HIGH PREDATOR DENSITIES IN YELLOWSTONE NATIONAL PARK MAY LIMIT RECOVERY OF BIGHORN SHEEP POPULATIONS FROM THE 1981 *CHLAMYDIAL* - CAUSED DIE OFF

Kayhan Ostovar, Biology Department, Montana State University, Bozeman, MT 59717
Lynn R. Irby, Biology Department, Montana State University, Bozeman, MT 59717

Abstract: Seventeen years have passed since bighorn sheep (*Ovis canadensis canadenesis*) in Yellowstone National Park (YNP) experienced a massive *Chlamydial*-caused die-off. Currently, no sign of *Chlamydia* or pneumonia is evident in the population, thus other factors are considered to be limiting the population. Populations directly outside YNP have also declined, suggesting the problem is not isolated to the Park. A suspected direct causal relationship between increasing elk (*Cervus elaphus*) and a decline in bighorn sheep has not been proven. The winter of 1996-1997 was one of the most severe on record, yet mortality was not abnormally high for bighorn sheep. The majority of lamb mortality occurred in early summer, except for a band on Mount Washburn that experienced no mortality until arrival on the winter range in October. Further evidence of predation was found in populations that remained close to the northern winter range during the summer. Large numbers of elk wintering along the northern boundary may provide a source of carrion for high densities of coyotes *(Canis latrans*) and golden eagles (*Aquila chrysaitos*) in the winter, and serve as a prey base for lions (*Puma concolor*). These predators may switch to bighorn sheep in the summer.

INTRODUCTION

Bighorn sheep (*Ovis canadensis canadensis*) populations on the northern winter range of Yellowstone National Park (YNP) have ranged from a high count of 487 in 1981 to a low of 134 in 1998 (Meagher et al 1992, Caslick 1993, Lemke 1998, Unpublished Report, (Montana Fish, Wildlife and Parks, MFWP). Extensive aerial surveys (both fixed wing and helicopter) have been conducted almost every year since 1958 (Barmore 1980, Caslick 1993, Lemke 1996, Unpublished report, MFWP). Prior to 1958, surveys were conducted in conjunction with other activities, and are only useful for rough estimates of the population. The largest population of wintering sheep are located on the Everts winter range (EWR), comprised of approximately 480 ha at 1500-2000 m in elevation (Keating et al. 1985).

During the winter of 1981-1982, an outbreak of infectious keratoconjunctivitis resulted in the mortality of approximately 60% of the total northern range population and up to 80% of the EWR population (Keating 1982, Meagher 1982, Legg 1996, Meagher et al. 1992, Caslick 1993). Seventeen years later the population has not shown significant signs of recovery and may be decreasing. In addition to declines on the EWR, populations to the north and east have also declined. Recent studies found that human disturbance, poaching, inbreeding suppression, disease, and interspecific competition were unlikely to be important in limiting populations north of the EWR (Irby et al. 1986, 1989, Legg 1996). Predation and weather are 2 factors that have not been fully examined (Legg et al. 1996).

In response to the unknown factors limiting bighorn sheep population recovery on the EWR and a proposed resiting of the Gardiner-Mammoth highway, a behavioral observation study was begun in order to evaluate the potential impacts of the road realignment. This study focused on the impacts of human related stress on the bighorn sheep population. Our data on movements and mortality patterns allowed us to make a preliminary assessment of the role of predation in this population.

