HUMAN DISTURBANCE IN BIGHORN SHEEP HABITAT, PUSCH RIDGE WILDERNESS, ARIZONA

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ABSTRACT

Bighorn sheep (*Ovis canadensis mexicana*) in Pusch Ridge Wilderness (PRW), Arizona have declined since 1978. We conducted a study from October 1994 to June 1996 to evaluate human activity within bighorn sheep habitat, including off-trail use, hunting, and potential disturbance from noise. We recorded anthropogenic activity from three vantage points and recorded noise with a digital sound pressure level meter. We observed 711 hiker-groups in 3 canyons representative of PRW. Eighteen percent were off-trail in areas historically used by bighorn sheep; 8% of off-trail hikers were accompanied by dogs. Hunting of mammals and birds was limited in sheep habitat. The average sound pressure level recorded in PRW was 45.4 ± 3.3 decibels (db). We suggest that increased cumulative effects of the array of human activities in PRW contributed to the population decline.

INTRODUCTION

Bighorn sheep historically inhabited mountainous areas near Tucson, Arizona (Krausman 1997). As the city expanded, valleys between mountain ranges were developed (i.e., housing, agriculture, towns), resulting in disjunct, small populations of bighorn sheep (*Ovis canadensis*). In 1994, one of two remaining populations adjacent to Tucson was in Pusch Ridge Wilderness (PRW), Santa Catalina Mountains. The PRW was established in 1978, in part to protect habitat for desert bighorn sheep (Krausman et al. 1979). In 1927, the population was estimated at 220 animals (Krausman et al. 1979), but by 1993 the population declined to <20. The Arizona Game and Fish Department (AGFD) conducted surveys by helicopter in 1994, 1996, and 1997, and located nine, zero, and two sheep, respectively (J. Heffelfinger, AGFD, pers. comm.). We saw three bighorn sheep (two male, one female) in 864 hr of ground observations between June 1995 and June 1996, and there have been other verified reports of sheep in PRW in 1996 and 1997. Based on these observations, the bighorn sheep population in PRW is not viable and nearing extinction.

Past studies of the population have centered on biology and human attitudes towards bighorn sheep. Bugarsky (1986), Harris and Shaw (1993), and Harris et al. (1995) examined human attitudes toward the bighorn sheep population and determined activities of recreators in PRW (Krausman et al. 1979, Purdy and Shaw 1981). Residents of Tucson placed an economic value on the population between $2 million and $4 million/year (Burgarsky 1986), and visitors to the area support restrictions on human activity and closing portions of PRW to preserve the herd (Purdy 1981, Purdy and Shaw 1981, Harris and Shaw 1993, Harris et al. 1995). Past studies were conducted in PRW where people concentrated, not necessarily in areas used by bighorn sheep. Activities of humans in that part of PRW used by bighorn sheep are unknown.

Several causes for the population decline have been proposed. Fire suppression has allowed vegetation to reduce visibility (Krausman et al. 1996), which may be detrimental to bighorn sheep habitat (Etchberger et al. 1989, 1990). Other human disturbances such as hunting or noise may be factors in the population decline. When approached by humans, hunted populations of bighorn sheep experience greater flight response and exhibit more wariness than non-hunted populations (King 1984). Conversely, some populations of bighorn sheep are able to coexist with considerable human activity when sport hunting is prohibited (Geist 1971, Hicks and Elder 1979).

Major increases in human recreational activity may have negative effects on bighorn sheep populations (Van Den Akker 1960, DeForge 1972). The PRW is only 9 km from the center of Tucson. As the population of Tucson expands, so will the demand for more recreation areas, including areas within bighorn sheep habitat. Our objective was to determine and describe human activities and noise levels within bighorn sheep habitat in PRW

METHODS AND MATERIALS

Study Area

The PRW encompasses 22,837 ha in the southwest corner of the Santa Catalina Mountains, Coronado National Forest, Arizona. The wilderness area is adjacent to the city of Tucson, and is bordered by several housing developments and a major resort. Construction on these projects began in 1986 and was in progress throughout our study. Elevations ranged from 905 to 1,710 m, and annual rainfall was about 27 cm. Mean temperatures ranged from 16°C in winter to 30°C in summer. Topography is rugged,

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with vertical cliffs interspersed with deep canyons, eroded granitic outcrops and poorly developed soils. Dominant vegetation associations are Sonoran Desert scrub, semi-desert grassland, and Madrean evergreen woodland (Gionfriddo and Krausman 1986). Bighorn sheep used 4,700 ha in the southwest portion of PRW (Gionfriddo and Krausman 1986). Further description of the study area was provided by Whittaker and Niering (1964, 1965), Krausman et al. (1979), Gionfriddo and Krausman (1986), Etchberger et al. (1989, 1990), and Mazaika et al. (1992).

