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SUMMER HABITAT USE BY MOUNTAIN SHEEP

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SUMMER HABITAT USE BY MOUNTAIN SHEEP

by

James P. Gionfriddo

A Thesis Submitted to the Faculty of the
SCHOOL OF RENEWABLE NATURAL RESOURCES
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE ECOLOGY
In the Graduate College
THE UNIVERSITY OF ARIZONA

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PREFACE

This thesis was prepared in the form of a manuscript written in a format which would facilitate immediate submission to a scientific journal for publication. The manuscript was written according to the format specifications of THE JOURNAL OF WILDLIFE MANAGEMENT.

Approval for presenting the thesis in this format was based upon (1) approval by the Graduate College, and (2) my graduate committee's agreement.

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SUMMER HABITAT USE BY MOUNTAIN SHEEP

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Abstract: Summer habitat use by mountain sheep (Ovis canadensis mexicana) was examined in the Santa Catalina Mountains near Tucson, Arizona during the summers of 1982 and 1983. Diurnal sheep activity concentrated in areas within 50 m of escape terrain. Sheep preferred semidesert grassland at the desert-oak woodland ecotone, especially on north and west aspects at the bases of large rocky cliffs. Slopes of 59-79% and elevations of 1098-1341 m were preferred on upper slopes of drainages or on the tops of ridges or mountains. Ewe-juvenile groups preferred more precipitous areas than ram bands and mixed groups. Groups with lambs used steeper and lower areas than groups without lambs.

Key words: aspect, bighorn sheep, elevation, habitat use, mountain sheep, slope steepness, topographic position, vegetative association.

Mountain sheep (Ovis canadensis) numbers and distribution in western North America have declined substantially during the past 150 years (Cowan 1940, Buechner 1960). Effective management of the remaining mountain sheep populations will be necessary to ensure their survival.

The key to successful management of mountain sheep is the identification, protection, maintenance, and enhancement of critical habitat (Wilson 1975, Wishart 1978). Although the general features characteristic of mountain sheep habitat are well known (Hansen 1980, Van Dyke et al. 1983), available information regarding the responses of mountain sheep to specific habitat components is limited. Detailed knowledge of habitat preferences and requirements is particularly important given the frequency of reintroductions and transplants of mountain sheep in recent years, and the species' apparently limited ability to disperse and pioneer new habitats (Geist 1967, 1971:125-128).

A remnant population of mountain sheep (O. c. mexicana) inhabiting the Pusch Ridge Wilderness (PRW) of the Santa Catalina Mountains near Tucson, Arizona (Fig. 1) provides a unique opportunity for the study of mountain sheep habitat use. Not only can PRW habitat use information be compared with data from other sheep populations, it can also, with periodic updating, be used to monitor the impact of extensive suburban development occurring immediately adjacent to mountain sheep range. PRW encompasses the southwestern corner of the Santa Catalina Mountains, which comprise a portion of the Coronado National Forest. Vast tracts of privately-owned land abutting the wilderness-national forest common boundary are undergoing development. This private land is within 0.6 km of the most heavily used mountain sheep habitat. A sprawling golf and tennis resort and a 2,225-ha state park were recently completed. Catalina State Park (Fig. 1) is expected to attract 180,000 visitors per year (Neil Donkersley, pers. commun.) and provides direct access to mountain sheep range in PRW via 2 major hiking trails. On days of peak

park visitation, an estimated 200-300 hikers enter PRW via Catalina State Park (Neil Donkersley, pers. commun.). Scheduled for construction on and around the foothills along the west edge of the study area are an industrial park and homes for over 9,000 people (S. Hagedorn, pers. commun.; J. Ulma, pers. commun.). Residential lots will border PRW, which has already been cited as an example of "wilderness trammled by man" (Zaslowsky 1984:29). Some residents will likely take frequent recreational hikes into the nearby canyons and mountains. The impact this human encroachment will have on mountain sheep abundance, distribution, and habitat use should be carefully monitored. The present study provides information on mountain sheep habitat use prior to this encroachment.

Financial support was provided by the Estes Company, the University of Arizona (UA) Graduate Student Program Development Fund, and the UA School of Renewable Natural Resources. Special thanks are due to my major advisor, Dr. P. R. Krausman, for his encouragement, guidance, and support throughout this project. I am also grateful to S. Seidler, who assisted tirelessly in all phases of the field work. I thank S. W. Carothers, R. W. Mannan, J. Rodiek, W. W. Shaw, and V. Supplee, who provided guidance throughout the study and offered constructive comments on an earlier draft of this manuscript. I also thank J. deVos, S. Lawry, R. Miller, and R. Olding of the Arizona Game and Fish Department and P. Karp and C. Kennedy of the USDA Forest Service for technical assistance. The cooperation and assistance of Catalina State Park Manager N. Donkersley is also appreciated. B. D. Leopold and M. C. Wallace provided statistical and technical advice. B. H. Smith typed

the manuscript and D. Shaw prepared the figures. Vegetation was sampled by J. Cashman, M. Cashman, J. Cole, D. Doan, and S. Seidler.

STUDY AREA

The study area is located in the western portion of PRW, 14 km northeast of downtown Tucson. It is bordered on the west and south by Tucson's metropolitan fringe. Elevations range from 850 m on the desert floor to 1910 m at the summit of Table Mountain. The study area is covered by shallow, rocky, poorly developed soils and massive, highly eroded granitic outcrops.

