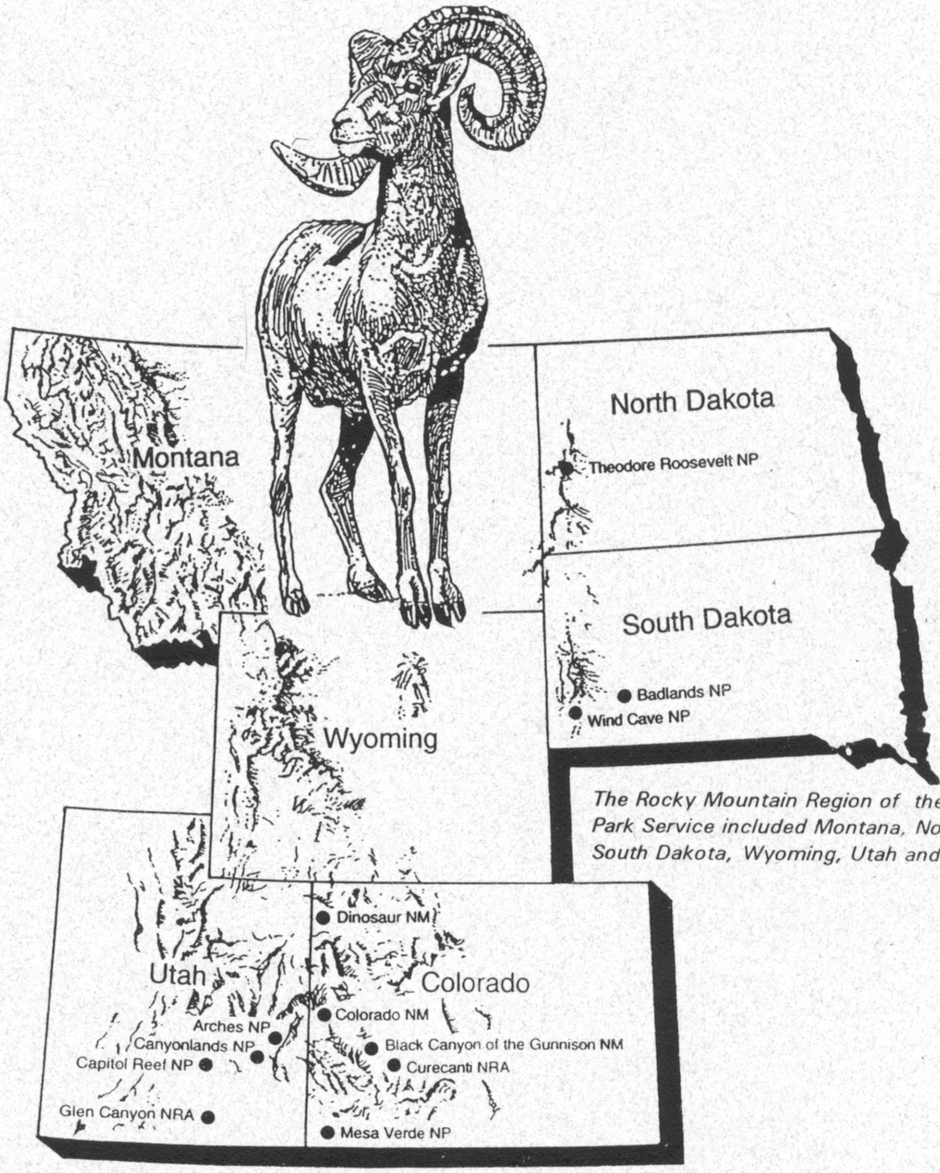
Bighorn Sheep in the Rocky Mountain Region

Reports of Five Scientific Advisory Committees to the National Park Service



The Rocky Mountain Region of the National Park Service included Montana, North Dakota, South Dakota, Wyoming, Utah and Colorado

National Biological Service Report to the National Park Service

1996

Bighorn Sheep in the Rocky Mountain Region

Reports of Five Scientific Advisory Committees to the National Park Service

Meetings Coordinator

Francis Singer[1]
National Park Service, Natural Resource Ecology Laboratory
Colorado State University, Fort Collins, Colorado 80523

Committee Members

William Adrian
Colorado Division of Wildlife, 317 West Prospect Drive
Fort Collins, Colorado 80523

Fred Allendorf
Department of Biology, University of Montana
Missoula, Montana 59801

James Bailey[2]
Department of Fisheries and Wildlife, Colorado State University
Fort Collins, Colorado 80523

Joel Berger
Program in Ecology, Evolution and Conservation Biology
University of Nevada, Reno, Nevada 89557

Vernon Bleich
California Department of Fish and Game, 407 West Line Street
Bishop, California 93514

Michael Bogan
National Biological Service, Museum of Southwestern Biology
University of New Mexico, Albuquerque, New Mexico 87131

[1] Presently with the National Biological Service.

[2] Present address: New Mexico Department of Game and Fish, P.O. Box 25112, Santa Fe, New Mexico 87504.

Peter Brussard
Program in Ecology, Evolution and Conservation Biology
University of Nevada, Reno, Nevada 89557

Steven Buskirk
Department of Zoology and Physiology, Box 3166
University of Wyoming, Laramie, Wyoming 82071

N. Thompson Hobbs
Colorado Division of Wildlife, 317 West Prospect Drive
Fort Collins, Colorado 80523

Thomas Smith[3]
401 WIDB, Brigham Young University
Provo, Utah 84602

Dave Stevens[4]
Rocky Mountain National Park
Estes Park, Colorado 80517

Charles Van Riper, III
National Park Service, Northern Arizona University
Box 5614, Flagstaff, Arizona 86011

Ernie Vyse
Department of Biology, Montana State University
Bozeman, Montana 59717

Gary White
Department of Fisheries and Wildlife
Colorado State University, Fort Collins, Colorado 80523

---

[3] Present address: Katmai National Park. Kodiak Field Station, P.O. Box 7, King Salmon, AK 99613.

[4] Present address: National Park Service, 2525 Gambell Street, Anchorage, AK 99503.

Preface

In 1991, the Washington Office of the National Park Service, through its Natural Resource Preservation Program, funded a 3-year assessment of research and management needs for bighorn sheep in the Rocky Mountain Region (RMR) National Parks. Eighteen National Park Service (NPS) units historically supported populations of three subspecies of bighorn sheep. These populations were decimated by market hunting, overgrazing, and diseases contracted from domestic livestock. By 1950, populations of bighorn sheep survived in only five of the National Park Service units, and the Audubon's subspecies had been extirpated from its range. There have been some efforts to restore bighorn sheep to historical ranges, but two-thirds of National Park area populations today number less than 100 animals and of these, six herds number less than 30 individuals. Chronically poor recruitment, loss of traditional migration routes, isolation, and low dispersal rates are typical of many herds.

Five scientific advisory committees were convened to assess the research and management needs for bighorn sheep, . Fourteen scientists from 11 institutions were invited to assess the needs of 15 of the 18 National Park Service units. The committees were asked to address commonality of needs on a regional, subregional, or metapopulation basis. We thank the 14 members for contributing their time and expertise to the analysis, particularly S. Buskirk who sat on two committees, and D. Murphy who chaired two sessions. We also thank the many National Park staff who helped organize the field trips and logistics for the meetings, and the many biologists and managers from other agencies who participated in these meetings. Following the suggestion of the committees, 10 interagency working groups have been convened to coordinate research and management on a metapopulation basis. To the largest extent possible, jurisdictional boundaries on public lands will be ignored in order to reestablish and manage self sustaining, viable populations of bighorn sheep.

Acknowledgments

D. Huff, R. Schiller, and F. Singer, requested the problem analyses by the scientific review committees. These perspectives by peers were felt to be essential prior to further assessments or management actions. This work was funded by the Natural Resource Preservation Priority initiative, Washington Office, National Park Service. P. Y. Sweanor wrote some sections on bighorn sheep herd histories. M. E. Moses, P. Y. Sweanor, and D. E. Medellin of the National Biological Service facilitated production of the final report.

Contents

Suggestions for Implementation of Region-wide Monitoring and Research

Phase One: 1991-1993

Collate information about present and past bighorn sheep (Ovis canadensis) populations in all RMR, NPS units and present it to the Regional Chief Scientist or F. Singer for eventual consideration in a regional plan.

Obtain information on park resources and management during park visits or at inter-agency meetings involving park resource personnel and bighorn sheep biologists.

Standardize a system for surveying, monitoring, and evaluating changes in bighorn sheep populations. Include information on population dynamics, sex and age characteristics, recruitment, and survey methodology. A workshop with biologists and resource managers from all NPS units and independent scientists should be encouraged.

Develop a study of the history and ecology of translocated bighorn sheep populations. The objectives should include identification of closely and distantly related populations, founder population structure sizes, distance from initial release site, criteria for definition of reintroduction success or failure, source stock, and sites for reintroduction of bighorn sheep.

Planning and implementation should be coordinated through the Regional Chief Scientist's Office. Appointment of a coordinator is encouraged.

Phase Two: 1994-1997

Implement experimental strategies for reintroduction of bighorn sheep.

Monitor extant and reintroduced populations.

Survey genetic variability using techniques developed for allozyme and DNA and fluctuating asymmetry.

Gather additional data on disease, individual growth rates, dispersal, and comparative ecology of populations.

Park Unit Reports
Badlands National Park

Joel Berger, Peter Brussard, Ernie Vyse

Introduction

While it is desirable to develop a regional plan that can be applied to bighorn sheep in all NPS units, this cannot be accomplished without analyses of problems specific to individual sites.

Conservation tactics for individual species must be based on sustaining viable populations. Management strategies, designed on the basis of species life-history, should be employed to assure long-term persistence of populations in the face of unknown environmental and demographic perturbations. There are numerous problems common to virtually all of the NPS units that have resident or migratory bighorn sheep or that are considering the reintroduction of bighorn sheep into former habitats. This report summarizes those problems, outlines a monitoring and research program to develop information necessary to maintain viable bighorn sheep populations, and suggests how these ideas may be implemented at Badlands National Park, the first of the NPS units considered.

The Audubon's subspecies of bighorn sheep (O. c. auduboni) was extirpated throughout its range, including the Badlands of South Dakota, by 1925 (Buechner 1960). In 1964, 22 Rocky Mountain bighorn sheep (O. c. canadensis) from Colorado were translocated to a 370 acre enclosure in Badlands National Park. The herd, which continued to number less than 30 individuals, remained in the enclosure until August 1967, when Pasteurella infection caused a die-off (Hazeltine 1967). The surviving 14 bighorn sheep were released from the enclosure.

The free-ranging herd was not routinely monitored until June 1980 when McCutchen (1980) conducted a 1-week ground survey and observed 27 bighorn sheep in the North Unit. Ground counts were again conducted from 1987 through 1990. During the winter of 1989-90 the population of bighorn sheep in the North Unit was estimated to be between 133-200 (Benzon 1992). Thirty bighorn sheep were sighted in the South Unit during an aerial survey in September 1991. By fall 1994, there were estimated to be 163 $\pm$ 55 bighorn sheep, distributed in the North and South Units of Badlands National Park (Singer, unpublished data).

Bighorn sheep typically live in widely scattered small populations in rugged terrain where it is difficult to assess population size. Bighorn sheep have high site fidelity, are poor colonizers of new habitats, are highly susceptible to disease, and often experience low reproductive and recruitment rates. These factors have contributed to the rapid loss of local populations. Recent research indicates that populations of bighorn sheep with fewer than 50 animals have less than a 1% chance of persisting for 50 years. Therefore, the most immediate problems facing the viability of bighorn sheep populations are likely to be demographic. However, other problems may exist, but in the absence of accurate data on population size, standardized procedures to gather data on population size, and long-term monitoring, it is difficult to know what factors significantly influence population levels.

Major factors that might negatively impact bighorn sheep include poor habitat, disease, predation, loss of genetic diversity, human disturbance, competition with other species, and migration beyond park boundaries. The potential effects of one or more of these will vary among parks.

Recommendations

The goal for bighorn sheep management should be to maintain viable populations (i.e., one capable of maintaining itself for 100-200 years with minimal management). This will require a strategy that differs from that of maintaining productivity for maximum harvest, as is done in bighorn populations that are hunted.