ACKNOWLEDGEMENTS

This study was funded by the Federal Highways Department of Transportation in conjunction with the National Park Service (NPS) and Montana State University (MSU) in Bozeman. Montana Fish, Wildlife and Parks (MFWP), the Biological Research Division (BRD), the Mountain Research Center, and the Northern Yellowstone Cooperative Wildlife Working Group provided additional support. Roger Stradley of Gallatin Flying Service provided a wealth of knowledge about bighorn distributions in YNP and conducted amazing flights during migrations. Tom Roffe of the National Wildlife Federation (NWF) and Kerry Gunther of the NPS collared two additional sheep in the fall. Dan Tyers of the USFS in Gardiner assisted with captures and organized housing and volunteers. Keith Aune, Tom Lemke, Neil Anderson and David Worley assisted with laboratory work and offered many useful suggestions. We were lucky to have the support of Emily Cayer, Triss Hoffman, Payam Ostovar, Tobias Swank, Marett Taylor and Amy Zimmerman, who hiked over 6,500 km during 15 months of fieldwork. Many people in Yellowstone park provided assistance: Mark Biel, Jim Caslick, Stu Coleman, Eric Compass, Wendy Clark, Robert Furhman, Mike Heiner, Gregg Kurz, Terry McEneaney, and Mary Meagher.

METHODS

Fourteen ewes and 4 young rams (1-3 year olds) were radio collared, using helicopter net guns and drug immobilization from the ground (Andryk et al. 1983, Bates et al. 1985, Kock et al. 1987, Heimer et al. 1990). Serology, virology and bacteriology tests were performed on samples collected during the capture process. Collared animals were used to track bighorn sheep groups on their migration from winter to summer ranges and also as focal animals for behavioral observations. Focal animals were located daily during the winter and several times a week during the summer on random days and times. Individual and group behavior data were recorded, including information on group size, composition, distance moved, spread of the group, distance to other species, habitat features and distance to human activity. All locations were plotted into a geographic information system (GIS) and used to evaluate potential impacts of proposed road corridors. Monthly fecal samples were collected from known individuals for a period of 1 year. These samples are being analyzed for lungworm and cortisol levels.

In order to increase our sample size to approximately 50% of the females and 23% of the males, other individuals were sampled by using identifiable, unique physical features. Using these methods, a total of over 400 fecal samples were collected during the period of 1 year.

RESULTS

The level of habituation and accessibility of the EWR bighorn sheep allowed us to get an accurate population estimate of 60 individuals. In the winter of 1996-1997 we estimated 32 adult females, 2 yearling females, 20 adult males, and 6 yearling males associated with the EWR. Our monitoring of summer migration revealed 3 bands of ewes from the EWR with separate lambing sites. Migrations varied from partial short distance movements (5 km or less) to long distance movements (45 km). Rams were found to move into the Gallatin Range or remain near the EWR for the summer.

Our serology, bacteriology and virology lab results were negative for all captured animals. However, we did see some sick lambs in populations that remained around the EWR during the summer months. The other stress related factors we observed near the EWR were helicopter flights and the presence and activity of predators. Since the Yellowstone sheep are very habituated to humans, most recreational activity does not seem to disturb daily behavior. An exception to this would be during the first couple months of lambing when ewes are extremely skittish and will not tolerate human presence to the same degree as other times of the year.

Helicopter flights occur primarily between June and September around the EWR due to topography and the heliports in Gardiner and Mammoth. We totaled the number of contract flights out of the Mammoth heliport during 1995 and 1997 and found 170 and 175 flights, respectively. During the winter of 1997-98 an increase in flight activity occurred during the winter months, primarily related to research within Yellowstone National Park. On several occasions flights over the EWR caused sheep to abandon open wind blown slopes at lower elevations and move up into steep terrain for up to 10 days.

Lamb mortality in 1997 occurred during the early months of summer in most populations. By the end of August the semi-migratory bands had no lamb survival, while the migratory band that moved to Mount Washburn still had lambs. When the Washburn band returned to the winter range in the fall they immediately lost two more lambs. This was consistent with the hypothesis that predation was severely impacting lamb survival in all populations associated with the EWR (6 lambs/100 ewes, fall 1997).

We conducted coyote howling surveys to determine rough pack densities around the winter range and found approximately four packs of 2-3 individuals in the EWR area. Behavioral observations recorded numerous coyote sightings on the winter range and only 2 on Mount Washburn. In addition, we observed 1 attempted predation by a golden eagle, 4 attempts by packs of coyotes, 1 attempt by a lion and 2 documented kills of adult ewes by lions. A lion study that began during the winter of 1998 found an adult lion with 2 kittens frequenting an area near the EWR. The density of predators near the EWR can be explained by the numbers of elk (1998 estimate11,736 Mack pers. commun., NPS) which may serve as both a prey base and carrion supply.

