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The Decline of Bighorn Sheep in the Santa Catalina Mountains, Arizona

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Abstract.—Desert bighorn sheep (*Ovis canadensis mexicana*) are an important component of the biodiversity in the Pusch Ridge Wilderness (PRW), Santa Catalina Mountains, Arizona. The population has decreased from approximately <20 in 1926 to in 1994 and their distribution is limited to < 50 km^2 in the PRW. The population decline has been attributed to human activities including the development of roads and trails, housing and resorts, hiking, dogs, and fire suppression. Fire suppression effectively has altered vegetation so parts of the PRW are not suitable for bighorn sheep. Human encroachment into the remaining areas has been too severe for the population to increase. Disease, predation, and hunting may have contributed to the recent decline but their influence has not been evaluated. Prior to any reintroduction efforts, managers should understand the factors that have caused the decline. The public is supportive of management options including those that restrict the use of areas and prohibit dogs from bighorn sheep habitat. However, human intrusion into bighorn habitat may be too severe for recovery efforts to be successful.

Since the 1920s desert bighorn sheep in PRW have declined from >200 to <20 (fig. 1). Likely cause for the decline are directly related to human activity (i.e., construction of roads, trails, hunting, hiking, fire suppression). Unfortunately, as the population declined the efforts to maintain a viable population were not successful. Our objectives were to summarize the decline of desert bighorn sheep in PRW, review the research that has been conducted related to bighorn in PRW.
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THE PUSCH RIDGE WILDERNESS

The PRW (fig. 1) was established 24 February 1978 through the Endangered American Wilderness Act. One of the major goals of the 22,837 ha wilderness was to protect habitat for desert bighorn sheep (Anon. 1978). The PRW formed the southwest portion of the Santa Catalina Mountains located in the Coronado National Forest, Arizona. The Santa Catalina Mountains are roughly triangular in shape with an east-west base of about 32 km and the apex 32 km north of the base (Krausman et al. 1979). Elevations ranged from >2,745 m at Mount Lemmon to 854 m at the southwestern base of the range (Whittaker and Niering 1965).

The Santa Catalina Mountains are unique among Arizona and New Mexico mountain ranges because they possess a full sequence of plant communities from subalpine fir (*Abies lasiocarpa*) forests to Sonoran Desert. Vegetation patterns of other ranges in southeastern Arizona are similar (Blumer 1909, Martin and Fletcher 1943, Nichol 1952, Wallmo 1955, Lowe 1961) to the Santa Catalinas but differ because the forest types are reduced or absent and/or Sonoran Desert communities are limited or absent (Whittaker and Niering 1964). Vegetation of the Santa Catalina Mountains brings together mountain coniferous forests, Mexican oak (*Quercus oblongifolia*) and pine (*Pinus* spp.)-oak communities of southern affinities, desert grasslands with affinities to the east and Sonoran Desert with affinities to the west and south (Whittaker and Niering 1965).

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Figure 1.—Estimates of desert bighorn s heep in the Santa Catalina Mountains, Arizona. Data are from the United States Forest Service and Arizona Game and fish Department files.

The PRW consists of steep, highly erosive areas with large, deep canyons that support riparian vegetation. Hogbacks rise from the desert floor to higher elevations forming vertical rock faces and spectacular geologic formations. Vegetation varies from desert grassland at the lower elevations to ponderosa pine (*Pinus ponderosa*) and mixed conifers at higher elevations (Krausman et al. 1979). Whittaker and Niering (1964, 1965) provide a physical and vegetation analysis of the Santa Catalina Mountains. The PRW is further described by deVos (1983), Gionfriddo and Krausman (1986), Etchberger et al. (1989, 1990), and Mazaika et al. (1992).

PREVIOUS STUDIES

Krausman et al. (1979) recommended that the "... future well-being of this population will require management and planning based on a sound understanding of basic biological parameters of the herd and of human intrusions into it's habitat." Krausman et al. (1979) recommended that information on density, distribution, lambing, habitat, fire, recreation, and human impacts as they relate to desert bighorn sheep were needed for efficient management. Each of these arenas has been addressed to a limited degree and research has been conducted in 2 major areas: habitat and biology, and human influences.

Biological Studies

Krausman et al. (1979) reviewed the literature and status of bighorn sheep in PRW and recommended that more information was needed to understand the ecological relationships between sheep and their habitat and between humans and bighorn sheep in PRW. The first study was conducted by deVos (1983) to collect data to be used as a basis for management decisions. He radio collared 11 bighorn sheep (5M, 6F) and made recommendations based on 374 locations of sheep from November 1981 through June 1983. deVos (1983) reported 6 important results.