Deterministic sources of mortality (e.g., habitat loss, overharvest) are controlled in the park. Thus, population viability will largely be influenced by stochastic (random) factors over which managers have little or no control, although their effects can be ameliorated. These stochastic factors can be categorized as: (1) individual demographic stochasticity (random variation in birth or death); (2) environmental stochasticity (environmental-driven variation in birth or death rates); (3) probability of catastrophe (100-year drought or severe winter); and (4) genetic stochasticity (loss of genetic variation and exposure of deleterious genes through inbreeding).

It is quite likely that the Badlands National Park bighorn sheep population is depleted in genetic variation resulting from past bottlenecks. Even though it apparently has sufficient variability to maintain fitness in the short-term, the prospects for adaptation to long-term environmental changes are reduced.

Thus, new genetic material should be introduced by translocating animals with high reproductive potential from populations genetically similar to the founding stock but richer in genetic variation. In this case, management intervention is justifiable on the grounds that the population's lack of genetic variation is the result of human activities.

1. Identify occurrence of satellite populations, such as the population in the South Unit. Determine sex and age distribution, presence of lambs, and make assurances for the success of that population.

2. Continue demographic monitoring of all populations. Develop a long-term perspective that focuses on reproduction of known individuals.

3. Develop management guidelines for bighorn sheep that disperse beyond the park's borders.

4. Develop criteria for reintroduction into other sites within or adjacent to the park (e.g., Palmer Creek).

5. Develop genetic baselines for the bighorn sheep herds.

National Parks in Colorado

Tom Hobbs, Francis Singer, Tom Smith, Dave Stevens

Introduction

A four-member advisory team met with resource personnel from six NPS units in Colorado on 14-19 March 1991. The members included Dr. T. Hobbs, Dr. T. Smith, Dr. F. Singer, and D. Stevens. The purpose of the visit was to obtain information necessary to set priorities and guide the funding initiative. The team visited Curecanti National Recreation Area, Black Canyon of the Gunnison Monument, and Mesa Verde National Park. Presentations were given by Rocky Mountain National Park and Colorado Monument staff. Dinosaur National Monument staff were unable to attend. The staffs of each NPS unit, Bureau of Land Management (BLM) staff, and Colorado Division of Wildlife staff presented their perspective on bighorn status and needs. We acknowledge the assistance of T. Blank of Curecanti and D. Welch of the Black Canyon staff in helping to organize the meetings. J. Olterman of the Montrose Office of the Colorado Division of Wildlife visited all three units with the advisory team and his insight on bighorn restoration was also greatly appreciated. The input of all attendees contributed to this report.

Recommendations

The team identified several needs that were common to all of the NPS units in Colorado. These common needs included:

1. Evaluate unoccupied habitat.

Map and calculate acreage of unoccupied habitat. Evaluate potential conflicts from domestic sheep, goats and exotic wild sheep, human developments, and intense human recreation. Assess the area's ability to support a minimum viable bighorn population. Establish priorities for further translocations based on criteria described above.

As a minimum, the team recommended a field reconnaissance be conducted by one to three bighorn sheep biologists to answer these questions. Where feasible, the evaluation should be quantified through a Geographic Information Systems (GIS) analysis to map escape terrain and potential foraging areas. The GIS-based procedure requires field surveys and reconnaissance.

Several habitat models are being developed or tested for GIS analysis of bighorn habitat (see review in Smith et al. 1991). Several parks have indicated an interest in acquiring the LANDSAT imagery, USGS maps, and GIS workstations to conduct such an analysis; however, at this time, only Mesa Verde has an operational system.

2. Evaluate human-caused changes to bighorn habitat.

Bighorn sheep tend to avoid areas with poor visibility such as tall and dense shrub or conifer cover. Shrubs and conifers have increased as a result of fire suppression on many historical bighorn habitats. Moreover, decades of overgrazing by cattle may have resulted in an unnatural abundance of tall sagebrush stands that bighorn sheep avoid. The extent of these changes should be assessed. Any reintroduction plan should include efforts to restore natural open conditions on bighorn sheep habitat before the restoration.

3. Inventory existing populations.

Any remnant or existing bighorn populations should be surveyed before any new translocations occur.

4. Evaluate the translocations' success.

Bighorn sheep distributions and numbers should be monitored for several years following any release. At least five of the translocated bighorn sheep should be radio-collared to facilitate monitoring. Specific criteria for success need to be established.

5. Establish regional working groups

Few NPS units in Colorado are large enough to totally contain viable populations of bighorn sheep. Possibly only Rocky Mountain National Park meets this criterion. Long-term viability of bighorn sheep population will be enhanced by regional planning, research, and translocation efforts. Research and translocation efforts could be cost-shared.

The Regional Office of the NPS needs to provide overall coordination and guidance to the state-wide program. The NPS should be allowed to participate in developing Colorado's translocation priorities, and the NPS should assume an active role in regional planning and funding of research and translocations.

6. A plan should be developed for each release effort, to include:

- Prioritization of release sites.

- We recommend 50 or more bighorn sheep be involved in the restoration (any remaining resident animals could be part of these 50). A recent review by Griffith et al. (1989) suggests few reintroductions succeed when less than 50 animals are involved in the initial relocation.

- Habitat restoration should occur prior to the translocation.

- Translocation programs that will likely result in isolated bighorn populations of <125 are not recommended. A recent review by Berger (1990) of 122 native bighorn populations across the southwest suggested that populations of <50 have no probability of survival for 50 years; populations >100 bighorns had a high probability of survival for 50 years.

- Most translocated populations of bighorn sheep have demonstrated poor dispersal tendencies. Several translocations may be necessary to achieve occupation of an area.

Curecanti National Recreation Area

Tom Hobbs, Francis Singer, Tom Smith, Dave Stevens

Introduction

A one-day visit was made to the recreation area on 19 March 1991. Represented in the discussions were Curecanti National Recreation Area staff T. Blank, J. Chapman, and K. Stalnicker and Colorado Division of Wildlife staff J. Olterman, J. Young, C. Coghill and M. Potter.

Sixty Rocky Mountain bighorn sheep were translocated to Curecanti National Recreation Area in three releases during 1974, 1975, and 1977. There have been two translocations of bighorn sheep north of Blue Mesa Lake. In January 1974, 25 bighorn sheep (3 males, 22 females) from Trickle Mountain were released in Dillon Gulch and in March 1977, 19 bighorn sheep (5 males, 14 females) from Pikes Peak were released at Soap Creek (Colorado Division of Wildlife, unpublished data). The present distribution of bighorn sheep, north of Blue Mesa Lake, extends from Soap Creek eastward to Dry Gulch, and is concentrated around Dillon Mesa. The highest post-release count was 21 bighorn sheep in February 1980. From 1982 through 1994, yearly counts have ranged from 5 to 14. In September 1993, 14 bighorn sheep were counted in Soap Creek and Dillon Mesa.

There was one translocation of bighorn sheep south of Blue Mesa Lake. In January 1975, 16 bighorn sheep (5 males, 11 females) from Trickle Mountain were released at Gateview Ranch (Colorado Division of Wildlife, unpublished data). Decendents of this translocation now occupy the Lake Fork River drainage from Red Bridge Campground, north to Blue Mesa Lake on the eastern side of Lake Fork Canyon. The Colorado Division of Wildlife has conducted periodic counts of this population since 1982. A high count of 20 bighorn sheep occurred in February 1991. In the summer of 1994, 15 bighorn sheep were observed during a combined aerial and ground censuses. It has been speculated that bighorn sheep from this area may cross Blue Mesa Lake and mix with bighorn sheep north of Blue Mesa Lake.

Recommendations

The committee suggested that local management agencies consider the following actions for Curecanti National Recreation Area and surrounding lands:

1. Evaluate unoccupied habitat, prioritize remaining potential translocation sites, identify habitat changes, and identify habitat restoration needs.

2. Translocate bighorn sheep. The committee felt after the cursory visit that much potential habitat remains unoccupied by bighorns. The two small groups of bighorn sheep in the recreation area have not grown and dispersed into new habitats. It cannot be concluded if the severe winters, poor survival of young, or other problems such as habitat limitation or lack of genetic diversity have depressed these populations. As described above, a translocation plan is suggested before further efforts take place, and any habitat restoration such as prescribed burning should precede the translocation.

   Domestic bighorn sheep grazing south of the river severely limits the prospects for further restoration of bighorn sheep in that area. Periodic severe winters will also make restoration more difficult in Curecanti National Recreation Area. On the other hand, recent prospects for habitat acquisitions and improvements north of the Gunnison River and the high potential for watchable wildlife north of the river greatly increase that area's value for bighorn sheep restoration.

3. Continue population and sex/age surveys of the population.

4. If the staff of the recreation area is agreeable to handling animals, surveying the genetic heterozygosity in the existing herd prior to translocation is recommended. The Dillon Pinnacles group may possibly be inbred, but inbreeding has rarely been documented in the wild, and other rams may be visiting the Pinnacles area during the breeding season.

Colorado National Monument

Tom Hobbs, Francis Singer, Tom Smith, Dave Stevens

Introduction

Colorado National Monument staff J. Taylor and J. Paynter attended the desert bighorn sheep meeting in Moab, Utah, and the Colorado bighorn sheep meeting in Montrose on 20 March 1991. Colorado Division of Wildlife staff J. Ellenberger, J. Olterman, D. Coven, and M. Potter were present at the Montrose meeting. On 7 March 1991, Dr. G. White and F. Singer briefly visited Colorado National Monument.

Bighorn sheep historically occupied the Colorado River canyons to the west of Colorado National Monument. Although there are no historical records specifically from the Colorado National Monument, pictographs and petroglyphs of bighorn sheep within the monument present evidence that bighorn sheep occurred there prehistorically (Stroh and Ewing 1964; Denny 1976).

In November 1979, 11 desert bighorn sheep from southwestern Arizona were released in Devils Canyon, 1 km west of the northwestern corner of Colorado National Monument (Ravey 1984; Creeden 1986). By fall 1980, these bighorn sheep had dispersed 5 km to the west and 3 km to the east. In June 1980, 16 desert bighorn sheep from Lake Mead National Recreation Area were released in Monument Canyon in Colorado National Monument and immediately dispersed from the release site (Ravey 1984; Creeden 1986). Most individuals dispersed to the head of Devils Canyon and continued westward into areas occupied by the first release. In November 1981, another nine desert bighorn sheep from the Lake Mead National Recreation Area were released in Devils Canyon (Ravey 1984; Creeden 1986). By 1994 the population distribution extended along Black Ridge from the northwestern corner of Colorado National Monument approximately 15 km west to Mee Canyon. During 1991-1994, the population was estimated to range between 125 and 150 bighorn sheep (Creeden, personal communication).

In addition to the herd on the Black Ridge west of Colorado National Monument, there is a small herd of bighorn sheep in the Westwater Creek area, 25-30 km west of Colorado National Monument. This herd may be descended from seven bighorn sheep translocated from the San Juan herd in Utah in 1979, and 20 Nelson's desert bighorn sheep translocated from Lake Mead in 1990 (Karpowitz, personal communication).

Recommendations

The staff of Colorado National Monument received input from the scientists at the meetings in Moab, Montrose, and Colorado National Monument prior to preparing their submission. The scientific committee concurred with the excellent report from Colorado Monument. The committee agrees with the monument's priorities:

1. A survey of habitat suitability needs to be completed prior to any further translocations into the monument.

2. A survey of genetic heterozygosity of the existing animals would be highly informative. It should resolve whether translocations should be comprised of bighorn sheep from dilution populations or from one of the original parent populations.

The desert bighorn sheep committee that met in Moab during the first week of March strongly recommended that interagency cooperation be pursued to facilitate a larger desert bighorn sheep population in this area. Through further translocations and population growth it appears possible for desert bighorn sheep to completely occupy the area from the east edge of the Colorado National Monument westward to West Water Creek, Utah. Several hundred to 500 desert bighorn sheep could potentially occupy this area, thus representing one of the largest essentially disease-free reserves for the subspecies. Bighorn sheep restoration into Colorado National Monument should be a high priority, assuming the area contains all of the elements required for bighorn occupation. The value of a watchable population of bighorn sheep close to Grand Junction, should also be stressed when evaluating Colorado National Monument for future translocations.

The mixing of two subspecies or varieties of desert bighorn sheep in the initial translocations does not appear to have compromised NPS policies, guidelines, or objectives. Recent enzyme work by R. Ramey of Cornell University suggests the two forms of desert bighorn sheep are unrecognizable from each other and he suggests that all desert bighorn sheep should be combined into one subspecies. One genetics expert serving on the desert team suggested to the NPS that translocations and any future augmentations come from only indigenous sources. A genetics expert serving on the prairie teams, Dr. E. Vyse, however, suggested using several source stocks since so little of the parent population's heterozygosity is represented in the typical founder group of 20-30 bighorns.

