Cattle nutrition and grazing behavior during short-duration-grazing periods on crested wheatgrass range

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Abstract

Daily changes in diet quality, ingestive behavior, and daily forage intake were investigated using crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult. and *A. cristatum* (L.) Gaertn.] range in a 3-year study to provide an understanding of how the rapid defoliation that occurs under the high stocking density of short duration grazing (SDG) affects livestock nutrition. A 10-paddock short duration grazing cell was stocked with yearling Angus heifers. Grazing periods in paddocks varied from 1 to 4 days. Dietary quality was assessed daily within pre-selected paddocks by determining crude protein content and in vitro organic matter digestibility of extrusa samples collected from esophageally fistulated animals. Three variables of ingestive behavior were measured concurrently, including ingestion rate, biting rate, and grazing time. Daily forage intake was estimated by multiplying ingestion rate and grazing time. There were large daily changes in diet quality, ingestive behavior, and forage intake during the grazing period within particular SDG paddocks. Diet quality declined significantly during the 2 or 3 day grazing period in all 3 years. Although not as consistent throughout the study, ingestive behavioral responses changed significantly, indicating declines in forage intake during the grazing period on a particular paddock. Ingestive behavior was correlated with several characteristics of the sward that changed as it was defoliated. Ingestion rate decreased with herbage availability, apparently causing the animals to compensate by increasing biting rate or grazing time. Ingestion rate and biting rate decreased as nutritional quality of the sward declined, as indicated by decreased crude protein content and digestibility, and increased fiber content. Based on the system studied, grazing periods in SDG paddocks should be no more than 2 days to maintain high levels of livestock performance on crested wheatgrass range.

Key Words: diet quality, ingestive behavior, feed intake, crested wheatgrass, *Agropryon desertorum, A. cristatum,* sward characteristics, grazing management

An important feature of short duration grazing (SDG) is the postulated effect of rapid rotation on dietary quality (Savory 1978). This purportedly allows animals to maximize selectivity and plants to regrow during the rest period, providing young and highly nutritious forage for the next grazing period. Thus, animal nutrition and resultant performance under SDG are hypothesized to be better than under traditional grazing schemes (Kothmann 1980). However, under the high stocking density in SDG paddocks, sward characteristics may change rapidly. For example, Heitschmidt et al. (1982) reported significant differences in crude protein content (CP) of available herbage before and after grazing in SDG paddocks. Thus, animal nutritional response, in terms of diet quality, ingestive behavior, and forage intake may also fluctuate in response to such changes.

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Taylor et al. (1980) found no change in dietary CP over the course of 7-day grazing periods in individual paddocks of an SDG system, but dietary in vitro organic matter digestibility (IVOMD) declined significantly, presumably leading to decreased nutrient intake. They felt this could be overcome by using more paddocks and decreasing the length of grazing periods. Subsequently, Ralphs et al. (1986) repeated the trial with 3-day grazing periods on a similar site, and found that CP and IVOMD both declined significantly in the diets of sheep and cattle.

If management of SDG is to improve dietary nutrition and resultant animal performance, length of grazing periods in paddocks must be controlled so that fluctuating forage conditions do not develop that negatively impact animal nutrition. A scientific understanding of this and other principles of SDG is currently lacking (Kothmann 1984). Applying SDG as a scientifically founded program for grazing management requires that the principles upon which it is based be clearly defined, quantified, and validated. This includes understanding the sequence of events in the plant-animal interface that transpire from introduction of animals into paddock until they are rotated to the next paddock. Guidelines concerning the length of grazing periods in each paddock could then be developed to optimize animal nutrition by minimizing declines in diet quality or forage intake that may develop as the vegetation is defoliated. In addition, improved management may be obtained by better understanding which sward characteristics are responsible for changes in dietary nutrition. Sward-based criteria could then be developed to assist SDG managers in livestock rotation decisions. Therefore, the objectives of this study were to (1) determine if SDG causes changes, and the magnitude of those changes, in dietary quality, forage intake, and ingestive behavior during the grazing period of individual paddocks, (2) determine sward characteristic and ingestive behavior relationships under SDG, and (3) define management guidelines for length of grazing period in individual paddocks to maintain nutrient intake at high levels.

