Influence of range site on diet selection and nutrient intake of cattle

KAREN L. LAUNCHBAUGH, JERRY W. STUTH, AND J.W. HOLLOWAY

Abstract

It is common in range science to base stocking rate estimates on range sites as units of forage production. However, little is known about how diet composition, quality, and intake may differ by range site. This study examines the influence of 2 range sites on the diet selection and nutrient intake of cattle. A sandy loam (SL) and a clay loam (CL) range site were compared in 4 seasonal, trials on an *Acacia* dominated, mixed-brush savanna on the Texas Rio Grande Plains. Diet composition and quality, and nutrient intake of cattle were determined throughout each 16–21 day trial using esophageally fistulated cattle and daily dosing with ytterbium acetate. The range sites differed widely in proportions of grass, forb, and browse biomass. Cattle generally selected similar diets and adjusted diets to increasing grazing pressure and decreasing forage availability in a similar manner regardless of site, except in fall when cattle selected more browse on the SL site where herbaceous forage was severely limited. Fecal output of cattle differed between sites only in fall when cattle on the SL site had lower fecal output than cattle on the CL site. Cattle on the site of lower herbaceous mass (SL site) generally achieved higher diet quality and nutrient intake during the growing season, when herbaceous forage was readily available because of greater access to green forage. Therefore, the SL site yielded higher diet quality at low grazing pressure during the growing season. Conversely, the CL site, because of its greater herbaceous mass, yielded higher nutrient intake in the fall and at high levels of grazing pressure.

Key Words: intake, range site, fecal output, esophageal fistula, graze-out

The range site concept has been widely employed to describe rangelands since its introduction in 1949 (Dyksterhuis 1949). Range sites are complexes of soil and climatic conditions which create measurable differences in botanical composition and biomass of climax vegetation (Dyksterhuis 1949, 1958). Range sites have been described and quantified throughout North American rangelands. However, grazing management applications of the range site concept have been primarily limited to setting initial stocking rates (Shiflet 1973). An understanding of how herbivores adjust their diets and nutrient intake on different range sites could lead to greater accuracy in setting stocking rate, season of use, pasture rotation, and desired level of range utilization.

There are several mechanisms by which range site could influence livestock diet selection and nutrient intake. Although livestock select diets differ in composition from the available forage (Hardison et al. 1954, Heady 1964), range site and condition define vegetal composition and set limits on diet selection. Furthermore, range sites describe potential and temporal forage production, which influences an herbivore's ability to meet intake requirements, thereby affecting both diet selection and nutrient intake.

Range sites also mediate selection by affecting plant nutrient quality, live:dead and leaf:stem ratios (Cook and Harris 1950, Sims et al. 1971, Araujo 1985). Plant quality (i.e., crude protein, digestibility) is positively correlated with species preference (Hardison et al. 1954, Heady 1964, Arnold and Hill 1972, Marten 1978). Similarly, livestock generally prefer plant parts with highest nutrient concentration, preferring leaves to stems and green to senescent material (Hardison et al. 1954, Arnold 1964). Livestock have also been shown to prefer plants with high potential intake rates (Kenney and Black 1984). Therefore, differences between range sites in height and density of a plant species could influence diet composition by regulating potential intake rate (Black and Kenney 1984).

The influence of grazing pressure on diet quality and nutrient intake may also differ by range site due to differences in species accessibility and quality. The purpose of this study was to examine the effect of range site on the diet selection and nutrient intake of heifers subjected to a rapidly decreasing forage supply.

Methods

Study Site

The mixed-brush community of the study sites was composed primarily of blackbrush *(Acacia rigidula),* guajillo *(Acacia berlandieri),* granjeno *(Celtis pallida),* and whitebrush *(Aloysia lyciodes).* The SL site produced 3,419 ± 174 kg/ha of browse compared to 1,652 ± 102 kg/ha on the CL site, with little seasonal variation. The major browse species were similar between sites. However, the SL site produced several palatable secondary browse species which were absent on the CL site. These secondary species include kidneywood *(Eysenhardtia texana),* elbowbush *(Forestieria cunifolia),* wolfberry *(Lycium berlandieri),* and shrubby bluesage *(Salvia bullotaeflora).*

The understory grass included curlymesquite *(Hilaria berlangeri),* tobosa *(Hilaria mutica),* Hall's panicum *(Panicum hallii)* and pink pappusgrass *(Pappophorum bicolor).* Dominant forb species in winter and spring were annual forbs including plantago (*Plantago* spp.), vervain (*Verbena* spp.), and evening primrose (*Oenothera* spp.). Summer and fall were dominated by perennial forbs such as broomweed (*Xanthocephalum* spp.), western ragweed *(Ambrosia psilostachya),* and false ragweed *(Parthenium confertum).* Herbaceous biomass standing crop at the beginning of each trial and the percentage of green and grass biomass are shown in Table 1.

Data Collection

Diet composition and nutrient intake of (Brahman × Simmental) heifers (445 kg mean weight) were estimated on a clay loam (CL) and a sandy loam (SL) range site in Texas. The sites were located on nearly level uplands on the Rio Grande Plains Experimental Ranch near Uvalde, Texas. The subtropical steppe climate (Norwine 1978) is characterized by 49.5 cm average annual precipitation, occurring mostly in May and September with common periodic droughts (Gould 1960, USDA 1977).

