Rocky Mountain Bighorn Sheep Management In Badlands National Park

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Abstract: Rocky Mountain bighorn sheep were extirpated from most of their historical range in the western United States by the turn of the century. Since 1967, 3 bighorn subpopulations have been established at Badlands National Park through translocation efforts by the South Dakota Department of Game, Fish and Parks (SDGF&P), Colorado Division of Wildlife (CDW) and the National Park Service (NPS). Fourteen bighorn sheep (2 ewes, 2 rams, 4 yearling ewes and 6 lambs) were released to the wild on August 31, 1967. The population size has fluctuated during the last 35 years with total numbers estimated at 163 in 1994 to our present population in 2002 of 58 individuals found in three separate subpopulations. Future long-range goals for Badlands National Park include continue to gain an understanding of bighorn sheep dynamics by inventory and monitoring populations, habitat relationships as well as detecting both natural and human caused changes in abundance and distribution. Our current major objective for the Badlands National Park Bighorn Sheep population is to secure animals for translocation into the park to minimize the danger of extirpation in the next 1-200 years.

Key words: Rocky Mountain Bighorn Sheep, *Ovis canadensis canadensis,* South Dakota, Badlands National Park, Management.

Badlands National Monument (BNM) was authorized by Congress in 1929 and was established to preserve the scenery, protect fossils and wildlife, and to conserve the mixed-grass prairie. The monument boundary was laid out to primarily protect the Badlands scenery and their constituent fossil material. Prairie areas in and around the Badlands were excised throughout the first two decades of the existence of the BNM to support cattle grazing. The monument boundary stabilized over time with the growing realization that BNM was the only major representation of mixed prairie in all of the National Park Service (NPS) system.

In 1976, an agreement between the Oglala Sioux Tribe (OST) and the NPS added 133,000 acres of the Pine Ridge Reservation to BNM. This stunning landscape of high grassy tableland and spectacular buttes is the scene of much of Sioux history. In 1978, Congress elevated the status of BNP to Badlands National Park (BADL), emphasizing the value of the landscape to present and future generations.

Widespread population declines and local extinction during the past century eliminated bighorn sheep (*Ovis canadensis)* from most of their historical range in the western United States (Buechner 1960). Reductions in numbers and distribution of bighorn sheep have been largely attributable to habitat alteration caused by human activities and land management practices (Bear and Jones 1973, Wishart 1978, Wakelyn 1987). The Audubon's bighorn sheep (O. c. *auduboni*) once occupied suitable habitat throughout the Black Hills and badlands of South Dakota (Buechner 1960). By 1925 this subspecies was considered extinct throughout its range (Buechner 1960) as a result of over-hunting combined with urban, mining and agrarian development.

BACKGROUND

Bighorn Sheep Population Origin and History

In 1964, the National Park Service (NPS) cooperated with the South Dakota Department of Game, Fish and Parks (SDGF&P) and the Colorado Division of Wildlife (CDW) to reintroduce 22 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis)* from the Pikes Peak, Colorado source herd, into Badlands National Park (Bessken and Plumb 1997). The area of restoration was a 150-hectare enclosure located approximately 1 km west of the Conata Road Picnic Area. The goal of the agreement between the NPS and SDGF&P was to establish a herd at Badlands National Park. After establishing the herd, animals could then be translocated to other areas of South Dakota initiating additional populations within suitable habitat within Badlands National Park as well as two locations in the northwest part of the state (Hjort and Hodgins 1964).

Following an approximate 50% loss to the enclosed population attributed to *Pasteurella* infection during late-summer 1967 (Hazeltine 1967, Powell 1967, Weide 1967), the remaining 14 bighorn sheep (2 ewes, 2 rams, 4 yearling ewes and 6 lambs) were released to the wild on August 31, 1967 (Badlands National Park Bighorn Sheep Restoration Program 1969). For two years, periodic, opportunistic observations suggested that a band of 10-12 animals remained within 2 km of the release site (Badlands National Park Bighorn Sheep Restoration Program 1969).

The first post release population survey was conducted in June 1980. During a one-man, one-week ground survey, 27 bighorn sheep (9 ewes, 8 rams, 2 yearlings and 8 lambs) were observed within a 13.5 km^2 area adjacent to the release enclosure (McCutchen 1980). McCutchen (1980) considered the population to be stable but not increasing based on a 100:22 ewe:lamb ratio he derived from his survey. No definite factors limiting population growth were identified at this time although water, forage and genetic factors were considered.

