DESERT BIGHORN COUNCIL TRANSACTIONS

Desert Bighorn Council

50

Conserving Desert Bighorn sheep for 50 years

VOLUME 49 2007

Editor's Note – Desert Bighorn Council's 50th Anniversary

In 1957, the first meeting of the Desert Bighorn Council was held in Las Vegas, NV. To commemorate the 50 years of research and management, the Desert Bighorn Council again met in Las Vegas in 2007. These *Desert Bighorn Council Transactions* are the official record of that meeting.

I did not attend the 1957 inaugural meeting of the Desert Bighorn Council. The first meeting I attended was held in Page, AZ in 1986. I attended regularly during my graduate years while studying bighorn sheep, but after the 1989 meeting in Grand Junction, CO, I was unable to attend other meetings as I was preoccupied studying the other charismatic megafauna: wild turkeys. In fact, I did not return to another meeting until 2003 in St. George, UT when I agreed to serve as the editor of the *Transactions*.

On returning to the Desert Bighorn Council Meetings, I was at first surprised at the number of familiar faces that had been returning for the entire length of time I had been away. Many of those faces had been quite intimidating to me as a graduate student when I was presenting results of research in which I had been involved; Dick Weaver, John Wehausen, Rick Brigham, and Vern Bleich are only a few of the names that had been involved in landmark management and research activities, and they were well respected. I was certain that my underfunded research, which could have benefited from better planning, would get me laughed off the speaker's platform. Quite the opposite, constructive criticism and encouragement is what I received.

With every passing year, and each subsequent volume of the *Transactions*, we learn more about bighorn sheep conservation. I am impressed with the advances wildlife science has made, yet substantial basic knowledge is still lacking in some arenas. Studies continue to fill in the knowledge gaps. And we continue to discover things we need to learn more about.

After 50 years, there is much the same as in the early days. We are still encouraging each other to get the most from the data we collect. We continue to break new ground and learn more about relationships we once believed were well understood. We are also learning to deal with new challenges to bighorn sheep management that have not been considered before. The Desert Bighorn Council was vital to sharing knowledge and identifying needs 50 years ago. I believe that it will still play that same role in another 50 years.

As you read the papers in this volume, I encourage you to reflect on the past while looking toward the future.

-- Brian Wakeling

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2007

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Invited Paper
Desert bighorn sheep management: reflecting on the past and hoping for the future

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Abstract This paper is a compilation of comments made by an invited panel of experts at the Desert Bighorn Council meetings in Las Vegas on Thursday, April 5, 2007. The experts were asked to speak on the topic of bighorn sheep (*Ovis canadensis*) management from the past and into the future. The panel included Rick Brigham (Bureau of Land Management), John Wehausen (White Mountain Research Station), Eric Rominger (New Mexico Department of Game and Fish), Alejandro Espinosa (Desert Bighorn Restoration Program, CEMEX), and Todd Esque (USGS Western Ecological Research Center) because of their diversity and breadth of experience. Three of these experts agreed to collaborate on a written commentary.

Desert Bighorn Council Transactions 49:1–7

William R. Brigham.—I will reflect on the past–what the Desert Bighorn Council (Council) has accomplished, and what I see as opportunities for the future, based on my perspective as 1 of the older members of this group.

From the *historical perspective*, the annual and now biennial *meeting rotation* has worked very well, because it has allowed many biologists, particularly agency biologists, to attend meetings in-state, where they would not otherwise have been able to attend due to difficulties associated with out-of-state travel. This continually changing mix of people has helped better this group's overall understanding of desert bighorn sheep and their role in desert ecosystems because of the exchange of ideas, including anecdotal information from non-technical people, such as wildlife management area staff.

The *actual mechanism* leading to the deaths of many bighorn sheep from some form of pneumonia following nose-to-nose contact with domestic sheep (and goats) continues to elude us. I have been listening to discussions about what we do *not* know about that mechanism for >35 years. I believe, however, that we are much closer to the answer now with Sri Srikumaran, a top-notch researcher occupying the Rocky Crate Foundation for North American Wild Sheep endowed chair at Washington State University at Pullman, WA. I sat through 1 of Sri's discussions the year before last, and even I, as a retired field biologist, learned much. I believe the Council would be well served to have him as a speaker at our next meeting. Perhaps by then he will have learned the entire process. Then we can show and tell the woolgrowers exactly what happens, because they currently assert that there is no hard evidence that contacts with domestics lead to the deaths of bighorn sheep, regardless of university experiments and reams of anecdotal cases of these occurrences, dating all the way back to the 1800s.

The Council has done well with its written and published stands on such issues as feral burros and embryo transfer, and publishing "*Desert bighorn habitat requirements and management recommendations*" (Wilson et al. 1980) in the 1980 *Desert Bighorn Council Transactions*. It also did very well, at the request of the Bureau of Land Management (BLM) in 1989, in putting together guidelines for the management of domestic sheep in bighorn sheep habitat, published in the 1990 *Desert Bighorn Council Transactions* (Technical Staff 1990). This publication led to the adoption of these guidelines as advisory policy in 1992, followed by required policy for the field offices in 1995. The BLM policy was revisited and renewed in 1998. These guidelines within that BLM policy are fixed, and address such things as spatial separation between domestic and bighorn sheep. They thus differ from the U. S. Forest Service approach, which uses collaboration with local domestic sheep grazers.

Management of bighorn sheep and bighorn sheep habitat in wilderness areas continues to perplex and annoy because habitat improvements such as water developments, low-level monitoring flights, and the rights of states to manage native wildlife are verboten in the eyes of many land management agency wilderness personnel. The key to overcoming these obstacles lies in the *wording* of the enabling legislation which established each wilderness area. If *management wording* was inserted, then management can be done (usually after a battle with local wilderness specialists). If not, nothing will be done. The Council and Council members should follow proposed wilderness legislation and provide appropriate management wording input. Council members must be aware not only of the legislative process, but the use of politics as well. In Nevada, for example, after federal legislation established 11 wilderness areas in the north central part of the state (and eliminated the cherry-stemmed access roads into what were then wilderness study areas), the citizenry through the organized *Conservation Coalition* was able to have the cherry stems reestablished (by federal law) through pressure on Nevada's senior senator. It involved working directly with that senator's local office managers and resource specialists. The task took 6 months, but it got done.

For the future, the Council should focus on 2 things: outreach and mentoring. The first to me means better educating the public and ourselves about desert bighorn sheep, where they fit into our world view, and what positively (and negatively) affects them. A better job of educating the public, including domestic sheep grazers, must be done. There is a good opportunity to do this by updating the 1980 bighorn sheep habitat recommendations treatise (Wilson et al. 1980), particularly the sections on *Interactions with Other Animals* (specifically information on disease and transmission) and *Livestock Grazing*. The entire revision, besides being published in a future volume of the *Desert Bighorn Council Transactions*, could be published as a brochure and made available to the public, schools, game and fish agencies, and land management agencies. It could be posted on the Council's web site. Second, there is much anecdotal information about desert bighorn sheep and their habitat, as observed by many non-technically trained personnel, such as those who work on established wildlife management areas, and those who make their living in the field either by grazing livestock or by guiding people to hunt or photograph. These people should be encouraged to share their experiences and knowledge through the *Desert Bighorn Council Transactions*. These types of papers are accepted as opinions, comments, and case histories in complement to the technical papers and state status reports. Based on my experience, technically trained people stand to learn much if presentation and documentation of information from non-technically trained individuals is encouraged. I would like to see a session at the next Council meeting devoted solely to anecdotal information.

Last, I would like to discuss something which is done very little: *mentoring*. There are many in the Council presently who are either retired or who are close to retirement. Looking back (and ahead) reveals that the numbers of biologists to fill in behind us is dwindling. Take the BLM for example: 3 recently retired biologists who focused on bighorn sheep in their careers–Don Armentrout, Joe Cresto, and me–are being replaced by only 1 person in 1 BLM district–Pam Riddle, a protégée of Joe Cresto. The BLM Washington Office has been questioned from within recently about this very topic: who will continue the BLM bighorn sheep program? Who will serve on a BLM task force or working group? As of now, only Pam Riddle from the Moab, UT Field Office comes to mind. This is not a good omen because so much bighorn sheep habitat occurs on BLM-managed land. The same is occurring in other agencies throughout the west: who will replace Vern Bleich? Or Bruce Zeller? Or Mark Jorgensen? There is a definite need to find and mentor potential bighorn sheep biologists: those men and women who have the passion, perseverance, and love of bighorn sheep to continue desert bighorn sheep management. The situation within this Council is also illustrative: there were only 2 applications for Hansen-Welles funds, and indication of the lack of interest in the megafauna that are desert bighorn sheep. In my opinion, the biologists from all agencies who do succeed us old hands must not only be technically trained and have as much field (and anecdotal) experience as possible, but they must also have the people skills to work with outside groups, primarily sportsmen, like the Foundation for North American Wild Sheep, Nevada Bighorns, and the Arizona Desert Bighorn Sheep Society. It is these groups who pay for most of the bighorn sheep programs, regardless of whether they are translocations, equipment purchases, or water developments. Most state wildlife and land management agencies could not have accomplished what has been done in the past 25 years without the outside help and funding from these groups. The Council has the opportunity, with its growing number of retired and soon-to-retire bighorn sheep biologists, to mentor new and not-so-new bighorn sheep biologists. The question is how, when, and where? Council meetings are a great place to start, but they are only a start. Another place would be a registry of retired bighorn sheep biologists on the Council's web site. The registry would need current contact information so that agency biologists and students could delve into the wealth of information stored in experienced minds.

Eric Rominger.—In the grand scheme of things, being provincial is not generally considered to be a good thing. However, I think there are valid reasons for provincial attitudes among people across the range of desert bighorn sheep. That is because 1 size does not fit all situations. This pertains to survey methodology and correction factors, predator control, artificial water sources, habitat models, and myriad other issues. My perceptions regarding these issues will certainly differ from other biologists in other areas. One dominating factor is the very different human populations across the range of desert bighorn sheep today. For example nearly 30 million people live in California, whereas only 2 million people live in New Mexico. The every day issues relating to desert bighorn sheep are magnified by high densities of *Homo sapiens*. Let's look at a short list of important issues across the range of desert bighorn sheep.

(1) Under-occupancy. Although the successes of state wildlife agencies in the restoration of desert bighorn sheep are numerous, virtually all states have but a fraction of the potential desert bighorn sheep ranges occupied. Two states in Mexico, Nuevo Leon and Chihuahua, have no wild desert bighorn sheep, and Coahuila just reestablished the first wild population since extirpation. Two U.S. states, of which I am aware, have reported potential and current population estimates which are 75–80% below projected maximums. In some instances this is under-occupancy in large ranges and in others it is the complete absence of desert bighorn sheep. Although lots of work has been done, it is clear that lots of work needs to be done to restore desert bighorn sheep into all potential habitats.

Of concern is the recent decline in wild herds that have historically provided much of the translocation stock including the Kofa and Black ranges in Arizona. I am only aware of 3 captive breeding facilities that are producing bighorn sheep at levels able to start new populations. Two of these are in Mexico, the Pilares facility in Coahuila and the La Guarida facility in Chihuahua; the third is the Red Rock facility in New Mexico. Tiburon Island and Isla Carmen in the Sea of Cortez are currently functioning as natural breeding facilities. Predation is an insignificant mortality factor on these islands. These insular populations will be integral to the restoration of populations on mainland Mexico. The potential to begin restoration of desert bighorn sheep in Coahuila, Chihuahua, and Nuevo Leon will be extremely important to the biodiversity of these desert regions.

(2) Predation. Historical reviews of the role of predation on desert bighorn sheep dynamics barely mention mountain lions (*Puma concolor*) as predators of concern (Desert Bighorn Council 1957, Blaisdell 1961). Only in the last 20–25 years have we seen the potential effect of a recovered mountain lion population on desert bighorn sheep (Wehausen 1996, Creeden and Graham 1997, Hayes et al. 2000, Ernest et al. 2002, Kamler et al. 2002, Rominger et al. 2004). We ignore the seminal work of Wehausen and others at the peril of desert bighorn sheep populations. In my mind it has become a bigger issue at each succeeding meeting of the Desert Bighorn Council and research should be addressing this. Mountain lions can drive small, isolated populations of desert bighorn sheep to extinction and if we as wildlife managers allow it…that is called wildlife "watching" not wildlife "management."

(3) Disease. Pneumonia remains the principal killer that can set restoration programs back decades. It seems that for less catastrophic diseases (e.g., blue-tongue), desert bighorn sheep are able to recover much more quickly. I do not think we will develop a "silver-bullet" for stopping the cross-transmission of pneumonia from domestic sheep to wild sheep. We never have come up with a vaccine for the human bacterial disease gonorrhea which for some reason I think might just precede a vaccine for pneumonia in bighorn sheep.

Because of the new endowed chair position at Washington State University, I think we are finally going to be able to shed additional light on this issue that profoundly affects the restoration effort. I would encourage all those who manage wild sheep to look at ways they might be able to assist in the future research efforts at WSU. My personal opinion is that selection for bighorn sheep with resistance to pneumonia will ultimately play a role in the west-wide restoration of wild sheep.

(4) Other Issues. Other controversial issues that are important today and may become more important tomorrow include the positive and/or negative roles of fire, water, and designated wilderness rules in bighorn sheep habitat. I am certain that desert bighorn sheep managers will have plenty to keep them busy for the foreseeable future.

Alejandro Espinosa T.—I will present primarily an overview of the management and conservation of the desert bighorn sheep in Mexico**.** In Mexico, desert bighorn sheep occurred geographically and numerically widespread throughout the northern states of Baja California, Baja California Sur, Sonora, Chihuahua, Coahuila, and Nuevo Leon, but apparently have been extirpated from the vast region of northeastern Mexico, encompassing Chihuahua, Coahuila, and Nuevo Leon.

(1) Conservation measures. The first protective legislation intended specifically for the conservation of wildlife in Mexico was enacted in 1894. By the early 1900s, however, numerous populations of desert bighorn sheep had been hunted to extinction, particularly in Nuevo León. Concern over the decline of desert bighorn sheep populations prompted the federal government to establish a 10-year prohibition on hunting desert bighorn sheep in 1922. The prohibition was extended for another decade in 1933, and declared permanent in 1944. Because the public was ill informed about the laws, and because there were no penalties enforcing them, poaching remained unabated. Corruption at various levels of the government exacerbated the problem.

The prohibition on hunting desert bighorn sheep was lifted in 1964, with the authorization of 100 permits/year at the national level. Between 1977 and 1982, the annual average was 114 permits. Between 1980 and 1989, 625 bighorn sheep hunting permits were issued for Sonora, with a hunter success rate of 75%. This resulted in a harvest of 469 bighorn or about 47/year . In Baja California Sur, 111 sheep were harvested between 1978 and 1993. Permits issued gradually declined from 24 to 6 per year. Concern regarding excessive harvest, illegal take, and reported decline of desert bighorn sheep in Baja California resulted in the cessation of all bighorn sheep hunting by Mexican Presidential decree in 1990 until accurate population estimates could be obtained and evaluated. This ban remains in place today.

In 2000, the Wildlife General Law was enacted with profound implications. The objectives of this law are to establish partnerships between federal, state, and county governments, to provide local governments authority to manage wildlife within their jurisdiction, and to encourage social participation in the use and conservation of wildlife and its habitat. The law provides a new approach for wildlife and habitat management through the establishment of the Wildlife Management and Conservation Unit system (UMA). The UMA system objectives are to restore, protect, maintain, allow for the reproduction and sustain the use of wildlife and its habitat.

The UMA system allows an individual landowner to construct an enclosed facility for the captive propagation of wildlife. By 2006, 26 UMAs had been established specifically for desert bighorn sheep in Sonora and contained >700 desert bighorn sheep. UMAs Pilares in Coahuila and La Guarida in Chihuahua contained >120 animals by 2006.

Several state governments, namely Coahuila, Chihuahua, Sonora and Nuevo Leon, obtained the jurisdiction for wildlife management in 2005, and created their own state wildlife agencies. Sonora and Chihuahua created their state programs specifically for the conservation and management of desert bighorn sheep, and Coahuila and Nuevo Leon area following the same direction.

(2) Protection. Although wildlife resources are federal property and currently are managed by the federal government, almost all of the land is under private ownership. The federal government is discouraging the illegal take of bighorn sheep by implementing stiff penalties and increased surveillance in bighorn sheep areas. Certain areas, namely Sierra Maderas del Carmen Protected Area, Coahuila, Isla del Carmen, Baja California Sur, El Pinacate Biosphere Reserve, Sonora, and El Vizcaino Biosphere Reserve, Baja California Sur offer special protection for desert bighorn sheep by restricting conflicting land use practices.

(3) Restoration. Translocations have been used as the primary management tool for restoring bighorn sheep populations in the western United States, Canada, and, more recently, Mexico. In 1975, New Mexico Game and Fish personnel assisted Mexican officials in the capture of 20 desert bighorn sheep (16 ewes and 4 rams) from the Sonora mainland and the subsequent release on Isla Tiburon located in the Sea of Cortez. This translocation was highly successful, with a current population estimate of >600. Since 1998, >300 animals have been removed from Isla Tiburon for reestablishing new populations in mainland Sonora, Coahuila, and Chihuahua.

During 1995 and 1996, 30 desert bighorn sheep were captured in the Punta El Mechudo area of Baja California Sur. Twenty-six sheep (22 ewes and 4 rams) survived and were released on Isla del Carmen located in the Sea of Cortez. This transplant was successful, with sheep well distributed in the 3 mountain chains that characterize the island. The main objective of this project is to maintain a genetically and demographically viable population from which progeny may be used to enhance wild populations by augmenting remnant wild populations or restoring populations that have been extirpated in Baja California Sur. Since 2005, >30 bighorn sheep have been captured on Isla del Carmen and released on the mainland in Baja California Sur.

Between 2000 and 2002, 48 desert bighorn sheep (37 ewes and 11 rams) were translocated from Sonora to the 5,000 ha Sierra Pilares UMA in northern Coahuila for captive propagation purposes. In 2004, 24 desert bighorn sheep (11 ewes and 13 rams) were captured in the UMA Yaqui, Sonora and released directly into the wild in Sierra Maderas del Carmen, Coahuila This release represents the first free-ranging population of desert bighorn sheep in Coahuila in >30 years. Desert bighorn sheep from Sonora have also been used to establish a captive population in UMA La Guarida located in northeastern Chihuahua.

Literature Cited

BLAISDELL, J. A. 1961. Bighorn-cougar relationships. Desert Bighorn Council Transactions. 5:42–46a.

CREEDEN, P. J., AND V. K. GRAHAM. 1997. Reproduction, survival, and lion predation in the Black Ridge, Colorado National Monument desert bighorn herd. Desert Bighorn Council Transactions 41:37–43.

DESERT BIGHORN COUNCIL TRANSACTIONS–PANEL. 1957. Predation. Desert Bighorn Council Transactions 1:43–50.

ERNEST, H. B., E. S. RUBIN, AND W. M. BOYCE. 2002. Tracking mountain lion predation of desert bighorn sheep with fecal DNA. Journal of Wildlife Management 66:75–85.

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 Peninsular Ranges, California. Journal of Wildlife Management 64:954–959.

KAMLER, J. F., R. M. LEE, J. C. DEVOS, JR., W. B. BALLARD, AND H. A. WHITLAW. 2002. Survival and cougar predation of translocated bighorn sheep in Arizona. Journal of Wildlife Management 66:1267–1272.

ROMINGER, E. M., H. A. WHITLAW, D. L. WEYBRIGHT, W. C. DUNN, AND W. B. BALLARD. 2004. The influence of mountain lion predation on bighorn sheep translocations. Journal of Wildlife Management 68:993–999.

TECHNICAL STAFF, DESERT BIGHORN COUNCIL. 1990. Guidelines for the management of domestic sheep in the vicinity of desert bighorn habitat. Desert Bighorn Council Transactions 34:33–35.

WILSON, L. O., J. BLAISDELL, G. WELSH, R. WEAVER, R. BRIGHAM, W. KELLY, J. YOAKUM, M. HINKS, J. TURNER, AND J. DEFORGE. 1980. Desert bighorn habitat requirements and management recommendations. Desert Bighorn Council Transactions 24:1–7.

WEHAUSEN, J. D. 1996. Effect of mountain lion predation on bighorn in the Sierra Nevada and Granite Mountains of California. Wildlife Society Bulletin 24:471–479.

William R. (Rick) Brigham *is a retired biologist with the Bureau of Land Management. Rick spent much of his career in an attempt to further the knowledge and management of bighorn sheep. Rick has served on the Technical Staff of the Desert Bighorn Council for many years, and continues to serve in the capacity even in retirement.* ***Eric M. Rominger*** *received a B. S. in Wildlife Biology from the University of Arizona, a M. S. in Wildlife Biology from Colorado State University, and a Ph. D. in Zoology from Washington State University. Since 1996 Eric has worked on bighorn sheep in New Mexico and is currently a bighorn sheep biologist for the New Mexico Department of Game and Fish. Much of his work in New Mexico has dealt with mountain lion predation on endangered desert bighorn sheep. Prior to that, he worked for 11 years on endangered Selkirk woodland caribou in Idaho, Washington, and British Columbia as a wildlife biologist for the U. S. Fish and Wildlife Service and subsequently as a doctoral candidate at Washington State University.* ***Alejandro Espinosa-T.*** *is a biologist from the Biological Science Faculty in the Universidad Autonoma de Nuevo León in Mexico and a PhD Candidate in wildlife management and sustainable development in the same University. Since 1994, he has been involved in research and wildlife restoration projects in north Mexico. His main professional interest is wildlife management in arid ecosystems. From 2000 to the present, he coordinates the CEMEX Desert Bighorn Sheep Restoration Program.*

Bighorn sheep use of a developed water in southwestern Arizona

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Abstract Documentation of bighorn sheep (*Ovis canadensis*) use of developed and natural water sources often has been anecdotal or of short duration. In order to better understand the pattern and amount of such use, we used remote videography to monitor a wildlife water development on the Kofa National Wildlife Refuge, Arizona for 12,422 hours between July 2002 and November 2005. We observed 2,529 bighorn sheep in 1,423 visits. Bighorn sheep visited the water 10 months of the year (April–January), with 74% of visits occurring June–August. Sheep of both sexes and all age classes were observed, with adult ewes and rams being most common. Mean weekly visits by bighorn sheep were correlated with mean weekly temperature ($r = 0.5$, $n = 174$, $P < 0.001$). Bighorn sheep use of the water development was primarily diurnal (80% of sheep recorded), whereas mule deer (*Odocoileus hemionus*) use was primarily nocturnal (87% of deer recorded). Visits to the water development by adult male and female bighorn sheep were similar in 9 of 10 months; the greatest difference occurred during June when more females visited the water development than did males. Bighorn sheep typically visited the water development individually (65% of visits), though groups ranging from 2–14 were commonly observed (35% of visits). Visits to the water development usually lasted $\leq$5 minutes (77% of visits), and 73% of the visits resulted in at least 1 bighorn sheep in the group drinking. Bighorn sheep visiting the water development interacted with other bighorn sheep, mule deer, bobcats (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), Cooper's hawk (*Accipiter cooperii*), and turkey vulture (*Cathartes aura*); however, no instances of predation were observed. While limited to a single site, our results provide new insight into watering patterns of desert bighorn sheep, including nocturnal visits and frequent use outside the hot-dry summer period.

Desert Bighorn Council Transaction 49:8–17

Keywords behavior, *Ovis canadensis*, Sonoran Desert, video monitoring, wildlife water development

Wildlife biologists and managers have used a variety of techniques to monitor use of water by desert bighorn sheep, including direct observation (e.g., waterhole counts; Blong and Pollard 1968, Turner 1970, Cunningham and Ohmart 1986), time-lapse photography (Helvie 1972, Leslie and Douglas 1980, Campbell and Remington 1979, Bleich 1997), and digital web-based photography (Locke et al. 2005). Although these studies delineated certain aspects of bighorn use of waters, observations were limited in duration and scope, with most activity recorded during daylight hours of the hot-dry summer months. Documentation of nocturnal use (Miller et al. 1984) and seasonal variations in activity at water by desert bighorn sheep has been largely anecdotal. No previous study has undertaken 24-hour, year-round monitoring of a developed water source (O'Brien et al. 2006) used by this species.

To better evaluate desert bighorn use of developed waters, we quantified activity at a developed water source via remote, time-lapse videography for >3 years. Our objectives were to record frequency and timing of visits by bighorn sheep, behavioral interactions and other activities that occurred at the water source, and assess the influence of weather variables (temperature and humidity) on visitation rates.

Study area

We conducted our study on the 2,693 km^2 Kofa National Wildlife Refuge (KNWR) in southwestern Arizona (Figure 1). Topography was diverse and typical of the Sonoran Desert section of the Basin and Range physiographic province; the area consisted of rugged mountain ranges, bajadas, broad valleys, and dry washes (Chronic 1983). The Lower Colorado River Valley (LCRV) subdivision of Sonoran desertscrub was the dominant plant community at our study site and included creosote bush (*Larrea tridentata*), palo verde (*Parkinsonia* spp.), ironwood (*Olneya tesota*), mesquite (*Prosopis* spp.), and smoketree (*Psorothamnus spinosa*; Turner and Brown 1994). Long-term average annual precipitation at the nearest weather station (Kofa Mine, 543-m elevation; Western Regional Climate Center 1952–2005) was 17.63 cm. Mean daily minimum (January) and maximum (July) temperatures at this station were 8.1 and 39.8 º C, respectively.

We installed a remote videography system at Adam's Well, a windmill-powered well in the Castle Dome Mountains of southern KNWR. The well was at 568 m elevation and located next to a major wash adjacent to rugged upland used by bighorn sheep. We chose this water because it had been operational for a long period of time (>40 yrs), had relatively little human disturbance, and was heavily used by bighorn sheep (Arizona Game and Fish Department, unpublished data).

Methods

Remote videography and weather monitoring.—We installed a custom, remote videography system made from commercially available components (O'Brien et al. 2006) in July 2002. We mounted a 2.9 mm focal length, black-and-white surveillance video camera (#CB-01, Opticom Technologies, Inc., Burnaby, B.C., Canada) approximately 2.5 m above ground level beneath a shade cover mounted over the water trough. The camera provided a view of the drinker and immediate surrounding area, with approximately 44-m² and 36-m² fields-of-view (area in which animals could be identified and activities could be discerned) during daylight and nighttime hours, respectively. To facilitate nighttime viewing, we installed a 12-volt infrared illuminator (#IRI-2060, Scopus Inc., Naples, Fla., U.S.) adjacent to the camera. We housed a 168-hour time-lapse videocassette recorder (VCR; Sony #SVT3050 or #SVT168R, Sony Corporation of America, New York, N.Y., USA) and

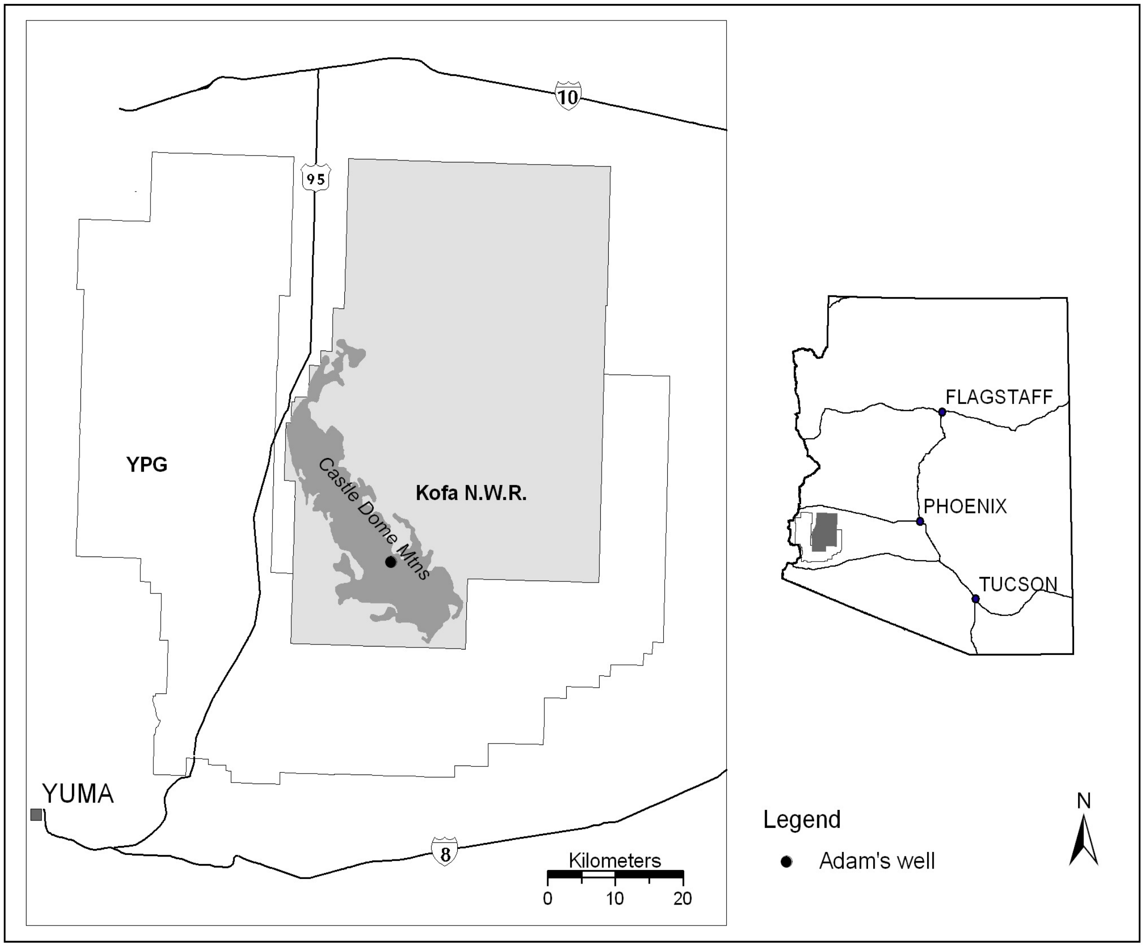

Figure 1. Study area where we monitored bighorn sheep use of a water development via remote, time-lapse videography, Kofa National Wildlife Refuge, Arizona, July 2002–November 2005.

associated system electronics in a below-ground, insulated metal box ≤3 m from the camera. The video camera, infrared illuminator, timer, and VCR were powered by 2 12-volt, 90 amp-hr gel cell batteries (#SG-90, Trojan Battery Company, Santa Fe Springs, Calif., USA) recharged by 2 75-watt solar panels (#SP75, Siemens Solar Industries, Camarillo, Calif., USA) and a 20-amp charge controller (Sunsaver #20L, Morningstar Corporation, Washington Crossing, Pa., USA). Power for the VCR (110V AC) was provided through a 50-watt inverter (#PW-50, Statpower Notepower, Xantrex Technology, Burnaby, B.C., Canada). The VCR recorded 1 frame/second for approximately 75 consecutive hours each week (1700 hrs Monday through 2030 hrs Thursday) onto 160-hr VHS videocassettes. To reduce battery drain, we used a timer (#DIGI 42E, Grasslin Controls, Inc., Mahwah, N.J., USA) to turn off power to the system when not in use. We changed videocassettes every 3 weeks after 3 consecutive surveillance periods. We mounted a HOBO Pro™ weather data logger (#H08-032-08; Onset Computer Corporation, Pocasset, Massachusetts, USA) next to the trough, 1.5-m above ground level, which recorded hourly temperature and relative humidity. We installed a rain gauge adjacent to the water development and recorded precipitation levels on a bi-weekly basis. Video and weather data recording systems were operational from July 2002–November 2005.

Video processing.—Observers watched videos on a 2-speed VCR setting, which resulted in 1 real time hour passing during 1 minute of review. When animals entered the field-of-view, the observer paused the tape and reviewed it at a slower speed or advanced it frame-by-frame. We recorded date, entry and exit times, species, minimum group size, and activities of humans, bighorn sheep, mule deer, and mammalian predators and considered each record an "event." We defined entry time as the first frame when part of an animal other than the shadow was visible and the exit time as the last frame when a part of an animal of the same species was visible. If >10 seconds passed between the exit time of the last animal and the entry time of an individual of the same species, we recorded a new event. We considered group size to be a minimum estimate because animals would enter and exit the field-of-view and individuals often could not be identified. We added the largest number of animals seen in 1 frame of the event plus additional identifiable individuals to determine total group size. For example, if the largest group of bighorn sheep seen in 1 frame during an event was 5 ewes, but a ram was also recorded during the event, total group size was 6. We identified the following activities: approaching (entered field of view but did not drink), drinking, bathing, foraging, predation, and behavioral interactions with conspecifics and other species. We took additional notes to describe other behavior or activities of interest. We classified sheep by sex and age class and further categorized adult males into classes (I–IV) based on horn size (Geist 1968).