Each range site was divided into two, 1.8-hectare paddocks. Two paddocks, one from each range site, were compared in 4 trials

Authors Launchbaugh and Stuth are former graduate research assistant and professor, Department of Range Science, Texas A & M University, College Station, Texas 77843; Holloway is professor and resident director, Texas Agr. Exp. Sta., Uvalde, Texas 77801. Launchbaugh is currently a research assistant, Department of Range Science, Utah State University, Logan, Utah 84322.

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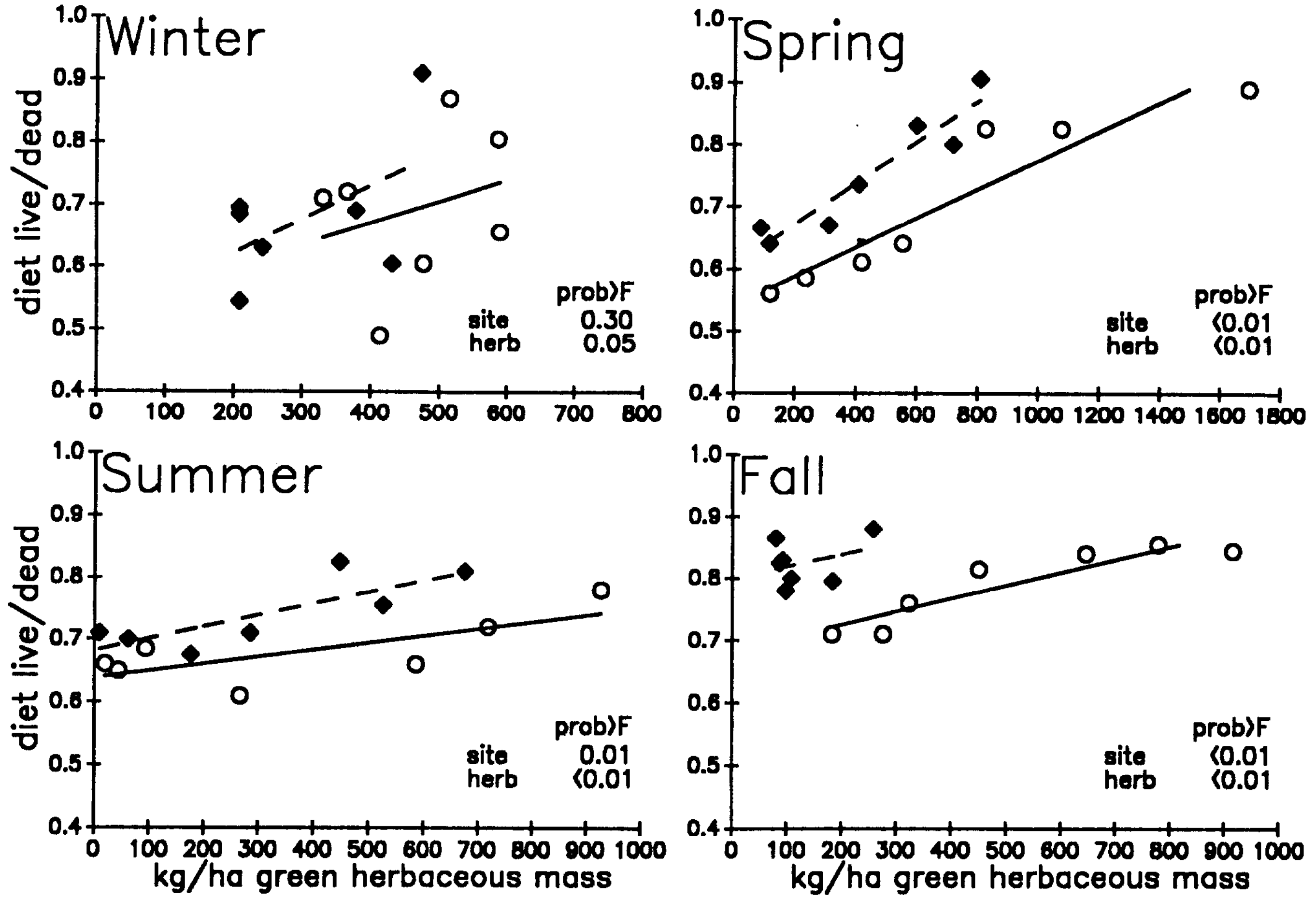

Fig. 1. Live:dead ratio of cattle diets from a clay loam (○ ———) and a sandy loam (◆ - - - -) range site. Statistics presented for range site (site) and green herbaceous mass (herb) effects. Site*herb interactions were not significant therefore the interaction was dropped from the model.

during 1986: winter (26 Jan.–22 Feb.), spring (14 May–6 Jun.), summer (30 Jul.–22 Aug.), and fall (23 Oct.–2 Nov.). Paddocks examined within each site were alternated each season. Near complete removal of herbaceous forage during each trial was achieved by including animals of similar size, sex, and background as experimental animals in proportion to forage available.