The study area experiences a semi-desert climate, with about half of the annual precipitation falling during the monsoon months of July, August, and September (Sellers and Hill 1974). These summer rains are typically associated with thunderstorms that develop in the flow of moist tropical air sweeping into Arizona from the Gulf of Mexico. Mean annual precipitation for the period 1949-1970 at the University of Arizona's Tucson Campbell Avenue Experimental Farm, located at an elevation of 710 m on the desert floor 8 km south of the study area, was 28.3 cm (Sellers and Hill 1974). During 1982 and 1983, the months of June and July were drier than the 22-year average (1949-1970), and the months of August and September were wetter (Fig. 2) (Sellers and Hill 1974; NOAA 1982, 1983). Mean monthly temperatures during the summers of 1982 and 1983 did not differ substantially from the 22-year averages (Fig. 3) (Sellers and Hill 1974; NOAA 1982, 1983).

Climatic conditions at higher elevations on the study area are generally cooler and wetter than those on the desert floor. Lowe (1964) cited several studies which demonstrated a 10-13 cm increase in annual

precipitation for each 305 m increase in elevation in the mountains of Arizona and other southwestern states.

Three major biotic communities are present on the study area: Sonoran desertscrub, semidesert grassland, and Madrean evergreen woodland (Brown et al. 1979). Sonoran desertscrub is represented at lower elevations and on southern aspects by palo-verde-saguaro (Cercidium microphyllum-Carnegiea gigantea) communities. At their upper elevational limits these communities intergrade with semidesert grassland, much of which has been invaded by Arizona rosewood (Vauquelinia californica) and/or evergreen oak (Quercus spp.) trees, in addition to numerous species of shrubs. At higher elevations, open evergreen oak woodland (Madrean evergreen woodland) predominates, with tree density increasing with elevation (Whittaker and Niering 1964). To the north and east of the study area, ponderosa pine (Pinus ponderosa)-mixed conifer forest covers the highest elevations in PRW. Detailed descriptions of the vegetation of the Santa Catalina Mountains may be found in Whittaker and Niering (1964, 1965) and McGinnes (1981).

Mountain sheep in PRW share their range with white-tailed deer (Odocoileus virginianus) and collared peccaries (Dicotyles tajacu). The lowest portions of mountain sheep range are shared with desert mule deer (O. hemionus). Livestock grazing has not been permitted in PRW since 1978, except on a small portion of the northwest corner of the wilderness.

The study area included that portion of mountain sheep range (deVos 1984) which could be monitored on foot with portable telemetry equipment.

METHODS

Five mountain sheep rams and six ewes were captured and equipped with radio telemetry collars in November 1981 and March 1982 by the Arizona Game and Fish Department (deVos 1984). From late May through September 1982, and from early May through September 1983 I located these collared sheep from the ground, using a model TR-2 receiver and a handheld, 2-element yagi directional antenna (Telonics Inc., Mesa, Arizona). Triangulation was hampered by rugged topography and dense vegetation. To ensure accurate locations of sheep only visual observations were used. While searching for radio-collared sheep I occasionally located groups of uncollared sheep and included such observations in this study.

Each group of sheep was observed for at least an hour, when possible. Data recorded for each observation included location, time of day, temperature, and group size and composition. Rams were classified into 5 age classes (Geist 1968); ewes were classified as yearling or adult.

I visited each sheep location and recorded the following data: vegetative association; slope steepness class (0-20%, 21-39%, 40-58%, 59-79%, 80-100%, 101-120%, $\geq 121\%$); aspect (1-120°, 121-240°, 241-360°); elevational class (≤ 975 m, 976-1097 m, 1098-1219 m, 1220-1341 m, 1342-1463 m, 1464-1585 m, ≥ 1586 m); topographic position (drainage bottom, lower slope, middle slope, upper slope, top of ridge or mountain); distance to escape terrain (m); and predominant overstory, understory, and graminoid species. Escape terrain was defined as steep, rocky,

broken terrain on which mountain sheep would be able to safely outmanuever or outdistance predators.

Vegetative associations were identified by ground reconnaissance. During June, July, and August 1982, and July and August 1983, perennial vegetation was sampled on at least 100 0.004-ha circular plots per vegetative association (to determine plant composition and density) and along at least 100 30.5-m line intercept transects per vegetative association (to measure thermal cover, defined as any vegetation beneath which a standing or bedded mountain sheep could seek shelter from direct sunlight). Riparian woodland was sampled by line intercept transects only. Botanical nomenclature follows Kearney and Peebles (1960).

Availability of various habitat components was determined by the non-mapping technique described by Marcum and Loftsgaarden (1980). I visited 385 random points on the study area and recorded the vegetative association, slope steepness, aspect, elevation, topographic position, and distance to escape terrain. Chi-square analysis was used to test the null hypothesis that PRW bighorn sheep used habitat components in proportion to their availability on the study area. Simultaneous confidence intervals were then constructed for the use proportions to determine whether sheep use of each value or class of each habitat component was significantly ($P = 0.05$) greater than or less than its availability (Neu et al. 1974, Byers et al. 1984).

To detect differences in habitat use among various types of mountain sheep social groups, each group observed was classified as a ram group, ewe-juvenile group, or mixed group, and also as a group with lambs or without lambs. Chi-square tests for differences in

probabilities (Conover 1980:153) were used to test the null hypotheses that there were no differences in summer habitat use among ram, ewe-juvenile, and mixed groups, and between groups with lambs and groups without lambs.

