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Mazaika, Rosemary, M.S.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

DESERT BIGHORN SHEEP AND NUTRITIONAL CARRYING CAPACITY IN PUSCH RIDGE WILDERNESS, ARIZONA

by

Rosemary Mazaika

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APPROVAL OF THESIS COMMITTEE

This thesis has been approved on the date shown below:

[signature] 19 March 1989

Paul R. Krausman, Thesis Director
Professor of Wildlife Ecology
Date

[signature] 19 March 1989

William W. Shaw
Professor of
Renewable Natural Resources
Date

[signature] 3-24-89

Frank M. Whiting
Professor of Animal Sciences
Date

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ABSTRACT

The number of desert bighorn sheep (*Ovis canadensis mexicana*) in Pusch Ridge Wilderness (PRW), Santa Catalina Mountains, Arizona has declined to between 50 and 100 animals. Sheep have restricted movements to the southwest corner of PRW. I developed a model based on nitrogen (N) content of forage and forage quantity to measure seasonal changes in nutritional carrying capacity of sheep use areas in PRW. Forage based estimates of animal numbers were greater for April to September than for October to March. My study suggests that forage is not limiting desert bighorn sheep in PRW and illustrates the potential to support more desert bighorn sheep than the current population. Seasonal fluctuations in range productivity should be examined in relation to human disturbances proximal to desert bighorn sheep habitat and fire management programs for PRW.

INTRODUCTION

Desert bighorn sheep in the PRW have declined in numbers since 1926. Present estimates of desert bighorn sheep are 50-100 animals (R. J. Olding, Annu. Bighorn Surv., Ariz. Game and Fish Dep., Tucson, 1988). Presently, sheep use 44 km^2 in the extreme western edge of the Santa Catalina range (Etchberger 1988). Data on the nutritional value (nitrogen content) of forage and estimates of pasture yield are lacking for this area.

Diets of desert bighorn sheep in Arizona have been described (Seegmiller and Omhart 1982, Dodd 1986, Morgart et al. 1986). These studies documented seasonal shifts in diet; however, they did not relate changes in diet to vegetation characteristics. A seasonal measure of forage N would allow us to understand why seasonal diet shifts occur (Van Dyne et al. 1980). Nitrogen is essential for building tissue and reduced intake can limit animal growth and production. Integrating these data with estimates of plant biomass and animal diet is necessary to understand the plant-herbivore equillibrium and nutritional carrying capacity. Changes in range-herbivore relationships over an annual cycle illustrate the timing of critical balances when other limiting factors may impact sheep (Moen 1973). Human encroachment (Purdy 1981) and fire suppression in relation to nutritional carrying capacity may impact desert bighorn sheep in PRW. Data on seasonal limitations of nutritional carrying capacity can be incorporated into habitat management plans for PRW. My objectives were to quantify seasonal changes in nutritional carrying capacity of desert bighorn sheep and to discuss vegetation characteristics as they relate to human disturbance, fire suppression, and animal numbers.

I. STUDY AREA

The study area was 2,052 ha in the 44-km^2 still used sheep habitat (Etchberger 1988) in the southwestern corner of the PRW, Santa Catalina Mountains, in the Cornado National Forest, Arizona. Elevations range from 900 to 1,700 m. The area is characterized by deep canyons, vertical cliffs, highly eroded granitic outcrops, and poorly developed soils. Sonoran desert scrub, semi-desert grassland, and Madrean evergreen woodland are the dominant vegetation types on the study area. Mean seasonal precipitation during 1987-88 was 14 cm. Mean seasonal temperatures range from 16 C in winter to 30 C during the summer.