It is unknown if the sources for the original translocations were optimal. The question of past source stock appears to be a moot point since the founders represent the historic subspecies and recent work suggests only one subspecies of desert bighorn sheep should be recognized. The bighorn population is doing well and mixing the races is acceptable given what information is available.

Recently the staff of Lake Mead National Recreation Area agreed to provide desert bighorn sheep stock should it be resolved that the monument needs further translocations. Additionally, the herd of bighorn sheep thriving on BLM land west of the monument might provide adequate stock. This group likely has high genetic heterozygosity due to the mix of original founders, but this should be verified. J. Ellenberger of the Colorado Division of Wildlife has expressed an interest in obtaining genetic information from this herd. The desert bighorn sheep recently translocated into the nearby West Water Creek by the State of Utah came from Lake Mead. Most disease experts (D. Jessup, personal communication, California Department of Fish and Game) recommend against indiscriminate mixing of bighorn sheep source stock because of the possibility of introducing virulent disease. However, since the Colorado and West Water herds of desert bighorn sheep may soon intermix, the precedent for bringing in Lake Mead animals has now been established.

Black Canyon of the Gunnison National Monument

Tom Hobbs, Francis Singer, Tom Smith, Dave Stevens

Introduction

A one-day visit to Black Canyon of the Gunnison National Monument (BLCA) and a meeting with various agency representatives was made by the team on 20 March 1991. Represented in discussions on BLCA were members of the monument staff D. Roberts, J. Welch, D. Smith; Division of Wildlife staff J. Olterman, D. Coven, M. Potter; and Bureau of Land Management staff J. Ferguson.

Eighty Rocky Mountain bighorn sheep have been translocated near the northwestern boundary of Black Canyon of the Gunnison National Monument in four releases during 1986, 1987, 1988, and 1990. In 1986, 20 bighorn sheep (3 males, 12 females, 5 lambs) from Cebolla Creek were released near Chukar Trail, 5 km from the northwestern boundary of the monument. In 1987, the second translocation of 23 bighorn sheep (2 males, 12 females, 9 lambs), also from Cebolla Creek, were released near Ute Trail, approximately 6 km north of the 1986 release. In 1988, the third translocation of 19 bighorn sheep (3 males, 16 females) from the Almont Triangle were released along Ute Trail, north of the 1987 release (Colorado Division of Wildlife, unpublished data). In 1990, the fourth translocation of 20 bighorn sheep (5 males, 15 females), from Georgetown, were released near Duncan Trail approximately 5 km south of the 1988 release (Colorado Division of Wildlife, unpublished data).

By 1990, it was estimated that there were more than 100 bighorn sheep in the release area. However, by 1995 the population had decreased to approximately 40 bighorn sheep (D. Masden, CDOW, personal communication).

Recommendations

1. Remove threat of exotic ungulates from the area

The key to the recovery of bighorn sheep in the Black Canyon of the Gunnison National Monument is the control of exotic wildlife species, primarily mouflon, and, if feasible, separation of bighorn sheep from domestic sheep. If exotics inhabit the canyon there will be the continued threat of interbreeding, disease transmission, and interspecific competition. Numerous studies have verified the incompatibility of domestic sheep, goats, and other exotic species with bighorn sheep. It is well documented that disease transmission from domestic sheep has been responsible for all-age die-offs in bighorn sheep. Although several investigators have recommended minimum distances for separation of bighorn sheep and domestic species, the potential for die-off justifies a policy of uncompromisable separation which may require fencing to keep domestic bighorn sheep out. Any portion of the range that allows contact between these species cannot be considered potential bighorn sheep habitat and further management action would be unwarranted in those areas.

2. Evaluate the bighorn sheep habitat potential

A technique has been developed by T. Smith, Utah State University to evaluate potential bighorn sheep ranges (Smith et al. 1991). This habitat evaluation procedure combines: (1) a quantitative assessment of bighorn sheep range to determine if adequate area exists to support a minimum viable population of bighorn sheep; and (2) a qualitative assessment to predict probable densities of bighorn sheep those ranges can be expected to support.

Clearly BLCA does not lack in the rugged escape terrain that is the core of good bighorn sheep habitat. However, relatively level buffer zones surrounding the escape cover along the rim play an important role in sustaining a viable herd. This would be especially important for feeding areas, since the forage production in the steep cliffs may not be sufficient. Unfortunately, the kind of open, high visibility, grasslands preferred by bighorn sheep appear to be lacking along the canyon rims and may present a factor limiting the establishment of permanent herds. This question and others like it are identified through the formal habitat evaluation of Smith et al. (1991).

3. Implement habitat management program

The Habitat Evaluation Procedure recommended above will point out deficiencies in the present habitat for bighorn sheep in BLCA. A management plan should be developed to eliminate these deficiencies so that the potential of the area for bighorn sheep can be realized. This should be a fairly long-term incremental habitat improvement program that works toward the final goal of sufficient habitat to support a minimum viable population of bighorn sheep. The plan should also include provisions for separating bighorn sheep from domestic sheep with fencing or other habitat barriers.

4. Monitor the establishment of bighorn sheep in the monument

There have been reports of bighorn sheep in the canyon area of the monument and movements of bighorn sheep through the canyon to Curecanti National Recreation Area upstream. To determine whether a stable reproducing population is present within Black Canyon on a year-round basis, it is very important to document the distribution and movement of bighorn sheep. This will be even more important as the habitat improvement program develops. The documented use of these areas by bighorn sheep will support further habitat management or justify augmentation of the population to attain a viable level.

5. Augment the population

The stocking of the lower Black Canyon Gorge through four separate translocations totalling 80 bighorn sheep may be sufficient to establish a bighorn sheep population in the monument area. However, if these bighorn sheep do not establish permanent herd segments in BLCA and the habitat assessment indicates sufficient habitat is present, then further augmentation may be necessary. This may be the case if the habitat deficiencies can be alleviated by management action since established populations do not often pioneer new habitat. The goal for population numbers in the area including the lower gorge, Black Canyon National Monument, and Curecanti National Recreation Area should be 500 bighorn sheep for long-term viability. The source of stock for translocation may depend on availability. National Park Service policy is to obtain animals that most nearly approximate the historic population.

6. Continue to monitor the restoration program

The follow-up monitoring of the status of the restored population should continue for several years.

Mesa Verde National Park

Tom Hobbs, Francis Singer, Tom Smith, Dave Stevens

Introduction

A one-day visit to the park and a meeting with the staff and Colorado Division of Wildlife personnel was made by the team on 21 March 1991. Represented in the discussion were park staff Superintendent R. C. Heyder, S. Budd-Jack, M. Colyer; and Division of Wildlife staff J. Olterman and R. Rice.

Bighorn sheep were apparently numerous in Mesa Verde during the Anasizi occupation of the area, based upon their remains in occupation sites. Anasizi probably burned the mesa tops to clear fields and encourage game, thus improving bighorn sheep habitat. Bighorn sheep were apparently extirpated from the area around the turn of the century. Cowan (1940) states that the Rocky Mountain subspecies of bighorn sheep originally occupied this area; however, the area is very close to the boundary for the range of the desert subspecies. Since identification of the subspecies original range is somewhat conjectural, it is possible that desert bighorn sheep were the original subspecies present in the area. In 1946, the Colorado Division of Wildlife released 14 Rocky Mountain bighorn near Spruce Tree Lodge in the park. The population apparently grew slightly over the years and some animals left the park to occupy Webber Canyon. The largest groups, 22 in 1951 and 10 in 1953, were observed in Webber Canyon. No estimate of the population was ever made, and the last large group, 19 animals, was observed in 1980. Recent sightings have been of one to four animals, and the population is felt to number less than 10, and possibly less than five individuals.

Recommendations

1. Determine the current status and distribution of bighorn sheep in Mesa Verde National Park (MEVE).

The park staff believes that as few as three bighorn sheep may remain from the translocation effort in 1949. Bear and Jones (1973) listed the population at 30, and Bailey (1990) stated the population as 25 in 1988. It is important to document the present status, distribution, and habitat use of this population. These data would be useful to determine: (1) the need for augmentation of the population, (2) the location for the releases, (3) those areas that bighorn sheep have selected, and (4) sites for habitat improvement. This would require a systematic search of the canyon areas from the ground and by helicopter.

2. Evaluate the habitat potential

Using the technique developed by Smith et al. (1991), a thorough biological assessment of the potential of these ranges to provide habitat for a viable bighorn sheep population needs to be made. Through this assessment the issue of habitat visibility would quickly surface as possibly the most important issue. There may also be more suitable areas available than were apparent in our limited survey of the park.

3. Implement habitat management program

The Habitat Evaluation Procedure recommended should point out deficiencies in the present habitat in MEVE for bighorn sheep. If, as expected, this assessment recommends a reduction in the density of the pinyon/juniper community on key areas, a plan will need to be developed. This plan will have to contain provisions for the cyclic maintenance of the habitat over the long term. The preferred manipulation is generally prescribed fire. However, prior to recommending techniques, a study of fire history that looks at the effects of fire on the artifacts of the park must be completed. There are also other methods of either applying fire or using chemical means to reduce density in a forest overstory without affecting the surface. Depending on the habitat evaluation, habitat management is probably the key to the successful restoration of a viable bighorn sheep population to Mesa Verde. The park personnel, therefore, will have to decide if a restored bighorn population is important enough to proceed with some method of habitat improvement. Without adequate steep, open habitat the restoration of bighorn sheep to MEVE will not be successful.

4. Augment the population

It is probably not possible for the bighorn sheep population in MEVE to recover without supplemental translocations. Mesa Verde National Park and the Division of Wildlife have a plan to release bighorn sheep on Long Mesa, an area burned by wildfire in 1989. If this release takes place and bighorn sheep are established in that area, it probably will only be a short-term improvement.

Plant succession will rapidly reduce the quality of bighorn sheep habitat in this area. If a program of habitat management can be instituted that will provide a series of good sites across the park, then several releases should be planned. These translocations should occur over a period of years to fill the gaps in distribution between the present population, the Long Mesa population, and any improved sites. The total minimum number released should be at least 50 with a population goal of 125 for the park and surrounding areas.

5. Monitor the restoration program

The follow-up monitoring of the population as pointed out in the unit-wide perspective will be needed for several years. The successional stages of the habitat should also be monitored.

Colorado Plateau

Dennis Murphy, Fred Allendorf, Vern Bleich, Charles van Riper, III, and Gary White

Introduction

In the nineteenth century bighorn sheep were dispersed across steep rugged terrain from Canada through the United States to Mexico, in areas including the highest peaks of the Rocky Mountains and the lowest desert ranges of the Mojave. As the West was explored, hunters discovered the bighorn sheep. Mature rams became popular game trophies; the hides and flesh of the animals were also commonly sought. The arrival of Europeans also brought domestic sheep, sources of forage competition and disease, both significant threats to the bighorn sheep. By the end of the nineteenth century, bighorn sheep populations had been significantly reduced by hunting, competition from livestock, and disease. Although subsequent hunting regulations and wildlife management slowed the population decline, bighorn sheep populations remain reduced from their previous levels. Bighorn sheep are found on a variety of public and private lands in Canada, the U.S., and Mexico, including a number of U.S. national parks. Concern about long-term conservation of these populations led the National Park Service to establish a scientific advisory committee for the species on the Colorado Plateau. The committee, chaired by D. Murphy, convened in March 1991 at Canyonlands National Park to develop a set of conservation recommendations for bighorn sheep in Canyonlands, Arches, Capitol Reef, and Zion National Parks, and Glen Canyon National Recreation Area.

Bighorn sheep herds may have big ranges and roam freely across lands managed by a variety of federal, state, and private entities. Communication among national park units is good, but interaction of park staff, staff managing the surrounding Bureau of Land Management lands, and Utah's Department of Wildlife Resources is limited. Acknowledging the regional nature of the management challenge, the committee strongly encouraged greater cooperation among agencies responsible for managing the bighorn sheep and its habitat.

