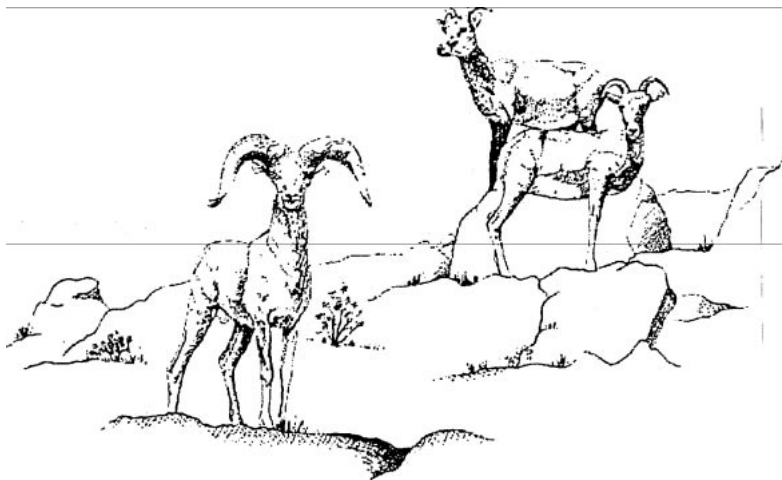


Table 1. Population estimated for desert bighorn sheep populations in New Mexico from 1996-2001.

| Herd | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|----------------|------|------|------|------|------|------|
| Ladron | 35 | 30 | 35 | 30 | 20 | 26 |
| Peloncillo | 50 | 45 | 60 | 55 | 48 | 30 |
| Animas | 15 | 15 | 10 | 10 | 6 | 0 |
| Alamo Hueco | 5 | 5 | 10 | 5 | 1 | 0 |
| Little Hatchet | 30 | 30 | 30 | 30 | 19 | 20 |
| Big Hatchet | 30 | 30 | 30 | 30 | 24 | 20 |
| Fra Cristobal | 33 | 44 | 46 | 53 | 55 | 66 |
| San Andres | 25 | 1 | 1 | 1 | 5 | 4 |
| Total | 221 | 200 | 222 | 214 | 178 | 166 |



PROGRAM



PROGRAM FOR THE 46TH ANNUAL MEETING OF THE DESERT BIGHORN COUNCIL

Palm Springs, California
APRIL 10-12,2002

WEDNESDAY, APRIL 10,2002

- 7:30am** Registration
- 8:30am** Convene the 46th Annual Meeting of the Desert Bighorn Council, Inc.
- 8:35am** Welcome to California
James R. DeForge, **Chair**, Desert Bighorn Council
- 8:45am** Introductions of Attendees
- 9:00am** Keynote Welcome Address
Mark C. Jorgensen, Superintendent, Anza-Borrego Desert State Park
- ~~9:15am~~ Meeting Schedule Announcements
Introduction of Technical Sessions

MORNING SESSION

Session **Chair**:

STATE STATUS REPORTS

- 9:30am** ARIZONA
Jon **Hanna**, Arizona Game and Fish Department
- 9:45am** CALIFORNIA
Steven Torres, California Department of Fish & Game
- 10:00am** COLORADO
- 10:15am** NEVADA
Pat Cummings, Nevada Department of Wildlife
- 10:30am** BREAK



- 11:00am** **NEW MEXICO**
Elise Goldstein, New Mexico Department of Game & Fish, Division of Wildlife
- 11:15am** **TEXAS**
Clay Brewer, Texas Parks and Wildlife
- 11:30am** **UTAH**
Jim Karpowitz, Utah Division of Wildlife Resources
- 11:45am** **MEXICO**
- 12:00pm** **LUNCH**

AFTERNOON SESSION

Session Chair:

TECHNICAL PRESENTATIONS

1:30pm

PREDATION RISK IN DESERT BIGHORN SHEEP

MICHAEL S. MOORING, THOMAS A. FITZPATRICK, TARA T. NISHIHIRA, AND DOMINIC D. REISIG, Department of Biology, Point Loma Nazarene University, San Diego, CA

