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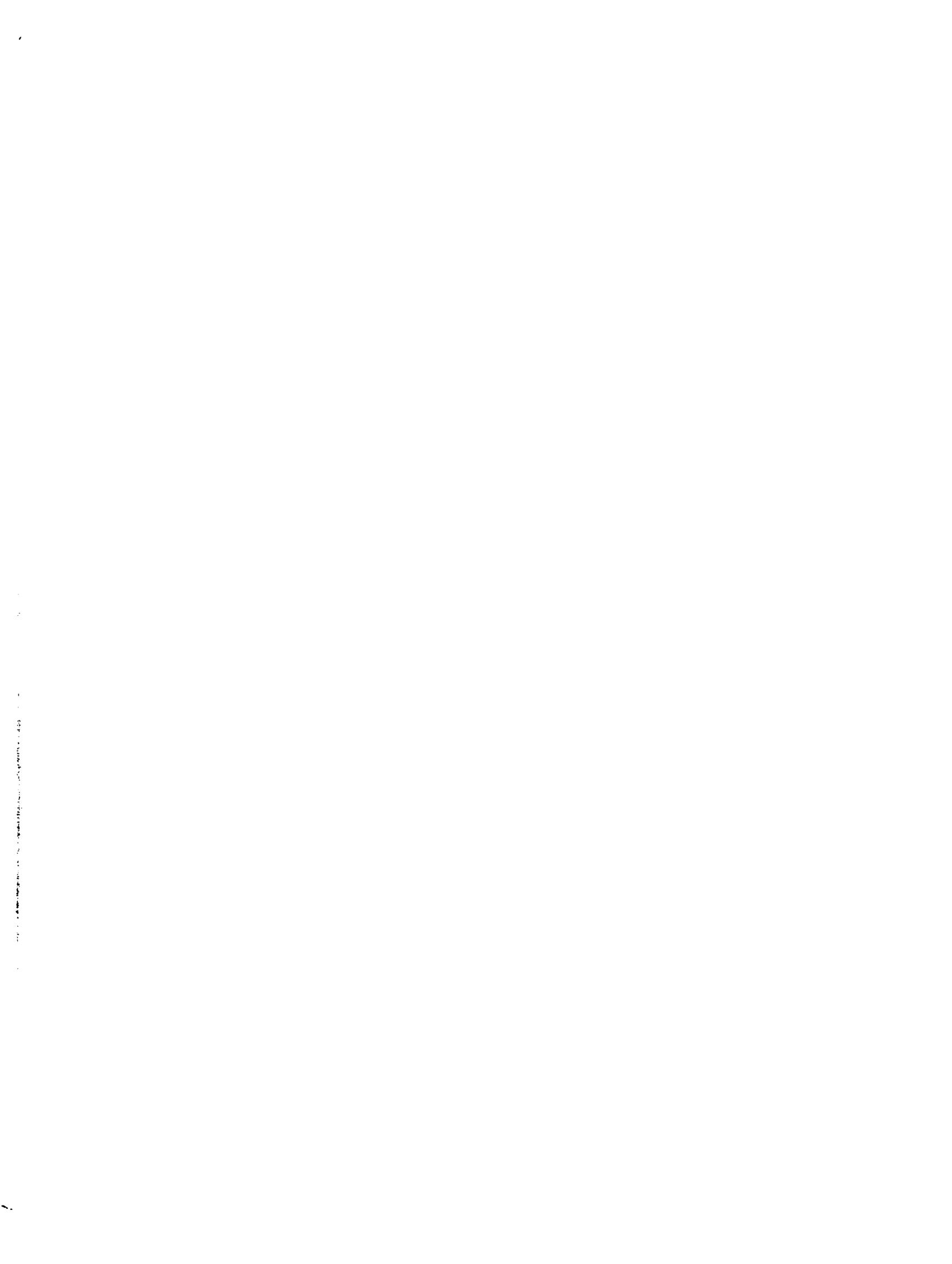
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HUMAN DISTURBANCE IN BIGHORN SHEEP HABITAT,
PUSCH RIDGE WILDERNESS, ARIZONA

by

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A Thesis Submitted to the Faculty of the
SCHOOL OF RENEWABLE NATURAL RESOURCES
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For the Degree of
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In the Graduate College
THE UNIVERSITY OF ARIZONA

