Nutrition and Production of Domestic Sheep Managed as Manipulators of Big Game Habitat

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Highlight: Weight gains of ewes and lambs, forage intake, and dietary quality of ewes were evaluated from mid-May to early July on foothill ranges under two intensities and durations of grazing management. Dietary quality was poorer and forage intake was lower under heavy than under moderate stocking. Individual lambs gained somewhat less weight under heavy stocking but ewes were not affected. A short-term, rotational grazing scheme, as compared to season-long grazing, did not appear either beneficial or detrimental to sheep. Response of the plant community will be a major factor determining which grazing system provides the best winter range for big game, but heavy stocking was decidedly superior when lamb production was considered on a land area basis.

The concept of controlling livestock grazing for the specific purpose of directing plant community succession in a manipulative sense is well recognized (Lewis 1969). Applications have generally been in the realm of specialized grazing systems aimed primarily at increasing range carrying capacity for livestock (reviewed by Herbel 1974), and to a smaller extent in the control of undesirable woody plants (DeToit 1974) and as a tool in forest management (reviewed by Adams 1975).

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Recent research indicates an additional potential for using controlled livestock grazing in management of wildlife habitat. For example, Anderson and Scherzinger (1975) reported a three-fold increase in winter elk (*Cervus canadensis*) numbers following implementation of planned cattle grazing on pine-bunchgrass range in Oregon. In other studies, Jensen et al. (1972) suggested that judiciously applied sheep grazing during spring could effectively increase yields of important shrub species for subsequent winter use by big game animals.

Unlike the direct and immediate cost outlays for plant community manipulation by conventional means (e.g. mechanical, chemical, or controlled burning), use of the grazing animal as a management tool is generally expected to yield a return (from livestock products) while the manipulation program is in progress. Thus, productivity aspects of the manipulator animal population must be considered in the overall evaluation. The research described in this paper was designed to evaluate possible nutritional limitations to production of domestic sheep managed under grazing regimes designed to benefit winter habitat of mule deer (*Odocoileus hemionus*) and elk. The major treatment variables were intensity and duration of grazing by sheep.

A preliminary assessment of plant community responses to the grazing treatments imposed has been presented by Jensen et al. (1976). Additionally, Smith (1976) and Fulgham et al. (1977) have reported initial data on the winter diets and nutrition of mule deer in response to one of the sheep grazing treatments.

Methods and Materials

Study Site

Field research was conducted at Hardware Ranch, located approximately 40 km southeast of Logan, Utah. The area, situated at approximately 1,750 m elevation, is typical of much of the intermediate elevation foothill range type found throughout Utah and much of the Intermountain West.

Vegetation of the area is characterized by the dominant big sagebrush complex (*Artemisia tridentata* subsp. *tridentata* and *A. tridentata* subsp. *vaseyana*) and to a lesser degree by bitterbrush (*Purshia tridentata*). Other shrubs such as snowberry (*Symphoricarpos oreophilus*), little rabbitbrush (*Chrysothamnus viscidiflorus*), low sagebrush (*Artemisia arbuscula*), and serviceberry (*Amelanchier alnifolia*) are common. Important contributors to the herbaceous component include the forbs: Pacific aster (*Aster chilensis* var. *adcendens*), mulesears wyethia (*Wyethia amplexicaulis*), tailcup lupine (*Lupinus caudatus*), and arrowleaf balsamroot (*Balsamorhiza sagittata*). Common grasses include: beardless bluebunch wheatgrass (*Agropyron inerme*), Kentucky bluegrass (*Poa pratensis*), Sandberg bluegrass (*Poa secunda*), Junegrass (*Koeleria cristata*), and Great Basin wildrye (*Elymus cinereus*).

Annual precipitation in the area varies from 46 to 66 cm, with the major portion falling as snow. The frost-free period ranges from 90 to 130 days.

Soils of the study area are derived from quartzite and quartzite-calcareous sandstone and range in texture from loam to stony, silty clay loam. They have a relatively slow rate of permeability and a moderate runoff potential.

The study site had not been grazed by domestic animals for approximately 25 years preceding this research, but the area annually sustains moderate grazing use by elk and mule deer during winter and early spring.