Data analysis.—We used descriptive statistics to summarize patterns of bighorn sheep use on an hourly, daily, or monthly basis. For interspecific comparison, we summarized patterns of mule deer use on an hourly basis. We determined the relative occurrence of behaviors and intra- and inter-specific interactions by bighorn sheep. We calculated weekly mean temperatures and relative humidity from weather data collected by the HOBO weather station and, where needed, filled gaps with measurements from a weather station approximately 36 km away on the U.S. Army Yuma Proving Ground. We used semi-partial correlation (StatSoft 2004) to examine relationships between weekly visits of bighorn sheep and mean weekly relative humidity and temperature. We selected the semi-partial correlation because it controls for the effect of additional predictor variables and measures the correlation between each predictor variable and the dependent variable. The squared semi-partial correlation represents the amount of total variance of the dependent variable that is accounted for by each predictor variable (StatSoft 2004).

Results

We recorded 12,422 hrs of video and observed 2,529 bighorn sheep in 1,423 separate visits. Bighorn sheep visited the water development 10 months of the year (April–January), with 74% of visits occurring June–August; no visits were documented February–March. Visits were primarily by adult females (44.1%) and adult males (32.4%), followed by lambs (6.8%), yearling females (6.6%), unidentifiable bighorn sheep (6.5%), and yearling males (3.6%). Bighorn sheep visits increased as mean weekly temperature increased (r = 0.5, n = 174, P < 0.001); however, there was no correlation with weekly relative humidity (r = 0.004, n = 174, P = 0.953; Figure 2). Bighorn sheep use of the water development was primarily diurnal (80% of sheep recorded), peaking at 0800 hours (12% of sheep recorded) and decreasing through the day, with a slight increase in activity at 1800 hours (Figure 3). In contrast, mule deer use was primarily nocturnal (87% of 3,529 deer recorded; Figure 3), peaking at 2000 hours (11% of deer recorded) and decreasing through the night, with activity dropping precipitately after 0700 hours. Nocturnal visits by bighorn sheep were minimal (20% of visits), but occurred at all hours during the night (Figure 3). Visits to the water development by adult female bighorn sheep were similar to adult males for 9 of 10 months; during June, we documented the greatest difference in visitation numbers with more females visiting the water development than males (Figure 4). Class III and IV rams visited the water development May–January, with highest visits July–August and lowest visits December–January (Figure 5). Bighorn sheep visits consisted of groups of >1 individual (range = 2–14) 35% of the time.

We witnessed no predation or attempted predation events involving bighorn sheep. Visits typically lasted ≤5 minutes (77% of visits), though on 2 occasions a total of 8 bighorn sheep loitered at the drinker for >60 minutes. Seventy-three percent of visits (n = 1,044) involved at least 1 bighorn sheep drinking, whereas bathing and foraging were rare (<1% of visits). Two hundred visits (14%) involved interactions, including 95 (6%) and 111 (8%) visits with intra- and inter-specific interactions, respectively; 6 of 200 visits (<1%) involved both intra- and inter-specific interactions. Interspecific interactions occurred with mule deer (n = 104 visits), bobcats (n = 2 visits), a Cooper's hawk, a grey fox, a turkey vulture, and unknown animals (n = 2 visits). Interactions included kicking, pushing, chasing, or mating behavior between bighorn sheep, lambs nursing or attempting to nurse from ewes, 2 species drinking simultaneously, 1 species startled by another species' arrival at the drinker, and 1 species deterred from approaching because of another species' presence at the drinker.

Discussion

Remote videography has been used to monitor nest predation (Thompson et al. 1999, Liebezeit and George 2002) and activity (Kristan et al. 1996), record animal behavior (London et al. 1998), and monitor site visitations by animals (Shivik and Gruver 2002). We found videography likewise suitable for quantifying desert bighorn sheep use of a water source. Our system functioned reliably in high summer temperatures >44°C and allowed more intensive data collection and less potential disturbance (e.g., flash) than triggered still cameras commonly placed at water sources. We caution, however, that videotape data require extensive post-processing, which can be labor-intensive and requires concentration and attention to detail while performing highly repetitive tasks.

We observed similar seasonal patterns of water use by bighorn sheep as reported in previous studies (e.g., McQuivey 1978; Campbell and Remington 1979; Simmons 1978, 1990). Use was heaviest from May–September, with peak activity in July. Visitation decreased after July, likely in response to decreasing temperatures and precipitation events associated with summer monsoon activity. Male and female bighorn sheep had similar monthly visitation rates, except during June, when adult ewes visited the water development more often than rams. This likely was due to increased physiological water demand during lactation (Turner and Weaver 1990). Visits by

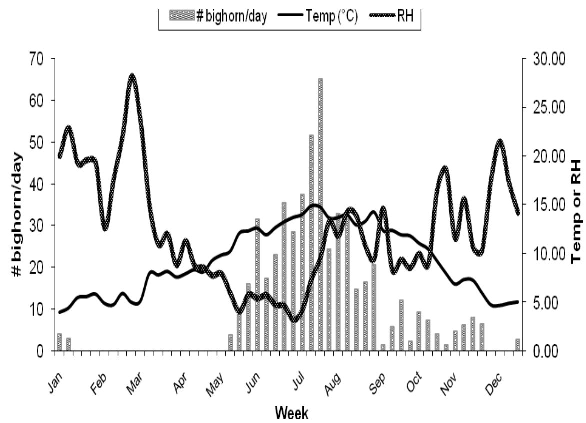

Figure 2. Bighorn sheep visits to a water development in relation to mean temperature and relative humidity, Kofa National Wildlife Refuge, Arizona, July 2002–November 2005.

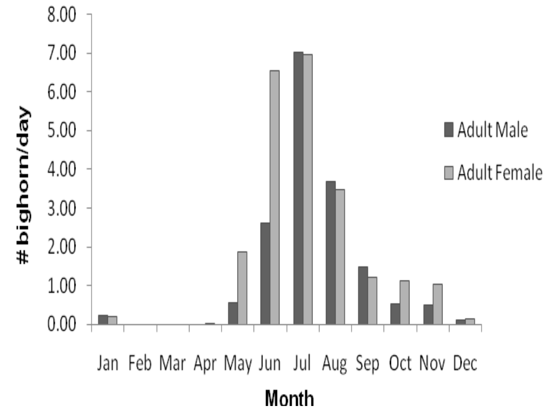

Figure 4. Visits by adult male and female bighorn sheep per month to a water development, Kofa National Wildlife Refuge, Arizona, July 2002–November 2005.

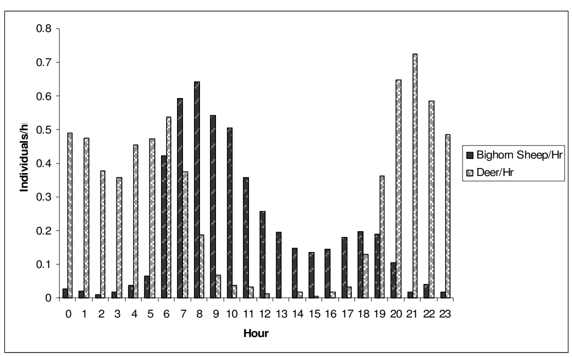

Figure 3. Hourly visits at a water development by bighorn sheep and mule deer, Kofa National Wildlife Refuge, Arizona, July 2002–November 2005.

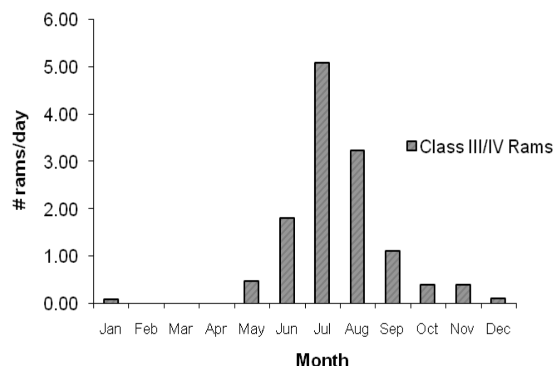

Figure 5. Visits by Class III and IV bighorn sheep rams per month to a water development, Kofa National Wildlife Refuge, Arizona, July 2002–November 2005.

mature males aged 6–16 years old (class III and IV rams) paralleled those of other bighorn sheep that visited our study site. In general, we documented little to no bighorn sheep use of the water development during fall-winter months. One notable exception was unusually high sheep use from August 2000–January 2003, a period characterized by extremely dry conditions and well-below average precipitation during the preceding winter and summer monsoon.

We recorded bighorn sheep visits during all hours of the day, with the greatest number of visits occurring between 0600–1000 hours and a smaller peak between 1700–1900 hours. Use at night was minimal and occurred primarily during summer months, likely to reduce metabolic heat gain and stress (Simmons 1969). Similar temporal patterns of water use by bighorn sheep have been reported in other Arizona studies (Simmons 1964, Simmons 1969, Campbell and Remington 1979).

Heavy diurnal use of the water development by bighorn sheep contrasted with heavy nocturnal use by mule deer; O'Brien et al. (2006) also documented heavy nocturnal use of water developments by mule deer. Bighorn sheep activity peaked approximately 2 hours after peak mule deer activity during morning hours and then approximately 2 hours before peak mule deer activity during evening hours. While both species occasionally visited the water development simultaneously, our results suggest temporal partitioning of this important resource.

Predation events involving bighorn sheep were not recorded during video observations. While the camera had a limited field-of-view, we examined the area surrounding the water development for evidence of predation during each bi-weekly visit. These searches likewise found no signs of bighorn sheep predation events. A previous study in Arizona (Cunningham and deVos 1992) documented predation on bighorn sheep near water sources by coyotes (*Canis latrans*) and mountain lion (*Puma concolor*). Coyotes were common visitors to our study site, and we observed 1 mountain lion during video observations, though we believed them to be uncommon and largely transient in this area during the study. We hypothesize that the observed lack of predation on desert sheep reflected the low incidence of predation on large mammals at wildlife water developments (O'Brien et al 2006) and low density of the primary predator (mountain lion).

Management Implications

Our scope of inference is constrained by having only 1 study site. It represented a typical location for a desert bighorn sheep water development and did not have unusual characteristics expected to cause different patterns of use than at other water developments in the Sonoran Desert. With these caveats in mind, we consider our results generally applicable to southwestern Arizona and possibly other portions of the Sonoran Desert.

Our video camera observations have implications for users of triggered, still-cameras, which are commonly placed at water developments. Still-cameras commonly trigger during an animals' approach, creating uncertainty as to whether or not the water source was actually used. Our results suggest that most bighorn sheep recorded approaching a water source can safely be assumed to have consumed water. If sampling periods are constrained and one wishes to sample activity at a water source used by bighorn sheep and mule deer, we recommend operation from 0600–1200 hrs, a period encompassing activity peaks for both species.

Development of water sources is a widely used but often controversial wildlife management practice (Rosenstock et al. 1999, Krausman et al. 2006). We contend that water developments are important for conservation of desert bighorn sheep in arid regions, given the widespread loss or degradation of natural water sources, recurrent drought, and predictions for increased aridity due to climate change (Epps et al. 2004). Water is a critical limiting factor for desert bighorn sheep; reduced availability of water can affect lamb survival (Turner and Weaver 1990), and drying of water sources has been linked to mortalities of adult animals (Dolan 2006). Water developments in desert bighorn sheep habitat should be monitored and maintained to ensure reliable provision of water during the May-August period of peak use and into fall and early winter months during extreme drought. Desert bighorn make heavy use of water developments; however, the ultimate importance of water developments remains unknown. We recommend further research on the water physiology of free-ranging desert bighorn during critical periods, including estimates of the proportion of body water obtained from freestanding sources (e.g., water developments) versus preformed water contained in forage plants.

In recent years, critics have suggested that wildlife water developments can adversely affect desert bighorn sheep (Broyles 1995, Broyles and Cutler 1999) and various interest groups have filed administrative and legal challenges to water development projects. A recent lawsuit (Wilderness Watch, Inc. and Arizona Wilderness Coalition v. U.S. Fish and Wildlife Service) alleged that water developments on KNWR would make desert bighorn sheep more vulnerable to hunters, who would presumably ambush animals at these facilities. However, our results do not support this assertion. The Arizona desert bighorn sheep hunt typically occurs during December, a period during which developed waters receive minimal use by mature rams.

Acknowledgements.—This project was supported by a Pittman-Robertson Federal Aid in Wildlife Restoration State Trust Grant to the Arizona Game and Fish Department and funds provided by the U.S. Army, Yuma Proving Ground Conservation Program. Authors thank staff of the Kofa National Wildlife Refuge for logistical and field support, particularly R. Kearns, S. Henry, R. Varney, and P. Cornes. Special thanks to K. Ogren for her diligence and attention to detail in video-tape processing.

Literature Cited

BLEICH, V. C., R. T. BOWYER, AND J. D. WEHAUSEN. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs 134:1–50.

BLONG, B., AND W. POLLARD. 1968. Summer water requirements of desert bighorn in the Santa Rosa Mountains, California, in 1965. California Fish and Game 54:289–296.

BROYLES, B. 1995. Desert wildlife water developments: questioning use in the Southwest. Wildlife Society Bulletin 23:663–675.

BROYLES, B., AND T. L. CUTLER. 1999. Effect of surface water on desert bighorn sheep in the Cabeza Prieta National Wildlife Refuge, southwestern Arizona. Wildlife Society Bulletin 27:1082–1088.

CAMPBELL, B. H., AND R. REMINGTON. 1979. Bighorn use of artificial water sources in the Buckskin Mountains, Arizona. Desert Bighorn Council Transactions 23:50–56.

CHRONIC, H. 1983. Roadside geology of Arizona. Mountain Press Publishing Company, Missoula, Montana, USA.

CUNNINGHAM, S. C., AND J. C. DEVOS, JR. 1992. Mortality of mountain sheep in the Black Canyon area of northwest Arizona. Desert Bighorn Council Transactions 36:27–29.

CUNNINGHAM, S. C., AND R. D. OHMART. 1986. Aspects of the ecology of desert bighorn sheep in Carrizo Canyon, California. Desert Bighorn Council Transactions 30:14–19.

DOLAN, B. F. 2006. Water developments and desert bighorn sheep: implications for conservation. Wildlife Society Bulletin 34:642–646.

EPPS, C. W., D. R. MCCULLOUGH, J. D. WEHAUSEN, V. C. BLEICH, AND J. L. RECHEL. 2004. Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology 18:102–113.

Geist, V. 1968. On the interrelation of external appearance, social behaviour and social structure of mountain sheep. Zeitschrift für Tierpsychologie 25:199–215.

HELVIE, J. B. 1972. Census of desert bighorn sheep with time-lapse photography. Desert Bighorn Council Transactions 16:3–6.

KRAUSMAN, P. R., S. S. ROSENSTOCK, AND J. W. CAIN III. 2006. Developed waters for wildlife: science, perception, values, and controversy. Wildlife Society Bulletin 34:561–567.

KRISTAN, D. M., R. T. GOLIGHTLY, JR., AND S. M. TOMKIEWICZ, JR. 1996. A solar-powered transmitting video camera for monitoring raptor nests. Wildlife Society Bulletin 24:284–290.

LESLIE, D. M., JR., AND C. L. DOUGLAS. 1980. Human disturbance at water sources of desert bighorn sheep. Wildlife Society Bulletin 8:284–290.

LIEBEZEIT, J. R., AND T. L. GEORGE. 2002. Comparison of mechanically egg-triggered cameras and time-lapse video cameras in identifying predators at dusky flycatcher nests. Journal of Field Ornithology 74:261–269.

LOCKE, S. L., M. D. CLINE, D. L. WETZEL, M. T. PITTMAN, C. E. BREWER, AND L. A. HARVESON. 2005. From the field: a web-based digital camera for monitoring remote wildlife. Wildlife Society Bulletin 33:761–765.

LONDON, G. D., K. L. BAUMAN, AND C. S. ASA. 1998. Time-lapse infrared videography for animal behavior observations. Zoo Biology 17:535–543.

MCQUIVEY, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Department of Fish and Game, Biological Bulletin No. 6, Reno, Nevada, USA.

MILLER, G. D., M. H. COCHRAN, AND E. L. SMITH. 1984. Night-time activity of desert bighorn sheep. Desert Bighorn Council Transactions 28:23–25.

O'BRIEN, C. S., R. B. WADDELL, S. S. ROSENSTOCK, AND M. J. RABE. 2006. Wildlife use of water catchments in southwestern Arizona. Wildlife Society Bulletin 34:582–591.

ROSENSTOCK, S. S., W. B. BALLARD, AND J. C. DEVOS, JR. 1999. Viewpoint: Benefits and impacts of wildlife water developments. Journal of Range Management 52:302–311.

SIMMONS, N. M. 1964. A desert bighorn study: part two. Desert Bighorn Council Transactions 8:103–112.

SIMMONS, N. M. 1969. Heat stress and bighorn behavior in the Cabeza Prieta Game Range, Arizona. Desert Bighorn Council Transactions 13:55–63.

SIMMONS, N. M. 1980. Behavior. Pages 124–144 *in* G. Monson and L. Sumner, editors. The desert bighorn: its life history, ecology and management. University of Arizona Press, Tucson, Arizona, USA.

SHIVIK, J. A., AND K. S. GRUVER. 2002. Animal attendance at coyote trap sites in Texas. Wildlife Society Bulletin 30:502–507.

STATSOFT. 2004. Electronic Statistics Textbook. Available online at http://www.statsoft.com/textbook/stathome.html (Accessed 14 August 2007).

THOMPSON, F. R., III, W. DIJAK, AND D. E. BURHANS. 1999. Video identification of predators at songbird nests in old fields. Auk 116:259–264.

TURNER, J. 1970. Water consumption of desert bighorn sheep. Desert Bighorn Council Transactions 15:189–197.

TURNER, R. M., AND D. E. BROWN. 1994. Sonoran Desertscrub. Pages 181–221 *in* D. E. Brown, editor. Biotic communities: southwestern United States and northwestern Mexico. University of Utah, Salt Lake City, Utah, USA.

TURNER, J. C., AND R. A. WEAVER. 1980. Water. Pages 100–112 *in* G. Monson and L. Sumner, editors. The desert bighorn: its life history, ecology and management. University of Arizona Press, Tucson, Arizona, USA.

VALDEZ, R., AND P. R. KRAUSMAN. 1999. Description, distribution, and abundance of mountain sheep in North America. Pages 3–22 *in* R. Valdez and P. R. Krausman, editors. Mountain sheep of North America. University of Arizona Press, Tucson, Arizona, USA.

WESTERN REGIONAL CLIMATE CENTER. 1952–2005. Arizona climate summaries. Available online at http://www.wrcc.dri.edu/summary/climsmaz.html (accessed 23 October 2007).

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Mortality of bighorn sheep along U.S. Highway 191 in Arizona

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Abstract Highways have been shown to be a significant source of mortality for wildlife and can fragment habitat, thereby reducing suitability and productivity. Because 92 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were killed in vehicle collisions on a 13-km stretch of U. S. Highway 191 near Clifton-Morenci, Arizona, we investigated patterns in collision frequency to determine potential mitigation options. The bighorn sheep population near Clifton-Morenci provides hunting opportunity and serves as source stock for translocations that expand Arizona's bighorn sheep population. Vehicle collisions occur more frequently in hot, dry months, and ewes were disproportionately more involved in collisions than rams or lambs. A 5-km section of the highway had more vehicle collisions than other portions, although all sections have a relatively high rate of collision. Physical barriers, such as fencing, with structures to facilitate crossing are the best solutions to reducing highway mortality. Mitigating actions that include increasing water and forage distribution may reduce highway collisions with bighorn sheep, but will not reduce further fragmentation of the habitat.

Desert Bighorn Council Transactions 49:18–22

Key Words bighorn sheep, highway mortality, mitigation, *Ovis canadensis*, vehicle collision

Highways have been characterized as a predominate factor that influences wildlife habitat fragmentation in the United States (Noss and Cooperrider 1994, Trombulak and Frissell 2000, Dodd et al. 2007*a*). For bighorn sheep (Cunningham et al. 2003), highway mortality was a significant mortality factor in some habitats. High mortality reduces population growth, limits hunting opportunities, and reduces numbers for translocation source stock.

In Arizona, Rocky Mountain bighorn sheep occupy habitat in the Eagle Creek drainage and surrounding areas that include the Freeport McMoRan Mine, Inc. (FMI) copper extraction operations near Clifton-Morenci in southern Game Management Unit (Unit) 27 and northern Unit 28 (Figure 1). The bighorn sheep population in this area is relatively abundant, and population is estimated at about 250–300 bighorn sheep (Arizona Game and Fish Department, unpublished data). The bighorn sheep use the mine because of increased water and forage availability. Decreased risk of mortality from predators, including

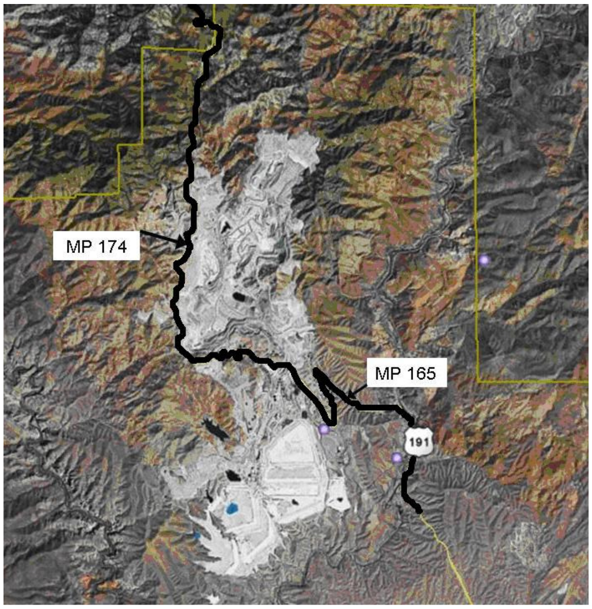

Figure 1. Aerial view of active mine and U. S. Highway 191 in Game Management Unit 28, Arizona.

mountain lion (*Puma concolor*), probably plays a role in the occupation of the mine as well. The Arizona Game and Fish Department, in cooperation with Freeport Mine and the Arizona Desert Bighorn Sheep Society, have used this population as source stock for translocations to other areas (Wakeling 2005). Unit 28 is open to bighorn sheep hunting, offering about 6 permits annually.

Despite the apparent benefits associated with living near active mining operations, a large number of bighorn sheep have been involved in collisions with vehicles along U. S. Highway 191 that bisects the mine and much of the occupied habitat beyond the mining operations. Occasionally, bighorn sheep are killed on the active mine due to collisions with mining equipment, but the primary anthropogenic mortality factor is highway collisions. Our objective was to evaluate vehicle collision patterns to determine if location or season directly influenced bighorn sheep mortality.

Methods

We investigated collisions reported by the public, law enforcement, Arizona Department of Highways, and FMI mine personnel between bighorn sheep and vehicles on U. S. Highway 191 from August 2001 to February 2007. For each confirmed collision, we recorded age (adult or lamb), gender, and mile post at which the collision occurred. We examined mortality patterns graphically and with chi-square contingency tables (Zar 1984).

Results

We confirmed that 92 bighorn sheep (68 adult females, 14 adult males, 7 female lambs, 3 male lambs) were killed in vehicle collisions between August 2001 and February 2007, or about 17 per year, between mile posts 165 and 173 on U.S. Highway 191. Ratios of rams:ewes:lambs killed on highways (20:100:15) did not reflect ratios observed in surveys (46:100:40; Arizona Game and Fish Department 2007), indicating that ewes were killed in vehicle collisions at a disproportionately higher rate than rams or lambs ($\chi^2 = 20.60$, 2 df, $P < 0.01$).

Mortalities did not occur uniformly from mile post 165 to 173 ($\chi^2 = 31.54$, 7 df, $P < 0.01$). Mortalities exceeded the uniform distribution between mile posts 168 to 171, but were less than uniform between mile posts 165 to 166 and 171 to 173 (Figure 2). Bighorn sheep mortalities between mile posts 166 to 168 were roughly equivalent to a uniform distribution of mortalities (Figure 3).

Mortalities along U.S. Highway 191 demonstrated a seasonal pattern as well, with 52% (48 of 92) occurring between May and August, although another 10 mortalities occurred in October (Figure 4). Mortalities during the months of January, February,

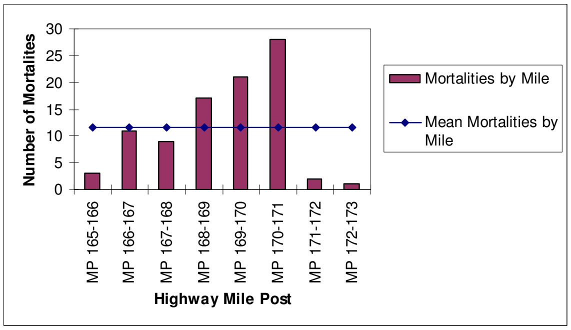

Figure 2. Frequency and mean bighorn sheep mortalities by mile along U. S. Highway 191 from August 2001 to February 2007.

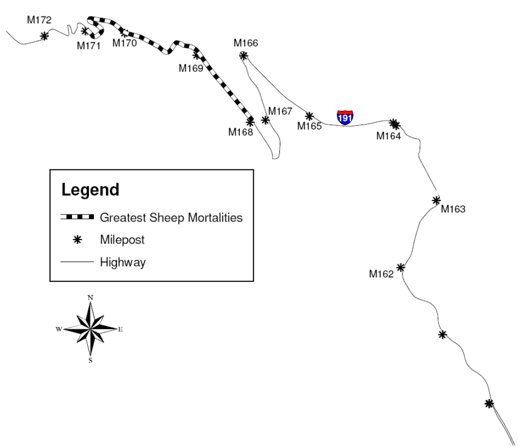

Figure 3. Stretch of U. S. Highway 191 where greatest mortality rate for bighorn sheep resulted from vehicle collisions from August 2001 to February 2007.

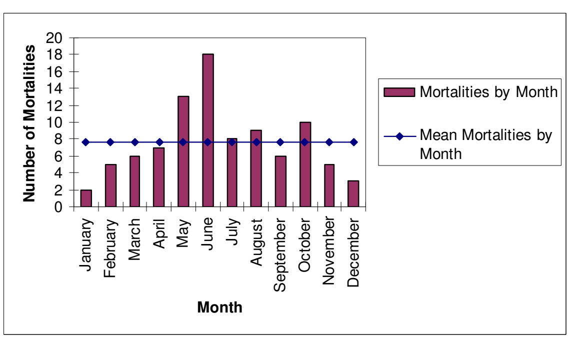

Figure 4. Frequency and mean bighorn sheep mortalities by month along U. S. Highway 191 from August 2001 to February 2007.

March, September, November, and December were less, although this pattern did not differ significantly from a uniform distribution ($\chi^2 = 12.98$, 11 df, $P = 0.29$)

Discussion

We documented a high rate of vehicle collisions with bighorn sheep along U.S. Highway 191. Cunningham et al. (2003) found desert bighorn sheep along U.S. Highway 93 in northwestern Arizona crossed predominately in late summer and fall. In their 2-year study, 25 bighorn sheep were killed crossing this highway, averaging 12.5 deaths per year. Cunningham et al. (2003) noted that fewer mortalities occurred along straight sections of roadway, despite the apparent higher vehicle speeds on straighter roads. In our study, vehicles speeds generally seemed to be relatively low (<70 kph) over most stretches of highway because of the curves associated with U. S. Highway 191. Higher vehicle speed does not seem to be a predictor of bighorn sheep vehicle collision mortality.

In our study, bighorn sheep were involved in more collisions during hot or dry periods than in cooler or wetter periods. Cunningham et al. (2002) found a similar, although not identical, distribution of highway mortalities for bighorn sheep in northwestern Arizona. Waddell et al. (2007) demonstrated desert bighorn sheep visited a water source more frequently during periods of high temperature substantially more so than in periods with low temperature, and bighorn sheep movement in our study may increase during periods of greater temperature or lesser rainfall in an effort to acquire necessary resources. Periods when forage or water is limited seems to increase mortality for bighorn sheep associated with highways.

Factors that influence likelihood for collision include age, gender, and group size

(Singer 1978). Because out study did not include radiomarked individuals or observational data, our only comparison was with observed ratio data collected during October aerial surveys of the overall game management unit. Based on that information, adult ewes were more likely to be involved in vehicle collisions. Ewes have greater biological demand for water consumption when nursing lambs, although lactation tends to occur for a shorter period (2 months) than the time frame over which we observed increased mortality.

Vehicular activity on the mine did not appear to influence bighorn sheep movement patterns to a large degree, as many crossing occurred in proximity to active mining efforts. Bighorn sheep exhibit substantial individual heterogeneity in responses to disturbance (Papouchis et al. 2001), yet most sheep near mines seem habituated to vehicular activity. During this study, bighorn sheep were observed crawling under an active conveyor belt moving ore between areas. These sheep had to crawl under the moving belt on their knees; twenty-two sheep did so in single file. In other studies, bighorn sheep have changed activity periods to avoid disturbance (Cambell and Remington 1979, 1981). However, vehicular traffic may be less disturbing than people on foot (MacArthur et al. 1982).

Mitigation measures to reduce wildlife collisions with vehicles include highway fencing, construction of crossing structures, habitat alteration adjacent to roadways, and placement of alternate water and mineral sources (Clevenger et al. 2001, Dodd et al. 2007*a*). Fencing as a mitigation measure can be expensive and a barrier if not constructed with wildlife crossings to minimize barrier effects (e.g., Dodd et al. 2007*b*). Even with crossing structures to improve highway permeability to wildlife movement, fencing can result in increased vehicle collisions at the terminal ends of the fencing (Clevenger et al. 2001) or from entrapment within fenced sections.

Increasing water or forage availability on both sides of a highway may prove useful in reducing highways crossings, but may not entirely eliminate the propensity for individual sheep from choosing to exploit habitats that require highway crossing. Elimination of metabolic need to cross highways or enforcing limited movements by fencing will increase the fragmentation of bighorn sheep habitat. Fencing with wildlife crossings to facilitate permeability is probably the most viable option to minimizing highway mortality on this bighorn sheep population.

Literature Cited

Arizona Game and Fish Department. 2007. Hunt Arizona. 2007 edition. Arizona Game and Fish Department, Phoenix, USA.

Campbell, B. H., and R. R. Remington. 1979. Bighorn use of artificial water sources in the Buckskin Mountains, Arizona. Desert Bighorn Council Transactions 23:50–56.

Campbell, B., and R. Remington. 1981. Influence of construction activities on water-use patterns of desert bighorn sheep. Wildlife Society Bulletin 9:63–65.

Cunningham, S. C., L. Hanna, and J. Sacco. 2003. Possible effects of the realignment of U. S. Highway 92 on movements of desert bighorns in the Black Canyon Area. Proceedings of the Biennial Conference of Research on the Colorado Plateau 1:83–100.

Dodd, N. L., J. W. Gagnon, S. Boe, and R. E. Schweinsburg. 2007*a*. Assessment of elk highway permeability by using global positioning system telemetry. Journal of Wildlife Management 71:1107–1117.

Dodd, N. L., J. W. Gagnon, A. L. Manzo, and R. E. Schweinsburg. 2007*b*. Video surveillance to assess highway underpass use by elk in Arizona. Journal of Wildlife Management 71:637–645.

MacArthur, R. A., V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351–358.

NOSS, R. F., AND A. Y. COOPERRIDER. 1994. Saving nature's legacy. Island Press, Washington, D. C., USA.

PAPOUCHIS, C. M., F. J. SINGER, AND W. B. SLOAN. 2001. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management 65:573–582.

SINGER, F. J. 1978. Behavior of mountain goats in relation to U. S. Highway 2, Glacier National Park, Montana. Journal of Wildlife Management 42:591–597.

TROMBULAK, S. C., AND C. A. FRISSELL. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18–30.

WADDELL, R. B., C. S. O'BRIEN, AND S. S. ROSENSTOCK. 2007. Bighorn sheep use of a developed water in southwestern Arizona. Desert Bighorn Council Transactions 49:

WAKELING, B. F. 2005. Status of bighorn sheep in Arizona, 2004–2005. Desert Bighorn Council Transactions 48:50–52.