RESULTS

Vegetative Associations Available

Six major vegetative associations were identified on the 4,700-ha study area: Palo-verde-Saguaro Foothills (PSF), Palo-verde-Saguaro Desert Floor (PSDF), Palo-verde-Saguaro Mountain Slopes (PSMS), Non-precipitous Open Oak Woodland (NOOW), Precipitous Open Oak Woodland (POOW), and Riparian Woodland (RW) (Tables 1, 2).

Palo-verde-Saguaro Foothills association covers the series of low, rolling foothills along the western margin of the study area (Fig. 1). Palo-verde-Saguaro Desert Floor occurs to the east of these foothills, at their base, and extends into the mouths of several of the wide, west-draining canyons of the Santa Catalina Mountains (Fig. 1). Palo-verde-Saguaro Mountain Slopes association occurs on many of the lower, south-facing mountain slopes throughout the study area. Non-precipitous Open Oak Woodland includes pure and mixed open stands of evergreen oak or Arizona rosewood trees, on terrain of relatively gentle slope and configuration. At its lowest elevations this association includes tree-invaded semidesert grassland. Some NOOW sites are nearly covered with amole (Agave schottii) and Gnaphalium sp. Precipitous Open Oak Woodland differs from NOOW in that it includes those areas having extremely steep, craggy, or broken terrain. Soils are rockier and there is more exposed bedrock than on any other vegetative association on the

study area. Mexican pinyon pine (Pinus cembroides) and alligator juniper (Juniperus deppeana) are locally abundant in association with evergreen oaks, which generally predominate. Riparian Woodland occurs along watercourses in the larger, wetter drainages, where surface or subsurface flow is sufficient to support it. This broadleaf deciduous woodland is replaced at lower elevations and at other less mesic sites by riparian communities having an overstory of catclaw acacia (Acacia greggii), Arizona rosewood, Mexican blue oak (Quercus oblongifolia), and common mesquite (Prosopis juliflora).

Habitat Use by All Sheep Groups

Summer habitat use by mountain sheep was examined by analyzing observations of 234 sheep groups containing 1010 individuals. The six habitat variables tested were not used by sheep in proportion to their availability on the study area ($P < 0.00001$). Mountain sheep in PRW were not randomly distributed over the study area, but instead showed definite patterns of preference for specific classes or values of habitat components.

Non-precipitous Open Oak Woodland was preferred by sheep, while Palo-verde-Saguaro Foothills and Palo-verde-Saguaro Desert Floor were not used. The other vegetative associations were used in proportion to their availability on the study area (Table 3). Of 110 groups of sheep observed in NOOW, 94 (85%) were on sites located at the bases of large rocky cliffs. Areas within 150 m of cliff bases accounted for only 0.8% of the aerial surface on the study area, yet 40% of all sheep groups observed were using these sites. I sampled vegetation (100 0.004-ha circular plots and 3,048 m of line-intercept transects) on cliff base

sites throughout the study area. These sites were typically tree-invaded semidesert grassland at the lower fringe of evergreen oak distribution. Arizona rosewood and catclaw acacia were by far the predominant overstory species, followed by common mesquite, desert hackberry (Celtis pallida), and evergreen oaks. The extremely diverse understory included worm-wood (Artemisia ludoviciana), wild buckwheat (Eriogonum wrightii), globe mallow (Sphaeralcea spp.), turpentine-brush (Aplopappus laricifolius), prickly-pear (Opuntia engelmannii), and Gnaphalium sp. Thermal cover was sparse (15.5%).

Mountain sheep in PRW preferred areas having slopes of 59-79° (126 of 234 observations) and rarely used areas where slopes were less than 40° or greater than 120° (Table 4). Most sheep observed on extremely steep terrain were resting.

Northern, northwestern, and western aspects were strongly preferred (Table 5). Of 234 observations, 196 (84%) occurred on aspects having compass bearings between 241° and 360°. Other aspects received very light use, compared with their availability on the study area (Table 5).

Sheep did not often use elevations below 1098 m (17 of 234 observed groups) or above 1585 m (6 groups), and preferred elevations between 1098 m and 1341 m (Table 6). Topographically, sheep preferred the upper slopes of drainages and the tops of ridges and mountains. Use of other (lower) topographic positions was much less than their availability (Table 7).

Mountain sheep in PRW restricted their diurnal activities to those areas within or near escape terrain. Areas within 50 m of escape terrain were strongly preferred (219 of 234 observed groups), while

areas more distant were rarely used (Table 8). Over 80% (193) of all observed sheep groups were within 20 m of escape terrain.

In summary, during diurnal hours, mountain sheep in PRW used sites within 50 m of escape terrain. The Non-precipitous Open Oak Woodland vegetative association, slopes of 59-79%, north and west aspects, and elevations of 1098-1341 m were used in greater proportions ($P < 0.00001$) than their availability.

Habitat Use by Social Groups

Chi-square analysis showed a significant ($P < 0.01$) difference in the use of vegetative associations by ram bands, ewe-juvenile groups, and mixed groups. Ram bands ($n = 62$) and mixed groups ($n = 122$) preferred Non-precipitous Open Oak Woodland, while ewe-juvenile groups ($n = 40$) preferred Precipitous Open Oak Woodland. Use of the other 4 vegetative associations did not differ significantly ($P < 0.01$) among these 3 types of sheep groups.

Use of elevational classes by ram groups, ewe-juvenile groups, and mixed groups was significantly ($P < 0.001$) different. Rams preferred both middle and higher elevations, while mixed groups preferred only middle elevations. Ewe-juvenile groups used all middle and higher elevational classes in proportion to their availability. Use of lower elevations was very light by all 3 types of sheep groups.