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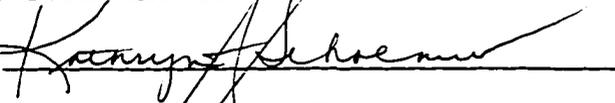
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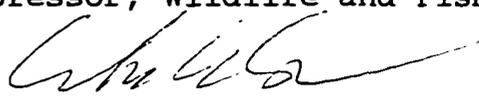
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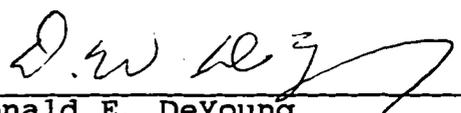
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TABLE OF CONTENTS

	Page
LIST OF TABLES	5
ABSTRACT	6
INTRODUCTION	7
Human Disturbance in Bighorn Sheep Habitat, Pusch Ridge Wilderness, Arizona	8
Abstract	8
Study Area	16
Methods	17
Human Activity	18
Hunting Activity	19
Sound Levels	20
Results	20
Human Activity	20
Dogs	21
Hunting Activity	22
Sound Levels	22
Discussion	23
Human Activity	23
Dogs	25
Hunting Activity	25
Sound Levels	26
Management Implications	27
Literature Cited	29
CONCLUSION	41

LIST OF TABLES

	Page
Table 1. Activities of 126 off-trail hiker-groups in bighorn sheep habitat, Pusch Ridge Wilderness, Arizona. Hiker-groups could have >1 activity	38
Table 2. Average decibel (dB) levels of noise recorded at 50, 1-minute intervals, Pusch Ridge Wilderness, Arizona	39
Table 3. Average frequency of noises heard during 206 4-hour observation periods in the Pusch Ridge Wilderness, Arizona	40

ABSTRACT

I monitored and recorded human activities in bighorn sheep habitat to determine the role of human activity in the decline of an indigenous population of bighorn sheep in the Pusch Ridge Wilderness, Santa Catalina Mountains, Arizona. I recorded hiker activity, sound levels, presence of dogs, and hunting activity in off-trail areas of bighorn sheep habitat from June 1995 to June 1996. Eighteen percent of hiker-groups entering the study area hiked off trails in bighorn sheep habitat, and 8% were accompanied by dogs. Although I observed very little hunting activity in the area, noise disturbance may be a factor in the decline of the population. The cumulative affect of these and other activities probably contributed to the decline of the herd.

INTRODUCTION

I present the results of my thesis research as a manuscript I will submit to the Wildlife Society Bulletin for publication. I followed manuscript guidelines for the Wildlife Society Bulletin (Guidelines for authors and reviewers of Wildlife Society Bulletin manuscripts. 1988. Wildl. Soc. Bull. 16[1, Suppl.]:23pp.). I am the senior author on the article and my co-author was involved in the 5 basic portions of scientific investigation: conception, design, data collection, data analysis, and manuscript preparation.

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RH: Human disturbance in sheep habitat · Schoenecker and Krausman

Human disturbance in bighorn sheep habitat, Pusch Ridge
Wilderness, Arizona

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Abstract: Since 1977 an indigenous population of bighorn sheep in the Pusch Ridge Wilderness has been declining and several potential causes have been examined, including fire, recreational trail use, habitat quality, and use of the area by dogs. We conducted a study from June 1995 to June 1996 to evaluate human activity in bighorn sheep habitat focusing on use of the area by hunters, off-trail hikers, and potential disturbance from noise. We observed 711 hiker-groups in 3 canyons representative of PRW. Eighteen percent were off-trail in areas historically used by bighorn sheep. Eight percent of off-trail hikers were accompanied by dogs. Although we observed almost no hunting activity, noise disturbance could be a factor in the

decline of the herd. The cumulative affect of many activities probably contributed to the decline of the population.

Key words: Arizona, bighorn sheep, dogs, human disturbance, hunting, noise disturbance, Ovis canadensis.