ZAR, J. H. 1984. Biostatistical analysis. Second edition. Prentice-Hall, Inc., Englewood Cliffs, NJ, USA.

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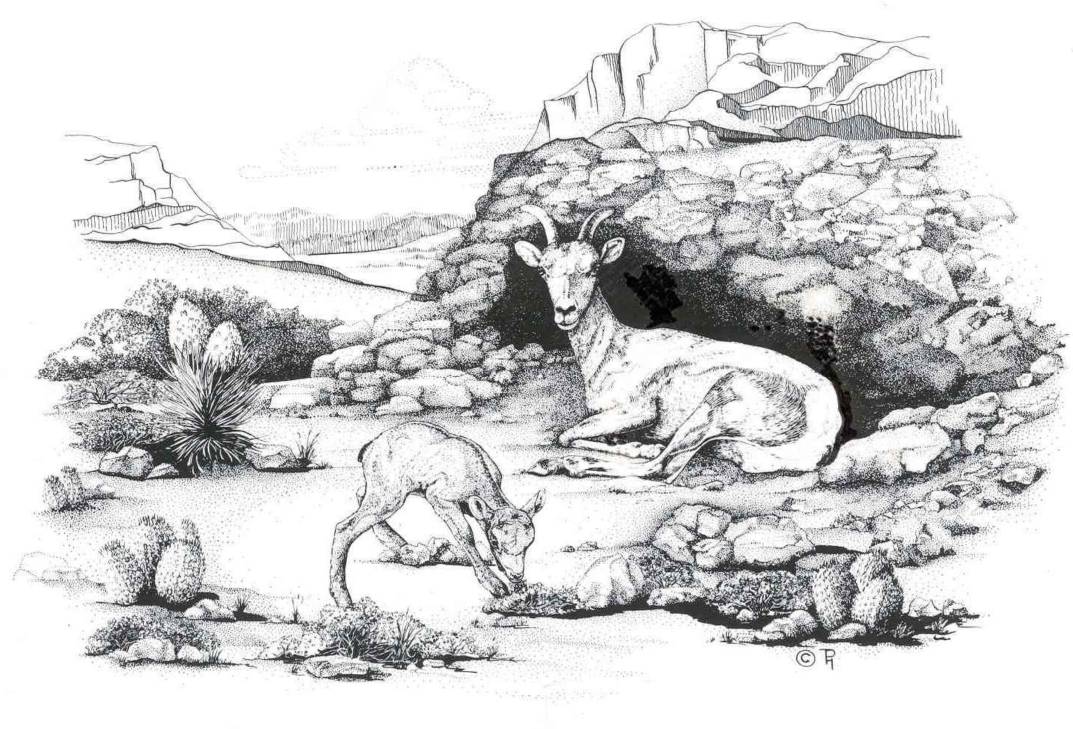

The effect of survey intensity on bighorn sheep helicopter counts

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Abstract Comparisons of catch per unit effort (CPUE) measures assume a linear relationship between catch and effort where effort varies. However, because effort theoretically is unlimited, the relationship between catch and effort should be curvilinear and asymptotic. We confirmed such a relationship for aerial surveys of desert bighorn sheep by varying sampling intensity from 0.74–3.15 minutes/km^2 in a series of 5 helicopter counts conducted over a 10-day period. These results emphasize the need for consistency when conducting surveys to maximize ability to detect population trends. For CPUE measures to be most meaningful, it is important that investigators be cognizant of the asymptotic relationship between catch and effort and standardize survey intensity and area.

Desert Bighorn Council Transactions: 49:23–29

Key words catch per unit effort, bighorn sheep, *Ovis canadensis*, helicopter sampling, sampling intensity, Mojave Desert

Population indices have long been used to make inferences about population dynamics (Overton 1969). Survey results frequently are expressed relative to survey intensity in "catch per unit effort" (CPUE) measures (Caughley 1977), with sightings used as "catches." A sometimes unrecognized assumption of such indices is a linear relationship between "catch" and effort. Such an assumption is inherent in comparisons between survey results where effort has varied. While linearity might be a reasonable approximation for a portion of this relationship, overall it should be curvilinear and asymptotic. Because survey effort theoretically is unbounded, diminishing returns can be expected to be associated with increasing survey effort, with an upper bound (asymptote) set by population size.

For decades, helicopter surveys have been a common tool for surveying bighorn sheep (*Ovis canadensis*) populations. These surveys fit the concept of CPUE well and can be expressed as sheep observed per hour of survey. Where a survey region is defined, effort is the time allocation per unit area (e.g., minutes per km^2). We conducted an experiment designed to investigate whether the relationship between numbers of bighorn sheep observed and helicopter survey effort followed the predicted curvilinearity.

Study Area

This experiment took place in the Marble Mountains in the eastern Mojave Desert of California, a narrow mountain range with elevations of 300–1,150 m, extending about 28 km in a southeasterly direction from the junction of Interstate 40 and Kelbaker Road, San Bernardino County.

Methods

This experiment took place during 11–20 April 1986. Helicopter surveys were flown at 5 different intensities, varying in total time from 1.05–4.48 hrs. Total survey area was 89 sq. km and was broken into three polygons to aid in keeping a consistent intensity for each survey. Total survey times were proportioned among the 3 polygons relative to area and intensities (total hrs) of surveys were randomized relative to the order in which they occurred as follows: 1.98; 4.48; 1.05; 3.40; and 2.82 hrs.

Each survey was conducted by 3 observers and the pilot, all of whom had considerable experience in such activities. Doors were removed from the Bell 206B helicopter to facilitate observations. We plotted each group of sheep on a topographic map and classified individual sheep as adult females, yearling females, young-of-the-year, or 1 of 4 size classes of males defined by Geist (1971).

To place the results on a scale of actual population density, a mark-resight estimate of the female segment of the population was carried out following the experiment. In late June 1986, 13 female sheep were captured throughout the mountain range using a helicopter and hand-held net gun (Krausman et al. 1985) and each received ear tags and individually recognizable radio or marking collars. Over a subsequent 6-month period, sheep in the entire mountain range were sampled without replacement 7 times to develop a mark-resight estimate of the number of adult and yearling females. Two of those were from helicopter surveys and 5 were from ground counts designed to survey the entire population. All collared sheep were alive throughout this period, and a very high annual survivorship for these collared sheep over subsequent years indicated that potential loss of unmarked females between April and the final mark-resight sampling effort could be ignored. We used NOREMARK (White 1996) to calculate mark-resight estimation statistics.

The size of the male population was estimated from the ratio of males to females obtained from all sampling in the second half of the year when the sexes are most mixed for breeding (Bleich et al. 1997). Young of the year were not included in analyses, in part because the birthing period was still underway in April; thus, the ratio of that class to adult and yearling females was not constant through the 5 surveys in that month.

Burnham and Anderson (1998:72) list a variety of equations that might be used to model the expected asymptotic relationship between survey time and sheep seen. The high cost of helicopter time and potential negative effects on the sheep of additional helicopter surveys limited us to 5 data points, resulting in statistical power that was inadequate to distinguish among different potential mathematical models. Consequently, we offer no such comparisons; instead this study was a qualitative evaluation of whether the expected curvilinearity of the relationship was evident, to help inform the design and interpretation of helicopter surveys of bighorn sheep.

Results

A curvilinear relationship between numbers of sheep seen and survey intensity was evident (Figure 1). The mark-resight estimate of the female population yielded an estimate of 67 (95% CL = 56-84) for the joint hypergeometric estimator (Neal et al. 1993) and 65 (95% CL = 53-80) for the Bowden estimator (Bowden and Kufeld 1995). We used the average of those estimates, 66, which is corroborated by similar estimates made in succeeding years of 64 and 62 for 1987 and 1988, respectively, under recruitment and survivorship levels consistent with a slow population decline (Wehausen, J. D. 1992, Demographic studies of mountain sheep in the Mojave Desert: report IV, Unpublished report to the California Department of Fish and Game, White Mountain Research Station, Bishop CA, USA, 54 pages.). Surveys during the breeding season (July–December) yielded total cumulative counts of 207 males and 200 females, for a ratio of 103.5 males:100 females. Applying this ratio to the estimated number of females yielded an estimate of 68 males.

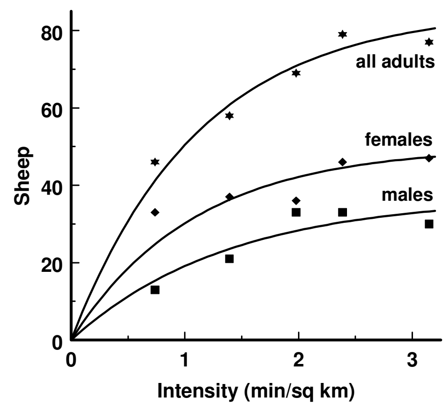

Figure 1. The curvilinear, asymptotic relationship between helicopter survey intensity and numbers of desert bighorn sheep at least 1 year of age observed in the Marble Mountains, California, 11–20 April 1986.

During the April surveys, the average size of groups in which females were found was 7.2 sheep (range 1–16), whereas in the hot season helicopter surveys it was 3.0 (range 1–7). The respective mean numbers of females per group for those 2 seasons were 2.2 and 1.6.

Discussion

The data for total adults exhibited the best curvilinear relationship between effort and catch, whereas noise from sampling variation seemed to obscure this relationship more when each sex was considered independently (Figure 1). There are logistical limits to survey intensity that largely preclude sampling outside of the bounds that we used; thus it may not be possible to further approach the asymptotes suggested by the data. One limiting factor is the need to stay ahead of groups of sheep already counted so as to minimize the probability of re-encountering them. Our longest flight was the highest intensity survey that we considered possible for the population density and distribution we encountered; even that survey intensity was difficult to achieve. The shortest flight involved simply flying one mid-level contour on each side of the mountain range. A shorter survey would be difficult to achieve without eliminating portions of the study area.

Group size is a potentially important variable affecting helicopter survey results. Groups are the units sampled and survey results can be decomposed into the product of the number of groups observed and mean group size. For a given population, mathematically there is an inverse, hyperbolic relationship between the mean group size and the number of groups. Helicopter survey results of bighorn sheep potentially are affected by this in multiple ways. The probability of detection of ungulates from aircraft may increase with group size (Bleich et al. 2001, but see Bodie et al. 1995); however, with fewer groups a higher variance in results can be expected because each group has a proportionally greater effect on results. For our April flights, group size apparently played an important role in differences between sexes. In the most intense flights, we observed about 70% of the estimated number of females compared with 2 subsequent summer helicopter surveys of similar intensity that averaged only 44%. The mean number of females per group dropped 38% from April to the hot season surveys, with considerably more variation in April. The larger residual variation for females (Figure 1) is likely due to the effects of some larger groups that, due to sampling variation, were observed or missed in 2 of the surveys.

Sheep and other ungulates that are moving are more detectable during aerial surveys (Bodie et al. 1995, Bleich et al 2001). The high asymptotic percentage of females observed during April surveys probably also reflected the greater tendency of females with small lambs to take flight compared with less flighty responses later in the year when lambs are much larger (Wehausen 1980).

Our estimated sex ratio that slightly favored males is atypical (Wehausen et al. 1987) and reflects female-biased removals from this population for translocations during 1983–1985 (Bleich et al. 1990). The maximum counts of males during the April helicopter surveys were about 48% of the number of males estimated from that sex ratio. Because of sexual segregation during April (Bleich et al. 1997) and the possibility that a portion of the males estimated from later sex ratios might have been in neighboring mountain ranges during that season, there is some uncertainty about the validity of percentages of males sighted. However, the April maximum percentage of males sighted was consistent with the 2 subsequent summer helicopter surveys in 1986, which averaged 45% for that sex when the sexes were aggregated. Those percentages of males seen also are consistent with the percentages of females seen during the summer surveys; 9 helicopter surveys of this population in summer and fall of 1986–

1993 at comparable higher intensity averaged 44.8% of the number of females estimated independently by mark-resight methods (unpublished data). Consequently, the high maximum percentages of females counted in April are exceptions overall, and probably reflect higher sightability due to more flighty behavior of females with small lambs and larger group sizes.

The curvilinear relationship between survey intensity and sheep observed for helicopter surveys of bighorn sheep also was reported by Gasaway et al. (1986) for fixed-wing surveys of moose in Alaska, and has important implications for the planning and interpretation of such surveys. Comparisons of CPUE measures (e.g., sheep/survey hr; Lee and Lopez-Saavedra 1993) may only be meaningful if survey intensities are similar. Our 2 highest survey intensities were 2.4 and 3.1 min/km^2 and yielded similar results. Because the slope of the relationship between effort and yield is so small above about 2.3 min/km^2, it may be most meaningful for surveys in that intensity range to make direct comparisons over time of unaltered count results, provided conditions and seasons are the same. In contrast, the use of a CPUE index in such comparisons may produce erroneous conclusions because of the negligible influence of variation in effort on yield as the asymptote is approached because the slope approaches 0. In our experience, helicopter surveys for bighorn sheep fall naturally into a range of about 2.3–2.7 min/km^2. However, where survey time is limited, there will be a tendency to survey a subset of the habitat most likely to yield sheep, and such results expressed as direct counts or sheep/hr are unlikely to be comparable with flights of higher intensity and greater coverage. Consequently, for populations that are surveyed repeatedly, we recommend that easily recognizable geographic polygons be defined (Norton-Griffiths 1978) and fixed survey times be allocated to each polygon relative to its area, to make sampling effort consistent and thereby maximize the resolution of comparisons over time.

Our April surveys clearly yielded a higher proportion of females seen than did summer and fall surveys. However, surveys in spring will produce results that may be difficult to compare across years because the geographical distribution and size of groups of females can vary greatly depending on forage phenology, which is driven by variation in rainfall in certain months in this arid and highly variable environment (Wehausen 2005). The use of helicopter surveys during the season when lambs are young is also questionable on the basis of the extremely flighty behavior of females and the potential for this to lead to injuries and separation of lambs from their mothers, both of which we have observed. Fall helicopter surveys have become the norm for population assessments of bighorn sheep in desert environments. A primary reason for this has been the high level of sexual aggregation (Bleich et al. 1997) at that time, thereby providing the best opportunity to develop data on both sexes. Another reason to use that season for surveys is the likelihood that results will have a higher consistency across years and, thereby, have a higher probability of being comparable to detect population trends.

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(CDFG), the Bureau of Land Management, the Society for the Conservation of Bighorn Sheep, and Foundation for North American Wild Sheep. J. Bickett, L. Coombes, A. Pauli, and R. Vernoy participated as observers, and D. Landells was the pilot for surveys and captures. D. Jessup participated in the capture and collaring of sheep. We thank reviewers L. McDonald and M. Garel for useful comments on the mansuscript. This paper is dedicated to the memory of D. Landells and J. Bickett, who died in a tragic helicopter crash in the fall of 1986. This is a contribution from the CDGF Mountain Sheep Conservation Program and is Professional Paper 064 from the Eastern Sierra Center for Applied Population Ecology.

Literature Cited

BLEICH, V. C., R. T. BOWYER, AND J. D. WEHAUSEN. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Mongraphs 134:1–50.

BLEICH, V. C., C. S. Y. CHUN, R. W. ANTHES, T. E. EVANS, AND J. K. FISHER. 2001. Visibility bias and development of a sightability model for tule elk. Alces 37:315–327.

BLEICH, V. C., J. D. WEHAUSEN, K. R. JONES, AND R. A. WEAVER. 1990. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Desert Bighorn Council Transactions 34:24–26.

BODIE, W. L., E. O. GARTON, E. R. TAYLOR, AND M. MCCOY. 1995. A sightability model for bighorn sheep in canyon habitat. Journal of Wildlife Management 59:832–840.

BOWDEN, D. C., AND R. C. KUFELD. 1995. Generalized mark-resight population size estimation applied to Colorado moose. Journal of Wildlife Management 59:840–851.

BURNHAM, K. P., AND D. R. ANDERSON, 1998. Model selection and inference: a practical information-theoretic approach. Springer Verlag, New York, USA.

CAUGHLEY, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, USA.

GASAWAY, W. C., S. D. DUBOIS, D. J. REED, AND S. J. HARBO. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska 22:1–108.

GEIST, V. 1971. Mountain sheep, a Study in Behavior and Evolution. University of Chicago Press, Illinois, USA.

KRAUSMAN, P. R., J. J. HERVERT, AND L. L. ORDWAY. 1985. Capturing deer and mountain sheep with a net-gun. Wildlife Society Bulletin 13:71–73.

NEAL, A. K., G. C. WHITE, R. B. GILL, D. F. REED, AND J. H. OLTERMAN. 1993. Evaluation of mark-resight model assumptions for estimating mountain sheep numbers. Journal of Wildlife Management 57:436–450.

LEE, R. M., AND E. E. LOPEZ-SAAVEDRA. 1993. Helicopter survey of desert bighorn sheep in Sonora, Mexico. Desert Bighorn Council Transactions 37:29–32.

NORTON-GRIFFITHS, M. 1978. Counting animals. African Wildlife Leadership Foundation, Nairobi, Kenya.

OVERTON, W. S. 1969. Estimating the numbers of animals in wildlife populations. Pages 403–455 *in* R. H. Giles, Jr. (editor), Wildlife Management Techniques. The Wildlife Society, Washington, D. C., USA.

WEHAUSEN, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. Thesis, University of Michigan, Ann Arbor, USA.

WEHAUSEN, J. D. 2005. Nutrient predictability, birthing seasons, and lamb recruitment for desert bighorn sheep. Pages 37-50 *in* J. Goerrissen and J. M. Andre (editors), Sweeney Granite Mountains Desert Research Center 1978–2003: A Quarter Century of Research and Teaching. University of California Natural Reserve Program, University of California, Riverside, USA.

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.

WHITE, G. C. 1996. NOREMARK: Population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50–52.

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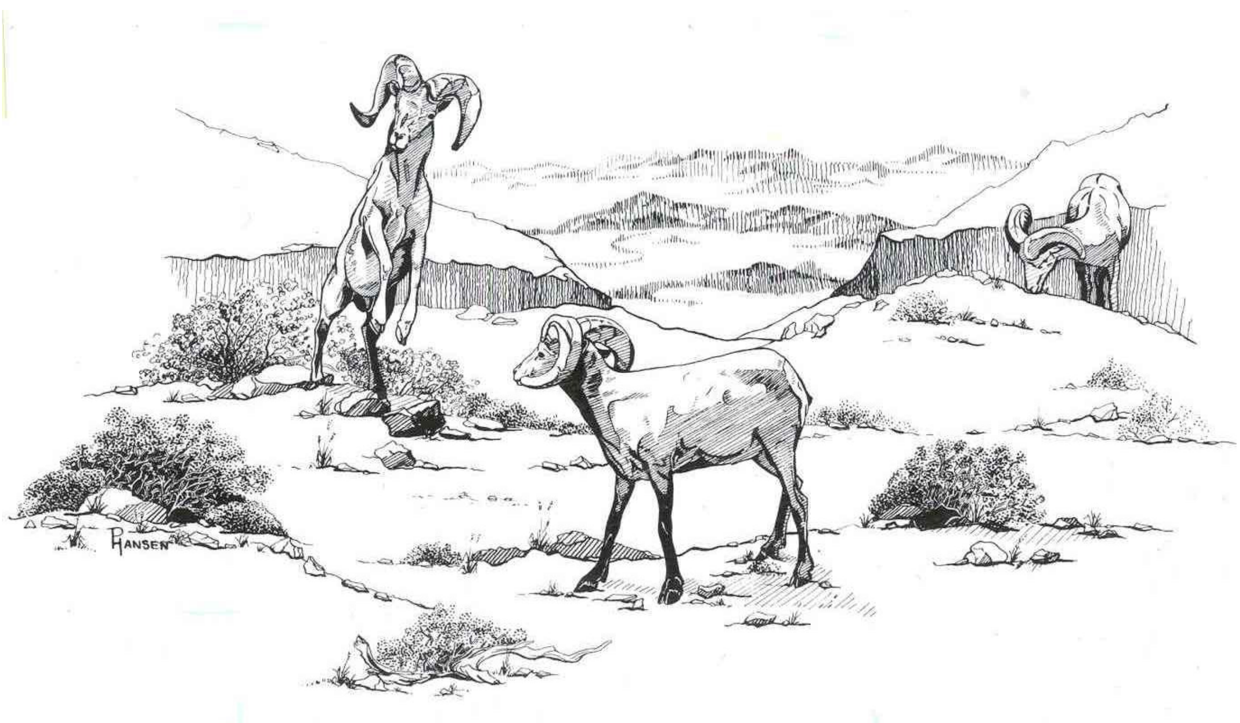

Evaluation of historical desert bighorn sheep habitat in Coahuila, Mexico

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Abstract We analyzed the known historical desert bighorn sheep (*Ovis canadensis*) habitat in Coahuila, Mexico, which consists of 14 mountain ranges: Sierra Maderas del Carmen, Sierra Hechiceros, Sierra la Encantada, Sierra el Pino, Sierra el Almagre, Sierra el Fuste, Sierra Mojada, Sierra el Rey, Sierra la Madera, Sierra la Fragua, Sierra San Marcos y del Pino, Sierra los Alamitos, Sierra la Gavia, and Sierra la Paila. The analysis was conducted through the use of a Geographic Information System. Habitat components that we measured were the availability of escape terrain, the presence of vegetative community types that permit a high degree of horizontal visibility (semidesert grassland and desert succulent-scrub), and potential suitable habitat. The results were expressed as a habitat suitability index. The areas containing the most habitat include the region of Cuatro Cienegas (La Madera, La Fragua, San Marcos y del Pino, Los Alamitos and La Paila), located in southcentral Coahuila, and Maderas del Carmen located in extreme northern Coahuila. These areas were considered priority transplant sites. Competition with domestic and exotic animals, transmission of disease by domestic sheep and goats, are potential impediments to the restoration of desert bighorn sheep.

Desert Bighorn Council Transactions 49:30–39

Key words bighorn sheep, GIS, habitat evaluation, suitable habitat, *Ovis canadensis mexicana,* restoration, potential impediments, Coahuila, Mexico.

Historically desert bighorn sheep occurred throughout much of northern Mexico, including the states of Chihuahua, Coahuila, Nuevo Leon, Sonora, Baja California, and Baja California Sur (Baker 1956, Leopold 1959, Cossio 1974, Sandoval 1985). The subspecies apparently was extirpated from Chihuahua, Coahuila, and Nuevo Leon (Krausman et al. 1999). In the state of Coahuila, desert bighorn sheep were widely distributed and occurred in at least 14 different mountain ranges, where they persisted until ca. 1970 (Espinosa et al. 2006). Factors possibly responsible for the subspecies extirpation include disease(s), competition with domestic sheep and goats, and illegal and excessive harvest (Baker 1956, Espinosa et al. 2006).

Information on desert bighorn sheep in Mexico is lacking (Tarango and Krausman 1997), and little is known about the subspecies in Coahuila (Eaton-Gonzalez and Martinez-Gallardo 2001). In 2000, a captive population was established in Coahuila to serve as source stock for repopulating northeastern Mexico (Sandoval and Espinosa 2001). The objectives of our present study were: 1) to quantitatively determine the suitability of historical habitat in Coahuila; 2) to prioritize potential transplant sites for the restoration of free-ranging populations of desert bighorn sheep; and 3) to identify potential impediments.

Study Area

The state of Coahuila is located in northeastern Mexico and is bounded on the east by Nuevo Leon and on the west by Chihuahua (Figure 1). The Rio Grande (Rio Bravo) separates Coahuila from Texas in the United States. Our study was focused on mountain ranges with known historical documentation of desert bighorn sheep (Espinosa et al. 2006). These include: Sierra Maderas del Carmen, Sierra Hechiceros, Sierra la Encantada, Sierra el Pino, Sierra el Almagre, Sierra el Fuste, Sierra Mojada, Sierra el Rey, Sierra la Madera, Sierra la Fragua, Sierra San Marcos y del Pino, Sierra los Alamitos, Sierra la Gavia, and Sierra la Paila (Figure 1).

The climate throughout this region is arid, characterized by hot summers and cool winters. Most of the precipitation falls as summer thunderstorms (SPP 1981). The vegetation of the study area is typical of the Chihuahuan Desert, consisting of desert succulent-scrub (DSS), stem succulents, and semi-desert grassland (SDG) communities (Brown 1982). Dominant species include lechugilla (*Agave lecheguilla*), sotol (*Dasylirion texanum*), yucca (*Yucca* spp.), species of cacti (*Opuntia* spp.), candelillia (*Euphorbia antisiphylitica*), sweet acacia (*Acacia farnesiana*), mesquite (*Prosopis* spp.), creosote (*Larrea tridentata*), and ocotillo (*Fouqueria splendens*). Desert grasslands are dominated by several grasses (*Muhlenbergia* spp., *Bouteloua* spp., and *Heteropogon* spp.) (Villareal and Valdes 1993).

Methods

The evaluation of potential habitat for desert bighorn sheep in Coahuila was conducted between April 2003 and June 2006. The analysis was conducted through the use of a Geographic Information System (GIS), incorporating 1995 Instituto Nacional de Estadistica Geografia e Informatica (INEGI) land use and vegetation digital information overlays (*Vector* format), with a scale of 1:250,000; INEGI digital elevation models (DEM *Raster* TIFF format), with a

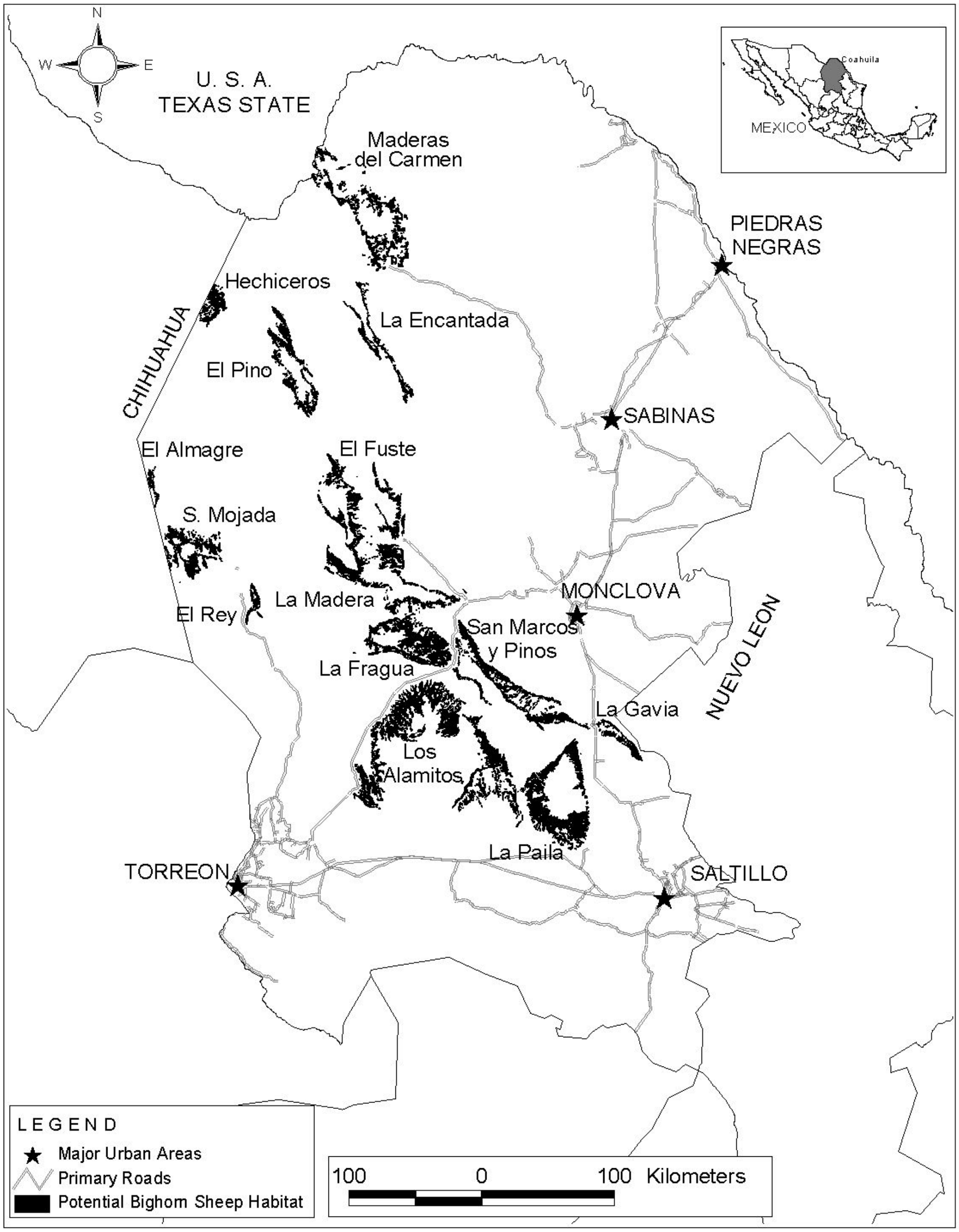

Figure 1. Potential desert bighorn sheep habitat in the known historical range in Coahuila, Mexico.

resolution of 30 × 30 m/pixel, and location of permanent and temporary water sources digitized from INEGI topographic maps, with a scale of 1:50,000. Portions of DEMs encompassed by each study area were extracted and converted to Universal Transverse Mercator (UTM) projections Zone 13, DATUM NAD27 coordinate system, using ArcView GIS 3.2.

Within each study area we obtained measurements of topography based on the elevation of the central (target cell), compared to the elevation of, and distance to, surrounding cells encompassed within a 3 × 3 cell window. The maximum slope determined in each window was assigned by GIS to the target cell and stored in an initial topographic spatial database (hereafter referred to as coverages), that contained percent slope for each cell of the study area. We followed the criteria defined by Dunn (1996) and Locke et al. (2005) to measure bighorn sheep escape terrain in the Chihuahuan Desert, selecting those areas ≥60% slope gradients. The coverage of slopes ≥60% was intersected with the coverage of open vegetation (SDG and DSS) to create a coverage of potential escape terrain. The amount of potential escape terrain for each study area was determined, and an index of contiguity (CI) was calculated based on the following perimeter (km) to area (km²) ratio formula, whereby escape terrain is more contiguous as the indices approaches 0:

$$CI = \frac{\sum \textit{ perimeter of polygons with escape terrain}}{\sum \textit{ area of escape terrain}}$$

Potential suitable habitat was defined as cells between 20 and 59% slope gradients situated ≤150m of escape terrain, intersected with the coverage of open vegetation (SDG and DSS). A coverage of impacts was created that included: 1) 3 km buffers around residential areas; 2) 2 km buffers around paved roads; and 3) 500 m buffers around secondary roads. Impacted areas were eliminated from potential suitable habitat, and potential suitable escape terrain, respectively.

Water availability was measured as the amount of potential suitable habitat ≤3.5 km from permanent and temporary water sources, situated ≤200 m of escape terrain. A coverage of water sources was intersected with a coverage of escape terrain that had been buffered to 200 m to create a coverage of water sources near escape terrain. A 3.5 km buffer was then created around these water sources, and this coverage was intersected with the coverage of potential suitable habitat to measure water availability.

To rank study areas we calculated a habitat suitability index (Dunn 1996) based on the total area of escape terrain, contiguity index, potential suitable habitat, and water availability with the formula:

$$HSI = \frac{(TSH_i/TSH_{max})+(ET_i/ET_{max})+(CI_i/CI_{max})+(WA_i/WA_{max})}{N}$$

where:

HSI	= habitat suitability score index
TSH	= total amount (km²) of suitable habitat
$_i$	= value for the study area
$_{max}$	= maximum value of that component for all study areas
ET	= amount (km²) of escape terrain
CI	= contiguity index
W	= water availability (km²)
N	= number of study areas

Habitat components that we measured were the availability of escape terrain (slopes ≥60%), vegetative community types that permit a high degree of horizontal visibility (SDG and DSS), suitable habitat defined as slope gradients between 20 and 59% situated within 150 m of escape terrain, and water availability defined as the amount of suitable habitat ≤3.5 km radius of water sources.

To corroborate potential suitable habitat identified by GIS, we conducted field verification through ground and aerial reconnaissance. Aerial surveys were accomplished with a Cessna 182, flying a mean distance of 300 m from the mountain side. Ground observations were conducted by vehicle and on foot. Observation and photo points were marked with a hand held Global Positioning System (GPS) or the aircraft´s GPS, and entered in a field notebook.