II. METHODS

Vegetation was sampled during spring (April-June), summer (July-September), fall (October-December), and winter (January-March) from April 1987 to March 1988. Six vegetation associations identified by Gionfriddo and Krausman (1986): paloverde (Cercidium spp.)-saguaro (Carnegia gigantea) foothills (PSF) (20%), paloverde-saguaro mountain slopes (PSMS) (13%), paloverde-saguaro desert floor (PSDF) (22%), non-precipitous open oak (Quercus spp.) woodland (NOOW) (14%), precipitous open oak woodland (POOW) (29%), and riparian woodland (RW) (2%) were sampled in proportion to availability in known sheep use areas in the study area. I estimated vegetation biomass and composition (% browse, forb, and grass) during spring, summer, fall, and winter from 2,939, 2,789, 2,835, and 2,889 visually estimated and 134, 143, 149, and 136 visually estimated and clipped 1.4-m^2 plots, respectively. Forage biomass and composition was measured using the comparative yield (Haydock and Shaw 1975) and dry-weight rant (Mannetje and Haydock 1963) techniques, respectively. The optimum number of comparative yield samples (i. e., 20 visula:1 clipped ratio) for minimum standard error and sample time for each vegetation association was determined prior to data collection (Haydock and Shaw 1975). Entire grass and forb plants and $\leq$15 cm of terminal browse shoots comprised the visual and clipped estimate of biomass and forage composition for all plots. Comparative yield rank estimates were converted to weights using linear regression (Haydock and Shaw 1975). Regression coefficients were calculated at the $P \leq 0.05$ significance level. The precision of estimates was measured for individual vegetation associations. Percentage of browse, forb, and grass of total biomass estimates were determined by dry-weight rank. We tested rank multipliers (Mannetje and Haydock 1963) against observed plot production using Chi-square nonparametric statistics.

Three samples (≥ 10 g) of browse, forb, and grass were randomly selected from the clipped samples for each vegetation association and analyzed seasonally for percent crude protein content. Vegetation was dried for 48 hours at 35 C in a convection oven and material was ground to 2-mm partical size with a wiley laboratory mill for analysis. Crude protein was determined using micro-Kjeldahl digestion procedure (Assoc. Off. Agric. Chem. 1980). Each sample was analyzed in triplicate and reanalyzed if results differed by ≥5%. Results are presented on a dry-weight basis. I compared protein content of forage using Kruskal-Wallis nonparametric statistics.

Seasonal consumption of native browse, forb, and grass was measured using 2 captive, adult male desert bighorn sheep and the Calan feeding control system (Mazaika et al. 1988). Seven days prior to the feeding trials, which ranged from to 5 to 7 days, animals were fed native forage to stimulate rumen innoculation (Hudson and White 1979) and stabalize the rumen microbial population. During trials animals were fed known amounts of browse, forb, and grass that was harvested from the study area. Forage was collected ≤7 days prior to feeding and stored at 0 C until feeding. Forage remaining in feeders after 24 hours elapsed was retrieved and separated by hand to determine total consumption and percentages of browse, forb, and grass consumed. Forage lost 15% of total weight (water loss) over the 24-hour period. Data for individuals were compared within seasons using Mann-Whitney U tests and pooled in $P \leq 0.05$. I compared within and between season selection using Kruskal-Wallis nonparametric statistics.

The measure of seasonal nutritional carrying capacity was based on a modification of the equation by Mautz (1978):

$$k = \frac{\sum_{i}^{n} (B_i \times F_i)}{Rq_1 \times \text{days} + Rq_2 \times \text{days}}$$

where k = animals/ha, n = number of available lifeforms, B_i = consumable biomass (kg/ha), F_i = nutrient content of consumable biomass, Rq = animal requirements (g/day), and days = days on range/season.

Consumable biomass was calculated from the percentages of browse, forb, and grass (dry-weight rank) times the available biomass (comparative yield) in desert bighorn sheep use areas. Summer- and annual-use areas were described by Gionfriddo and Krausman (1986) and deVos (1984), respectively. I assumed that use patterns during 1987-88 were consistant with those reported previously for sheep in PRW. The model is based on N requirements for desert bighorn sheep and white-tailed deer (*Odocoileus virginianus couesi*) in PRW. Nitrogen Rq for desert bighorn sheep were calculated from the percent browse, forb, and grass comprising the mean daily intake (kg/animal/day) by captive animals tiem the N content of plants. I assumed total N was fulfilled by daily and seasonal consumption by captive animals (Robbins 1983:99). Similarly, Rq for sympatric white-tailed deer were calculated from daily consumption (2.90 kg/animal/day) (Halls 1982:56); seasonal selection of browse, forb, and grass; and protein content of forage (Myers et al. 1984). I assumed 95.7% digestibility of protein by sheep and deer (Robbins et al. 1975). The number of days of the range was determined by season length.