Desert bighorn sheep (Ovis canadensis mexicana) are an important natural resource in the Pusch Ridge Wilderness (PRW), Santa Catalina Mountains, Arizona. Bighorn sheep historically inhabited many mountainous areas near Tucson, Arizona (Krausman 1997), but as the city of Tucson expanded, valleys between mountain ranges were developed resulting in disjunct, small populations of bighorn sheep. Today, 1 of the 2 remaining populations adjacent to the metropolitan area is found in the PRW, Santa Catalina Mountains. The PRW was established in 1978 through the Endangered American Wilderness Act to protect habitat for desert bighorn sheep (Krausman et al. 1979). In 1927 the population was estimated at 220 animals (Krausman et al. 1979). By 1993 the population declined to <20. The Arizona Game and Fish Department (AGFD) conducted a 5-hour helicopter survey in March 1994, located 9 sheep (J. Heffelfinger, AGFD, pers. commun.), and estimated the population at <20. We saw a total of 3 bighorn sheep (2 rams, 1 ewe) in 864 hours of observations from June 1995 to June 1996. In another AGFD survey in fall, 1996, no bighorn sheep were located, although there have been some verified reports from

November, 1996 of sheep in the area. In 1997 2 rams were observed. Based on this trend, the population is not likely viable, and probably nearing extinction.

Past studies of the population have been in 2 areas: sociology of human attitudes and biology of the herd. Sociological studies have been conducted to determine human attitudes toward the bighorn sheep population and to determine the activities of recreators in PRW (Burgarsky 1986, Harris and Shaw 1993, Harris et al. 1995, Krausman et al. 1979, Purdy and Shaw 1981). Support for the population is strong in Tucson. Residents 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 people to preserve the herd (Purdy and Shaw 1981, Harris and Shaw 1993). Harris and Shaw (1993) determined that >66% of homeowners who reside within 1.6 km of PRW were willing to give up their activities within PRW for the long-term survival of the sheep. Other studies looked at activities of recreators in the wilderness area. Purdy's (1981) study reported people day-hiking, overnight camping, horseback riding, backpacking, hunting, and rock climbing in PRW. Visitors to PRW also engaged in birdwatching, walking dogs, swimming, picnicking, and watching wildlife (Harris et al. 1995). Harris (1992) found at least 25% of individuals hiked or walked off designated trails. Although citizens of

Tucson value the population, the long-term future of bighorn sheep in PRW is not secure.

Several causes for the decline of the population have been proposed. Fire suppression has allowed vegetation to reduce the visibility of sheep (Krausman et al. 1996b). Bighorn sheep prefer grassy, open areas where they can detect predators rather than areas with dense vegetation that obscures visibility (Etchberger et al. 1990). Etchberger et al. (1989) found that sheep used areas where periodic fires burned and prevented visibility-obstructing vegetation from replacing grasslands. These investigations also noted that sheep abandoned some areas where fires were suppressed. Forage abundance is unlikely as a cause of decline. Mazaika et al. (1992) determined that forage quality and quantity are not limiting bighorn sheep in PRW, and recommended that habitat management for bighorn sheep should concentrate on factors other than availability and quality of forage.

Disturbance from hunting activities may be a factor in the decline of the population. When approached by humans, hunted populations of 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 hunting of the population is prohibited (Geist 1971, Hicks and Elder 1979). Between 1962 and 1981, 78

permits were issued for hunting sheep in the Santa Catalina Mountains and 23 rams were shot. From 1982 to 1992, 14 permits were issued and 14 rams were shot. The last ram was harvested in December 1992, and no additional permits have been issued. Although sheep hunting is no longer allowed in PRW, there are currently hunting seasons for desert mule deer (Odocoileus hemionus crooki), collared peccary (Tayassu tajacu), and quail (Callipepla spp.). Also, there are year-round open hunting seasons for mountain lion (Puma concolor) and coyote (Canis latrans). It is not known what effect these activities may have on sheep.