Aboveground biomass was estimated 4 times in each trial along 20 permanent transects (30 m) systematically distributed in each paddock. On each sampling date, 2 quadrats (0.5 m²) were randomly placed along each transect, clipped to ground level, and separated into grasses or forbs. Species composition and percent green of each quadrat were visually estimated on a weight basis. Browse biomass was estimated in 1×30 m belts parallel to each permanent transect using the browse weight/volume method described by Lopes and Stuth (1984). Browse weight/volume was determined by clipping 2 cubic frames ($0.3 * 0.3 * 0.3$ m) from the surface of 10 plants of each major browse species represented on both sites. Interpolation was used to estimate herbaceous, browse, and green biomass on each day during trials.

Table 1. Total herbaceous standing crop, and the percentage of green and grass biomass at the beginning of seasonal, 21-day, grazing trial on a clay loam (CL) and a sandy loam (SL) range site.

Season	Initial herbaceous biomass CL	Initial herbaceous biomass SL	Grass biomass CL	Grass biomass SL	Green biomass CL	Green biomass SL
	——kg/ha ± SE——		——% herbaceous biomass——			
Winter	977±137	610±100	56	41	60	82
Spring	2648±173	1055± 63	29	18	58	72
Summer	1189± 95	876±150	61	24	46	57
Fall	1022±140	302± 23	58	30	84	83

Diet samples from 3 esophageally fistulated heifers on each site were collected in the morning and evening on 7 dates per trial. Fresh extrusa samples were oven-dried (60° C). Lesperance et al. (1974), Smith et al. (1967), and Burritt et al. (1988) have reported that oven-drying of extrusa samples, particularly those containing large proportions of browse, tends to deflate digestibility values when compared to freeze drying. Results which may have been affected by drying method will be noted.

Botanical composition of extrusa samples was assessed using the macrofragment technique described by Araujo (1985). Preference ratios were based on plant frequency using the equation of Durham and Kothmann (1977). Ratings of +10, −10, and 0 indicate maximum preference, minimum preference, and selection in proportion to availability, respectively. The overall diet selectivity was determined using the selection index described by Van Dyne et al. (1978), in which selectivity ranges from 0 to 100%, 0% denotes equal diet and pasture composition, and 100% indicates maximum selection.

Percent nitrogen, on an organic matter basis, was determined for each extrusa sample by the micro-Kjeldahl method (AOAC 1960) and converted to crude protein (CP = nitrogen * 6.25). In vitro organic matter digestibility (IVOMD) was determined using the first digestion stage of Tilley and Terry (1963), followed by neutral

