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Botanical Composition of Sheep and Cattle Diets on a Mature Annual Range

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Percentage botanical composition on a weight basis of cattle and sheep diets, and preference ratings for certain plants, for animals grazing on a mature annual range are presented. Composition of the dietary samples was determined by the microscopic point method on forage material collected through esophageal fistulas. The same microscopic techniques were used to determine composition of herbage clipped in the field. Dietary comparisons are made between individual animals, cattle and sheep, morning and evening grazing, grazing on consecutive days, and between lightly and heavily used range. Individual sheep differed more in diet than did cattle. Differences in most dietary components among cattle and sheep decreased as herbage became limited.

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INTRODUCTION

BOTANICAL AND CHEMICAL analyses of the diets of freely grazing range animals are essential in determining forage digestibility and nutritive values. The problem is further complicated by the fact that animals are selective in their grazing and thereby affect botanical composition of their range. Statements in the literature of forage intake and selectivity are often contradictory, or unsupported in fact, because of inadequate techniques for studying the problem (Sell *et al.,* 1959; Am. Soc. Animal Production, 1959; National Acad. Sci., 1962; Joint Committee, 1963).[2]

Methods based on hand sampling, observations, and stomach analyses are of questionable accuracy for evaluating quantitatively the dietary botanical composition of animals on range areas. The most recent techniques of determining diets employ esophageal and ruminal fistulas. The esophageal fistula, a surgical opening in the esophagus, has considerable advantage over the ruminal fistula for range sampling, and appears to be the most effective method thus far developed for sampling diets of freely grazing animals (Van Dyne and Torell, 1964).

The objectives of the present study were the utilization of esophageal-fistulated animals to (1) compare the dietary composition of cattle and sheep freely grazing together on a mature annual range; (2) to evaluate changes in dietary composition with changes in herbage availability; and (3) to determine differences and variability in diets selected in the early morning and late afternoon, during consecutive days, and throughout the summer.

As this study reports the botanical composition of dietary intake (forage) and of range vegetation (herbage), the word "composition" means botanical composition unless otherwise noted. Analyses of dietary chemical composition, intake, and digestion of forages by livestock on a mature annual range were parts of the study reported elsewhere (Van Dyne, 1963; Van Dyne and Heady, 1965; Van Dyne and Lofgreen, 1964; Van Dyne and Meyer, 1964).

THE EXPERIMENT

These studies were conducted in the summer of 1961 on the Hopland Field Station, Mendocino County, California. The experimental pasture, approximately 100 acres of diverse topography, was 800 to 1500 feet above sea level.

[1] Submitted for publication October 26, 1964.
[2] See "Literature Cited" for publications referred to in the text by author and date.

Vegetation was predominantly an open oak-annual grassland (Heady, 1958) with a few areas of dense shrubs along the drainages and on north slopes. The herbaceous vegetation was fully mature before initiation of this investigation. Seed heads had not shattered from many of the grass species during the first one-third of the summer, but by late summer seeds were completely shattered from almost all species. The area has wet winters and hot, dry summers. No measurable rainfall fell during the study, and day temperatures of greater than 100°F were frequent.

Experimental animals were grade Hereford steers and crossbred (whiteface *x* Suffolk) wethers, all about 1.5 years old. The steers had been raised on a foothill annual range similar to the experimental pasture, and the wethers were raised on the Hopland Field Station. Esophageal fistulas in five steers and nine sheep were installed by procedures described by Van Dyne and Torell (1964) and were healed prior to collection of the first samples. Animals were placed on the range 2 weeks before sampling. Small weight losses or gains were made by the esophageal-fistulated animals during the summer. Dry annual range forage generally is considered a maintenance or below maintenance ration for range livestock, so these weight changes are comparable to those expected for similar non-fistulated animals. Salt was the only supplementary feed available.

Dietary samples were collected through the fistulas from each animal in the morning and evening on five consecutive days in early July, early August, and early September (periods I, II, and III). On a typical day the animals were corralled at daybreak to remove esophageal fistula plugs and to attach forage collection bags. After they grazed from 0.5 to 2 hours, they were re-corralled, the sample bags removed, and the fistula plugs replaced. The animals had an opportunity to graze during the remainder of the day, and sampling was repeated in the evening. When the animals were turned out for sampling they were driven to the general area of the pasture in which they were found before corralling. The samples, wet with saliva, were frozen until they could be analyzed.

Pasture vegetation was sampled in each of the three periods. Twenty cluster sampling areas of 1 acre each were randomly located in the experimental pasture (Van Dyne, 1960). In each period, five plots of 1 sq. ft. were randomly located in each cluster for point analysis and clipping to ground level. Plots occurring under tree canopy were recorded separately from those in open grassland. A point-frame apparatus (Heady and Rader, 1958) was used in the field to obtain 30 points in each plot. Plant species and plant part (stem, leaf, or head) were recorded for the first hit of each pin. Oven-dry weights of herbage were obtained.

The 300 clipped herbage samples and the 270 fistula, or forage, samples were analyzed in the laboratory. After thawing, forage samples were placed in several layers of cheese cloth, washed, and kneaded lightly under running tap water to remove saliva. They were then allowed to dry partially before being spread uniformly on trays. The trays were systematically passed under an 18-power binocular microscope which had a cross hair in one eyepiece, and species and plant part under the cross hair at each tray stop were recorded for 200 hits in each sample. The terms "laboratory point" and "microscopic point" refer to data collected by this technique (Heady and Torell, 1959), which necessitated pretraining on hand-clipped samples and required reference to mounted specimens for accurate determinations. Characteristics aiding in identification included: types of pubescence, ligules, venation, color, size, texture, and floral parts. Percentage point data for species and species groups were converted to percentage weight by use of equations developed by Heady and Van Dyne

(1965). All plant part data remain as percentage points.

Analysis of variance was used to compare period effects, morning *vs.* evening grazing, cattle *vs.* sheep, differences among days within sampling periods, and interactions among primary factors. Differences in dietary composition among individual animals were compared in separate analyses. Unpaired t tests were used to determine differences in herbage yield between open and shaded locations. Where analysis of variance indicated significant differences for a factor, means were compared by Tukey's test (1953). The number of animals required to sample botanical constituents of the diet within a desired level of precision was calculated by the procedure of Stein (1945).

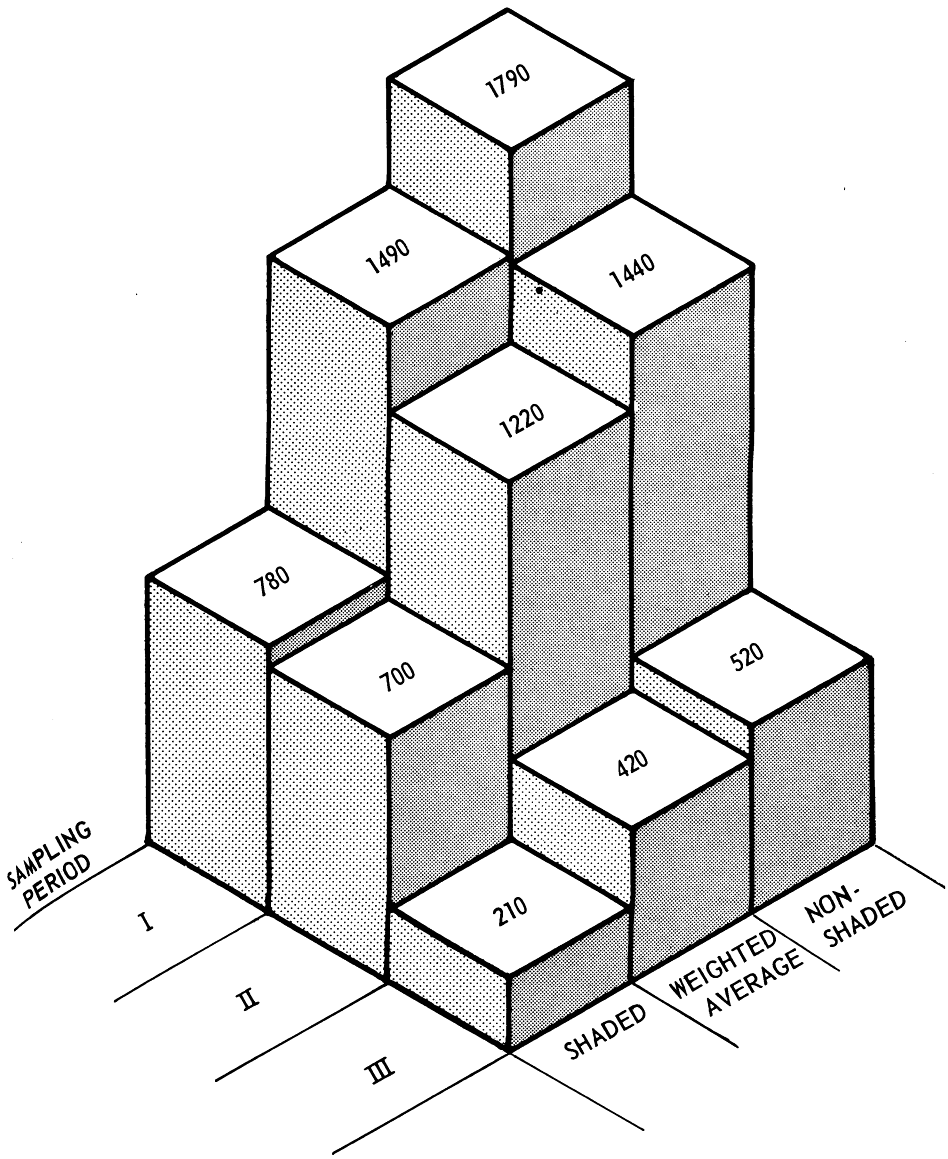

Fig. 1. Herbage in pounds per acre for shaded and non-shaded areas during early (I), middle (II), and late (III) summer.

