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MANAGEMENT IMPLICATIONS OF AN INTENSIVE STUDY OF WINTER FORAGING ECOLOGY OF BIGHORN SHEEP

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Abstract: Factors limiting nutrition of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were investigated on 2 montane winter-spring ranges in north-central Colorado. Under snow-free conditions, we investigated effects of rapid increase in forage quality during green-up (Mar-Apr) on feeding behavior, diet quality, and nutrition of ewes. Bighorn switched to green forage when availability of fresh vegetation was limited. Consequently, bite size and dry-matter intake rates declined, and increases in nutrition often lagged a month behind increases in diet quality. Snow caused bighorn to nose or paw to reach forage resulting in lower bite rates. Although bite size of ewes increased on both ranges with snow; dry matter intake rates declined at 1 area. Diet quality declined in both areas because bighorn were unable to forage selectively. With snow, bighorn shifted from feeding in open sites to areas of shrub cover and cliffs which enhanced forage accessibility. Managers need to determine preferred habitats of bighorn under both snow-free and snow-covered conditions even on ranges where snow is usually shallow and transitory. If bighorn sheep have adequate habitat during snow-covered conditions, enhancing availability of green forage during green-up will likely benefit them. This objective can often be met by removing overstory of shrubs, trees, or dead herbs through prescribed fire, chemical, or mechanical treatment. In some cases, availability of snow habitat and/or green forage can be improved by extending ranges of bighorn to lower elevations or into different habitats through transplanting.

Factors limiting nutrition of free-ranging ungulates are difficult to determine. Observational studies can often identify important factors, however, without experimental control researchers are limited in determining their relative importance (Lauer and Peek 1976). Experimental studies using tame, supplementally fed animals can control variables more efficiently (Hobbs et al. 1983), however, results may not accurately represent natural conditions. We combined observational and experimental approaches in order to define limiting factors for nutrition of free-ranging bighorn ewes on 2 montane winter-spring ranges in north-central Colorado.

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Two major natural contrasts were used to identify factors limiting nutrition of bighorn ewes: the dramatic increase in availability of high quality forage from March to April; and the contrast between forage availability under snowfree conditions and with snow cover. Our objective was to document behavioral responses of free-ranging bighorn ewes to changes in forage availability and quality; and to determine the effects of changes in behavior and forage supply on nutrition. To accomplish this objective we estimated habitat selection, activity budgets, biting rates, bite sizes, and diet quality of ewes under different environmental conditions. Major guiding hypotheses were (1) that foraging behavior of ewes was sensitive to changes in foraging conditions, and (2) that changes in feeding behavior acted to enhance nutrition.

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STUDY AREAS AND BIGHORN POPULATIONS

The 2 study areas were similar in size (2 km^2) and located on predominantly south-facing slopes above the Fall River in north-central Colorado (Goodson et al. 1991a,b). The Fall River area was bisected by the east boundary of Rocky Mountain National Park and included private lands. The Endovalley area was within the Park.

Distinct subpopulations of female and juvenile bighorn sheep used the areas although adult rams moved between them (Stevens and Hanson 1986). Herds were estimated at 100 bighorn at Fall River; and 80-100 bighorn at Endovalley. On both areas, due to lack of hunting and abundant human activity, bighorn were habituated to people and easily observed.

Study areas were accessible parts of the total winter range of each subpopulation, and have been previously described (Goodson et al. 1991a,b). The Endovalley area was higher in elevation (2,590-2,900 m) than Fall River (2,400-2,650 m). Important foraging areas at Endovalley were aspen (*Populus tremuloides*)-Kentucky bluegrass (*Poa pratensis*) associations and grasslands dominated by bluegrass and cheatgrass (*Bromus tectorum*). These areas were interspersed with Douglas-fir (*Pseudotsuga menziesii*) stands with understories dominated by sedge (*Carex spp.* and mountain muhly (*Muhlenbergia montana*).

Mountain shrub with variable overstory of ponderosa pine (*Pinus ponderosa*) and Douglas-fir was the dominant vegetation type at Fall River. Dominant understory species were mountain muhly, blue grama (*Bouteloua gracilis*), and needle-and-thread (*Stipa comata*). Bluegrass lawns and sparsely vegetated disturbed sites were associated with residences and motels.