Results

A total of 3,647 km² of potential suitable habitat was identified in the known historical desert bighorn sheep range in Coahuila. The areas containing the most suitable habitat include the region of Cuatro Cienegas (La Madera, La Fragua, San Marcos y del Pino, Los Alamitos and La Paila), located in southcentral Coahuila, and Maderas del Carmen located in extreme northern Coahuila (Table 1 and Figure 1).

Discussion

Our study indicates that the area around Cuatro Cienegas located in the southcentral portion of Coahuila has the highest potential for the initial restoration of desert bighorn sheep. Habitat suitability indices for the top 5 ranked mountain ranges (i.e., Sierra la Fragua, Sierra la Paila, Sierra San Marcos y del Pino, Sierra la Madera and Sierra Alamitos) are all located in this region (Table 1, Figure 1). According to Espinosa et al. (2006), desert bighorn sheep persisted in this area until the 1950s. The second region with good potential for desert bighorn sheep is located in the extreme northwestern portion of the State, adjacent to the international boundary with Texas (Sierra Maderas del Carmen) (Table 1, Figure 1) where the subspecies persisted until the 1940s (Espinosa et al. 2006).

The initial restoration of desert bighorn sheep in Coahuila actually took place in 2000 in vicinity of Sierra Maderas del Carmen; a captive propagation program (actual population N = 150) using progeny from Sonora, in a 5,000 ha game proof enclosure (Sandoval and Espinosa 2001). This was followed by a release directly into the wild on Maderas del Carmen with sheep (n = 30) from Sonora in 2004 (McKinney and Delgadillo Villalobos 2005). The free-ranging population was augmented in 2005 with an additional 6 animals. Given the close proximity to occupied desert bighorn sheep habitat in the Black Gap Wildlife Management Area, Texas (n = 104) (M. Pittman pers. com.), bighorn sheep movements across the international border are a distinct possibility. A male desert bighorn sheep from the Texas population did cross the Rio Grande and resided on the north end of Sierra Maderas del Carmen for 1 year before returning to Texas (McKinney and Delgadillo Villalobos 2005). Thus the potential for establishing a metapopulation between the United States and Mexico is quite high.

The western region of Coahuila encompassing Sierra Mojada, Sierra el Almagre, Sierra Hechiceros, and Sierra el Rey has a lower potential for desert bighorn sheep restoration (Table 1, Figure 1). Interestingly, this area was the last stronghold for the native bighorn sheep of Coahuila where they persisted until the

Table 1. Potential suitable habitat for desert bighorn sheep in Coahuila, Mexico.

Mountain Range	Escape Terrain km^2	Suitable Habitat km^2	Water Availability km^2	Contiguity Index	Habitat Suitability Index
La Fragua	166.19	401.38	8.11	0.027	0.277
La Paila	140.44	466.32	4.99	0.025	0.237
San Marcos y del Pino	159.52	351.58	5.32	0.024	0.234
La Madera	131.95	365.17	7.20	0.021	0.230
Los Alamitos	152.66	663.09	0.73	0.025	0.228
Maderas del Carmen	98.75	299.81	8	0.023	0.223
El Fuste	92.79	307.24	0[2]	0.022	0.147
Hechiceros[1]	25.04	88.66	4.43	0.023	0.137
El Pino	70.07	216.81	0[2]	0.022	0.128
Sierra Mojada[1]	60.88	201.28	0[2]	0.023	0.126
La Gavia	44.14	87.79	0[2]	0.027	0.120
La Encantada	42.34	121.69	0[2]	0.022	0.106
El Almagre[1]	13.99	29.17	0[2]	0.024	0.090
El Rey	19.19	47.46	0[2]	0.022	0.088

[1] Includes only the portion of the mountain range located within the State of Coahuila.
[2] No data available.

1970s (Espinosa et al. 2006). This area will require additional work including the evaluation of potential habitat in the portion of the mountain ranges located in the State of Chihuahua, and location of permanent and temporary water sources. We believe that relatively lower suitable scores for these areas is partially due to limitations resulting from the resolution of digitized water availability data from current INEGI maps, rather than true lack of water.

Habitat components essential to bighorn sheep include food, water, escape terrain, and living space. We defined living space as unfragmented habitat with little or no competition with other ungulates and humans. Bighorn sheep, especially ewe-lamb groups require open rugged terrain as a predator-evasion strategy, and restrict most of their activities in close proximity to steep terrain (Bailey 1992). Escape terrain is defined as rough, broken topography, with many rock outcroppings and precipitous cliffs where a bighorn sheep can outmaneuver a potential predator (Hansen 1980). These areas are characterized by slope gradients ≥60% (Holl 1982, Smith and Flinders 1992).

Bighorn sheep prefer open slopes with ≤25-30% vegetative cover (Tilton and Willard 1982), which permits good horizontal visibility (Risenhoover and Bailey 1985; Smith and Flinders 1992). Chihuahuan Desert communities exhibiting these characteristics include semidesert grassland (SDG) and desert succulent-scrub (DSS). Both community types have a mean height of 40 cm (SPP 1981).

Use of GIS and a landscape approach to evaluate desert bighorn sheep habitat in the Chihuahuan Desert has been done in New Mexico (Dunn 1996) and Texas (Locke et al. 2005). Dunn (1996) also used the same approach to evaluate alpine and low elevation Rocky Mountain bighorn sheep (*O. c. canadensis*) habitat in New Mexico.

Our application of GIS at the landscape perspective in Coahuila proved an effective and efficient means of evaluating and comparing many areas of bighorn sheep habitat and provided consistent measurements across all study areas, thereby reducing bias within any single study area. Furthermore, a measurement of the amount and patchiness (Contiguity Index) of bighorn sheep habitat and a final score and ranking was obtained directly from the values of the habitat components. Finally, it provided for the evaluation of a large geographic area with much less effort than if it was analyzed in the field, and it allowed to graphically display the amount and distribution of bighorn sheep habitat.

Our work in Coahuila represents the first attempt to quantitatively evaluate bighorn sheep habitat in Mexico using GIS. Colchero et al. (2003) analyzed bighorn sheep habitat through the use of Genetic Algorithm for Rule-Set Prediction (GARP), based on logarithmic predictions of habitat use studies from Sonora, Baja California, Baja California Sur, and Tiburon Island. The above study identified 55% (673 km²) of the total bighorn sheep escape terrain in Coahuila compared to the results of our work (1,218 km²). According to Colchero et al. (2003), Sierra Alamitos, Sierra la Fragua, Sierra Hechiceros, and Sierra el Rey lack escape terrain for desert bighorn sheep. Nonetheless, our study identified 363 km² of escape terrain in these same study areas. We believe that the disparity is due to limitations in the spatial resolution of data sources used by Colchero et al. (2003); Comision Nacional Para La Biodivesridad (CONABIO) topographic maps (1:250,000) and 1:1,000,000 scale for vegetation and habitat use. This illustrates the relative predictive factor of different spatial and vegetation data sources.

We found that 1 of the probable factors responsible for the extirpation of desert bighorn in Coahuila is still present. Coahuila is the major producer of goat meat in Mexico (SAGARPA 2002), and we found the grazing of domestic goats to be widespread in most of the 14 study areas. Goat husbandry is extensive and frequently includes mixed herds of domestic sheep. The potential transmission of disease from these exotics to bighorn sheep is of concern, and we believe that it may be 1 of the major obstacles to the restoration of desert bighorn sheep in Coahuila.

Conclusions

Based on the results of our work, the regions of Maderas del Carmen and Cuatro Cienegas should be the priority restoration sites for desert bighorn in Coahuila. In addition to the availability of suitable habitat, the entire El Carmen area is under federal protection (SEMARNAP 1997), as is a small portion of Cuatro Cienegas (SEMARNAP 1999). Grass-root conservation initiatives were behind federal protection designation, and currently both areas have active wildlife management and conservation programs, and law enforcement activities conducted by trained personnel. We believe that restoration of desert bighorn sheep in these areas will enhance bio-diversity; a diversity that prior to the advent of Europeans included viable populations of desert bighorn sheep and predators. The only impact we anticipate is that desert bighorn sheep will again become a viable component of the desert ecosystem they once occupied, but from which they were extirpated 35–40 years ago.

Our analysis of the areas of known historical occurrence of desert bighorn sheep indicates that approximately 3,648 km² of suitable habitat exists for the restoration of the subspecies in Coahuila. We found the use of GIS and a landscape approach an effective and efficient means of evaluating and comparing 14 study areas throughout the state of Coahuila. The method provided a general panorama of the amount, distribution, and contiguity of potential suitable habitat. Additional work will be required to delineate specific initial release sites, followed by field verification of GIS results.

The analysis of potential habitat for a subspecies that was extirpated 35–40 years ago is a difficult task. The historical bighorn sheep habitat in Coahuila is extensive, consisting of many interconnected mountain ranges extending southeasterly from the Chihuahua border for 450 km (Espinosa et al. 2006). Many mountain ranges without historical records, but within the overall known historical distribution of desert bighorn sheep need to be evaluated and ranked in order of suitability at the regional scale.

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Literature Cited

BAKER, R. H. 1956. Mammals of Coahuila, Mexico. University of Kansas Publication, Museum of Natural History 9:327–329.

BAILEY, J. A. 1992. Managing bighorn habitat from a landscape perspective. Biennial Symposium of the North American Wild Sheep and Goat Council 8:49–57.

COSSIO, M. L. 1974. Report from Mexico. Pages 72-74 in J. B. Threfeten, editor. The wild sheep in modern North America. Boone and Crockett Club, New York, USA.

COLCHERO F. VALDES-M., J. GONZALEZ, Y C. MANTEROLA. 2003. Estrategia Nacional para la recuperación del borrego cimarrón en México. Analisis GARP 2002-2003. Reporte Interno de Unidos Para La Conservación A.C., Mexico.

DUNN, W. C. 1996. Evaluating bighorn habitat: a landscape approach, Technical Note 395. New Mexico Department of Game and Fish and Bureau of Land Management National Applied Resource Sciences Center. BLM/RS/ST-96/005+6600, USA.

EATON-GONZALEZ, R. B., AND MARTINEZ-GALLARDO, R. 2001. Analysis of the current knowledge of the peninsular bighorn sheep (*Ovis canadensis cremnobates*) and its implications for the conservation and management in the state of Baja California. Desert Bighorn Council Transactions 45:26–36.

ESPINOSA-T, A., A. V. SANDOVAL, AND A. J. CONTRERAS-B. 2006. Historical distribution of desert bighorn sheep (*Ovis canadensis mexicana*) in Coahuila, Mexico. The Southwestern Naturalist 51:282–288.

FOREYT, W. J., AND D. A. JESSUP. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. Journal of Wildlife Diseases 18:163–168.

GROSS, J. E., F. J. SINGER, AND M. E. MOSES. 2000. Effects of disease dispersal and area on bighorn sheep restoration. Restoration Ecology 8:25–37.

HANSEN, C. G. 1980. Habitat evaluation, pages 320–335 *in* G. Monson and L. Sumners, editors. The desert bighorn: its life history, ecology, and management. University of Arizona Press, Tucson, USA.

HOLL, S. A. 1982. Evaluation of desert bighorn habitat. Desert Bighorn Council Transactions 26:47–49.

KRAUSMAN, P. R., A. V. SANDOVAL, AND R. C. ETCHBERGER. 1999. Natural history of desert bighorn. Pages 139–208 *in* R. Valdez and P. R. Krausman, editors. Mountain sheep of North America. University of Arizona Press, Tucson, USA.

LEOPOLD, A. S. 1959. Wildlife of Mexico: the game birds and mammal. University of California Press, Berkely, USA.

LOCKE, S., C. BREWER, AND L.A. HARVESON. 2005. Identifying landscapes for desert bighorn translocations in Texas. Texas Journal of Science 57(1):25–33.

MCKINNEY R. B AND J. DELGADILLO VILLALOBOS. 2005. Desert bighorn sheep reintroduction in Maderas del Carmen, Coahuila, Mexico. Desert Bighorn Council Transactions 48:46–49.

RISENHOOVER, K. L., J. A. BAILEY, AND L. A. WAKELYN. 1985. Assessing the Rocky Mountain bighorn sheep management problem. Wildlife Society Bulletin 16:346–352.

RUDOLPH, K. M., D. L. HUNTER, W. J. FOREYT, E. F. CASSIRER, R. B. KIMLER, AND A. C. S. WARD. 2003. Sharing of *Pasteurella* spp. between free-ranging bighorn sheep and feral goats. Journal of Wildlife Diseases 39:897–903.

SANDOVAL, A. V. 1985. Status of bighorn sheep in the republic of Mexico. Pages 86–94 *in* M. Hoefs, editor, Wild sheep: distribution abundance, management and conservation of the sheep of the world and closely related mountain ungulates. Northern Wild Sheep and Goat Council Special Report. Yukon, Canada.

SANDOVAL, A. V. 1988. Bighorn sheep die-off following association with domestic sheep: case history. Desert Bighorn Council Transactions 32:36–38.

SANDOVAL, A. V., AND A. ESPINOSA-T. 2001. Status of bighorn management programs in Coahuila, Mexico-2000. Desert Bighorn Council Transactions 45:53–61.

SECRETARIA DE AGRICULTURA, GANADERÍA, DESARROLLO RURAL, PESCA, Y ALIMENTACIÓN (SAGARPA). 2002. Producción de carne de caprino en México. Sistema de Información y Estadística Agroalimentaria y Pesquera (SIAP). http://www.sagarpa.gob.mx. (accessed 10 July 2006).

SECRETARIA DE MEDIO AMBIENTE, RECURSOS NATURALES Y PESCA (SEMARNAP). 1997. Programa de manejo del Área Protección de Flora y Fauna "Maderas del Carmen". Instituto Nacional de Ecología, México.

SECRETARIA DE MEDIO AMBIENTE, RECURSOS NATURALES Y PESCA (SEMARNAP). 1999. Programa de manejo del Área de Protección de Flora y Fauna Cuatrociénegas. Instituto Nacional de Ecología, México.

SMITH, T. S., AND J. T. FLINDERS. 1992. Evaluation of mountain sheep habitat in Zion National Park, Utah. Desert Bighorn Council Transactions 36:4–9.

SECRETARIA DE PROGRAMACIÓN Y PRESUPUESTO (SPP). 1981. Síntesis geográfica de Coahuila. México.

TARANGO, L. A., AND P. R. KRAUSMAN. 1997. Desert bighorn in Mexico. Desert Bighorn Council Transactions 41:1–7.

TILTON, M. E., AND E. E. WILLARD. 1982. Winter habitat selection by mountain sheep. Journal of Wildlife Management 46:359–366.

VILLARREAL QUINTANILLA, J. A., AND J. VALDES REYNA. 1993. Vegetación de Coahuila. Manejo de Pastizales Vol.6 No.1 Diciembre 1992-Abril de 1993. 9–18 pp.

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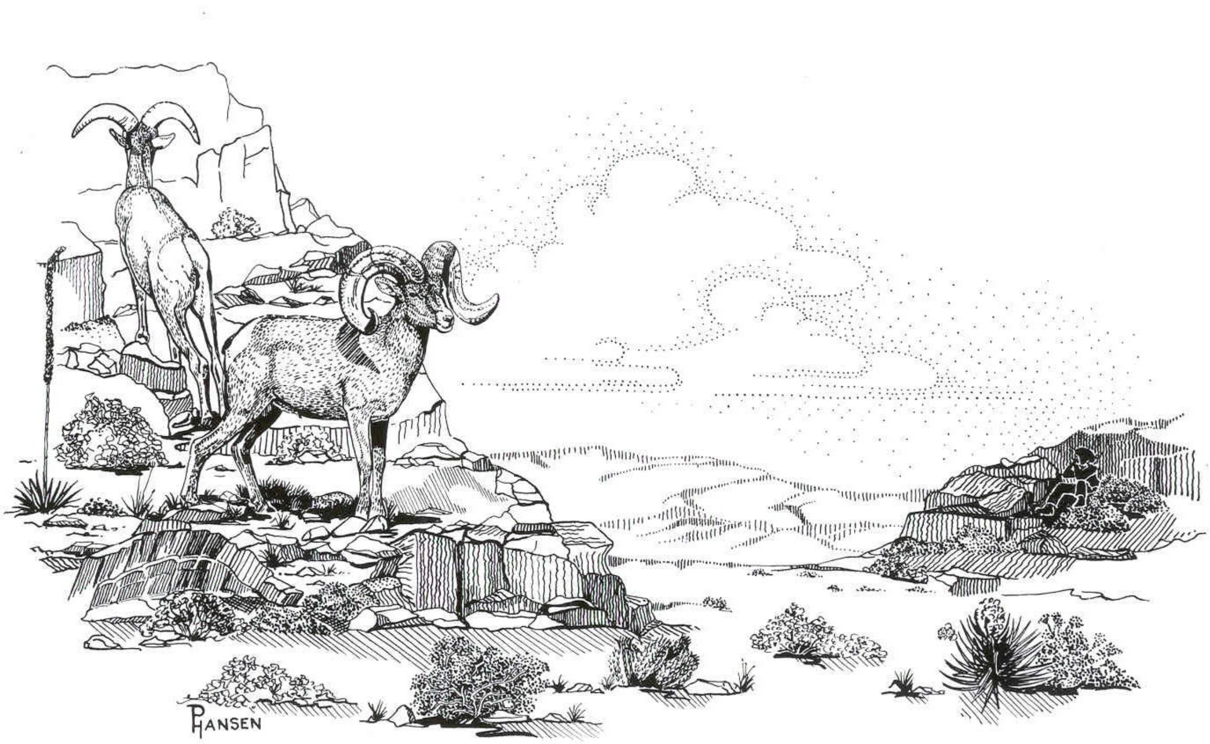

Restoration of desert bighorn sheep on the Navajo Nation

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Abstract Recovery of a desert bighorn sheep (*Ovis canadensis nelsoni*) herd on the Navajo Nation has provided the opportunity to restore desert bighorn sheep to suitable, historical habitat within the Navajo Nation. Bighorn sheep were observed in the Upper Canyon of the San Juan River in 1983 after about 20 years when their presence was not detected. The population increased to about 30 bighorn sheep by 1997. Initial monitoring was used to develop a management program. With improved management, the bighorn sheep herd increased rapidly. During the drought of 2001–2002, the population stabilized at about 100 bighorn sheep. Concerns arose that density of the herd had exceeded the capacity of the bighorn sheep range, at least during drought conditions. Surveys were initiated to locate suitable areas for reestablishment of bighorn sheep populations on the Navajo Nation. In 2003, 24 bighorn sheep were transplanted from the Upper Canyon to the Lower Canyon of the San Juan River. Objectives were to reestablish bighorn sheep in vacant suitable historic range on the Navajo Nation and to reduce density of bighorn sheep on the Upper Canyon range. The source herd in the Upper Canyon recovered rapidly from the first transplant and is currently estimated at >150 bighorn sheep. The transplanted herd in the Lower Canyon is estimated at >50 bighorn sheep and has established a range incorporating over 41 km of river canyon. We are currently developing a plan to transplant bighorn sheep from the original population in the Upper San Juan River Canyon to initiate a new herd in Wetherill Canyon on the south shore of Lake Powell.

Desert Bighorn Council Transactions 49:41–51

The objectives of desert bighorn sheep management on the Navajo Nation are to (1) conserve existing herds for their ecological, aesthetic, and traditional values, (2) manage harvest to provide funding for continued research and management, while providing traditional hunting opportunities for tribal members, and (3) restore desert bighorn sheep to suitable habitat throughout the Navajo Nation.

Desert bighorn sheep are native to the San Juan River and Colorado River canyons on the Colorado Plateau. Desert bighorn sheep images are prominent in rock art of the area dating from the Archaic, Basketmaker, and Pueblo periods (4000 BC–1350 AD (Kearsley 2002). In 1880, Mormon settlers founded Bluff City on the San Juan River a few km upriver of the current bighorn sheep range (Kearsley 2002). In 1884, the Navajo Nation was expanded to include the land between the south side of the San Juan River and the Arizona border (Goodman 1987). Navajos settled the area during the next 50 years, bringing herds of sheep, goats, and cattle. During the same period Mormon settlers expanded cattle grazing on the north side of the river.

The native pueblo, Navajo, and Ute peoples and Mormon settlers hunted bighorn sheep in the canyons, but major declines in the bighorn sheep populations occurred after European man began prospecting for minerals and oil and Navajos began grazing domestic sheep and cattle in the canyons. Beginning in the 1890s, the San Juan River Canyon was influenced by gold prospectors and oil men, who undoubtedly shot bighorn sheep for food and brought in domestic stock. W. E. Mendenhall, a gold prospector, built a cabin in the upper part of the Lower Canyon in 1894 (Baars and Stevenson 1991). Below the Goosenecks, Henry Honaker built a toll trail into the Lower Canyon in 1894 for prospectors. Near Slickhorn Rapids in the Lower Canyon, the river cuts through oil bearing strata and oil seeps were noticed by early explorers (Baars and Stevenson 1991). In the 1910s, E. L. Goodridge built a road into the Canyon at Slickhorn Rapid to facilitate oil drilling (Baars and Stevenson 1991). In 1928, the Utah Southern Oil company built a road into Soda Basin in the Upper Canyon (Kearsley 2002). In 1952, Don Danvers improved the road into Slickhorn and drilled 2 wells (Baars and Stevenson 1991). The Slickhorn area shows evidence of extensive disturbance including probable use by domestic stock brought in by the oilmen.

Uranium exploration began in the 1940s and drew additional people to the area. Mines and mills were developed, but most closed by the mid-1970s (Valle 1986). With progressive settlement of the area by Native Americans and Europeans, unregulated hunting and grazing by large herds of cattle, sheep, and goats occurred on both sides of the river. Navajos operated sheep camps in the San Juan Canyon at the mouth of Chinle Wash in the 1960s and early 1970s (Charles Delorme, personal communication, Wild Rivers Expeditions). A domestic sheep camp existed above Eight Foot Rapid in the heart of the present bighorn sheep range in 1959 (Gene Stevenson, personal communication).

While unregulated hunting probably caused the first declines in bighorn sheep herds in the area, competition for forage with domestic livestock and transmission of diseases from domestic sheep and goats were the likely causes of the apparent disappearance of bighorn sheep from the San Juan River Canyons. Bighorn sheep were rare by the late 1950s, and the last observations of bighorn sheep were reported in the canyon below Mexican Hat in the mid-1960s and in the canyon above Mexican Hat about 1962 (Charles Delorme, personal communication; Cory Perkins, personal communication; Doug Ross, personal communication; Wilson 1968).

Kenny Ross established Wild Rivers Expeditions in 1957 in Bluff, Utah and began a guided raft service on the San Juan River through the bighorn sheep range

(Baars and Stevenson 1991, Kearsley 2002). In the early years of the guide service, bighorn sheep were observed although they were considered rare. From about 1962 to 1982 Wild Rivers recorded no bighorn sheep observations between Bluff and Mexican Hat (Charles Delorme, personal communication). A few observations of bighorn sheep were reported in the San Juan River Canyon below Mexican Hat between 1960 and 1965 (Wilson 1968; Doug Ross, personal communication).

Recent observations of bighorn sheep between Bluff and Mexican Hat date from the early 1980s. In 1983, Wild Rivers' boatmen reported a single ewe and a lamb above Eight Foot Rapid in the center of the current Upper Canyon bighorn sheep range. The next year a ewe, a lamb, and a yearling were observed. The first ram was reported in 1985 or 1986 (Charles Delorme, personal communication). It is not known if bighorn sheep moved into the San Juan River Canyon from the closest native herds in Red or White Canyons to the north or if the herd grew from a few individuals that survived somehow in the San Juan Canyon without being observed for many years. Hanley Begay (a Navajo who worked for Wild Rivers) reported a few observations of bighorn sheep in the Chinle Wash area during 1960s and 1970s (Charles Delorme, personal communication).

As the tiny herd in the Upper San Juan River Canyon grew, reports of their existence reached the Navajo Department of Fish and Wildlife (NDFW). After aerial surveys confirmed the existence of the bighorn sheep, the NDFW initiated a study of the ecology of the herd in 1997. Funding was obtained by auctioning permits to hunt bighorn sheep rams through the Foundation for North American Wild Sheep (FNAWS) and from mitigation funds for a microwave tower and access road built on the bighorn sheep range. Radiotelemetry was used to monitor the population, estimate population size and trend, to identify conflicts between river-based recreation and bighorn sheep use of the habitat, and to determine the potential for competition between bighorn sheep and cattle, feral horses and burros, and domestic sheep.

Methods

At the initiation of the study in 1997, 18 of 31 bighorn sheep in the Upper Canyon population were radiocollared. Additional bighorn sheep in the Upper Canyon were radiocollared in December 1997, March 2002, December 2002, and December 2005. Thirteen (11 ewes and 2 rams) of 24 bighorn sheep transplanted to the Lower Canyon in October 2003 were radiocollared.

Radiocollared bighorn sheep were visually located about 1×/week yearlong during 1997 and 1998. During 1999–2006, intensive fieldwork was conducted during spring (late March or early April through late June) and for 6 weeks to 3 months during fall (September through mid-December). Radiocollared bighorn sheep in the Upper Canyon herd were visually located or their locations estimated by triangulation 2–4 ×/month during intensive field periods during 1999–2006. Radiocollared bighorn sheep in the Lower Canyon transplant herd were visually located or their location estimated by triangulation 1–2×/month during intensive field periods during 2004–2006. During other periods, radio signals were monitored for mortality signals about 1 ×/month.

For each visual observation, we recorded location, group size, sex-age composition, marked bighorn sheep present, and social behavior of marked and unmarked individuals. Interactions between bighorn sheep and domestic livestock, interactions between bighorn sheep and predators, and interactions between bighorn sheep and humans or humans with dogs were recorded. Lactation status was recorded for marked and unmarked ewes. Radiocollars were equipped with motion sensors with a 6-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 sheep prior to death and 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 through the Navajo Nation Veterinary Program.

Because lambs did not necessarily stay with their mothers though October, lamb survival from birth through October was determined based on the estimated number of lambs born and the maximum, unduplicated count of lambs alive in late October. The number of lambs born was known for marked ewes. The number of lambs produced by unmarked ewes was considered as the higher of: the maximum unduplicated count of lactating unmarked ewes and the maximum unduplicated count of unmarked ewes with lambs <1 week of age.

Results

During 1997 when the population was estimated to include only about 31 bighorn sheep, we observed boaters and their dogs disturbing bighorn sheep when they came to the river to drink and forage in the riparian zone. A gate that protected the bighorn sheep range from motorized access was vandalized during fall 1997, and poachers used the road to gain access and kill a radiocollared ram. In 1998, competition between bighorn sheep and domestic livestock increased when Navajo ranchers moved cattle into the center of the bighorn sheep range above Eight Foot Rapid, and cattle were driven into the head of the canyon from Chinle Wash.

In response to these early findings, the NDFW ceased legal hunting of rams and coordinated with the Bureau of Land Management and local grazing authorities to improve management of the bighorn sheep range. Barriers were erected in the canyon to prevent cattle access to much of the riparian zone in the bighorn sheep range. These barriers were important in protecting bighorn sheep habitat, especially during drought conditions. NDFW was also able to achieve a temporary moratorium on grazing in the central valley of the bighorn sheep range.

Bighorn sheep access to the river and riparian vegetation was improved by eliminating dogs from the river and by closing camping within 2 important access and riparian feeding areas. Gates on the road into the bighorn sheep range were repaired and improved to limit access and minimize poaching.

These improvements in management contributed to a rapid increase in the bighorn sheep population in the Upper Canyon. During the next 3 years, the herd increased from 31 to 56 bighorn sheep, and the following 3 years from 56 to 100 bighorn sheep. Causes of population increase were excellent lamb production, lamb survival, and survival of adult ewes.

Record low precipitation from fall 2001 through summer 2002 correlated with a change in population trend from increasing to stable. Annual survival of lambs and adult ewes declined markedly. Rams and ewes extended their ranges into new areas. Some rams moved out of the original range to areas close to Navajo homes and domestic sheep and goat flocks. Based on these observations, we concluded that the population had reached the capacity of its habitat at least during drought conditions. The NDFW decided that a transplant from the Upper San Juan Canyon (Mexican Hat) herd and resumption of legal harvest of rams would benefit the population by decreasing density and decreasing ecological pressure for the bighorn sheep to expand their range.

Legal hunting provided a reliable source of funding for research and management of desert bighorn sheep on the Navajo Nation and reduced ram numbers. Single permits were auctioned to the highest bidder in 2002 and 2003 through the FNAWS. Continued growth of the herd enabled hunting to be expanded. From the beginning of monitoring, an objective was to provide the opportunity for tribal members to legally harvest a bighorn sheep ram. In 2004, 2 permits for rams were auctioned to the highest bidder and the first drawing was held for a tribal member permit. In 2005 and 2006, 2 permits were auctioned through FNAWS and a third permit was drawn by a tribal member.

Transplant to the Lower San Juan River Canyon

Objectives of the transplant were to reestablish bighorn sheep in suitable historically-occupied habitat on the Navajo Nation, to reduce density of bighorn sheep on the original range, and to create multiple herds on the Navajo Nation.

We surveyed 5 kilometers of the Little Colorado River Canyon south from its confluence with the Colorado River by vehicle and on foot (Figure 1). We received several reports of bighorn sheep in the Little Colorado Canyon and between it and the Grand Canyon. We noted bighorn sheep sign in these areas during our survey. We also discovered corrals and bedding areas of domestic sheep near the canyon rim on the mesa above. The Little Colorado Canyon is adjacent to occupied bighorn sheep habitat in the Grand Canyon. We surveyed the Lower San Juan River Canyon below Mexican Hat by fixed-wing aircraft and raft, and hiked areas of excellent habitat on foot (Figure 1). We decided to focus on the Lower San Juan River Canyon because the habitat was excellent, conflicts with livestock were minimal, and we found no evidence of use by bighorn sheep.

The Lower San Juan River Canyon from Mexican Hat to Oljeto Wash was historical desert bighorn sheep habitat and was occupied by bighorn sheep until the mid-1960s. Surveys by boat, foot, and fixed-wing aircraft during 1998–2003 found vegetation in the Lower Canyon was in excellent condition. Potential for competition with domestic stock was low. No domestic sheep or goats were grazed in the canyon. Cattle were grazed in the top 2 km of the canyon, and horses, cattle and domestic sheep were grazed on the mesa top above the canyon rim. One report of a single bighorn sheep in the Lower Canyon was received in 1998. We received no reports of bighorn sheep from 1999 through 2003 and found no sign of bighorn sheep during surveys by boat and foot in 1998, 1999, and 2003. We concluded that no

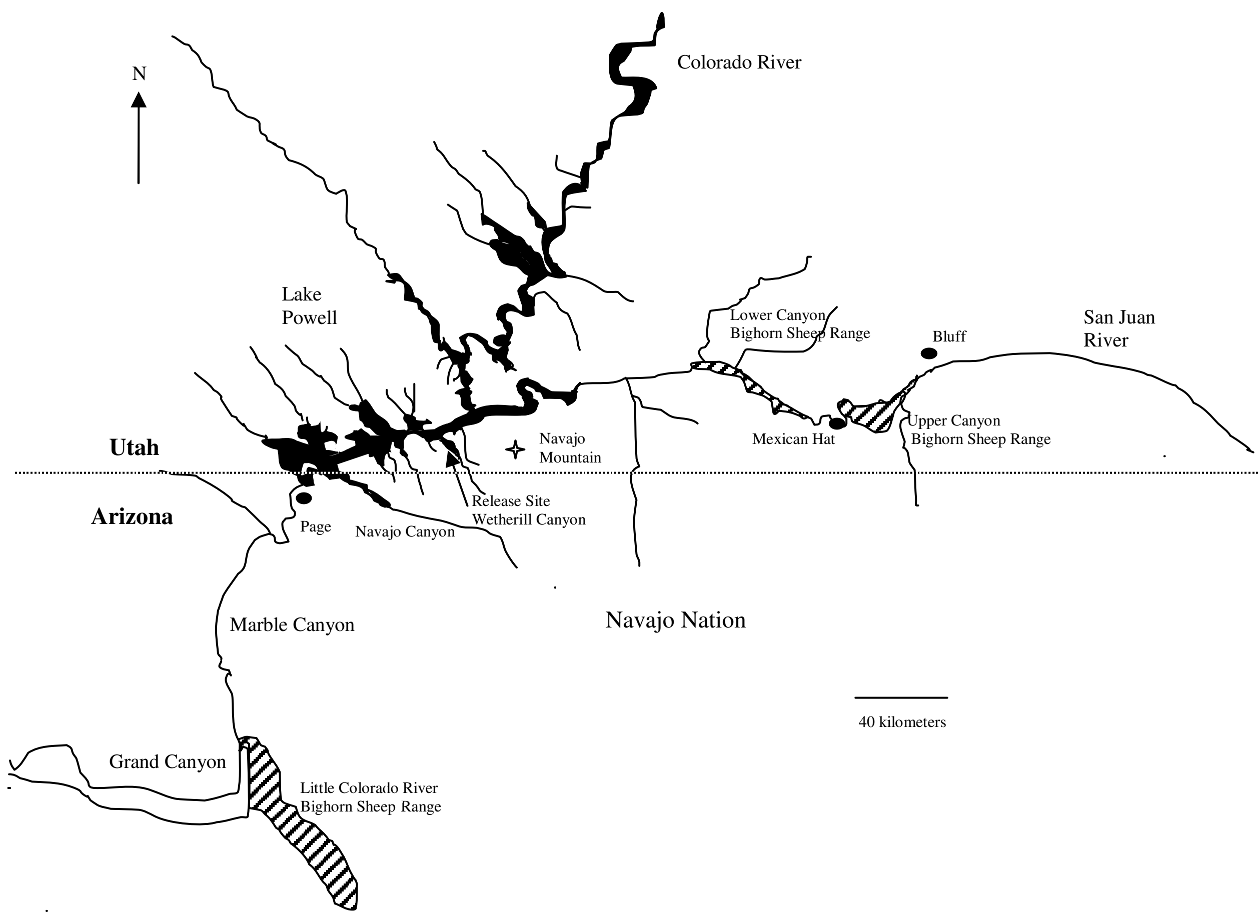


Figure 1. Area map showing the approximate ranges of desert bighorn sheep populations on the Navajo Nation. We surveyed the area between Navajo Canyon and Navajo Mountain and selected Wetherill Canyon as the best site to release bighorn sheep to initiate a new population.

viable bighorn sheep population existed in the San Juan River Canyon below Mexican Hat.