AMOUNT AND COMPOSITION OF AVAILABLE HERBAGE

The grazing treatments caused herbage availability to decrease during summer from 1490 pounds per acre in the first grazing period to 420 pounds per acre in the third (fig. 1). Approximately 70 per cent of the pasture area was in the open and 30 per cent under tree canopies. More herbage occurred in open than in shaded areas. The percentage decrease in herbage between periods I and II occurred primarily in the open, but by period III both types showed 71 to 73 per cent less herbage than at the beginning. This was a planned condition, attained by adding extra sheep between sampling periods. Sheep and cattle grazing were equal in animal-unit months for the whole summer, with five sheep equivalent to one steer.

As extra sheep were added after the first and second sampling periods, use of the herbage was greater between sampling periods than within periods. This resulted in large differences in herbage availability between the three periods with a minimum of difference within the periods. Between early and middle summer approximately 29 pounds of herbage disappeared per animal-unit day, and between middle and late summer about 60 pounds of herbage disappeared per animal-unit day. Although there was a large decrease in herbage availability during the summer—due in part to trampling and to natural shattering of vegetation (Ratliff and Heady, 1962)—adequate amounts were always available.

Shrubs were present in the pasture, but only their fallen leaves and twigs of the current growing season were sampled. Shrubs contributed a relatively small part of the herbage.

Grass species varied widely in percentage composition. The most important of 21 grass groups throughout the summer was *Bromus* (table 1). Only the genus was recognized in laboratory analyses but in field analysis individual species were identified. Results of field and laboratory point analyses were similar, so only laboratory data are here discussed in detail. *Bromus* composed 36 per cent or more of the pasture vegetation in all periods. *Gastridium ventricosum, Avena barbata,* and *Aira caryophyllea* were other important grasses, each comprising between 3 and 15 per cent of the vegetation. As a group, grasses were relatively uniform throughout the summer (table 2), ranging from 56 to 61 per cent of the available herbage, with a standard error of about 5 per cent of the mean.

None of the 43 forb species or groups accounted for more than 6 per cent of the herbage available (table 1). The more important forbs were: *Daucus pusillus, Erodium botrys, Galium parisiense, Hypochaeris glabra, Micropus californicus, Trifolium* species, and *Linanthus ciliatus.* As a group, forbs contributed 33 to 44 per cent of the herbage available, based on point analysis of hand-clipped samples. Apparently the proportion of forbs decreased in the pasture as the summer progressed. Legumes contributed 2.5 to 5 per cent of the composition; less than 7.3 per cent of the composition was perennial.

An average of 60 to 70 per cent of laboratory points fell on stems. The data indicate that the plants had a high stem: leaf ratio or that they lost their leaves through shattering by the time they were sampled (Ratliff and Heady, 1962), or both. About 15 per cent of the points were on leaves, and 15 to 20 per cent on heads. Grasses were 44 to 54 per cent stems throughout the summer, whereas forbs were about 15 per cent stems (table 2). Grass heads contributed 14 to 15 per cent of the composition during early and middle summer and about 11 per cent in late summer. Forb heads declined in composition during

TABLE 1

PERCENTAGE BOTANICAL COMPOSITION OF THE EXPERIMENTAL PASTURE, BASED ON LABORATORY ANALYSIS OF CLIPPED HERBAGE SAMPLES

Type of herbage	Early summer	Middle summer	Late summer
	per cent		
GRASSES:			
*Aira caryophyllea**	3.7	2.8	3.2
Avena barbata	8.6	9.7	8.9
Briza minor	0.5	0.6	0.2
Bromus spp.	36.1	37.8	40.4
Bromus mollis	0.0†	0.0	0.0
Bromus rigidus	0.0	0.0	0.0
Bromus rubens	0.0	0.0	0.0
Cynodon dactylon	0.0	0.0	0.2
Cynosurus echinatus	0.4	0.5	0.0
Elymus caput-medusae	0.2	0.0	0.2
Festuca spp.	0.2	0.1	0.1
Festuca dertonensis	0.0	0.0	0.0
Festuca megalura	0.0	0.0	0.0
Gastridium ventricosum	5.5	6.6	5.0
Hordeum spp.	0.1	0.2	0.7
Hordeum leporinum	0.0	0.0	0.0
Juncus spp.	<.1	0.0	0.0
Lolium multiflorum	<.1	0.0	0.0
Poa spp.	0.0	0.0	<.1
Stipa pulchra	<.1	0.7	1.7
Unidentifiable grasses	1.0	0.4	0.4
FORBS:			
Achyrachaena mollis	0.1	0.2	<.1
Allium spp.	0.1	<.1	0.0
Allocarya californica	0.0	0.0	0.0
Anagallis arvensis	<.1	0.1	0.0
Carduus spp.	0.1	0.0	0.0
Centaurea melitensis	0.0	0.0	0.0
Centaurea spp.	0.4	0.7	0.1
Cerastium spp.	0.0	<.1	0.0
Cirsium spp.	0.0	0.0	0.0
Daucus pusillus	4.3	3.0	2.0
Eremocarpus setigerus	0.0	0.0	0.4
Erodium botrys	4.5	3.5	3.1
Filago gallica	0.7	2.0	1.5
Galium parisiense	2.9	2.0	2.4
Geranium spp.	0.1	0.1	0.1
Gilia tricolor	0.3	0.3	0.1
Godetia spp.	0.2	0.1	0.3
Hypochaeris glabra	1.4	1.2	0.6
Iris spp.	0.0	0.0	0.0
Linanthus ciliatus	2.6	2.2	2.5
Lupinus bicolor	0.2	0.2	0.3
Madia spp.	0.1	0.2	0.2
Medicago hispida	0.5	0.3	0.2
Micropus californicus	5.9	3.5	2.3
Navarretia spp.	0.2	0.3	0.2
Orthocarpus spp.	<.1	0.1	0.2
Plagiobothrys spp.	1.0	1.4	1.9
Plagiobothrys nothofulvus	0.0	0.0	0.0
Polypodium spp.	0.0	0.0	0.0
Silene gallica	1.3	0.6	0.5
Specularia spp.	0.0	0.0	0.0
Torilis nodosa	3.7	3.3	2.0
Trifolium spp.	1.9	4.7	4.4

* Nomenclature follows that of Munz and Keck (1959).
† Species recorded as 0.0 per cent in all three periods were found in at least trace amounts in field analyses.

TABLE 1—Continued

Type of herbage	Early summer	Middle summer	Late summer
	per cent		
FORBS—Continued:			
Trifolium ciliolatum	0.0	0.0	0.0
Trifolium fucatum	0.0	0.0	0.0
Trifolium hirtum	0.0	0.0	0.0
Trifolium incarnatum	0.0	0.0	0.0
Trifolium microcephalum	0.0	0.0	0.0
Trifolium variegatum	0.0	0.0	0.0
Veratrum spp.	0.0	0.0	0.0
Verbascum spp.	0.4	0.3	0.0
Vicia spp.	<.1	0.0	0.0
Unidentifiable forbs	10.9	10.1	7.4
OTHERS:			
Quercus spp.	0.0	0.0	5.4
Spanish moss	0.0	0.0	<.1
Unidentifiable plants	0.0	0.2	0.8
Unidentifiable shrubs	0.0	0.0	<.1

the summer from 7 per cent to about 3.5 per cent. Data presented in figure 1 and tables 1 and 2 indicate that a wide variety of individual species and plant parts were available to the grazing animals throughout the summer, although there was a considerable decrease in the amount of herbage.

BOTANICAL COMPOSITION OF AVERAGE DIETS

The 24 species and plant groups occurring in 75 per cent or more of the dietary samples were selected for detailed study by analysis of variance (table 3). The four columns on the left in table 3 are the principal results from an analysis involving three periods, five sampling days per period, two times of day, two classes of animals, and the interactions. The analysis for each component is based on 60 data items, each of which is the mean of four to eight samples collected at one time of day on a given day for cattle or for sheep. The three columns on the right give data obtained from analysis of individual animal data for the entire summer. Each animal provided from 24 to 29 samples.

Periods, time of day, and class of stock were important factors affecting dietary composition, and period × class of stock was the only significant interaction (table 3). Less than 3 per cent of the various data groups were significantly different among days or for the other nine interactions tested. A separate analysis was made to determine individual differences of sheep and cattle.

Thus, the most important differences in dietary composition occurred between large, medium, and small amounts of available herbage, between cattle and sheep, between morning and evening grazing, and between the period × kind of animal interactions. These data indicate that within a given sampling period of five successive days animals are relatively consistent in their diet selectivity. Grazing selectivity changes as herbage availability changes through the dry season. Therefore, composition of sheep and cattle diets must be analyzed on a basis of period (table 4).