Methods and Procedures

Study Site

This study was conducted from 1983 to 1985 on the Tintic Experimental Pastures in Juab County, Utah. Average annual precipitation for the experimental area is 330 mm, distributed evenly through all seasons. The area is typical of Intermountain foothill range that is usually used for spring or fall grazing. Prior to this study, it had traditionally been used as spring or summer range. The SDG cell consisted of 10 equal-sized 8.4-ha (21 acre) paddocks arranged radially around a central watering and handling facility. The site was renovated in 1951 by removing unpalatable woody species, including big sagebrush (*Artemisia tridentata* Nutt.), rabbitbrush [*Chrysothamnus nauseosus* (Pallas)Britt.], and juniper trees (*Juniperus* spp. L.), and seeding to introduced wheatgrasses (*Agropyron* spp. Gaertn.) (Cook 1966). Most of the SDG cell was seeded to crested wheatgrass [*A. desertorum* (Fisch.) Schult. and *A. cristatum* (L.) Gaertn.], but a portion was seeded to intermediate wheatgrass [*A. intermedium* (Host)Beauv.]. The area dominated by intermediate wheatgrass was avoided as much as possible for sampling in this study. The study area was grazed with sheep until 1964 (Cook 1966). Because research efforts at this site were quiescent from 1964 to 1979, grazing history during that period is unknown. The area was grazed on a season-long basis with yearling heifers from 1979 to 1982 at an average stocking rate of 1.3 ha (3.3 ac) per animal unit month (AUM)[1]. During this study, the vegetation was dominated by crested wheatgrass with localized patches of western wheatgrass (*A. smithii* Rydb.). Big sagebrush and rabbitbrush were encroaching throughout the SDG cell and localized stands of juniper occurred.

Grazing Management

The grazing season commenced on 22 April 1985 or 6 May 1983 and 1984, and ended on 13 June 1985 or 1 July 1983 and 1984. Dates varied among years because of differences in herbage availability.

The grazing cell was stocked with 90 yearling black Angus replacement heifers and 3 to 5 bulls, resulting in a stocking rate of 0.7 ha (1.7 acres) per AUM and a stocking density of 0.14 ha (0.35 acres) per animal unit (AU)[1]. This stocking rate was in accordance with the Bureau of Land Management allotment management plan for the study site. The heifers weighed 230 to 270 kg (500 to 600 lbs.) at the beginning of each grazing season.

Animals were moved among paddocks approximately every 3 days in 1983 and 1984. Two complete cycles were made through the grazing cell. In 1985, animals were moved approximately every 2 days during the first 2 cycles, and every day during a third cycle. Length of grazing period in specific paddocks was adjusted based on herbage availability (±1 day). When moved, the animals were rotated clockwise to the adjacent paddock. Animals were moved at midday to avoid interference with normal morning and evening grazing activity.

Field Methodology

Dietary Quality

Heifers with esophageal fistulae were used to collect samples of grazed forage for nutritional analysis. In 1983, three fistulated animals were used. In 1984 and 1985, this number was increased to 5 animals. Fistulated animals were contemporaries of the larger herd of heifers that grazed the experimental paddocks. In addition, they always grazed with the herd, and were thus accustomed to the vegetation, the other animals, and the grazing system.

Samples were collected in the early morning or when animals entered particular paddocks. Animals were fasted for 5 to 10 hours prior to sample collection to encourage grazing. Chacon and Stobbs (1977) found that bite size and diet quality were influenced more by stage of defoliation and individual animal variability than by fasting or diurnal variation in time of sampling, as long as fasting was less than 12 hours. Therefore, by keeping fast periods relatively short, we assumed there would be no measurable effects on experimental results. Fistula extrusa samples were frozen in the field immediately following collection by immersion in a dry ice-alcohol bath. Samples were then stored in a freezer until laboratory analysis.