In June 2003, we surveyed the canyon below Mexican Hat to locate a release site. A site was selected at river mile 65.5 about 1–2 km above Slickhorn Rapid and about 65 km downriver from the bighorn sheep range in the Upper Canyon. It included a sandy outwash area at the mouth of a large draw. The site itself and the draw above it had excellent habitat with good interspersion of cliffs and foraging areas. A large, level area with short, herbaceous vegetation was available on which to set transport crates.

During fall 2003, the NDFW contracted with Hawkins and Powers Aviation to capture bighorn sheep from the original herd in the Upper Canyon above Mexican Hat and to sling crates with bighorn sheep from the nearest road access into the Lower Canyon. Mara Weisenberger brought specialized crates, tarps, and a knowledgeable crew from the U. S. Fish and Wildlife Service office in Las Cruces, New Mexico. Mark Meloy and Liam (Bill) Downey represented the Bureau of Land

Management and provided essential help. Guy Wallace of the Utah Department of Natural Resources obtained permission to process the bighorn sheep in Utah. Ellen Meloy, a prominent local writer, recorded the transplant in an article in the journal "Orion," and in several chapters in her book *Eating Stone*.

The transplant was conducted in late October 2003. The bighorn sheep were captured and slung (2 or 3 at a time) to a processing area near the Mexican Hat Rock. With a large tarp to provide protection from the sun, the bighorn sheep were treated under the supervision of Dr. Scott Bender of the Navajo Nation Veterinary Program. A microchip was inserted in the horn base of each bighorn sheep for permanent identification. Ear swabs and blood and fecal samples were taken. Each bighorn sheep was treated with antibiotics, for parasites, and vaccinated for respiratory viruses and pneumonia. Bighorn sheep were ear tagged for individual recognition and 13 of the 24 bighorn sheep were fitted with radiotransmitters.

Twelve bighorn sheep were captured, treated, tagged, and crated by noon on the first day. The crates were trucked to a site above the release site on Douglas Mesa. The crates were lifted singly off the trucks and slung about 1 km to the canyon rim then lowered carefully to the release site. When all 4 crates were lined up at the release site, the bighorn sheep were released together. The operation was repeated the second day. Twenty-four bighorn sheep (16 ewes and 8 rams) were released in 2 days.

The population in the Lower Canyon remained stable at 24 bighorn sheep during the first year following the transplant (2004). Although lamb production and survival were excellent, adult ewe mortality was high. Five of 16 ewes died the first year and 2 radiocollared adult rams left the Lower Canyon. In 2005, lamb production and survival remained excellent, and survival of adult ewes improved. One adult radiocollared ram returned for the rut. The population began to increase. By the end of the third year post transplant (2006), >40 bighorn sheep inhabited the Lower Canyon. In spring 2007, 16 new lambs were born in the population in the Lower Canyon, raising the population estimate to >50 bighorn sheep.

The bighorn sheep in the Lower Canyon explored about 6 km downriver from the release site and about twice that far upriver during first fall and winter following the transplant. Several of the transplanted bighorn sheep were reported by local Navajos on top of Douglas Mesa above the canyon rim within 2 months after the release. The bighorn sheep had moved 13 km upriver and discovered the first possible passage through the canyon headwall and moved onto the mesa top. At least 1 transplanted ewe (with a radiocollar) was illegally killed on Douglas Mesa during the first winter post-transplant.

The surviving marked ewes were observed the next spring (2004) in the canyon. Ewes, juveniles, and young rams remained within the canyon walls and within the area explored overwinter during lambing and lamb rearing.

This pattern was followed during the next 2 years. Groups including radiocollared ewes explored new terrain in the fall and winter then used known areas for lambing and lamb rearing. After the first fall–winter period, exploration was exclusively upriver. During fall–winter 2004–2005, the bighorn sheep explored 13 km of river canyon to river mile 49. During fall–winter 2005–2006, the bighorn sheep increased their range 5 km upriver to river mile 46, and during fall-winter 2006–2007 the bighorn sheep moved another 5 km up river to river mile 43.

Each spring and summer the ewes lambed and reared their lambs in areas that they had explored previously. Ewe-juvenile groups preferred areas of the canyon with large side draws. Draws concentrated available precipitation and provided free water during early to late May depending on moisture conditions. Forage production, high quality green forage, and cool shade were concentrated in draws. Larger draws also provided access through canyon rims to higher levels of the canyon or the canyon rim. Ewe-juvenile groups avoided areas of the canyon with vertical walls close to the river level.

Since the transplant in fall 2003, the ewe-juvenile segment of the population has expanded its range downriver 6 km and upriver 35 km from the release site. The single radiocollared ram that remains in the population migrates seasonally from the Lower Canyon across the San Juan River and out of the canyon to Cedar Mesa and the Valley of the Gods. Since October 2005, he has spent the rut in the Lower Canyon and left during late winter or spring to return to Cedar Mesa.

The ewe-juvenile segment of the population has moved steadily upriver since the transplant and is currently 24 km downriver from the original range. It is possible that contact will be reestablished eventually between the original population and the transplant herd; however, it seems unlikely that the transplant herd would desert its excellent new range to return to the Upper Canyon.

The source herd in the Upper San Juan River Canyon recovered numerically from the transplant in a single year (2004). From fall 2004 to fall 2005, the Upper Canyon herd increased from about 100 to 120 bighorn sheep, and from fall 2005 to fall 2006 the Upper Canyon herd increased from about 120 to 130 bighorn sheep. The current estimate is about 150 bighorn sheep.

With the increase in bighorn sheep numbers, we observed range expansion in both the ram and ewe-juvenile segments of the population. Rams were observed moving upstream to an area used during the dry years of 2001 and 2002 that is close to Navajo homes and domestic sheep. We also received reports of rams east of the study area near Navajo villages with local flocks of domestic sheep. Rams also increased use of the mesa top adjacent to the canyon rim, an area that is heavily used by free-ranging horses. Ewes expanded their ranges to the northeast, west, and southwest into areas that were already overgrazed by cattle, horses, and burros.

These changes in distribution increased the vulnerability of rams and ewes to poaching. One report was received that rams observed close to villages were hunted illegally. Rams that wandered near villages also increased their risk of contact with domestic sheep or goats and exposure to diseases carried by domestic livestock. In captive trials, contact with domestic sheep invariably led to development of pneumonia and death of most or all bighorn sheep (Foreyt et al. 1994).

Planned transplant to Glen Canyon (Lake Powell)

Range expansion of bighorn sheep in the Upper San Juan Canyon population into areas proximate to domestic sheep flocks and areas overgrazed by domestic cattle, horses and burros created concerns about the effects of increasing density on the long term survival of the population. We began again to search for an appropriate release site to reduce density in the Upper San Juan River Canyon bighorn sheep population and to reestablish desert bighorn sheep in suitable unoccupied habitat on the Navajo Nation. Our criteria were adequate separation from areas where domestic sheep or goats were grazed, a low level of competition with domestic cattle, suitable range with steep, rocky areas for escape intermixed with foraging areas, adequate forage in good condition, access to water, and limited human access.

In December 2005, we conducted a helicopter survey from the Lower Canyon of the San Juan River, through the San Juan Arm of Lake Powell, to the south shore of Lake Powell and its canyons to Navajo Canyon east of Page, Arizona (Figure 1). The area has always been remote and we were unable to find historical information about desert bighorn sheep occupancy, or the cause of their extirpation. The only evidence we have that the area was formerly inhabited by desert bighorn sheep is the name Mountain Sheep Canyon on the U. S. Geologic Survey maps. This canyon lies between Navajo Mountain and Wetherill Canyon on the south shore of current Lake Powell (formerly Glen Canyon). We presume it was named for the native desert bighorn sheep that once occupied it.

We found excellent habitat east and north of Navajo Mountain; we also found a number of roads, trails, and corrals. We observed several small flocks of domestic sheep near Navajo Mountain Village. West of Navajo Mountain the terrain was steep and rugged. Between West Canyon and Navajo Canyon the terrain became less steep but we observed herds of cattle and horses and abundant stock trails.

Based on the helicopter survey, we determined to conduct a more intensive boat-based survey of the area west of Navajo Mountain and east of Navajo Canyon (Figure 1). In early October 2006, we surveyed the near-mouth areas of 4 canyons between Navajo Canyon and Navajo Mountain by motor boat and foot (Figure 1). Areas near the mouths of the 2 canyons nearest to Navajo Canyon (Labyrinth and Face Canyons) were severely overgrazed. The vegetation was depleted, perennial grasses and forbs were all but eliminated, and only unpalatable shrubs and shrubs resistant to grazing remained. Many of the surviving plants were pedestaled. We saw sign of both horses and cattle, but cattle were apparently the dominant grazer. Despite the fact that we were more than 16 km from the nearest road access and Navajo homesteads, the vegetation in these areas was severely abused by domestic livestock.

Next we surveyed the near-mouth areas of West Canyon. We found vegetation in good condition and moderate terrain. However, we also found a hogan and corral with evidence of recent use. An ATV trail led from the lake shore to the hogan and there was evidence of activity at the site, salt blocks in the corral, and deep accumulations of domestic sheep droppings in the corral.

We continued to Wetherill Canyon and found a much more promising situation. There was gentle terrain near the mouth, yet much of the canyon was rugged. Vegetation was in excellent condition with no evidence of recent or past use by domestic livestock. No sign of use by feral goats, cattle, or horses was observed. A level spit extending into the lake appeared to provide a good location for helicopter landing or landing crates. The relatively gentle terrain near the mouth provided a number of areas where bighorn sheep could safely access the lake for water. We learned from a Park Service Ranger that reintroduced desert bighorn sheep inhabit similar terrain across Lake Powell and come down to the Lake to drink near Dangling Rope Marina.

The proposed release site at Wetherill Canyon is 22 km by water from the hogan in West Canyon, but bighorn sheep would probably travel around the lake edge to reach the location, which would be more than twice as far. Twenty-four km of very rugged terrain and precipitous walls of Mountain Sheep and Forbidding Canyons separate the release site from Navajo Mountain Village with its resident flocks of domestic sheep. Tall cliffs wall the canyon from Cummings Mesa to the east and west. Navajos formerly drove stock to Cummings Mesa, but the area is seldom grazed now (according to local residents). The trail to the top of Cummings Mesa is long, rugged, and steep. Navajos are unlikely to graze domestic sheep that would require daily herding in this area; cattle, horses or burros may continue to use the mesa top.

Wetherill Canyon is remote (Figure 1). Access is limited to boats. The closest marinas are Wahweep Marina (66 km), Antelope Point Marina (58 km), or Halls Crossing (83 km). Large houseboats, smaller motor boats, and jet skis are abundant on Lake Powell during spring through fall and use all protected anchorages. High recreational use during summer coincides with the greatest need of bighorn sheep for access to the lake for water. Boats of all sizes are generally limited to areas with some sand deposition to provide for safe beaching. Bighorn sheep would be able to access the water from rocky and fairly steep shores which should enable them to avoid direct competition with boaters.

We are planning to conduct additional surveys by boat or helicopter to identify a suitable site for landing crates and personnel. We also intend to extend our survey of Wetherill Canyon farther from the mouth. Objectives are to further assess habitat suitability including availability of forage and escape terrain, determine if any other permanent water sources exist other than the Lake, and investigate any evidence of past or current livestock use.

We are developing a plan for the transplant that will cover capture, treatment, radiocollaring, tagging, and transportation of captured bighorn sheep from the Upper Canyon herd to the release site near the mouth of Wetherill Canyon. At this point, we plan to contract with a helicopter wildlife capture company to capture the bighorn sheep and sling load them to a staging area where a crew will take blood samples, treat bighorn sheep for common diseases, parasites, and infection, collar and ear tag, and crate each bighorn sheep. The crates with bighorn sheep will be trucked about 112 km to a staging area on the west side of Navajo Mountain, about 16 km from the release site. Then a helicopter will transport a crew and sling load the crates with bighorn sheep about 16 km to the release site.

Acknowledgements.— We thank FNAWS, Arizona Desert Bighorn Sheep Society, and Safari Club International for their help in auctioning permits to support this study. Ray Lee in his former capacity with the Arizona Game and Fish Department provided essential expertise for the first capture and radiocollaring of bighorn sheep to initiate the study. Kathleen McCoy, former Wildlife Biologist for the Navajo Nation Department of Fish and Wildlife, provided impetus for initiation of the study and administrative and field support during the early years of the study.

Literature Cited

BAARS, D. AND G. STEVENSON. 1991. San Juan Canyons: A river runner's guide and natural history of San Juan River Canyons. Canon Publishers Ltd., Grand Junction, CO, USA.

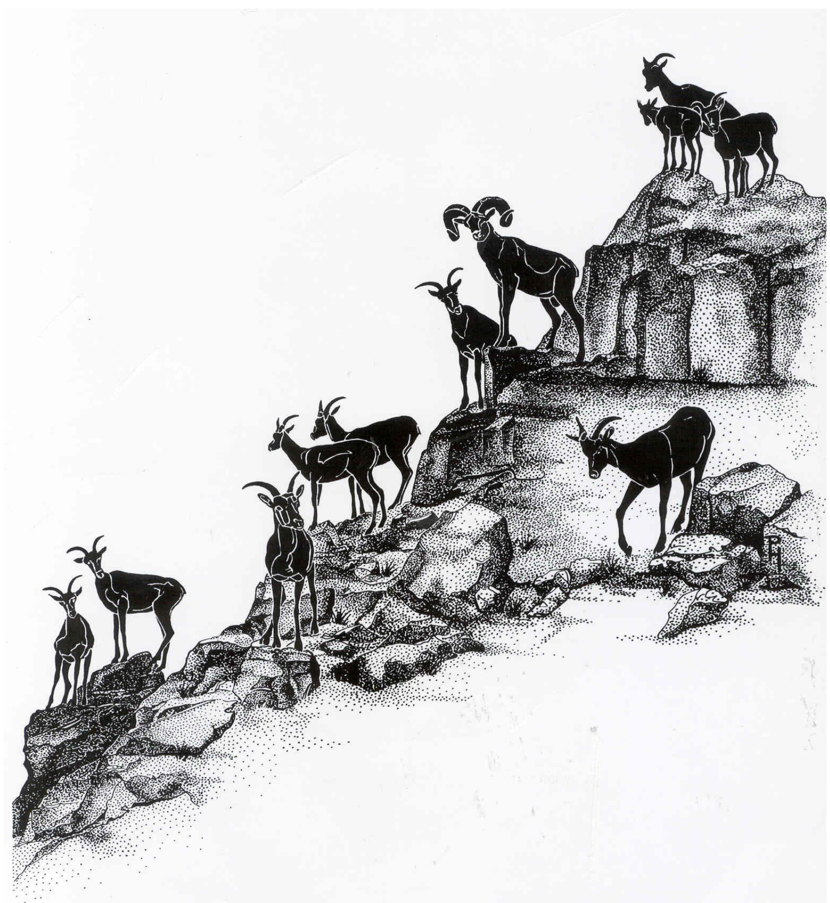
GOODMAN, J. M. 1987. The Navajo Atlas: Environments, resources, people and history of the Dine Bikeyah (Civilization of the American Indian Series), University of Oklahoma Press, Oklahoma City, USA.

FOREYT, W. J., K. P. SNIPES, AND R. W. KASTEN. 1994. Fatal Pneumonia following inoculation of healthy bighorn sheep with *Pasteurella haemolytica* from healthy domestic sheep. Journal of Wildlife Diseases 30:137–145.

KEARSLEY, L. 2002. San Juan River Guide: Sand Island to Clay Hills Crossing. Shiva Press, Flagstaff, AZ, USA.

VALLE, D. 1986. Looking back around the Hat: A history of Mexican Hat. Self published by Doris Valle. 60 pp.

WILSON, L. O. 1968. Distribution and ecology of the desert bighorn sheep in southeastern Utah. Publication Number 68-5, Utah State Department of Natural Resources, Division of Fish and Game, Salt Lake City, UT, USA.



Status of bighorn sheep in Arizona, 2006–2007

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Desert Bighorn Council Transactions 49:52–54

Populations

Estimates of Arizona's desert bighorn sheep (*Ovis canadensis mexicana and O. c. nelsoni*) populations have continued to decline over the past 2 years. Desert sheep are estimated to number about 4,500. Ram:100 ewes:lamb ratios averaged 60:100:24 in 2006 (*n* = 1,249) and 57:100:31 in 2007 (*n* = 1,403).

Declines occurred primarily in the Kofa Mountains (Units 45A, 45B, and 45C) in southwestern Arizona and in the Black Mountains (Units 15B West, 15C, and 15D) of northwestern Arizona. Both populations have stabilized at lower numbers than in 2000. Management plans that address recovery have been drafted for both areas; predation management remains the most controversial component of each, although water developments and wilderness issues also influence management on the Kofa. The Kofa population is estimated at about 400 animals, which is about half of the 2000 population. Bighorn sheep in the Silver Bell Mountains in Unit 37B continue to remain free of any clinical symptoms from the previous disease outbreak.

Rocky Mountain bighorn sheep (*O. c. candensis*) continue to prosper in Arizona. This population is estimated at about 800 animals. Ram:100 ewes:lamb ratios averaged 48:100:38 in 2006 (*n* = 331) and 51:100:54 in 2007 (*n* = 253). For both Rocky Mountain and desert bighorn sheep, Arizona surveys about one third of the population annually, although the Kofa and Black Mountain populations have been surveyed annually since declines were first noted.

Research

Department personnel assisted in authoring several recent papers on bighorn sheep recently. Papers included research on the disease outbreak in the Silver Bell bighorn sheep herd (Jansen et al. 2007), bighorn sheep and water developments (Krasman eta al. 2006, Waddell et al. 2007), effects of mining activity (Jansen et al. 2006), survival as affected by habitat quality (Wakeling and Riddering 2007), and road effects on mortality (Wakeling et al. 2007). Ongoing research is focused primarily on highway influence on survival and movement.

Habitat

The Department works with private organizations (primarily the Arizona Desert Bighorn Sheep Society [ADBSS]) and federal agencies to achieve habitat improvements. Many of these projects are solicited each year through the Department's Habitat Partnership Committees and are funded with Special Big Game License-Tag funds generated through the sale of 2 sheep tags. In 2005, this law was amended to allow for the sale of 3 Special Big Game License-Tags.

In 2006, the Department and ADBSS coordinated on individual projects for $350,272, and in 2007 we coordinated on projects for $706,589. Most projects involved building or maintaining water sources, but also included prescribed fire, sheep survey, and translocations. Habitat evaluations for potential Rocky Mountain bighorn sheep translocations were funded and completed using with these funds.

Translocations

The Department conducted 2 translocations in 2006. During 7–9 November, 28 bighorn sheep were captured in the Virgin Mountain in Unit 13B and moved to Hell's Half Acre in southern Unit 18B. During 14–16 November, 31 Rocky Mountain bighorn sheep were translocated from Eagle Creek and adjacent active mining operations in Unit 27 to West Clear Creek in Unit 6A. Four mortalities occurred during this capture effort.

In 2007, the Department conducted 4 translocations. The second translocation constituted was the 100th involving Arizona and about 1,874 bighorn sheep moved.

The first translocation occurred during 4–6 November, and 27 bighorn sheep were moved from the Virgin Mountains to Hell's Half Acre. The second translocation of the year (and 100th in history) originated from the Imperial Hills in Unit 43B and 13 bighorn sheep were moved to the Big Horn Mountain in Unit 42. The third translocation originated in the Trigo Mountains in Unit 43B and were moved to the Mineral Mountains in Unit 37B. The final translocation moved 14 Rocky Mountain bighorn sheep from mining operations in Unit 27 to West Clear Creek. Because the captures on the mine cannot be conducted via helicopter-net gun, drugs administered from pneumatic guns discharged from the ground are used. Experimentation with A3080 continues to be successful, although another 4 bighorn sheep died from complications. Another died shortly after release in West Clear Creek.

The Department continues to plan for additional transplant opportunities, especially for Rocky Mountain bighorn sheep. The Chevelon Canyon area has remained a high priority for future releases, although a domestic sheep allotment in close proximity has kept this transplant from becoming a reality. Other areas under consideration include Hell's Gate, Mazatzal Wilderness, and Sycamore Canyon (north of Sedona). Domestic sheep allotments play a determining role in several potential desert and Rocky Mountain bighorn sheep sites. The propensity for Rocky Mountain bighorn sheep to wander from the releases site in West Clear Creek also raises concerns about hybridization between desert bighorn sheep. Rocky Mountain bighorn sheep from West Clear Creek have moved west to Oak Creek Village, south to Wickenburg and Lake Pleasant, northeast to Hondah Arizona, and southeast to Winkleman. Their roaming behavior have brought them in proximity to desert bighorn sheep ranges and perhaps some domestic sheep.

Harvest

Bighorn sheep permits remain the most sought after hunting permits in Arizona. In 2006, 16,332 individuals applied for the 93 available permits, whereas in 2007, only 10,930 individuals applied for the 86 available permits. Arizona's inability to consistently provide an online application for which credit cards can be used to pay application fees influences demand for permits substantially.

During the 2006 season, 92 hunters participated, harvesting 84 rams in 673 days of hunting. Hunt success averaged 91.6%. In 2007, 95 hunters participated, harvesting 88 rams in 671 days of hunting. Hunt success averaged 92.9% in 2007.

In 2006, age of harvested rams ranged from 3 to 12 ($\bar{x}$ = 7.3), and horns green scored from 100 2/8 to 187 1/8 ($\bar{x}$ = 156 1/8 B&C). In 2007, age ranged from 3 to 11 ($\bar{x}$ = 7.1) on harvested rams, and green scores on horns ranged from 120 1/8 to 194 6/8 ($\bar{x}$ = 156 5/8 B&C).

Continuing a long history, the Arizona Game and Fish Commission awarded the Special Big Game License Tags for bighorn sheep (2 tags per year) to ADBSS in 2006 and 2007, with a third tag in each year through the Arizona Big Game Super Raffle (AZBGSR). Each year, ADBSS has traditionally auctioned 1 tag at the Foundation for North American Wild Sheep Annual Convention and now auctions the second at their fundraising banquet. The third is now raffled through AZBGSR. In 2006 and 2007, $422,525 and $316,449 were raised with these permits, respectively.

Literature Cited

JANSEN, B. D., P. R. KRAUSMAN, J. R. HEFFELFINGER, J. C. DEVOS, JR. 2006. Bighorn sheep selection of landscape features in an active copper mine. Wildlife Society Bulletin 34:1121–1126.

JANSEN, B. D., P. R. KRAUSMAN, J. R. HEFFELFINGER, T. H. NOON, AND J. C. DEVOS, JR. 2007. Population dynamics and behavior of bighorn sheep with infectious keratoconjunctivitis. Journal of Wildlife Management 71:571–575.

KRAUSMAN, P. R., S. S. ROSENSTOCK, AND J. W. CAIN III. 2006. Developed waters for wildlife: science perception, values, and controversy. Wildlife Society Bulletin 34: 563–569.

WADDELL, R. B., C. S. O'BRIEN, AND S. S. ROSENSTOCK. 2007. Bighorn sheep use of a developed water in southwestern Arizona. Desert Bighorn Council Transactions 49:8–17.

WAKELING, B. F., H. S. NAJAR, AND J. C. O'DELL. 2007. Mortality of bighorn sheep along U. S. Highway 191 in Arizona. Desert Bighorn Council Transactions 49:18–22.

WAKELING, B. F., AND E. RIDDERING. 2007. Relationship between measured habitat quality and first and second year survival for transplanted bighorn sheep. Pages 167–170 *in* C. van Riper II and M. K. Sogge, editors. The Colorado Plateau III: integrating research and resources management for effective conservation. University of Arizona Press, Tucson, USA.

Status of mountain sheep in California: comparisons between 1957 and 2007

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This paper differs from the majority of status reports in the *Desert Bighorn Council Transactions*. It is not our intent to provide an exhaustive overview of the status of mountain sheep (*Ovis canadensis*) in California as of 2007. Rather, we review the current status of specific populations discussed in the first-ever report on the status of mountain sheep in California, which was presented to the Desert Bighorn Council 50 years ago (Weaver 1957). That report was delivered during the first annual meeting of the Council, which took place in Las Vegas, Nevada, 23–25 September, 1957. In attendance at that meeting were 27 dedicated individuals with a vision for the conservation of mountain sheep in desert environments.

Among the aforementioned attendees were 2 Game Managers with the California Department of Fish and Game (CDFG): Richard Weaver and Robert Cowell. Both were graduates of Peon University (Weaver 1957), both cared deeply about wild sheep that inhabited the deserts of California, and both traveled surreptitiously to Las Vegas from California in a state truck to participate in that historic meeting. Their official justification for that forbidden out-of-state trip was that, "Las Vegas was the closest place to buy supplies." Also present from California were Meredith Ingham (Death Valley National Monument [now Death Valley National Park]), Lowell Sumner (Sequoia National Park [now Sequoia-Kings Canyon National Park]), and John Goodman (University of Redlands).

In his formal remarks, Weaver (1957) noted little interest in California's mountain sheep among individuals outside CDFG, but that the species was of personal interest to some within that agency. When V. C. Bleich began work with CDFG in 1973, he raised some questions about the status and conservation of those unique ungulates, and a high-level administrator responded that, "We don't talk about them, because they are controversial and the subject is politically sensitive." As reported by Weaver (1957), California did not then have a full-time investigation or management program for mountain sheep. With the exception of the Sierra Nevada Bighorn Sheep Recovery Program, little has changed. In the last 50 years we have made progress, however, some of which was reflected in a lengthy series of reports (Appendix I) that resulted from implementation of California Senate Concurrent Resolution 43 in 1968.

Since then, we've made additional gains on behalf of those specialized ungulates, but there remains no program dedicated to work specifically on desert ecotypes of mountain sheep; indeed, in 1972 following completion of the field work mandated by the California Legislature, Weaver's position was moved to Sacramento and responsibilities for mountain lions and black bears were added to his work assignments. Two years following Weaver's 1989 retirement from state service, S. G. Torres filled the position and assumed responsibility for mountain lions and mountain sheep. When Torres took a promotion to another program several years ago, his position (i.e., Weaver's former position) was eliminated, and the responsibility was shifted to the Department's Region 6. V. Bleich, who at that time directed the Sierra Nevada Bighorn Sheep Recovery Program, was provided the opportunity to retain that position and assumed the additional responsibility for statewide coordination of the CDFG mountain sheep conservation program. Like Weaver, Bleich had cut his teeth on the wildlife habitat improvement project, and spent numerous years working in desert areas inhabited by mountain sheep. Unlike Weaver, however, Bleich was in the enviable position of having a fully-funded project that allowed him to work extensively on projects to benefit mountain sheep.

As did Weaver (1957), we make reference to an antiquated map of California, on which Joseph Grinnell of the Museum of Vertebrate Zoology had delineated the distribution of mountain sheep (Figure 1). In this review, we follow the format used by Weaver (1957), and make comparisons between information provided at the initial meeting of The Desert Bighorn Council and what is known today in the geographic areas described by Weaver at that meeting.

As Weaver (1957) reported, there was an effort in 1938 to determine, "about how many bighorn sheep we had in California." That initial estimate was 1,500 animals, but Weaver (1957) suggested 3,000 as a more realistic figure. Since then, several efforts to derive population estimates have occurred. Most recently, Epps et al. (2003) reported their best estimate as 4,500 individuals, and that the trend in numbers generally was upward when compared to information reported previously by Torres et al. (1994, 1996).

Weaver began his 1957 report by discussing the status of mountain sheep in the Sierra Nevada. Since then, mountain sheep inhabiting that range were declared to be threatened by the California Fish and Game Commission in 1972, and were classified as endangered by the federal government in 1999 (Bleich 2001), when only about 100 adults remained. That figure was down substantially from the roughly 350 individuals reported to occur there by Jones (1950). Based on work by Wehausen (1980), 3 additional populations were established in the Sierra Nevada during the

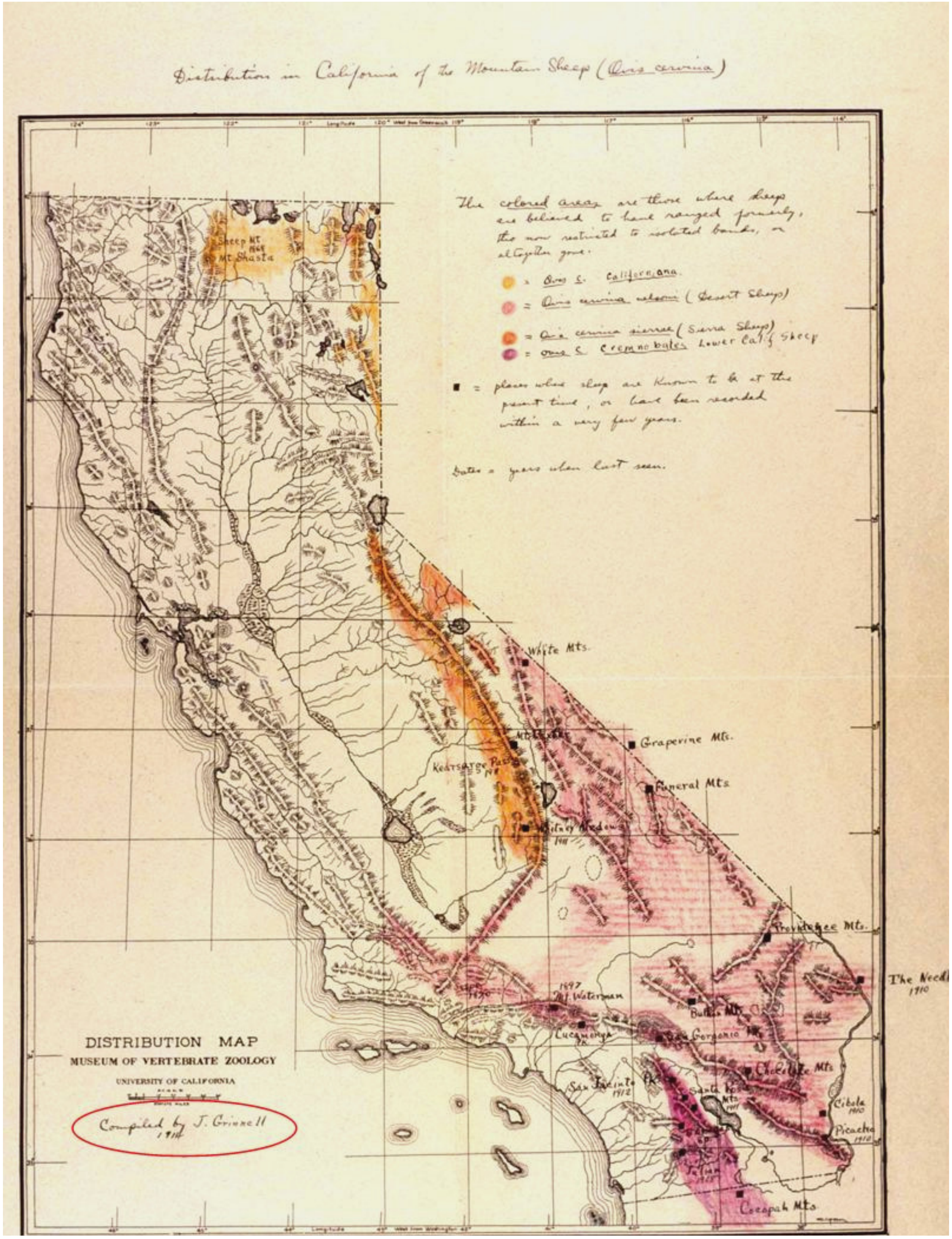

Figure 1. Map of distribution of mountain sheep in California prepared by Joseph Grinnell, University of California, Berkeley, 1914.

late 1970s and 1980s. The number of mountain sheep inhabiting the Sierra Nevada now approaches what Weaver (1957) reported as a population estimate in 1957: about 400 mountain sheep inhabited that range in 2007 (T. R. Stephenson and J. D. Wehausen, unpublished data).