Coefficients of variation for plant species and genera in the diets of cattle and sheep within a period were commonly 200 to 400 per cent and only a few were less than 100 per cent (table 4). These values are based on 35 to 62 samples and thus indicate the highly variable nature of grazing. Six species or groups contributed over 50 per cent to the diets in

TABLE 2

PERCENTAGE BOTANICAL COMPOSITION OF PLANT GROUPS IN EXPERIMENTAL PASTURE*

Plant group	Early summer		Middle summer		Late summer	
	Mean	Standard error	Mean	Standard error	Mean	Standard error
	per cent weight					
Grasses	56.5	2.3	59.3	2.2	61.0	2.2
Forbs	43.5	2.3	40.5	2.2	32.7	2.1
Shrubs	<.1	....	<.1	....	5.4	0.8
Unidentifiable as to genus	11.9	0.8	10.7	0.8	8.7	0.7
Legumes	2.6	0.6	5.3	0.6	4.9	0.8
Perennials	0.1	0.1	0.7	0.5	7.3	1.5
	per cent points					
Stems	60.7	1.4	62.3	1.1	69.5	1.2
Leaves	14.0	1.0	15.9	1.0	15.8	1.3
Heads	21.4	0.8	21.8	0.8	14.7	0.7
Grass stems	44.0	1.4	47.1	1.2	54.2	1.5
Grass leaves	13.0	1.0	15.2	1.0	12.9	1.3
Grass heads	14.3	0.6	14.8	0.6	11.1	0.6
Forb stems	16.7	1.2	15.1	1.1	14.7	1.2
Forb leaves	1.0	0.2	0.8	0.1	1.4	0.3
Forb heads	7.1	0.6	6.9	0.6	3.5	0.4

* Calculations based on laboratory analysis of hand-clipped samples.

TABLE 3

PRINCIPAL STATISTICAL DIFFERENCES IN DIETARY BOTANICAL COMPONENTS FOR NINE SHEEP AND FIVE STEERS

Plant category	Period	Time of day	Class of stock	Period x class	Within all animals†	Within sheep†	Within cattle†
Stems	★★*	NS	★★	NS	★★	NS	NS
Leaves	★★	★★	★★	★	★★	NS	NS
Heads	NS	★★	NS	NS	★	★	NS
Grass stems	★★	★	★★	★	★★	NS	★★
Grass leaves	★★	★★	★★	★	★★	NS	NS
Grass heads	★★	NS	NS	NS	★	★★	NS
Forb stems	NS	NS	NS	★★	★★	★★	★★
Forb leaves	NS	NS	★	NS	★★	★	NS
Forb heads	★★	★★	NS	★	★	NS	★★
Number of genera	★	★	★★	NS	★★	★★	NS
Grasses	NS	★	★	★★	★★	★★	★★
Forbs	NS	★	NS	★★	★★	★★	★
Shrubs	★	NS	NS	★	★	★★	NS
Plants unidentifiable to genus	NS	NS	NS	★	★★	★★	★★
Legumes	★★	NS	NS	NS	NS	NS	NS
Perennials	★★	★	NS	NS	★	NS	NS
Aira caryophyllea	NS	NS	NS	★	NS	★	NS
Avena barbata	NS	NS	★★	★	★★	★	NS
Bromus species	NS	NS	NS	NS	★★	★★	NS
Gastridium ventricosum	★	NS	★	★★	NS	NS	NS
Unidentifiable grasses	★	★	★	★	NS	NS	NS
Erodium botrys	★★	★★	★	★★	★	NS	NS
Trifolium spp.	★★	NS	NS	NS	NS	NS	NS
Unidentifiable forbs	★★	NS	NS	★★	★★	★★	★★

* NS, ★, ★★ respectively refer to nonsignificant, significant (P <.05), and highly significant (P <.01).
† Analysis of differences between individual animals was based on the 5 sheep and 4 steers which yielded 24 or more fistula samples.

TABLE

PERCENTAGE BOTANICAL COMPOSITION BY WEIGHT OF CATTLE

Species or group	Mean per cent and coefficient of variation*											
	SI		CI		SII		CII		SIII		CIII	
Grasses:												
Aira caryophyllea	1.0	114	3.0	107	1.5	82	1.1	73	1.4	69	0.9	92
Avena barbata	3.0	90	4.4	120	2.6	101	3.9	50	1.7	62	7.1	51
Briza minor	<0.1	428	0.1	281	<0.1	319	<0.1	308	<0.1	460	<0.1	458
Bromus spp.	30.3	54	34.3	35	37.4	29	35.4	25	35.2	22	33.4	25
Cynodon dactylon	5.3	186	1.1	225	1.4	332	<0.1	640	1.9	231	0.0	0
Cynosurus echinatus	0.1	539	0.1	592	<0.1	384	0.0	0	0.0	0	0.0	0
Elymus caput-medusae	0.0	0	0.0	0	0.0	0	<0.1	447	0.0	0	0.0	0
Festuca spp.	<0.1	392	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Gastridium ventricosum	1.3	75	7.1	110	4.7	90	10.8	46	9.6	48	4.5	40
Hordeum spp.	0.2	148	0.3	167	0.1	328	0.2	206	0.2	205	<0.1	336
Juncus spp.	0.1	360	<0.1	592	<0.1	640	0.0	0	0.0	0	0.0	0
Lolium multiflorum	0.6	241	0.1	536	0.0	0	0.0	0	0.0	0	0.0	0
Phalaris tuberosa	<0.1	546	0.0	0	<0.1	640	0.0	0	0.0	0	0.0	0
Poa spp.	<0.1	787	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Stipa pulchra	3.9	131	4.8	155	2.3	297	0.5	108	0.4	223	0.6	172
Unidentifiable grasses	4.8	51	4.5	45	4.2	70	6.8	37	6.1	38	6.1	36
Forbs:												
Achyrachaena mollis	<0.1	578	0.0	0	<0.1	640	<0.1	640	0.0	0	0.0	0
Anagallis arvensis	0.0	0	0.0	0	0.5	640	0.0	0	0.0	0	<0.1	656
Carduus spp.	1.1	486	<0.1	592	0.3	250	0.0	0	0.1	507	0.2	583
Cerastium spp.	0.1	539	<0.1	592	0.0	0	0.0	0	0.0	0	0.0	0
Cirsium spp.	<0.1	787	0.0	0	0.4	358	0.0	0	0.2	641	0.1	656
Daucus pusillus	0.9	164	0.8	158	1.1	184	0.4	188	0.2	253	0.2	224
Eremocarpus setigerus	0.0	0	0.0	0	0.0	0	0.0	0	0.2	396	0.0	0
Erodium botrys	1.5	125	1.7	136	3.4	118	2.9	102	7.1	66	11.6	67
Filago gallica	<0.1	787	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Galium parisiense	1.2	379	1.1	119	0.8	123	0.2	207	0.1	224	<0.1	316
Gilia tricolor	<0.1	553	<0.1	592	0.0	0	0.0	0	<0.1	700	0.1	371
Godetia spp.	0.1	387	<0.1	592	0.3	427	<0.1	640	0.0	0	0.1	370
Hypochaeris glabra	0.4	245	0.5	186	0.2	236	1.5	167	0.7	185	1.5	172
Linanthus ciliatus	0.5	223	1.0	133	0.7	135	0.1	509	0.8	176	0.1	316
Lupinus bicolor	0.1	343	0.1	415	0.2	305	0.1	374	0.1	700	0.8	130
Madia spp.	3.1	318	0.1	333	0.8	148	0.2	317	<0.1	490	0.4	274
Medicago hispida	0.7	188	0.6	174	2.9	315	0.5	173	4.1	153	0.9	172
Micropus californicus	0.4	220	0.1	347	0.5	207	<0.1	640	0.2	262	0.1	318
Navarretia spp.	0.0	0	0.1	592	0.0	0	0.0	0	0.0	0	0.0	0
Orthocarpus spp.	0.2	294	0.2	509	0.3	267	0.2	352	<0.1	490	0.0	0
Plagiobothrys spp.	0.1	379	0.3	279	0.4	162	0.1	332	0.1	369	0.1	281
Plagiobothrys nothofulvus	0.0	0	<0.1	592	0.1	640	0.0	0	0.0	0	0.0	0
Polypodium spp.	<0.1	787	1.7	422	0.0	0	0.0	0	0.0	0	0.0	0
Silene gallica	0.7	232	0.3	255	1.1	194	0.1	311	0.1	271	0.3	195
Specularia spp.	0.0	0	0.0	0	0.1	481	0.0	0	0.0	0	0.0	0
Torillis nodosa	0.2	262	0.4	283	0.9	346	0.1	309	0.2	269	0.0	0
Trifolium spp.	4.6	65	4.9	64	7.2	63	5.9	44	7.0	52	8.7	35
Veratrum spp.	<0.1	448	<0.1	592	<0.1	640	<0.1	640	<0.1	700	0.1	371
Unidentifiable forbs	15.2	82	11.9	87	8.2	68	8.0	46	6.0	48	9.4	39
Others:												
Quercus spp.	10.1	83	6.3	128	5.9	112	12.1	130	6.0	111	3.9	90
Spanish moss	<0.1	552	<0.1	436	<0.1	272	<0.1	308	0.1	137	<0.1	473
Unidentifiable plants	8.0	56	8.0	68	9.5	39	8.5	37	10.0	47	8.7	42

* S and C refer to sheep and cattle and I, II, and III refer to sampling periods in early, middle, and late summer, respectively. Numbers of samples were: SI, 62; CI, 35; SII, 41; CII, 41; SIII, 49; and CIII, 43.