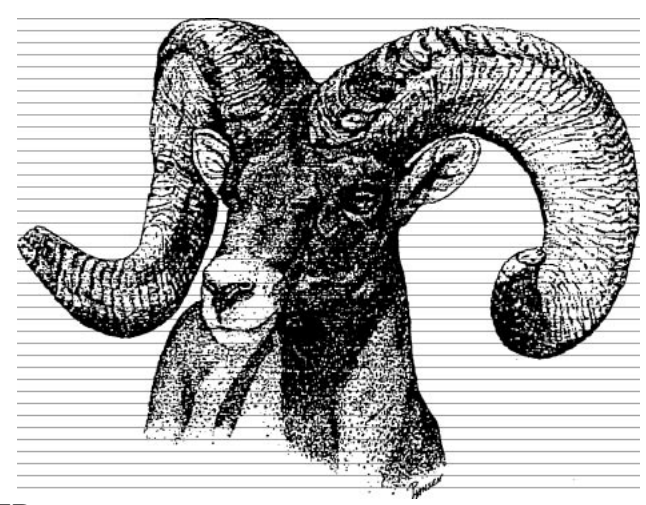
2:00pm

SEXUAL SEGREGATION IN DESERT BIGHORN SHEEP (*OVIS CANADENSIS MEXICANA*)

MICHAEL S. MOORING, THOMAS A. FITZPATRICK, JILL E. BENJAMIN, IAN C. FRASER, TARA T. NISHIHIRA, DOMINIC D. REISIG
Department of Biology, Point Loma Nazarene University, San Diego, CA
ERIC M. ROMINGER
New Mexico Department of Game and Fish, Santa Fe, NM

2:30pm

PENINSULAR BIGHORN SHEEP RECOVERY THE ROLE OF THE U. S. FISH & WILDLIFE SERVICE



PETE SORENSEN, U.S. Fish & Wildlife Service, Carlsbad Field Office, Carlsbad, CA
GUY WAGNER, U.S. Fish & Wildlife Service, Carlsbad Field Office, Carlsbad, CA

3:00pm BREAK

3:30pm

PROGRESS REPORT: CEMEX DESERT BIGHORN SHEEP REESTABLISHMENT PROGRAM

ALEJANDRO ESPINOSA T., Cemex-Direccion de Tecnologia, Independencia 901-A OTE.,
COLONIA CEMENTOS, Monterrey, N.L., Mexico

ANDREW V. SANDOVAL, Borrego Cimarron Wildlife Consulting, PO Box 238, Chacon, NM

RAUL VALDEZ, New Mexico State University, Box 30003; MSC 4901, Las Cruces NM

4:00pm

A FOUR-YEAR STUDY OF CAUSE-SPECIFIC MORTALITY OF DESERT BIGHORN LAMBS NEAR AN URBAN INTERFACE AND A COMMUNITY RESPONSE

JAMES R. DEFORGE, Bighorn Institute, P.O. Box 262, Palm Desert, CA 92261-0262

6:00 pm EVENING BANQUET

Bighorn Institute, Transportation Provided
Dinner and Socializing Till 9:00pm



THURSDAY, APRIL 11TH

MORNING SESSION

8:00am

HOW RELIABLE IS TOOTH CEMENTUM RING AGING FOR BIGHORN SHEEP?

JOHN D. WEHAUSEN, U.C. White Mountain Research Station

CHRISTOPHER J. O'BRIEN, Dental Increment Laboratory, Dept. of Anthropology,
California State University, Chico

DALE R. MCCULLOUGH, Dept. of Environmental Science, Policy, and Management,
U.C. Berkeley

8:30am

POPULATION HISTORY OF BIGHORN SHEEP IN THE SIERRA NEVADA

JOHN D. WEHAUSEN, U.C. White Mountain Research Station

9:00am

**A SIMULATION MODEL FOR EXPLORING DEMOGRAPHIC PROCESSES IN AN
ENDANGERED POPULATION OF BIGHORN SHEEP**

ESTHER S. RUBIN,¹ Department of Veterinary Pathology, Microbiology, and Immunology,
University of California, One Shields Avenue, Davis, CA 95616, USA; and California

Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814, USA

WALTER M. BOYCE, Department of Veterinary Pathology, Microbiology, and Immunology,
University of California, One Shields Avenue, Davis, CA 95616, USA

EDWARD P. CASWELL-CHEN, Department of Nematology, University of California, One
Shields Avenue, Davis, CA 95616, USA

9:30am

**THE DETAILED MOLECULAR GENETICS INVESTIGATIONS OF BIGHORN
SHEEP IN OWENS VALLEY REGION**

ROB R. RAMEY II, U.C. White Mountain Research Station

JOHN D. WEHAUSEN, U.C. White Mountain Research Station

10am BREAK

10:30am

EFFECTS OF CLIMATE CHANGE ON POPULATION PERSISTENCE OF DESERT-DWELLING MOUNTAIN SHEEP IN CALIFORNIA.