DISCUSSION

The EWR is located within 2 km of the northern boundary of YNP. Elk hunting and harassment on agricultural lands directly north of the park may cause elk to pool unnaturally along the boundary in the winter (Houston 1982, Keating 1985). This may directly impact the bighorn population through interspecific competition with elk (Woolf 1968, Oldenmeyer et al. 1971, Constan 1972, Barmore 1980, Kasworm et al. 1984, Picton 1984, Keating 1985, Singer 1991). After the *Chlamydia* epizootic, Keating (1982) proposed three hypotheses to explain the level of interspecific competition between elk and bighorn sheep. 1. The bighorn sheep population would recover rapidly to 150-200 individuals after several years (indicating minimal interspecific competition). 2. The population would grow but stabilize at a lower median level (indicating that sheep-elk interactions may occur to some degree). 3. The population would remain around 60 individuals similar to the pre-elk reduction program. (indicating elk numbers have a negative influence on bighorn sheep populations). Keating's third hypothesis is very similar to what has occurred in the population. Kasworm et al. (1984) and Singer and Norland (1991) also found that elk and bighorns had the greatest degree of winter diet overlap among ungulates in north central Montana and Yellowstone National Park, which might suggest interspecific competition.

The large numbers of elk on the EWR may result in interspecific competition, especially during severe winter conditions (Buechner 1960, Oldenmeyer et al. 1971, Barmore 1980). However, direct forage competition may be too simplistic to explain the interactions between elk and bighorn sheep. A sheep faced with starvation can decrease this risk by increasing either the amount of food obtained or the protein content in the vegetation consumed. The increased risks taken to obtain food can increase the probability of predation (McNamara and Houston 1987). Sinclair (1985) examined the relationships of nine species of herbivores in the Serengeti and determined that predation played as important a role in structuring the community as interspecific competition. Migratory ungulates may be less likely to be regulated by predators than resident populations. Simulations run by Fryxell et al. (1988) found that predators could regulate resident herbivores at low population densities. This could explain the disparity between lamb survival in the different bands of bighorn sheep that winter on the EWR.

The large numbers of elk and winter carcasses on the EWR may also result in high predator densities that may be more limiting and detrimental to bighorn sheep on the EWR than interspecific competition. While population trends of predators are not well known, there is evidence that many predators such as golden eagles (*Aquila chrysaitos*), coyotes (*Canis latrans*) and lions (*Puma concolor*) have increased in the northern Yellowstone ecosystem during the past 10 years (Legg et al. 1996, Murphy 1998, Stradley Pers. Commun.). Further supporting the hypothesis that predation is limiting the recovery of this population is the decline of bighorn sheep outside YNP where interspecific competition with elk is lower. Legg (1996) and Murphy (1998) found instances of lion predation on bighorn sheep both in and out of the park. Recent studies have recorded selective predation by lions on bighorn sheep in British Columbia, California, and Alberta (Harrison et al. 1988, Wehausen 1996, Ross et al. 1997). The documentation of lion kills may be biased towards adult sheep since lambs can be rapidly consumed and are therefore difficult to confirm. An intensive study on lion-bighorn interactions revealed that lions were selecting lambs over adult bighorn sheep (Ross et al. 1997). Unfortunately their study utilized lambs collared in August, leaving many questions about mortality in the first two months after parturition. Scotton (1998 in press) and Haas (1988) marked lambs within several days of birth and attributed the majority of lamb mortality to coyote predation within the first few weeks of life.