We selected three canyons in PRW (i.e., Pima, Catchment, and Bighorn Canyons) from which to collect data on human activity, hunting , and noise. These canyons varied in recreational activity and public access and were a representative sample of bighorn sheep habitat (Gionfriddo and Krausman 1986; J. C. deVos, Jr., *Desert bighorn sheep in the Pusch Ridge Wilderness area*, USFS, Coronado National Forest, Unpubl. Rep.).

Pima Canyon has a well-marked hiking trail along a riparian zone. The trail is well maintained, and there is a parking lot at the trailhead. Harris (1992) estimated Pima Canyon had 24,000 visitors/year in 1990. Bighorn Canyon has a major resort at the base of the canyon, and the adjacent area is criss-crossed by many wildcat trails (i.e., created by hiking off designated trails to form new trails that are not maintained or authorized). New homes are being constructed at the base of Catchment Canyon as part of a gated community, and access to the area by the general public is limited. There are no hiking trails in Catchment Canyon except for an old US Forest Service (USFS) road that leads from a paved street approximately 500 m to a water catchment.

Human Activity

We monitored noise events and anthropogenic activity in PRW from June 1995 to June 1996. Hunting activity was only monitored from October 1994 to March 1995, and ambient sound pressure level meter readings from March to June 1996. We categorized data by type of activity, number and gender of individual(s), number of dogs, dogs on or off leashes, distance from trail or road, duration of time off-trail or road, time and date of off-trail event, description of noise event, and duration of noise event.

We observed and recorded human non-hunting activity from off-trail areas (≥20m from an established trail) using 10×50 binoculars. We observed each canyon from vantage points where we could view the canyon and surrounding area and could remain out of visitors' sight. There are fewer hikers on trails when ambient temperature in Tucson is comparatively high versus low (Harris 1992); therefore we made morning observations from 0600 to 1000 and afternoon observations from 1400 to 1800 in summer (Jun-Aug). We made morning observations from 0800 to 1200 and afternoon observations from 1200 to 1600 in autumn (Sep-Nov), winter (Dec-Feb) and spring (Mar-May). We observed each of the three canyons four times/month (i.e., two mornings and two afternoons) on weekdays, and two times/month on weekends (i.e., one morning and one afternoon).

We monitored hunting activity for the first 3 days of the respective seasons (from sunrise to 4 hr after sunrise) of Gambel's quail (*Callipepla gambelli*), collared peccary (*Tayassu tajacu*), and deer (*Odocoileus* spp.) season, when the most hunters are in the field (J. Heffelfinger, AGFD, pers. comm.) in 1994, 1995, and 1996. We recorded number of hunters, number of dogs, how far hunters traveled away from trails, and number of shots fired.

Sound Levels

We recorded all noise that occurred during 4-hr observation periods. We gathered ambient noise data from March to June 1996 (n = 31 days) using a digital sound pressure level meter (Model Number 407735 Extech Instruments, Taiwan). We took readings at 1-min intervals for 50 min and determined ambient noise levels on an A-weighted scale.

RESULTS

Human Activity

Hikers engaged in a variety of activities in the canyons (Table 1). Eighty-two percent of hiker-groups (n = 711) remained on trails; 126 hiker-groups containing 280 people hiked off trails. The majority (82%) of off-trail events occurred in Bighorn Canyon; 10% occurred in Pima Canyon, and 8% occurred in Catchment Canyon. All 104 hiker-groups (230 individuals) in Bighorn Canyon hiked off-trail in bighorn sheep habitat. In Pima Canyon, there were 594 hiker-groups (1,408 individuals) in the canyon, and 12 hiker-groups (33 individuals) hiked off-trail. In Catchment Canyon, there were 13 hiker-groups (24 individuals) in the canyon, and 10 hiker-groups went off-trail (19 individuals).