With respect to slope steepness, aspect, topographic position, and distance to escape terrain, differences in summer habitat use among ram bands, ewe-juvenile groups, and mixed groups were not significantly ($P < 0.05$) different.

Sheep groups with lambs ($n = 92$) used steeper slopes and lower elevations than groups without lambs ($n = 142$). Differences in use of vegetative associations, aspects, topographic positions, and distance to escape terrain were not statistically significant ($P < 0.10$) for these 2 types of sheep groups.

DISCUSSION

Most descriptions of the general features of bighorn sheep habitat depict open landscapes with stable plant communities dominated by grasses and low-growing herbs and shrubs, with steep, broken terrain nearby. Structural openness of the vegetation and the proximity of precipitous escape terrain are emphasized.

Mountain sheep avoid tall, dense vegetation, including dense woodlands and forest. Such behavior influences sheep selection of forage areas (Oldemeyer et al. 1971, Shannon et al. 1975, Hicks and Elder 1979), water sources (Turner and Weaver 1980), and migration routes (McCann 1956, Geist 1967, Martin 1981). Shannon et al. (1975) and Tilton and Willard (1982) suggested that heavily-timbered areas may not be used because they offer less forage than other vegetation types. A more important factor, however, may be the reduced visibility these areas impose upon sheep (Risenhoover and Bailey 1980). The discovery that mountain sheep heart rates were higher when sheep moved through timber than when they moved across open slopes (MacArthur et al. 1979) supports the latter contention.

The predator-evasion strategy of mountain sheep is based on their ability to detect predators visually, alert other group members via attention or alarm postures (Geist 1971:132-133), and quickly dash to

nearby escape terrain if necessary. Visibility is thus important both in detecting predators and in communication among sheep in a group. In open habitats offering good visibility, a large group of sheep may spread out while foraging and thereby detect predators over a large area. Foraging efficiency is maximized under such conditions, as each individual is able to spend more time feeding and less time scanning for predators and watching other sheep for signs of danger (Berger 1978). Intragroup competition for forage plants is also reduced.

When sheep forage in areas of relatively poor visibility, they must remain closer together to maintain visual contact. Predators can be detected over a comparatively small area, and intragroup social interactions and competition for forage increase, reducing foraging efficiency (Risenhoover and Bailey 1980).

The importance of maintaining open landscapes through vegetation control on sheep ranges has been recognized (Wilson 1975, Wishart 1975, Wilson et al. 1980). Management practices such as controlled burning may enhance visibility and forage availability and thus may promote use of areas not previously used by sheep (Peek et al. 1979, Graf 1980, Risenhoover and Bailey 1980, Martin 1983).

In PRW, fire suppression has eliminated fire as a natural ecosystem component since 1940 (USDA Forest Service 1979). As a result, periodic lightning-caused fires, which had previously maintained semidesert grassland conditions over large areas in PRW, no longer curb the invasion of grassland by tree and shrub species more common at higher elevations. This woodland expansion, and dramatic increases in man's activities in other portions of the Santa Catalina Mountains, have

caused serious reductions in the range and abundance of PRW mountain sheep (Krausman et al. 1979). Estimated at 220 sheep and considered the largest mountain sheep population in the state in 1926 (Buechner 1960), the PRW population today comprises 50-70 sheep (Krausman et al. 1979, deVos 1984) and is using only the extreme western edge of the range it occupied 50 years ago (Krausman et al. 1979).

As noted earlier, precipitous escape terrain is a common feature of all mountain sheep ranges, and its importance cannot be overemphasized. Van Dyke et al. (1983:6) concluded that "The distribution of escape terrain regulates the extent to which other habitat components are used." Several other authors have cited escape terrain as one of the principal factors affecting mountain sheep distribution (Robinson and Cronemiller 1954, McQuivey 1978, Bates and Workman 1983, Elenowitz 1983). In the San Andres Mountains of New Mexico, Sandoval [1979, cited by Elenowitz (1983)] found that areas lacking escape terrain, but otherwise constituting optimum mountain sheep habitat, were not used by sheep. Elenowitz (1983) noted that 91% of the sheep groups she observed in New Mexico's Peloncillo Mountains were within 75 m of escape terrain, and attributed the lack of sheep use of grassland on her study area to the absence of escape terrain in that vegetation type. Oldemeyer et al. (1971) reported that 86% of the mountain sheep they observed on winter range in Yellowstone National Park were within 91 m of escape terrain. Only 1 of 1319 sheep observed in Canyonlands National Park, Utah was more than 0.6 km from escape terrain (Bates and Workman 1983). Similar dependence of mountain sheep on escape terrain has been reported in many other sheep populations (Robinson and Cronemiller 1954, Shannon et al.

1975, Martin 1981, Tilton and Willard 1982). The dependence of PRW mountain sheep on escape terrain is therefore not surprising, particularly for a hunted population on a range receiving heavy recreational use. Mountain sheep in PRW are the only huntable population of O. c. mexicana in the National Forest system (USDA Forest Service 1979).