During the early 1980's, the population continued to inhabit an area of about 40 km^2 in the Pinnacles area of the Park. From 1987-1990, SDGF&P conducted winter ground counts in the North Unit and estimated a population of 133-200 bighorn sheep with a ewe: lamb ratio of 100:53 during the winter of 1989-90 (Benzon 1992). During an aerial survey in September 1991, 30 bighorn sheep were observed in the South Unit of Badlands National Park, approximately 20 km south of the Pinnacles population. Qualitative accounts from local ranchers suggest that a small band had been established in the South Unit as early as 1981 (Badlands National Park Resource Management Plan and Environmental Assessment 1984).

During 1992-94, Badlands National Park conducted aerial surveys of the North and South Units. The estimated population size at this time was 163 +/-55 (90% C.I.) using the sightability model developed by Unsworth et al. (1994). Air surveys in October 1994 indicated a ewe: lamb ratio of 100:39.

A period of heavy decline and poor recruitment from 1995 to 1997 was attributed to an outbreak of Epizootic Hemorrhagic Disease (EHD). A November 2000 survey found the BADL population with a minimum number of 58 individuals occupying three separate habitat patches. However, one documented case of the often fatal Bluetongue disease was found from the

carcass of a radio-collared ewe in the Cedar Pass Area in October 2000, and three other collared ewes were found dead in the South Unit during the November 2000. Cause of death for these three ewes, all at least 6 years of age, was unknown. A pronghorn antelope found dead in the North Unit of the Park in September was also found to have Blue tongue. So, while the Cedar Pass and Stronghold subpopulations appear stable, disease is a very real concern.

MANAGEMENT DIRECTION

Philosophy

Ecologists with the USGS-BRD believe that restoration efforts at BADL to date have not been sufficient, since only 14 individuals comprised the founder population in 1967; optimal size for success of a translocation has been documented at greater than 40 individuals. Several unoccupied suitable habitat patches in the greater badlands ecosystem also remain. Recent research (Singer et al 1999, Gross et al 1999) indicates that colonization into new habitat are most likely to occur: from populations stemming from larger founder groups; when the new population is migratory or partially migratory; when there are few barriers to movements to the new patches; and, when the population is growing at a rate greater than 21% per year. Recent analysis of over 100 translocations also indicates that restoration is more successful when at least three translocations or founder groups (of 25 or more animals each) are placed into clusters of suitable habitat separated by 16 to 50 km. This potential metapopulation structure has been shown to increase dispersal, population growth rates, range expansions, contacts between subpopulations, and the probability of long-term persistence. Conservation biologists recommend restorations only into very large blocks of suitable habitat likely to support a minimum of 300 animals. The greater Badlands National Park area should be able to support more than 300 Bighorn Sheep based on GIS modeling efforts by Sweanor et al (1995). Only populations of this size retain genetic diversity, are more likely to recover and persist following a catastrophe such as an epizootic, and are predicted to persist with minimal management for 100 to 200 years.

The greater badlands ecosystem comprises lands administered by several different state and federal agencies. The core bighorn sheep habitat is on public lands administered by the NPS as Badlands National Park. This includes the federally owned North Unit as well as the South Unit, tribal lands of the Pine Ridge Indian Reservation managed under an agreement with the Oglala Sioux Tribe (OST). Additional adjacent grasslands are administered by the USDA, Forest Service (USFS) as the Buffalo Gap National Grasslands. The SDGF&P has an interest in the establishment and perpetuation of a healthy, stable metapopulation of bighorn sheep in the greater badlands ecosystem and will be a key partner in the translocation.

Goals

- BADL will continue to support a bighorn sheep population.
- BADL will continue to gain an understanding of bighorn sheep dynamics by inventory and monitoring populations, habitat relationships as well as detecting both natural and human caused changes in abundance and distribution.
- BADL staff will ensure that the parks' activities do not adversely

impact bighorn sheep using NEPA and NPS-77 as guidance.

Objectives

- Identify habitat areas that are critical to the bighorn sheep population and protect these areas.
- Work cooperatively with BADL personnel by providing assistance on bighorn sheep issues.
- Work cooperatively with other agencies and landowners to resolve human/ bighorn related conflicts.
- Maintain the bighorn sheep population at a level that does not exceed the carrying capacity of the park.
- Maintain the bighorn sheep population at a level to minimize the danger of extirpation in the next 1-200 years.
- Seek funding from cooperative sources.
- Seek to build partnerships.
- Educate BADL personnel and park visitors concerning their potential impact to the parks' bighorn population.

Badlands National Park Resource Management staff are responsible for the inventory and monitoring the Bighorn Sheep population within the boundaries of Badlands National Park. The population is presently found in 3 areas of the park (Pinnacles, Cedar Pass and Stronghold, Figure 1).