III. RESULTS

Desert bighorn sheep used the non-precipitous open oak woodland, precipitous open oak woodland, and the paloverde-saguaro mountain slope during all seasons and included the paloverde-saguaro foothills in their range during winter. Total consumable biomass in use areas declined through fall; and with the exception of the non-precipitous open oak woodland, increased with regeneration of browse, forbs, and grasses in winter (Table 1). I multiplied total consumable biomass of each use area by the percent estimate of browse, forb, and grass for use areas and summed the values across use areas for total biomass of each lifeform available to sheep within the study area (Table 2). The trend was for increased browse and grass and lowest forb availability for all seasons. During all seasons we summed consumable biomass across vegetation associations because indices of structural similarity (Sorenson 1948) between vegetation associations were 87, 87, 93, and 86% for spring, summer, fall, and winter, respectively. Estimates were used to derive N availability for the area. Nitrogen availability for spring, summer, fall, and winter was 1,886.70, 1,864.28, 1,094.70, and 1,491.00 g/ha, respectively.

I recorded siginificant differences in protein between browse, forbs, and grasses within all seasons, with the exception of browse, and forbs during spring and fall (Table 3). Nitrogen intake for bighorn sheep for spring, summer, fall, and winter was 3.65, 3.13, 3.98, and 6.13 g/animal/day, respectively. Estimates for white-tailed deer were 5.71, 4.99, 6.06, and 7.98 kg/animal/day for spring, summer, fall, and winter, respectively and summed to determine total Rq.

Data for mean daily consumption and percent use of browse, forb, and grass were pooled ($\underline{P} \leq 0.05$) for individuals within seasons (Table 4). I recorded significant differences in consumption of forbs between spring and summer, summer and fall, and fall and winter; use of grasses between seasons differed significantly between spring and summer and summer and fall. Use of browse did not differ between seasons. Use of all lifeforms varied significantly during summer. During fall significant differences in use were recorded between grass and forbs and grass and browse. Use of forbs and browse and grass and browse differed during winter.

Carrying capacity for desert bighorn sheep and white-tailed deer based on N Rq for the 2,052-ha sheep use area was 100 sheep/km^2 for spring and summer and 50 sheep/km^2 for fall and winter.

Table 1. Total consumable biomass (kg/ha) of browse, forbs, and grass in non-precipitous open oak woodland (NOOW), precipitous open oak woodland (POOW), paloverde-saguaro mountain slope (PSMS), and paloverde-saguaro foothills (PSF) in Pusch Ridge Wilderness, Arizona, 1987-88.

	NOOW		POOW		PSMS		PSF[a]	
Season	x	SE	x	SE	x	SE	x	SE
Spring	760.85	87.39	522.82	76.15	689.98	156.98		
Summer	454.38	103.62	485.29	60.15	576.02	117.89		
Fall	298.90	49.31	307.60	62.18	252.34	72.33		
Winter	236.77	81.49	333.33	63.75	456.13	117.94	363.01	104.86

[a]Blank spaces indicate seasons when PSF was not included in desert bighorn sheep use area.

Table 2. Consumable biomass (kg/ha) available to desert bighorn sheep in Pusch Ridge Wilderness, Arizona, 1987-88.

	Lifeform		
Season	Browse	Forb	Grass
Spring	823.56	428.65	733.13
Summer	584.28	307.03	574.94
Fall	326.30	210.53	313.88
Winter	461.80	267.48	494.97

Table 3. Percent protein (dry-weight basis) and nitrogen (N) (g/kg) of consumable biomass in Pusch Ridge Wilderness, Arizona, 1987-88.

	Lifeform								
	Browse			Forb			Grass		
Season	x	SD	N[a]	x	SD	N	x	SD	N
Spring	9.01A[b]	3.22	1.24	7.36ab[c]	2.23	1.01	4.29AB	1.02	0.59
Summer	9.71A	3.54	1.34	15.08Aa	5.61	2.08	4.42A	1.62	0.61
Fall	10.91A	2.85	1.51	13.28Bb	4.61	1.83	6.30AB	4.26	0.87
Winter	8.75A	2.98	1.21	18.76Ab	6.16	2.58	3.41A	1.62	0.49

[a]N derived from Hobbs et al. (1982:17); protein/6.25 (0.90).

[b]Values in rows with the same upper case letter are significantly different (P = 0.05); value corresponds to $T > 0.95$ quantile for Chi-square distribution with k - 1 degrees of freedom (Conover 1980:231).

[c]Values in columns with the same lower case letter are significantly different (P = 0.05) (Zar 1974:156).

Table 4. Daily consumption (kg/animal/day) and percent consumption of native browse, forb, and grass by penned desert bighorn sheep, Arizona, 1987-88. Data for 2 individuals pooled within seasons (P 0.05).