Esophageal extrusa was collected whenever animals were in 3 preselected paddocks. These paddocks were spaced evenly around the grazing cell. As animals were moved around the grazing cell, this allowed the opportunity to record dietary response to defoliation as a function of advancing plant maturity and regrowth during the rest period. In 1983, extrusa was collected on the days cattle entered and left paddocks 3, 6, and 9. In 1984 and 1985, extrusa was collected on each consecutive morning that the heifers occupied paddocks 1, 4, and 7. In 1985, extrusa was also collected immediately after movement into the paddocks (i.e., at midday), to gain information on response to ungrazed swards.

Ingestive Behavior and Forage Intake

Because measures of ingestive behavior make it possible to relate forage intake with sward structure and to make relatively instantaneous measures of forage intake (Stobbs 1974), it should be useful in developing a mechanistic understanding of animal response as the sward is rapidly defoliated under SDG. Therefore, 3 variables of ingestive behavior (ingestion rate, biting rate, and grazing time) were measured in 1984 and 1985.

Ingestion rate, or intake per unit time, was measured in conjunction with collection of esophageal extrusa. Extrusa collected during timed periods of sampling was weighed in the field immediately following collection. To improve the probability of collecting all forage ingested during an extrusa collection, foam rubber plugs were placed in the esophagus posterior to the fistula during collections in 1983, as recommended by Stobbs (1973a). However, animals were often observed to be disturbed by the presence of the foam rubber plug, and did not appear to graze normally. In 1984 and 1985, a cannula insert (Olson and Malechek 1987) was used in lieu of the foam plugs to facilitate total sample collection. Although evidence that the insert improves the probability of total sample collection is not available, the insert held the fistula lumen open, apparently making it the path of least resistance for boli. Additionally, use of the cannula did not affect animal behavior.

Biting rate was visually counted during the period of intense grazing in early morning, immediately prior to esophageal extrusa collections. Animals to be observed were selected in a stratified manner to maximize independence of samples. Consecutively observed individuals were separated by a distance that was deemed adequate to minimize possible effects of social facilitation on behavior. For a particular animal, time elapsed to prehend and ingest 100 to 200 bites was recorded with a stop watch while counts were made. Timing was interrupted during nongrazing intervals, such as when animals were disturbed by insects or walking.

Four intact animals were randomly selected from the herd and fitted with vibracorders to record grazing time. These instruments remained on the animals throughout the grazing season, and grazing time was recorded continuously.

Estimated daily forage intake was the product of ingestion rate and grazing time (Freer 1981).

Sward Characteristics

Total aboveground herbaceous plant biomass was estimated by double sampling procedures (Pechanec and Pickford 1937). The harvested samples were dried for 24 hours at 60° C, weighed, and saved for laboratory analyses. Plant height was measured on 100 plants located on a pace transect positioned lengthwise through the center of the paddock. The height from the ground to the top of a randomly selected tiller in the tussock was measured. The tiller was measured as it stood naturally rather than manually straightening it to its maximum height. Forage bulk density was calculated by dividing biomass by plant height, and is expressed as g dry matter (DM) per cm^3. Data concerning sward characteristics were collected daily, immediately following esophageal extrusa collections.

Laboratory Methodology

A subsample of each extrusa sample was used to determine DM and organic matter (OM) content (Harris 1970) to adjust ingestion rates to an OM basis. Another subsample of each frozen extrusa sample was freeze-dried and ground through a 1-mm screen. Extrusa samples were not composited across animals, days, or paddocks, because all these sources of variation were of interest. Ground samples were analyzed for Kjeldahl nitrogen (Harris 1970) and IVOMD by use of a cellulase technique (McLeod and Minson

[1]AUM (animal unit month) and AU (animal unit) follow the standard definition wherein 1 animal unit equals a 454-kg cow with calf or the equivalent, and an animal unit month is the forage demand of 1 animal unit for 1 month.