The wide-ranging tendencies of the bighorn sheep presents another, more systematic threat: the interaction of bighorn sheep populations with domestic sheep grazing in critical habitat areas. In a number of releases, bands of 20 to

40 bighorn sheep were translocated into unoccupied portions of the historical range of the species. Translocated populations rapidly expanded, but some populations crashed after animals were observed or were suspected to have made contact with livestock and exposure to diseases to which they are not resistant.

The difficulty of confining healthy populations of bighorn sheep, and their susceptibility to introduced diseases suggests that bighorn sheep populations will not be stable until domestic sheep grazing allotments in critical habitats are rescinded. Committee scientists underscored that such systematic impacts of human activities must be alleviated before management planning for the species can be effective.

Political resolutions to these two threats will allow conservation biologists and wildlife managers to address biological issues, particularly stochastic environmental perturbations that put bighorn sheep populations at risk of extinction. The committee called for controlled experiments to conclusively quantify parameters of habitat suitability, the effects of temporal variation in habitat quality, and the impacts of natural catastrophes such as fire and severe drought. A conservation strategy that adequately mitigates the likelihood of regional species extinction must consider the interaction among populations across habitat corridors, as well as the roles of special landscape features. For the bighorn sheep, these include water sources, bedding and breeding sites.

Studies, and long-term data on bighorn sheep population size and distribution, demand rigorous inventory and monitoring programs that are usually logistically difficult. To resolve these difficulties, the advisory committee recommended methods of trend counts and population estimates. Similarly, the committee discussed means of evaluating the role of density-dependence in bighorn sheep populations. The latter is particularly important in assessing the role of disease in the regulation of population size, evaluating the potential impacts of removal of individuals for translocation, and interpreting the low reproductive rates of small populations which might be smaller than a threshold size required for population growth.

Finally, the advisory committee considered the role of genetics in bighorn sheep population dynamics. The group focused on genetic divergence in groups of bighorn sheep from different geographic areas, a factor important in analyzing the likelihood of success in translocation, and genetic variation within demographic units, noting that the deleterious impacts of inbreeding are persistent threats in small populations of many species.

Conservation of the bighorn sheep presents political, logistical, and biological problems typical of large vertebrates, particularly those with large ranges and narrow habitat requirements. The very nature of acceptable bighorn sheep habitat, craggy, high wildlands far from domestic animals, has led to its fragmentation and further complicates the conservation of this magnificent species.

Today small, scattered populations of bighorn sheep exist across vast federal, state, and private lands that are subject to ever-increasing levels of human impact as diverse as mineral extraction, agriculture, and recreation. Bighorn sheep struggle to survive in the face of daunting environmental conditions, including frequent drought and habitat succession that can render habitat unsuitable to the species. Furthermore, bighorn sheep, like many megavertebrate species that exist today in remnant populations across fragmented habitats, are subject to the deleterious genetic consequences of small population size. Add to that the susceptibility of bighorn sheep to a host of diseases borne by the domestic livestock with which they share rangelands, and one has a blueprint for species extinction.

We offer a framework within which these recommendations might be considered by noting that conservation planning addresses two interactive sources of threats to species persistence. First are what we refer to as systematic threats or pressures, those associated with human activities, including impacts due to pollution or competition from domestic animals. Such pressures must be eliminated or controlled before management can effectively address the second suite of threats, those resulting from natural stochastic phenomena. These threats include natural random population and habitat perturbations that affect population persistence, such as the loss of genetic diversity, demographic stochasticity, environmental uncertainty, and disruptions to dispersal. With these two sources of threats in mind, we suggest the following priority scheme for management of bighorn sheep on the Colorado Plateau.

Canyonlands and Arches National Parks

Bighorn sheep populations in eastern Utah were severely reduced during the late nineteenth and early twentieth centuries by hunting and land use changes such as livestock grazing and uranium mining. However, small bands of bighorn sheep persisted in remote locations, including the Needles and Island in the Sky districts of present-day Canyonlands National Park (Buechner 1960). Bighorn sheep from these two districts have been translocated to the Maze district of Canyonlands National Park, Arches National Park, and other locations throughout Utah.

Bighorn sheep populations in Canyonlands National Park have been surveyed since 1974. In 1974-1975 it was estimated that there were 80 to 130 bighorn sheep in the park (Dean et al. 1977). During a 1978 aerial survey, 232 bighorn were counted. Counts decreased during the 1980's, but population estimates varied due to different methods used to extrapolate counts into population estimates. In 1989, 67 bighorn sheep were counted during aerial surveys of the park and the population was estimated to contain 281 to 368 bighorn sheep. In 1994, 143 bighorn sheep were counted in the park and the population was estimated at 445.

Arches National Park received two translocations of 6 and 19 bighorn sheep in 1985 and 1986, respectively. In 1988, 11 bighorn sheep were counted during the aerial survey, and the population was estimated at 36 individuals. In 1991, 10 additional bighorn sheep were translocated to the Professor Valley, southeast of Arches National Park. A total of 62 bighorn sheep were counted during the 1994 aerial survey of Arches National Park.

Neighboring herds of bighorn sheep occur in the Potash region north of the Island in the Sky district; in the Lockhart Basin, east of the Needles district; and in the North San Juan Unit, south of the Needles district.

Capitol Reef National Park

The park is within the historic range of the desert subspecies of bighorn sheep (Cowan 1940). The Fremont and Anasizi cultures left behind rock art of bighorn sheep in the area (National Park Service 1982). The Escalante party observed bighorn sheep in great abundance in the Capitol Reef area in 1776, as did the Fremont party in 1871 (Wilson 1968). Native bighorn sheep were extirpated by the early 1940's (Kelly 1948). Desert bighorn sheep from the Canyonlands (Island in the Sky, North San Juans) area were translocated into Capitol Reef National Park in 1984 and 1985 and into Moody Canyon adjacent to the park during 1975 through 1978 by the National Park Service and the Utah Division of Wildlife Resources (Steel et al. 1994). These translocations grew steadily and, in 1994, were estimated to number about 400 animals (Bellew 1995).

Glen Canyon National Recreation Area

(herd histories excerpted from McCutchen 1994)

Historically, desert bighorn sheep were common and widespread along the Colorado and San Juan Rivers and adjacent watersheds in the Glen Canyon National Recreation Area. In the late 1800's, the area was overstocked with domestic sheep and cattle, which competed with bighorn sheep for forage. In addition, diseases of domestic sheep were transmitted to the bighorn sheep (Wilson 1967). In the 1890's, drought caused large losses of livestock. The impacts of livestock on the range and unregulated hunting are attributed to causing drastic declines in desert bighorn sheep populations.

In the 1950's, there was a boom in the exploration for uranium in the area. Habitat disturbance, usurpation of critical watering areas and unrestricted illegal hunting by miners and prospectors negatively impacted bighorn sheep in the region (Wilson 1967, 1968; Irvin 1969).

Wilson (1967) determined that relict bighorn sheep populations were located in the following areas: Escalante River, goosenecks of the San Juan River to Grand Gulch, junction of San Juan River and Colorado River to Mancos Mesa, Halls Creek to the Dirty Devil River, White Canyon, and Dark Canyon to Spring Creek east of the Colorado River. In 1969, the Utah State Division of Wildlife initiated helicopter surveys and found desert bighorn sheep along the east side of the Colorado River in what are now the North and South San Juan management units.

The North San Juan Unit lies on the east side of the Colorado River south of Canyonlands National Park and north of Highway 95. It has an established native population. When the Utah Division of Wildlife Resources began to conduct aerial surveys in 1969, this unit was noted as having more desert bighorn sheep than any other unit in the state. In 1976, 225 bighorn sheep were observed during the winter survey (Dalton 1978). Bighorn sheep were captured and used in translocations from 1975 through 1980. In 1985, a decline was noted in the herd. In 1988, only seven bighorn sheep were observed, and observations declined to zero in 1990. The cause of the decline was attributed to disease due to contact with domestic sheep.

The South San Juan Unit lies east of the Colorado River south of the North San Juan Unit. It contains a native population of bighorn sheep. For many years, beginning with the 1969 aerial surveys by the Utah Division of Wildlife Resources, the unit was considered to be second only to the North San Juan Unit in numbers of desert bighorn sheep. Seventy bighorn sheep were observed during the surveys of 1975 (Dalton 1978), and in 1987 140 were seen. Beginning in 1988, there was a definite decline in the numbers of bighorns observed, with 30 bighorn sheep observed in 1990 and none seen in 1991. In 1992, the populations trend began to move upward with about 60 bighorn sheep observed. In 1993, 80 bighorn sheep were observed. The cause of decline in the 1980's was believed to be related to domestic sheep diseases. Bighorn sheep in this unit were also used for translocations.

A relict population of bighorns is believed to have persisted in the Escalante Unit. Three translocations of bighorn sheep from the North San Juan Unit were made into the East Moody Canyon area. In 1985 30 bighorn sheep were observed and in 1993 79 were observed in the Escalante Unit.

Other herds in the area occur on the Kaiparowits Plateau, Rock Creek, Rogers Canyon, the Little Rockies, the Paria Wilderness, and the Navajo Nation.

Recommendations

1. Conservation planning for any wide-ranging species that exists in fragmented distributions across patchy habitats demands cooperation among agencies. The diverse spectrum of land use practices and political and legal mandates complicate preservation of bighorn sheep. Although interagency cooperation is often overlooked in wildlife restoration activities, it is the most fundamental component in conservation planning. Present distribution patterns predispose bighorn sheep to genetic bottlenecks, potential inbreeding depression, and local extinction. Park and monument boundaries that create long, narrow reserves may even encourage contact between bighorn sheep from reserve areas and domestic sheep on adjacent lands.

The benefits of interagency cooperation are many. The creation of a larger effective reserve will minimize chances of local extinctions, facilitate dispersal of individuals, and minimize genetic isolation. Cost sharing is enhanced for big ticket expenses such as helicopter surveys. Interagency leverage of monies encourages the budget planning process. And, additional chances to implement policy emerge; for example, the ability of the BLM to regulate domestic sheep grazing allotments, should increase with linkage with the National Park Service.

Some drawbacks are concomitant to interagency efforts. Substantial advanced planning must accompany efforts to assure that future activities are not restricted. An example might be the designation of wilderness when, at a later date, wheeled vehicles would be needed to translocate bighorn sheep. Each agency may have to modify or perhaps relax present management guidelines. For example, NPS areas might permit guzzlers to be situated throughout lands under park jurisdiction, or the BLM might exchange certain grazing allotments.

The ultimate recovery of bighorn sheep will depend not only on the success of cooperative efforts from state and federal agencies, but from the many individuals and private organizations associated with bighorn sheep preservation. Groups such as the Arizona Desert Bighorn Society, Fraternity of the Desert Bighorn, Society for the Conservation of the Desert Bighorn, and the Foundation for North American Wild Sheep will be critical in obtaining financial, as well as political, support for future preservation projects.

2. On the Colorado Plateau, a lead must be taken in putting together an effective interagency team. Establishing formal lines of communication among authorities is the essential first step in regional bighorn sheep conservation. State and federal agencies that are involved in proposed interagency cooperative efforts include the National Park Service, Bureau of Land Management, Utah's Department of National Resources, Colorado Division of Wildlife, and representatives of the Navajo Reservation lands.

3. The first priority of an interagency committee will be to develop a Memorandum of Understanding among the cooperating agencies. Next should be development of a master plan of operation between the agencies, outlining an overall strategy and assigning roles. This operational plan should be delineated and signed at the local level.

4. Geographic Information Systems (GIS) should serve as the nexus among agencies and can provide the foundation for information sharing among participants. GIS permits planning at the landscape level.

The planning arena for bighorn sheep conservation must be described on maps delineating the location, size, shape, and spacing of habitat patches to be managed. The first step is to convey spatially explicit information on the distribution of target populations, their habitats, and resources. That information is best presented as independent map layers that, when overlaid to create a composite map, define areas subject to a comprehensive conservation strategy.

For bighorn sheep we suggest four key map layers. The first should outline both the current and historical (as can best be surmised) geographic distribution of the target species. The second map layer should portray the current and historical distribution of suitable habitat, and should include disturbed areas or seral stages that through recovery or management could become suitable habitat. This map layer must be based on substantial basic research on habitat identity and quality and patterns of habitat use. The third map layer should convey census information. Even limited information from localized habitat areas may be used to identify population centers and, importantly, identify quantifiable environment correlates of habitat quality that then may be mapped. The association of survey data with specific habitat types allows projection of potential population sizes for habitats that may be temporarily unoccupied, may be unaccessible, or may simply lack observations. The fourth map layer should depict land ownership and use patterns. Lands available for conservation planning should be distinguishable from lands not available for planning. For bighorn sheep, lands and public lands subject to domestic livestock grazing that otherwise may be physically suitable for the species should be excluded from consideration for planning.