METHODS

Foraging Behavior, Diet Quality, and Nutrient Intake Rates

Bighorn were observed at Fall River from January through mid-May, 1985 and 1986; and at Endovalley from January to mid-May 1985 and 1987, and from March to May 1986. We located bighorn groups from roads or by traversing study areas on foot. The first group sighted that included adult ewes were approached for behavioral observations.

Methods were described in Goodson et al. (1991a,b). We observed foraging activity of individual adult ewes with 9 X 35 binoculars from distances of 6-76 m ($\bar{x}$ = 30 m). Bites of herbs and shrubs were recorded orally on tape. An experimental unit was a foraging sequence ($\geq$3 min long) of 1 ewe. We recorded 141 sequences at Fall River, and 166 sequences at Endovalley.

For each foraging sequence, the path of the ewe was described using landmarks. After the bighorn left the area, we retraced the ewe's path and located freshly bitten vegetation. To estimate diet composition we mimicked individual bites by clipping nearby vegetation. At least 20 bites of herbs ($\bar{x}$ = 32) and 10 of each species of shrub consumed were collected per sequence. For each sequence simulated herb bites were combined and separated into dead material, green grass, and green forbs. We oven-dried and weighed samples to estimate mean bite sizes and diet composition. To estimate dry-matter intake we multiplied biting rates by mean bite size (dry weight) for each sequence.

Diet components (green grass, green forbs, dead herbs, browse) comprising $\geq$5% of monthly diets were analyzed for protein concentration (Kjeldahl nitrogen X 6.25), in vitro dry matter digestibility, and neutral detergent fiber. Nutrient intake rates were estimated by multiplying nutrient concentrations by dry matter intake rates.

Activity Budgets

We estimated activity budgets of ewes during dawn-dusk observations under snow-free conditions and snow-covered conditions at Fall River (n = 6, with snow; n = 6, without snow) and Endovalley (n = 2, with snow; n = 10, without snow). We classified activities of all ewes in the group at 5-minute intervals as resting, resting-ruminating, standing, traveling, socializing, or foraging.

Statistical Analyses

We used linear regression to analyze relationships between proportions of green forage in ewe diets and diet concentrations of neutral detergent fiber, protein, and digestible dry matter. We used t-tests with separate estimates of variances if needed (Steel and Torrie 1980:106-107) to test differences in bite size, bite rate, dry-matter intake rate, and foraging time (as a percent of daylight time) between pre green-up and green-up conditions and between snow-free and snow-covered conditions within each study area.

RESULTS

Diet Composition

Diets of ewes in both study areas were dominated (85%, Fall River; and 96%, Endovalley) by graminoids (grasses and sedges) (Goodson et al. 1991b). During mid-winter (Jan-Feb), there was some green material available at the bases of graminoids, and ewes typically selected foraging areas where they could obtain a mixture of green and dead forage. Because percent green material in the diet was positively correlated with percent diet protein (r^2 = 0.88) and percent diet in-vitro digestibility (r^2 = 0.80) and negatively correlated with percent diet fiber (r^2 = 0.62), we used percent green material to indicate diet quality.

Snow-free Conditions

The major impact of foraging behavior and nutrition of bighorn ewes under snow-free conditions was the dramatic increase in diet quality that occurred during green-up (Mar-Apr) each year. Ewes began switching to new green grasses as soon as green growth began in March. Because new grasses were short, bite size declined (Table 1). Bite rates increased during green-up but only partially compensated for declines in bite size and dry-matter intake rates declined in both study areas (Table 1).

The limiting effect of availability of green forage on ewe nutrition was further demonstrated by the inverse relationship between bite size and diet quality during green-up (r^2 = 0.55, $P < 0.0001$, Fall River; r^2 = 0.44, $P < 0.0001$, Endovalley, Goodson et al. 1991b). Despite increases in bite rates dry-matter intake rates were also inversely related to diet quality during green up (r^2 = 0.27, $P < 0.0001$, Goodson et al. 1991b).

Bighorn shifted to green forage during green up although its limited availability caused intake rates to decline. Effects on nutrition were mixed. Intake rates of protein generally but not always increased during green-up (Goodson et al. 1991b, Table 1). However, intake of digestible dry matter which provides energy did not increase significantly (Fall River) or declined (Endovalley) (Table 1). Levels of energy intake finally increased in May as green grass became more abundant, and new growth of shrubs and forbs increased in availability (Goodson et al. 1991b).