EPPS, CLINTON W., University of California, Berkeley
MCCULLOUGH, DALE R., University of California, Berkeley
WEHAUSEN, JOHN D., White Mountain Research Station
BLEICH, VERNON C., California Dept. Fish and Game
RECHEL, JENNIFER L., USDA Forest Service

11:00am

COACHELLA VALLEY RESIDENT SURVEY OF TRAIL USE AND ATTITUDE TOWARDS BIGHORN CONSERVATION

CARRIE MCNEIL, Senate Natural Resources and Wildlife Committee, California State Senate
WALTER BOYCE, Wildlife Health Center, School of Veterinary Medicine, University of California—Davis
JONNA A.K. MAZET, Wildlife Health Center, School of Veterinary Medicine, University of California—Davis
DAVID HIRD, Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California—Davis

11:30am

GENETIC CONSIDERATIONS FOR REINTRODUCING BIGHORN SHEEP TO THE SAN ANDRES MOUNTAINS, NEW MEXICO

WALTER BOYCE, Wildlife Health Center, University of California, One Shields Avenue, Davis, CA 95616, USA
STACEY OSTERMANN, Wildlife Health Center, University of California, One Shields Avenue, Davis, CA 95616, USA
MARA WEISENBERGER, San Andres National Wildlife Refuge, PO Box 756, Las Cruces, NM 88004

12:00pm LUNCH

1:30pm

USE OF GPS/SATELLITE TELEMETRY SYSTEMS IN DESERT BIGHORN SHEEP RESEARCH

JAMES W. CAIN, Graduate Student, Wildlife and Fisheries Science Program, School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721

PAUL R. KRAUSMAN, Wildlife and Fisheries Science Program, School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721,

JOHN R. MORGART, United States Fish and Wildlife Service, Cabeza Prieta National Wildlife Refuge, 1611 North Second Avenue, Ajo, AZ 85321

JOHN J. HERVERT, Arizona Game and Fish Department, 9140 E. 28th Street, Yuma, AZ 85365.

2:00am

SURVIVAL RATES AND CAUSES OF MORTALITY IN A DESERT BIGHORN SHEEP POPULATION ON THE NAVAJO NATION

NIKE J. GOODSON, Bluff, UT

DAVID R. STEVENS, Stevens Wildlife Consulting, Bozeman, MT

JEFF COLE, Navajo Nation Department of Fish and Wildlife, Window Rock, AZ

PAMELA KYSELKA, Navajo Nation Department of Fish and Wildlife, Window Rock, AZ

2:30pm BUSINESS MEETING



CRITERIA FOR DESERT BIGHORN RESEARCH FUNDING FROM THE HANSEN-WELLES SCHOLARSHIP

Eligibility:

1. Any organization or person submitting a project and I or program proposal shall be an active member of the Desert Bighorn Council, or shall be sponsored in writing by an active current member of the Desert Bighorn Council.
2. Proposed projects and / or programs must be for the benefit of desert bighorn sheep, or desert bighorn sheep habitat.
3. Graduate Students must be accepted as an advanced degree candidate at an accredited college or university and have an advisor in an appropriate department (i.e. Wildlife Management, Science, Zoology, etc.).