Carrying Capacity

The greater Badlands National Park area should be able to support more than 300 Bighorn Sheep based on Geographic Information System (GIS) modeling efforts by Sweanor et al (1995). In fact, only populations of this size retain genetic diversity and are more likely to recover and persist following a catastrophe such as an epizootic, and are predicted to persist with minimal management for 100 to 200 years. Consequently, the minimum size of the Badlands Bighorn Sheep Population should be approximately 300 animals to maintain population stability.

Some biologists believe that Badlands National Park cannot support numbers as high as those projected by the model by Sweanor et al (1995). This is based on observations of the population decline observed at Badlands National Park after 1990 when total numbers plummeted from greater than 160 animals in 1992-94 to less 100 presently. This population crash could have been the result of the documented epizootic outbreak or some unknown behavioral/nutritional deficit not yet discovered. Ted Benzon, Big Game Biologist for the South Dakota Department of Game, Fish and Parks, believes that the maximum ecological carrying capacity for the Pinnacles area is approximately 165 bighorn sheep, for the Cedar Pass area is approximately 75, and, the Stronghold area, approximately 150 sheep (Figure 1). These estimates correspond closely to those projected by Sweanor et al (1995) in those focus areas analyzed. Consequently, maximum ecological carrying capacity for the three areas that presently have Bighorn Sheep within Badlands National Park is probably between 300 and 400 animals.

Maintenance

Bighorn sheep are a high maintenance species and to manage them properly requires time, effort and expense. Negative factors that effect populations include habitat changes, disturbance, disease, competition for space and forage and other human caused disturbance. All of these factors are known to exist at Badlands National Park and has probably at one time or another during the last 35