Noise disturbance to bighorn sheep in PRW could also be contributing to their decline. Excessive excitement (e.g., from noise and aircraft overflights) may cause stress and interfere with health, reproductive fitness, and growth (Geist 1971). However, evidence of disturbance to bighorn sheep from noise is conflicting. Bighorn sheep can become habituated to noise after repeated exposures (Krausman et al. 1992; Workman et al. 1992; Krausman et al. 1993 b, c, d; Weisenberger et al. 1996), and Krausman and Hervert (1983) reported bighorn sheep were undisturbed by overflights of small fixed-wing aircraft >100 m above ground level (agl). However, helicopters and low altitude aircraft create a different response. Helicopters caused negative behavioral responses in bighorn sheep (Bleich et al. 1990a, Stockwell et al. 1991) and low-altitude jet aircraft caused caribou

(Rangifer tarandus) to modify their activity budgets and daily movements (Murphy et al. 1993_{a,b}). Females with newborn calves were less tolerant of aircraft disturbance and moved away from disturbed areas (Murphy et al 1993_{a,b}). Habituation to intermittent noise and bursts of sound from 75-100 decibels (dB) (A-weighted scale: selectively discriminates against low and high frequencies) is gradual and minimal, and the greatest influence of noise is seen in females and lambs (Ames and Arehart 1992).

DeForge (1976) suggests that stress is a limiting factor on bighorn sheep. Stress may produce excessive stimulation of the endocrine system, thereby increasing mortality by lowering resistance to disease, infection, and parasites, inhibiting reproductive functions, and causing behavioral disturbances. Human disturbance can also have negative impacts on the energy budget of sheep (DeForge 1976). Human activities potentially disturbing to bighorn sheep in PRW include hiking and recreation, road building, trails, housing development, and hunting (Purdy 1981). Distance to human disturbance is a factor in whether bighorn sheep abandon areas (Etchberger et al. 1989), and bighorn sheep will alter behavior in response to construction activities (Leslie and Douglas 1980), traffic, and road building (Krausman and Leopold 1986). In addition, while studying heart rate response of sheep to human harassment (focusing on approaches by humans), MacArthur et al. (1982)

found that sheep experienced maximum heart rate response as opposed to minor heart rate response when the person approaching was accompanied by a dog or when the person approached from above. In PRW, Harris et al. (1995) reported that the annual estimated number of dogs in bighorn sheep habitat is 3,300 with 50% unleashed for all or part of the time. Canine leash laws exist in PRW but are ineffective due to lack of user compliance (U.S. Forest Service draft management options for desert bighorn sheep recovery in the Pusch Ridge Wilderness, Coronado National Forest, Tucson, 5pp., 1995). All of these activities may be causing disturbance to bighorn sheep in PRW.

Small populations of bighorn sheep are threatened by human destruction and disturbance of their habitat (Krausman and Leopold 1986). Berger (1990), Krausman et al. (1993a, 1996a), and Goodson (1994) indicate that small populations of mountain sheep require deliberate management to ensure persistence of the population. In addition, Bleich et al. (1990b) and Krausman (1997) suggest that areas between bighorn sheep habitat, "nontraditional habitat," need to be retained to connect intermountain ranges for bighorn sheep. Bighorn sheep habitat occurs in a naturally fragmented pattern with expanses of unsuitable habitat between suitable patches, and these intermountain areas need to be given conservation consideration along with the primary bighorn sheep habitat associated with steep mountains (Bleich et al.

1990b). Krausman (1997) further outlines the situation for bighorn sheep, and indicates that although metapopulations have not previously been discussed in the management of bighorn sheep in PRW, consideration to connectivity of habitat should be considered.

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 thorough literature search and documentation of historic range and habitats, a determination of causes of extinction or decline and removal of those factors, predator control if necessary, 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 extent of potentially disturbing human activity needs to be determined to manage the existing animals, and to determine if translocating more bighorn sheep to PRW is warranted. The factors limiting the herd need to be identified and addressed before translocation occurs.

Major increases in human recreational activity may have negative affects on sheep populations (Van Den Akker 1960, DeForge 1972). The PRW is 9 km from the center of Tucson and provides a unique outdoor recreation experience for visitors. As the population of Tucson expands, so will the

demand for more recreation areas, and bighorn sheep are being displaced from their habitat. Wildlife managers need reliable information about human activities in sheep habitat to better manage the sheep population in PRW.