Submission Requirements :

1. Must have demonstrated desert bighorn experience or be supervised by an individual with such experience.
2. Must submit:
 - a. An acceptable research project outline, Including:
 - i. in-depth literature review,
 - ii. clearly stated objectives,
 - iii. comprehensive research methods,
 - iv. time frame for all work,
 - v. resume of appropriate experience
 - vi. written approval from appropriate state / federal agency
 - vii. complete budget
 - b. A brief critique of the student and proposed project from the student's major professor.
3. Proposals must be submitted to the Desert Bighorn Council Technical Staff Chairman for consideration prior to December 31 of each year. □.
4. Proposals will be screened by the Technical Staff of the Desert Bighorn Council and presented to the membership at the annual business meeting for final selection of the recipient(s). ,
5. Recipients must sign a contractual agreement with the Desert Bighorn Council stating that results of the research project will either be published in a refereed journal and l or presented at the Desert Bighorn Council for inclusion ion the Transactions within a 5-ye a. period following receipt of funds from the Hansen-Welles Scholarship. The Technical Staff of the Desert Bighorn Council will determine acceptability of the publication.

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6. Upon completion of the project and / or program, a complete accounting of the funds expended will be forwarded to the Technical Staff of the Desert Bighorn Council. None of the funds awarded are to be used for administrative purposes by the sponsoring college, university, or agency, or for travel to meetings.

SUGGESTED RESEARCH PROPOSAL OUTLINE:

-
1. **TITLE:** A concise, clear, and specific description of the proposed research.
 2. **APPLICANT:** Name, address, and telephone number of applicant plus signatures of pertinent people; i.e. advisor, sponsor.
 3. **TIME PERIOD:** Proposed initiation and completion dates for the project.
 4. **OBJECTIVES:** A clear, concise, and complete presentation of primary research objectives.
 5. **INTRODUCTION:** An in-depth presentation of the research, including an extensive review of the pertinent literature.
 6. **METHODS AND PROCEDURES:** A statement of working plans, methods to be used, or experimental design.
 7. **JUSTIFICATION:** A description or statement as to the importance for the proposed research, and qualifications of the principal investigator(s) to undertake the project. Include what would be lost if the project is not funded.
 8. **FACILITIES AND EQUIPMENT:** A list of facilities and / or equipment needed and available.
 9. **BUDGET:** Amount requested from Council and amount needed for entire proposal.
 10. **PERSONNEL:** A list of qualified persons assisting or supporting the applicant.
 11. **PUBLICATION:** Potential journals or other publications in which anticipated results from the proposed research might be published.