During green-up, Fall River bighorn preferred open mountain shrub-mountain grass areas, disturbed areas and blue-grass lawns. Ewes favored previously grazed areas of mountain grass that began growth early due to removal of dead material through previous grazing. At Endovalley, bighorn preferred open areas dominated by bluegrass and/or cheatgrass. These areas were heavily grazed and formed grazing lawns (McNaughton 1984) characterized by dense, continuous short grasses. In both areas, selected types offered low total biomass but a high percentage of new growth.

Table 1. Changes between pre green-up (Jan-Mar) and green-up (Apr) in average diet quality (estimated by percent green material in diet), bite size, bite rate, and intake rates of dry-matter, protein, and energy (estimated by in-vitro digestible dry-matter (DDM)) of bighorn ewes at Fall River and Endovalley, north-central Colorado, 1985-87.

	Fall River			Endovalley		
	Pre Green-up	Green-up	P	Pre Green-up	Green-up	P
Diet quality	0.26	0.75	0.001	0.37	0.74	0.001
Bite size (g)	0.12	0.08	0.001	0.08	0 05	0.001
Bites/min	36.7	50.5	0.001	47.06	61.32	0.001
Intake rates (g/min)						
Dry-matter	4.45	3.79	0.038	3.76	2.70	0.001
Protein	0.35	0.63	0.001	0.41	0.54	0.001
DDM	2.16	2.58	0.06	2.13	1.81	0.006

Snow-covered Conditions

With snow cover, foraging conditions for bighorn ewes changed dramatically. Bighorn had to nose or paw through the snow layer to reach forage. As a result, biting rates declined in both study areas (Table 2). Ewes shifted foraging from open areas with short forage and low biomass to areas which shed snow (cliffs) or vegetation types providing snow shielding (shrub types) (Fig. 1). In these areas, ewes were able to obtain larger bites. Despite the increase in bite size, dry-matter intake rates declined with snow at Fall River. At Endovalley, the increase in bite size offset the decline in bite rate and intake rates increased (Table 2).

At both areas, diet quality declined steeply (Table 2). Bighorn were unable to forage selectively with snow. New green forage was short and buried under the snow and provided such small bite sizes that with reduced bite rates intake rates would have been inadequate. At Fall River, bighorn ewes shifted to areas with dense shrubs and rock outcrops that were lightly grazed and had higher biomass of forage with a low proportion of green material (Fig. 1). Ewes fed around the bases of shrubs where the shrub canopy intercepted snow and made forage more accessible. At Endovalley, ewes shifted to areas with shrub overstories and also to cliffs (Fig. 1). The south-facing cliffs shed snow and ewes fed at rock edges where snowmelt was most rapid.

The inability of ewes to maintain intake rates and/or diet quality influenced their activity budgets. Without snow, Fall River bighorn ewes foraged 63%, and Endovalley ewes foraged 79% of total daylight time (Table 2). With snow, ewes at Fall River increased their foraging time to 75% of daylight time. In contrast, foraging time at Endovalley fell to 58% (Table 2). Ewes at Fall River were able to compensate for