	Consumption		Browse		Forb		Grass	
Season	x	SE	x	SE	x	SE	x	SE
Spring	3.87	0.30	33.22	2.83	33.39A[a]	3.78	34.35	0.90
Summer	2.66	0.39	29.32a[b]	5.22	23.75ABCa	2.63	47.28ABCa	4.53
Fall	2.91	0.44	31.16a	3.97	31.22BDb	3.73	37.62Bab	3.86
Winter	4.25	0.50	28.68ab	4.65	36.75CDb	5.54	34.65Ca	4.69

[a]Values in columns with the same upper case letter are significantly different ($P = 0.05$); value corresponds to $T >$ 0.95 quantile for Chi-square distribution with k - 1 = 3 degrees of freedom (Conover 1980:231).

[b]Values in rows with the same lower case letter are significantly different ($P = 0.05$) (Zar 1974:156).

IV. DISCUSSION

Concepts of carrying capacity traditionally assumed the influence of external regulatory mechanisms. Edwards and Fowle (1965) maintain that carrying capacity can be quantified by counting the animals that use a unit of land. Caughley (1979) stresses the need to recognize plant and herbivore densities in carrying capacity measures. Vegetation measurements that have been examined relative to animal diets are estimates of plant biomass or the nutritional quality of forage (Hobbs et al. 1982, Hobbs and Swift 1985). Hobbs et al. (1982) maintain that carrying capacity estimates that reflect individual animal condition and population density must account for the amounts of food of varying nutrient concentration and for total food available. Nitrogen is essential for building tissue and reduced intake can limit animal growth and production and system functions. We have accounted for the amount of forage and protein available to bighorn sheep in PRW and conclude that sheep are not limited by forage quality or quantity. Given the results of this study and the population decline over the last 50 years we may speculate what may be limiting sheep to approximately 100 animals.

Etchberger (1988) illustrated that human disturbance and abundant vegetation characterize abandoned historic sheep habitat in PRW. Increases in available biomass imply increased production of seasonal grasses and forbs or an abundance of perennial trees and half-shrubs. Results of dry-weight rank estimates from this study reveal a perponderance of browse in the study area. Results of similarity indices (Sorenson 1948) illustrate little variation in structure and relative abundance of browse, forb, and grass between vegetation associations. Dominant browse included half-shrubs paloverde, common mesquite (*Prosopis juliflora*), turpentinebush (*Aplopappus laricifolius*), acacia (*Acacia* spp.), and spiny hackberry (*Celtis pallida*). Higher elevation species include jojoba (*Simmonsdia* spp.), desert hopbush (*Dodonea viscosa*), Arizona rosewood (*Vauquelinia californica*), and Mexican blue oak (*Quercus oblongifolia*). Percent crude protein of browse range from 8.75 to 10.91%. Cogswell and Kamstra (1976) reported that dietary crude protein in young plants ranged from 20 to 30% but dropped to 3 to 4% with maturity. The percent crude protein of perrenial browse on the study area may be reflective of maturing vegetation.

The above data has implications in fire management. Until recently fire was suppressed in the Santa Catalina Mountains. Fire suppression and habitat succession may play a part in reduced quality of maturing vegetation. As plants mature their structural components increase. Ingestion of mature forage results in decreased eating rates and decreased ruminating efficiency (Ruckebush and Thivend 1980:11). Increased rumination time associated with mature forage ingestion becomes a concern in areas where disturbance is a potential limiting factor. Rumination can be disrupted by mild and/or frequent disturbance of an animal (Church 1988:114). Purdy (1981) identified disturbance factors which may impact sheep in PRW (i. e., roads, recreationists, hunters, and development). Etchberger (1988) demonstrated that distance to human disturbance was a characteristic separating abandoned habitat and habitat still used by sheep. The disturbance factors and their timing are potential concerns for PRW bighorn sheep given the period of lowest range carrying capacity (fall and winter) and highest human activity. Pusch Ridge Wilderness receives the greatest recreational use from November to March with peak use in December and March (Purdy 1981). Carrying capacity estimates from this study identify fall and winter (October-March) as periods of reduced (50%) nutritional yield. Human disturbance during this period may limit availability of apparently abundant forage. Additional research to assess the response of bighorn sheep and vegetation to fire and the impacts of disturbance factors is necessary to manage a viable population of desert bighorn sheep in PRW.

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