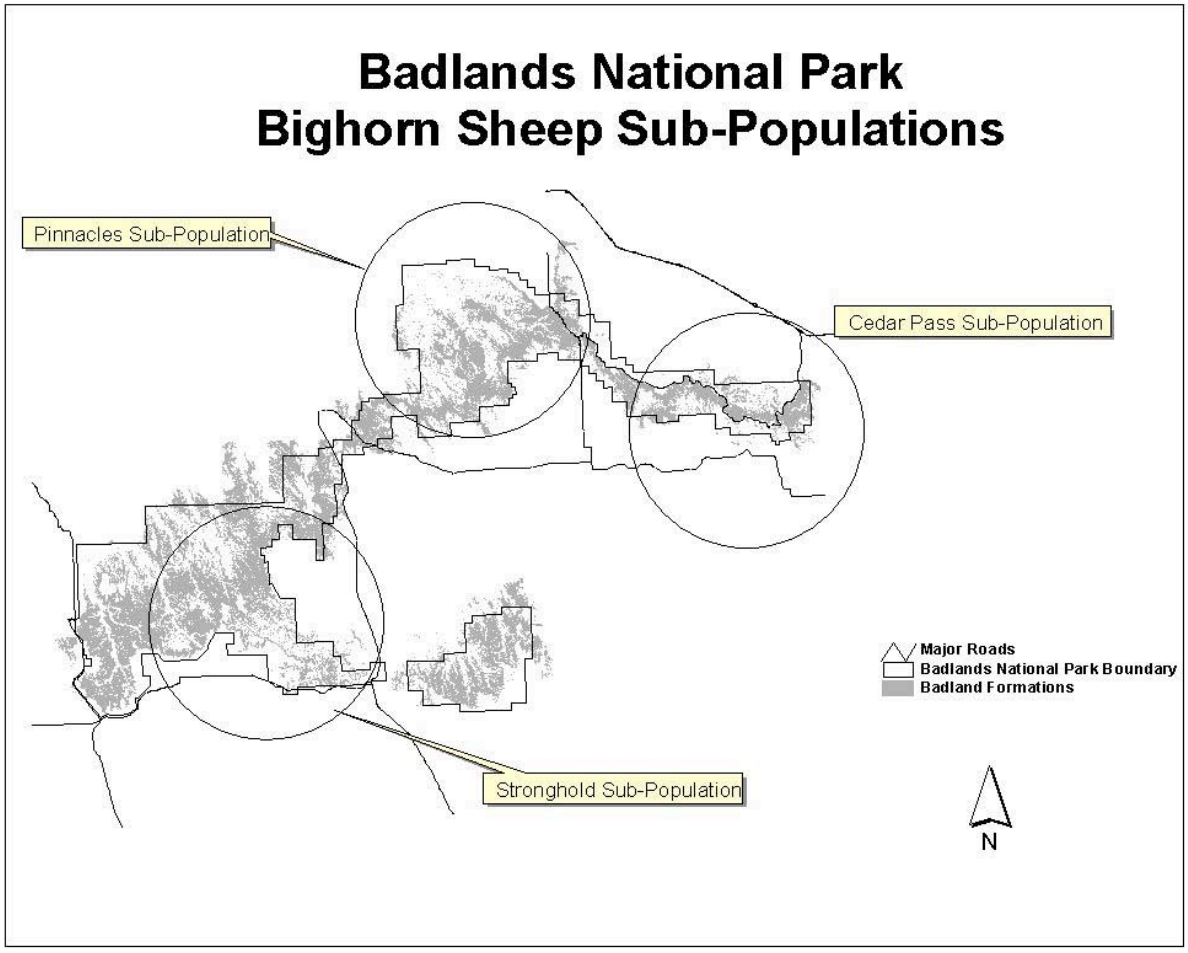

Figure 1. Map of Badlands National Park Bighorn Sheep Sub-Populations.

years contributed to the Bighorn Sheep population increases or decreases to varying degrees. The park now has monitoring strategies are in place to consider these factors and their impact on the Badlands Bighorn Sheep population.

Prescribed fire is the most prevalent habitat change that resource managers utilize at Badlands National Park. Prescribed fire has been found to provide positive benefits to bighorn sheep populations in mountain areas as it removes woody vegetation that provides cover for predators to hide in as they prey upon young bighorn sheep (Bleich 1999). Moses et al 1997 found few significant differences in forage quality as a result of prescribed burns at Badlands National Park with the only advantages being short term increases in nitrogen levels of *A. smithii* and increased digestability of *Stipa spp*. Careful, consistent monitoring of the Bighorn sheep population will be continued as the Park prepares to burn approximately15, 000 acres during the next 15 years.

While disturbance and or urbanization is not a major concern for Badlands National Park, development in the form of new road construction in the north unit of

the park and visitor Center Construction in the South Unit is under consideration as part of the alternatives for the Park's General Management Plan. Monitoring of the Bighorn sheep population during this road construction period during the 2001 lambing season revealed a slight decline in the number of lambs found; however, there were 4 fewer adult breeding ewes in the population in 2001 as a result of an epizootic outbreak the previous year. Again, careful, consistent monitoring of the population will continue to determine the impacts of any future construction activities that occur within the Park, especially during the critical lambing period from April 1 to Jun 30.

Disease continues to be a factor for the Bighorn sheep population at Badlands National Park. Badlands appears to provide environmental conditions for outbreaks of EHD in the fall when dry conditions produce "mud-flats" throughout the Park that are favorable to outbreaks of the midge *culioides* that pass the virus to sheep by biting them. Sheep can then spread the virus by orally. It is believed that there could also be some holdover of the virus in the park's bison population because domestic cattle are known to harbor the disease and bison (*Bison bison*) could be serving as a reservoir for the disease (Dr. Margaret Wild, pers. comm.). In any event, disease monitoring will continue at Badlands National Park will continue and any animals translocated into the population or found dead will be sampled and analyzed for cause of death or possible disease transmission.

Human disturbance is common at the park as visitors frequently encounter bighorn sheep while hiking or traveling throughout the park. Human recreation has been implicated in the decline of several populations of bighorn sheep and recreational activity, especially hikers has been shown to disturb sheep, with recreational hikers causing the greatest behavioral response measured in terms of total distance fled when encountering a hiker (Papouchis 2000). Other behavioral responses to sheep include those of causing sheep to vacate suitable habitat enough to reduce the population's carrying capacity or rate of growth; frequent vehicle activity that may cause sheep to reduce or abandon their use of water sources; energetic losses due to disturbances that might effect the physiology, amount of fat reserves and reproductive success or human habituation (Geist 1975, Wehausen et al. 1977, Kovach 1979, Horesji 1976, Hicks and Elder 1979). Consequently, continued monitoring of the population will document any negative responses from human disturbance to the bighorn sheep population. Known lambing areas will be closed to off trail hiking during the lambing season, if necessary. The impacts of visitor use on bighorn sheep movement and habitat use and bighorn sheep use of man-made versus natural watering sources throughout the badlands are important research considerations for the future.

Population Size

The population of bighorn at Badlands National Park has fluctuated since its early beginnings of 14 animals in 1967 to approximately 160 in 1992 to the present minimum size of approximately 50 animals in 2002. Table 1 is a summary of the average population size for the last five years throughout the park.

Census Protocols

Bighorn Sheep surveys at Badlands National Park have been performed in the past using both ground and air surveys. On the ground surveys were performed in 1980 by McCutchen and in the late 80's

Table 1. Bighorn Sheep November population estimates, 1996-2001, Badlands National Park, South Dakota.