Grazing Treatments

Experimental treatments consisted of four combinations of time and intensity of grazing applied to eight separate but adjacent pastures (Table 1). The grazing treatments were repeated in three successive years (1972–74). During the initial 2 years, each pasture was grazed by seven head of Columbia × Targhee ewes with their lambs and three yearling Targhee × Columbia × Suffolk esophageally fistulated wethers used as collector animals for nutritional determinations. The third year no fistulated animals were grazed and the number of ewes per treatment was increased to nine. Ewes and lambs were obtained from a local farm flock in 1972 and from a neighboring range sheep operation in 1973 and 1974.

The two stocking intensities defined as moderate and heavy were designed to achieve, respectively, about 35% and 70% mean utilization of the total available forage by the end of a particular grazing period. All herbaceous species and the current year's twigs of all shrubs except *Artemisia* species were considered as available forage for sheep. The two levels of utilization were achieved by constructing the pastures of various sizes, based on the results of a forage inventory of the area conducted the year prior to initiation of the study. Pastures varied in area from 0.6 to 6.5 ha each.

Initial assignment of ewe and lambs to treatments at the beginning of each grazing season was not entirely random, in that we attempted to achieve a uniform distribution of ewes with twin lambs among all treatments. During a particular year, ewes and lambs initially assigned to the two short-term treatments were moved to new pastures of like grazing intensity on the approximate calendar dates designated on the pasture schedule (Table 1), while animals assigned to the two season-long treatments remained in their respective pastures for the duration of each year's grazing season. Fistulated sheep were randomly assigned among the four pastures being grazed during a particular time period in the grazing schedule (Table 1).

All animals were identified by numbered ear tags and were weighed individually (following a 12-hour fast) at the beginning of the grazing season, at each date when animals in the short-term treatments were moved to new pastures (Table 1), and again at the termination of the grazing season.

Table 1. Grazing treatment design for comparing production and nutrition of sheep stocked to achieve moderate and heavy grazing intensities during short-term and season-long grazing periods.

Grazing treatment	Pasture schedule[1]	Pasture area (ha)	Stocking density (sheep da/ha)[2]	Season-long stocking rate (sheep/ha)
Short-term moderate	May 15–May 31	2.6	65	
	June 1–June 17	2.0	85	
	June 18–July 2	1.6	100	
	Total	6.2		1.6
Short-term heavy	May 15–May 31	1.3	130	
	June 1–June 17	1.0	170	
	June 18–July 2	0.8	200	
	Total	3.1		3.2
Season-long moderate	May 15–July 2	6.2	81	1.6
Season-long heavy	May 15–July 2	3.1	161	3.2

[1] Approximate dates of pasture entry and exit. As much as 10 days variation existed in initiation of grazing from year to year, depending on plant phenology and range readiness. Length of grazing season was constant over years.
[2] A sheep day is defined as one day of grazing used by the average 60-kg ewe and her lamb(s).

Nutritional Determination

Nutritional determinations were conducted only during 1972 and 1973. Fistulated animals were allowed a 5-day period for adjustment to prevailing pasture conditions before any samples were collected. Samples of ingested forage were collected via fistula early each morning during weekly periods of 5 days each. A daily sample collection interval for a particular animal varied from 20 to 40 minutes, after which the sample, wet with saliva, was transferred from the screen-bottom collection bag to a porcelain laboratory tray where it was thoroughly hand mixed. The sample was then bagged in polyethylene, labeled, and immediately transferred to a chest-type freezer where it was stored at −20°C until analysis.

Preparatory to laboratory analysis, each individual sample was hand-chopped while frozen and then freeze-dried. Dried material was then ground to pass through a 40-mesh screen in a Wiley laboratory mill. After grinding, individual daily samples were aggregated over 5-day collection periods for each fistulated animal.

Laboratory analyses for the initial year's samples included crude protein (N × 6.25) by the macro-Kjeldahl method (A.O.A.C. 1970), cell soluble components (Van Soest and Wine 1967), cell wall constituents (Van Soest 1963), ash, and dry matter (A.O.A.C. 1970). Estimates of digestibility were derived through in vitro fermentations according to the two-step method of Tilley and Terry (1963). Rumen liquor inoculum for fermentations was obtained by vacuum aspiration from two ruminally fistulated donor sheep maintained on a diet of native hay. Diet samples obtained during the second year of the study were analyzed only for crude protein and in vitro digestibility. Data from all chemical analyses, as well as from in vitro fermentations were corrected to an organic matter basis in view of probable salivary ash contamination of samples (Hoehne et al. 1967).