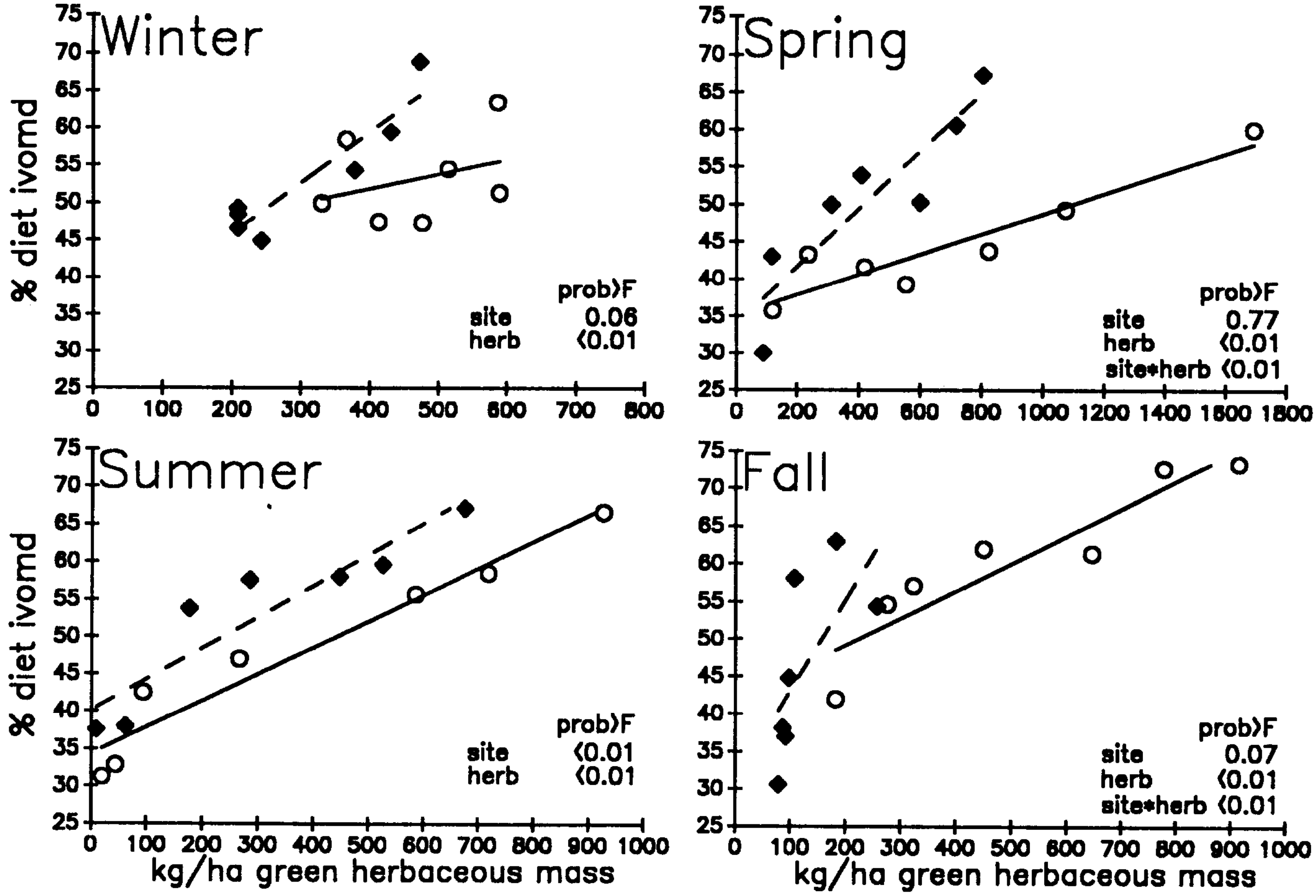

Fig. 2. In vitro organic matter digestibility (IVOMD) of cattle diets from a clay loam (○ ———) and a sandy loam (◆ - - - -) range site. Statistics presented for range site (site) and green herbaceous mass (herb) effects. When site*herb interaction was not significant the interaction was dropped from the model.

detergent fiber analysis (Goering and VanSoest 1970). Rumen inoculum was obtained from a steer grazing warm-season introduced pasture. IVOMD was corrected to apparent digestibility by including 1 sample of known in vivo digestibility per 24 in vitro samples.

The rare-earth marker, ytterbium, was used to estimate fecal output of the 3 fistulated and 3 intact heifers of similar breeding, weight, and condition per site. Heifers received daily ytterbium doses of 0.5 g in acetate form. Ytterbium concentration in daily fecal grab samples was analyzed by atomic absorption spectroscopy with samples prepared as described by Ellis et al. (1980). Organic matter intake (OMI) was calculated as in Cordova et al. (1978). Multiplication of OMI and diet CP yielded crude protein intake (CPI).

Statistical Data Analysis

This was a case study of 2 range sites using animals within site as replicates. Data on diet composition samples taken from 7 dates in each trial were grouped into beginning (2 dates), middle (3 dates), and end (2 dates) time periods to facilitate statistical analysis. Effects of site and time period on diet composition (% grass, forbs, and browse) were tested with repeated measures analysis of variance with measurements repeated over time (Engeman et al. 1985). Sites were also compared within each time period with a 2 sample *t*-test.

The effect of range site on diet quality, fecal output, and nutrient intake within each season was tested by equal slopes analysis with green herbaceous standing crop (HERB) as a covariate. When the site by HERB interaction was not significant, meaning the slope of

Table 2. Composition of cattle diets at the beginning, middle, and end of 21-day, grazing trials on a clay loam (CL) and sandy loam (SL) range site.

		Diet composition					
		Grass		Forb		Browse	
Season	Period	CL	SL	CL	SL	CL	SL
		%					
Winter							
	Begin	22.5	26.0*	64.3	67.5	13.3	6.5
	Mid	43.3	35.0*	52.5	58.5	4.2	6.5
	End	35.8	23.5*	32.0	61.0	2.3	15.5*
Spring							
	Begin	58.3	57.8	38.8	35.0	3.0	7.3*
	Mid	29.7	33.3	66.5	58.7	3.8	8.0
	End	29.3	23.0	50.5	42.3	10.3	34.8*
Summer							
	Begin	87.3	86.8	12.3	11.5	0.5	1.8
	Mid	57.3	31.5*	36.6	60.2*	6.3	8.3
	End	35.8	29.8	38.3	42.3	26.0	28.0
Fall							
	Begin	90.5	53.3*	8.3	39.0*	1.3	7.8
	Mid	46.0	32.7	50.7	29.7*	3.3	37.7*
	End	52.3	19.5*	36.3	23.5*	10.5	57.0*

*Denotes statistical differences (pr <0.10) between sites by period within season.