1. Over 70% of bighorn sheep locations were in oak associations.
2. Approximately 80% of bighorn sheep locations occurred within 700 m of a burned area. "The differences between the use of burned area and the random values was highly significant ($P \geq 0.99$) deVos 1983:26."
3. Bighorn sheep preferred areas > 700 m from trails.
4. Bighorn and Pusch peaks and west of Montrose Canyon and south of Buster Springs are lambing and nursing areas.
5. Home-range size varied from 7.1 to 34.4 km^2.
6. The population estimate was from 45 to 75 sheep. Unpublished data reported by deVos (1983:29) indicated the best estimator available revealed a population of 60. "It is important that any future research be directed and sufficiently funded to provide an accurate population estimate."

Based on these data deVos (1983) recommended 5 areas for continued research that would ".... alleviate much of the jeopardy to this herd."

1. Obtain better lambing data and refine population estimates.
2. Monitor recreation and the response of sheep to humans.
3. Discourage human development adjacent to bighorn sheep habitat.
4. Allow fires to burn in sheep habitat.
5. Controlled burns should be planned to enhance sheep habitat.

During the study by deVos (1983), Gionfriddo and Krausman (1986) began a study examining summer habitat use by bighorn sheep on PRW. The land adjacent to the PRW was being developed for housing and the study was to establish information on bighorn sheep habitat use prior to encroachment by humans. Gionfriddo and Krausman (1986) described summer (May-Sep) habitat use in 1982 and 1983 based on 234 observations of sheep groups containing 1,010 individuals.

Sheep selected the nonprecipitous open oak woodland in 47% of the observations and 85% were on sites located at the base of large rocky cliffs. Areas ≤150 m from cliff bases accounted for <1% of the aerial surface on the study areas but 40% of all sheep groups observed were using these sites. These areas were tree-invaded semidesert grassland at the lower fringe of evergreen oak distribution with 15.5% thermal cover.

Sheep habitat in summer in PRW was characterized by 59-79% slopes, western aspects, elevations between 1,098 and 1,341 m, upper slopes of drainages, tops of ridges and mountains, and areas ≤20 m from escape terrain.

These findings are characteristic of sheep habitat in southwestern Arizona. However, Gionfriddo and Krausman (1986:334) stated that "Responses of bighorn sheep to slope steepness, elevation, and topographic position may be related to other factors such as visibility, forage availability, and proximity to escape terrain rather than to steepness, elevation or topographic position ..." Because fires in PRW have been suppressed in the past 70 years, Gionfriddo and Krausman (1986:335) recommended a program of habitat rehabilitation through prescribed burning. Because human recreation was occurring they also suggested a well enforced set of recreational use restrictions to improve the chances of long-term survival of mountain sheep in PRW. Another recommendation was for "... close monitoring of the population's responses to management actions and to the nearby suburban development ..."

Etchberger et al. (1989) conducted a study in the Santa Catalina Mountains in 1987-1988 to contrast habitat used by desert bighorn sheep (44 km^2) with habitat that had been abandoned (206 km^2). "Habitat currently used by mountain sheep in PRW has greater distance to human disturbance, greater visibility, more side oats grama (*Bouteloua curtipendala*), red brome (*Bromus rubens*), brittle bush (*Encelia farinosa*), and forbs, but less ground cover, bush muhly (*Muhlenbergia porterii*), and turpentine bush (*Haplopappus laricifolius*) than abandoned habitat (Etchberger et al. 1989:905)."

Differences between currently used and abandoned habitat were not found for variables commonly considered important to bighorn sheep: steep, rugged terrain with considerable topographic relief (Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986, Wakelyn 1987). In PRW other factors influenced sheep distribution: human disturbances in and adjacent to PRW and fire suppression. Fire suppression in abandoned habitat that has encouraged vegetation that obstructs visibility has been detrimental to bighorn sheep. Fire suppression reduces the amount of high-visibility habitat used by mountain sheep (Risenhoover 1981, Wakelyn 1987). Risenhoover and Bailey (1985) documented a strong preference by bighorn sheep for grassy, open areas with high visibility (Etchberger et al. 1989:906). Fires have been suppressed in the PRW until the early 1980s and although approximately 3,000 ha have burned since 1958 <2% burned >125 ha at one time.