1978). Crude protein was calculated as Kjeldahl nitrogen times 6.25.

Five oven-dried herbage samples from each sampling date were ground through a 1-mm screen and analyzed for nutritional characteristics by near infrared reflectance spectroscopy (NIRS) Marten et al. 1985). These analyses included crude protein, IVOMD, neutral detergent fiber, acid detergent fiber, permanganate lignin, cellulose, and hemicellulose (Goering and Van Soest 1970). A subset of 100 herbage samples were randomly selected for wet chemistry analysis to develop calibration equations for NIRS.

All results for extrusa and herbage nutritive characteristics are reported on an OM basis (Harris 1970).

Data Analysis

Detection of significant daily changes in dietary quality and ingestive behavior was by least squares analysis of variance (ANOVA) using the Rummage statistical program (Bryce 1980). Statistical comparisons were not made between years because of differences in sampling schedules and grazing management. Mean separations were detected using LSD when ANOVA main effects were significant. Statistical significance was inferred at $P \leq 0.05$, unless otherwise stated. Replicates of the experimental range units (grazing cells) were not available. We recognize that this lack of replication of true experimental units limits the application of results to other swards. However, we feel that this study provides valuable insights concerning the relative effect of length of grazing period on diet quality and ingestive behavior.

To consider the relationship between sward characteristics and ingestive behavior, the correlation between each ingestive behavior variable and each sward characteristic was determined. Correlation coefficients (r values) were considered statistically significant at $P \leq 0.10$.

Optimum length of stay in a paddock was inferred by considering daily changes in diet quality, forage intake, and ingestive behavior.

Results and Discussion

Daily Dynamics in SDG Paddocks

Diet Quality

In 1983, CP and IVOMD (P=0.56) declined significantly from entry to day 3 (Table 1). These declines detected in the first year provided impetus for more intensive sampling on a daily basis in the ensuing years to better understand animal response to the rapid defoliation during the grazing of paddocks. In 1984, CP and IVOMD did not change from day 1 to day 2, but declined significantly by the third day (Table 1). In 1985, CP and IVOMD both declined significantly from entry into paddock to the first morning (day 1), but, like 1984, did not change from day 1 to day 2 (Table 1).

When comparing across years, no significant differences were detected between days 1 and 2 in 1984 and 1985. Apparently, animals attained a relatively high quality diet when they first entered a new paddock, as depicted at entry in 1985, but diet quality declined rapidly, with 18 to 20 hours. After that, diet quality was maintained for another day, as seen in both year's data. However, when the animals were left in the paddocks for a third day, as in 1984, diet quality declined appreciably.

This particular time sequence of declines in diet quality may be inherent to the study due to site characteristics and productivity. However, it can be concluded that the animal's ability to maintain selectivity for high quality forage decreases rapidly during the relatively short grazing periods under SDG.

Ingestive Behavior and Forage Intake

Ingestive Behavior in 1984. Ingestion rate and grazing time did not change over days in a paddock (Table 1), while biting rate increased from day 1 to day 2, and then remained the same on day 3. Although bite size was not measured, a value can be calculated (bite size = ingestion rate/biting rate). Bite size apparently declined from day 1 to day 2, and remained unchanged on day 3 (Table 1). These calculated values for bite size and the actual means for ingestion rate, biting rate, and grazing time fall within the range of data reported in the literature for both temperate (Jamieson and Hodgson 1979a, 1979b) and tropical swards (Chacon and Stobbs 1976; Stobbs 1973a, 1973b, 1974, 1975). Animals apparently maintained ingestion rate by increasing biting rate as bite size declined due to defoliation of the paddock. Because ingestion rate did not decline, animals did not increase their grazing time. These results are consistent with those of Chacon and Stobbs (1976), who concluded that increases in biting rate or grazing time compensate for decreases in bite size as the sward is defoliated. However, these results disagree with those of Jamieson and Hodgson (1979a), who found that bite size, biting rate, grazing time, and daily forage intake all decreased as herbage availability decreased under intensive "rotational" grazing management (strip grazing). They concluded that animals did not increase biting rate or grazing time under strip grazing, as they did under continuous grazing (Jamieson and Hodgson 1979b), because they anticipated the move to fresh forage.