4

AND SHEEP DIETS DURING THREE SAMPLING PERIODS

Maximum per cent in diets						Per cent occurrence in diet					
SI	CI	SII	CII	SIII	CIII	SI	CI	SII	CII	SIII	CIII
5.6	14.5	5.1	3.4	4.2	3.6	74	91	93	95	98	84
15.4	31.7	14.0	7.6	3.7	22.6	95	100	95	100	96	100
0.3	0.9	0.4	0.3	0.8	0.1	6	17	10	12	8	5
68.4	59.2	78.3	52.5	47.9	51.1	100	100	100	100	100	100
49.3	13.1	18.8	0.3	21.5	0.0	60	34	12	2	47	0
2.6	4.3	0.6	0.0	0.0	0.0	5	3	7	0	0	0
0.0	0.0	0.0	0.7	0.0	0.0	0	0	0	5	0	0
0.3	0.0	0.0	0.0	0.0	0.0	6	0	0	0	0	0
4.0	34.6	20.1	25.8	20.9	7.8	94	97	93	100	100	100
1.2	2.2	2.3	1.6	1.8	0.9	40	43	15	27	26	12
2.8	1.1	0.3	0.0	0.0	0.0	11	3	2	0	0	0
8.6	2.8	0.0	0.0	0.0	0.0	32	6	0	0	0	0
1.5	0.0	0.8	0.0	0.0	0.0	5	0	2	0	0	0
2.1	0.0	0.0	0.0	0.0	0.0	2	0	0	0	0	0
23.2	37.7	41.3	1.8	4.1	5.0	71	86	58	61	31	58
11.2	9.3	12.7	11.6	13.0	12.6	100	100	100	100	100	100
1.5	0.0	1.0	1.2	0.0	0.0	3	0	2	2	0	0
0.0	0.0	21.0	0.0	0.0	1.0	0	0	2	0	0	2
39.4	1.0	3.2	0.0	3.4	8.4	21	3	17	0	4	5
4.3	1.1	0.0	0.0	0.0	0.0	5	3	0	0	0	0
1.0	0.0	6.6	0.0	10.6	4.3	2	0	10	0	4	2
6.0	5.2	9.6	3.2	1.7	2.0	40	43	46	27	14	19
0.0	0.0	0.0	0.0	4.6	0.0	0	0	0	0	10	0
7.5	9.2	17.0	16.1	18.7	43.6	61	51	71	83	98	100
0.9	0.0	0.0	0.0	0.0	0.0	2	0	0	0	0	0
32.2	5.3	4.8	1.8	1.3	0.3	68	77	66	32	24	9
1.0	1.2	0.0	0.0	1.1	1.1	3	3	0	0	2	7
1.0	0.9	9.2	1.2	0.0	1.0	6	3	12	2	0	7
6.6	2.7	1.8	8.7	6.6	14.3	24	26	17	42	35	56
6.8	3.9	3.2	3.6	6.8	1.1	32	43	44	5	39	9
2.3	1.4	2.4	2.0	4.2	4.0	10	6	12	7	2	44
63.7	1.2	4.2	2.4	1.1	5.3	34	9	44	10	4	19
6.5	4.9	56.6	3.3	31.9	7.5	34	34	46	29	63	40
4.0	2.1	4.1	1.2	2.3	1.2	24	9	27	2	14	9
0.0	2.4	0.0	0.0	0.0	0.0	0	3	0	0	0	0
2.7	5.2	5.0	4.1	1.1	0.0	13	6	20	10	4	0
2.3	3.1	2.2	2.4	2.0	1.1	8	14	32	10	8	12
0.0	1.2	2.2	0.0	0.0	0.0	0	3	2	0	0	0
0.9	36.6	0.0	0.0	0.0	0.0	2	6	0	0	0	0
8.7	2.2	10.6	1.2	1.1	2.2	27	14	37	10	12	23
0.0	0.0	1.8	0.0	0.0	0.0	0	0	5	0	0	0
2.9	4.2	19.0	1.2	2.5	0.0	16	14	27	10	14	0
14.0	10.8	19.8	10.4	16.7	17.5	97	100	95	100	100	100
1.0	1.0	0.9	1.3	1.0	1.1	5	3	2	2	2	7
50.8	38.6	23.1	17.2	14.3	18.4	98	100	100	100	100	100
33.7	26.5	28.4	54.7	24.0	12.8	95	60	73	73	71	81
0.1	0.2	0.3	0.1	0.4	1.0	3	6	15	10	45	12
32.8	30.8	18.9	16.7	20.9	16.2	100	100	100	100	100	98

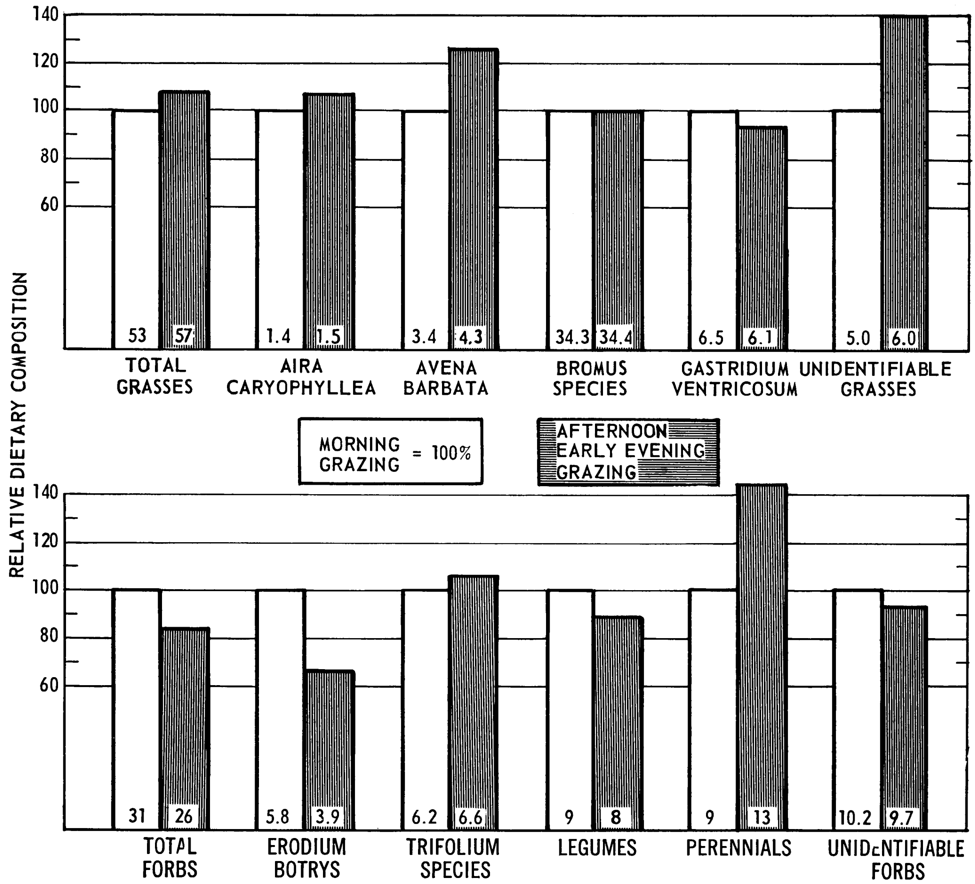

Fig. 2. Grasses and forbs in the diets of cattle and sheep combined to show differences in morning and evening grazing. For example, 53 per cent of the morning diet was grass (shown as equal to 100 on the left-hand bar) while the evening diets contained 57 per cent grass.

at least one period, yet the average for five of them was below 15 per cent. Samples composed predominantly of one species were more common for sheep than for cattle in all three periods. A single plant species frequently composed 50 per cent or more of a sheep sample, but only rarely did individual species or genera contribute 50 per cent of any cattle diet sample. This suggests greater selectivity by sheep and greater individual variation among sheep as compared to cattle.

GRASS COMPOSITION OF DIETS

Grasses averaged 55 per cent (by weight) of the diets (table 4). Per cent of grass in the fistula samples did not vary significantly among periods (table 3) or days, but afternoon samples contained 57 per cent grass and morning samples contained 53 per cent (fig. 2). Cattle grazed significantly more grass than did sheep (fig. 3), although in late summer sheep diets had 5 per cent more grass than did cattle diets. This is a result of increase in most minor grasses. Major grasses, *Aira, Bromus* and *Gastridium,* actually decreased in cattle diets in late summer, but one important grass, *Avena,* increased considerably in cattle diets in that period (fig. 3). The relationship of these dietary changes to available herbage may be deduced as follows: Cattle were notably lacking in

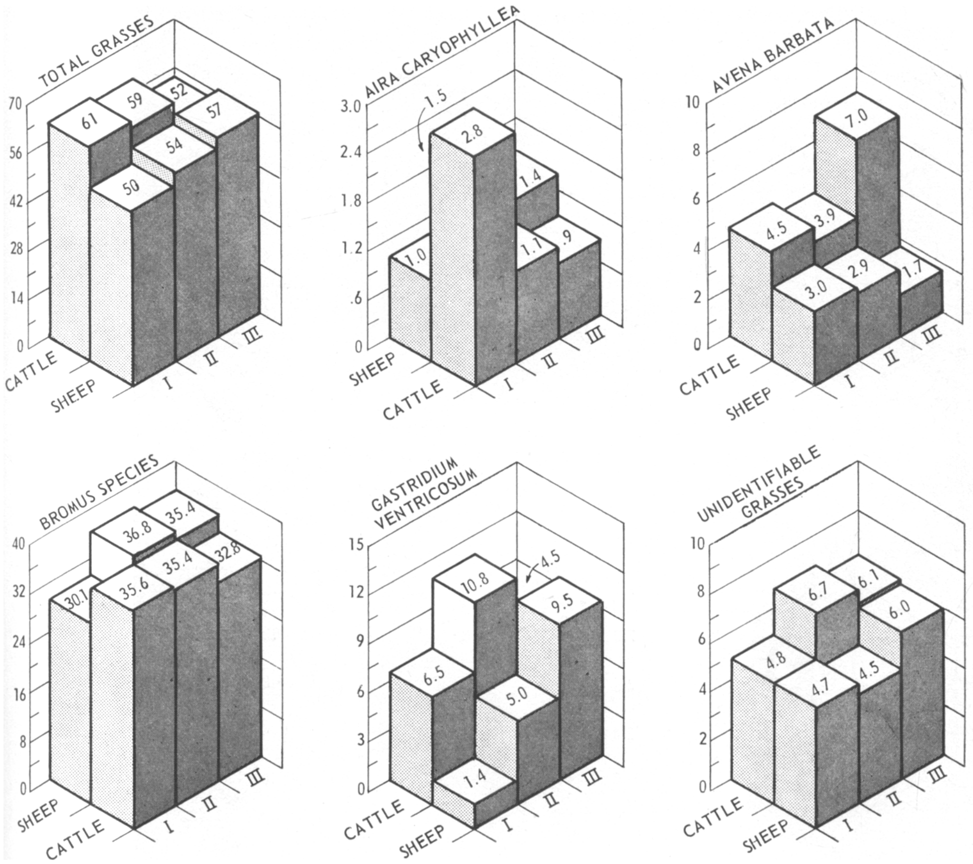

Fig. 3. Grass composition in the diets of sheep and cattle in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