Area		1996	1997	1998	1999	2000	2001
Pinnacles	Rams	28	28	28	25	25	11
	Ewes	6	6	2	1	2	6
	Yearlings	0	2	0	1	0	0
	Lambs	2	0	1	0	1	2
	Totals	36	36	31	27	28	19
Stronghold	Rams	No data	2	5	6	3	5
	Ewes		10	9	12	9	6
	Yearlings		2	3	7	1	2
	Lambs		5	8	1	4	1
	Totals		19	25	26	17	14
Cedar Pass	Rams	3	1	0	1	1	4
	Ewes	11	5	5	9	10	10
	Yearlings	1	1	5	1	4	0
	Lambs	1	5	1	4	5	4
	Totals	16	12	11	15	20	18
North Unit	Rams	31	29	28	26	26	15
	Ewes	17	11	7	10	12	16
	Yearlings	1	3	5	2	4	0
	Lambs	3	5	2	4	6	6
	Totals	52	48	42	42	48	37
Badlands National Park Total	**Rams**	**31**	**31**	**32**	**32**	**29**	**20**
	Ewes	**17**	**21**	**16**	**22**	**22**	**22**
	Yearlings	**1**	**5**	**8**	**9**	**5**	**2**
	Lambs	**3**	**10**	**10**	**5**	**10**	**7**
	Totals	**52**	**67**	**66**	**70**	**61**	**51**

and early 90's by Benzon (1992). Air surveys were performed in the late 90's as part of a sightability development model (Singer et al 1999). This model is still under development and should be completed for use by National Park Staff by 2002 (Dr. F. Singer, pers. comm.). Projections from this model documented the crash in the population that occurred in 1992 (Singer and Moses 1997).

Since 1996 ground counts have been performed consistently using protocols developed by Bourrassa (1999). These counts involve surveying the Pinnacles, Cedar Pass and Stronghold areas for sheep three consecutive days during the bighorn sheep rut, which usually peaks November

1. Consecutive counts in the same sub-population area during multiple days allow observers to get a good estimate of total numbers. These types of surveys will continue to be performed each year in perpetuity at Badlands National Park. The air sightability model under development by Singer will also be used after this work is completed if park staff determines that the ground counts are not providing reliable data. Park staff will continue to monitor the results using both methods and decide which method is best to use for Badlands National Park.

Translocation of Animals into and between sub-populations

It is critical to take management actions before sub-populations of sheep within Badlands National Park reach predicted carrying capacity; otherwise, populations are susceptible to rapid declines. Biologists in other areas have focused on removing ewes from their bighorn sheep population to alleviate over-crowding caused by too many sheep. We plan on using this same strategy at Badlands National Park. It may be necessary to move areas from one sub-population area within the park to another if the sub-population is approaching the projected carrying capacity. For example, if Park population model estimates show that Pinnacles subpopulation will reach 150 total sheep within the next 2 years and ewe:lamb ratios have been consistently greater than 100:50 during previous fall population surveys, immediate plans for a translocation will be initiated (Sweanor et al 1995). This same translocation strategy would apply given the same scenario for the Cedar Pass (Maximum ecological carrying capacity =75) or Stronghold sub-populations (maximum ecological carrying capacity = 190).

Priorities for translocation areas will be based on need. The priorities, in order of preference, are: other sub populations within the park in need of more ewes; previously identified areas of suitable habitat (Sweanor et al 1995) within the park that presently do not have sheep; other areas in South Dakota that need sheep as determined by the South Dakota Department of Game, Fish and Parks (Benzon 2000), or other National Parks. Badlands National Park staff will work closely with SDGF&P staff in determining the best sites for proposed translocations based on their long range Management Plan for Bighorn Sheep in the state of South Dakota (Benzon 2000).

GENETICS

Genetic bottlenecking has been observed in many ungulate species that have been restored to potential habitats. When a population crashes, a reduction in genetic diversity coupled with a loss of rare alleles may be expected (Allendorf 1986). The decline is dependent on effective population size (Ne), defined as the size of an ideal population that loses the same amount of genetic variability as an actual population under consideration (Crow and Kimura, 1970). Effective population size is one of the most important parameters that population ecologists can measure because it estimates the amount of inbreeding and loss of genetic variation in populations (Ramey et al 2000). Census size does not indicate the actual genetic variation of a population.

Another parameter that population ecologists measure is neutral heterozygosity. The rate of loss of selectively neutral heterozygosity (F) is estimated as $F = (1-1/(2*Ne))$.