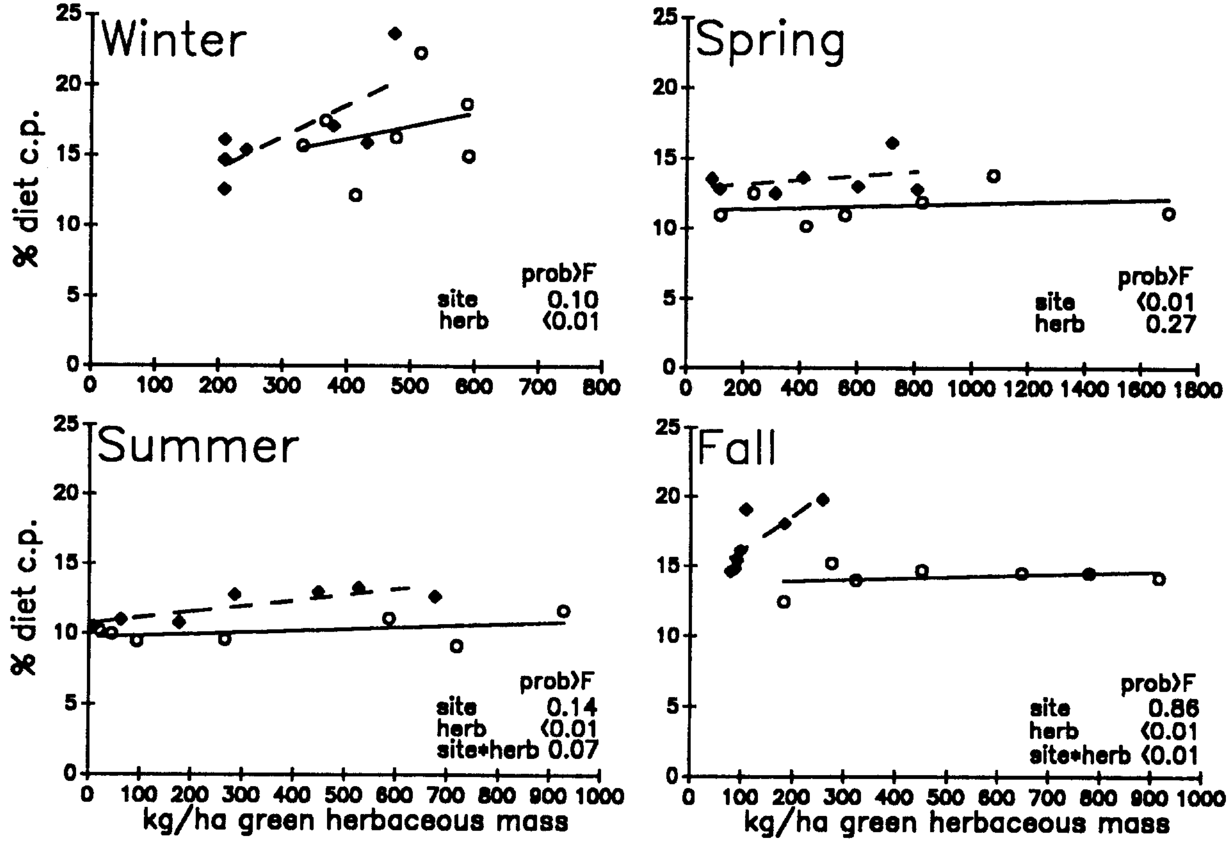

Fig. 3. Crude protein (% organic matter) of cattle diets from a clay loam (o ———) and a sandy loam range site. Statistics presented for range site (site) and green herbaceous mass (herb) effects. When site*herb interaction was not significant the interaction was dropped from the model.

the dependent variable on HERB was the same for both sites, the interaction was dropped from the model, and analysis of covariance was employed to infer site effects. When the site by HERB interaction was significant (i.e., slope differed by site) the site with the greater slope was termed less "stable" regarding change in the dependent variable. Thus, differences in magnitude and stability of variables is discussed. All differences were interpreted at the 0.10 probability level.

Results

Diet Composition and Selection

No differences were found between morning and evening samples in any parameter. All results are means of morning and evening samples. Cattle employed similar diet strategies regardless of range site. Generally, cattle focused on grass in the beginning of each trial (except in winter when palatable annual forbs were available), then switched to forbs mid-trial and only increased browse consumption significantly at the end of each trial when herbaceous forage was limited (<200 kg/ha) (Table 2). The proportions of grass, forbs, and browse in cattle diets were similar between sites with 2 major exceptions. First, cattle on the SL site selected a lower proportion of grass and forbs and a higher proportion of browse than cattle on the CL site during the fall because herbaceous forage was severely limited (maximum 302 kg/ha) on the SL site. Secondly, cattle on the SL site generally increased browse in their diets, as grazing pressure increased, more than cattle on the CL site in all trials except summer.

Forage of the SL site produced a lower proportion of grass and forbs than the CL site. Yet, diets were generally similar between sites. Consequently, cattle on the SL site showed greater selection for grass and forbs than cattle on the CL site, as indicated by higher preference ratios (Table 3). Preference ratios also indicate that browse was avoided less on the SL site than on the CL site at the end of the winter, spring, and fall trials.

Cattle on the SL site were generally more selective (proportions of grass, forbs, and browse in their diets differed more from the proportions available) than cattle on the CL site when herbaceous forage was readily available (beginning and middle of trials in Table 3). However, as herbage allowance decreased, cattle tended to conform diets more closely to the proportions of forage available. Therefore diet selectivity of cattle on the SL site was similar or lower than that of cattle on the CL site by the end of each trial.

Diets from the SL site had a higher live:dead ratio than diets from the CL site over all levels of green herbaceous mass in all trials except winter (Fig. 1). In winter, actively growing forbs were readily available on both sites. Greater selectivity by cattle on the SL site may explain the observed higher live:dead ratio of diets from the SL compared to the CL site. However, the SL site was characterized by lower herbaceous biomass and a higher proportion of green herbaceous forage than the CL site; therefore green forage was more accessible.