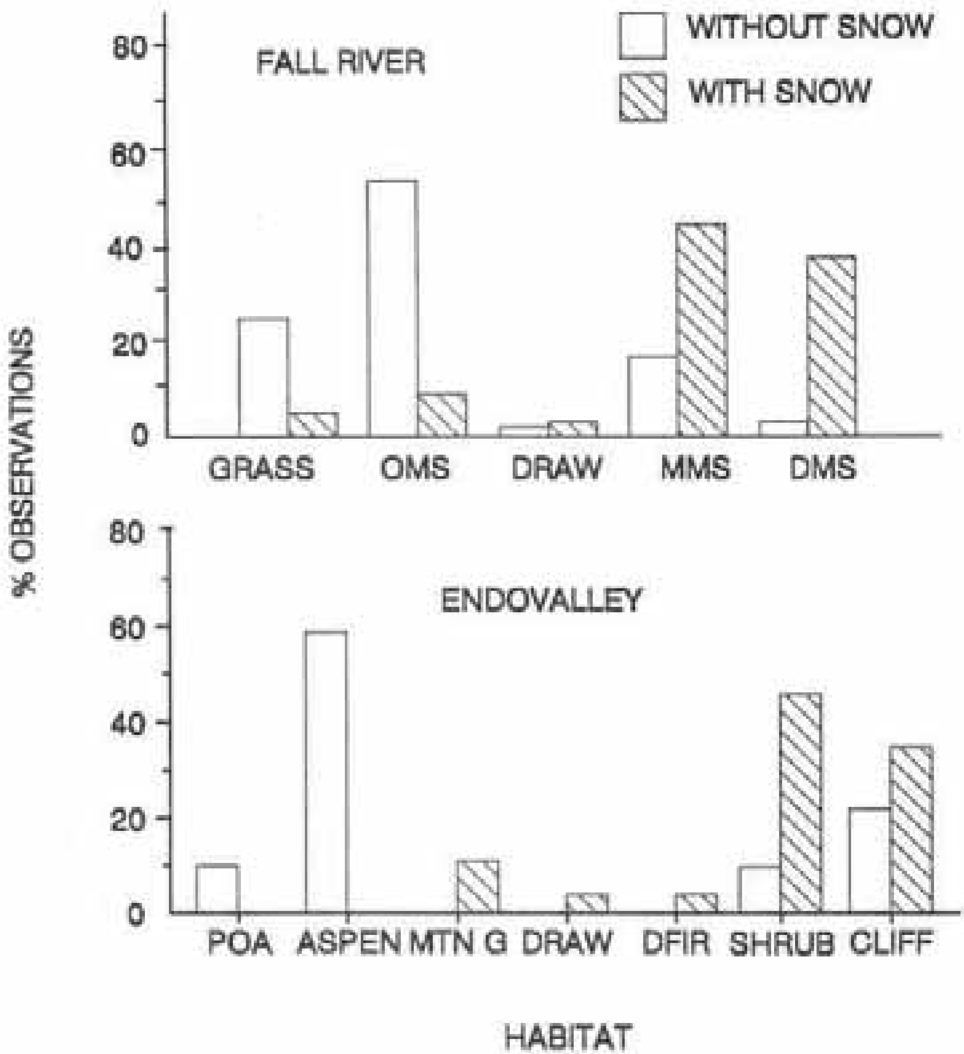

Fig. 1. Changes in habitat use between snow-free and snow-covered (5-12 cm) conditions for bighorn ewes on 2 montane study areas in north-central Colorado, 1985-87. Habitat types were GRASS (open grassland), OMS (open mountain shrub), DRAW (riparian), MMS (moderately dense mountain shrub), DMS (dense mountain shrub), POA (bluegrass-dominated grassland), ASPEN (open aspen stand with bluegrass-dominated understory), MTN G (bunchgrass-dominated grassland), DFIR (Douglas-fir stand with sedge-dominated understory), SHRUB (alder and/or gooseberry dominated habitats), and CLIFF (cliffs).

Table 2. Changes between snow-free and snow-covered (1-12 cm) conditions in average bite size, bite rate, dry-matter intake rate (DM intake), diet quality (estimated by percent green material in diet), and foraging time (expressed as a percent of total daylight hours) of bighorn ewes at Fall River and Endovalley, north-central Colorado, 1985-87.

	Fall River			Endovalley		
	No Snow	With Snow	P	No Snow	With Snow	P
Bite size (g)	0.12	0.18	0.001	0.07	0.13	0.001
Bites/min	45.07	27.19	0.001	50.07	35.04	0.001
DM intake (g/min)	4.99	4.75	0.001	3.44	4.26	0.025
Diet quality	0.60	0.12	0.001	0.50	0.17	0.001
Foraging time	0.63	0.75	0.001	0.79	0.58	0.001

declines in dry-matter intake rates and diet quality by increasing foraging time during the day. At Endovalley, foraging time was already near maximum during snowfree conditions. With snow, ewes at Endovalley decreased foraging time, presumably because foraging was unproductive.

Changes in ewe distribution during periods of persistent snow cover also indicated that snow prevented Endovalley ewes from foraging efficiently. In 1986, snow was unusually heavy during early winter. The Endovalley area was blanketed with over 20 cm of snow when fieldwork began in January and no bighorn were present. Periodic snowfalls maintained snow cover through most of February and bighorn did not return to stay in the study area until early March.