Consequently, larger population sizes will retain a higher proportion of F (e.g. a

population where Ne = 500 would retain greater than 99 % of its heterozygosity each generation). This is why population ecologists recommend population sizes greater than 300 to avoid extirpation of populations.

Most methods of estimating Ne require information on the genotypes of individuals from one generation to the next. Although the original founder population was 14 animals in 1967, the estimated Ne for the Badlands National Park Bighorn Sheep Population was 6 individuals counting only adults and yearlings. Assuming all of these individuals survived and reproduced, the maximum effective population size is only 12.9 (Singer 2000). This represents a significant bottleneck for the founding population and is probably one of the reasons why the population floundered for almost 20 years with relatively little increase in total population size, until through the process of genetic drift, the population was freed up to increase in size.

As mentioned, the population went through another disease-induced bottleneck during the outbreak of EHD 1992 and 1996 when total numbers of plummeted from 160 to less than 100 animals. Fortunately, blood samples were taken from the bighorn sheep in the Pinnacles area and were translocated to Cedar Pass in 1996. This valuable genetic information will be used by Dr. Francis Singer and R.R. Ramey to look past and recent bottlenecks in the Bighorn Sheep population to determine the effects this has had on the genetic health of the population.

Effective population (Ne) and rate of loss of neutral heterozygosity (F) have been calculated for the Badlands National Park population using the formula Ne = 4 Nm*Nf/(Nm+Nf), where Nm = total number of breeding males in the population and Nf = total number of breeding females. Ne was calculated for the North Unit only because there has been very little documented genetic flow between the North and South Unit sub-populations between 1997-2000. As Table 2 indicates the effective population size for the North unit has been less than 35 for the last 4 years, and the South Unit Population is less than 20. Loss of neutral heterozygosity follows a similar trend. Consequently, extirpation of the population is highly probable within the next 50 years, especially in the South Unit that appears to be a separate population.

One way to mitigate these effects has been suggested by Singer (2000). He recommends “prudent intervention” to the Badlands National Park population at this time and suggests a mixed sex augmentation of greater than 30 individuals from an out-bred native source population of Rocky Mountain bighorn sheep. However, he also recognizes that there may not be enough surplus animals available from other states or Provinces to complete such a restoration effort and recommends smaller augmentations be carried out over several years. Singer also recognizes that augmenting the present population with ewes is the most direct means of increasing population numbers even though it may take longer to have an effect on the population than introducing rams too. Augmenting the population with ewes also poses a smaller risk to the rest of the population in terms of diseases from other domestic animals that may be in the area because rams have been documented to wander great distances and are more likely to come into contact with domestic sheep. We currently have a verbal agreement with the SDGF&P to translocate ewes in the coming years, if they are available. Hopefully this will be

Table 2. Bighorn Sheep effective population size (Ne) and neutral heterozygosity loss (F) for the North Unit and South, Badlands National park, South Dakota 1996-2001.

Area	Parameter	1996	1997	1998	1999	2000	2001
North Unit (Pinnacles and Cedar Pass sub-populations)	Ne = Effective Population	45.7	33	22.9	30.2	34.6	30.96
	F = Neutral Hetero-zygosity loss (%)	1.1% loss	2% loss	2.2% loss	1.7% loss	1.5% loss	1.4% loss
South Unit (Stronghold sub-population)	Ne = Effective Population	No data	9.75	15.9	15.9	20.7	10.9
	F = Neutral Hetero-zygosity	No data	5% loss	3% loss	3% loss	2% loss	4% loss
Badlands National Park Total	Ne = Effective Population	No data	57.6	50.6	55.2	55.7	40
	F = Neutral Hetero-zygosity	No data	<1% loss	<1% loss	<1% loss	<1% loss	1.25% loss
Ne = 4 Nm*Nf/(Nm+Nf), where Nm = total number of breeding males in the population and Nf = total number of breeding females (not including yearlings). Neutral heterozygosity (F) is estimated as F = (1-1/(2*Ne)) for each generation.							

the beginning of increase genetic and population health for the sheep population at Badlands National Park.

Continued opportunistic blood and genetic sample will be collected from the Badlands bighorn sheep population and any translocated individuals to document its genetic health and provide data for current Ne estimates. Genetic studies will be funded when possible to document the on-going progress in genetic health augmentation.

POPULATION HEALTH

Disease Management

Various infectious and parasitic diseases are believed to have caused significant obstacles in restoring and managing populations of bighorn sheep. Bighorn numbers throughout western North America declined dramatically during the late 1800's and early 1900's and disease is believed to have played a key role in the historic decline along with unregulated market hunting, habitat loss, overgrazing and human development.