Our objective was to determine and describe human recreational activity in bighorn sheep habitat in PRW. We also wanted to evaluate hunting activity to determine if hunters in pursuit of deer, quail, and collared peccary are hunting in bighorn sheep habitat. Finally, we wanted to determine noise levels and noise activity in PRW.

Study Area

The PRW encompasses 22,837 ha of wilderness in the southwest corner of the Santa Catalina Mountains, Coronado National Forest, Arizona. The wilderness area is adjacent to the city of Tucson, and several housing developments and a major resort border PRW. Construction on these projects began in 1986 and is still in progress. Elevations range from 905 to 1,710 m, and annual rainfall is about 27 cm. Mean temperatures range from about 16°C in winter to 30°C in summer. Topography of the area is rugged with vertical cliffs interspersed with deep canyons, eroded granitic outcrops and poorly developed soils. The dominant vegetation types are Sonoran desert scrub, semi-desert grassland and Madrean evergreen woodland. Vegetation associations of PRW were described by Gionfriddo and

Krausman (1986). Bighorn sheep currently use 4,700 ha in the southwest portion of PRW (deVos 1983, Gionfriddo and Krausman 1986). Further description of the study area is provided by Whittaker and Niering (1964, 1965), Krausman et al. (1979), deVos (1983), Gionfriddo and Krausman (1986), Etchberger et al. (1989, 1990), and Mazaika et al. (1992).

Methods

We selected 3 canyons representative of bighorn sheep use of PRW to collect data on human activity, hunting, and noise: Pima, Catchment, and Bighorn canyons. We compared all canyons in the area and selected canyons that varied in recreational activity and public access to get a representative sample of the area. The 3 canyons are areas where sheep occurred in recent years based on telemetry studies by deVos (1983) and Gionfriddo and Krausman (1986). Pima Canyon has heavy human traffic and 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 that Pima Canyon had 24,000 visitors/year in 1990.

Bighorn Canyon has a major resort at the base of the canyon, and provides hikers with a steep, rugged climb. The area has many wildcat trails also (wildcat trails are created by hiking off designated trails to form new trails that are not maintained). The base of Catchment Canyon has continuous construction activity on new homes that are part of a gated community, so access to the area is somewhat

limited to the general public. There are no hiking trails in Catchment Canyon except for an old U.S. Forest Service road that leads from the paved street approximately 500m to a water catchment.

We monitored human activity and noise in PRW from June 1995 to June 1996, hunting activity from October 1994 to March 1995, and took sound level meter readings from March to June, 1996. We evaluated 2 types of data: how many individuals entered the study area, and what types of activities occurred in the study area. We categorized data by the following variables: activity of individual(s), number of individuals, gender of individuals, 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.

Human Activity

We observed and recorded human activity from off-trail areas (≥ 20 m from an established trail) of bighorn sheep habitat in Bighorn, Pima, and Catchment canyons using 10x50 binoculars. We observed each of these 3 sample-areas from vantage points where we had the most visibility of the area and could remain out of sight of visitors. We recorded number of hiker-groups (i.e. a hiker-group is ≥ 1 person hiking), and presence of dogs in PRW. There are fewer

hikers on trails when ambient temperature in Tucson is high versus low (Harris 1992), therefore we made morning observations from 0600-1000 and afternoon observations from 1400-1800 in summer (Jun-Aug), and we made morning observations from 0800-1200 and afternoon observations from 1200-1600 in autumn (Sep-Nov), winter (Dec-Feb) and spring (Mar-May). We observed each of the 3 canyons 4 times/month (2 mornings and 2 afternoons) on weekdays, and 2 times/month on weekends (1 morning and 1 afternoon). Total observation hours/canyon/month was 24 (6 4-hour observation periods for each of the 3 canyons/month).

Hunting Activity

To evaluate possible disturbance to desert bighorn sheep caused by hunting quail, collared peccary, and deer in PRW, we monitored hunting activity for the first 3 days of each season when the most hunters are in the field (J. Heffelfinger, AGFD, pers. commun.). We made observations from sunrise until 4 hours after sunrise when hunters are most active (J. Heffelfinger, pers. commun.). We watched from vantage points in Pima, Catchment, and Bighorn canyons where we had the best view of the area. We recorded number of hunters seen, number of dogs, how far hunters wandered off trails, and number of shots. We used 10 x 50 binoculars when necessary to identify hunters as opposed to hikers. We collected data during hunting seasons for quail, collared peccary, and deer from October 1994 to March 1995. Although

we did not search for hunters for the first 3 days of each season in 1996, we looked for hunters throughout regular hiker observation periods that overlapped hunting seasons (as we glassed for recreational hiker-groups).