Habitat fragmentation due to human disturbance threatens the survival of large mammalian populations because they require large spaces and specific habitat features (i.e., visibility) (Wilcox and Murphy 1985). Etchberger et al. (1989) recommended that fires should be used to maintain high visibility habitat and human encroachment should be monitored closely. In a later study Etchberger et al. (1990) examined the influence of a fire on sheep habitat in PRW and documented the beneficial aspects of fire. According to Etchberger et al. (1990:56) fire reduced visibility-obstructing vegetation and enhanced desirable species. These results are supported from long term evaluation of fire in PRW (P. R. Krausman and G. Long, unpubl. data).

Researchers also examined other aspects that may limit bighorn sheep in PRW. Mazaika et al. (1992) estimated seasonal forage availability and quality for bighorn sheep. The results suggested that bighorn sheep "... were not limited by forage quantity or quality ... (Mazaika et al. 1992:372)." Mazaika et al. (1992) concluded that habitat management for bighorn sheep in PRW should concentrate on factors other than the availability or quality of forage (i.e., fire management to enhance visibility).

Throughout these studies ≥3 consistent issues are raised in relation to bighorn sheep management in PRW.

1. Habitat features for bighorn sheep are similar to other habitat features for bighorn sheep in the Southwest.
2. Fire suppression is reducing visibility for bighorn sheep and effectively reducing PRW as bighorn sheep habitat.
3. Human disturbance and activities, including housing developments and recreation on forest lands, are eliminating habitat available for bighorn sheep in PRW.

Sociological Studies

Sociological studies were recommended by Krausman et al. (1979) and were initiated shortly thereafter. Purdy and Shaw (1981) examined the recreational uses and users of bighorn habitat in PRW. They described human use patterns of 2 groups: lower canyon visitors and backcountry visitors. Most humans were lower canyon visitors and <10% of all users entered the backcountry. The later group posed a greater threat to bighorn sheep due to their increased activities and longer duration of visits. Although backcountry users did not believe their activities were detrimental to bighorn sheep they did favor recreational use restrictions if necessary for the welfare of the sheep population. This is further reflected by the value of bighorn sheep to recreationists in PRW. Purdy and Shaw (1981) found <1% of 844 responses from backcountry users observed bighorn sheep. Most of those who observed sheep (60%) believed the "... sightings were the highlight of all past recreational experiences in PRW (Purdy and Shaw 1981)."

This attitude is supported by later studies of King et al. (1986, 1988). The total value of a resource is the sum of use and existence values. Use values include consumptive, nonconsumptive, and future use values. Existence values are motivated by altruism and is not derived from direct use of the resource (Randall and Stall 1983).King et al. (1986, 1988) estimated the total and existence values of bighorn sheep in PRW to residents of the Tucson urban area, and estimated the effects of socioeconomic and other preference related variables on the total and existence values of the herd. King et al. (1986, 1988) concluded that "when the sample values ae [are] projected to the population of metropolitan Tucson, total value falls within the range of 2.1 and 3.9 million dollars per year and existence values within the range of 1.3 to 2.4 million dollars per year." As with other authors, King et al. (1986, 1988) emphasized that increasing recreational use of PRW could be detrimental to bighorn sheep in PRW.

Although citizens of Tucson value bighorn sheep, the long-term future of bighorn in PRW is not secure (Purdy and Shaw 1981). Purdy and Shaw (1981:4-5) made 6 recommendations as safeguards against human/bighorn sheep conflicts in PRW.

"1. Continue to monitor trail traffic in lower Pima Canyon ... in order to obtain long-term indications of total canyon use.
2. Provide backcountry users of bighorn habitat ... with information that is designed to increase users' level of knowledge of bighorn sheep in PRW. This is perhaps best accomplished ... to make visitors aware of the possible consequences of activities in bighorn habitat in addition to determining the following specific backcountry activities:
   (i) backcountry travel with dogs
   (ii) cross-country travel
   (iii) camping within 1/4 mile (402 m) of wildlife water catchments
3. Enforce existing regulations against camping within 1/4 mile (402 m) of wildlife water ...

4. Provide no improvements of backcountry trails...
5. Obtain accurate PRW bighorn population data...
6. Use information from recommendation 5 as data base for monitoring the physiological and behavioral effects of recreational use on bighorn sheep in PRW."

More recently, Harris and Shaw (1993) and Harris et al. (1994) studied human attitudes related to the conservation of bighorn sheep in PRW. Based on interviews with 403 groups that used PRW for recreation from May 1990 to April 1991 Harris and Shaw (1993) and Harris et al. (1994) described the demographics of users of PRW.