Endovalley is the only low elevation winter range used by this subpopulation. The remainder of the winter range lies at higher elevations, primarily above treeline. Even during heavy snow periods there are some alpine areas blown free of snow by the strong winds typical above treeline. Our observations indicated that during periods of persistent snow, Endovalley bighorn were forced to leave the study area and move up to windswept alpine ridges to find foraging areas free of snow.

DISCUSSION

Factors limiting nutrition of ewes differed with snow conditions. Without snow, bighorn selected open areas providing opportunity for selective foraging. These areas were the first to green-up in spring and provided high quality forage. Without snow, our observations indicated nutrition of ewes was limited by the area and productivity of habitats providing early green-up.

With snow, ewes selected areas for snow shedding or shielding characteristics. These areas provided greater availability of forage with lower quality, and enabled ewes to enhance total intake. Nutrition of ewes during snow-covered conditions was limited by the extent and productivity of habitats providing accessible forage.

With snow, bighorn shifted foraging from open areas with low biomass and a high proportion of green growth which permitted selective feeding to areas providing more accessible forage of lower quality. Their foraging strategy changed from optimization of diet quality to maximization of bite size and total intake. Despite this change in foraging strategy, intake rates declined at Fall River and diet quality declined in both areas.

MANAGEMENT IMPLICATIONS

Managers need to determine habitat selection of bighorn sheep under snow-free and snow-covered conditions even if snow is normally shallow and transitory. Limiting habitats should be determined, then management strategies to extend or enhance these habitats can be planned.

If habitat preferences differ with snow conditions as in our areas, managers need to insure that sufficient areas of snow-shedding or shielding habitat are available to provide adequate forage even in severe winters. Information on frequency, and duration of snow cover during average and severe winters is necessary to estimate bighorn sheep requirements for snow habitat. If preferred habitat during snow-covered conditions is adequate or abundant, managers should consider increasing the area and/or productivity of vegetation types providing early green-up.

Two basic approaches are available to enhance limiting habitats. the more common way is to treat current ranges to change habitat composition or enhance productivity of limiting habitats. The second approach is to extend ranges of the population to increase the area of limiting habitat.

If areas providing early green-up are lacking habitat improvement will generally increase exposure to the sun through setting back succession. Options include converting tree stands to shrub-grass or grassland; converting dense-shrub to open-shrub or grassland; and enhancing grassland by removing dead material. Methods to accomplish these objectives include mechanical methods such as logging, chaining, and chopping; chemical treatment; and burning.

Methods which provide longterm habitat enhancement are to be preferred over methods such as fertilization, which provide only shortterm benefits. Natural or prescribed fire that maintains grasslands or converts tree stands to grasslands can provide lasting benefits on bighorn ranges. The aspen-dominated slopes which provide most of the foraging areas on the Endovalley range were created by fires about 100 years ago. These areas are still providing habitat for bighorn and will continue to do so for the indefinite future. Wakelyn (1987) documented the negative effects of advancing forest succession (permitted by fire suppression) on bighorn ranges in Colorado.

Range extension can effectively improve habitat for bighorn sheep. Our 2 study areas provide an example. The Endovalley areas is a small low-elevation range used by a bighorn population whose primary winter range is above treeline in the Mummy Mountains of Rocky Mountain National Park. The Mummy Range bighorns are a native herd which lost most of their lower elevation range through human interference (Goodson 1980). Our results indicate that the remaining low elevation winter range at Endovalley is inadequate to support bighorn during winters of above average snowfall.

The Fall River bighorn population is the result of a 1977 transplant in which Rocky Mountain National Park and the Colorado Division of Wildlife cooperated (Stevens and Hanson 1986). The objective of the transplant was to restore bighorn sheep to low elevation winter range near the east boundary of Rocky Mountain National Park. The transplant reestablished use of low elevation winter range in the ponderosa pine zone which provides a complete winter range capable of supporting bighorn sheep through the normal range in winter snow conditions.

Although the Endovalley and Fall River ewes share summer range above treeline in the Mummy Range, the female-juvenile segments of these 2 herds remain distinct. Adult males, however, move between the areas. The transplant has succeeded in doubling the bighorn population in the area, and the Fall River herd has provided over 100 bighorn for transplants.

This example suggests the magnitude of benefits which successful range expansion can provide. Managers need to be open to opportunities to improve bighorn habitat through extending ranges into new areas capable of providing limiting resources.

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