The intersection of these four map layers defines the planning arena and conveys crucial information upon which a regional conservation strategy can be based. The distribution and abundance of bighorn sheep within planning boundaries should be managed to maximize the likelihood of persistence, a straightforward goal that presents substantial challenges. Management for most species would select populations that are as large as practicable, as widely distributed as possible and adequately interconnected by corridors that facilitate dispersal, and demographic and genetic intermixing. The specter of diseases that may be transferred from domestic livestock seem to argue for a different strategy for bighorn sheep. The optimal conservation for bighorn sheep may call for populations that may be below habitat carrying capacity, are well-buffered from planning area boundaries, and are isolated from one another.

The data necessary for the definition of explicit planning area boundaries will come from four (interactive) categories: (1) data on distributional dynamics, particularly metapopulation structure and patterns of dispersal; (2) observation of the effects of environmental phenomena, including frequent perturbations and infrequent catastrophic events, on population persistence; (3) demographic information, especially data related to age and sex ratios; and (4) genetic information, especially that associated with potential losses of genetic variation and the deleterious consequences of inbreeding. Because bighorn sheep exist in small and highly isolated demographic units, and recruitment is quite slow, the latter two areas of inquiry should be given special attention.

5. Bighorn sheep should only be translocated to areas without domestic sheep. The presence of domestic sheep limits available bighorn sheep habitat and only a fraction of the historical range of bighorn sheep may be available for translocation. Although Thorne and Miller (1989) suggested that the domestic sheep-bighorn sheep disease interactions should not preclude bighorn sheep translocations or traditional livestock grazing practices, we urge a more conservative approach. We suggest that restoring populations of bighorn sheep to vacant habitats may cause risk to existing populations that historically have been large and healthy, because of the vagility of bighorn sheep (Schwartz et al. 1986; Bleich et al. 1990). The restoration of populations to enhance genetic diversity, or to restore this large native ungulate to an otherwise intact ecosystem, may be a two-edged sword, necessary for gene flow, but potentially deleterious because of the enhanced likelihood of disease transmission (Simberloff and Cox 1987). For example, a ram wandering through an area with domestic sheep may contract a respiratory disease, and then expose bighorn sheep in other demographic units before dying. Managers must ask whether populations are in more jeopardy from the lack of gene flow between subpopulations, or by the risk of disease transmission via contact with domestic sheep. Lande (1988) suggests that the risk of disease transmission outweighs genetic concerns, on the short-term basis.

6. Land managers must make some hard choices regarding multiple use on public lands. Those choices are necessarily difficult, and will potentially lead to confrontations between advocates of wildlife concerns and those of the livestock industry. Every opportunity should be made to resolve conflicts in a cooperative rather than confrontational manner (Thorne and Miller 1989). We believe that the formation of an interagency working group will enhance the possibility of resolving potential conflicts. It will be necessary for the working group to include representatives of the livestock industry, as well as all agencies concerned with the long-term conservation of bighorn sheep on the Colorado Plateau.

The literature is replete with examples of the decimation and extirpation of local populations as a result of diseases associated with livestock, particularly domestic sheep (Buechner 1960; Robinson et al. 1967; Stelfox 1971; Lange 1980; Sandoval 1980; Jessup 1981; Blaisdell 1982; Foreyt and Jessup 1982; Goodson 1982; Onderka and Wishart 1984; Coggins 1988; Weaver and Clark 1988). Recently, a series of experiments provided strong evidence that: (1) bighorn sheep that come into contact with domestic sheep die shortly thereafter of respiratory ailments; and (2) the pathogens known to be absent in bighorn sheep, but present in domestic sheep, were confirmed to be present in the dead bighorn sheep upon necropsy (Foreyt 1989a; Callan et al. 1991). Moreover, Onderka and Wishart (1988) demonstrated pneumonia in bighorn sheep following experimental contact, that transmission of Pasturella haemolytica from clinically normal domestic sheep occurred. Onderka et al. (1988) found both bighorn and domestic sheep were susceptible to pneumonia induced by both bighorn sheep and domestic strains of P. haemolytica. It is recognized, however, that P. haemolytica is known to occur in some free-ranging populations of bighorn sheep, apparently without demographic consequences (see Thorne and Miller 1989, for review).

Domestic sheep in the vicinity of bighorn sheep habitat should be managed so that bighorn sheep never come into contact with domestic sheep. The Desert Bighorn Council Technical Staff (1990) prepared a series of five recommendations designed to minimize the potential for contact between domestic and bighorn sheep on public lands. These are: (1) buffer strips $\geq$13.5 km wide to minimize the potential for disease transmission between domestic and bighorn sheep; (2) domestic sheep that are trailed close to bighorn sheep habitat must be closely tended by capable and informed herders; (3) domestic sheep should be trucked, rather than trailed, when trailing would bring them closer than 13.5 km to bighorn sheep habitat, (4) trailing should never occur when domestic sheep are in estrus; and (5) bighorn sheep should not be translocated to areas where domestic sheep have been grazed within the past 4 years.

There is a pervasive notion that national parks are somehow inviolate, and that demographic units of bighorn sheep within the confines of national parks are secure from factors that impact populations inhabiting public lands managed by multiple-use agencies. That view, if actually held, is optimistic at best. In reality, bighorn sheep within units of the national park system are not immune to the diseases. The perception that national parks, in and among themselves, can provide for the long-term conservation needs of bighorn sheep on the Colorado Plateau is countered by the weight of scientific evidence.

7. Any translocations undertaken must have as their first objective that of enhancing the existing status of bighorn sheep. Bighorn sheep are an important wildlife resource on the public lands of the southwestern United States, and many translocations have been undertaken in efforts to reestablish populations on historical ranges. However, such translocations are exceedingly expensive (Bleich 1990), and require a great deal of interagency coordination (Keay et al. 1987; Bleich et al., in press). Because of the importance of maintaining existing, healthy populations, it is recommended that management on the Colorado Plateau focus on: (1) management for disjunct populations that are both large and geographically isolated from each other, thereby diminishing the likelihood of a catastrophic loss of all populations simultaneously; and (2) resolution of the potential conflicts that exist with current domestic sheep grazing allotments (Cresto et al. 1990; Wolfe 1990). It is reemphasized that such efforts must occur in the spirit of cooperation, as noted by Thorne and Miller (1989).

There are numerous opportunities to reestablish populations of bighorn sheep on public lands on the Colorado Plateau. A coordinated effort will be necessary to insure the success of any translocation. The desire of one unit of the national park system to reintroduce bighorn sheep could potentially place at risk other demes inhabiting adjacent lands, if such a translocation enhances the likelihood of contact with domestic sheep. Until a detailed management plan specific to the Colorado Plateau is devised, vacant national park lands and other public lands might better serve the species by remaining free of bighorn sheep. Those lands might best serve bighorn sheep in their current roles effectively buffering existing populations from exposure to potential sources of disease.

8. There is a need for a regional framework to facilitate interagency cooperation, alleviate threats to bighorn sheep from domestic livestock, and to develop an integrated scientific program. Land and resource managers on the Colorado Plateau have shown the ability to identify and grapple with the many management challenges posed by bighorn sheep. However, the landscape upon which that management is carried out has not received comparable attention. The ultimate goal of bighorn sheep planning efforts is the distribution of viable populations across the historical range of the species. To achieve that goal, reserves, set-asides, and easements must be melded into a system or network of habitat areas adequate to support those populations over the long-term. Biological data and other information is required in this reserve planning process to assist in defining the portions of the landscape available to bighorn sheep.

9. Conservation actions for bighorn sheep should be conservative. For example, we believe that management of extant populations should take priority over translocation efforts, and that large regional populations should be managed for stable numbers rather than as sources of colonists. In the near future, as more information becomes available from research and monitoring, management plans undoubtedly will have to be adapted.

10. The present monitoring system has limitations that must be addressed to interpret the past bighorn sheep data. The method involves aerial surveys and counting bighorn sheep observed. To compare the number of animals counted across years, this method requires that the probability of sighting remain constant across years. Neal (1990) estimated sighting probabilities for 15 independent surveys of similar search efforts from 0.31 to 0.86 ($\bar{x} = 0.57$, $SD = 0.153$), with significant differences between flights ($P = 0.014$); hence, the probability of sighting conditions being constant from year to year is probably incorrect, and comparison of the numbers of animals counted from year to year requires discretion. A more serious limitation of estimated population trends deduced from the number of animals counted from helicopter surveys is that no estimate of precision can be associated with the statistic reported. No aerial sampling system has been implemented that provides a measure of the variance associated with observed counts.

Another system employed in monitoring bighorn sheep populations has been based on the double count system. Bighorn sheep are located by ground observers and visually marked. A second sample of animals is obtained from a helicopter survey. Some bighorn sheep are counted by both ground and aerial observers, thus are sampled twice, providing the requisite recaptures. The double sample procedure can result in a potentially unbiased estimate of the population size. Further, more confidence intervals can be constructed to provide measures of the variation in the estimates. However, two problems can occur with this procedure. First, the confidence intervals are probably too narrow. Bighorn sheep do not move independently but occur in groups. Hence, sighting probabilities are not independent for animals that occur in the same group. Neal (1990) simulated such an operation, with group sizes observed in the Trickle Mountain herd that ranged to as many as 24 individuals. She found that the confidence interval coverage dropped to as low as 80% with increasing group size (versus the expected 95% coverage).

Second, the identification of groups that are counted by both ground and aerial observers is a judgement call. Observers are not in radio contact and may not necessarily be sighting bighorn sheep at the same time. Inexperienced observers often cannot correctly classify animals in a group by age and sex, thus clarification of which groups were observed by both ground and aerial observers can be confused. The ground observers may not be positioned accurately and no attempt is usually made to take a random sample of occupied bighorn sheep habitat. Finally, some confusion related to the recording and reduction of the data is inevitable. Quite different estimates have appeared in different memos, suggesting that expertise is often lacking to conduct this survey under proper constraints.

A crucial reason that some monitoring method is required for undisturbed populations is that disease eruptions can cause rapid declines. Such problems require a monitoring system that can detect at least a 50% decline between consecutive years. In addition, a monitoring method should be based on valid statistical sampling principles and should provide a measure of count precision. We recommend that a quadrat count system be implemented for this purpose. A rigorous sampling scheme puts the monitoring program on a sound statistical basis and provides an effective measure of the precision of the counts.

The area of occupied habitat for each subpopulation should be delineated and divided into quadrats. For example, the Colorado Division of Wildlife censuses mule deer in 1 mi^2 quadrats (Kufeld et al. 1980) and in high density areas in 1/4 mi^2 quadrats (Bartmann et al. 1986). A random sample of these quadrats is drawn and the probability of sighting is maximized on each of these quadrats. The spatial variation between quadrats provides an estimate of precision for the total population estimate.

The quadrat count method is limited by unknown sighting probabilities. However, the year-to-year variation in this sighting probability is likely to be considerably less than that from nonstructural surveys, because each quadrat is searched with greater intensity. If budget constraints limit helicopter time, a reduced number of quadrats can be surveyed, and a population trend count can still be achieved. Further, the quadrat sampling scheme provides confidence intervals on the trend counts, which are lacking with the present monitoring system. The method would continue to require the assumption that sighting probabilities are not different between years, but it would constitute a cost-effective method for detecting large declines in population size. In addition, the statistical sampling scheme would be useful in assessing age and sex ratios.

Lamb:ewe ratios must also be constructed from proper sampling frames. The quadrat count procedures would force survey of the entire area to produce an unbiased estimate of age and sex ratios. Confidence intervals on lamb:ewe ratios can be based on the estimator for groups developed by Bowden et al. (1984). Adequate data must be collected to construct $\pm 20\%$ confidence intervals. For data previously gathered, approximate confidence intervals for lamb:ewe ratios should be constructed based on the binomial distribution. Such confidence intervals of that magnitude indicate that large sample sizes are needed to detect even large differences in recruitment.