Table 1. Mean daily crude protein concentration and in vitro organic matter digestibility (IVOMD) of esophageal extrusa, ingestion rate, biting rate, grazing time, and daily forage intake by heifers during the grazing period within SDG paddocks.

Variables	Time	1983	1984	1985
Crude protein	at entry	14.87^{a}[1]		16.49^{a}
(%)	day 1	[2]	14.71^{a}	12.62^{b}
	day 2		14.23^{a}	11.75^{b}
	day 3	11.35^{b}	13.05^{b}	
IVOMD	at entry	68.19^{a}		71.79^{a}
(%)	day 1		68.32^{a}	67.10^{b}
	day 2		67.37^{a}	66.71^{b}
	day 3	60.34^{b}	64.48^{b}	
Ingestion rate	at entry			13.08^{a}
(g OM/min)	day 1		10.80^{a}	9.85^{b}
	day 2		9.27^{a}	7.86^{b}
	day 3		9.43^{a}	
Biting rate	day 1		47.70^{a}	52.58^{a}
(bites/min)	day 2		52.10^{b}	52.53^{a}
	day 3		51.28^{b}	
Grazing time	day 1		10.01^{a}	9.24^{a}
(hrs/day)	day 2		10.07^{a}	10.12^{b}
	day 3		10.17^{a}	
Bite size	day 1		0.23	0.19
(g OM/bite)	day 2		0.18	0.15
(IR/BR)	day 3		0.18	
Forage intake	day 1		6.49	5.46
(kg OM/day)	day 2		5.60	4.77
	day 3		5.75	

[1]Means within years and variable differ ($P \leq 0.05$) when followed by different letters.
[2]Data not collected for that day within that year if blank.

Ingestive Behavior in 1985. Ingestion rate declined significantly from sampling at entry to the paddock to the following morning (day 1), and subsequently remained unchanged (Table 1). Biting rate did not change between days 1 and 2. Grazing time increased significantly from the first to the second day in the paddock. Bite size appears to have declined slightly, but this is simply a reflection of the non-significant decline in ingestion rate from day 1 to day 2. Again, the range of data in this study is comparable to that of other studies of ingestive behavior done on a variety of swards (Jamieson and Hodgson 1979a, 1979b; Chacon and Stobbs 1976; Stobbs

1973a, 1973b, 1974, 1975).In contrast to 1984, animals increased grazing time in 1985, possibly to compensate for the decrease in ingestion rate that occurred following entry into a given paddock. Thus, animals used different components of ingestive behavior to compensate for apparent declines in bite size in each of the 2 years. This contrasts with the findings of Scarnecchia et al. (1985), who found that biting rate and grazing time increased simultaneously as a crested wheatgrass sward was defoliated under continuous grazing management. However, Scarnecchia et al. (1985) used a mature, primarily dormant sward, while this study was conducted during the growing season of crested wheatgrass. This seasonal effect would present a different sward structure with resultant implications to animal behavioral responses to that structure. These compensatory increases also contrast with Jamieson and Hodgson's (1979a) finding that biting rate and grazing time both declined as the sward was rapidly defoliated under strip grazing management.

Forage Intake. Daily forage intake was a direct reflection of ingestion rate (Table 1). Increased grazing time in 1985 apparently did not compensate for declining ingestion rate, thus having little effect on the decline in intake. It appears that sward characteristics that affect ingestive behavior can directly affect animal nutrient intake. Identifying and relating these sward characteristics to desired levels of ingestive behavior and intake should be useful in managing crested wheatgrass, particularly with SDG, to improve livestock performance.