Sound Levels

To determine possible disturbance to desert bighorn sheep caused by noise, we used a digital sound level meter (Extech Instruments, model 407735, Taiwan) to measure noise levels in the canyons. We took readings at 1-minute intervals for 50 minutes to determine ambient sound pressure levels. We gathered ambient noise data for 31 days, from March to June, 1996. We recorded number of aircraft overflights and all other noise events that occurred during 4-hour observation periods from June 1995 to June 1996. We determined ambient noise levels on an A-weighted scale.

Results

Human Activity

We observed 711 hiker-groups in PRW: 126 groups consisting of 280 people hiked off trails into bighorn sheep habitat (18%). Eighty-two percent of hiker-groups remained on trails ($n = 585$). The majority of off-trail events occurred in Bighorn Canyon (82%, $n = 104$), with 10% occurring in Pima Canyon ($n = 12$), and 8% occurring in Catchment Canyon ($n = 10$). Hiker-groups engaged in a variety of activities in bighorn sheep habitat (Table 1). We evaluated each canyon independently and found that 100%

of the hiker-groups (\underline{n} =104, 230 individuals) in Bighorn canyon hiked off trail in bighorn sheep habitat. In Pima canyon we observed 594 hiker-groups consisting of 1,408 individuals hiking in the canyon and 12 hiker-groups (33 individuals) hiked off trail. In Catchment canyon we observed 13 hiker-groups (24 individuals) in the canyon and 10 hiker-groups went off trail (19 individuals).

The greatest use of bighorn sheep habitat by off-trail hikers was in February (Fig. 1), primarily by all male groups (58%, \underline{n} = 73). Only 6% of hiker-groups were all-female (\underline{n} = 8), and 36% were mixed male-female groups (\underline{n} = 45). Average group size of hiker-groups was 2.2 ± 0.2 (95% CI) (range=1-9). Use of bighorn sheep habitat by hiker-groups occurred 48% on weekdays (\underline{n} = 60), and 52% on weekends and holidays (\underline{n} = 66). Hiker-groups spent a minimum average of 94 ± 12 minutes in bighorn sheep habitat. Fifty-one percent of bighorn sheep habitat use by hiker-groups occurred in mornings (\underline{n} = 64), and 49% occurred in afternoons (\underline{n} = 62).

Dogs

Forty-four of the total hiker-groups observed using the wilderness area brought dogs with them and 10 of those groups went off trails in bighorn sheep habitat (23%). When we concentrated on just off-trail hiker-groups (\underline{n} = 126), 8% brought dogs with them (\underline{n} =10). We saw 3 dogs unaccompanied

by owners in bighorn sheep habitat during 12 months of daytime observations. All of the dogs in off-trail areas were off leashes.

Hunting Activity

The most hunting of quail, deer, and collared peccary in PRW occurred in Pima Canyon; 7 hunters were seen and 9 shots were heard from October 1994 to March 1995. No hunters were observed in Catchment or Bighorn canyons during observations, although 8 shots were heard in Catchment Canyon, and 2 shots were heard in Bighorn Canyon. No hunters were observed in 1996 in any of the canyons we surveyed.

Sound Levels

Average noise levels in the Pusch Ridge Wilderness ranged from 31 to 45 dBs (Table 2). Readings were taken at set 1-minute intervals, so decibel levels are averages, not peaks and lows. The highest noise level we recorded during intervals was 68 dBs. We identified noise events and recorded duration of those events during 206 observation periods and found that noises contributing to decibel levels in PRW include construction and loudspeaker noise, crowds cheering, sirens, dogs barking, gunshot-like bangs, horns honking, vehicle noise, sonic booms and the sound of ceremonial cannonball explosions (Table 3). We found that construction activity lasted an average of 170.2 ± 10.1

minutes/4-hour observation period, and sirens that were > 1 minute in duration lasted 3.8 ± 0.3 minutes/4-hour observation period.