Accurate population estimates of subpopulations that are to serve as sources of animals for translocation are critical. The extinction of subpopulations due to disease requires that translocations always be considered as possible management strategies. The precision needed to estimate the sizes of source populations is greater than for trend counts. We recommend that declines in population sizes due to translocation removals (on the order of 50 animals) should be detected with $\alpha = 0.10$ level precision. Multiple resighting occasions are required to obtain population estimates of this level of precision (Bartmann et al. 1987; Neal 1990; White and Garrott 1990). Appendices in Neal (1990) provide confidence interval lengths for various capture probabilities, sighting probabilities, population sizes, and sighting occasions (5, 10, 15, and 20). Interpolation procedures can be performed from this data base with Program NOREMARK. In addition, Program NOREMARK has a Monte Carlo simulation capability to design mark-resight experiments outside the ranges provided by Neal (1990).

11. Radio collars must be placed on at least 10% of a population to achieve valid population estimates. Sufficient sightings should be realized to obtain confidence intervals on the estimate of ±50 animals. Radio-collared bighorn sheep can also be used to delineate movements and hence, define the occupied range. Animals with radio transmitters can also be used to construct a sightability model for bighorn sheep similar to that constructed by Samuel et al. (1987) for elk. One caution should be noted about this procedure. If bighorn sheep are captured for marking by helicopters, later resighting probabilities may be affected because of the stress of initial capture. If possible, other capture methods should be used to place radio transmitters on bighorn sheep.

12. The recurrence of disease necessitates evaluation of density-dependent population regulation in bighorn sheep. Some managers believe that disease can wipe out populations as they approach carrying capacity, because of subtle changes in a population that effectively reduce the quality of animals as density increases. Evidence for this assumption is lacking but certainly the potential for introduction of exotic disease increases with population size simply because of the enhanced likelihood of contact with domestic livestock.

Using currently available data, regression of lamb:ewe ratios relative to population size can be performed, with some of the variation in the data removed by including weather effects in the model. The relation of density and recruitment is required to examine the impact of removals on populations, and to evaluate the potential for sustained yield. The model proposed to evaluate this relation is:

$$R_t = \beta_0 + \beta_1 N_t + \beta_2 \text{ weather} + \varepsilon_t$$

where R_t is the lamb:ewe ratio, N_t is the estimated population size at time t, weather includes temperature and precipitation measurements, ε_t is the residual error, and β_i are parameters estimated from the observed data. β_0 can be interpreted as the per capita recruitment rate at zero density and β_1 as the per capita decline in recruitment as density increases. Under the assumption of density dependence, the slope of this regression should be negative, that is, $\beta_1 < 0$.

Regressions of R_t and N_t for the North San Juan and Potash populations (without weather included in the model) demonstrate that $\beta_1 > 0$ ($\underline{P} < 0.01$). For the South San Juan population, $\beta_1 = 0$ ($\underline{P} = 0.357$). However, a great deal of noise exists in current data due to trend count variation between years, and weather introduces additional variability. The density-dependence relation therefore may be masked by this variation. Alternatively, the introduced populations may exhibit low reproductive rates with some threshold density required to achieve maximum per capita recruitment.

13. National Park Service policy dictates that the reintroduced animals should be as closely related to the extirpated population as possible. Seven subspecies of bighorn sheep have been described (Cowan 1940), one of which, the Audubon bighorn sheep, is extinct. Implementation of this NPS policy requires that the historical geographic pattern of the relations among geographic populations of bighorn sheep be established. The taxonomy of mammals below the species level, however, has been found to be an unreliable guide for conservation policy (Ryder 1986). The current subspecific taxonomy of bighorn sheep is based upon morphological analysis of a relatively few specimens (Cowan 1940). As with most described mammalian subspecies, it is not clear which named subspecies actually represent significant adaptive variation worthy of consideration in guiding conservation policy (Ryder 1986).

We are faced with the task of identifying subspecies or populations that possess genetic attributes important for the persistence of the species. Such evolutionary significant units (ESUs) may serve as a better guide for conservation policy than existing taxonomy. The identification of ESUs is aided by information on a wide variety of population characteristics: life and disease history, habitat, range and distribution, morphology, cytogenetics, protein electrophoresis, and DNA. Therefore, a need exists for a species-wide coordination of these sources of information for the bighorn sheep. For example, studies of proteins and DNA designed to detect genetic variation should be standardized so that studies of different populations in different laboratories can be synthesized. Techniques should be standardized and samples shared among laboratories so that the same loci are examined and the results can be compared.

14. Reduce the chances of inbreeding in bighorn sheep populations. Bighorn sheep exist in naturally fragmented distributions, often with large areas of unsuitable habitat between suitable patches. Recent studies suggest that bighorn sheep are more vagile and populations occupying isolated patches of suitable habitat are probably genetically more substantially connected by movements among patches than previously thought. However, continued expansion of human activities (agriculture, transportation corridors, etc.) in areas subject to dispersal and migration threatens to genetically isolate populations (Bleich et al. 1990).

Matings between related individuals will begin to occur in the second generation in a translocated herd of typical size. The smaller the number of translocated animals that successfully reproduce, the greater this effect is. Existing data from bighorn sheep and other ungulates indicate that inbred individuals have a greatly reduced probability of survival in the first year of life (Ralls et al. 1979; Sausman 1984). Inbred individuals and populations may be more susceptible to disease because of their reduced genetic variation.

The effects of inbreeding on population growth only manifest after the first animals resulting from matings within the translocated herd begin to reproduce. Therefore, action should be taken before problems arise. We note, however, that increasing the size of initial releases is logistically difficult and does not necessarily resolve inbreeding problems. One possible solution is to make additional translocations of approximately equal size to the initial release one generation or so after the initial translocation. Additional translocations are desirable until the population has reached a previously determined demographic goal. Although additional translocations are expensive they are vital to insuring the long-term success of new herds.

Dinosaur National Monument

Dennis Murphy, William Adrian, James Bailey,
Michael Bogan, Steven Buskirk, Francis Singer

Introduction

The bighorn sheep advisory committee convened at Dinosaur National Monument from September 17 to September 21, 1990. The committee met with representatives of federal agencies and the States of Colorado and Utah, as well as other interested parties. Although this report focuses on site-specific recommendations, the committee recognizes numerous significant regional considerations that remain unresolved or inadequately studied. Many of these considerations bear directly on management issues at Dinosaur National Monument and must be addressed before local program success is possible. Six areas of concern central to bighorn sheep management in Dinosaur National Monument are identified below. The order of presentation should not be construed as a priority scheme.

The region encompassing Dinosaur National Monument supported widely distributed populations of bighorn sheep in the late 1800's and early 1900's (Barmore 1962). It is unknown if the indigenous bighorn sheep were the Rocky Mountain (O. c. canadensis) or desert bighorn sheep subspecies (O. c. nelsoni) (Cowan 1940). The last recorded sighting of native bighorn sheep in Dinosaur National Monument was in 1944 (Barmore 1962).

In 1952, 32 bighorn sheep from Rifle, Colorado were released near the eastern edge of the monument in Jack Springs Draw, also known as Trailer Draw. By 1959 the herd had increased to approximately 130 individuals and had dispersed into the Lodore Canyon. However, by 1979 the herd had subsequently decreased to 40 individuals (Skiba 1981).

A second reintroduction of 19 bighorn sheep from Rocky Mountain National Park were released at Pool Creek in Echo Park in 1984 (Petersburg 1984). By 1990 the population had expanded its range into Echo Park and Whirlpool Canyon and was possibly mixing with the Lodore Canyon herd (Chambers 1994). In 1993 there were 160 to 170 bighorn sheep, distributed in the Lodore Canyon-Echo Park-Whirlpool Canyon area of Dinosaur National Monument (Chambers 1994).

Recommendations

1. There needs to be a unified regional approach to bighorn management among responsible agencies and landowners. Therefore, we recommend that an interagency bighorn sheep steering committee be established for Dinosaur National Monument and adjacent areas of northwestern Colorado and northeastern Utah to coordinate management and research in a regional context. Such regional thinking appears to be informally underway. Furthermore, local management agencies seem to have fairly similar goals, i.e., to reestablish bighorn sheep in either all historic or occupiable habitat. A steering committee should coordinate cooperative research and translocation efforts and should periodically consult with biologists and/or establish a science advisory team.

2. There needs to be an adequate historical context to guide bighorn sheep reintroduction efforts in Dinosaur National Monument. Although Dinosaur National Monument has drawn together some information on historical bighorn sheep observations, few summaries of historical information and data on bighorn sheep and their occupied habitat exist for this general region. Therefore, attempts should be made to gather and collate historical data on the distribution and abundance of bighorn sheep, densities in specific areas, population fluctuations, seasonal migrations, movements of bighorn sheep among areas, habitat use, impact on bighorn sheep populations as domestic sheep were introduced, information on bighorn sheep populations from Native American sources, and taxonomy and variation.

An important part of that historical picture is the change in bighorn sheep habitat after settlement and how that habitat continues to change with current land management practices. Information should be gathered on the history of vegetation succession, from grasslands to shrublands to forests, and how this may have affected bighorn sheep distribution. Experimental studies of varying habitat management regimes on bighorn sheep need to be evaluated and the history of burning in areas of historical bighorn sheep habitat needs to be determined from fire history from scarring of trees, and from historical photographs of the area.

Although much of this information is best gathered by biologists, some historical information could be obtained by graduate students in anthropology and history. Most of these topics represent research projects that could be initiated immediately; the sooner that planning historical information is generated, the sooner reintroduction activities will be able to incorporate important new information. Many of these topics underscore a general deficiency of preparation and follow-up that have often characterized bighorn sheep reintroductions.

3. There needs to be rigorous experimental design in research and monitoring programs. Estimates of the numbers of bighorn sheep in the four populations in and adjacent to Dinosaur National Monument appear to be little more than guesses based on infrequent or otherwise inadequate censuses of the herds. Therefore, more precise estimates of population sizes, or at least assays of population trends, are needed to detect changes that may require management responses and to allow testing of any research hypotheses with these herds. The ability to monitor population sizes or trends, sex and age structure, and distributions and movements of bighorn sheep will vary with budget constraints, access, habitat, and terrain. Intensive monitoring of all these population characteristics may not be feasible for certain herds. The Lodore Canyon herd, in particular, may be difficult to evaluate.

An index that would detect important year-to-year population trends should provide adequate data for management purposes and testing research hypotheses. Use of an index requires that the index value (such as aerial counts of animals) is correlated with population size. This assumption may not be tested without direct measurement of herd size. Where not feasible to measure herd size, the assumption may be arbitrarily accepted. Standardizing index conditions (such as weather or time of season associated with counts of bighorn sheep) will reduce possibilities for bias.

Population indices without replication within years (such as the number of bighorn sheep seen on one annual visit) will be useless for detecting anything but long-term trends. To detect year-to-year differences, counts must be replicated under similar conditions each year. In Dinosaur National Monument, two possible population indices could be the proportion of designated rafters that observe bighorn sheep on each river trip and the average number of bighorn sheep seen by rafters per trip. Precision of the former index might be evaluated using statistics for binomial distributions, the latter index might be evaluated using statistics for normal distributions. Evaluation of these and other indices could be a research project.

If size, sex, and age structure of a herd are to be estimated, a necessary first step is to determine seasonal home ranges and identify movement corridors with an intensive, year-round radio-telemetry study. Selecting a census method and designing a sampling scheme require substantial knowledge of herd distribution. Distribution information will also be useful if animals are to be captured for marking or for evaluation of herd health or genetic composition.

Bighorn sheep populations are influenced by numerous factors including habitat quality, population density, disease, weather, and management. Consequently, neither short-term nor long-term observational studies offer much promise for identifying factors that influence local population dynamics or population viability. Manipulative experiments are best suited to meet research goals. Research or management hypotheses should be tested using rigorous experimental designs and should employ designated control herds or specified control time periods. If a hypothesis that addresses treatment-effectiveness is to be tested for one herd, adequate pretreatment data must be obtained before the treatment is applied. Normally, several years of data will be required to measure variation in population parameters among years.

The results of experimental tests of management-related hypotheses will be useful to a number of management agencies and should be applicable to many bighorn sheep herds. If a hypothesis of treatment effectiveness is to be tested for several herds, these herds may include those in the near Dinosaur National Monument, but it is likely that the four local herds will provide inadequate replicates for an appropriately designed experiment. Interagency coordination will be necessary to maximize experiment efficiency. Management treatments should not be confounded within herds if treatment effectiveness is to be evaluated.