Daily forage intake was estimated during the study's initial year according to the following rearrangement of the standard digestion-balance equation.

$$I = \frac{F}{100 - D} \times 100$$

where: I = daily forage organic matter intake; F = daily fecal organic matter output; and D = percentage organic matter digestibility of the diet. Fecal output was estimated by total collection, using standard fecal collection bags (Harris 1968) on the fistulated wethers. Digestibility was estimated from in vitro determination on fistula extrusa, as described above. No attempt was made to adjust in vitro digestibility estimates to an in vivo basis, nor were the intake estimates made on wethers adjusted for additional energy demands of lactation in ewes. Thus both digestibility and intake data presented here can be interpreted only as relative indices for among-treatment comparison.

Statistical Analysis

Data on animal weight responses were subjected to analysis of variance procedures (Snedecor and Cochran 1967) using a multiple least-squares regression program for unbalanced data. Main effects isolated by the analysis included years, grazing intensities, and grazing durations, as well as second- and third-order interactions of these effects. Data on nutritional parameters were analyzed by the same least-squares regression program as above. Components of variation tested were the same as those for animal weight responses,

Table 2. Crude protein content (CP), in vitro digestibility (IVD), and organic matter intake (OMI) of diets selected by sheep under two intensities and durations of spring grazing.

Duration of grazing	Grazing intensity						Grazing duration means[3]		
	Moderate			Heavy					
	CP[1]	IVD[1]	OMI[2]	CP	IVD	OMI	CP	IVD	OMI
Short-term	17.9	64.0	49.7	17.1	56.7	35.9	17.5b	60.4a	42.8a
Season-long intensity	18.8	62.9	44.6	18.4	61.4	42.3	18.6a	62.1a	43.5a
Means[3]	18.4a	63.5a	47.2a	17.8b	59.0b	39.1b			

[1] Expressed as percentages of organic matter. Tabular values are means of 1972 and 1973.
[2] Expressed as g/kg body wt$^{0.75}$. Intake measured during 1972 only.
[3] For a particular nutritional attribute, means followed by different letters are significantly ($P \leq 0.05$) different. Intensity means are averages of short-term and season-long grazing durations, and grazing duration means are averages of moderate and heavy grazing intensities.

Table 3. Cell wall (CW), cellulose (CEL), and lignin (LIG) in diets selected by sheep under two intensities and durations of grazing during spring, 1973. Values are expressed as percentages of dietary organic matter.

Duration of grazing	Grazing intensity						Grazing duration means[1]		
	Moderate			Heavy					
	CW	CEL	LIG	CW	CEL	LIG	CW	CEL	LIG
Short-term	39.8	21.5	6.4	46.5	23.5	9.0	43.2a	22.5a	7.7a
Season-long intensity	40.2	21.7	7.0	44.2	21.4	7.1	42.2a	21.6b	7.1a
Means[1]	40.0b	21.6b	6.7b	45.4a	22.5a	8.1a			

[1] For a particular fiber component, means followed by different letters are significantly ($P \leq 0.05$) different. Intensity means are averages of short-term and season-long durations, and grazing duration means are averages of moderate and heavy grazing intensities.

with the exception of organic matter intake and fiber constituents which did not entail a "years" component. The Studentized range test (Snedecor and Cochran 1967) was used to isolate significance of individual treatment means in both animal weight and nutritional analyses.

Results and Discussion

Forage Nutritional Quality and Intake

Animals in the short-term heavy treatment consumed forage with significantly ($P \leq 0.05$) less crude protein and with a lower digestibility than did those in any of the other three treatments (Table 2). This response was consistent during both 1972 and 1973; thus values presented in Table 2 are pooled means for the 2 years. Forage intake, measured only during 1972, was also lowest in the short-term heavy treatment (Table 2), while the three plant-fiber components were highest there (Table 3). In contrast, sheep in short-term moderate treatment consumed the most digestible forage and demonstrated the highest level of relative intake of all treatments, but protein content was highest in the season-long moderate treatment (Table 2). Dietary crude protein in all treatments was well above the 8% (dry matter basis) recommended for ewes during the first 10 weeks of lactation (N.A.S. 1968), even when measured levels (Table 2) were adjusted from an organic matter to a dry matter basis. None of the fiber components differed significantly ($P \leq 0.05$) among the short-term moderate or the two season-long treatments (Table 3).