We recorded number of aircraft overflights per 4-hour observation period to determine average frequency of aircraft flying over bighorn sheep habitat in PRW. We found that 11 ± 1.2 commercial jets or military aircraft, 6 ± 0.9 commuter/small aircraft, and an occasional helicopter (0.3 ± 0.1) flew over bighorn sheep habitat in a 4 hour observation period. None of the aircraft overflights were low to the ground, with the exception of a single helicopter during a 2-day search for a missing hiker.

Discussion

Human Activity

There is conflicting evidence about whether human activity disturbs bighorn sheep. In some studies sheep have acclimated to human activity (Hicks and Elder 1979, Hamilton et al. 1982), but in other studies behavior, movements, recruitment and lamb survival are negatively affected (Duncan 1960, DeForge 1972, MacArthur et al. 1982, Miller and Smith 1985). Bighorn coexist best with man when human use of sheep habitat is fairly predictable (Hamilton 1982). With 18% of trail users in PRW hiking off trails into sheep habitat, their movements are not predictable, suggesting that off-trail hiker activity may have a detrimental effect

on the bighorn sheep population. In March, 1996 the United States Forest Service implemented new regulations on use of PRW for hikers, such as eliminating use of the area by dogs and closing some areas to hikers during lambing season from January through June. They also set up informational bulletin boards at the trailheads of several canyons to let visitors know about the bighorn sheep, and how they can help conserve the population. However, these restrictions are voluntary and compliance with new rules is not enforced.

Although the potential habitat in PRW is substantially larger, nearly all sheep activity in recent years has occurred within a 17 km² area of habitat, which may be insufficient to sustain a viable population of animals. In computer simulations of bighorn sheep metapopulation dynamics, there is evidence that habitat patch size is relevant to long term survivorship, and can be a determining factor in survival of the population (Gross et al. 1997). In habitat patch sizes of <20 km², 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 hours and 50 minutes/4-hour observation period. Several studies have determined that construction activity changed watering behavior of bighorn sheep, which resulted in greater energy costs for sheep, 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 possibly altering foraging or watering behavior.

Dogs

Sayre (1996) evaluated responses of bighorn sheep to various disturbances and found that sheep fled on 78% of their encounters with coyotes. This strongly suggests that sheep are stressed by dogs. Also, dogs have been shown in other studies to cause negative responses in bighorn sheep (MacArthur et al. 1979, 1982; Stemp 1983). We found of the 126 off-trail hiker groups in bighorn sheep habitat, 10 of them had dogs with them, all off leashes, and we saw 3 dogs wandering the wilderness area with no owners. In addition to the presence of dogs, an average of 2 dogs per 4-hour observation period were heard barking in bighorn sheep habitat. The barking was from residential areas adjacent to PRW, but was audible in the wilderness area. Although we do not know whether sheep have the same negative response to dogs barking as they do to the presence of dogs, it may be a disturbance factor.

Hunting Activity

Hunting in the Pusch Ridge Wilderness of deer, quail and collared peccary is fairly insignificant today, although levels of hunting may have been higher in recent past years. The bighorn sheep population was hunted until 1992.

Previous studies indicate that hunted populations of bighorn sheep respond more negatively to human disturbance than unhunted populations (Geist 1971, King and Workman 1986, King 1984). Probably the high levels of hiker activity in the area, noise activity from planes flying overhead and dogs barking from the homes at the base of the ridge deter hunters seeking a true wilderness experience. Nonetheless, past hunting may have had a negative affect on the population by increasing the bighorns' wariness of humans.

Sound Levels

Noise levels in wilderness settings have been reported around 20 dB (Bowles 1995). Noise levels in PRW were higher, but still fairly low compared to levels that have found to be disturbing to bighorn sheep. Average decibel levels in PRW were generally <40.

Aircraft overflights in bighorn sheep habitat were common, but generally >100 m agl. Aircraft overflights that remain >100 m agl have been determined to 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. 1990a, Stockwell et al. 1991). There were 62 helicopters flying over bighorn sheep habitat in 206 4-hour observation periods, which may or may not be enough helicopter activity to impact the population. Only 2 of the helicopter flights were <100 m agl.