Use of Vegetative Associations

Mountain sheep in PRW live at the desert/oak woodland ecotone and use both vegetative formations. As is common for mountain sheep, requirements for survival are met through the use of several vegetative associations. Most strongly preferred are semidesert grassland areas on northern and western exposures, at the bases of large rocky cliffs. Several factors may account for this preference. First, escape terrain is readily accessible (cliffs are very steep, but most are at least partially ascendable by mountain sheep). Second, predators cannot approach sheep on these sites from above. Mountain sheep are more nervous when approached from above than from other directions (Graham 1980). Third, most of the rain falling against these massive rocky cliffs trickles to the soil at their bases. As a result, plant growth is comparatively lush. Finally, due to their exposures, many of these sites are shaded by cliffs throughout much or all of the day. During summers these cliff base sites constitute microhabitats cooler and moister than surrounding areas, with lush stands of low-growing perennial bunchgrasses, herbs and shrubs, plus a few scattered trees. Mountain sheep in PRW may be able to reduce thermoregulatory energy expenditures by foraging and resting in these areas.

That PRW sheep used Riparian Woodland in proportion to its availability on the study area is due to the very limited availability of such habitat, and the observation of 9 groups of sheep using dry desert washes (here considered a type of Riparian Woodland). Mountain sheep were never observed using Populus-Fraxinus-Salix riparian zones. Sheep may visit such areas at night to avoid encounters with hikers on trails which follow watercourses into the mountains (especially in Pima Canyon and Romero Canyon - see Fig. 1). Unfortunately, many overnight visitors to PRW camp next to streams (cf. Hicks and Elder 1979). Mountain sheep are selective in their use of water sources (Blong and Pollard 1968; Leslie and Douglas 1979, 1980; Campbell and Remington 1981; Elenowitz 1983) and may not use riparian zones in PRW because of the frequent presence of humans. Tall, dense vegetation at many of the most mesic riparian sites in PRW may also discourage sheep use (Krausman et al. 1979, Turner and Weaver 1980).

Of the 4 water developments located on the study area, 2 are within 200 m of future residential areas. The other 2 are in relatively remote mountain settings but are surrounded by dense woodland which may affect sheep use. Removal of some of these trees and development of additional backcountry water sources may be beneficial to PRW bighorn sheep.

Use of Other Habitat Components

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 the steepness, elevation, or topographic position per se (Shannon et al. 1975, Elenowitz 1983). For example, mountain sheep in PRW may not use

relatively flat areas (slopes < 40%) and low elevations (<1098 m) because such areas are generally too far from escape terrain. Similarly, lack of use of very steep (slopes > 120%) and very high (>1585 m) areas may be due to limited visibility and forage availability in such areas.

Shade was sought by mountain sheep in all vegetative associations as a means of moderating the effects of high temperatures. Geomorphic features and vegetation provided shaded foraging and bedding sites throughout the day on all aspects, with northern aspects offering the most consistent sources of shade. The importance of shade to desert mountain sheep has been well documented (Welles and Welles 1961, Leslie and Douglas 1979, Hansen 1980).

Habitat Use by Sex

Differences in use of habitat by mountain sheep rams and ewes are common (Tilton and Willard 1982, Bates and Workman 1983). Ewe-juvenile groups are often found on more rugged, precipitous terrain than ram bands (Blood 1963, Woolf et al. 1970, Geist and Petocz 1977, Leslie and Douglas 1979). Summer habitat use by mountain sheep in PRW followed this pattern. Ewe-juvenile groups preferred Precipitous Open Oak Woodland, and ram bands preferred Non-precipitous Open Oak Woodland. Although adult rams were commonly seen with ewe-juvenile groups during May and June, some segregation of rams and ewes was evident until the onset of the rut in July. Thereafter, mixed groups predominated.

Noting that Rocky Mountain bighorn (O. c. canadensis) rams and ewes on winter range were segregated both geographically and by habitat use, Geist and Petocz (1977) suggested that rams may segregate themselves

from ewes to minimize competition and disturbances for the mothers of their prospective offspring. Although the same advantage would exist for desert mountain sheep in PRW during early summer, it seems likely that ewes select more precipitous areas to minimize the chances of losing their lambs to predation. The latter hypothesis is supported by my finding that groups with lambs generally used steeper slopes than groups without lambs.

Management Considerations

The PRW mountain sheep population will face a critical test of its ability to withstand human encroachment. Some sheep populations and some individuals within populations seem better able than others to tolerate man's presence and activities. Although some sheep may become habituated to common human-related stimuli (Hicks and Elder 1979, MacArthur et al. 1982), others may temporarily or permanently abandon areas invaded by man (Welles and Welles 1961, Dunaway 1971, Ferrier 1974, Campbell and Remington 1981).

Several years ago, PRW received over 34,000 recreational visitors annually (Purdy and Shaw 1981). Visitation rates are certain to increase dramatically in the next few years. Although Purdy and Shaw (1981) found that survey respondents, given a hypothetically declining PRW sheep population, favored the implementation of mandatory restrictions on recreational use in specified mountain sheep habitat areas during critical seasons of the year, it is not clear whether such restrictions, if implemented, would be heeded. Hicks and Elder (1979) reported that 66% of the 35 groups of hikers they interviewed in California's Sierra Nevada Mountains stated that they had engaged in

some form of (prohibited) off-trail activity. In PRW, where only 8% of surveyed recreational users have claimed to have ever seen a mountain sheep (Purdy and Shaw 1981), it may be difficult to convince recreationists of the need to impose and obey use restrictions.

The timely implementation of a program of habitat rehabilitation through prescribed burning, and a well-planned and well-enforced set of recreational use restrictions may be necessary to improve the chances of long-term survival of mountain sheep in PRW. In addition, a close monitoring of the population's responses to any such management actions, and to the nearby suburban development, should be undertaken.