grazing selectivity in late summer when only limited herbage was available. They consumed trampled herbage from the soil surface, thus increasing the relative amounts of minor grasses and forbs; in early and middle summer, when more herbage was available, there was a higher grass content in their diet. A reduction of palatable forbs or parts of forbs which were grazed out in early summer may have caused sheep to eat more grasses in late summer. There was no consistent difference in grasses between morning and evening diets in early summer. In late summer afternoon samples were 3 to 20 per cent higher in grass than were morning samples.

Aira averaged 1.5 per cent weight in all diets through the three periods, and was found in 74 per cent or more of the sheep samples and in 84 per cent or more of the cattle samples (table 4) although it was less than 4 per cent of the herbage (table 1). Cattle had a higher dietary percentage of *Aira* than did sheep in early summer, but in middle and late summer the reverse was true (fig. 3, table 3). There was no significant difference for dietary percentages of this species during the three periods.

Avena contributed 9 to 10 per cent of the available herbage, and was found in all the cattle forage samples and in 95 per cent or more of the sheep samples (tables 1, 4). There was no difference in the per cent of *Avena* for periods, days, or time of day, but there was a highly significant difference between cattle and

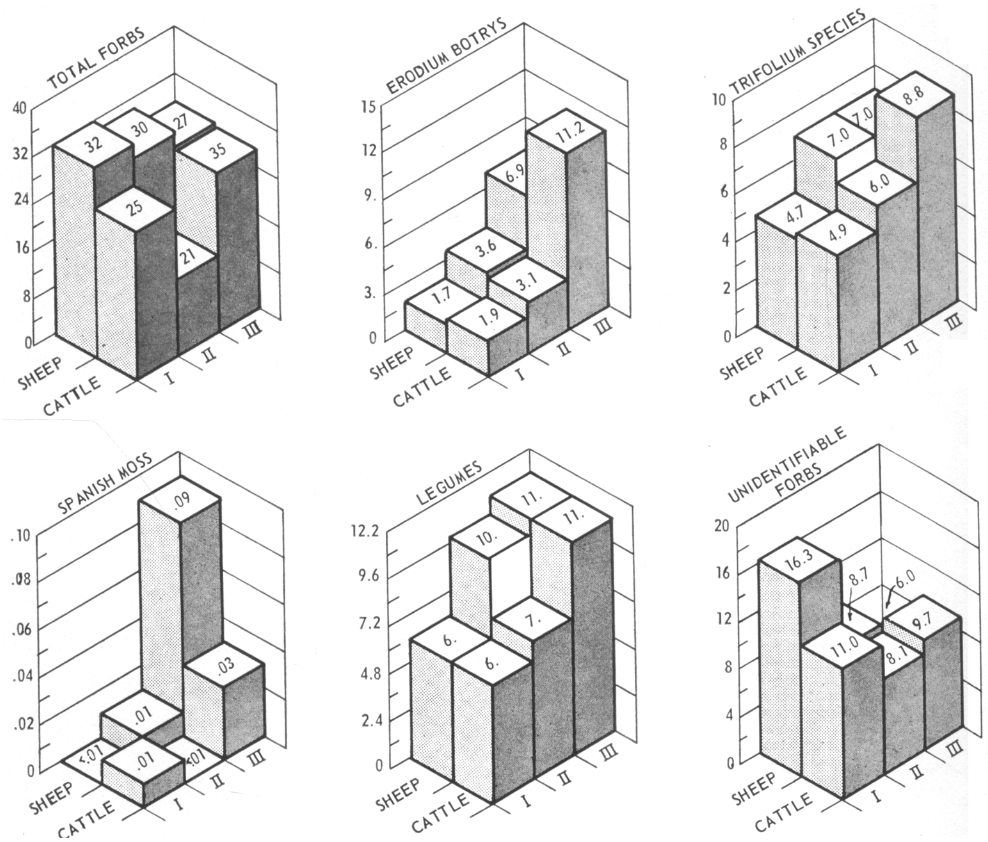

Fig. 4. Forb composition in the diets of sheep and cattle in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

sheep and a significant class × period interaction (table 3). Sheep diets contained about half as much *Avena* as did cattle diets (fig. 4); however, cattle diets were proportionally much higher in late than in early or middle summer for this species.

Bromus species (*mollis, rigidus* and *rubens*) were grouped because they were difficult to identify microscopically. *Bromus* occurred in all the diet samples in greatly varying percentages; coefficients of variation were as high as 54 per cent in early summer (table 4). There was no difference in the percentage composition of this genus between cattle and sheep diets, periods, days, or times of day (table 3, figs. 2 and 3).

Gastridium contributed 5 to 7 per cent of the available herbage (table 1) and averaged 6.3 per cent in the diets (table 4), occurring in 93 to 100 per cent of them. There was a significant difference in the percentage of *Gastridium* between periods and between classes of stock, and a highly significant period × class of stock interaction (table 3). This species made up about 4 per cent of the diets in early summer and 7 per cent or more in middle to late summer (fig. 3). The over-all difference between amount of *Gastridium* in cattle and sheep diets was 2 per cent, with cattle diets being higher—but in late summer sheep diets were higher in this species than were cattle diets (fig. 3). In the first two periods, cattle diets were double or more the percentage of sheep diets for *Gastridium*.

At least a small amount of unidentifiable grass material occurred in all samples, and the maximum amount in any forage and herbage sample was 13 per cent. The per cent of unidentifiable grass material in the diets increased significantly through the summer; means for early, middle, and late summer were 4.8, 5.6, and 6.1 per cent. This change is probably a result of greater consumption of trampled, fragmented, weathered material as herbage availability decreased. The per cent of unidentifiable grass was greater in dietary samples taken in the afternoon than in the morning (fig. 2). This suggests selectivity of shattered plant parts in the evening. In early and late summer cattle had approximately the same per cent unidentifiable grass in the diet as did sheep, but middle summer diets of cattle were considerably higher in unidentifiable grasses than were those of sheep. Mastication and selectivity are important factors in causing plant material to be unidentifiable in fistula samples. Microscopic point analysis of field-clipped herbage from plots showed 1 per cent or less unidentifiable grass material (table 1). The hand-clipped material was longer and more intact than the fistula samples. Sheep forage was more finely masticated than cattle forage; however, it did not contain more unidentifiable material than did cattle forage.

FORB COMPOSITION OF DIETS

Forbs were an important component of available herbage throughout the summer, especially in early and middle summer (table 2). Their decrease in late summer may be due to increased shattering and to selective grazing in the first two periods. Over the summer no significant dietary difference occurred in forbs for periods, days, or classes of stock (table 3). Morning samples were 5 per cent greater than afternoon samples in forb content (fig. 2) and there was a highly significant period × class interaction (table 3). Sheep grazed more forbs than did cattle in early and middle summer when herbage was plentiful, but in late summer with limited herbage, cattle had 8 per cent more forbs in their diets (fig. 4).

Erodium occurred at a higher percentage in the diet than in the available herbage (tables 1 and 4) and increased in frequency and amount in the diets of both classes as the summer progressed (fig. 4). Samples grazed in the morning contained more *Erodium* than did evening samples (fig. 2, table 3). Averaged over all periods, cattle had about 1.5 per cent more weight of this species in their diets than did sheep, but *Erodium* occurred in more sheep samples than cattle samples in all periods (table 4). *Erodium* was the only category which had a significant period × time of day interaction, with mean values as follows:

	Time of day	
Period	*AM*	*PM*
I	2.2^{a}	1.3^{a}
II	3.4^{a}	3.3^{a}
III	11.7^{b}	7.0^{c}

Means not followed by the same superscript are significantly different ($P < .05$).

In late summer, with limited herbage available, more *Erodium* occurred in the morning than in the afternoon samples. Cattle and sheep had about the same percentage of this species in their diets in early and middle summer, but in late summer the sheep had only 0.6 as much as the cattle (fig. 4). The high percentage of *Erodium* in the diets of cattle in late summer was due to unexplainably high percentages on the second and third days.

Trifolium species made up 2 to 5 per cent of the herbage (table 1) and occurred in 95 per cent or more of the diets of cattle and sheep (table 4). There was a highly significant increase in per cent *Trifolium* in the diets from about 5 per cent in early summer with high herbage availability, to about 8 per cent in late summer with low herbage availability (fig. 4). Increased consumption of *Trifolium* may be related to decreased availability of other herbage and the necessity for animals to graze nearer the soil surface as taller vegetation disappeared.