In developing a research program for bighorn sheep, management hypotheses should first be developed and ranked in order of importance. Once a hypothesis is selected for study, the most appropriate herds for testing that hypothesis should be selected, regardless of geographic location. In other words, research carried out in Dinosaur National Monument may be valuable in conservation planning elsewhere and vice versa.

4. Questions concerning genetics should be incorporated into research objectives and considered when translocating animals. The high habitat specificity and low dispersal rates of bighorn sheep suggest that bighorn sheep

have developed adaptations to local environments. These potential adaptations should be considered in conducting translocations to facilitate adaptation of bighorn sheep to new areas.

Factors that tend to decrease heterozygosity within bighorn sheep populations include small population size (especially if it is for long periods of time), a breeding system that limits participation among rams, limited genetic interchange among and within recognized populations, unequal sex ratios in populations, and relatedness among translocated animals. Many of these conditions exist in Dinosaur National Monument. Genetic variation is of concern because heterozygosity has been related in ungulates to neonate survival, growth rate, adult body size, reproductive rate, antler size, and longevity. A homozygous condition can predispose populations to several fitness-reducing conditions, including low fecundity, susceptibility to disease and predation, and nonspecific lamb mortality, that often are attributed to nongenetic factors.

Research problems involving genetics include: (1) whether homozygous condition results from population attributes found in small, isolated bighorn sheep populations; (2) what proportion of low fitness is directly or indirectly attributable to genetic factors; and (3) methods of minimizing and mitigating homozygous condition.

National Park Service policy indicates the subspecies used in a translocation should most nearly approximate the extirpated subspecies or race. Dinosaur National Monument is situated near the historical geographic margin of desert bighorn and Rocky Mountain bighorn ranges; however, previous translocations consisted solely of high elevation Rocky Mountain stock. Future bighorn sheep stocking attempts should use animals from habitats that most closely resemble those in Dinosaur National Monument.

5. Concurrent range occupancy of bighorn sheep and domestic livestock should be avoided. In Dinosaur National Park there is continuing or potential co-occurrence of bighorn sheep and domestic livestock. Domestic livestock, including sheep, cattle, and goats affect bighorn sheep in at least three ways: competition for forage, disease transmission, and potential interbreeding (with domestic sheep). Common range occupancy can lead to competition for forage, directly via competition for specific plants and indirectly via overgrazing which can encourage exotic plant species and heavy shrub cover. Moreover, where bighorn sheep range is used by other ruminant grazers, bighorn sheep may

avoid specific areas, further reducing usable range for bighorns. Disease transmission to bighorn sheep from domestic livestock is a crucial factor when these animals share common range. Examples of diseases known to be transported from domestic livestock to bighorn sheep include: Muellerius, Pasteurella, brucellosis, GI tract nematodes, Johne's disease, scrapie, bluetongue, contagious ecthyma, coccidiosis, scabies, ovine progressive pneumonia, and parainfluenza type-3 (PI-3); from cattle to bighorn sheep: Bovine respiratory syncytial virus (BRSV), Pasteurella, Johne's disease, bluetongue, leptospirosis, and PI-3; and from goats to bighorn sheep: brucellosis, BRSV, Pasteurella, and Johne's disease.

Interbreeding between bighorn and domestic sheep is well documented. Interbreeding not only reduces the genetic purity of bighorn sheep, but serves as an important vehicle for transmission of disease.

6. There is a need to assess unoccupied, suitable bighorn sheep habitat. More information is needed on prospective translocation sites. Such information would aid in relocating bighorn sheep into the best possible available habitat. The key ecological attributes for prospective sites should be thoroughly reviewed, including, but not limited to, suitability of escape terrain, visibility rating, adequacy of winter and summer range, assured separation from domestic livestock (especially domestic sheep), and proximity to additional occupied or potentially-occupiable bighorn sheep habitat. Wherever possible, clusters of sites should be considered for translocations. Small, isolated sites should be given lowest priority since they inevitably cause chronic management problems. Application of the Bear Mountain habitat model and GIS techniques with a hypothetico-deductive framework should improve success. This could enable the rapid evaluation of large areas of potential habitat. Management options should be included in such an analysis, including the distribution of grazing allotments, long-term plans for prescribed burning, and visitor-use management. The committee recommends a moderate level of analytical resolution, because analysis that is too cursory could result in error, yet excessive detail in analysis does not seem justified given the rather primitive current stage of habitat modeling. Potential translocation sites must be ranked.

Finally, the committee notes the fate of the bighorn sheep populations in the Dinosaur National Monument region is intimately tied to the fates of populations in the rest of the distribution of the species, arguably more so now than before the massive population declines and local extinctions induced by human activities during the past century. The fate of the entire species will be dependent on a conservation strategy that has as its goals populations that: are widely distributed across a significant portion of its historical range; occupy reserve areas that are as large in extent as possible; are situated as close together as possible; are configured in such a way as to reduce impacts that may be generated by the surrounding landscape matrix; and are connected by corridors of habitat that facilitate the demographic mixing necessary to allow the system to be self-perpetuating.

These goals can only be met by a scientifically credible regional management scheme that identifies explicit management goals and options, defines a universally acceptable monitoring program, and has a strictly controlled translocation agenda.

Theodore Roosevelt National Park

Ernie Vyse, Steve Buskirk, Francis Singer

Introduction

The Bighorn Sheep Advisory Committee met with officials from Theodore Roosevelt National Park, U.S. Forest Service and North Dakota State Game and Fish on Tuesday April 2, 1991.

California bighorn sheep (O. c. californiana) in the Badlands surrounding Theodore Roosevelt National Park originated from the Williams Lake herd in British Columbia. Recent translocations came from British Columbia and from Idaho in areas originally stocked with bighorn sheep from British Columbia.

Eighteen California bighorn sheep were introduced into the Badlands in an enclosure in 1957 with a subsequent release into a second enclosure in Theodore Roosevelt National Park. This introduced population initially expanded to 25 to 30 head but the animals started to die from undetermined causes. In 1986 three remaining ewes were trapped and placed in a 70-acre enclosure on the southwest edge of the park. These ewes were supplied with rams but failed to produce offspring. They were exchanged with animals from the surrounding Badlands but the replacements have also failed to produce any lambs. The Badlands non-park population expanded and was used as a source to establish other populations of 5 to about 50 animals each. Additional bighorn sheep from British Columbia and Idaho have been introduced into adjacent Badlands sites. The total bighorn sheep population numbers approximately 250 animals but it may be too fragmented to expect genetically effective levels of migrations, especially across the interstate highway.

Although both the North and South Units of Theodore Roosevelt National Park are fenced, we expect that given enough time, this barrier will be breached by bighorn sheep. Fence breaching could result from movements via the crawl through access routes provided for deer and antelope or from natural events such as flooding of the Little Missouri River.

Recommendations

1. The California bighorn sheep subspecies has been successfully established in the Badlands surrounding Theodore Roosevelt National Park and given the

probability for migration between Theodore Roosevelt National Park and these populations, we recommend that Theodore Roosevelt National Park should introduce the same subspecies. The continuity of this subspecies in the Badlands area will avoid potential mixing of subspecies, and increase the probability of mutually beneficial exchanges with North Dakota State Game and Fish managed populations.

2. Theodore Roosevelt National Park should maintain a close working relation with the agencies that manage bighorn sheep and their habitat in the adjoining Badlands. Although the goals of these agencies may differ, cooperative research efforts will be mutually beneficial to all bighorn sheep populations, particularly in the areas of genetics, habitat management, and control of infectious diseases.

3. Bighorn sheep within the small enclosure of Theodore Roosevelt National Park should be released since they have failed to produce any lambs. We recommend that this enclosure be maintained as a holding and treatment facility. The facility apparently lacks some necessary ingredient for bighorn sheep production, such as escape cover or sufficient area. The enclosed animals should be radio-collared before their release in order to see if they successfully reproduce in the wild. Genetic information from this nonproductive group would also be interesting.

4. Based on our cursory observations of bighorn sheep habitat in the surrounding Badlands and the Theodore Roosevelt National Park South Unit, we feel that there is bighorn sheep habitat within the South Unit. Resource specialist J. Bradybaugh informed us that there is less total area in the North Unit but with better escape cover. Local officials speculate there is enough habitat to maintain small populations (50 to 70 animals) in both of these units. Since bighorn sheep populations of <50 animals historically do not survive for any length of time we feel that these populations will have to be actively managed. Management might include removal of animals, should the populations expand beyond carrying capacity, and periodic genetic augmentation by translocating a few ewes if there is no documented migration between Theodore Roosevelt National Park and the surrounding Badlands populations. National Park Service policy suggests that natural processes be relied upon to control native animal populations to the largest extent possible. Native diseases may be viewed as a natural regulatory process in most situations. Theodore Roosevelt National Park, however, will clearly be an

exception to this guideline. The prospective populations will be smaller than minimum viable size, ingress and egress will be reduced or eliminated by the fence, some of the diseases involved may or may not be native to North America, and a disease die-off would jeopardize the bighorn recovery effort. Under these circumstances, the staff of Theodore Roosevelt National Park might consider population control with the goal of reducing (albeit not eliminating) the potential of a disease die-off.

5. Models for habitat evaluation such as Smith et al.'s (1991) model could be applied to targeted bighorn sheep ranges outside Theodore Roosevelt National Park and then tested against actual bighorn sheep range utilization. Thus, the model could be verified as a predictor for bighorn sheep habitat in the Badlands. If the model is a poor predictor it could be modified for the Badlands before it is applied to potential bighorn sheep habitat in Theodore Roosevelt National Park. We recommend that habitat evaluation should precede bighorn sheep introduction. Assessment of the potential bighorn sheep numbers that might occupy the units would aid in the planning process for locating source stock, determining the number of bighorn sheep required for a translocation, and in planning management programs.

6. Given the history of small translocations in the surrounding Badlands and the potentially deleterious consequences of genetic bottlenecks, the committee recommends that one of the first research objectives should be a genetic evaluation of the present Badlands populations and their source population in British Columbia. Historically, small bighorn sheep populations have expanded and then collapsed, often going extinct but occasionally recovering to flourish. The most commonly offered explanations for initial success and subsequent collapse are: disease die-offs triggered by contact with domestic livestock; disease die-offs triggered by high densities of bighorns and stress of animals; and lack of genetic variation. Inbreeding depression has been documented to cause serious deleterious physiological effects including increased juvenile mortality, morphological asymmetry, reproductive impairments and increased susceptibility to pathogens. Transplants into Theodore Roosevelt National Park should be genetically monitored and management objectives should include efforts to maintain genetic diversity.

We recommend that genetic evaluation should utilize both protein electrophoresis for allozymes, mitochondrial DNA and nuclear DNA RFLP analysis, and/or polymerase chain reaction amplification of DNA followed by sequencing. The Badlands-Theodore Roosevelt National Park bighorn sheep complex represents a unique opportunity for genetic research and planning. The populations are still largely isolated and the sources for each group are well known.

7. Recent thinking in conservation biology suggests an interbreeding population of several hundred would be an absolute minimum viable population and 500 animals would be more desirable. To that end, we suggest the participating agencies translocate more groups to link up isolated herds. Over a period of decades, bighorns, especially rams, may disperse or assume seasonal migrations and effectively connect the various groups. If Theodore Roosevelt National Park reintroduces bighorn sheep, we suggest development of escape gates that permit bighorn sheep egress/ingress to the park. When sufficiently motivated (i.e., to get to water holes), bighorn sheep have been known to pass through gates too narrow for burros. Thus, baiting on either side of the gates might encourage movements through the fence and reduce the need to shuffle animals.

Wind Cave National Park

Ernie Vyse, Steve Buskirk, Ted Benzon, Francis Singer

Introduction

The committee was convened at the headquarters of Wind Cave National Park on 1 April 1991 for the purpose of developing recommendations regarding possible reintroduction of bighorn sheep into the park. The committee met with representatives of Wind Cave National Park and the South Dakota Department of Game, Fish and Parks and toured the park, focusing on those areas that appear most suitable as bighorn sheep habitat.

Bighorn sheep were absent from Wind Cave National Park at the time of the review. The area encompassed within Wind Cave National Park was historic range for the Rocky Mountain bighorn sheep (Cowan 1940), but bighorns were extirpated in all of the Black Hills of South Dakota. The park was fenced in 1903 when it was established, thus isolating the very small amount of potential bighorn habitat from the rest of the Black Hills.