Most off-trail activity occurred in February, primarily by all-male groups (58%, n = 73). Only 6% of hiker-groups were all-female (n = 8), and 36% were mixed groups (n = 45). Average size of hiker-groups was 2.2±0.2 (95% CI; range = 1-9). Forty-eight percent of use by hiker-groups occurred on weekdays (n = 60), and 52% on weekends and holidays (n = 66). Hiker-groups spent an average of 94±12 min in bighorn sheep habitat. Fifty-one percent of bighorn sheep habitat use by hiker-groups occurred in mornings (n = 64), and 49% occurred in afternoons (n = 62).

Table 1. Activities of hiker-groups in bighorn sheep habitat in the Pusch Ridge Wilderness, Arizona (n = 126). Hiker-groups could have >1 activity.

Activity	N	%
Talking loudly	59	47
Shouting	46	37
Throwing rocks, plant parts, other items	19	15
Resting on rocks	12	10
Whistling	6	5
Rock climbing	2	2
Searching for something	2	2
Taking photographs	2	2
Camping	1	1
Smoking	1	1
Identifying plants	1	1
Spitting	1	1

Forty-four hiker-groups brought dogs, and 10 of those groups went off trails in bighorn sheep habitat (23%). Of the hiker-groups that went off-trail (n = 126), 8% brought dogs with them (n = 10). We saw three dogs unaccompanied by humans in bighorn sheep habitat during 12 months of daytime observations. All dogs observed in off-trail areas were off leashes.

The most hunting of quail, deer, and collared peccary in PRW during the first three days of the season occurred in Pima Canyon; seven hunters were seen and nine shots were heard from October 1994 to March 1995. No hunters were observed in Catchment or Bighorn Canyons but eight and two shots were heard in Catchment and Bighorn Canyons, respectively. No hunters were observed in 1996 in any of the canyons we surveyed.

Sound Levels

Average noise level in the PRW was 45.4±3.3 decibels (dB). Levels of noise recorded at 1-min intervals indicated 36.8±1.2, 33.3±0.7, and 31.3±0.7 dBs 10, 50, and 90% of the time, respectively. The highest noise level we recorded during intervals was 68 dBs. We identified noise events and recorded duration of those events during 206, 4-hour observation periods. Noises contributing to dB levels in PRW include construction and loudspeaker noise (n = 89, 0.4±0.2x/4 hr), crowds cheering (n = 17, 0.1±0.6x/4 hr), sirens (n = 32, 0.2±0.06x/4 hr), dogs barking (n = 417, 2.0±0.5x/hr), gunshots (n = 154, 0.7±0.4x/4 hr), horns honking (n = 21, 0.1±0.6x/4 hr), vehicle noise (n = 52, 0.3±0.01x/4 hr), sonic booms (n = 83, 0.4±0.2x/4 hr) and cannonball explosions (n = 14, 1x) . Construction activity lasted an average of 170.2±10.1 min/4-hr observation period, and sirens >1 min in duration occurred 3.8±0.3 min/4-hr.

Commercial and military jets, small fixed-wing aircraft, and helicopters, respectively, flew over bighorn sheep habitat 11.0±1.2, 6.0±0.09, 0.3±0.01x/4-hr observation period. None of the aircraft overflights were <100 m above ground level with the exception of a single helicopter during a 2-day search for a missing hiker.

DISCUSSION

There is conflicting evidence about whether human activity disturbs bighorn sheep. In some studies sheep acclimated to human activity (Hicks and Elder 1979, Hamilton et al. 1982). In others behavior, movements, recruitment and lamb survival were negatively affected by humans (Duncan 1960, DeForge 1972, MacArthur et al. 1982, Miller and Smith 1985). Our data suggest that bighorn sheep habitat in PRW has been negatively altered by humans. Bighorn sheep coexist best with people when human activity in sheep habitat is predictable (Hamilton 1982). With 18% of trail users in PRW hiking off-trail into bighorn sheep habitat, movements are not predictable, suggesting that off-trail hiker activity may have a detrimental effect on the bighorn sheep population. In March 1996 the USFS implemented new regulations on PRW for hikers, such as eliminating use by dogs and closing some areas to hikers during lambing season from January through June. The USFS also set up informational bulletin boards at trailheads of several canyons to inform visitors about bighorn sheep, and how they can help the population. However, restrictions are voluntary, and compliance with the new rules is not enforced.