Lupinus and *Medicago* were other important legume genera in the pasture that were selected in similar proportions as *Trifolium.*

Forbs were more difficult to identify by microscopic analysis than were grasses, and all 570 samples (both hand-clipped and fistula forage) averaged 10 per cent unidentifiable forbs. However, this percentage decreased through the summer because the easily shattered material had disappeared and the rigid plant parts were more readily recognizable.

BROWSE COMPOSITION OF DIETS

Shrubs and trees were common in the pasture. Forage from woody plants was mostly leaves and acorns from *Quercus douglasii, Q. kelloggii, Q. lobata,* and *Q. wislizenii.* More than 5 per cent of field-harvested material in late summer was fallen leaves and acorns of *Quercus* which occurred in 60 per cent or more of the diets and composed 4 to 12 per cent of the dietary weight (table 4). Sheep diets in late summer frequently contained newly-fallen acorns. Field observations indicated that cattle and sheep browsed on low-hanging branches and on fallen twigs and leaves, especially in early summer. Shrubs and trees seldom found in the diets included *Arctostaphylos manzanita, Rhus diversiloba, Arbutus menziesii, Aesculus californica, Heteromeles arbutifolia,* and *Umbellularia californica.*

The pasture had been grazed by sheep for many years and there was a browse line at approximately 4 feet. Thus, proportionally, more browse was always available to cattle than to sheep, but on the average cattle and sheep selected about the same amount. The average amount of total shrubs grazed in late summer was only 57 per cent of that grazed in early and middle summer. The significant period × class interaction for shrubs (table 3) was because of differences in middle and late summer cattle diets, as follows:

	Periods		
	I	*II*	*III*
Sheep	9.7^{bc}	6.4^{ab}	6.0^{ab}
Cattle	6.8^{ab}	11.9^{c}	3.9^{a}

Means not followed by the same superscript are significantly different (P < .05).

OTHER PLANT GROUPS IN DIETS

Perennial plants constituted only a small proportion of the herbage in the pasture (table 2), but there was con-

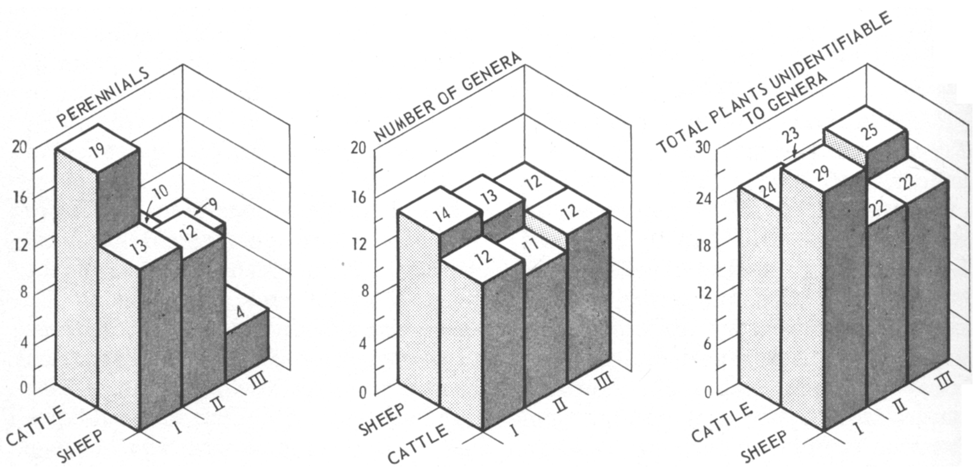

Fig. 5. Perennials, plants unidentifiable as to genus, and number of genera in the diets of cattle and sheep in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

siderable selectivity for them (table 4). The most commonly grazed perennials were *Stipa pulchra, Cynodon dactylon, Phalaris tuberosa,* and *Quercus* species. In early summer all diet samples contained perennials, and in middle and late summer the proportion was 80 to 90 per cent. Per cent weight of perennials in the diet decreased from 16 per cent in early summer to less than 8 per cent in late summer (fig. 5). Afternoon diets had about 50 per cent more perennials than did morning diets (fig. 2). Evidently cattle and sheep are more selective in the afternoon than in the morning. The preference exhibited for perennials was probably due to selection of green material in perennial grasses. All annual plants were mature.

In all fistula samples about 25 per cent of the material was readily identifiable only as to plant group (grasses, forbs, or shrubs) or plant part (stems, leaves, or heads). Early summer diets of sheep were considerably higher than cattle diets in such material, but in middle and late summer the relationship reversed. This was probably due to the proportion of forbs that was easily fragmented in mastication.

Spanish moss was not encountered in field plots in early and middle summer, and later it was found in trace amounts only (table 1), nevertheless 45 per cent of the sheep diets contained Spanish moss in late summer (table 4). Although an inconsequential part of the diet (fig. 4), this plant had about three times the crude protein content of most of the annuals (Van Dyne and Heady, 1965).

A small but significant decrease occurred in the number of genera found in fistula samples during summer (table 3, fig. 5). Samples from morning grazing had more genera than afternoon samples, and sheep always selected as many or more genera than did cattle.

PLANT PARTS IN DIETS

Plant part percentages are on a per cent point rather than a per cent weight basis because relationships between point hits and weight were not established for plant parts (figs. 6 through 9).

Sheep diets were consistently lower in stem percentage than cattle diets, averaging 67 and 72 per cent respectively (fig. 7). Grass stems differed between periods but forb stems did not vary significantly (table 3). Grass stems averaged for all animals increased from about 46 per cent in early summer to 58 per cent in both middle and late summer; forb stems varied from 6 to 13 per cent. The difference between classes of

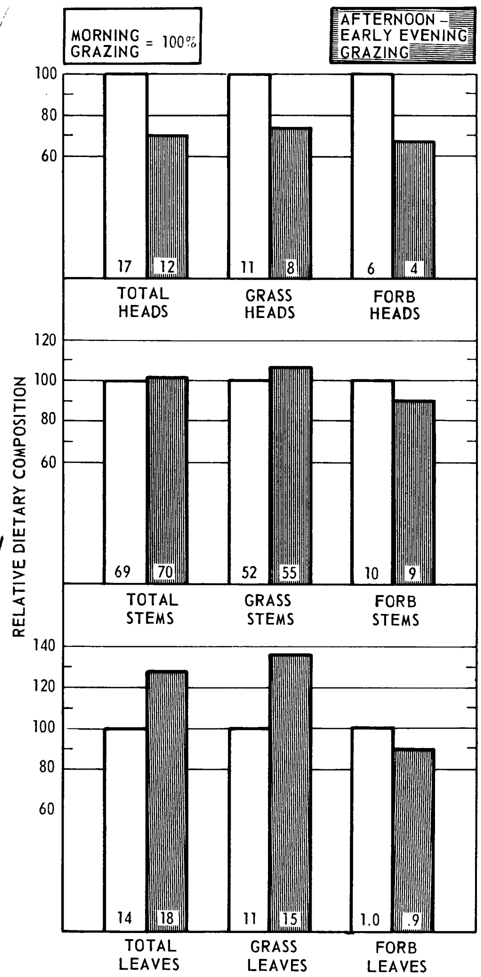

Fig. 6. Plant parts grazed in morning and evening for cattle and sheep combined. Proportions in morning diets are shown as 100 per cent (left-hand bar of each pair) and evening grazing as the black bars. Actual percentages in the diet are given at the base of each bar.

stock in dietary stem contents (table 3) was due to difference in grass stems, 58 per cent for cattle and 50 per cent for sheep. Forb stems were 9 to 10 per cent in both cattle and sheep samples. Little difference existed in the proportion of stems selected in morning and afternoon (fig. 6). Sheep had higher dietary percentages of forb stems in early and middle summer, but in late summer cattle diets were higher (fig. 7).

The percentages of total leaves and grass leaves were highest in early summer diets (fig. 8), but forb leaves were a relatively small part of the diet and did not vary significantly during the summer (table 3). Afternoon-grazed samples for cattle and sheep were higher in total leaves and grass leaves than were morning-grazed samples (fig. 6), indicating greater selectivity during afternoon grazing. Sheep selected more leaves of all categories than did cattle (fig. 8). A widening difference between cattle and sheep in their choice of leaves suggests that sheep became more selective than cattle as herbage availability decreased.

The fruiting portions of all plants, whether inflorescences or shattered seeds, were categorized as heads in these analyses. Laboratory analyses of hand-clipped samples showed that heads comprised 15 to 22 per cent of the herbage (table 2). Averaged over periods and classes of stock, heads composed about 14 per cent of the diets (fig. 9). Although there was no difference in dietary per cent of total heads between periods, days, or classes of stock, there was a difference between times of day (table 3). Forage samples collected in the morning had about 17 per cent heads and samples collected in the afternoon about 12 per cent (fig. 6). The time-of-day differences were not significant for per cent of grass heads, but forb heads occurred at higher percentages in morning samples than in afternoon samples—6 *vs.* 4 per cent.

Although total heads did not vary significantly among periods, there was an inverse relationship between grass and forb heads among the three periods (fig. 9). Grass heads decreased from about 12 per cent of the diet in early summer to 7 per cent in late summer, while forb heads increased from 4 per cent in early and middle summer to 7 per cent in late summer. Forb heads changed significantly in the diets between periods, times of day, and for period $\times$ class interaction (table 3). Sheep grazed more forb heads in early and middle summer, but less than cattle did in late summer (fig. 9).

These data show that cattle and sheep selectively graze certain stems, leaves, and heads as well as certain species and groups of species.