Contrasts designed to separate the effects of grazing intensity from grazing duration indicated that, on the average, moderate stocking yielded diets significantly higher in crude protein, digestibility, and relative intake (Table 2) and lower in cell walls, cellulose, and lignin (Table 3) than did heavy stocking. Differences between the two grazing durations were not as distinct, however. Season-long grazing appeared to provide an advantage over short-term grazing in all of the forage quality parameters, as well as relative intake; but differences between the two regimes were statistically significant only for crude protein (Table 2) and cellulose (Table 3). Differences approached significance at the 5% level for both dietary lignin and in vitro digestibility.

Our findings on qualitative attributes of diets in relation to grazing intensity closely resemble those of Cook et al. (1965), who conducted a study in similar plant communities but slightly later in the growing season. They attributed depressions of dietary crude protein and digestibility and increases in fiber components under heavy stocking to obligatory consumption of more fibrous portions (e.g. stems and stem bases) of the plants that constituted the available forage. A similar study of grazing intensity conducted during winter on desert shrub range (Pieper et al. 1959) attributed such responses to a shift in plant selection from grasses to shrubs; however, such a dietary shift was not observed in either the Cook et al. (1965) study or in the diet selection study conducted by Iskander (1973) in conjunction with our nutritional evaluation.

Reduction of forage intake under conditions of heavy grazing or limited food availability can often be related to the interaction of behavioral and nutritional factors. Arnold (1970) has presented compelling evidence that sheep faced with a diminished supply of palatable plants spend a disproportionately large amount of time seeking and regrazing such plants, sometimes at the expense of total forage intake. Nutritionally, the inverse relationship is well established between forage fiber content, particularly if highly lignified, and digestibility and intake (Montgomery and Baumgardt 1965). Cook et al. (1965), contrary to our findings, did not record reduced intake with increased levels of utilization. However, their heaviest utilization levels (30% for grasses and 29% for forbs) more nearly approximated levels we measured under moderate stocking (3-year mean: 29% for grasses and 39% for forbs) than under heavy stocking (3-year mean: 53% for grasses and 71% for forbs).

The slight nutritional advantage of season-long grazing over short-term grazing is difficult to assess causally and is probably of minor practical importance. For a given grazing intensity, the two durations were so designed that an equivalent amount of animal days of grazing (approximately 440) arose from equivalent areas of land (Table 1). Thus, when considered in total, season-long stocking rates under the two durations were equal; but the sequential pasture scheme employed under the short-term regime resulted in a higher animal density, and animals confronted conditions of heavily utilized forage on three occasions during each grazing season while those in the season-long regime faced such conditions once per season. Sheep in the season-long pastures were probably able to selectively utilize relatively nutritious plant regrowth during much more of the grazing season, whereas, the short time span and the recurring heavy utilization of forage in the short-term pastures provided no such nutritional advantage.

Animal Weight Responses

The farm flock ewes tested during 1972 lost weight under all treatment regimes (Table 4). They came onto the experiment from a dry-lot situation where they had been receiving concentrate feeds and alfalfa hay and all were in a relatively high state of body condition. Their lambs varied widely in age, and the consequent energy demand for lactation probably was equally variable. In contrast, the range ewes tested in 1973 and 1974 came to the experiment directly from lambing pens and

Table 4. Weight gains (kg/head) by ewes under two intensities and durations of spring grazing.

Duration of grazing	Moderate 1972	Moderate 1973	Moderate 1974	Moderate Means[2]	Heavy 1972	Heavy 1973	Heavy 1974	Heavy Means[2]	Grazing duration means[3]
Short-term	–2.6	3.0	2.3	0.9b	–2.7	4.8	3.0	1.7ab	1.3a
Season-long	–1.7	8.4	4.1	3.6a	–5.2	4.8	3.5	1.0b	2.3a
Year means[1]	–2.2c	5.7a	3.2b		–4.0b	4.8a	3.3a		
Intensity means				2.3a				1.4a	

[1] Within each grazing intensity category, year means having different letters differ significantly ($P \leq 0.05$).
[2] Means for the four intensity × duration treatment combinations having different letters differ significantly ($P \leq 0.05$).
[3] Intensity or duration means followed by common letters are not significantly different ($P \leq 0.05$).

were in low body condition relative to the 1972 animals. They gained weight under all treatments (Table 4). Averaged across all treatments, weight responses were −3.1, 5.3, and 3.2 kg per head for 1972, 1973, and 1974, respectively, and they all differed significantly from each other. We have no explanation for the greater gain in 1973 than in 1974, when comparable sheep were grazed.

The season-long moderate treatment yielded significantly higher weight gains by ewes than either the season-long heavy or short-term moderate treatments when all 3 years were considered (Table 4). However, when moderate grazing was compared to heavy grazing, and likewise, when short-term grazing was compared to season-long grazing, no statistical differences were evident.