Correlation of Sward to Behavioral Variables

Relationships between ingestive behavior and sward variables were analyzed using simple correlation techniques (Table 2). These sward characteristics can be considered in 3 groups: (1) sward physical structure, including sward bulk density, aboveground biomass, and plant height; (2) positive nutritive characteristics, including crude protein and IVOMD; and (3) fiber components (including neutral detergent fiber, acid detergent fiber, permanganate lignin, cellulose, and hemicellulose) that are typically considered as inversely related to forage quality.

Table 2. Correlation coefficients (r) between ingestion rate (IR, g OM/min), biting rate (BR, bites/min), and grazing time (GT, hrs/day) and several sward characteristics for each year.

Sward characteristics	IR	BR	GT
1984		r	
Bulk density (gm/cm³)	.54*	–.21	–.01
Biomass (kg/ha)	.51*	–.31	–.38
Height (cm)	.38	–.15	.16
Crude protein (%)	.42	.15	–.62
IVOMD (%)	–.03	.35	.06
Neutral detergent fiber (%)	.04	–.34	.20
Acid detergent fiber (%)	–.003	–.21	.55
Permanganate lignin (%)	.02	.20	.53
Cellulose (%)	.04	–.27	.15
Hemicellulose (%)	.09	–.48*	–.22
1985			
Bulk density (gm/cm³)	.51*	–.44*	–.79*
Biomass (kg/ha)	.61*	–.31	–.66*
Height (cm)	.19	–.55*	–.77*
Crude protein (%)	.31	.51*	.31
IVOMD (%)	.16	.38*	.19
Neutral detergent fiber (%)	–.38*	–.63*	–.20
Acid detergent fiber (%)	–.31	–.22	.11
Permanganate lignin (%)	–.13	.07	.07
Cellulose (%)	–.33*	–.51*	–.25
Hemicellulose (%)	–.30	–.73*	–.34

*significant at $P \leq .10$

Ingestion rate was positively correlated with physical characteristics, while biting rate and grazing time were negatively correlated. Results during both years were generally similar, although fewer correlation coefficients were significant in 1984, usually because of fewer samples, but also apparently because of weaker relationships. However, the signs and relative magnitudes of most correlation coefficients generally correspond across years. These results indicate that as biomass became more available, ingestion rate increased, while biting rate and grazing time decreased. This agrees with previously reported results (Allden and Whittaker 1970, Freer 1981, Short 1985). Thus, ingestion rate can increase as more forage is available and accessible. Changes in ingestion rate were inversely related to changes in biting rate and grazing time, as expected from results of Chacon and Stobbs (1976). The negative correlation between biting rate and plant height is consistent with the conclusion of Hodgson (1985) that animals take more bites and spend less time manipulating forage as the sward becomes shorter. Ingestion rate was more strongly correlated with biomass than with sward bulk density in 1985. These correlation coefficients were essentially equal in 1984. These results differ from the findings of Stobbs and Hutton (1974), and may reflect differences in structure of temperate and tropical grass swards. Tropical swards are typified as having much greater total biomass than temperate swards, but having a much lower sward bulk density and much higher stem content (Stobbs 1975, Whiteman 1980). Thus, sward bulk density rather than biomass availability probably first limits ingestive behavior in a tropical sward, while the opposite is true in a temperate sward.

Herbage CP and IVOMD indicate that increasing nutrient content and availability typically were positively related to all 3 behavioral responses. Correlations were significant only for biting rates in 1985, however. Increases in these nutrient characteristics is probably positively related to desirability, causing an animal to increase its rate of biting. They are also positively related to a high leaf content, thus allowing increased biting rate, because the animal spends less time manipulating stems out of its bite (Chacon and Stobbs 1976).