BOTANICAL COMPOSITION OF INDIVIDUAL ANIMAL DIETS

In this section results are given for the five main sheep and four steers. Data from these nine animals were selected on the basis that at least 24 of the 30 attempted collections per animal provided sufficient amounts of forage for analyses (table 3). The five animals not included in this analysis each yielded less than 15 fistula samples. Table 4 includes data based on collections from all 14 animals.

Almost two-thirds of the dietary constituents analyzed showed some combination of differences within all animals, within sheep, and within cattle (table 3). Most dietary constituents which were different within animals were different within one or both classes of stock. Some categories were different among all animals, but there was no difference within cattle or within sheep. These categories included stems, leaves, grass leaves, perennials and *Erodium.*

The following individual species or groups were not different among all animals and will not be discussed: *Aira*,

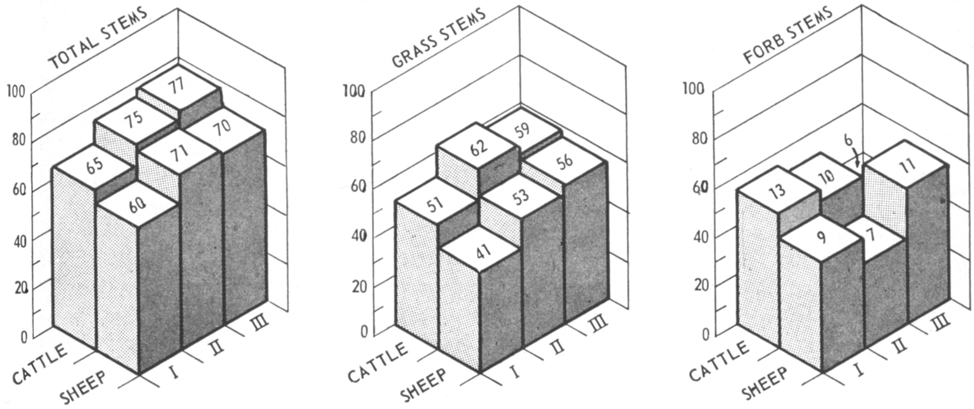

Fig. 7. Stems in the diets of sheep and cattle in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

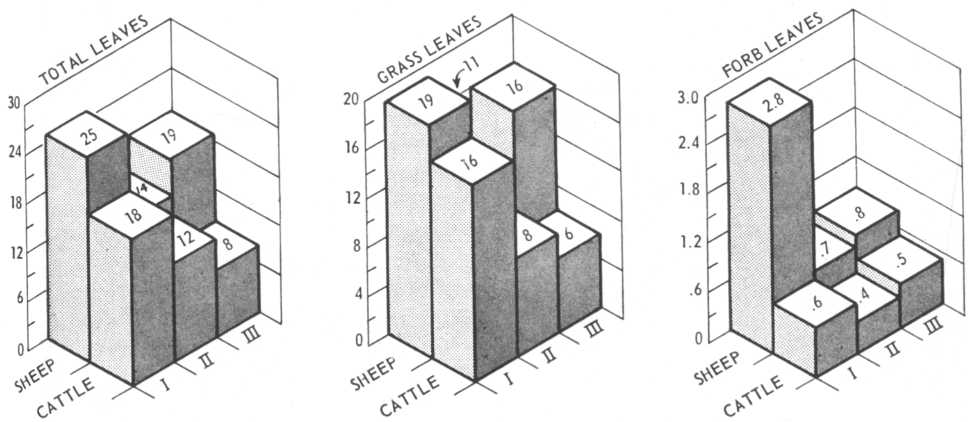

Fig. 8. Leaves in the diets of sheep and cattle in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

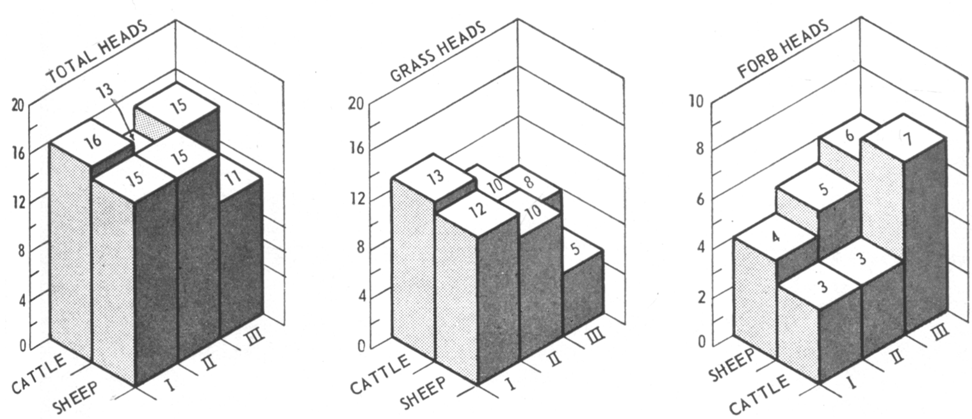

Fig. 9. Heads in the diets of sheep and cattle in early (I), middle (II), and late (III) summer. All arabic numbers are per cents.

Gastridium, unidentifiable grasses, *Trifolium* species, unidentifiable forbs, Spanish moss, and legumes.

DIFFERENCES AMONG ANIMALS FOR GRASSES

There were differences among all animals and within both classes of animals for percentage of grasses in the diet. Figure 10 shows the mean values for five sheep and four steers for the entire summer.

A 10 per cent difference was required for high significance in percentage grass composition of steers' diets (fig. 10); two steers were different from each other. The required difference for sheep, about 11 per cent, shows that one wether

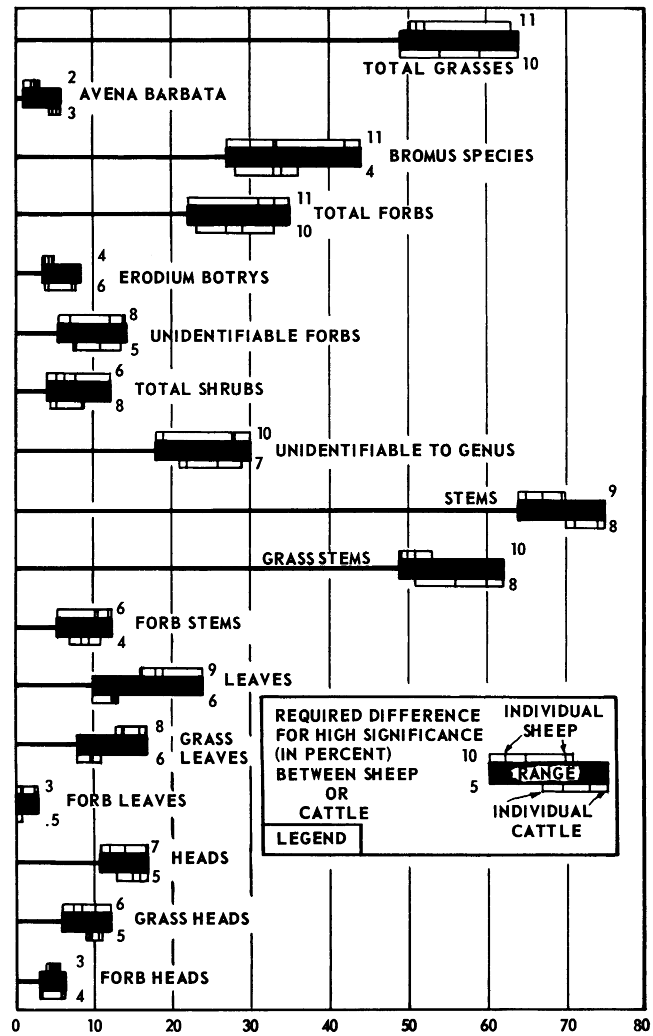

Fig. 10. Composition by species, groups of species and plant parts in the diets. (Each heavy black bar shows the range among diets and the individual animal diets are indicated by the vertical lines above [sheep] and below [cattle] the bar.) Required differences in per cent between pairs of animals for significance at the 0.01 probability level are shown for sheep and cattle after each bar.

(number 18) ate more grass than did the other sheep. A wide overlap existed in the grass percentage in the diets of sheep and cattle.

More *Avena* was grazed by cattle than by sheep (fig. 10), but the sheep showed individual preferences for this species while cattle did not. One wether (number 18) grazed significantly less of this species than the other sheep. *Bromus,* the most important genus on the range, varied significantly in dietary composition among all animals and within sheep. For *Bromus,* an 11 per cent difference was required for high significance.

DIFFERENCES AMONG ANIMALS FOR FORBS AND SHRUBS

Differences in forbs were significant within cattle and highly significant within sheep (table 3). Also, cattle had lower average percentages of forbs than sheep (fig. 4). The steers with the greatest and least amount of total forbs in their diet were different, and one wether (number 18) grazed significantly less forbs than did other sheep.

Individual sheep and cattle were consistent in the *Erodium* content of their diet (fig. 10), but there was a difference in consistency between cattle and sheep (table 3).

OTHER DIETARY CATEGORIES FOR INDIVIDUAL ANIMALS

Wider variation occurred among sheep than cattle in the portion of the diet unidentifiable as to genus (fig. 10). The animals with highest and lowest amounts of this category were significantly different. Individual animals were relatively constant throughout the summer in the portion of their diets unidentifiable as to genus.

The number of genera in the diets varied between cattle and sheep and among individual sheep. One wether (number 18) averaged 12 genera per sample, while another averaged 15.