Management Implications

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). Where escape terrain is still available and the herd has somewhere to take refuge from humans, or if they have other means to avoid people, such as using salt licks or watering holes at different times to avoid humans, coexistence is possible (Hamilton 1982). In PRW, however, the bighorn sheep have no refuge from human contact. They are surrounded on all sides by heavy vegetation, homes, a resort, construction activity, or the city of Tucson (Krausman 1993). Because the population has been essentially fenced-in, hikers and dogs that enter their habitat, especially those that hike off trails in unpredictable fashion, may create a significant amount of stress for bighorn sheep.

Another important factor to consider is the cumulative effect of disturbance. 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). 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 been shown independently to have negative effects on bighorn sheep. It is likely that the cumulative affect 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 things are happening 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 probably not be able to attain nor maintain a viable population.

Desert bighorn sheep have many values other than hunting, including inspirational and aesthetic values, gaining knowledge about the habitat and habits of bighorn sheep, appreciation of the challenges of survival, and photography (Grater 1959). Although hunting desert bighorn sheep in PRW has been eliminated, the population has many other values to hikers and residents of metropolitan Tucson. Managers need to consider these other uses of the population

and manage the herd accordingly, and recognize that the population has economic value to the citizens of Tucson beyond hunting (Burgarsky 1986). Primarily, managers need to enforce the existing rules and regulations regarding trail closures and dog restrictions. The bighorn sheep in PRW have no alternative habitats to avoid disturbances, therefore, the disturbances need to be reduced if the population is to be protected or additional bighorn sheep are translocated to the area in the future.

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Table 1. Activities of 126 off-trail hiker-groups in
bighorn sheep habitat, Pusch Ridge Wilderness, Arizona.
Hiker-groups could have > 1 activity.

<u>Activity</u>	<u>N</u>	<u>%</u>
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 something	1	1
Identifying plants	1	1
Spitting	1	1

Table 2. Average decibel (dB) levels of noise recorded at 50, 1-minute intervals, Pusch Ridge Wilderness, Arizona.

<u>Level of time</u>	<u>\bar{X} db</u>	<u>95% CI</u>
Upper limit	45.4	± 3.3
Noise level 10% of time	36.8	± 1.2
Noise level 50% of time	33.3	± 0.7
Noise level 90% of time	31.3	± 0.7

Table 3. Average frequency of noises heard during 206 4-hour observation periods in the Pusch Ridge Wilderness, Arizona.

<u>Type of noise</u>	<u>No. occurrences</u>	<u>\bar{X} no. occurrences/ 4-hour period</u>	<u>95% CI</u>
Loudspeaker noise	89	0.4	± 0.2
Crowds cheering	17	0.1	$\pm .06$
Dogs barking	417	2.0	± 0.5
Loud vehicle noise	52	0.3	± 0.1
Sirens (<1 minute duration)	32	0.2	$\pm .06$
Horns honking	21	0.1	$\pm .06$
Gunshot-like bangs	154	0.7	± 0.4
Sonic booms	83	0.4	± 0.2
Ceremonial cannonball explosions	14 (single occasion)		

CONCLUSION

My study is one of a series of studies looking at human activities and disturbance in the Pusch Ridge Wilderness (PRW), Santa Catalina Mountains, Arizona. Researchers from The University of Arizona have been trying to determine the causes for decline of an indigenous population of desert bighorn sheep that inhabit the mountains near Tucson. My research and findings are a contribution to that pool of knowledge. I observed human activities in off-trail areas of bighorn sheep habitat in PRW from June 1995 to June 1996. I also recorded noise activity, and hunting activity in the area. There was very little hunting activity in bighorn sheep habitat, however, I observed 18% of all hiker-groups in the area hiking off trails into bighorn sheep habitat and 8% of off-trail hiker-groups were accompanied by dogs. Noise disturbance may also be contributing to the decline of the herd. The cumulative affect of many disturbance factors is probably responsible for the decreasing population. Based on the information gathered in this and previous studies, reintroduction of bighorn sheep into PRW should only occur if these disturbance factors are reduced or eliminated.