LITERATURE CITED

- Bates, J. W., Jr., and G. W. Workman. 1983. Desert bighorn sheep habitat utilization in Canyonlands National Park. Desert Bighorn Counc. Trans. 27:25-28.
- Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Behav. Ecol. Sociobiol. 4:91-99.
- Blong, B., and W. Pollard. 1968. Summer water requirements of desert bighorn sheep in the Santa Rosa Mountains, California, in 1965. Calif. Fish and Game 54:289-296.
- Blood, D. A. 1963. Some aspects of behavior of a bighorn herd. Can. Field Nat. 77(2):77-94.
- Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. Ariz.-Nev. Acad. Sci. 14 (Suppl. 1):1-16.

- Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. 4:1-174.
- Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage 48:1050-1053.
- Campbell, B., and R. Remington. 1981. Influence of construction activities on water-use patterns of desert bighorn sheep. Wildl. Soc. Bull. 9:63-65.
- Conover, W. J. 1980. Practical nonparametric statistics. 2nd ed. John Wiley and Sons, New York. 493pp.
- Cowan, I. M. 1940. Distribution and variation in the native sheep of North America. Am. Midl. Nat. 24:505-580.
- deVos, J. C., Jr. 1984. Desert bighorn sheep in the Pusch Ridge Wilderness Area. Desert Bighorn Counc. Trans. 28:in press.
- Dunaway, D. J. 1971. Bighorn sheep habitat management in the Inyo National Forest, a new approach. Desert Bighorn Counc. Trans. 15:18-23.
- Elenowitz, A. S. 1983. Habitat use and population dynamics of transplanted desert bighorn sheep in the Peloncillo Mountains, New Mexico. M.S. Thesis, N.M. State Univ., Las Cruces. 158pp.
- Ferrier, G. J. 1974. Bighorn sheep along the lower Colorado River: 1974 and 2050. Desert Bighorn Counc. Trans. 18:40-45.
- Geist, V. 1967. A consequence of togetherness. Nat. Hist. 76(8):24-31.
- _____. 1968. On the interrelation of external appearance, social behavior and social structure of mountain sheep. Z. Tierpsychol.

25:199-215.

_____, 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, Chicago. 383pp.

_____, and R. G. Petocz. 1977. Bighorn sheep in winter: do rams maximize reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.

Graf, W. 1980. Habitat protection and improvement. Pages 310-319 in G. Monson and L. Sumner, eds. The desert bighorn: its life history, ecology, and management. Univ. Ariz. Press, Tucson.

Graham, H. 1980. The impact of modern man. Pages 288-309 in G. Monson and L. Sumner, eds. The desert bighorn: its life history, ecology, and management. Univ. Ariz. Press, Tucson.

Hansen, C. G. 1980. Habitat. Pages 64-79 in G. Monson and L. Sumner, eds. The desert bighorn: its life history, ecology, and management. Univ. Ariz. Press, Tucson.

Hicks, L. L., and J. M. Elder. 1979. Human disturbance of Sierra Nevada bighorn sheep. J. Wildl. Manage. 43:909-915.

Kearney, T. H., and R. H. Peebles. 1960. Arizona flora. 2nd ed. Univ. Calif. Press, Berkeley. 1085pp.

Krausman, P. R., W. W. Shaw, and J. L. Stair. 1979. Bighorn sheep in the Pusch Ridge Wilderness Area, Arizona. Desert Bighorn Council. Trans. 23:40-46.

Leslie, D. M., and C. L. Douglas. 1979. Desert bighorn sheep of the River Mountains, Nevada. Wildl. Monogr. 66:1-56.

_____, and _____. 1980. Human disturbance at water sources of desert bighorn sheep. Wildl. Soc. Bull. 8:284-290.

- Lowe, C. H. 1964. Arizona's natural environment. Univ. Ariz. Press, Tucson. 136pp.
- MacArthur, R. A., R. H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Can. J. Zool. 57:2010-2021.
- _____, V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manage. 46:351-358.
- Marcum, C. L., and D. O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. J. Wildl. Manage. 44:963-968.
- Martin, S. A. 1981. Summer and fall habitat use and migration patterns of the Rock Creek segment of the Beartooth sheep herd. Mont. Dep. Fish, Wildl., and Parks, Fed. Aid Proj. BG-7.1-2.
- Martin, S. C. 1983. Responses of semidesert grasses and shrubs to fall burning. J. Range Manage. 36:604-610.
- McCann, L. J. 1956. Ecology of the mountain sheep. Am. Midl. Nat. 56:297-324.
- McGinnes, W. G. 1981. Discovering the desert. Univ. Ariz. Press, Tucson. 276pp.
- McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nev. Dep. Fish and Game, Reno. Biol. Bull. 6:1-81.
- Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.
- National Oceanic and Atmospheric Administration. (NOAA). 1982, 1983.

- Climatological data, Arizona. Environ. Data Serv., Asheville, N.C., vols. 86-87.
- Oldemeyer, 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.
- Peek, J. M., R. A. Riggs, and J. L. Lauer. 1979. Evaluation of fall burning on bighorn sheep winter range. J. Range Manage. 32:430-432.
- Purdy, K. G., and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: the Pusch Ridge Wilderness case. Desert Bighorn Counc. Trans. 25:1-5.
- Risenhoover, K. L., and J. A. Bailey. 1980. Visibility an important factor for an indigenous, low-elevation bighorn herd in Colorado. Proc. Biennial Symp. North. Wild Sheep and Goat Counc., Salmon, Idaho:18-28.
- Robinson, C. S., and F. P. Cronemiller. 1954. Notes on the habitat of the desert bighorn in the San Gabriel Mountains of California. Calif. Fish and Game 40:267-271.
- Sandoval, A. V. 1979. Preferred habitat of desert bighorn sheep in the San Andres Mountains, New Mexico. M.S. Thesis, Colo. State Univ., Fort Collins. 314pp. Cited in Elenowitz (1983).
- Sellers, W. D., and R. H. Hill, eds. 1974. Arizona climate: 1931-1972. 2nd ed. Univ. Ariz. Press, Tucson. 616pp.
- Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39:387-401.