As mentioned previously, disease is a very real concern at Badlands National Park. Lower recruitment rates throughout the 90's (100:32 ewe:lamb ratios) as compared to those in during the mid 80's (100:70) indicated that some type of mortality was beginning to occur in the Badlands. While predation could have been a factor, disease was probably the more probable cause. Outbreaks of EHD

were documented in the 90's and as recently as 2000. Immunization has proven ineffective in other populations of Bighorn Sheep because of the many different strains of EHD that presently exist (Dr. M Wild, DVM, pers. comm). Consequently, management for disease outbreaks will continue on a case by case basis that will include continued monitoring of the bighorn sheep population and necropsy of any dead individuals. Necropsies of other ungulates that are suspected of carrying disease or found dead will also be performed using the protocols developed below.

Necropsy Protocols

All bighorn sheep necropsies will be performed by a professional veterinary pathologist, if possible. If it is impossible to collect the carcass and transport it to a professional biologist, the wildlife biologist or the field technicians will perform the necropsy. Necropsy protocols will follow those outlined by Wobeser and Spraker (1980:89-98). All specimens will be collected and general condition will be noted. Outer skin, under the skin, Cardiovascular, Lymph, Digestive, Respiratory, Musculoskeletal, Urogenital, Endocrine, Brain, Spinal Cord and Eye tissues will be examined and placed in formalin. If lesions or abnormalities are observed, a sample of the lesion will also be collected and kept in a separate container. Sample will then be shipped to the laboratory for analysis of the suspected disease vector.

THE FUTURE

Badlands National Park will continue to support and gain an understanding of bighorn sheep dynamics by inventory and monitoring populations, habitat relationships as well as detecting both natural and human caused changes in abundance and distribution. The Park will ensure that the parks' activities do not adversely impact bighorn sheep using NEPA and NPS-77 as guidance.

Badlands National Park Staff will continue to identify habitat areas that are critical to the bighorn sheep population and protect these areas and work cooperatively with other agencies and landowners to resolve human/ bighorn related conflicts. The bighorn sheep population will be maintained at a level that does not exceed the carrying capacity of the park to minimize the danger of extirpation in the next 1-200 years.

LITERATURE CITED

ALLENDORF, F. W. 1986. Genetic drift and the loss of alleles versus heterozygosity. Zoo Biology 5:181-190.

BLEICH, V. C. Mountain Sheep and Coyotes: Patterns of Predator Evasion in a mountain ungulate. Journal of Mammalogy. 80(1):283-389, 1999.

BADLANDS NATIONAL PARK BIGHORN SHEEP RESTORATION PROGRAM. 1969. Badlands National Park Resource Management Division Files.

BADLANDS NATIONAL PARK RESOURCE MANAGEMENT PLAN AND ENVIRONMENTAL ASSESSMENT. 1984. Badlands National Park Resource Management Division Files.

BEAR, G. D. AND G. W. JONES. 1973 . History and distribution of bighorn sheep in Colorado. Colo. Div. Wildl. Spec. Rep. 45. 12 pp.

BESSKEN, B. AND G. PLUMB. 1997. Bighorn Sheep in Badlands National Park,. Badlands National Park Resource Management Division Files. 6pp.

BENZON, T. 1992. Rocky Mountain Sheep Management Plan for South Dakota. Unpubl. Report. South Dakota Game,

Fish and Parks. Rapid City, SD. 10 pp.

BENZON, T. 2000. Population status of Badlands National Park bighorn sheep herd. Unpubl. Report. South Dakota Game, Fish and Parks. Rapid City, SD. 23 pp.

BENZON, T. Big Game Biologist. South Dakota Department of Game, Fish and Parks. Personal Communication on January 29, 2001 (605-394-2391).

BOURASSA, M. 2000. Bighorn Sheep Population Counts for Badlands National Park.

BUECHNER, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildlife Monographs. 4. 174 pp.

BEAR, G. D. AND G. W. JONES. 1973 . History and distribution of bighorn sheep in Colorado. Colo. Div. Wildl. Spec. Rep. 45. 12 pp.

CROW, J. F. AND M. KIMURA. 1970. An introduction to population genetics theory. Harper and Row, New York.

GEIST, V. 1975. On the management of mountain sheep: theoretical considerations. Pages 77-98 in J.B. Trefethen, editor. The wild sheep of modern North America. Winchester Press, New York, New York, USA.