Fiber fractions tended to be negatively correlated with ingestive behavior variables. However, few of the correlations were significant. Increasing herbage fiber content signifies declining leaf:stem content because of selective defoliation of leaves or an increase in the proportion of stems as maturity advances (Chacon and Stobbs 1976). The resulting decrease in accessibility of available leaf can cause a reduction in ingestion rate and biting rate in an attempt to increase selectivity (Chacon and Stobbs 1976). Increasing fiber content also makes the plant material tougher, causing prehension of bites to become more difficult. This can also cause a decline in rates of ingestion and biting. Note the relatively strong correlation of biting rate to hemicellulose content in both years. Hemicellulose is a fiber matrix of branched-chain polysaccharides that bind the cellulose fibers of the cell wall together (Albersheim 1975), thus providing structural rigidity and strength to the plant cell walls. Therefore, increased hemicellulose is probably related to increased "toughness", causing the animal to expend more time and effort to prehend a bite. Visual observations indicated that the animals had to put a great deal more effort and time into tearing off individual bites as the sward matured.

Management Guidelines for SDG Paddock Grazing Periods

Diet quality, ingestive behavior, and forage intake all changed rapidly as paddocks were grazed under the conditions of this study. Diet quality and ingestion rate both declined within the first day in a paddock, but then remained constant into the second day of grazing. However, significant declines occurred on the third day in 1984. Therefore, livestock should be moved among paddocks at least every 2 days during the rapid growth stage of crested wheatgrass. This time period may be specific to this study site, and other swards with different production capabilities may sustain nutrition over a different time period. However, regardless of site characteristics, it can be concluded that animals will have to be moved very rapidly when vegetation is actively growing. In addition, these rapid declines in intake and nutrition indicate elevated risk of loss in animal performance due to mismanagement. Moving the cattle a day late could seriously impact animal performance. In fact, animal performance, in terms of heifer growth, was greater relative to season-long grazing in 1985 compared to 1983 and 1984, possibly as a result of using 2-day rather than 3-day grazing periods (Olson and Malechek 1988). Thus, decision-making on a daily basis and the risks involved make SDG an extremely management-intensive form of grazing management. The correlations between ingestive behavior and some sward characteristics (Table 2) indicate that a predictive relationship could be developed between these variables, allowing the determination of optimum sward conditions to maintain a high level of animal nutrition. Animals could be moved whenever the sward was defoliated to a condition that limited dietary nutrition to a pre-selected minimal standard. Such a predictive model using this data was developed (Olson et al. 1986). However, because data were collected over a limited range of spatial and temporal conditions, this model currently has limitations that make it unsuitable for use as a management tool.

These management guidelines are based on animal nutritional responses, and intended to provide improved animal performance. They are not based on plant response and resultant effects on productivity of the crested wheatgrass sward.

Conclusions

Diet quality significantly and rapidly decreased over the grazing period in all 3 years as the paddocks were defoliated (Table 1). Ingestion rate declined significantly during the grazing period in 1985, but not in 1984. Significant increases in biting rate during the grazing period in 1984 indicated that animals may have tried to compensate for a decline in bite size, thus maintaining constant ingestion rate. Biting rate did not change during the grazing period in 1985, thus allowing the decline in ingestion rate. Grazing time did not change during the grazing period in 1984, but increased significantly in 1985. Evidently, when ingestion rate declined, as in 1985, grazing time increased to compensate. The resultant effect was a decline in daily forage intake as the paddock was defoliated.

Significant correlations existed between sward characteristics and ingestive behavior. Physical structure of the sward, including aboveground biomass, sward bulk density, and sward height, was positively related to ingestion rate, and negatively related to biting rate and grazing time. This indicated that ingestion rate increased as forage became more available, and compensatory declines in biting rates and grazing time occurred. Further correlations indicated that increases in the nutritional value of the herbage, as indicated by increased crude protein and digestibility, and decreased fiber content, were associated with increased ingestion rate and biting rate.

Because of the rapid declines in diet quality and ingestion rate, it is recommended that paddocks be grazed for 2 or fewer days during the active growth period of crested wheatgrass.

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