Although the landscape in PRW is substantially larger, nearly all sheep activity in recent years has been confined to 17 km^2 (Etchberger et al. 1990) that may be insufficient to sustain a viable population of animals. Based on computer simulations of bighorn sheep metapopulation dynamics, habitat patch size is relevant to long-term survivorship and can be a determining factor in survival of populations (Gross et al. 1997). In habitat patch sizes <20 km^2, bighorn sheep populations invariably go extinct, even if disease and other factors are controlled (Gross et al. 1997).

Construction activity near PRW continued for an average of 2 hr and 50 min/4-hr observation period. Several studies determined that construction activity changed watering behavior of bighorn sheep, which resulted in greater energy costs, and possibly affected lamb survival (Leslie and Douglas 1980, Campbell and Remington 1981). Thus, continuous construction activity at the base of Catchment and Bighorn Canyons may negatively affect the population by driving sheep away, or altering foraging or watering behavior.

Sayre (1996) evaluated responses of bighorn sheep to various disturbances and found that sheep fled on 78% of their encounters with coyotes. Dogs also cause negative responses in bighorn sheep (MacArthur et al. 1979, 1982; Stemp 1983). Our observations of dogs were not common, but we heard a mean of two dogs/4-hr observation period barking in bighorn sheep habitat. The barking originated from residential areas adjacent to PRW.

Hunting in PRW is probably insignificant. Past hunting may have had a different affect on the population. Noise levels in wilderness settings have been reported around 20 dB (Bowles 1995). Noise levels in PRW were generally < 0 dB and still fairly low.

Aircraft overflights in bighorn sheep habitat were common, but generally >100 m above ground level. Aircraft overflights >100 m above ground level cause substantially less disturbance to bighorn sheep than lower flights (Krausman and Hervert 1983). However, helicopters cause stress responses in bighorn sheep (Bleich et al. 1990*a*, Stockwell et al. 1991). We observed 62 helicopters flying over bighorn sheep habitat in 206, 4-hr observation periods. Only two of the helicopter flights were <100 m above ground level.

Translocating sheep from other areas to PRW is a potential management option to increase the declining population and promote genetic vigor. A precursor to any translocation should include a determination of causes of extinction or decline and removal of those factors, and forming cooperative agreements for management between the different natural resource agencies involved (Wilson et al. 1973). Wildlife managers need reliable data on the cause of decline if supplementing the population is considered.

The welfare of bighorn sheep will be determined by the control of encroachment on their habitat (Van Den Akker 1960, Bleich et al. 1990*b*, Krausman 1997). Bighorn sheep can adapt to the presence of humans in certain situations (Hamilton 1982). Coexistence is possible where escape terrain is available and the herd has somewhere to take refuge from humans, or if they have other means to avoid people, such as using resources at different times to avoid humans (Hamilton 1982). However, bighorn sheep have limited refuge from human contact in PRW. They are surrounded on all sides by dense vegetation, homes, a resort, construction activity, or Tucson (Krausman, 1993). Because the population has been essentially fenced-in, hikers and dogs that enter their habitat, especially those that hike off-trail in unpredictable fashion, may stress bighorn sheep.

Although human activities, such as hiking, do not necessarily destroy bighorn sheep habitat, habitat can be functionally lost to sheep as a result of disturbance and displacement (Stemp 1983); the cumulative effects of disturbance have to be considered. Even if sheep do not leave their home ranges, the consequences of their avoiding humans may include lost opportunity to feed or rest, and increased energy expenditure (Stemp 1983). This may prevent build up of adequate fat reserves for survival. Dogs, recreation activity, construction activity, fire suppression, and loss or alteration of habitat between mountain ranges have negative effects on bighorn sheep. It is likely that the cumulative effect of all these disturbances to this population is taxing their energy budget via stress and threatening their survival. Geist (1971) proposes that bighorns can live compatibly with man in circumstances that are free of hunting and unexpected frights. In PRW stress factors and "unexpected frights" have not been eliminated. We cannot point to any one cause of decline, but we know that many potentially negative human-created activities occur in PRW. Collectively, these may explain why sheep have abandoned otherwise useful habitat. Until individual stress factors are controlled or eliminated, bighorn sheep in PRW will not be able to maintain a viable population.

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