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HABITAT USE BY DESERT BIGHORN SHEEP IN SONORA, MEXICO

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ABSTRACT.– The use of habitat components by desert bighorn sheep (Ovis canadensis) *was examined to explain sexual segregation of sheep in Sierra el Viejo, Sonora, Mexico. We evaluated 265 plots used by bighorns and 278 random plots from April 1997 to December 1998. Groups of segregated males and females preferred the elephant tree* (Bursera microphylla)*-salvia* (Salvia mellifera)*-limber bush* (Jatropha cuneata) *association (ESL) and avoided the foothill palo verde* (Cercidium microphyllum)*-desert ironwood* (Olneya tesota) *association (FDI). Segregated females selected the ocotillo* (Fouquieria splendens)*-desert agave* (Agave spp.)*-hop bush* (Dodonoea viscosa) *(OAH) vegetation association, formed larger groups, were closer to escape terrain, and occupied more rugged areas during autumn and spring than males. Segregated females selected areas that provided more opportunities to evade predation than did males.*

RÉSUMÉ.– Nous avons étudié les différents composants de l'utilisation de l'habitat par le mouflon américain (Ovis canadensis) *afin d'expliquer sa ségrégation sexuelle dans la Sierra el Viejo, à Sonora, Mexique. D'avril 1997 à Décembre 1998, on a évalué 265 parcelles utilisées par les mouflons et 278 parcelles au hasard. Différents groupes séparés de mâles et femelles préféraient l'association (ESL) formée par l'arbre* Bursera microphylla, *la sauge* (Salvia mellifera) *et l'arbuste* Jatropa cuneata *et ils évitaient l'association (FDI) composée du* Cercidium microphyllum *et l'*Olneya tesota. *Les groupes de femelles sélectionaient l'association végétale (OAH) de* Fouquieria splendens, Agave spp. *et l'arbuste* Dodonoea viscosa; *et par rapport aux mâles, elles formaient de plus grands groupes, étaient plus proches de la zone de fuite et elles occupaient des terrains plus accidentés en automne et au printemps. Les groupes de femelles, plus que les mâles, cherchaient des zones avec moins de risque de prédation.*

RESUMEN.– Se examinó el uso del hábitat del muflón americano Ovis canadensis *para explicar su segregación sexual en Sierra el Viejo, Sonora, Méjico. Se*

establecieron 265 parcelas usadas por el muflón y 278 tomadas al azar, desde abril de 1997 hasta diciembre de 1998. Los grupos segregados de machos y hembras prefirieron la asociación (ESL) torote blanco (Bursera microphylla)*-salvia* (Salvia mellifera)*-sangreado* (Jatropha cuneata) *y evitaron la asociación (FDI) palo verde* (Cercidium microphyllum)*-palo fierro* (Olneya tesota). *Los grupos de hembras seleccionaron la asociación ocotillo* (Fouquieria splendens)*-ágave* (Agave spp.)*-chirca* (Dodonaea viscosa) *(OAH); formaron grandes grupos, estando más próximos a zonas de huída y ocupando lugares más accidentados durante el otoño y la primavera que los machos. Las hembras seleccionaron lugares que ofrecen más oportunidades de eludir la depredación que los machos.*

1. Introduction

In Mexico, desert bighorn sheep (*Ovis canadensis* spp.) are an important game species but they have not been systematically studied since 1980 (TARANGO & KRAUSMAN, 1997). The objective was to determine use of habitat components by desert bighorn sheep in Rancho el Plomito, northwestern Sonora, Mexico. The hypothesis was that during sexual segregation females would occupy more rugged areas that offer greater opportunities to evade predators than do groups of males (BLEICH *et al.*, 1997).

2. Study area and methods

This study was conducted in Rancho el Plomito located in the southern portion of Sierra el Viejo approximately 70 km south of Caborca, northwestern Sonora, Mexico (30° 12′ and 30° 20′ N, 112° 18′ and 112° 22′ W) (Secretaría de Programación y Presupuesto 1980). The study area is described by Tarango (2000).