In 1957, the number of sheep inhabiting the White Mountains in Mono and Inyo counties was thought to be between 50 and 100. Currently, we recognize 2 distinct populations of sheep in the White Mountains, totaling nearly 400 individuals (Epps et al. 2003). Ground and aerial surveys repeatedly have yielded observations of nearly 300 individuals in the northern end of that range (Schroeder 2004, 2005; A. E. Ellsworth, unpublished data), >4× what Weaver (1957) estimated the population to be.

In the Deep Springs Range south of the White Mountains, Weaver (1957) referred to a water source that was "... pretty well known as a place to observe bighorn sheep." That population is thought to have been extirpated (Torres et al. 1994) as a result of unknown causes. Weaver (unpublished data) located skeletal remains of mountain sheep and feral goats in the Deep Springs Range, but he found no evidence of an extant population of the former. Thus, the potential for disease contracted from feral goats to have resulted in the extirpation of native sheep from that range cannot be dismissed. We recently have become aware of the presence of mountain sheep in the Deep Springs Range (V. C. Bleich, unpublished data); Epps et al. (2003) reported that <25 sheep were thought to occur there.

Continuing southward, Weaver (1957) reported that few sheep inhabited the Inyo Mountains. We are aware of only one individual (J. D. Wehausen) that has spent time assessing the population of mountain sheep in that range, and his observations are consistent with what Weaver (1957) reported: animals seem to be distributed primarily on the east side of the Inyo Mountains. Epps et al. (2003) estimated the population at between 101 and 150 individuals, but the definition of what constitutes that population has changed since Torres et al. (1994) reported that 51–100 animals inhabited the Inyo Mountains.

To the east of the Inyo Mountains lie Eureka Valley and Saline Valley, and further to the east is an area that Weaver (1957) described as being so remote that, "... even beer cans are scarce" and as having a rather sparse population of mountain sheep; that assessment was based on an absence of observations and a scarcity of sign. The specific area, as described by Weaver (1957), is located "near the boundary of Death Valley National Monument," and included Dry Mountain in central Inyo County. An absence of permanent water at Dry Mountain, caused Weaver (unpublished) to suggest that mountain sheep at Dry Mountain moved to the Panamint Range during summer. As a result of recommendations provided by Weaver and Mensch (1970), permanent sources of water were developed in the Last Chance Range and at Dry Mountain in the 1970s and 1980s (Bleich and Pauli 1990), and those water sources currently receive extensive use by mountain sheep. In 2003, Epps et al. estimated that between 51 and 100 mountain sheep occupied Dry Mountain and the Last Chance Range. Recent investigators (Oehler et al. 2003, 2005) have confirmed the presence of a healthy population of mountain sheep in the Panamint Range, and Epps et al. (2003) estimated that between

101 and 150 animals inhabit the southern end of those mountains.

No estimates of the various mountain sheep populations in Death Valley National Monument were provided by Weaver (1957), but Welles (1957) speculated that 420 sheep inhabited the Monument. Although no detailed surveys have been conducted throughout the newly created Death Valley National Park, and there is some question about the exact geographic boundaries recognized by Welles (1957), data provided by Epps et al. (2003) suggest that the number of mountain sheep currently inhabiting Death Valley National Park is about 275, excluding those inhabiting the Funeral and Black mountains, and the Panamint Range.

Weaver (1972) published an estimate of ~600 for Death Valley National Monument; included in that estimate were populations inhabiting the Grapevine, Funeral, Greenwater, Black, Cottonwood, and Panamint ranges, as well as the Ibex Hills. Welles and Welles (1961) had estimated, however, that 900 mountain sheep inhabited Death Valley National Monument. Recent changes in land management responsibilities have complicated efforts to derive a population estimate for Death Valley National Park and surrounding areas. With the exception of the Panamint Range (Oehler et al. 2005) and Black Mountains (Douglas et al. 1992, Douglas and Longshore 1995), the status of populations in that area is poorly known. In 1989, D. Racine (unpublished data) observed 20 sheep in the Funeral Mountains.

Little was known about mountain sheep in either the Argus and Coso ranges in 1957, in part because they were (and remain) high-security areas to which access is controlled by the Department of Defense. A remnant population estimated at 12 animals was thought to exist in the Argus Range, Inyo County, by Weaver and Mensch (1970). Based on an abundance of petroglyphs, however, Weaver and Mensch (1970) speculated that mountain sheep in the Argus Range and the Coso Range once occurred at higher densities and had a wider distribution.

Mountain sheep were translocated to the Argus Range from Old Dad Peak in 1986 (Bleich et al. 1990*b*). In 2005, 3 mountain sheep were photographed on the west end of the Coso Range, Inyo County (V. C. Bleich, unpublished data), and a haplotype representative of mountain sheep inhabiting Old Dad Peak was confirmed using DNA obtained from feces deposited by those animals (J. D. Wehausen, unpublished data). Epps et al. (2003) placed the number of mountain sheep in the Argus Range at 51–100.

Weaver (1957) also noted the difficulty in obtaining access to other areas controlled by the Department of Defense in northern San Bernardino County, but described some of those areas as containing good sheep habitat. Following removal of several thousand donkeys from the China Lake Naval Weapons Station (Kovach 1983), mountain sheep were translocated to the Eagle Crags during the 1980s (Campbell 1984, Bleich et al. 1990*b*). That population was thought to be small (<25) by Epps et al. (2003); in 2006, 13 additional females were translocated to the Eagle Crags from Old Dad Peak (V. C. Bleich, unpublished data) to augment the population.

The Kingston Range was described as good sheep habitat by Weaver (1957), and he reported an observation of 25 animals in a single group. Jaeger (1994) provided a combined estimate of 75 females for the Kingston Range and the nearby Mesquite Mountains. During 1993–2006, estimates ranging from 53 to 96 were reported within aerial visibility polygons (Graham and Bell 1989) by A. M. Pauli (unpublished data). Epps et al (2003) reported that between 51 and 100 individuals comprised that population. The Kingston Range and Mesquite Mountains, along with the Clark Mountain Range, were opened in 1990 to a very limited harvest of mature male mountain sheep.

The New York Mountains (including the Castle Buttes and Castle Mountains, which were identified as part of the New York Mountains 50 years ago) were described by Weaver (1957) "as some of our better sheep habitat." In contrast, however, Epps et al. (2003) described the New York Mountains as "poor habitat" that "may never have supported a viable population." Although not stated explicitly in his early status report, we here clarify that Weaver's (1957) reference to the New York Mountains included the Castle Buttes and Castle Mountains; further, we emphasize that in 1957 Weaver did not consider the main mass of the New York Mountains to be habitat suitable for mountain sheep, and he speculated that only wandering males would move west of Ivanpah Road into that range. Epps et al. (2003) included the area east of Ivanpah Road (Castle Buttes, Castle Mountains, Hart Mountains, Piute Range) in a separate population estimate ($N = 51–100$), and Weaver (1957) described mountain sheep moving from the "New York Mountains" eastward to the McCullough Mountains in Nevada. Clarification of Weaver's inclusion of the Castle Buttes and Castle Mountains in his reference to the "New York Mountains" is important because Epps et al. (2003) removed the main mass of the New York Mountains from their inventory. In the absence of this clarification and adequate historical research, future investigators could erroneously conclude mountain sheep had been extirpated from the New York Mountains as they now are defined.

The current population estimate for the Providence Range, southwest of the New York Mountains but in the same chain of mountain ranges, is between 51 and 100 animals (Epps et al. 2003). Weaver (1957) provided no population estimate for that geographic area, but reported that a local rancher had seen more sheep "...recently than he has seen for 35 years." Weaver (1957) also noted an increase in the number animals inhabiting the Providence Range over the 9 years he had been working in that area.

Currently, the population in the Granite Mountains, located immediately west of the Providence Range, is thought to number between 25 and 50 (Epps et al. 2003). That population was thought to be limited by mountain lion (*Puma concolor*) predation during the 1980s (Wehausen 1996). Weaver (1957) had described the Granite Mountains as "good sheep habitat" with a probable population of 50 mountain sheep.

The Old Woman Mountains currently support 50 to 100 individuals (Epps et al. 2003); Weaver described that mountain range as 1 of California's better sheep areas, with an upward trend in numbers. Little change in the populations of mountain sheep occupying the Granite Mountains or the Old Woman Mountains appears to have occurred since 1957.

Several mountain ranges located adjacent to the Colorado River in San Bernardino County, including the Whipple and Chemhuevi mountains, were addressed in Weaver's (1957) initial report. The situation in both of those areas is substantially different than it was in 1957, when Weaver reported no evidence of sheep, and almost lacking sheep, for those 2 ranges, respectively. In 1983, 1984, and 1985, mountain sheep were translocated to the Whipple Mountains from Old Dad Peak and the Marble Mountains (Berbach 1987, Bleich et al. 1990*b*), and a small (25–50 individuals; Epps et al. 2003), but apparently stable, population currently exists there. In the Chemhuevi Mountains, a recent (2006) aerial survey yielded observations of 42 mountain sheep, including 24 adult females (A. M. Pauli, unpublished data), suggesting that substantially more sheep are present in that range than thought by Epps et al. (2003). Weaver (1957) noted that the Whipple Mountains supported a large population of donkeys, and little has changed in that regard; in the near absence of active management, donkeys remain numerous in that area.

In central San Bernardino County, no fresh sign of mountain sheep had been observed at Ord Mountain, and, based on the presence of old skulls and very old sign, Weaver (1957) speculated that sheep had been extirpated from that area. He also described use of 1 spring in the adjacent Newberry Mountains as being very light. In contrast, Epps et al. (2003) estimated that 25–50 animals inhabited the Newberry and Ord mountains, which formerly had been treated as separate populations (Torres et al. 1994).

Weaver (1957) described the Boullion [*sic*] Mountains, which are almost entirely within the Twenty Nine Palms Marine Corps Aerial Combat Range, as having only a sparse population of mountain sheep. Jones and Deming (1953) were unable to locate any sources of water on the military reservation and concluded that sheep ranged into the Bullion Mountains only seasonally. In the early 1990s, 2 permanent water sources were constructed in the Bullion Mountains, and mountain sheep were translocated from Old Dad Peak in the eastern Mojave Desert to that area in 1992 (V. C. Bleich, unpublished data). Epps et al. (2003) reported that <25 individuals comprised that population, but the basis for that estimate is uncertain. Mountain sheep are reproducing in that range, and they use the aforementioned wildlife water developments (Figure 2).

Mountain sheep move between the Bullion Mountains and the Sheephole Mountains (Bleich et al. 1990*a*), located immediately southeast of the Bullion Mountains. In 1957, Weaver described a resident population that persisted in the Sheephole Mountains despite the apparent absence of a permanent source of water.

Figure 2. Females and young mountain sheep at the Cleghorn wildlife water development in the Bullion Mountains, San Bernardino County, California, 9 May 2006. Photograph courtesy of S. Marschke, Society for the Conservation of Bighorn Sheep.

Subsequently, Weaver and Mensch (1971) estimated that 12 animals inhabited that range, and a wildlife water development was constructed there in 1982. In a cooperative project with the Bureau of Land Management (1984), CDFG translocated 11 animals from Old Dad Peak to the Sheephole Mountains in 1984 (Bleich et al. 1990*b*). Augmentations occurred in 1985 (Bleich et al. 1990*b*) and 1992 (V. C. Bleich, unpublished data).

Telemetry data (Bleich et al. 1992) were used to select a location for a second wildlife water development in the southeastern part of the Sheephole Mountains, which was constructed in 1993, and the population has since expanded its distribution substantially (A. M. Pauli, unpublished data). Epps et al. (2003) estimated the population at 51–100 animals, but recent aerial surveys (A. M. Pauli, unpublished data) suggest the population is larger. In 2000, the Sheephole Mountains were opened to a limited harvest of mature male mountain sheep. Conservation measures involving additional water developments in that range (and in adjacent areas) have been impossible to implement. Indeed, wilderness advocates (e.g., Donnelly 2007) have continually challenged actions proposed to benefit those populations despite the pivotal roles (Bleich et al. 1990*a*, Epps et al. 2007) they likely play in the dynamics of the South-Central Mojave Desert Metapopulation (as defined by Epps et al. 2003).

In 1957, Weaver provided little information on the status of mountain sheep in Joshua Tree National Monument, which has since been designated Joshua Tree National Park. He did note, however, that sheep were distributed "... pretty much throughout the Little San Bernardino range, the Eagle Mountains and clear out in the Coxcomb Mountains." He described 1 spring in the Eagle Mountains as having a heavy concentration of sheep; Divine (1998) recently reported that a substantial population inhabits that range, and Epps et al. (2003) provided an estimate of 51–100 individuals. Based on recent aerial surveys (J. H. Davis, CDFG, unpublished data), Epps et al. (2003) estimated the population in the Little San Bernardino Mountains at 151–200, and that the Coxcomb Mountains supported <25 individuals. Movement by mountain sheep between the Coxcomb and Eagle mountains was reported by Divine and Douglas (1996).

At the initial meeting of the Desert Bighorn Council, little, if anything, was known about mountain sheep in the San Bernardino Mountains. Based on limited field work at Mount San Gorgonio, Weaver (1957) concluded either that the population was very small, or that he had not adequately investigated the area; the latter was likely correct. Epps et al. (2003) estimated the current population at 51–100 individuals. In 1996, the San Bernardino Mountains became the fifth area to be opened to the limited harvest of mature male mountain sheep, and the California state record was taken from that zone in 1999 (A. M. Pauli, personal communication).

Based on information received from U. S. Forest Service personnel, Weaver (1957) reported an estimate of 65 mountain sheep in the vicinity of Mount San Antonio and Cucamonga Peak on the Angeles National Forest at the east end of the San Gabriel Mountains. The population in the San Gabriel Mountains was estimated at 740 ± 49 (SE) in 1980 (Holl and Bleich 1983), and has undergone substantial dynamics over the past several decades (Holl et al.

2004). Following a marked decline, perhaps associated with changes in habitat quality due to an absence of fire and further confounded by mountain lion predation (Holl et al. 2004; Bleich et al. *in press*), the population appears in 2007 to be increasing (J. T. Villepique, unpublished data). Epps et al. (2003) placed the population at 251–300, and in March 2007 J. T. Villepique (unpublished data) reported an estimate of 308 (95% CI = 277–340 individuals).

Mountain sheep in the peninsular ranges were listed as an endangered population segment by the federal government in 1998 (U. S. Fish and Wildlife Service 2000). Based in part on data from Jones et al. (1957), Weaver (1957) reported an estimate of 350 for the Santa Rosa Mountains, the population of which has undergone substantial shifts in dynamics (Wehausen et al. 1986; U. S. Fish and Wildlife Service 2000). Weaver (1957) was unaware of any efforts to determine the status of sheep within "Borrego and Anza State Parks," but did report an observation of 22 individuals near the Mexican border. Epps et al. (2003) reported a median population estimate of 731 animals for the peninsular ranges metapopulation, with a range of 554 to 900. During 2006, the population in the Santa Rosa Mountains east of Highway 74 was estimated at 342 individuals, west of Highway 74 at 49 individuals, and in the San Jacinto Mountains at 21 individuals; 381 mountain sheep were estimated to inhabit the remainder of the peninsular ranges (S. G. Torres, unpublished data). Populations in the northern Santa Rosa Mountains and in the San Jacinto Mountains remain small despite releases of >100 captive-bred animals (Ostermann et al. 2001). Nevertheless, the number of mountain sheep inhabiting the peninsular ranges is approaching a level consistent with criteria for downlisting to threatened status (U.S. Fish and Wildlife Service 2000).

In the 1950s, the majority of mountain ranges in eastern Riverside County and Imperial County were reported "to have some sheep in them at some time" but Weaver (1957) could provide no details, in part because of security concerns associated with the Chocolate Mountains Aerial Gunnery Range. Our knowledge of sheep in that general area has increased substantially as a result of work by Andrew (1994) and Andrew et al. (1997, 1999). In 1994 the East Chocolate Mountains were opened to the limited harvest of mature males, but that zone has since been closed to hunting. The population there has declined substantially (N. G. Andrew, unpublished data) due to extended drought, the effects of which have been exacerbated by the large population of donkeys in that geographic area (Marshal et al. *in press*). Currently, Epps et al. (2003) place the number of sheep in the Sonoran Desert Metapopulation (East Chocolate, West Chocolate, Orocopia, Chuckwalla, Cargo Muchacho, and Palo Verde mountains) at 316 animals (range 228–400).

Weaver (1957) concluded his status report by noting that the desert ranges in the vicinity of Blythe (the Big Maria, Little Maria, McCoy, and Riverside mountains) may no longer have sheep in them. There has been no recent work to assess the status of mountain sheep in those ranges, largely because of budget constraints. However, there is no reason to suspect any change since Weaver's (1957) assessment, and Epps et al. (2003) categorized those populations as extirpated.

This status report, although unconventional in format, serves to place in perspective the knowledge gained since the first meeting of the Desert Bighorn Council in 1957. Further, it provides some important clarifications regarding the geographic areas described by Weaver (1957). Although there remains an absence of a position dedicated solely to the conservation of mountain sheep in desert regions of California, there now exists a well-funded and successful program to conserve mountain sheep in the Sierra Nevada (Bleich 2001). Knowledge and conservation activities have increased substantially since the initial gathering of biologists in Las Vegas who established the Desert Bighorn Council. We are proud of the accomplishments of that organization to date, and are optimistic that interest among current and future members of the Council will ensure continued successes in the conservation of those magnificent ungulates.

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Literature Cited

ANDREW, N. G. 1984. Demography and habitat use of desert-dwelling mountain sheep in the East Chocolate Mountains, Imperial County, California. M.S. Thesis, University of Rhode Island, Kingston, USA.

ANDREW, N. G., V. C. BLEICH, P. V. AUGUST, AND S. G. TORRES. 1997. Demography of mountain sheep in the East Chocolate Mountains, California. California Fish and Game 83:68–77.

ANDREW, N. G., V. C. BLEICH, AND P. V. AUGUST. 1999. Habitat selection by mountain sheep in the Sonoran Desert: implications for conservation in the United States and Mexico. California Wildlife Conservation Bulletin 12:1–30.

BERBACH, M. W. 1987. The behavior, nutrition, and ecology of a population of reintroduced desert mountain sheep in the Whipple Mountains, San Bernardino County, California. M.S. Thesis, California Polytechnic State University, Pomona, USA.

BLEICH, V. C. 2001. Restoring bighorn sheep to the Sierra Nevada: a new challenge for wildlife biologists. Wild Sheep 24(4):47–50,52.

BLEICH, V. C., AND A. M. PAULI. 1990. Mechanical evaluation of artificial watering devices built for mountain sheep in California. Pages 65–72 *in* G. K. Tsukamoto and S. J. Stiver, editors. Wildlife water development. Nevada Department of Wildlife, Reno, USA.

BLEICH, V. C., J. D. WEHAUSEN, AND S. A. HOLL. 1990*a*. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4:383–390.

BLEICH, V. C., J. D. WEHAUSEN, K. R. JONES, AND R. A. WEAVER. 1990*b*. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Desert Bighorn Council Transactions 34:24–26.

BLEICH, V. C., M. C. NICHOLSON, A. T. LOMBARD, AND P. V. AUGUST. 1992. Preliminary tests of mountain sheep habitat models using a geographic information system. Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council 8:256–263.

BLEICH, V. C., H. E. JOHNSON, S. A. HOLL, L. KONDE, S. G. TORRES, AND P. R. KRAUSMAN. *In press*. Fire history in a chaparral ecosystem: implications for conservation of a native ungulate. Rangeland Ecology and Management.

BUREAU OF LAND MANAGEMENT. 1984. Sheephole mountains habitat management plan for the reestablishment of desert bighorn sheep. Sikes Act Plan CA–06WHA–W63. Needles Resource Area, California Desert District, Bureau of Land Management, Riverside, California, USA.

CAMPBELL, T. G. 1984. A report on the reintroduction of bighorn sheep onto the Naval Weapons Center China Lake, California. Desert Bighorn Council Transactions 28:55–56.

DIVINE, D. D. 1998. Habitat patch dynamics of desert bighorn sheep *Ovis canadensis nelsoni* in the eastern Mojave Desert. Ph.D. Dissertation, University of Nevada, Las Vegas, USA.

DIVINE, D. D., AND C. L. DOUGLAS. 1996. Bighorn sheep monitoring program for the Eagle Mountains landfill project: phase one report. Department of Biological Sciences, University of Nevada, Las Vegas, USA.

DONNELLY, P. 2007. Big game guzzler is threat to wilderness area. http://www.hidesertstar.com/articles /2007/03/14/editorial /opinion2.txt (accessed 14 September 2007).

DOUGLAS, C. L., AND K. M. LONGSHORE. 1995. Population monitoring and habitat analysis for the Black Mountain bighorn sheep, Death Valley National Park, California. Contribution 064/03, National Biological Service Cooperative Unit, University of Nevada, Las Vegas, USA.

DOUGLAS, C. L., K. M. LONGSHORE, AND T. COONAN. 1992. Interim report: population monitoring and habitat analysis for the Black Mountain bighorn, Death Valley National Monument, California. Cooperative National Park Resource Studies Unit, University of Nevada, Las Vegas, USA.

EPPS, D. W., V. C. BLEICH, J. D. WEHAUSEN, AND S. G. TORRES. 2003. Status of bighorn sheep in California. Desert Bighorn Council Transactions 47:20–35.

EPPS, C. W., J. D. WEHAUSEN, V. C. BLEICH, S. G. TORRES, AND J. S. BRASHARES. 2007. Optimizing dispersal and corridor models using landscape genetics. Journal of Applied Ecology 44:714–724.

GRAHAM, A., AND R. B. BELL. 1989. Investigating observer bias in aerial survey by simultaneous double-counts. Journal of Wildlife Management 53:1009–1016.

HOLL, S. A., AND V. C. BLEICH. 1983. San Gabriel mountain sheep: biological and management considerations. USDA Forest Service, San Bernardino National Forest, San Bernardino, California, USA.

HOLL, S. A., V. C. BLEICH, AND S. G. TORRES. 2004. Population dynamics of bighorn sheep in the San Gabriel Mountains, California, 1967–2002. Wildlife Society Bulletin 32:412–426.

JAEGER, J. R. 1994. Demography and movements of mountain sheep in the Kingston and Clark mountain ranges, California. M.S. Thesis, University of Nevada, Las Vegas, USA.

JONES, F. L. 1950. A survey of the Sierra Nevada bighorn. Sierra Club Bulletin 35(6):29–76.

JONES, F. L., AND O. V. DEMING. 1953. Report on a survey of bighorn habitat in the Twenty-nine Palms Marine Corps Artillery Training Center. Unpublished report, included as Appendix III in Weaver and Mensch (1971).

JONES, F. L., G. FLITTNER, AND R. GARD. 1957. Report on a survey of bighorn sheep in the Santa Rosa Mountains, Riverside County. California Fish and Game 43:179–191.

KOVACH, S. D. 1983. Report of the feral burro committee. Desert Bighorn Council Transactions 27:37–38.

MARSHAL, J. P., V. C. BLEICH, AND N. G. ANDREW. *In press*. Evidence for interspecific competition between feral ass and mountain sheep in a desert environment. Wildlife Biology.

OEHLER, M. W., SR., R. T. BOWYER, AND V. C. BLEICH. 2003. Home ranges of mountain sheep: effects of precipitation in a desert ecosystem. Mammalia 67:385–402.

OEHLER, M. W., V. C. BLEICH, R. T. BOWYER, AND M. C. NICHOLSON. 2005. Mountain sheep and mining: implications for conservation and management. California Fish and Game 91:149–178.

OSTERMANN, S. D., J. R. DEFORGE, AND W. D. EDGE. 2001. Captive breeding and reintroduction evaluation criteria: a case study of peninsular bighorn sheep. Conservation Biology 15:749–760.

SCHROEDER, C. A. 2004. Bighorn sheep in the White Mountains, California: 2004 survey results. Unpublished Contract Report, California Department of Fish and Game, Bishop, California, USA.

SCHROEDER, C. A. 2005. Bighorn sheep in the White Mountains, California: 2005 survey results. Unpublished Contract Report, California Department of Fish and Game, Bishop, California, USA.

TORRES, S. G., V. C. BLEICH, AND J. D. WEHAUSEN. 1994. Status of bighorn sheep in California, 1993. Desert Bighorn Council Transactions 38:17–28.

TORRES, S. G., V. C. BLEICH, AND J. D. WEHAUSEN. 1996. Status of bighorn sheep in California, 1995. Desert Bighorn Council Transactions 40:27–34.

U. S. FISH AND WILDLIFE SERVICE. 2000. Recovery plan for bighorn sheep in the peninsular ranges, California. U. S. Fish and Wildlife Service, Portland, Oregon, USA.

WEAVER, R. A. 1957. Status of the bighorn sheep in California. Desert Bighorn Council Transactions 1:8–11.

WEAVER, R. A. 1972. Desert bighorn sheep in Death Valley National Monument and adjacent areas. Wildlife Management Administrative Report 72–4. California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1970. Bighorn sheep in northwestern San Bernardino and southwestern Inyo counties. Wildlife Management Administrative Report 70–3. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1971. Bighorn sheep in southwestern San Bernardino [County]. Wildlife Management Administrative Report 71-2. California Department of Fish and Game, Sacramento, USA.

WEHAUSEN, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. Dissertation, University of Michigan, Ann Arbor, USA.

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

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.

WELLES, R. E. 1957. Status of bighorn sheep in Death Valley. Desert Bighorn Council Transactions 1:22–25.

WELLES, R. E., AND F. B. WELLES. 1961. Fauna of the national parks of the United States: the bighorn of Death Valley. National Park Service Fauna Series 6. U.S. Government Printing Office, Washington, D.C., USA.

Appendix I. Federal Aid in Wildlife Restoration Project reports resulting from implementation of California Senate Resolution 43, 1968, which led to specific management actions to benefit mountain sheep. The reports are listed in order of publication.

WEAVER, R. A., J. L. MENSCH, AND W. V. FAIT. 1968. A survey of the California desert bighorn (*Ovis canadensis*) in San Diego County. Pittman-Robertson Project Report W–51–R–14. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1969. A report on desert bighorn sheep in eastern Imperial County. Pittman-Robertson Project Report W-51-R-14. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., J. L. MENSCH, AND R. D. THOMAS. 1969. A report on desert bighorn sheep in northeastern San Bernardino County. Pittman-Robertson Project Report W–51–R–14. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1970. Bighorn sheep in northwestern San Bernardino and southwestern Inyo counties. Wildlife Management Administrative Report 70–3. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1970. Bighorn sheep in southern Riverside County. Wildlife Management Administrative Report 70–5. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1970. Desert bighorn sheep in northern Inyo and southern Mono counties. Wildlife Management Administrative Report 70–7. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1971. Bighorn sheep in northeastern Riverside County. Wildlife Management Administrative Report 71–1. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. L. MENSCH. 1971. Bighorn sheep in southwestern San Bernardino [County]. Wildlife Management Administrative Report 71–2. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. HALL. 1971. Bighorn sheep in Joshua Tree National Monument and adjacent areas. Wildlife Management Administrative Report 71–7. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. HALL. 1971. Desert bighorn sheep in southeastern San Bernardino County. Wildlife Management Administrative Report 71–8. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., J. L. MENSCH, W. TIMMERMAN, AND J. M. HALL. 1972. Bighorn sheep in the San Gabriel and San Bernardino mountains. Wildlife Management Administrative Report 72–2. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A., AND J. M. HALL. 1972. Bighorn sheep in the Clark, Kingston and Nopah mountain ranges (San Bernardino and Inyo counties). Wildlife Management Administrative Report 72–3. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A. 1972. Desert bighorn sheep in Death Valley National Monument and adjacent areas. Wildlife Management Administrative Report 72–4. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

WEAVER, R. A. 1972. California bighorn in the Sierra Nevada mountain range. Wildlife Management Administrative Report 72–7. Wildlife Management Branch, California Department of Fish and Game, Sacramento, USA.

Status of desert bighorn sheep in New Mexico, 2006

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Desert Bighorn Council Transaction 49:68–70

Desert bighorn sheep (*Ovis canadensis*) continue to increase in New Mexico. Population augmentations have been occurring more regularly in the 2000s. There were 183 bighorn sheep released in the wild from 1987–2001, and 178 bighorn sheep released between 2002–2006. Augmentations, combined with significantly lower adult mortality rates, have resulted in an increase in the New Mexico population from <170 bighorn sheep in 2001, to about 390 in autumn 2006 (Figure 1).

Fra Cristobal and Caballo Mountains Metapopulation

There are about 90–100 bighorn sheep in the Fra Cristobal-Caballo Mountains metapopulation. For several years, reports of bighorn sheep in the Caballo Mountains have been filed, but were not verified by photographs or by NMDGF helicopter surveys. In October 2006, a small group of bighorn sheep was observed during a deer helicopter survey. A ewe was netgun captured and radiocollared. This self-starting herd, assumed to have been started by Fra Cristobal bighorn sheep, is estimated at 10–20 bighorn sheep.

In 2006, NMDGF and the Turner Endangered Species Fund completed a management agreement that lays the foundation for mountain lion (*Puma concolor*) management in the Fra Cristobals. This agreement incorporates a flexible mountain lion control program based on the size of the bighorn sheep population. There continues to be full time bighorn sheep and mountain lion monitoring in the Fra Cristobal portion of this metapopulation.

San Andres Mountains

The San Andres population was reestablished in 2002 with bighorn sheep from Red Rock and Kofa National Wildlife Refuge (KNWR) in Arizona. A second transplant from the KNWR in 2005 increased the population number to about 105–115 bighorn sheep. In September–October 2006, the population declined with 9 of 42 radiocollared bighorn sheep dying from causes other than predation. Two bighorn sheep sent to the Veterinary Diagnostic Laboratory tested positive for pneumonia. This is the second decline since 2002 where pneumonia has played a role. It is unknown where the pneumonia comes from as there are no known domestic sheep or goats in the area. The 2006 population estimate is 70–80.

Following the removal of 18 mountain lions from this bighorn sheep range there was no documented mountain lion predation from January 2004 through January 2006. However, 4 mountain lion-killed bighorn sheep between February and August 2006 triggered the reinstatement of range wide mountain lion removal through May 2007. The removal of 6 mountain lions between September 2006 and May 2007 has resulted in a cessation of documented mountain lion predation.

Bootheel Metapopulation

The 2 populations in the Bootheel continue to increase. The estimate for this metapopulation, excluding bighorn sheep in the Arizona portion of the Peloncillo Mountains, is 160–185. The Peloncillo Mountains population, augmented in 2003, has increased slowly to the autumn 2006 estimate of 70–80 bighorn sheep. The Little Hatchets sub-population was augmented in autumn 2005, and has remained at the post-release size of about 50–55 bighorn sheep. Only 1 mountain lion was removed from the Hatchet Mountains in the 12 months prior to the bighorn sheep release. Four bighorn sheep were killed by mountain lions in the first 3 months post-release. Documented predation ceased after 3 more mountain lions were removed. The Big Hatchets sub-population was augmented in autumn 2006 for a post-release population of about 40–50 bighorn sheep. Six mountain lions were removed from the Hatchet Mountains in the 12 months prior to the Big Hatchets bighorn sheep release (this includes the 3 mountain lions removed after the Little Hatchets release), and there has been no mountain lion predation documented as of spring 2007. A full time employee monitors both of these populations.