- Tilton, M. E., and E. E. Willard. 1982. Winter habitat selection by mountain sheep. *J. Wildl. Manage.* 46:359-366.
- Turner, J. C., and R. A. Weaver. 1980. Water. Pages 100-112 in G. Monson and L. Sumner, eds. *The desert bighorn: its life history, ecology, and management.* Univ. Ariz. Press, Tucson.
- USDA Forest Service. 1979. Pusch Ridge Wilderness management plan. Coronado Natl. For. 138pp.
- Van Dyke, W. A., A. Sands, J. Yoakum, A. Polenz, and J. Blaisdell. 1983. Wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon: bighorn sheep. Pacific Northwest For. and Range Exp. Sta., Gen. Tech. Rep. PNW-159.
- Welles, R. E., and F. B. Welles. 1961. The bighorn of Death Valley. *U.S. Natl. Park Serv., Fauna Ser.* 6:1-242.
- Whittaker, R. H., and W. A. Niering. 1964. Vegetation of the Santa Catalina Mountains, Arizona. I. Ecological classification and distribution of species. *J. Ariz. Acad. Sci.* 8:9-34.
- _____, and _____. 1965. Vegetation of the Santa Catalina Mountains, Arizona: a gradient analysis of the south slope. *Ecology* 46:429-452.
- Wilson, L. O. 1975. Report and recommendations of the desert and Mexican bighorn sheep workshop group. Pages 110-131 in J. B. Trefethen, ed. *The wild sheep in modern North America.* Winchester Press, New York.
- _____, J. Blaisdell, G. Welsh, R. Weaver, R. Brigham, W. Kelly, J. Yoakum, M. Hinks, J. Turner, and J. DeForge. 1980. Desert bighorn habitat requirements and management recommendations. Desert

- Bighorn Counc. Trans. 24:1-7.
- Wishart, W. 1975. Report and recommendations of the Rocky Mountain bighorn workshop group. Pages 165-207 in J. B. Trefethen, ed. The wild sheep in modern North America. Winchester Press, New York.
- _____. 1978. Bighorn sheep. Pages 161-171 in J. L. Schmidt and D. L. Gilbert, eds. Big game of North America: ecology and management. Stackpole Books, Harrisburg, Pa.
- Woolf, A., T. O'Shea, and D. L. Gilbert. 1970. Movements and behavior of bighorn sheep on summer ranges in Yellowstone National Park. J. Wildl. Manage. 34:446-450.
- Zaslowsky, D. 1984. Managing the dream. Wilderness 48(165):27-33.

Table 1. Characteristics of 6 vegetative associations in Pusch Ridge Wilderness, Arizona.

Vegetation association	Number of plots sampled	Total perennial plant density ^a	Tree density	Shrub density	Succulent density	Forb density	Grass density	Thermal cover (%)
Palo-verde-Saguaro Foothills	100	68,782	1,114	26,915	1,527	1,468	37,758	24.7
Palo-verde-Saguaro Desert Floor	100	34,447	1,063	17,139	1,038	1,789	13,418	20.9
Palo-verde-Saguaro Mountain Slopes	100	24,315	472	14,097	1,584	2,150	6,012	31.6
Non-precipitous Open Oak Woodland	205	57,094	217	6,850	24,308	13,430	12,289	15.1
Precipitous Open Oak Woodland	200	40,635	739	6,150	15,933	6,323	11,490	38.9
Riparian Woodland	0							44.2

^a Density = plants/ha

Table 2. Overstory and understory dominants of 6 vegetative associations in Pusch Ridge Wilderness, Arizona.

Vegetative Association	Proportion of study area (%)	Overstory dominants ^a	Understory dominants ^a
Palo-verde- Saguaro Foothills	20.3	<u>Cercidium microphyllum</u> <u>Acacia greggii</u> <u>Prosopis juliflora</u> <u>Celtis pallida</u> <u>Carnegiea gigantea</u>	<u>Calliandra eriophylla</u> <u>Opuntia engelmannii</u> <u>Janusia gracilis</u> <u>Porophyllum gracile</u> <u>Jatropha cardiophylla</u>
Palo-verde- Saguaro Desert Floor	6.8	<u>Acacia greggii</u> <u>Cercidium microphyllum</u> <u>Prosopis juliflora</u> <u>Carnegiea gigantea</u> <u>Celtis pallida</u>	<u>Calliandra eriophylla</u> <u>Janusia gracilis</u> <u>Opuntia engelmannii</u> <u>Jatropha cardiophylla</u> <u>Aplopappus laricifolius</u>
Palo-verde- Saguaro Mountain Slopes	16.6	<u>Coursetia microphylla</u> <u>Acacia greggii</u> <u>Carnegiea gigantea</u> <u>Cercidium microphyllum</u> <u>Celtis pallida</u>	<u>Janusia gracilis</u> <u>Selaginella</u> spp. <u>Calliandra eriophylla</u> <u>Opuntia engelmannii</u> <u>Fouquieria splendens</u>

Table 2. Continued.