Rancho el Plomito is located in the Sonoran Desert where the terrain is rugged, rocky, and often interspersed by canyons and washes. The area is Sonoran desertscrub within the subdivision of the Lower Colorado River Valley. This is the largest and most arid subdivision of the Sonoran Desert. There were >300 sheep in Sierra el Viejo.

Only identified 3 vegetation associations within the study area based on field reconnaissance. The elephant tree (*Bursera microphylla*) – salvia (*Salvia mellifera*) – limber bush (*Jatropha cuneata*) association (ESL) (2,144 ha) occurs in foothills and mountains on steep slopes. The foothill palo verde (*Cercidium microphyllum*) – desert ironwood (*Olneya tesota*) association (FDI) (1,138 ha) is along "bajadas" and riparian areas ("arroyos" and washes). The ocotillo

(*Fouquieria splendens*) – desert agave (*Agave* spp.) – hop bush (*Dodonoea viscosa*) association (OAH) (1,094 ha) occurs along ridgetops with scattered palo verde and desert ironwood trees.

This study was conducted from April 1997 to December 1998. Direct observations of free-ranging groups of desert bighorn sheep formed the basis of our data. To identify patterns of habitat use by groups of desert bighorn sheep, we traveled the area on foot and surveyed sheep by inspecting each major canyon systematically. Only used 10 x 50 binoculars and a 30 x 16 spotting scope to age and sex sheep size according to horn and body size and development (GEIST, 1968, 1971). Habitat use information was collected for groups of males, females, and mixed groups of desert bighorn sheep classified as small (1-3), medium (4-6), and large (>6). Only considered each observation of bighorn sheep as an independent observation and we did not collect data from the same animal more than 1 time per 24 hours.

Once bighorn sheep were located, we established a 30 m-habitat-evaluation plot within the center of the area being used. At each plot, we recorded: group size and composition, landscape location [i. e., ridgetop, middle slope, bajada, and riparian (arroyos and washes)], slope, aspect, elevation, land-surface ruggedness (modified from BEASOM *et al.*, 1983), visibility at 20 and 40 m from the center of the plot, distance to escape terrain (defined as areas having ≥60% slope), vegetation association, vegetative ground cover and density (number of plants/ha) of agaves and mamillarias (*Mammillaria* spp.), and thermal cover [i. e., any topographic structure or vegetation ≥2 m high beneath which a standing or bedded desert bighorn sheep could seek shelter from direct sunlight (GIONFRIDDO & KRAUSMAN, 1986)] per ha. Methods are described in detail by TARANGO (2000).

Analyses pertaining to the comparison of habitat variables between groups of males and female bighorn sheep, seasons, and years were conducted through a 3-way ANOVA. We used chi-square analysis to determine if vegetation associations, categories of slope, aspect, and elevation were selected (i. e., used more in proportion to availability), or avoided (i. e., used less than proportion to availability) by groups of males, females, and mixed groups by seasons. Statistical tests were run with SAS and JMP IN statistical packages.

3. Results

Data on habitat use were obtained on 265 plots used by desert bighorn sheep and compared with information from 278 random plots. 116 plots used by groups of females were evaluated, 105 by groups of males, and 44 by

mixed groups. Habitat data were collected for 872 sheep. We found >65% of sheep in small groups, 28.8% in medium, and 11.3% in large groups. We found most sheep on ridgetops (55%), middle slope (33.9%), bajadas (6.0%) and riparian areas (4.9%).

The NE, SE, SW, and NW included 421, 854, 1,796, and 1,305 ha, respectively. Flat, middle-slope, steep, and very steep areas covered 1,786, 1,701, 824, and 65 ha, respectively. Low-elevational areas covered 2,547 ha, middle-elevational areas 1,601, while high-elevational areas 228 ha.

The ESL vegetation association was always selected ($P<0.05$), while FDI was always avoided ($P<0.05$) except during winter when it was used in proportion to its availability. The OAH vegetation association was always used in proportion to its availability.