1. More males (57%) than females (43%) used the wilderness trails.
2. Visitors were between 20 and 49 years old (83%).
3. Most (66%) had ≥ a college degree.
4. Most (92%) were caucasian.
5. Most (83%) previously visited the wilderness and the recreational experience PRW provided was important to them.
6. Recreational experiences included hiking (>90%), watching wildlife (except birds) (79%), and bird watching (26%).
7. Only 15% of the respondents observed sheep but 90% were aware that sheep were in the area.

Harris and Shaw (1993) and Harris et al. (1994) also asked wilderness users to respond to management strategies that benefit mountain sheep: dog restrictions, controlled burns, and recreational closures. An estimated 1,650 dogs that are unleashed at least during part of the stay in PRW visit the area annually. Respondents (67%) favored restricting dogs completely from the wilderness. Almost half (46%) favored planned burns to improve bighorn sheep habitat, and 59% of the visitors were willing to give up their wilderness activities to protect bighorn sheep from human pressure. People who use trails in bighorn habitat are concerned about the well-being of the herd. They are willing to accept dog control, controlled burns, and recreational closures as acceptable management strategies (Harris et al. 1994).

As with the biological studies, certain trends emerged from the sociological research.

1. Bighorn sheep are important to citizens of Tucson, Arizona and those that use PRW.
2. Recreational activities by humans will continue to increase in PRW.

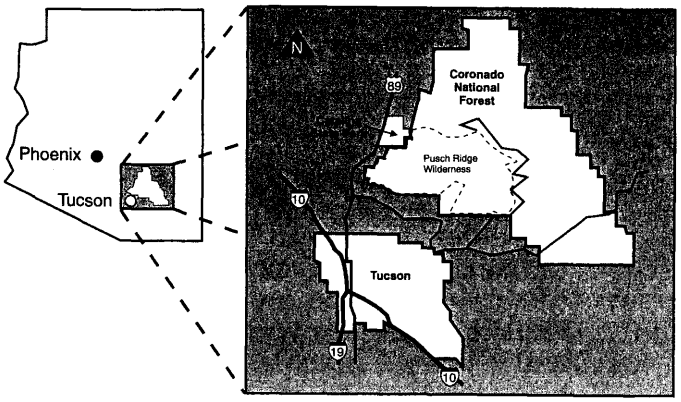

Figure 2.—Pusch Ridge Wilderness in the Santa Catalina Mountains, Arizona.

3. The same recreational activities are detrimental to the long-term survival of sheep in PRW.
4. Recreational users are willing to give up their activities in the wilderness to minimize human pressure on bighorn sheep.

DISCUSSION

Unfortunately the biological data and sociological data acquired are too little too late. Economic forces have created a human barrier around PRW effectively fencing them in (Krausman 1993) while at the same time reducing their habitat. The decline of desert bighorn sheep in PRW is a surprise to no one and was predicted 15 years ago. Unfortunately, now that the population is nearly eliminated (fig. 2) managers will have to decide if PRW is suitable for the continued habitat for bighorn sheep and if not what modifications need to be made to make it suitable. The other decision would be to do nothing and accept the decline of the herd as human induced.

Berger (1990) examined the extinction of mountain sheep populations in 5 western states and concluded that extinction times were related to initial population size. Native populations of <50 individuals were subject to rapid extinction. Populations with >100 individuals persisted for ≥70 years. Although populations in Arizona do not follow Berger's (1990) predictions (Krausman et al. 1993) the population in PRW declined rapidly after abundance decreased to <100 individuals (fig. 2). Krausman et al. (1993) agree with Berger (1990) that "... it is clear that small

(and especially single) mammalian populations are in imminent need of enhanced management to enhance their persistence." Enhanced management has not occurred for bighorn sheep in PRW and the indigenous herd has effectively been eliminated.

The elimination of sheep in the PRW has been gradual. Metapopulations were first eliminated from the surrounding mountains restricting sheep to PRW. Habitat alteration occurred as fire suppression techniques became more effective. In addition, the increasing human population in Tucson has literally pushed bighorn sheep over the brink (Krausman 1993). The bighorn sheep in PRW of the Santa Catalina Mountains may be the next indigenous herd to be replaced with transplants. However, prior to any transplant effort, we recommend a complete census of all potential sheep habitat in PRW done on a systematic basis to obtain the best possible census. If <50 sheep exist a transplant may be warranted but only after the human disturbance, including fire suppression that has been instrumental in eliminating sheep and their habitat has been minimized. An unique population of desert bighorn sheep is in jeopardy and may be lost forever; to transplant additional sheep into the area without solving the problems of disturbance and habitat alteration would be akin to a put and take fisheries operation.

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