There is a possibility that the EWR population of sheep exist in a multi-equilibrium system. The fact that the population remained over 150 individuals for more than ten years and now seems stuck in a "predator pit" at around sixty individuals (Seip 1992) is typical of a multi-equilibrium system (Dublin et al. 1990) (Fig 1). An increase in alternate prey (in this case elk) can increase predation by the resultant numerical increase of predators in the system. This has been described with expanding moose (*Alces alces*) populations and the subsequent decline of woodland caribou (*Rangifer tarandus*) due to wolf predation (*Canis lupus*) (Bergerud and Elliot 1986, Seip 1992). In a similar case the increase of wood bison (*Bison bison athabascae*) in the Mackenzie Bison Sanctuary may have exacerbated predation on moose (Gates and Larter 1990).

CONCLUSION

It is obvious that we have not answered whether interspecific competition or predation may regulate the population of bighorn sheep on the EWR. We hope that our final field season and analysis of cortisol and behavioral observations will reveal factors related to the inability of the population to recover from the epizootic. If bighorn sheep are experiencing a "predator pit" than one would expect the situation to remain unchanged until the system experiences a large perturbation. This could be an epidemic in the coyote population, a decline in the elk population or some other unknown factor. It is clear that if the poor lamb recruitment trend continues there will be cause for concern. Managers need to keep in mind the potential accumulation of detrimental factors impacting the population of bighorn sheep on the EWR.

LITERATURE CITED

Andryk, T. A., L.R. Irby, D. L. Hook, J. J. McCarthy and G. Olson. 1983. Comparison of Mountain Sheep Capture Techniques: Helicopter Darting Versus Net-Gunning. Wildl. Soc. Bull. 11:184-187.

Barmore, W. J. 1980. Population characteristics, distribution, and habitat relationships of six ungulate species on winter range in Yellowstone National Park. National Park Service, Yellowstone National Park, Wyoming.

Bates, J. W. Jr., J. W. Bates and J. G. Guymon. 1985. Comparison of Drive Nets and Darting for Capture of Desert Bighorn Sheep. Wildl. Soc. Bull. 13:73-76.

Bergerud, A. T., and J. P. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Can. J. Zool. 64:1515-1529.

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

Caslick, J. W. 1993. Bighorn Sheep in Yellowstone: A Literature Review and Some Suggestions for Management, 1993. Yellowstone National Park. 1-45 pp.

Constan, K. J. 1972. Winter Foods and Range Use of Three Species of Ungulates. J. Wildl. Manage. 36:1068-1076.

Dublin, H. T., A. R. E. Sinclaire, and J. McGlade. 1990. Elephants and fire as causes of multiple stable states in the serengeti-mara woodlands. J. Anim. Ecology 59:1147-1164.

Fryxell, J. M., J. Greever and A. R. E. Sinclair. 1988. Why are Migratory Ungulates so Abundant. Am. Nat. 131:781-798.

Gates, C. C. and N. C. Larter. 1990. Growth and dispersal of an erupting large herbivore population in northern Canada: the Mackenzie wood bison (*Bison bison athabascae*). Arctic 43:231-238.

Haas, C. C. 1988. Bighorn lamb mortality: predation, inbreeding, and population effects. Can. J. Zool. 67:699-705.

Harrison, S. and D. Hebert. 1988. Selective predation by cougar within the junction butte wildlife management area. Bienn. Symp. North. Wild. Sheep and goat council. 6:292-306.

Heimer, W. E. and F. J. Mauer. 1990. Comparison of Helicopter-Supported Chemical Immobilization and Skid-Mounted Projectile Net Capture of Dall Sheep in Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:171-175.

Houston, D. B. 1982. The northern Yellowstone elk: ecology and management. Macmillan, New York, N.Y. 474 pp.

Irby, L. R., J. E. Swenson and S. T. Stewart. 1986. Management of bighorn sheep to optimize hunter opportunity, trophy production, and availability for non-consumptive uses. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:113-127.

Irby, L. R., J. E. Swenson and S. T. Stewart. 1989. Two Views of the Impacts of Poaching on Bighorn Sheep in the Upper Yellowstone Valley, Montana, USA. Biol. Conserv. 47:259-272.

Kasworm, W. F., L. Irby and H. Pac. 1984. Diets of ungulates using winter ranges in north central Montana. J. Range Manage. 37:67-71.