The NE aspect was selected during winter and the SW aspect was avoided during winter and autumn. There was not preference for a particular aspect during spring ($X^2=4.63$, $0.25<P<0.10$; $X^2_{0.05.3}= 7.81$) or summer ($X^2=2.70$, $0.25<P<0.50$; $X^2_{0.05.3}=7.81$). Flat areas were always avoided by bighorns, whereas steep terrain was selected by all groups of sheep throughout the study except during winter when it was avoided. Low-elevational areas were mostly avoided throughout the study. Middle-elevational areas were preferred during winter and summer, while high-elevational areas were preferred in spring and summer.

Groups of segregated males and females selected ESL, males avoided OAH and FDI, and females avoided FDI. The NE aspect was selected by males and females while SW aspects were avoided by males. Also, females selected steep terrain but avoided flat areas, as did males. Males and females selected high and avoided low-elevational areas.

Land surface ruggedness was an index important for all groups of sheep. However, the odds of finding females as the ruggedness index increased were higher than finding either groups of males or mixed groups. The probability of selection of NW aspects by males was higher than for any other aspect and the likelihood of finding females on NW aspects was greater than for SW aspects (odds ratio =0.320, $P\leq0.001$). The probability of finding males and mixed groups on ESL was higher than finding them on OAH. On the other hand, the odds of finding females groups on OAH was higher than finding them on FDI, and the probability of selection for areas of escape terrain by mixed groups was greater than the probability of selection for areas outside of escape terrain.

We found no significant effect for elevation for the year X season ($F_{2,170}=0.59$, $P=0.551$), year X sex ($F_{1,170}=0.06$, $P=0.799$), and season X sex interaction ($F_{2,170}=0.69$, $P=0.499$), but there was an effect for elevation for the year X season X sex interaction ($F_{2,170}=3.06$, $P=0.049$) where year explained more

variation ($F_{1,170}$=35.78, $P \leq 0.001$) followed by season ($F_{2,170}$=13.33, $P \leq 0.001$). For the variable group size, no effect was found for year ($F_{1,170}$=0.07, P=0.770), season ($F_{2,170}$=0.71, P=0.489) and year X sex interaction ($F_{1,170}$=0.40, P=0.528); however, a year X season X sex interaction did occur ($F_{2,170}$=2.67, P=0.072) where sex explained most for the variation ($F_{1,170}$=35.49, $P \leq 0.001$). Females formed larger groups than did males (=3.4±0.30 versus 1.5±0.09). We found a year X season ($F_{2,170}$=8.07, $P \leq 0.001$) and season X sex interaction ($F_{2,170}$=2.65, P=0.002) for ruggedness index where sex contributed more to this variation ($F_{1,170}$=11.65, $P \leq 0.001$). Females used more rugged areas during autumn and spring than did males. We also found a 3-way interaction of year x sex x season for vegetation ground cover ($F_{2,170}$=4.04, P=0.019) and year explained more of the variation ($F_{1,170}$=64.1, $P \leq 0.001$), followed by season ($F_{2,170}$=5.91, P=0.003) and sex ($F_{1,170}$=3.63, P=0.058).

Of 66 plots that were on escape terrain, 41 (62.1%) were locations of groups of females and 25 (37.1%) were locations of groups of males. In addition, groups of females found outside of escape terrain occupied areas closer to escape terrain than did groups of males (=77.26±7.03 m versus =119.86±11.31 m). We found no difference between females with lambs and females without lambs on the use of slope; however, females with lambs used areas with a higher density of mammillarias than did females without lambs (=742.5 versus 376.2, P=0.027). Females formed larger groups, occupied more rugged areas, and were closer to escape terrain than were males. Segregated females formed larger groups, were closer to escape terrain, and occupied more rugged areas during autumn and spring than males. All results are presented in more detail by TARANGO (2000).