Mountain Lion Control

A preventative mountain lion control program was initiated in 4 desert bighorn sheep ranges in 1999. The average annual mortality rate from mountain lion kills was 0.16 during years without mountain lion control, versus 0.03 during years with mountain lion control. These mortality rates were calculated using the program MARK. During the preventative mountain lion control program, an average of 3.4 mountain lions has been removed from each of 4 mountain ranges annually. The areas where preventative mountain lion control occurs comprised <1% of the statewide mountain lion habitat.

Red Rock Management

Since its inception in 1972, 354 bighorn sheep (158 ewes, 196 rams) have been transplanted out of the Red Rock captive breeding facility into the wild during 29 capture events. From 1979–1994, an average of 6.9 bighorn/year were removed, compared with 1999–2006 when an average of 20.2 bighorn sheep/year were removed. Bighorn sheep density in the pens has ranged from 11–26/km^2, with an average of 19/km^2. Red Rock remains the backbone of the desert bighorn sheep recovery program by providing transplant stock for release into the wild. A half-time contractor maintains the fence, supplies supplemental feed and water, and removes mountain lions from inside, and a buffer zone outside, of the pens.

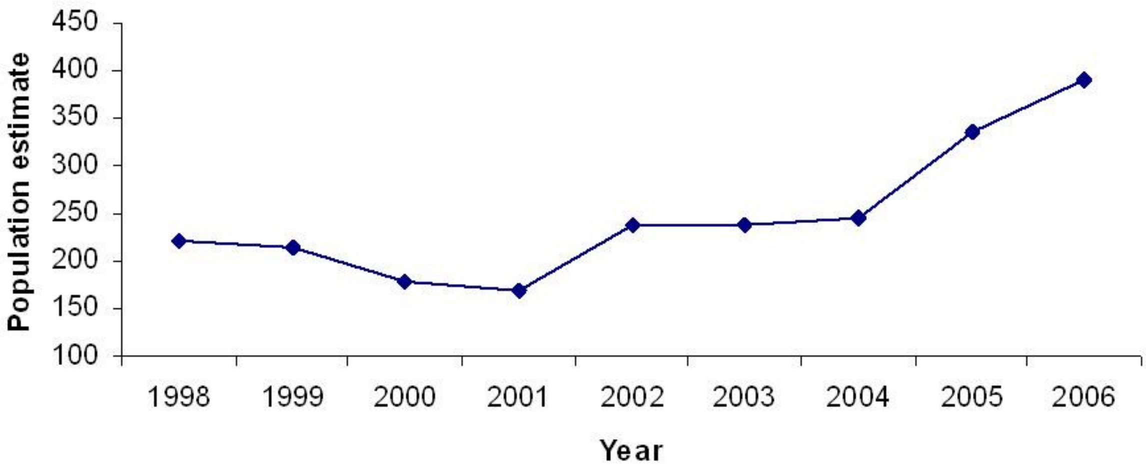

Figure 1. Autumn population estimate of desert bighorn sheep in New Mexico, 1998–2006.

Hunting

In 2006, the new state record desert bighorn sheep was harvested by the auction hunter, scoring 188 2/8 Boone and Crockett points. The public license was held by a youth hunter who harvested a ram scoring 158 6/8. The auction tag price has increased every year since 2004, for an average of $160,000 from 2002–2007. In 2007, the auction tag sold for $105,000, and was donated back to NMDGF. The license was sold a second time to a different individual, for another $105,000, for a total of $210,000. Each year, 1 auction tag is sold at the National FNAWS convention to hunt either Rocky Mountain or desert bighorn sheep, and 1 permit is drawn in a raffle conducted by the New Mexico Chapter of FNAWS.

Status of desert bighorn sheep in Texas, 2006–2007

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Desert Bighorn Council Transactions 49:71–75

POPULATIONS

Seven free-ranging populations of desert bighorn sheep (*Ovis canadensis*) currently exist in Texas, and all occur in the Trans-Pecos region of the state. Areas supporting sheep include 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). Field staff and private landowners continue to observe substantial movement of desert bighorn sheep between mountain ranges. Bighorn sheep are currently occupying suitable habitat between management areas on both private and public land, including Big Bend National Park. Bighorn sheep production in these areas is limited because of high numbers of exotic or feral animals, mountain lion (*Puma concolor*) predation, and often poor water availability.

Desert bighorn sheep numbers in Texas have far exceeded the population levels of the early 1900s (~500) with numbers currently estimated at over 1,000 animals. Helicopter surveys conducted during August-September of 2005 and 2006 indicated an increasing bighorn sheep population (Fig. 1). An incomplete survey in 2005 resulted in only 440 sheep observed (338 in the Baylor-Beach-Sierra Diablo metapopulation). However, a complete survey in 2006 indicated that during the past 2-year period, total bighorn sheep numbers have increased by 42%. The most significant increases were observed in the Baylor-Beach-Sierra Diablo Metapopulation (599 sheep observed in 2006). A 53% increase was observed in the Sierra Diablos alone during the past 2-year period. The 2006 surveys produced a record 822 classifications in 73.3 hours of survey time (11.2 sheep/hour). Survey results yielded ratios of 52 rams:100 ewes:44 lambs.

RESEARCH

No research was completed during the last 2 years.

HABITAT IMPROVEMENTS

In March 2006, 2 guzzlers were installed to benefit bighorn sheep at Sierra Diablo WMA. In September 2006, the water system near the Sierra Diablo headquarters was refurbished. A submersible pump was installed that is used to fill a water storage tank on the rim. In March 2007, a "super guzzler" was installed near the rim at Sierra Diablo WMA. These

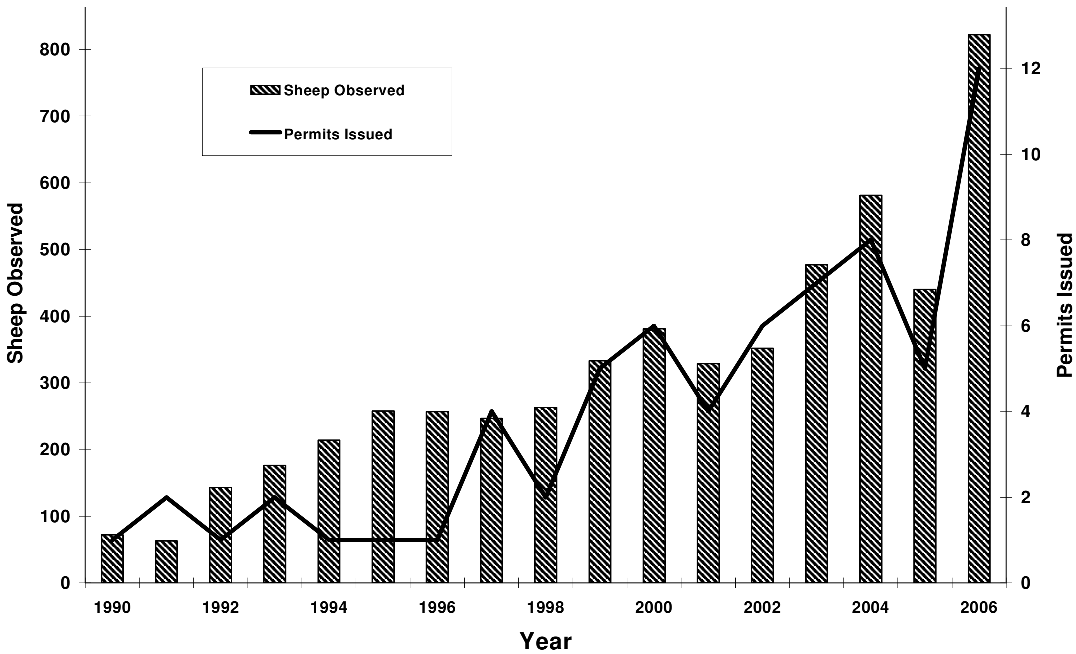


Figure 1. Bighorn sheep numbers observed annually during August helicopter surveys and number of hunting permits issued annually since 1990.

new facilities consist of 2 runoff aprons, 3 storage tanks, 2 water lines, and 3 drinkers. Also included is a system of interconnected pipes and valves that maximize flexibility for maintenance and providing water to drinkers. These projects were accomplished through the cooperative efforts of the Texas Bighorn Society (TBS), private landowners, and TPWD. WMA staff refurbished and/or maintained about 40 water facilities that were constructed to benefit desert sheep on Elephant Mountain, Sierra Diablo, and Black Gap WMAs.

During the past 2 years, the TBS helped to resolve fragmentation issues and improve habitat integrity for desert bighorn sheep on Black Gap WMA by contributing in excess of $286,000 toward the purchase of 4,125 acres of private and General Land Office (GLO) inholdings on the area. Through these purchases and a land trade with the GLO, the Black Gap WMA has increased from 83,000 to 103,000 deeded acres.

Lightning-strike fires on Elephant Mountain WMA in 2005 and 2006 have benefited bighorn sheep and other wildlife on the area by setting back brush encroachment, maintaining visibility, temporarily increasing palatability and nutrient content of forage, and improving overall plant species composition.

HARVEST

Bighorn sheep restoration and management in Texas continues to be funded by hunters through the Federal Aid in Wildlife Restoration Program, Foundation for North American Wild Sheep (FNAWS) auction permits, and the Texas Grand Slam Hunt Program. Seventy desert bighorn sheep hunting permits have been issued since the Texas Legislature reinstated hunting in 1988. These include: 39 private landowner permits, 19 public hunting permits, 9 FNAWS permits, 2 TBS permits, and 1 Operation Game Thief permit. Since 1989, $645,500 has been generated from 9 FNAWS permits. Additional funding for research and management has been generated from 8 Texas Grand Slam permits. Overall success for desert bighorn sheep hunting in Texas is 89.5%.

Several milestones were reached in the 2005–2006 hunting season. In October 2005, Randy Pittman harvested a trophy book ram (169 5/8) at Elephant Mountain WMA. This hunting opportunity was purchased at the previous FNAWS convention for a record $87,500. Five bighorn sheep hunting permits were issued for the 2005–2006 hunting season, and the success rate was 100%. Permits issued for the 2005–2006 season included: 2 private landowner (1 Sierra Diablo Mountains and 1 Baylor Mountain), 1 FNAWS permit (Elephant Mountain WMA), 1 Texas Grand Slam Permit (Elephant Mountain WMA), and 1 Operation Game Thief permit (Sierra Diablo WMA).

The 2006–2007 hunting season proved to be another record year for the desert bighorn program in Texas. The second ever TBS permit was issued to assist in generating revenue for bighorn restoration efforts. The hunting opportunity was purchased by Mr. Walter Ford at the annual TBS fundraiser auction for a record $105,000 (surpassing the previous record of $102,000). In October 2006, Mr. Ford harvested a trophy book ram (179 0/8) at Elephant Mountain WMA. On January 9, 2007 the less than 2-year old state record (183 5/8 ram harvested in 2005 by Terry Fricks) was surpassed. Stephanie Altimus harvested a new state record ram that scored 184 0/8. The ram was harvested in the Beach Mountains and was the first 180+ ram taken in the Beach-Baylor-Sierra Diablo metapopulation since the legislature reinstated sheep hunting in 1988. Four days later, Dallas Safari Club auctioned a "next available" permit at Elephant Mountain WMA. The hunting opportunity was purchased by Bernie Fiedeldey for $101,000. Dallas Safari Club donated 100% of the proceeds to the TPWD Sheep Fund for the management and restoration of desert bighorn sheep. A new record 12 bighorn hunting permits were issued for the 2006–2007 season including: 9 private landowner permits (4 Sierra Diablo Mountains, 1 Baylor Mountain, 2 Beach Mountain, and 2 Black Gap area), 1 Texas Grand Slam Permit (Elephant Mountain WMA), 1 Public Hunter permit (Sierra Diablo WMA), and 1 TBS permit (Elephant Mountain WMA).

PROBLEMS-OPPORTUNITIES

Desert bighorn sheep herds in Texas are increasing in numbers and distribution. Documenting and quantifying this trend through expanded survey efforts continue to be challenging regarding increased demands on human resources and the Wildlife Division budget.

Regarding stocking priorities, Black Gap WMA is scheduled to receive the next available source of sheep to augment the current population (soft-release pen will be used). However, planning efforts are currently underway for establishing the eighth free-ranging desert bighorn sheep population in Texas. Big Bend Ranch State Park is considered to be the top priority. However, success will require overcoming many obstacles including human disturbances, predator issues, free-ranging exotics, as well as political pressure from diverse user groups.

One of the most exciting projects on the horizon for desert bighorn sheep in Texas is the El Carmen-Big Bend Conservation Corridor Initiative. This international mission involves the conservation of a very large, diverse, contiguous tract of land—a *transboundary megacorridor*. The project involves partners such as Cemex (a global cement company), TPWD, the National Park Service, private landowners, Mexican conservation agencies, and TBS. While protecting a diversity of flora and fauna, the desert bighorn sheep will benefit greatly by the establishment of a free-ranging bighorn sheep population in the Maderas del Carmen Protection Area (514,000 acres) that is immediately south and southeast of Black Gap and Big Bend National Park, respectively. Sheep numbers in the 12,300-acre brood facility are already approaching 150 animals. Combined with the growing sheep population in the Black Gap area and recent expansion into Big Bend National Park and nearby private ranches, this area has tremendous potential for supporting a stable desert sheep metapopulation (but not without persistence in managing exotics and predators).

Elephant Mountain is expected to serve as a potential source of brood stock for future restoration efforts in Texas. However, herd recovery has been slower than expected following the removal of 45 sheep in year 2000. Brood stock from out of state may be needed to facilitate restoration of desert bighorn sheep in areas of suitable habitat.

Aoudad sheep (*Ammotragus lervia*) continue to be observed in bighorn sheep habitat in Texas and in potential desert sheep range, especially in the southern mountain ranges. Competition for forage, dominance over bighorn sheep at water locations, and disease risks are among serious concerns. TPWD has the authority, with landowner consent, to eliminate aoudads by lethal means for controlling encroachment in desert sheep habitat. TPWD views the implementation of this authority as an important factor in the successful management of bighorn sheep in Texas.

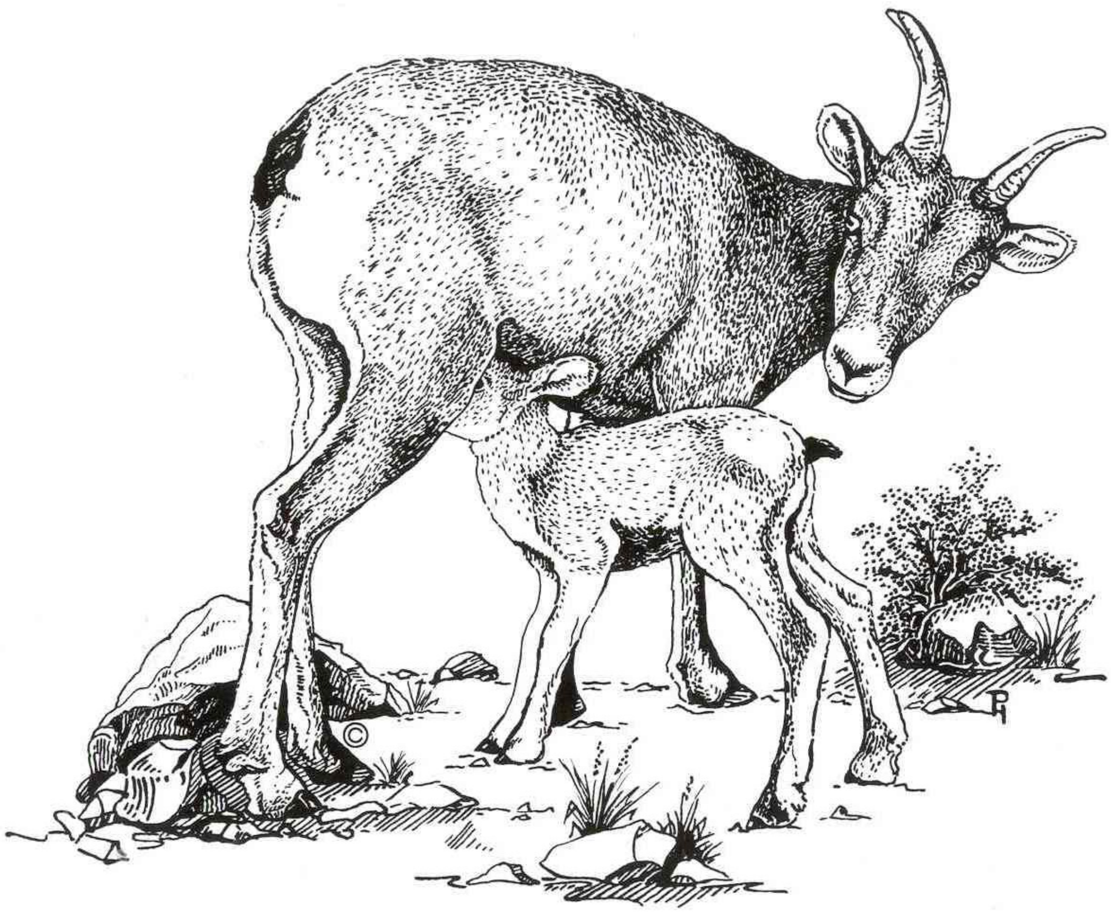
Mountain lion predation continues to be one of the limiting factors for desert bighorn sheep populations in Texas. Predator control efforts must be continued in sheep restoration areas to minimize losses to desert bighorn sheep brood stock.

Construction of wind-power generators within desert bighorn sheep habitat continues to be a threat. A "wind farm" has been constructed in the Delaware Mountains, a potential corridor for natural sheep movement from the Sierra Diablos to the Guadalupe Mountains (currently uninhabited by bighorn sheep). The noise and motion produced by the structures, and increased human disturbances resulting from road construction and other maintenance activities are among the concerns. Efforts will continue to inform landowners of potential conflicts of wind-power development within critical bighorn sheep habitat.

The future of desert bighorn sheep management in Texas must be addressed through appropriate planning strategies. Evaluation of existing management efforts, establishment of long-term goals, and long-term planning are critical for proper management.

As mentioned previously, hunters through the Federal Aid in Wildlife Restoration Program, FNAWS, and the

Texas Grand Slam Hunt Program have been important to bighorn sheep restoration and management in Texas. In addition, partners such as the TBS are critical for continued success. However, the private landowner remains the single most important factor in restoring and maintaining viable bighorn populations in Texas. Efforts to educate landowners regarding proper management of desert bighorn sheep must continue to be expanded.



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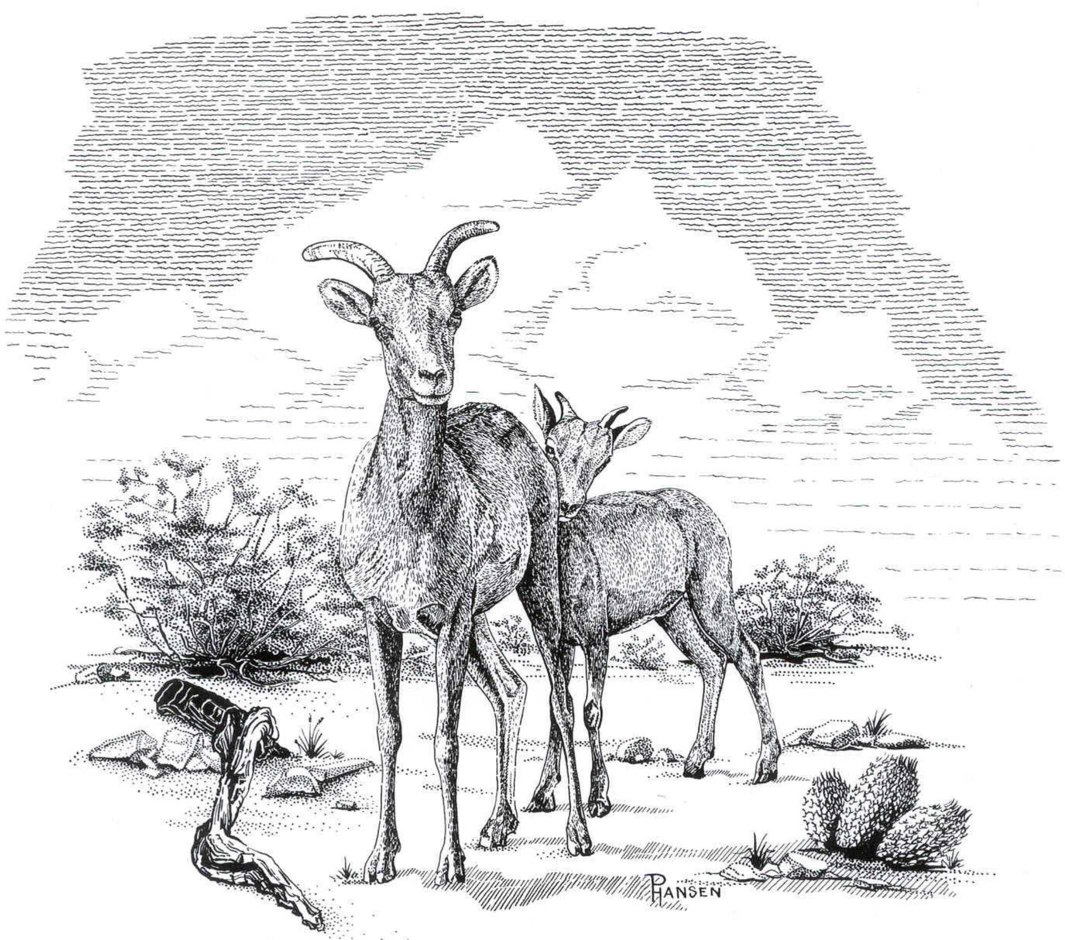

DESERT BIGHORN REINTRODUCTIONS INTO GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

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In 1999, 21 desert bighorn sheep (*Ovis canadensis nelsoni*) were trapped along the shore of Lake Mead in Arizona and released in Grand Staircase-Escalante National Monument (GSENM). Seventeen of these animals were fitted with radiotransmitters. In 2000, 20 more bighorn sheep were trapped near Lake Mead and released in GSENM. Three of these animals received radiotransmitters. In 2006, 20 more bighorn sheep were trapped near Fallon, Nevada and transported to GSENM. There were 17 sheep in this group fitted with radiotransmitters. All of these sheep were transported to GSENM in horse trailers. Trap and release efforts were part of cooperative projects between the Foundation for North American Wild Sheep (FNAWS), The Utah Division of Wildlife Resources (DWR), and the GSENM. Both FNAWS and DWR have expressed interest in expanding the current range of bighorn sheep in GSENM to mirror historic numbers. Monitoring work has been carried out mainly by graduate students from Brigham Young University (BYU). Two years of data has been collected by BYU (2000–2001). GSENM biologists continue to work towards bringing more bighorn sheep into the area and work towards maintaining a strong relationship with FNAWS and DWR. Monitoring sheep movements and maintaining sheep habitat is a high priority in GSENM.

SERODIAGNOSTIC TEST RESULTS OF DESERT BIGHORN SHEEP TRANSPLANTED TO COAHUILA, MEXICO

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Between 2000 and 2005, 91 desert bighorn sheep *(Ovis canadensis mexicana)* were captured from 4 different areas in Sonora and translocated to Coahuila, Mexico as part of the national recovery program for the subspecies. We conducted sampling and testing protocols to address concerns regarding disease compatibility and to provide an assessment of overall herd health status. Sixty-eight bighorn sheep were serologically tested for evidence of exposure to infectious agents or diseases by competitive enzyme-linked immunosorbent assay (c-ELISA) protein G. Serodiagnostic test assay data was obtained for evidence of exposure to bluetongue virus (BTV), parainfluenza 3 virus (PI-3), bovine viral diarrhea (BVD), infectious bovine rhinotracteitis (IBR), rotavirus, *Pastuerella multocida, Manheimia haemolytica, Anaplasma* spp., *Brucella abortus, Brucella melintesis, Campilobacter fetus, Chlamydia* spp., *Leptospira hardjo, Mycobacterium bovis, Mycobacterium paratuberculosis, Bordetella* spp., *Salmonella dublin, Salmonella typhimorium, Toxoplasma* spp., and *Mycoplasma bovis.* Positive e-ELISA test results of those diseases of concern on the epizootiology in bighorn sheep were corroborated by agar-gel immunodiffusion (AGID), serum neuralization (SN), and complement fixation (CF) diagnostic tests. Medical testing indicated sero-prevalence to PI-3 (32%, n = 68), BVD (22%, *n* = 63), *BTV* (19%, *n* = 68), *Mycoplasma bovis* (39%, *n* = 38), *Anaplasma* spp. (19%, *n* = 63), *Pasteurella multocida* (8%, *n* = 63), and *Manheimia haemolytica* (5%, *n* = 63). None of the animals showed any clinical signs or lesions suggestive of infectious disease when examined at the time of capture, with the exception of 3 individuals with psoroptic scabies (*Psoroptes* spp.) lesions in both ears. These animals were treated with injectable ivermectin, quarantined, and subsequently released after receiving a clean bill of health. Overall population health was evaluated based on positive test results, known detrimental infectious pathogens, physical examination of each animal, post-release lamb production, and recruitment. Lamb production and recruitment in the founding population has been good, which leads us to believe that the desert bighorn population in Coahuila is healthy, and poses little risk from a disease standpoint to other bighorn sheep populations and sympatric native wildlife.

TRANS-HIGHWAY MOVEMENTS AND USE OF WILDLIFE CROSSING STRUCTURES BY DESERT BIGORN SHEEP AT ARIZONA STATE ROUTE 68

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Highway construction can affect desert bighorn sheep (*Ovis canadensis*) populations by increasing habitat fragmentation and isolation, which can impede access to critical habitats, increase effects of stochastic events, and reduce gene flow. With the rapid expansion of road networks in proximity to desert bighorn sheep habitat and the increased use of high animal fencing along such roads to reduce wildlife-vehicle collisions, the need for proper design and placement of crossing structures becomes imperative to allow for animal movement and reduce the potential for habitat fragmentation. With the realignment and improvement of State Highway 68 between Kingman and Bullhead City, Arizona, 3 design features (underpasses) were incorporated to facilitate movement of desert bighorn sheep. To evaluate the effectiveness of the different underpasses we fitted 25 desert bighorn sheep with GPS radiotelemetry collars and tracked movements in proximity to the highway for 15 months beginning in November

2006. To evaluate use of underpasses by all ungulates, we installed 5 remote, passive, infrared-triggered cameras at each underpass. We monitored wildlife use at the underpasses for 1,032 camera days and documented 10 crossing events by desert bighorn sheep (17 individuals). All but one (94%) of the crossings by desert bighorn sheep occurred at the easternmost underpass. There were no highway crossings by desert bighorn sheep at the remaining underpasses, however other ungulates, such as wild burros (*Equus asinus*, 42%) and mule deer (*Odocoileus hemionus*, 6%), as well as humans (*Homo* sapiens, 51%) were seen more often. While we have not completed data collection, preliminary data analysis suggest that proximity to steep terrain, sightability, underpass structure, and presence of conspecifics may all be important factors affecting desert bighorn sheep use of highway underpasses.

EVALUATION OF POTENTIAL HABITAT FOR DESERT BIGHORN SHEEP IN COAHUILA, MEXICO

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We analyzed the known historical desert bighorn sheep (*Ovis canadensis*) habitat in Coahuila, Mexico, which consists of 14 different mountain ranges: Sierra Maderas del Carmen, Sierra Hechiceros, Sierra la Encantada, Sierra el Pino, Sierra el Almagre, Sierra el Fuste, Sierra Mojada, Sierra el Rey, Sierra la Madera, Sierra la Fragua, Sierra San Marcos y del Pino, Sierra los Alamitos, Sierra la Gavia, and Sierra la Paila. The analysis was conducted through the use of Geographic Information System (GIS), incorporating 1995 INEGI land use and vegetation digital information overlays (Vectorial format) with a scale of 1:250,000; INEGI digital elevation models (DEM Raster TIFF format), with a resolution of 30x30 m/pixel; and location of permanent and temporary water sources digitized from INEGI topographic maps with a scale of 1:50,000. Habitat components that we measured were the availability of escape terrain (slopes ≤60%), the presence of vegetative community types that permit a high degree of horizontal visibility (Semidesert Grassland and Desert Succulent-scrub), suitable habitat defined as slope gradients between 20 and 59% situated within 150 m of escape terrain, and water availability defined as the amount of suitable habitat 3.5 km radius of water sources situated ≥200 m of escape terrain. The results were expressed as a habitat potential index. Field verification was subsequently accomplished through ground and aerial surveys. The areas containing the most habitat include the region of Cuatro Cienegas (La Madera, La Fragua, San Marcos y del Pino, Los Alamitos and La Paila), located in southcentral Coahuila and Maderas del Carmen located in extreme northern Coahuila. These areas are considered priority transplant sites.

SELECTION OF DESERT BIGHORN SHEEP (*OVIS CANADENSIS*) TRANSPLANT SITES IN SIERRA MADERAS DEL CARMEN AND SIERRA SAN MARCOS Y DEL PINO IN COAHUILA, MEXICO

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Between January 2004 and November 2006 we conducted a Geographic Information System (GIS) based habitat evaluation of Sierra Maderas del Carmen (MDC) and Sierra San Marcos y del Pino (SMP), to select the most suitable sites for the initial restoration of desert bighorn sheep (*Ovis canadensis*) in Coahuila, Mexico. The components that we analyzed included amount of escape terrain, vegetation, and water availability. To identify areas of escape terrain we used 1995 Instituto Nacional de Estadistica Geografia e Informatica (INEGI) digital elevation models (DEM Raster TIFF format), with a resolution of 30 x 30 m/pixel, selecting sites characterized by slope gradients ≥60%. Satellite imagery (LANDSAT ETM) with a 30 x 30 m/pixel resolution was used to construct a coverage of vegetation (spacial database) to identify open community types preferred by desert bighorn sheep. Water availability was analyzed through the use of a water source coverage, digitized from INEGI topographic maps (1:50,000 scale), and field notes. We selected priority transplant sites based on potential contact with exotics *(Ovis aries, Capra hircus,* and *Ammotragus lervia),* amount and juxtaposition of escape terrain, and water availability. Priority transplant sites contain ≥15 km² of escape terrain, water, and are spatially segregated from exotic ungulates. Field verification was subsequently accomplished through ground and aerial surveys. We evaluated 1159.5 km² of MDC; 23% (271 km²) was suitable habitat for desert bighorn sheep. Two priority transplant sites consisting of 25 and 34 km², respectively, were delineated in MDC. In the SMP, we evaluated 871.6 km², and 20% (175 km²) was classified as suitable habitat. One area consisting of 18 km² was selected in SMP as a priority transplant site. Management recommendations include development and improvement of water

source, control and eradication of exotic ungulates, and control of predators until transplanted populations of desert bighorn sheep become viable and self-sustaining.

HABITAT SUITABILITY STUDY FOR REINTRODUCING DESERT BIGHORN SHEEP INTO GUADALUPE MOUNTAINS NATIONAL PARK

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Desert bighorn sheep (*Ovis canadensis*) were once part of the Guadalupe Mountains ecosystem but were extirpated in the 1930s due to disease transmittance from domestic sheep and goats, habitat loss, and unregulated hunting. The Guadalupe Mountains (Texas) are now managed by the National Park Service, which wishes to restore native species to their historical range. A habitat suitability study is an important step in restoring desert bighorn sheep to the mountains since restoration efforts are labor intensive and expensive. This study uses GIS modeling to identify suitable areas within the park for bighorn sheep, evaluate their connectivity to the areas of suitable bighorn sheep habitat in nearby Sierra Diablo mountain ranges, which currently supports more than 400 bighorn sheep. Landscape analysis was conducted to compare the spatial attributes of the habitat areas in the Guadalupe Mountains to those in the Sierra Diablo mountain ranges. Our results showed there were 7,995 ha of suitable habitat for desert bighorn sheep in the Guadalupe Mountains. Landscape analysis showed a greater amount of optimal habitat areas with larger mean patch size, lower edge density, and shorter mean nearest neighbor distance in the Guadalupe Mountains than in the Sierra Diablo mountain ranges. These results suggest that Guadalupe Mountains National Park has sufficient suitable habitat to support a viable population of desert bighorn sheep. We also established that there is continuation of suitable escape terrain for bighorn sheep stretching from the Sierra Diablo through the Delaware Mountains and to the Guadalupe for future migration and gene flow.