Lambs' weight gains were relatively high in all treatments during all 3 years, with the season-long moderate treatment demonstrating a distinct advantage (Table 5). The two short-term treatments yielded intermediate gains; and the season-long heavy treatment tended to yield the least, although the 3-year means of the season-long heavy treatment and the short-term heavy treatment did not differ significantly.

Lamb gains differed among years, averaging 13.5, 15.3, and 17.0 kg/head for the three respective years. The relatively low gain during the initial year can be attributed, at least partly, to the pre-experiment husbandry of both ewes and lambs used that year. However, the reason for the relatively high gain in the final year is not evident, and it is not consistent with performance of ewes that gained the most during the second year.

The interaction of year and grazing intensity was significant, and can be seen in a comparison of year means in Table 5. Lambs under moderate grazing developed a 3 kg/head advantage over those under heavy grazing in 1972, a 1.5 kg/head advantage in 1974, but no discernible differences in 1973.

Animals assigned the two grazing durations did not respond uniformly within the two grazing intensities, as indicated by a significant intensity × duration interaction in the analysis of variance and by a comparison of the four intensity × duration means in Table 5. Lambs grazed season-long gained the most under moderate stocking, but heavy stocking appeared to overshadow any effects of either grazing duration tested.

The effects of stocking rate upon animal production have been studied widely, and it is commonly accepted that individual animal performance is depressed by stocking rates sufficiently high to elicit intraspecific competition for food (Heady 1975). We found no evidence from the present study to refute this hypothesis. Weight gains of both ewes and lambs, as well as forage intake and forage quality indicators, were lower under the heavy intensity than under the moderate intensity. Our findings also support the hypothesis that within the realm of realistic stocking rates, production expressed as a function of land area is highest under the relatively heavy stocking rates. We found lamb production to be highest under the short-term heavy treatment (57 kg/ha), followed by the season-long heavy treatment (50 kg/ha), and finally by the two moderate treatments (30 kg/ha).

Little research has apparently been done on grazing duration effects upon animal performance, despite mounting importance of the question in relation to designing specialized grazing systems. We had hypothesized that both individual animal performance and nutritional intake would be limited by the short-term grazing schedule, as instantaneous stocking denisty was higher there than under the season-long regime. Also, the shifts to unfamiliar pasture conditions twice during each grazing season would lead to temporary periods of behavioral and nutritional stress. All of our results on nutrition and production suggested small advantages to season-long grazing over short-

Table 5. Weight gains (kg/head) by lambs under two intensities and durations of spring grazing.

Duration of grazing	Moderate 1972	Moderate 1973	Moderate 1974	Moderate Means[2]	Heavy 1972	Heavy 1973	Heavy 1974	Heavy Means[2]	Grazing duration means[3]
Short-term	13.6	15.3	17.4	15.4b	12.2	15.5	16.8	14.8bc	15.1a
Season-long	16.4	15.3	18.2	16.6a	11.6	14.9	15.8	14.1c	15.4a
Year means[1]	15.0b	15.3b	17.8a		11.9b	15.2a	16.3a		
Intensity means[3]				16.0a				14.5b	

[1] Within each grazing intensity category, year means having different letters differ significantly ($P \leq 0.05$).
[2] Means for the four intensity × duration treatment combinations having different letters differ significantly ($P \leq 0.05$).
[3] Intensity or duration means having different letters differ significantly ($P \leq 0.05$).

duration, but only two nutritional parameters (crude protein and cellulose) differed statistically between the two time regimes imposed. Thus, we must conclude that duration of the grazing period is a much less important consideration in designing grazing systems than is the stocking rate. However, the grazing period employed in this study was confined to the spring season when forage quality and plant growth is generally considered as maximal. Different responses might be expected at other seasons.

In designing a spring grazing management program with the specific goal of manipulating vegetation to favor subsequent forage values for big game, plant community response must be given primary consideration over aspects of domestic animal production. Most range managers would logically expect some degree of sacrifice in livestock response where the primary management goal is plant community manipulation. However, results of this study indicate that this tradeoff need not be large. For example, if pending analyses of vegetational data indicate that heavy stocking yields the quickest and most desirable plant community response, the slight disadvantage imposed on individual animal performance (1.5 kg/head for lambs over the 49-day grazing season) is not great, especially in view of the decided advantage to heavy stocking if production per unit land area is considered.

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