Diet Quality

Cattle diets from the SL site had higher IVOMD than diets from the CL site in the winter and summer over all levels of green herbaceous mass (Fig. 2). The digestibility of diets from the SL site was less stable (decreased more quickly, as herbaceous mass

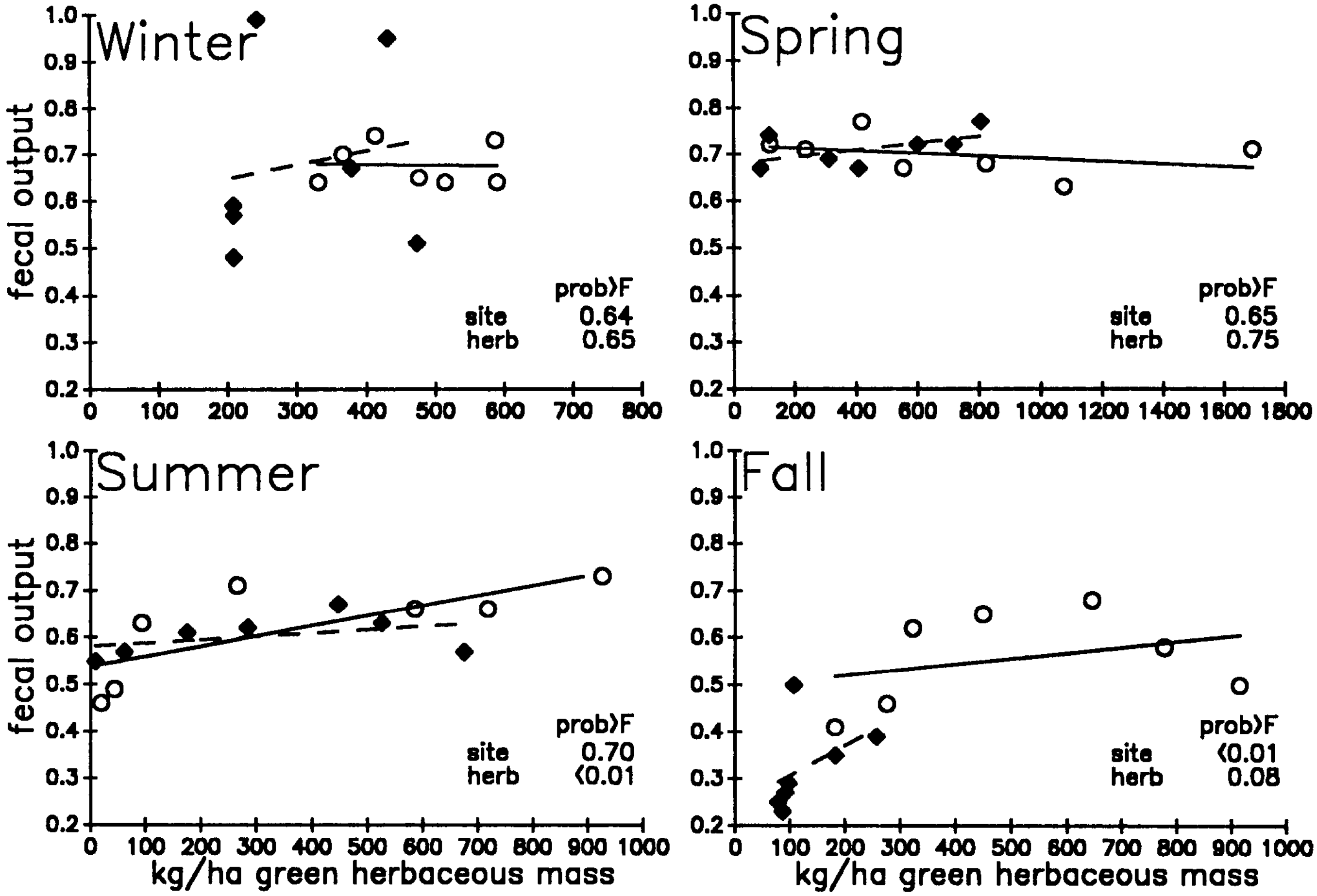

Fig. 4. Daily fecal output (% body weight) of cattle on a clay loam (○ ——) and a sandy loam (◆- - - -) range site. Statistics presented for range site (site) and green herbaceous mass (herb) effects. When site*herb interaction was not significant the interaction was dropped from the model.

Table 3. Preference ratios and overall selection index of cattle diets at the beginning, middle, and end of 21-day, grazing trials on a clay loam (CL) and sandy loam (SL) range site.

		Preference ratios						Selection Index	
		Grass		Forb		Browse			
Season	Period	CL	SL	CL	SL	CL	SL	CL	SL
								%	
Winter									
	Begin	0.3	5.3*	5.9	7.5*	-6.9	-8.9	62.0	81.0
	Mid	4.0	9.0*	6.2	7.9*	-8.9	-8.7	69.0	85.0*
	End	3.2	9.5*	7.7	8.4*	-9.4	-7.2*	77.0	79.0
Spring									
	Begin	5.2	8.8*	-1.4	2.4	-8.8	-8.4	61.0	75.0*
	Mid	6.4	9.0*	3.7	6.8*	-8.9	-8.4	61.0	80.0*
	End	8.1	9.0*	4.9	8.4*	-7.7	-4.8*	70.0	60.0
Summer									
	Begin	5.6	8.8*	-1.7	-2.4	-9.8	-9.6	67.0	83.0*
	Mid	5.3	8.1*	5.7	6.8*	-8.5	-8.3	65.0	77.0*
	End	6.4	9.2*	6.2	8.4*	-5.5	-5.6	61.0	67.0
Fall									
	Begin	6.1	9.2*	-3.5	7.5*	-9.6	-8.5	71.0	85.0*
	Mid	4.6	9.2*	6.5	8.5	-9.2	-4.4*	72.0	59.0*
	End	6.8	8.6*	7.4	8.3*	-7.8	-2.6*	75.0	40.0*

*Denotes statistical difference (pr <0.10) between sites by period within season.