Keating, K. A. 1982. Population Ecology of Rocky Mountain Bighorn Sheep in the Upper Yellowstone River Drainage, Montana/Wyoming. M. S. Thesis, MSU, Bozeman. 1-79 pp.

Keating K. A., L. Irby and W. Kasworm. 1985. Mountain sheep winter food habits in the upper Yellowstone Valley, J. Wildl. Manage. 49:156-161.

Kock, M. D., D. Jessup, R. K. Clark and C. E. Franti. 1987. Effects of Capture on Biological Parameters in Free-Ranging Bighorn Sheep (*Ovis Canadensis*): Evaluation of Drop-Net, Chemical Immobilization and the Net-Gun. J. Wildl. Dis. 23:641-651.

Legg, K. L. 1996. Movements and habitat use of bighorn sheep along the upper Yellowstone River valley, MT. M.S. Thesis, Montana State Univ. Bozeman. 73pp.

Legg, K. L., Irby R.L. and T. Lemke. 1996. An analysis of potential factors responsible for the decline in bighorns in the Tom Miner Basin. Bienn. Symp. North. Wild Sheep and Goat Counc. 10:26-34.

Lemke, T. 1996. Northern Yellowstone Cooperative Bighorn Sheep Survey, 1996. A Project of the Northern Yellowstone Cooperative Wildlife Working Group.

Lemke, T. 1998. Northern Yellowstone Cooperative Bighorn Sheep Survey, 1998. A Project of the Northern Yellowstone Cooperative Wildlife Working Group.

Meagher, M. 1982. An outbreak of pinkeye in bighorn sheep, Yelowstone National Park: A preliminary report. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:198-201.

Meagher, M., W. J. Quinn and L. Stackhouse. 1992. Chlamydial-Caused Infectious Keratoconjunctivitis in Bighorn Sheep of Yellowstone National Park. J. of Wildl. Dis. 28:171-176.

Messier, F. 1994. Ungulate population models with predation: A case study with the north american moose. Ecology 75: 478-488.

Mc Namara, J. M. and A. I. Houston. 1987. A general framework for understanding the effects of variability and interruptions on foraging behaviour. Acta Biotheoretica 36: 3-22.

Mc Namara, J. M. and A. I. Houston. 1987. Starvation and predation as factors limiting population size. Ecology. 68:1515-1519.

Murphy, K. 1998. Ecology of the cougar in the Northern Yellowstone ecosystem (*Puma concolor*). Ph. D. Thesis. University of Idaho, Moscow, ID.

Oldenmeyer, J. L., W. J. Barmore, and D. L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. J. Wildl. Manage. 35:257-269.

Picton, H. D. 1984. Climate and Prediction of Reproduction of Three Ungulate Species. J. Appl. Ecol. 21:869-879.

Ross, P. I., M. G. Jalkotzy and M. Festa-Bianchet. 1997. Cougar predation on bighorn sheep in Southwestern Alberta during winter. Can. J. Zool. 74:771-775.

Scotton, B.D. In Press. Timing and causes of neonatal Dall sheep mortality in the central Alaska range. Wildl. Soc. Bull.

Seip, D. R. 1992. Wolf predation, wolf control and the management of ungulate populations. Pages 331-340. *in* D.R. McCullough and R.H. Barrett, editors. Wildlife 2001: Populations. Elsevier Applied Science. London and New York.

Singer, F. J. and J. E. Norland. 1994. Niche Relationships within a Guild of Ungulate Species in Yellowstone National Park, Wyoming, Following Release from Artificial Controls. Can. J. Zool. 72:1383-1394.

Sinclair, A. R. E. 1985. Does interspecific competition or predation shape the African ungulate community. J. Anim. Ecology 54:899-918.

Wehausen, J. D. 1996. Effects of Mountain Lion Predation on Bighorn Sheep in the Sierra Nevada and Granite Mountains of California. Wildl. Soc. Bull. 24:471-479.

Woolf, A. 1968. Summer ecology of bighorn sheep in Yellowstone National Park. M.S. Thesis. Colorado State University, Fort Collins. 112pp.