No bighorn sheep have been seen in the park in recent decades and the sole physical evidence of their presence in historic times is the skull of a ram found at the north end of Rankin Ridge in the early 1960's. The committee believed that this animal had been dead for less than 5 years. This single individual likely originated from one of several successful transplanted populations in the Black Hills and entered Wind Cave by crossing the fence.

Bighorn sheep translocated from Whiskey Mountain, Wyoming, are found in Custer State Park, which adjoins Wind Cave National Park to the north. The boundary between the two jurisdictions is fenced for bison and elk, although some movements of ungulates of various species in both directions is believed to occur.

The quantity and quality of potential bighorn sheep habitat in Wind Cave National Park is low. Areas with slope equal to or greater than 60% (27°), or within 300 m of such slopes are considered suitable in terms of escape terrain and areas with these characteristics are limited to small sites in Reeve Gulch, Beaver Creek, and Boland Ridge. Much of the vegetation in the park is dominated by grasslands; however, extensive encroachment of woody plants, especially ponderosa pine (Pinus ponderosa), appears to have reduced the value of the potential bighorn sheep habitat. Open water is available at relatively few sites near the areas of suitable slope.

Recommendations

The committee concluded that reintroduction of bighorn sheep would require extensive habitat treatment and a high level of intervention and management relative to that now required for other ungulate populations in Wind Cave National Park. The committee believed that the likelihood that Wind Cave National Park could support a self-sufficient population of bighorn sheep for many generations is almost nil.

The amount of habitat with suitable slope for bighorn sheep appears to be less than 1 mi^2 (perhaps as little as 0.5 mi^2 when distance to water is taken into account), which compares with a minimum of 10-20 mi^2 which has been proposed as a minimum for a population of 125 bighorns (Smith 1991), which is near the lower limit for long-term viability.

Quality of potential habitat for bighorn sheep appears to be negatively affected by the encroachment of ponderosa pine into grasslands, and low availability of water near areas with adequate slopes.

The presence of the ungulate fence between Wind Cave National Park and Custer State Park appears to eliminate the possibility that a population of bighorn sheep in Wind Cave National Park could function, via natural movements, as a satellite to the Custer State Park herd. Indeed, because of the potential for disease transmission, movements of bighorn sheep back and forth between the existing bighorn herd in Custer State Park and a postulated one in Wind Cave National Park may not be desirable at this time.

Literature Cited

Bailey, J. A. 1980. Desert bighorns, forage competition, and zoogeography. Wildlife Society Bulletin 8:208-216.

Barmore, W. J. 1962. Bighorn sheep and their habitat in Dinosaur National Monument. Master thesis. Utah State University, Logan. 134 pp.

Bartmann, R. M., L. H. Carpenter, R. A. Garrott, and D. C. Bowden. 1986. Accuracy of helicopter counts of mule deer in pinyon-juniper woodland. Wildlife Society Bulletin 14:356-363.

Bartmann, R. M., G. C. White, L. H. Carpenter, and R. A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. Journal of Wildlife Management 51:41-46.

Bear, G. D., and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Division of Wildlife, Species Report 45. 12 pp.

Bellew, S. 1995. History and demographics of several desert bighorn sheep herds in and near Capitol Reef National Park. National Park Service report, Denver, Colo. 9 pp.

Benzon, T. 1992. Population status of Badlands National Park bighorn sheep herd. Unpublished report. South Dakota Department of Game, Fish and Parks, Rapid City, S. Dak.

Berger, J. 1990. Persistence of different-sized populations: An empirical assessment of rapid extinction of bighorn populations. Conservation Biology 4:91-98.

Blaisdell, J. A. 1982. Lava beds wrap-up: what did we learn? Desert Bighorn Council Transactions 26:32-33.

Bleich, V. C. 1990. Costs of translocating mountain sheep. Pages 67-75 in P. R. Krausman and N. S. Smith, editors. Managing wildlife in the southwest. Arizona Chapter of The Wildlife Society, Phoenix.

Bleich, V. C., J. D. Wehausen and S. A. Holl. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4:383-390.

Bleich, V. C., C. D. Hargis, J. A. Keay, and J. D. Wehausen. In press. Interagency coordination and the restoration of wildlife populations. Proceedings of the Yosemite Centennial Symposium: Prospects for the future.

Bowden, D. C., A. E. Anderson, and D. E. Medin. 1984. Sampling plans for mule deer sex and age ratios. Journal of Wildlife Management 48:500-509.

Buechner, H. K. 1960. The desert bighorn sheep in the United States: Its past, present, and future. Wildlife Monographs 4:1-174.

Callan, R. J., T. D. Bunch, G. W. Workman, and R. E. Mock. 1991. Development of pneumonia in desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. Journal of American Veterinary Medicine Association 198:1052-1056.

Chambers, S. 1994. Bighorn sheep herds of the Green River corridor: 1950-1994. Unpublished report. Dinosaur National Monument, Colorado. 47 pp.

Coggins, V. L. 1988. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. Biennial Symposium of the Northern Wild Sheep and Goat Council 6:57-64.

Cowan, I. M. 1940. Distribution and variation in the native sheep of North America. American Midland Naturalist 24:505-580.

Creeden, P. J. 1986. The ecology of desert bighorn sheep in Colorado. M.S. thesis. Colorado State University, Fort Collins. 72 pp.

Cresto, J., J. Karpowitz, and L. Seibert. 1990. Status of desert bighorn sheep in Utah, 1989. Desert Bighorn Council Transactions 34:31-32.

Dalton, L. B. 1978. Utah's desert bighorn sheep - a status report, 1978. Desert Bighorn Council Transactions 22:6-9.

Dean, H. C., J. J. Spillett, G. W. Workman, D. D. May, and J. W. Bates. 1977. Desert bighorn sheep in Canyonlands National Park. National Park Service report. Project No. UNWRH-007-1. Canyonlands National Park, Moab, Utah. 86 pp.

Denny, R. N. 1976. The status and management of bighorn sheep in Colorado. Desert Bighorn Council Transactions 20:5-10.

Desert Bighorn Council Technical Staff. 1990. Guidelines for management of domestic sheep in the vicinity of desert bighorn habitat. Desert Bighorn Council Transactions 34:33-35.

Foreyt, W. J. 1989a. Fatal Pasteurella haemolytica pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. American Journal of Veterinary Research 50:341-344.

Foreyt, W. J. 1989b. Bighorn sheep - domestic sheep controversy. American Association of Wildlife Veterinary Newsletter, April 1989.

Foreyt, W. J., and D. J. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. Journal of Wildlife Disease 18:163-168.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Biennial Symposium of the Northern Wild Sheep and Goat Council Proceedings 3:287-313.

Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a conservation tool: status and strategy. Science 245:477-480.

Guymon, J. C., and J. W. Bates. 1984. Utah's desert bighorn sheep status report, 1984. Desert Bighorn Council Transactions 28:49-50.

Hazeltine, B. S. 1967. Memorandum of bighorn sheep die-off. Badlands National Park files. Interior, S. Dak.

Irvin, C. A. 1969. The desert bighorn sheep of southeastern Utah. M.S. thesis. Utah State University, Logan. 100 pp.

Jessup, D. A. 1981. Pneumonia in bighorn sheep: effects on populations. Cal-Neva Wildlife Transactions 17:72-78.

Jessup, D. A. 1985. Diseases of domestic livestock which threaten bighorn sheep populations. Desert Bighorn Council Transactions 29:29-33.

Keay, J. A., J. D. Wehausen, C. D. Hargis, R. A. Weaver and T. E. Blankenship. 1987. Mountain sheep reintroduction in the central Sierra: a cooperative effort. Western Section of the Wildlife Society Transactions 23:60-64.

Kelly, C. 1948. Wildlife of Capitol Reef National Monument. Capitol Reef National Park files. 6 pp.

Kufeld, R. C., J. H. Olterman, and D. C. Bowden. 1980. A helicopter quadrat census for mule deer on Uncompahgre Plateau, Colorado. Journal of Wildlife Management 44:632-639.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lange, R. E., Jr. 1980. Psoroptic scabies in wildlife in the United States and Canada. Desert Bighorn Council Transactions 24:18-20.

McCutchen, H. E. 1980. A preliminary report on the status of bighorn sheep in Badlands National Park, South Dakota. Unpublished report. Badlands National Park, Interior, South Dakota. 13 pp.

McCutchen, H. E. 1994. Professional biological report on the status of desert bighorn sheep and their management for the Glen Canyon National Recreation Area. National Park Service and National Biological Service cooperative report. Glen Canyon National Recreation Area, Utah.

National Park Service. 1982. General Management Plan Statement of Findings, Capitol Reef National Park. Capitol Reef National Park, Torrey, Utah. 9 pp.

Neal, A. K. 1990. Evaluation of mark-resight population estimates using simulations and field data from mountain sheep. M.S. thesis, Colorado State University, Fort Collins. 198 pp.

Onderka, D. K., and W. D. Wishart. 1984. A major bighorn sheep die-off from pneumonia in southern Alberta. Biennial Symposium of the Northern Wild Sheep and Goat Council Proceedings 4:356-363.

Onderka, D. K., and W. D. Wishart. 1988. Experimental contact transmission of Pasteurella haemolytica from clinically normal domestic sheep causing pneumonia in Rocky Mountain bighorn sheep. Journal of Wildlife Diseases 24:663-667.

Onderka, D. K., S. A. Rawluk, and W. D. Wishart. 1988. Susceptibility of Rocky Mountain bighorn sheep to pneumonia induced by bighorn and domestic livestock strains of Pasteurella haemolytica. Canadian Journal of Veterinary Research 52:439-444.

Petersburg, S. 1984. Bighorn sheep transplant memo. Dinosaur National Monument, Colorado.

Ralls, K., K. Brugger, and J. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206:1101-1103.

Ravey, R. R. 1984. Reintroduction of desert bighorn sheep into western Colorado. M.S. thesis. Colorado State University, Fort Collins. 93 pp.

Robinson, R. M., T. L. Hailey, C. W. Livingston, and J. W. Thomas. 1967. Bluetongue in the desert bighorn sheep. Journal of Wildlife Management 31:165-168.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622-630.

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

Sausman, K. 1984. Survival of captive born Ovis canadensis in North American zoos. Desert Bighorn Council Transactions 26:26-31.

Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep Ovis canadensis nelsoni. Biological Conservation 37:179-190.

Simberloff, D., and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology 1:63-71.

Skiba, G. T. 1981. Ecological evaluations of the Dinosaur National Monument bighorn sheep. M.S. thesis. Colorado State University, Fort Collins. 107 pp.

Smith, T. S., J. T. Flinders, and D. S. Winn. 1991. A habitat evaluation procedure for Rocky Mountain bighorn sheep in the Intermountain West. Great Basin Naturalist 51:205-225.

Steel, T. L., M. J. Machalek, P. E. Rentschler, G. W. Workman, T. D. Bunch, P. J. Urness, and J. A. Bissonette. The ecology of an introduction population of desert bighorn sheep at Capital Reef National Park. Final report. Utah State University, Logan. 274 pp.

Stelfox, J. G. 1971. Bighorn sheep in the Canadian Rockies: A history 1800-1970. Canadian Field-Naturalist 85:101-122.

Stroh, G., and G. H. Ewing. 1964. Archaeological survey of Colorado National Monument. Unpublished report. Colorado National Monument, Fruita. 60 pp.

Thorne, E. T., and M. W. Miller. 1989. Bighorn sheep - domestic sheep "controversy": second opinions. American Association of Wildlife Veterinarians Newsletter, July 1989:6-8.

Weaver, R. A., and R. K. Clark. 1987. Status of bighorn sheep in California, 1987. Desert Bighorn Council Transactions 32:20.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New York. 383 pp.

Wilson, L. O. 1967. Past and present distribution of bighorn sheep on the Colorado and Green rivers in Utah. Desert Bighorn Council Transactions 11:65-72.

Wilson, L. O. 1968. Distribution and ecology of desert bighorn sheep in southeastern Utah. Utah Department of Natural Resources and Division of Fish and Game Publication No. 68-5:1-220.

Wolfe, J. 1990. Status of desert bighorn sheep in Colorado, 1989. Desert Bighorn Council Transactions 34:27.

Workman, G. W., T. D. Bunch, P. J. Urness, J. A. Bissonette, M. J. Machalek, T. L. Steele, and P. R. Rentschler. 1994. The ecology of a reintroduced population of desert bighorn sheep at Capitol Reef National Park. Utah State University, Logan. Final report to the National Park Service, PX 1350-8-0069. 152 pp.