GROSS, J. E., F. J. SINGER AND M. E. MOSES. 1999. Assessing restoration decisions to enhance the persistence of translocated populations of bighorn sheep: Implications of disease. Pages 104-121 in F. J. Singer and M. A. Gudorf, Eds. Restoration of bighorn sheep metapopulations into and near 15 national parks: Conservation biology of a severely fragmented species. Volume III. Research Findings. 391pp.

HAZELTINE, B. A. 1967, Memorandum of bighorn sheep die-off. Badlands National Park. Interior, SD.

HICKS, L.L. AND J.M.ELDER. 1979. Human disturbance of Sierra Nevada bighorn sheep. Journal of Wildlife Management. 43:909-915.

HJORT F. A. AND R. A. HODGINS, 1964. Cooperative agreement between the National Park Service and the South Dakota Department of Game, Fish and Parks for the reintroduction and management of bighorn sheep. Badlands National Park files, Interior, SD.

HORESJI, B. 1976. Some thoughts and observations on harrasment and bighorn sheep. Proceedings of Northern Wild Sheep Council:1-4.

JOHNSON, T. E. AND D. M. SWIFT. 2000. A test of a habitat evaluation procedure for Rocky Mountain Bighorn Sheep. Restoration Ecology Vol. 8, No. 4S, pp. 47-56

KOVACH, S.D. 1979. An ecological survey of desert bighorn sheep to human harassment: A comparison of disturbed and undisturbed populations. Ph.D. dissertation, Utah State University, Logan, USA.

MCCUTCHEN, H. E. 1980. A preliminary report on the status of bighorn sheep in Badlands National Park, South Dakota. Unpubl. Report. Badlands National Park, Interior, SD. 13 pp.

MOSES, M. E. AND F.J. SINGER. 1995 Development of Sightability models for the census of Bighorn Sheep of Badlands and Canyonlands National parks, 1992-95.

PAPOUCHIS, C.M., F. J. SINGER AND W.S.SLOAN. 2000. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management, Spring 2000.

POWELL, R. D. 1967 Memorandum of bighorn sheep population status. Badlands National Park files, Interior SD 57750.

RAMEY, R. R., G. LUIKART AND F. J. SINGER. 2000. Genetic Bottlenecks Resulting from restoration efforts: The case of Bighorn Sheep in Badlands National Park. Restoration Ecology Vol. 8 No. 4S, pp 85-90.

SINGER, F. J., C. M. PAPOUCHIS AND L. C. ZEIGENFUSS. 1999. Guidelines for the restoration of bighorn sheep into large landscapes: report of recent findings. Pages 229-240 in Allan and Harriet Thomas, Eds. 2nd North American Wild Sheep Conference. Reno, Nevada. 470 pp.

SINGER, F. J., M.E. MOSES, S. BELLEW, W.SLOAN., 2000. Correlates to Colonizations of New Patches by Translocated Populations of Bighorn Sheep. Restoration Ecology Vol. 8 No.4S, pp. 66-74.

SINGER, F. J. AND M.E. MOSES. 1997 Badlands National Park Sightability modeling of Bighorn Sheep: Progress Report. In Restoration of Bighorn Sheep Metapopulation In and Near 15 National Parks. Conservation of a severely fragmented species. Vol 3.

SWEANOR, P., M. GUDORF, F. SINGER, T. BENZON, J. BERGER, B. BESSKEN, S. CORDTS, C. DOUGLAS, M. MOSES, G. PLUMB, R. SHERMAN, AND E. WILLIAMS. 1995. Bighorn sheep habitat assessment of the greater Badlands National Park area. National Park Service and National Biological Service cooperative report. Badlands National Park, Interior, SD. 66pp.

UNSWORTH, J. W., F. A. LEBAN, D. J. LEPTICH, E. GARTON, P. ZAGER. 1994. Aerial survey: Users manual. 2nd edition. Idaho Department of Fish and Game, Boise, ID. 84pp.

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

WEIDE, K. D. 1967. Letter of post-mortem examination of bighorn sheep. Department of Veterinary Science, Animal Disease Research and Diagnostic Lab, South Dakota State University, Brookings SD.

WILLIAMS, E. S.,M. W. MILLER. F.J. SINGER, T.R. SPRAKER AND S.K. TAYLOR. 1999. A preliminary survey for select diseases in wild Bighorn Sheep populations in the Rocky Mountain Region Parks.

WISHART, W. 1978. Bighorn Sheep pp. 161-171 in J. L. Schmidt and D. L. Gilbert, eds. Big Game of North America. Stackpole books, PA. 494 pp.

WOBESER, G. A. AND T. R. SPRAKER 1980). Post-Mortem Examination. Chapter 7. Wildlife Techniques. Manual The Wildlife Society