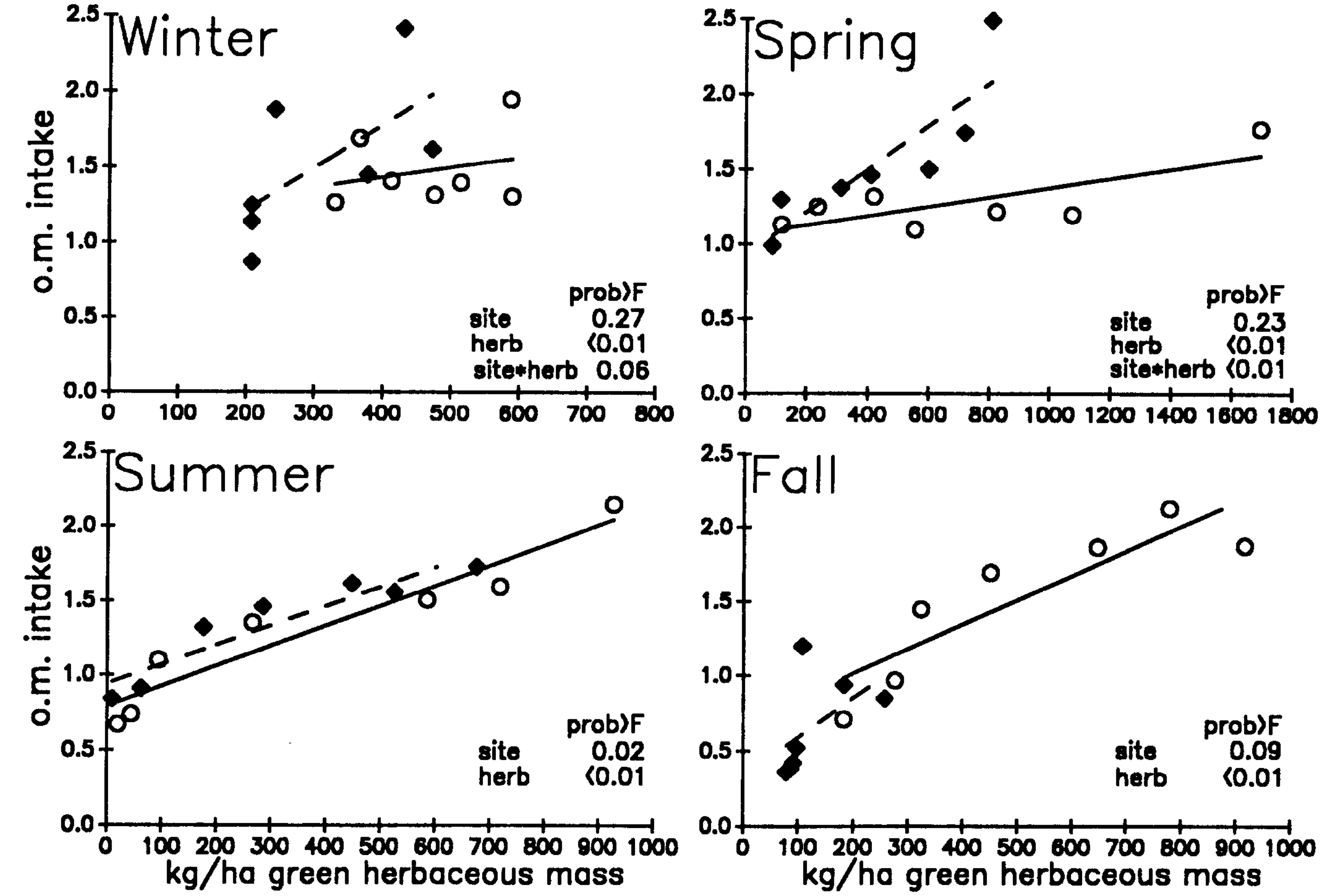

Fig. 5. Daily organic matter (OM) intake of cattle a clay loam (○ ——) and a sandy loam (◆ - - - -) range site. Statistics presented for range site (site) and green herbaceous mass (herb) effects. When site*herb interaction was not significant the interaction was dropped from the model.

decreased) than that of diets from the CL site in the spring and fall but was generally higher when herbaceous mass was highest. This greatest rate of decline in diet IVOMD on the SL site, in the spring and fall, may be associated with a greater increase in browse consumption by cattle on the SL site as compared to the CL site. However, oven drying of extrusa samples may have caused diets with large proportions of browse to appear less digestible than they actually were (Burritt et al. 1988). Increased browse consumption by cattle on the SL site let them maintain a greater diet live:dead ratio than cattle on the CL site. However, the senescent grass selected by cattle on the CL site was probably more digestible than the live browse selected by cattle on the SL site (Varner et al. 1979).