DESERT BIGHORN COUNCIL MEETINGS 1957 - 2002

| Year | Location | Chairperson | Secretary | Treasurer | Transactions Editor |
|------|----------------------------|---------------------------------|-----------------|-----------------|------------------------------|
| 1957 | Las Vegas, NV | M. Clair Albous | | | |
| 1958 | Yuma, AZ | Gale Monson & Warren Kelly | | | |
| 1959 | Death Valley, CA | M. Clair Albous | Fred Jones | Fred Jones | |
| 1960 | Las Cruces, NM | Warren Kelly | Fred Jones | Fred Jones | |
| 1961 | Hermosillo, MX | Jon Akker | Ralph Welles | Ralph Welles | |
| 1962 | Grand Canyon, AZ | James Blaisdell | Charles Hansen | Charles Hansen | Charles Hansen & L. Fountein |
| 1963 | Las Vegas, NV | Al Jonez | Charles Hansen | Charles Hansen | Jim Yoakum |
| 1964 | Mexicali, MX | Rudolfo Corzo | Charles Hansen | Charles Hansen | Charles Hansen & D. Smith |
| 1965 | Redlands, CA | John Goodman | John Russo | John Russo | Jim Yoakum |
| 1966 | Silver City, NM | Cecil Kennedy | John Russo | John Russo | Jim Yoakum |
| 1967 | Kingman, AZ | Claude Lard | John Russo | John Russo | Jim Yoakum |
| 1968 | Las Vegas, NV | Ray Brechbill | John Russo | John Russo | Jim Yoakum |
| 1969 | Monticello, UT | R & B. Welles | W. G. Bradley | W. G. Bradley | Jim Yoakum |
| 1970 | Bishop, CA | William Graf | W. G. Bradley | W. G. Bradley | Jim Yoakum |
| 1971 | Santa Fe, NM | Richard Weaver | Tillie Barling | Tillie Barling | Jim Yoakum |
| 1972 | Tucson, AZ | George Welsh | Doris Weaver | Doris Weaver | Charles Hansen |
| 1973 | Hawthorne, NV | Warren Kelly | Doris Weaver | Doris Weaver | Juan Spillet |
| 1974 | Moab, UT | Carl Mahon | Lanny Wilson | Lanny Wilson | Juan Spillet |
| 1975 | Indio, CA | Bonnar Blong | Lanny Wilson | Lanny Wilson | Charles Hansen |
| 1976 | Bahia Kino, MX | Mario Luis Cossio | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1977 | Las Cruces, NM | Jerry Gates | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1978 | Kingman, AZ | Kelly Neal | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1979 | Boulder City, NV | Bob McQuivey | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1980 | St. George, UT | Carl Mahon | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1981 | Kerrville, TX | Jack Kilpatric | Peter Sanchez | Peter Sanchez | Charles Hansen |
| 1982 | Borrego Sprs., CA | Mark Jorgensen | Rick Brigham | Rick Brigham | Charles Hansen |
| 1983 | Silver City, NM | Andrew Sandoval | Rick Brigham | Rick Brigham | Charles Hansen |
| 1984 | Bullhead City, AZ | Jim deVos, Jr. | Rick Brigham | Rick Brigham | Charles Hansen |
| 1985 | Las Vegas, NV | David Pullman, Jr. | Rick Brigham | Rick Brigham | Charles Hansen |
| 1986 | Page, AZ | Jim Guymon | Bill Dunn | Bill Dunn | Paul Krausman |
| 1987 | Van Horn, TX | Jack Kilpatric | Bill Dunn | Bill Dunn | Paul Krausman |
| 1988 | Needles, CA | Vernon Bleich | Don Armentrout | Don Armentrout | Paul Krausman |
| 1989 | Grand Junction, CO | Jerry Wolfe | Don Armentrout | Don Armentrout | Paul Krausman |
| 1990 | Hermosillo, MX | Raul Valdez | Don Armentrout | Don Armentrout | Paul Krausman |
| 1991 | Las Cruces, NM | Bill Montoya | Don Armentrout | Don Armentrout | Paul Krausman |
| 1992 | Bullhead City, AZ | Jim deVos, Jr. | Stan Cunningham | Stan Cunningham | Paul Krausman |
| 1993 | Mesquite, NV | Kathy Longshore | Charles Douglas | Charles Douglas | Walter Boyce |
| 1994 | Moab, UT | Jim Guymon | Charles Douglas | Charles Douglas | Walter Boyce |
| 1995 | Alpine, TX | Doug Humphries | Charles Douglas | Charles Douglas | Ray Boyd |
| 1996 | Holtville, CA | Andy Pauli | Charles Douglas | Charles Douglas | Ray Boyd |
| 1997 | Grand Junction, CO | Dale Reed & Van Graham | Steve Torres | Charles Douglas | Raymond Lee |
| 1998 | Las Cruces, NM | Eric Rominger & Dave Holdermann | Danen Divine | Charles Douglas | Raymond Lee |
| 1999 | Reno, NV | Rick Brigham & Kevin Hurley | Darren Divine | Charles Douglas | Allen and Harriet Thomas |
| 2000 | Bullhead City, AZ | Ray Lee & Jim deVos | Darren Divine | Charles Douglas | Jon Hanna |
| 2001 | Hermosillo, Sonora, Mexico | Carlos Castillo & Jim de Vos | Darren Divine | Charles Douglas | Jon Hanna |
| 2002 | Palm Springs, CA | Mark Jorgensen | Darren Divine | Charles Douglas | Jon Hanna |

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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, and case histories and notes provide for philosophical presentations and the presentation of ideas and concepts. These papers are also peer reviewed. Additional papers may be published when reviewed and approved by the Editorial Board. Papers must be submitted to the Editor within 1 year of the Council's annual meeting to be considered for the current edition of the *Transactions*.

COPY: Use good quality white paper 215 x 280 mm (8.5 x 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 **Guidelines for Authors and Reviewers of *Wildlife Society Bulletin* manuscripts** (<http://www.wildlife.org/publications/bulletinguidelines.pdf>), or the CBE Style Manual Committee 1994.

TITLE: The title should be concise, descriptive, and 100 words. Use vernacular names of organisms.

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

ACKNOWLEDGEMENTS: Include acknowledgements 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.

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