GENETIC SURVEY OF MOUNTAIN LION OF GUADALUPE MOUNTAINS NATIONAL PARK

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Conservation biologists have used reintroduction as a method to reestablish extirpated species in their native habitat. Guadalupe Mountains National Park (GUMO) is examined as a possible reintroduction area for the desert bighorn sheep (*Ovis canadensis*). Because the mountain lion (*Felis concolor*) is considered a major predator of bighorn sheep, we used noninvasive genetic techniques to investigate the number and distribution of mountain lion using GUMO. Over a 7 year period, a minimum of 32 resident and/or transient mountain lions were genetically identified in GUMO, and a minimum of 15 cats used the park in 2002. Based on estimates of individual home range of males and females, GUMO should be able to support 4 to 5 resident individuals. The genetic data indicate a high number of transients and/or perhaps an unstable population of mountain lion.

RESTORATION OF DESERT BIGHORN SHEEP ON THE NAVAJO NATION

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The objectives of desert bighorn sheep (*Ovis canadensis nelsoni)* management on the Navajo Nation are: to conserve existing herds for their ecological, esthetic, and traditional values, manage harvest to provide funding for continued management, and traditional hunting opportunities for tribal members, and to restore desert bighorn sheep to suitable habitat throughout the Navajo Nation. Desert bighorn sheep occurred originally on the Navajo Nation throughout the San Juan River Canyon, Glen Canyon, the Grand Canyon, and the Little Colorado River Canyon. Bighorn disappeared from the San Juan River Canyon above Mexican Hat (Upper Canyon) and below Mexican Hat (Lower Canyon) in the early to mid 1960s after declines concurrent with over hunting, mining, and grazing of cattle and domestic sheep within bighorn sheep ranges. After an absence of about 20 years, bighorn sheep reappeared in the Upper San Juan River Canyon. The herd grew to about 30 bighorn sheep by 1997. At this time, bighorn sheep were rare in the Little Colorado Canyon, but present in the Grand Canyon, and absent from the south shore of Lake Powell and the San Juan Arm. During a serious drought 2001–2002 the population trajectory changed from increasing to stable and rams

extended their range into areas close to domestic sheep. Surveys were conducted in historic bighorn ranges and the Lower San Juan River Canyon was determined to be a suitable transplant site. In fall 2003, desert bighorn sheep were transplanted from the Upper San Juan River Canyon to the Lower San Juan Canyon. Monitoring during 2003 to 2006 indicated that this herd has a good potential for success. The source herd in the Upper Canyon recovered rapidly from removal for transplanting and now exceeds the population level prior to the 2003 transplant. In 2005 and 2006, surveys were conducted to locate a suitable transplant area on the south shore of Lake Powell. Results of those surveys and plans to restore bighorn sheep to Lake Powell are discussed.

COPING WITH LIFE AT THE URBAN INTERFACE: BIGHORN SHEEP IN THE RIVER MOUNTAINS

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The desert bighorn sheep (*Ovis canadensis nelsoni*) population inhabiting the River Mountains of Nevada has a long history of importance. Bighorn sheep in this range were the focus of an early ecological monograph on the species and have been used extensively as source stock for restoration of extirpated populations and augmentation of existing populations. These sheep are also popular with visitors to Lake Mead National Recreation Area and local residents. There has, however, been increasing concern about the status of this bighorn sheep population. Growth in Clark County has increased dramatically over the past decade. With this growth, there has been a concomitant increase in recreational activity (hiking, mountain biking, off-road vehicle use). Housing developments from both cities have expanded to the base of the mountain range. Water facilities servicing the metropolitan area have been developed, or expanded, on 3 sides of the range. A flood control retention basin cuts into the range on the west side. Boulder City has built a golf course on the southwest end of the range and has constructed an extensive mountain bike trail system in Bootleg Canyon. Using historic and GPS location data collected during 2003–2005, we present evidence showing how urban growth is currently affecting the River Mountain bighorn sheep population. This talk also provides background information for the field trip.

POTENTIAL EFFECTS OF HUMAN RECREATION ACTIVITY ON BIGHORN SHEEP HABITAT USE IN JOSHUA TREE NATIONAL PARK, CALIFORNIA

Christopher Lowrey and **Kathleen Longshore**, USGS-BRD. USGS Western Ecological Research Center, 160 Stephanie Street, Henderson, Nevada 89074, USA
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To study potential effects of the recreation activities on desert bighorn sheep (*Ovis canadensis nelsoni*) habitat use, we placed GPS collars on 10 bighorn sheep ewes within the Wonderland of Rock-Queen Mountain region of Joshua Tree National Park, California from 2002–2004. Recreation use was highest from February to May and during weekends throughout the year. We compared habitat use and movement patterns between weekdays and weekend days across the entire study area within each season each year. Within the (high recreation) February to May season, ewes were found on steeper slopes (>17% greater) during weekends than weekdays for both years of the study. Ewes traveled greater distances (0.4 km, or 24% farther) during weekends than weekdays within the February to May season of the first year, and within the (moderate recreation) October to January season of the second year. The most probable cause of differences in habitat use during weekends is the increase in recreation activity. Therefore we argue that moderate to high levels of activity may be temporarily excluding bighorn sheep ewes from preferred habitat.

BIGHORN SHEEP USE OF A DEVELOPED WATER IN SOUTHWESTERN ARIZONA

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Documentation of bighorn sheep (*Ovis canadensis*) use of developed and natural water sources has often been anecdotal or of short observation duration. To better understand the pattern and amount of bighorn sheep use at a developed water source, we used remote videography to monitor a developed water source in the Castle Dome Mountains, Kofa National Wildlife Refuge, Arizona for 12,422 hours between July 2002 and November 2005. We observed 2,529 bighorn sheep in 1,422 visits. Bighorn sheep visited this water 10 months of the year (April through January) with the majority of visits in summer months. Sheep of both sexes and all age classes were observed, with adult ewes and rams being most common. Seventy-three percent of the visits resulted in at least 1 bighorn sheep in the group drinking. Bighorn sheep visiting this developed water interacted with other bighorn sheep, mule deer (*Odocoileus hemionus*), bobcats (*Lynx rufus*), a grey fox (*Urocyon cinereoargenteus*), a Cooper's hawk

(*Accipiter cooperii*), and a turkey vulture (*Cathartes aura*); however no instances of predation were observed. While limited to a single site, our results provide insight into watering patterns of desert bighorn sheep, including nocturnal visits and use outside the hot-dry summer period.

DEVELOPMENT OF A PREDICTIVE HABITAT MODEL FOR BIGHORN SHEEP IN THE PENINSULAR RANGES, CALIFORNIA

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Habitat protection and restoration are important strategies identified for promoting recovery of bighorn sheep (*Ovis canadensis*) in the Peninsular Ranges of southern California. To further these efforts, we are developing a predictive habitat model for bighorn sheep in these mountains, using 2 recently-developed geographic information system modeling techniques, namely Ecological Niche Factor Analysis (ENFA) implemented in the program BioMapper, and the Genetic Algorithm for Rule-set Production (GARP) method implemented in the program DesktopGARP. Our objectives are to delineate bighorn sheep habitat in these mountains, and then to assess the extent of habitat loss due to urban development in the northern portion of the range. In this talk we will present the first phase of our project, which is the development of a habitat model using the program BioMapper. High-resolution GPS data were used as training data, along with a large set of selected habitat variables, to develop a set of preliminary maps, which were tested internally by the program and externally with independent sets of test data. We will present resulting habitat models, results of tests to evaluate these models, and a preliminary assessment of habitat loss in the north part of the range. The next phase of the project, which will include development of a model using the GARP method and subsequent comparison of the 2 methods to select a final habitat model, will be discussed.

DISTRIBUTION AND TRANS-HIGHWAY MOVEMENTS OF DESERT BIGHORN SHEEP ALONG U.S. HIGHWAY 93 IN NORTHWESTERN ARIZONA

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We captured and placed global positioning satellite (GPS) radiocollars on 36 desert bighorn sheep (*Ovis canadensis nelsoni*), conducted ground surveys, developed track beds, and incorporated vegetation surveys between 2004 and 2006 to study distribution and trans-highway movements of bighorn sheep along U. S. Highway 93 in northwestern Arizona. We focused investigations between highway mileposts 3 and 17 extending southward below Hoover Dam, a right-of-way segment proposed for transformation from a mostly unfenced, 2-lane highway to a 4-lane divided highway with ungulate-proof fencing. Highway 93 did not preclude bighorn sheep from crossing the right-of-way, but presented a barrier to distribution and movements of bighorn sheep. Fewer than random GPS fixes occurred within a 100-m buffer zone extending parallel to both sides of the highway than farther from the road. Moreover, the highway was the boundary of home ranges of multiple bighorn sheep. Areas where bighorn sheep crossed the highway were not distributed randomly and appeared to be independent of capture site locations. Using center of activity analyses for individual and grouped bighorn sheep, we identified 5 continuous, linear, elevated guide-ways (CLEGs) that corresponded to ridgelines where bighorn sheep concentrated activities and trans-highway movements. Ground observations and track beds supported these GPS data. Vegetation density and number of species of browse plants were greater, and vegetation tended to be shorter, on these CLEGs than on random surrounding areas. We concluded that construction of underpass or overpass structures in association with CLEGS along the proposed highway realignment would facilitate right-of-way permeability and highway crossings by bighorn sheep.

BIGHORN SHEEP MOVEMENTS IN THE SIERRA NEVADA: IMPLICATIONS FOR DISEASE AND METAPOPULATION STRUCTURE

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Understanding movements of bighorn sheep (*Ovis canadensis*) in the Sierra Nevada has broad implications for conservation of this endangered species. Large-scale, extralimital movements are essential for maintaining genetic diversity throughout the metapopulation, but conversely may be detrimental by increasing risk of disease transmission. We used location data from GPS and VHF collars to quantify movements of Sierra Nevada bighorn sheep in the context of migration routes, metapopulation structure, and disease risk. Considerable data (>100,000 locations) from telemetered bighorn in the Sierra Nevada reveal a

tendency for some males to make long-distance movements beyond their normal home range. Of the 25 bighorn sheep rams collared and with sufficient data as of May 2006, 7 (28%) have made substantial movements beyond their core home ranges. The most extensive movements observed were by a ram who traveled >53 air km beyond his range. Home ranges of male and female bighorn differed in size (t = -3.05, n = 61, P = 0.005); male ranges were almost twice as large on average. Mean minimum convex polygon home range of ewes was 53.0 km^2 (SD = 24.3). Mean size of home ranges for rams was 100.4 km^2 (SD = 75.0). We recently developed a habitat suitability model using resource selection probability functions in a GIS. By quantifying habitat suitability scores within home ranges, we determined that dispersing males used poor quality habitat to a greater extent (F – 6.2, df = 2,12, P = 0.014) than other males and females. The potential for males to move through habitats not typically used by bighorn sheep increases the risk of contact with domestic sheep.

PHYLOGEOGRAPHIC INVESTIGATION OF BIGHORN SHEEP IN CALIFORNIA FROM MITOCHONDRIAL DNA SEQUENCES WITH EMPHASIS ON THE EASTERN SIERRA REGION

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Many of the bighorn sheep (*Ovis canadensis*) subspecies differences proposed by Cowan in 1940 have not stood up to recent morphometric and genetic analyses when coupled with a sound definition of subspecies. However, the suggestion by Grinnell (1912) and Cowan (1940) that bighorn sheep in the Sierra Nevada of California were different from the desert sheep to the immediate east has found support. Ramey (1995) found differences in the mtDNA control region using RLFP data and Wehausen and Ramey (2000) found significant skull shape differences from cranial morphometric data. We have looked at this question further with DNA sequence data for a 515 bp section of the mtDNA control region for about 570 different sheep from 36 populations in California, and a scattering of other samples from Siberia to Arizona to provide perspective. A more conserved mtDNA gene, ND5, also was sequenced for a 1136 bp section for selected control region haplotypes. Bighorn sheep in the Sierra Nevada have only 1 haplotype, and it is as different from desert bighorn sheep as are Rocky Mountain haplotypes. However, on the Sierra Nevada clade are 3 additional haplotypes: 1 in the Inyo Mountains immediately east across the Owens Valley from the southern Sierra Nevada, a second that extends SE of the Inyo Mountains from Hunter Mountain to the Panamint Mountains and across Death Valley to the Black Mountains, and a third found only in a single individual in the Black Mountains. These 3 haplotypes east of the Sierra Nevada are mixed with desert bighorn sheep haplotypes and occur in a declining proportion of the individuals sampled with greater distance from the Sierra Nevada, ranging from 78% in the Inyo Mountains to 29% in the Black Mountains. Analyses of 12 nuclear microsatellite loci suggest an asymmetry of gene flow across the Owens Valley. These results will be discussed relative to the question of source and maintenance of uniqueness in the Sierra Nevada.

RESTORING DESERT BIGHORN SHEEP HABITAT WITH LANDSCAPE SCALE PRESCRIBED FIRE

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Mark Kaib, U.S. Fish and Wildlife Service, Fire Management, Albuquerque, New Mexico, USA
Don Kearney, U.S. Fish and Wildlife Service, Sevilleta National Wildlife Refuge, New Mexico, USA
Kevin Cobble, U.S. Fish and Wildlife Service, San Andres National Wildlife Refuge, Las Cruces, New Mexico, USA

The San Andres National Wildlife Refuge (Refuge) is located in the southern third of the San Andres Mountains in south central New Mexico. This mountain range is one of the largest contiguous, relatively undisturbed Chihuahuan Desert land masses in the United States. Since the Refuge's establishment in 1941, primary emphasis in resource management has been focused on restoring a remnant population of desert bighorn sheep (*Ovis canadensis mexicana*), a State-listed endangered species in New Mexico. The build-up of dry vegetation over many years will serve as fuel in a natural fire with disastrous consequences. A periodic controlled burning on the other hand is slow and will allow animals to escape and will burn up dead material that could ignite uncontrollably. For the desert bighorn sheep, the nutrients that are recycled after burning facilitate the growth of nutrient rich shoots, promote the growth of native species, and provide sufficient fodder. Also, escape routes are made available for bighorn sheep from predators like mountain lions (*Puma concolor*) and bobcats (*Lynx rufus*) that use dense vegetation to stalk their prey. Bighorn sheep will abandon suitable habitat as a result of decreased visibility. Given the rather small size of the Refuge, it was apparent from the very onset of the planning effort that the planning unit boundaries would need to encompass more acreage than is present within the Refuge itself. Refuge boundaries are administrative rather than physical and do not lend themselves well to the localized management of fire or the greater San Andres ecosystem.

DESERT BIGHORN COUNCIL
CONSTITUTION AND BYLAWS

ARTICLE I - NAME

Section 1 Name - The name of this organization shall be the DESERT BIGHORN COUNCIL and shall be referred to as the Council in this document.

Clause A Definition - For the purpose of this Council, the term "desert bighorn" is intended to include those bighorn sheep occurring in desert or semi-desert regions and belonging to the subspecies *Ovis canadesis mexicana, nelsoni, cremnobates, weemsi,* or *californiana*.

ARTICLE II - PURPOSE AND OBJECTIVES

Section 2 Purpose - To provide for the exchange of information on needs and management of desert bighorns through meetings and published transactions, by means of which new or important information, ideas, techniques, and problems can be presented and discussed by Council members.

Clause A Objective - To stimulate studies in all phases of the life history, ecology, management and protection, recreational and related economic values of desert bighorns, including studies of species that may be seriously detrimental to desert bighorns.

Clause B Objective - To provide a clearing house of information among all agencies, organizations, and individual professionally engaged in work on desert bighorns - through appointment of work committees, preparation of bibliographies and abstracts, and related methods, when desirable.

Clause C Objective - To function in a professional advisory capacity, where appropriate, on local, national, and international questions involving management, conservation, and protection of desert bighorn, and to adopt such measures as shall tend to promote advancement of knowledge concerning desert bighorns and the long-term welfare of these animals.

Clause D Objective - To recognize and commend outstanding work in the profession.

ARTICLE III - MEMBERSHIP

Section 1 Membership - Membership is open to all who are engaged in management, protection, or scientific study of desert bighorns, and to those active in some phase of desert bighorn conservation.

Clause A Privilege - Membership dues are due and payable in April of every odd numbered year and are good for two years. Only those whose dues are paid in current status shall be permitted to vote during general business sessions at the Council meetings.

Clause B Privilege - Paid members shall be entitled to one copy of the most current Transactions of the Council at a discounted rate.

Section 2 Constitution and Bylaws - Any person shall receive a copy of the Constitution and Bylaws upon request.

ARTICLE IV - BOARD OF TRUSTEES

Section 1 Powers - The exercise of the powers of this Corporation, with the right to delegate to officers and agents the performance of duties and the exercise of such powers, shall be vested in its Board of Trustees. The Board of Trustees shall also act as the Technical Staff as is hereinafter described.

Such Board of Trustees (Technical Staff) shall be elected at the Council meeting and shall serve for a term of five (5) years.

ARTICLE V - ELECTION OF OFFICERS

Section 1 Officers - The Officers of the Council shall be a Chair, a Vice-Chair, a Secretary, and a Treasurer.

Clause A Chair - The Chair shall have general direction of the Council Officers. The Chair shall appoint, with the assistance of the Executive Committee (Article VIII, Section 3) Chairs of all regular and special committees, with the exception of the Chair for the Technical Staff (Article VIII, Section 11). The Council Chair shall also preside at meetings of the Executive Committee and Council, and shall be an ex-officio member of all committees.

Clause B Vice Chair - The Vice-Chair shall assist the Chair in duties where needed. In the absence of the Chair, or in the event of Chair's inability to act, the Chair's duties shall be assumed by the Vice-Chair.

Clause C Secretary - The Secretary shall serve as general business manager and shall issue notices of annual or special meetings and other materials distributed by the Council to its membership and shall record the minutes of the meeting. A report concerning Council activities shall be made by the Secretary at the Council business meeting. In the event neither the Chair nor Vice-Chair can serve in their capacity, the Secretary shall serve pro tempore.

Clause D Treasurer - The Treasurer shall be responsible for receiving and dispersing all funds of the Council as well as the Hansen and Ralph E. Welles Scholarship Fund. An auditing of the Council's accounts shall be made by the Treasurer at the Council business meeting.

Section 2 Term of Office - The officers shall serve for approximately two (2) years, be installed at the Council meeting, take office immediately thereafter, and terminate their duties at the conclusion of the next Council meeting.

Section 3 Vacancies - Vacancies among officers shall be filled by the Chair, Vice-Chair, Secretary, or Treasurer, in the same order of successional responsibility previously indicated, for the unexpired term of office.

Section 4 Nomination - The three (3) member Nominating Committee (Article VIII, Section 4) shall present a slate of no more than two (2) candidates for each elective position, namely Chair, Vice -Chair, Secretary, and Treasurer.

Clause A Approval - Prior approval shall be obtained from said candidates.

Clause B Announcement - The Nominating Committee's list of nominees shall be sent to the Secretary, and shall be included in the meeting program.

Clause C Floor Nominees - Additional nominations from the floor may be placed on the Nominating Committee's slate at the time of the Council meeting. Such nominees must formally accept the nomination while present on the floor. No person can be nominated who is not present at the Council meeting.

Section 5 Balloting - When more than one nominee for an office has been nominated, written ballots shall be received from members present at the Council meeting by the Secretary and shall be counted by the Secretary and two members appointed by the Chair. Balloting for an individual nominee (a single candidate for an Office) may be taken by a show of hands or indicated by voice.

Clause A Alternate - If the office of Secretary is being contested, the Vice-Chair will fulfill the obligation of Balloting.

Clause B Election - The nominee receiving the largest number of votes (a plurality) shall be declared elected. No one may hold two elective positions simultaneously in the Council.

ARTICLE VI - MEETINGS

Section 1 Council Meeting - The meeting of the Council shall be within the first two weeks of April, on a biennial basis, during odd numbered years.

Clause A Location – The meeting location will rotate; with every other meeting being held in the states of Arizona, California, or Nevada. The intervening meetings shall be held in the State voted on by the Council members during the business meeting held at the previous Council meeting. The exact location for the meeting shall be determined by the Arrangements Committee (Article VIII, Section 6).

Clause B Meeting Notice - Notice of such meetings shall be given to the Secretary by November, at least six months prior to the annual meeting. Council members shall be notified at least 90 days prior to the Council meeting.

Clause C Quorum - The quorum shall be over 50 percent of the indexed membership, or 20 members, whichever is less.

Section 2 Meeting Rules - The rules contained in the latest revision of Roberts' Rules of Order shall govern the Council in all cases to which they are applicable, and in which they are not inconsistent with the Constitution and Bylaws or the special rules of order of the Council.

ARTICLE VII - MANAGEMENT OF FINANCE

Section 1 Management - The Council shall be governed by an Executive Committee (Article VIII, Section 3).

Section 2 Finance - Funds of the Council shall be received by the Treasurer, who will keep a record of all monies and produce the records for audit by the Executive Committee at the close of the fiscal year and prior to the business meeting, or at any time the Executive Committee deems necessary.

Clause A Duties - The Treasurer shall collect dues and distribute membership cards.

Clause B Payments - The Treasurer shall issue payment for all bills approved by the Chair. All bank withdrawals require the signature of the Treasurer and the Council Chair or the Tech Staff Chair.

Clause C Petty Cash - The Treasurer may keep a petty cash fund.

Clause D Bond - The Treasurer need not be bonded.

Clause E Funds - Funds shall be derived from dues, special assessments, work projects, and contributions. Royalties from the book, "The Desert Bighorn," are obligated to Hansen-Welles Scholarship Fund.

Clause F Safekeeping - Funds shall be placed in a federally insured bank or savings and loan association.

Section 3 Dues - Dues shall be set by quorum vote of Council members. Fiscal year of the Council shall commence on April 1 of each calendar year and shall terminate on March 31 of the following year.

Section 4 Publication - Dues will be apportioned between the various functions of the organization as appropriate to meet commitments of the Council.

Section 5 Files - The Council shall maintain a file containing: Constitution and Bylaws, minutes of all meetings, correspondence pertinent to Council affairs, all committee reports, financial statements and records, and any other material judged by the Executive Committee as pertinent. The files shall be housed and maintained by the Historian (see Article VIII, Section 13).

Section 6 Resolutions and Public Statements - Council member(s) shall submit resolutions for consideration to the Resolution committee (Article VIII, Section 9). These shall be accepted by the Committee and prepared for submission to the Council members. Information regarding previous actions taken by the Council may be issued by the Secretary upon request.

ARTICLE VIII - COMMITTEES AND STAFF

Section 1 Appointments - The Chair shall, with the help of the Executive Committee, appoint Chairmen of all regular standing and special committees, except that the Council Chair shall appoint the Chair and members of the

Nominating Committee, also the Chair of the Technical Staff shall be elected by the membership of the Technical Staff.

Section 2 <u>Committee Decision(s)</u> - Decision(s) of a committee shall be inviolate, and any desired revision or change would have to be appealed.

Clause A <u>Appeal</u> - Any appeal to change a committee decision(s) shall have to come from the floor in the form of a motion, at the Council meeting.

Section 3 <u>Executive Committee</u> - Shall be composed of the Officers of the Council and the immediate past Chair of the Council.

Clause A <u>Obligation</u> - The Executive Committee shall conduct its affairs to conform with the provisions of the Constitution and Bylaws. The Executive Committee is authorized to act for the Council between meetings and shall report its interim actions to the members at the succeeding Council meeting. Any action of the Executive Committee may be overridden by a two-thirds majority vote of the attending membership.

Clause B <u>Audit</u> - The Executive Committee shall audit the financial records of the Treasurer at the close of the fiscal year and prior to the Council meeting.

Section 4 <u>Nominating Committee</u> - Shall be composed of three (3) members of the Council appointed by the Council Chair.

Clause A <u>Obligation</u> - (See Article V, Section 4, clause A and B).

Section 5 <u>Publicity Committee</u> - Shall be composed of three (3) members of the Council.

Clause A <u>Obligation</u> - It shall be the responsibility of the Publicity Committee to make public contact through newspaper, radio, and television media for publicity.

Clause B <u>Restriction</u> - Publicity shall be restricted to Council action, programming, awards, and announcements. At no time will publicity be released that would discredit any person or organization, a member, state game and fish organization, federal agency, college, or university.

Section 6 <u>Arrangements Committee</u> - Shall be composed of three (3) members of the Council from within the state that the forthcoming meeting is to be held.

Clause A <u>Obligation</u> - It shall be the responsibility of the Arraignments Committee to make necessary contacts to provide meeting places, accommodations, and any arrangements that will promote the success of a meeting. Information pertaining to arrangements shall be given to the Secretary 90 days prior to the meeting date.

Section 7 <u>Program Committee</u> - Shall be composed of three (3) members of the Council.

Clause A <u>Obligation</u> - It shall be the responsibility of the Program Committee to developed an interesting and informative program and agenda for the Council meeting. The program agenda shall be given to the Secretary 90 days prior to the meeting date.

Section 8 <u>Constitution Committee</u> - Shall consist of the Chair, Secretary, and the immediate past Chair.

Clause A <u>Obligation</u> - It shall be the responsibility of the Constitution Committee to draft changes and revisions in the Constitution and Bylaws and present these changes to the Council for vote at the Council meeting.

Clause B <u>Recommendations</u> - Council members may recommend changes to the Constitution or Bylaws by submitting such changes to the Secretary for committee consideration.

Clause C Acceptance - Constitution and Bylaw changes must be voted on and passed by a two-thirds vote of members present at the Council meeting.

Section 9 Resolutions Committee - Shall be composed of three (3) members of the Council.

Clause A Obligation - It shall be the responsibility of the Resolutions Committee to draft resolutions in the accepted form and grammar, and present the resolution for Council consideration, discussion, and vote.

Clause B Recommendations - Council members may recommend adoption of resolutions by submitting such to the Chair of the Resolutions Committee no less than 24 hours prior to the Council business meeting.

Clause C Limitations - Resolutions will be limited to subjects directly related to the management, conservation, and protection of the desert bighorn sheep or its habitat, or resolutions of gratuity or memorial.

Section 10 Transactions Committee - Shall be composed of an editor and two (2) assistants.

Clause A Obligation - It shall be the responsibility of the Transactions Committee to publish the transactions of the Council meeting.

Clause B Transactions - It shall be the responsibility of the Secretary and/or a Transactions Sales Coordinator to store excess copies of past Transactions; maintain records for standing orders, incoming orders, and payment for transactions; and to fill/send out Transaction orders.

Section 11 Technical Staff - Shall be composed of not more than seven (7), nor less than five (5), members of the Council.

Clause A Obligation - It shall be the Technical Staff's responsibility to review and approve applications for funds collected in Hansen-Welles Memorial Fund. The Technical Staff will be guided by the Council's decision that these monies be donated to students or others for studies or research of the desert bighorn sheep. In addition, the staff will inform Dr. Charles Hansen's immediate family of all recipients of these funds.

Clause B Obligation - The Technical Staff will also provide or obtain advisor assistance for persons or agencies requesting information or help in desert bighorn sheep research and management, including review of environmental impact statements or other proposals which will impact desert bighorn sheep.

Clause C Election - Technical Staff members shall be elected by the Council when necessary; and the Chair of the Technical Staff shall be elected by members of the Technical Staff. In order to preserve continuity, at least 4 members shall have served for at least 3 years.

Clause D Term - The term of Technical Staff members shall be 5 years. Technical Staff members can be reelected for more than 1 term.

Section 12 Awards Committee - Shall be composed of three (3) members of the Council.

Clause A Obligation - It shall be the responsibility of the Awards Committee to evaluate and determine qualified Council members for consideration for the Council's awards, or any other recognition deemed suitable to the cause.

Clause B Criterion - Committee members shall follow the Council's accepted "criterion and guide for determining the Desert Bighorn Council Award for outstanding work relating to desert bighorn sheep."

Section 13 Historian - The Council Historian shall be appointed by the Chair, with approval of the members at the Council business meeting.

Clause A Obligation - It shall be the Historian's responsibility to keep and house all Council records, except records two years old or less, which shall be kept by the Secretary. The Secretary will, however, provide the Historian with copies of minutes of the Council business meeting and annual financial statements, which are less than two years old.

Clause B Limitations - The Historian shall serve as long as the Historian is able and wishes to, subject to regular confirmation by the Chair and membership.

Section 14 Dissolution Committee - Shall be an automatic committee and shall be composed of the existing Officers of the Council and a representative of each state and Mexico.

Clause A Obligation - (See Article IX, section 1).

Section 15 Miscellaneous Committees - Shall be appointed as needed to fulfill the desires of the Council in pursuing the objectives and purposes (Article II).

Section 16 Accountability - All committees shall be accountable to the Council Chair.

Section 17 Tenure - All committees shall serve until new committees are appointed in their stead, or until the duties assigned have been discharged, in conformance to Article V, Section 2.

ARTICLE IX - DISSOLUTION

Section 1 Dissolution - On dissolution of the Council, any assets remaining shall be distributed to a fund, foundation, or corporation organized and operated exclusively for the purpose specified in Section 501(c)3 of the Internal Revenue Code, as such section may be amended, superceded, or reformed.

BYLAWS

Section 1 Order of Business - The order of business at the Council business meeting, unless changed by a majority vote of members present, shall be as follows:

1. Reading of the minutes of the previous meeting
2. Reports of the Secretary and Treasurer
3. Reports of the committees
4. Election of Officers
5. Old Business
6. New Business

Section 2 Fiscal Year - The Fiscal year of the Council shall end on March 31.

Section 3 Enactment - Bylaws may be adopted, amended, or repealed at any Council business meeting by a majority vote of members present.

Approved: April 5, 2007

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

STYLE: Proceed from a clear statement of purpose through introduction, study area, methods, results, and discussion. Sequence of contents: title, authors, abstract, key words, introduction, study area, methods, results, discussion, literature cited, tables, and figures. Follow the CBE Style Manual Committee 1994. The former guidelines for the *Wildlife Society Bulletin* are the preferred style and are available from the editor on request. See a recent volume of the *Desert Bighorn Council Transactions* for examples.

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

FOOTNOTES: Use only for author's address if there are multiple addresses for authors and in tables.

ACKNOWLEDGEMENTS: Include acknowledgements at the end of the introduction as a titled 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 use.

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

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

LITERATURE CITED: Use capital and lower case letters for authors' last names, initials for given names. Do not abbreviate titles of serial publications; follow **Guidelines for Authors and Reviewers of *Wildlife Society Bulletin* manuscripts**. Show issue number or month only if pagination is not consecutive throughout the volume.

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

ILLUSTRATIONS: Illustrations and drawings must be submitted as an electronic file suitable for no larger than 215 x 280 mm (8.5 x 11 inches) final layout. Make all letters and numbers large enough to be ≥1.5 mm tall when reduced. Lettering size and style when reduced should be the same in all figures. Submit prints of good contrast on glossy paper. Type captions on a separate page in paragraph form. On the back of each illustration, lightly write the senior author's name, figure number, and "Top."

SUBMISSION AND PROOF: All papers will be reviewed for acceptability by the Editorial Board and 2 outside reviewers. Submit papers to Brian F. Wakeling, Arizona Game and Fish Department, Game Branch, 5000 West Carefree Highway, Phoenix, AZ 85086, USA**.** When papers are returned to authors for revision, please return revised manuscripts within the time allotted. Galley proofs should be returned within 72 hours.

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

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DESERT BIGHORN COUNCIL MEETINGS 1957–2007

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	Rudulfo 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	Bighop, 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	Darren Divine	Charles Douglas	Raymond Lee
1999	Reno, NV	Rick Brigham & Kevin Hurley	Darren Divine	Charles Douglas	Allan Thomas & Harriet Thomas
2000	Bullhead City, AZ	Ray Lee & Jim deVos	Darren Divine	Charles Douglas	Jon Hanna
2001	Hermosillo, Sonora, Mexico	Carlos Castillo & Jim deVos	Darren Divine	Charles Douglas	Jon Hanna
2002	Palm Springs, CA	Mark Jorgenson	Darren Divine	Charles Douglas	Jon Hanna
2003	St. George, UT	Jim Karpowitz	Darren Divine	Darren Divine	Brian Wakeling
2005	Alpine, TX	Clay Brewer	Esther Rubin	Stacey Ostermann	Brian Wakeling
2007	Las Vegas, NV	Ross Haley	Esther Rubin	Stacey Ostermann-Kelm	Brian Wakeling