Unlike diet IVOMD, diet CP concentration was not easily explained by diet composition variables. Diet CP was not different between sites in the winter (Fig. 3). In spring, diet CP was clearly higher on the SL site than on the CL site, but, unlike in other seasons, changes in forage availability had no effect on diet CP. Mean diet CP concentration was similar between sites in the summer and fall but diet CP was less stable on the SL site than the CL site.

Fecal Output

Fecal output, as a percent of body weight, was not sensitive to forage availability changes except for a slight relationship in summer ($r^2 = 0.18$) (Fig 4). Additionally, fecal output of cattle did not differ between sites except in fall, when cattle on the SL site had lower fecal output than cattle on the CL site.

Fecal output is a necessary determinant in most intake studies, but is seldom studied as a response variable (Kothmann and Hinnant 1987). Fecal output can, however, be used to detect differences in forage harvestability if significant changes in animal size and physiologic state do not occur. If forage intake is not restricted by available forage, then fecal output should remain a constant percent of body weight throughout a given trial. The lack of site effects on fecal output would indicate that any intake differences (discussed below) resulted primarily from differences in diet digestibility, not forage harvestability, except in fall.

Nutrient Intake

Organic matter intake (OMI) decreased as green herbaceous mass decreased in all trials (Fig. 5). In winter and spring, OMI was less stable on the SL site than the CL site. Generally, the SL site yielded greater OMI than the CL site when herbaceous forage was readily available, but OMI was similar between site at low forage availability. Cattle on the SL site achieved higher OMI than cattle on the CL site over all levels of green herbaceous mass in the summer. These effects of site and herbaceous mass on OMI were similar to those observed for diet IVOMD in winter, spring, and summer (Fig 2 & 5). However, forage supply in fall was not adequate to maintain intake on the SL site, resulting in greater OMI on the CL site.

Crude protein intake (CPI) averaged 0.63 ± 0.05, 0.99 ± 0.05, 0.62 ± 0.02, and 1.03 ± 0.06 kg/day on the CL site and 0.81 ± 0.05, 0.97 ± 0.07, 0.90 ± 0.05, and 0.58 ± 0.08 on the SL site in the winter, spring, summer, and fall, respectively. Crude protein intake decreased with decreasing herbaceous mass and was less stable on the SL, compared to the CL site, in all seasons. Site differences in mean CPI value follow the same patterns as those for OMI. Sites were similar regarding CPI in winter and spring, but CPI was greater on the SL site than on the CL site in summer, and CPI was greater on the CL site in fall than on the SL site.

Discussion and Conclusions

Range site and the associated differences in vegetation had little influence on the proportions of grass, forb, and browse in the diet. When herbaceous forage was abundant cattle maintained similar diets regardless of site. However, as herbaceous forage became limited, cattle diets conformed more closely to the proportions of food available, resulting in some site differences.

Fecal output did not differ by range site in winter, spring, and summer. However, in fall, cattle had lower output on the SL site than on the CL site, presumably because adequate herbaceous forage was not available. This suggests that large differences in available herbage mass are required to yield differences in fecal output.

Range site did influence cattle diet quality. Cattle on the SL site generally had higher, though often less stable, diet live:dead ratios and diet quality (IVOMD and CP) than cattle on the CL site. These differences are best explained by 2 factors: (1) cattle on the SL site used a more selective strategy in diet acquisition, and (2) the SL site had lower herbaceous biomass and a higher proportion of green herbaceous forage than the CL site, therefore green forage was more accessible on the SL site. To improve the utility of range site distinctions for grazing management decisions, a measure of "accessible" green forage should be developed and used. An increase in accessible green forage due to regrowth has frequently been reported to increase diet quality (Vavra et al. 1973, Kirby and Stuth 1982).

Although these range sites were studied in the Rio Grande Plains of Texas, analogous situations may occur elsewhere. Sites with low herbaceous standing crop are often characterized by high forage live:dead ratios and high quality plant species, while sites of high herbage mass are often composed of intermediate or low quality species with more litter and live:dead mixing (Cook and Harris 1950).

In this study, cattle on the SL site achieved higher nutrient intake (OMI and CPI) when herbaceous forage was readily available during the growing season, because of greater access to green forage. Therefore, forage on the SL site provided higher diet quality at low grazing pressure during the growing season. Conversely, the greater herbaceous mass of the CL site provided for greater OMI in the fall and at high levels of grazing pressure. Nutrient intake is commonly studied in relation to available forage or plant maturity (reviewed by Cordova et al. 1978 and Allison 1985). However, combined effects of different vegetation types on nutrient intake have not been addressed.

In the Rio Grande Plains it is commonly observed the SL sites are often in lower range condition than CL sites, when they occur in the same pasture. Cattle may be relying on the SL sites in the spring when grazing is most detrimental to key grass species. This is a possible mechanism for differential ecological retrogression of range sites on the same landscape. However, additional studies at the landscape level will be required to verify this hypothesis since this study was conducted at the community/patch level of the diet selection hierarchy. Valentine (1967) addressed this issue of differential grazing pressure by vegetation type in his proposed practice of "seasonal suitability grazing".

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