4. Discussion

Most sheep in Rancho el Plomito were found on ridgetops. It has been suggested that bighorn sheep depend on their visual capabilities for detection of predators (GEIST, 1971). Field of view for bighorn sheep was better from upper slopes than those from lower slopes (i. e., riparian areas and "bajadas" in our study). Selection of areas with a high degree of visibility may be a result of predator-evasion strategy displayed by bighorn sheep. Predators are visually detected, and the presence of danger is communicated among sheep by visual signals (GEIST, 1971).

Males and females generally were sexually segregated from October to June and aggregated from July to September. Medium-sized and large groups of sheep were mostly of groups of segregated females during winter and

spring, and mixed groups during summer. Groups of females were larger than groups of males.

Vegetation associations were not used according to their availability, ESL was preferred and FDI was avoided by all groups of sheep. The FDI vegetation association occurs mainly along riparian areas where only 5% of the locations of sheep were recorded. In contrast, ESL and OAH are located at higher elevations on areas that may provide sheep with higher fields of visibility and locations closer to escape terrain.

Preference for steep, middle, and high elevational areas by sheep indicate a predator avoidance strategy displayed by bighorns. Sheep on these areas were closer to escape terrain and consequently safer, especially on northeast facing areas. The NE aspects could also have provided shade for bighorns or other ways that allow bighorns to cope with desert conditions.

Land surface ruggedness index and visibility at 40 m were important features for segregated males and females (i. e., odds ratio >1). However, groups of females were more likely to be found on more rugged areas than groups of males and mixed groups. On the other hand, vegetation ground cover and visibility at 40 m were more important for males, while ruggedness index and being on escape terrain were important features for mixed groups. All groups of sheep use habitat features that provide security. However, we found females forming larger groups, being closer to escape terrain, and occupying more rugged areas than males. GIONFRIDDO & KRAUSMAN (1986) also found that males and mixed groups preferred less rugged terrain than female-juvenile groups. In contrast, groups with lambs selected steeper and lower areas than did groups without lambs. BLEICH *et al.* (1997) also reported that female groups with lambs occurred on steeper slopes and in more rugged and open areas during segregation. Female-juvenile groups were found more frequently on more rugged terrain compared with groups of males (LENARZ, 1979).

In Sonora, groups of females occupied areas closer to escape terrain than did males. Bighorns selected the upper portion of slopes (61%) in all seasons. We found no difference for visibility at 20 or 40 m between groups of males and females, but visibility at 40 m for males and females was important when compared to visibility at random locations.

Although females and males in Rancho el Plomito used a continuous range, selection did occur for particular habitat features such as northwestern aspects by males and females, and ESL vegetation association by groups of males and mixed groups. Segregated females used OAH, formed larger groups, were closer to escape terrain, and occupied more rugged areas during autumn and spring than males, thus supporting the hypothesis that females minimize predation by using rugged habitat features. In Sonora,

selection for areas of higher vegetative ground cover appears to be more important than selection for rugged areas by males. Our results agreed with the studies of BLEICH *et al.* (1997), and MAIN & COBLENTZ (1990). Sexual segregation exhibited by desert bighorn sheep in Rancho el Plomito could have been a response of different energetic and reproductive strategies of males and females where females tend to optimize conditions suitable for rearing offspring and males maximize body condition.

5. Management implications

The understanding of habitat selection by groups of segregated male and female desert bighorn sheep will complement the management tools available to managers of desert bighorn sheep in Mexico. We noticed preferences for specific habitat features by segregated males and females. Habitat selection at this scale is important when habitat improvement and conservation programs are to be implemented. The presence of small (<100) bighorn sheep populations over >80% of their range in Sonora suggests that intense management efforts are necessary. Because sheep are slow colonists, managers need to focus their efforts on the conservation of traditional habitats (BLEICH *et al.*, 1990). Habitat use by segregated males and females in Rancho el Plomito, Sonora, Mexico provided basic information of wild sheep in Sonora and data upon which to base management programs such as habitat improvement and protection of key lambing areas in the Sierra el Viejo.

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