Vegetative Association	Proportion of study area (%)	Overstory dominants ^a	Understory dominants ^a
Non-Precipitous	16.9	<u>Quercus oblongifolia</u>	<u>Agave schottii</u>
		<u>Vauquelinia californica</u>	<u>Gnaphalium</u> sp.
Open Oak		<u>Q. emoryi</u>	<u>Calliandra eriophylla</u>
Woodland			<u>Dasyllirion wheeleri</u>
			<u>Artemisia ludoviciana</u>
			<u>Eriogonum wrightii</u>
			<u>Opuntia engelmannii</u>
Precipitous	36.1	<u>Quercus emoryi</u>	<u>Dasyllirion wheeleri</u>
Open Oak		<u>Q. oblongifolia</u>	<u>Agave schottii</u>
Woodland		<u>Vauquelinia californica</u>	<u>Gnaphalium</u> sp.
		<u>Q. arizonica</u>	<u>Selaginella</u> spp.
		<u>Q. turbinella</u>	<u>Nolina microcarpa</u>
			<u>Arctostaphylos pungens</u>
Riparian	3.4	<u>Fraxinus velutina</u>	<u>Baccharis sarothroides</u>
Woodland		<u>Populus fremontii</u>	<u>Dodonaea viscosa</u>
		<u>Quercus oblongifolia</u>	<u>Dasyllirion wheeleri</u>
		<u>Platanus wrightii</u>	<u>Aplopappus laricifolius</u>
		<u>Salix</u> spp.	<u>Franseria ambrosioides</u>

^a Within each vegetative association, plant species are listed in order of decreasing frequency on sampled plots.

Table 3. Summer use of 6 vegetative associations by mountain sheep in Pusch Ridge Wilderness, Arizona, 1982-1983.

Vegetative association	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
Palo-verde-Saguaro Foothills	20.3	0	0	<
Palo-verde-Saguaro Desert Floor	6.8	0	0	<
Palo-verde-Saguaro Mountain Slopes	16.6	14.5	34	=
Non-precipitous Open Oak Woodland	16.9	47.0	110	>
Precipitous Open Oak Woodland	36.1	35.5	83	=
Riparian Woodland	3.4	3.0	7	=

^a N = 234, χ^2 (goodness of fit) = 189.72, 5 d.f., $\underline{p} < 0.00001$

Table 4. Summer use of slopes by mountain sheep in Pusch Ridge Wilderness, Arizona, 1982-1983.

Slope Steepness (%)	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
0-20	12.5	0.9	2	<
21-39	18.7	6.4	15	<
40-58	22.6	20.9	49	=
59-79	23.6	53.8	126	>
80-100	9.9	14.5	34	=
101-120	2.6	0.9	2	=
<u>>121</u>	10.1	2.6	6	<

^a N = 234, χ^2 (goodness of fit) = 155.94, 6 d.f., $\underline{P} < 0.00001$

Table 5. Summer use of aspects by mountain sheep in Pusch Ridge Wilderness, Arizona, 1982-1983.

Aspect (degrees)	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
1-120	25.7	10.7	25	<
121-240	26.8	5.6	13	<
241-360	47.5	83.8	196	>

^a N = 234, χ^2 (goodness of fit) = 124.46, 2 d.f., $\underline{p} < 0.00001$

Table 6. Summer use of elevational classes by mountain sheep in Pusch Ridge Wilderness, Arizona, 1982-1983.

Elevation (m)	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
<975	29.4	0.9	2	<
976-1097	11.9	6.4	15	<
1098-1219	13.2	25.6	60	>
1220-1341	14.0	27.4	64	>
1342-1463	14.0	19.7	46	=
1464-1585	11.9	17.5	41	=
>1586	5.5	2.6	6	<

^a N = 234, χ^2 (goodness of fit) = 142.45, 6 d.f., $\underline{P} < 0.00001$

Table 7. Summer use of topographic positions by mountain sheep in Pusch Ridge Wilderness, Arizona, 1982-1983.

Topographic position	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
Drainage bottom	7.8	2.6	6	<
Lower slope	32.2	2.1	5	<
Middle slope	24.2	9.0	21	<
Upper slope	25.2	68.8	161	>
Top of ridge or mountain	10.6	17.5	41	>

^a N = 234, χ^2 (goodness of fit) = 283.20, 4 d.f., $\underline{P} < 0.0001$

Table 8. Summer occurrence of mountain sheep at various distances from escape terrain in Pusch Ridge Wilderness, Arizona, 1982-1983.

Distance from escape terrain (m)	Proportion of study area (%)	Proportion of group observations (%)	Number of groups observed	Use in relation to availability ^a
0-50	54.5	93.6	219	>
51-100	15.8	5.6	13	<
<u>>101</u>	29.6	0.9	2	<

^a N = 234, χ^2 (goodness of fit) = 146.37, 2 d.f., $\underline{P} < 0.0001$

Fig. 1. Study area, Pusch Ridge Wilderness, Coronado National Forest, Arizona.

Fig. 2. Mean monthly temperatures ($^{\circ}\text{C}$) compared to 22-year means at University of Arizona Tucson Campbell Avenue Experimental Farm, 8 km south of study area.

Fig. 3. Mean monthly precipitation (cm) compared to 22-year means at University of Arizona Tucson Campbell Avenue Experimental Farm, 8 km south of study area.