PLANT PARTS IN DIETS OF INDIVIDUAL ANIMALS

There were differences among all animals for total stems, grass stems, and forb stems; within cattle for grass stems; and within sheep and cattle for forb stems (table 3). One steer grazed less grass stems and another steer less forb stems than the others (fig. 10). Wether number 18 was different from two others in grazing a lower percentage of forb stems. Almost all sheep grazed less total stems and grass stems than did individual cattle.

The percentages of total leaves, grass leaves, and forb leaves were different among animals, but the only within-class difference was among sheep for forb leaves (table 3). The cattle grazed a very small amount of forb leaves (fig. 10). For individual cattle and sheep there was no overlap in average percentages of total leaves and grass leaves.

The per cent of heads, grass heads, and forb heads, was different among all animals; individual sheep were different in total heads and grass heads but not in forb heads (table 3). One notable characteristic of selection for heads was that steers showed preference for grass heads and sheep showed preference for forb heads (fig. 10).

CONSISTENT DIFFERENCES IN DIETS

One wether (number 18) had a diet comparable to the average diet of cattle in many of the vegetational categories, but no steer had a diet comparable to the average of sheep. Cattle and sheep have a wide range of forage preference and individual animals select certain constituents in amounts which are not characteristic for all animals, but there is considerable similarity in diet on a between-class basis and a within-class basis. Although means were different between cattle and sheep for 18 of 24 dietary items (table 3), only *Avena,* total leaves, and grass leaves did not overlap in their proportion of the diets (fig. 10). Differences in percentage composition required to show high significance between individual animal diets were higher in three-fourths of the categories for sheep than for cattle, which indicates that sheep diets are more variable than cattle diets.

NUMBER OF ANIMALS REQUIRED FOR ESTIMATING DIETARY COMPOSITION

The variability among animals in composition of diet is reflected in the calculated sample size required to estimate dietary composition within 10 per cent of the mean with 90 per cent confidence (table 5). These numbers are based on the variability among means of five sheep and four steers for each period. Each mean was calculated from the seven to ten samples from one animal in one period.

In general, a large number of animals would be required for sampling the diet for most botanical constituents. More sheep than cattle usually would be re-

TABLE 5

NUMBERS OF ANIMALS REQUIRED FOR ESTIMATING PERCENTAGE BOTANICAL COMPOSITION OF THE DIET WITHIN 10 PER CENT OF THE MEAN WITH 90 PER CENT CONFIDENCE

Dietary constituent	Sheep			Cattle		
	Period					
	I	II	III	I	II	III
	number based on per cent weight					
Aira caryophyllea	136	29	12	90	51	59
Avena barbata	110	57	84	54	6	9
Bromus spp.	107	2	3	24	7	7
Gastridium ventricosum	49	35	4	77	7	1
Unidentifiable grasses	40	8	7	33	6	7
Erodium botrys	142	30	11	298	60	73
Trifolium spp.	42	34	34	32	4	16
Unidentifiable forbs	266	51	22	51	79	59
Unidentifiable as to group	38	4	5	61	7	2
	number based on per cent points					
Stems	7	1	1	1	1	1
Leaves	50	9	4	19	5	4
Heads	80	1	4	15	6	35
Grass stems	3	1	1	6	1	2
Grass leaves	30	35	7	36	5	11
Grass heads	114	5	30	14	8	17
Forb stems	91	13	14	93	9	1
Forb leaves	234	90	129	104	78	171
Forb heads	91	22	12	79	64	81
	number based on per cent weight					
Grasses	30	4	1	10	4	4
Forbs	57	8	6	40	9	7
Shrubs	266	51	22	51	79	59
Unidentifiable as to genus	90	4	5	80	1	1
Legumes	49	31	17	39	8	14
Perennials	110	11	47	27	71	64
	number based on count					
Number of genera	7	2	1	4	4	2

quired for a given constituent, and more animals of either class generally would be required in early summer, when there is a high availability of herbage, than in middle or late summer when less herbage is available. Fewer animals are needed with more inclusive plant groups.

Certain dietary components could be estimated in some instances with fewer than 12 animals; for example, *Aira* with sheep in period III, *Avena* with cattle in periods II and III, *Bromus* for both sheep and cattle in periods II and III, and *Trifolium* for cattle in period II. Because of high variability in early summer grazing, 24 animals would be required to estimate any individual species or genus group. Even for such broad plant categories as grasses, forbs, and shrubs, 10 animals or more would be required for either cattle or sheep in early summer.

Total stems were the most consistent dietary plant part and are estimated with a maximum of seven animals. To estimate leaves requires more animals than to estimate stems, and the different kinds of stems and leaves require still more. The number of animals needed for dietary items that are uncommon or found in small amounts only is unpractical.

The analysis of botanical composition of average diets appears to be based on an adequate number of samples. For example, the six main divisions in table 4 are based on 35 to 62 samples. Analysis for periods divides the total number of samples into three means of about 90 samples each. The class of stock and time of day analyses use two means with still more samples in each (table 3). The section on individual animal diets averaged summer-long (fig. 10) is based on 24 to 29 samples per animal.

RELATIVE PREFERENCE FOR ANNUAL RANGE PLANTS

The ratio of the amount or percentage of a plant or plant group in the diet to that available on the range is an index of preference. Since the cattle and sheep were grazed together on the same range, the preferences exhibited by them are directly comparable. All percentage estimates are corrected to the shrub-free portion of the diets and available herbage, as field sampling did not include all browse and slightly more browse was available to cattle than to sheep. Preference ratios were developed with laboratory point data from 300 clipped-plot samples, 152 sheep diet samples, and 118 cattle diet samples (figs. 11 and 12).

Three species, *Lolium multiflorum*, *Phalaris tuberosa*, and *Cerastium* sp., occurred at 10 times or more the concentration in sheep diets than they occurred on the range. No genus or species occurred in cattle diets at more than four times the concentration in available herbage, indicating that cattle graze less selectively than do sheep. Numerous species were less than 0.1 as abundant in cattle and sheep diets as in available herbage. These "rejected" plants included *Elymus caput-medusae*, *Festuca* spp., and several forbs.

In general, perennial grasses were more often selected by both cattle and sheep than were annual grasses or forbs. Of the forbs, *Medicago hispida*, *Trifolium* spp., and *Erodium* were from 1.2 to 7.6 times as abundant in the diet as in available herbage.

Most species in the pasture occurred in both cattle and sheep diets during the summer. Plants occurring in trace amounts composed the majority of those having preference ratings of 0.1 or less. Three genera, *Polypodium*, *Cirsium*, and *Veratrum*, were found in the diets but did not occur in the field plots (compare table 1 and 4), so these three are not rated. Species with a rating higher than 2.0 were also infrequent in the pasture and abundant species appear near 1.0 on the preference scale.

Five different genera or species occurred in sheep diets at greater concen-

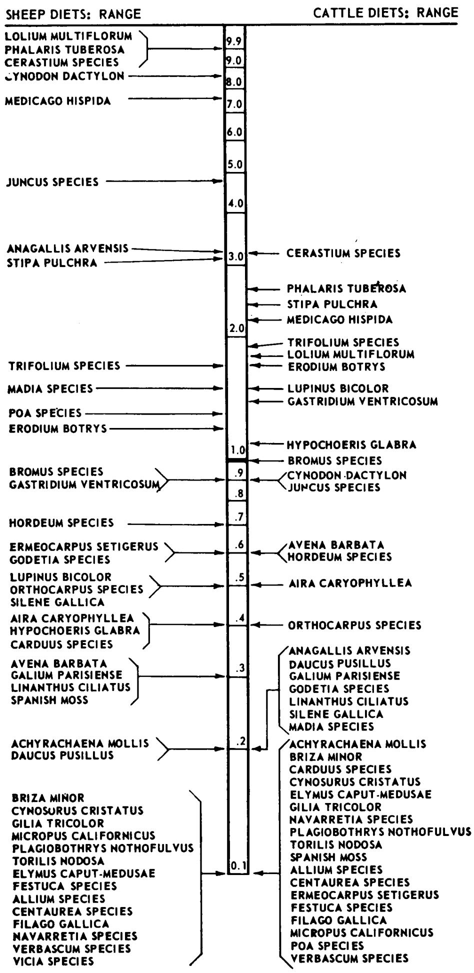

Fig. 11. Preference ratings exhibited by sheep and cattle for plant species. Ratings shown on the central axis are ratios of dietary composition to range composition. Ratios larger than 1.0 indicate preference and those below 1.0 indicate rejection.

tration than in available herbage, but in cattle diets they were less than in the herbage. These plants were *Cynodon dactylon, Juncus* spp., *Poa* spp., *Anagallis arvensis,* and *Madia* spp. Three species, *Gastridium ventricosum, Hypochaeris glabra,* and *Lupinus bicolor,* occurred in cattle diets at a higher ratio than 1.0, but were lower than 1.0 for sheep.

Several of the species had unexpected preference ratings. Those selected to a greater extent than previous range ap-

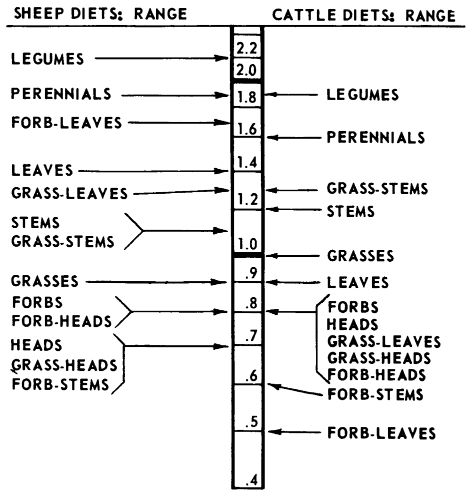

Fig. 12. Preference ratings exhibited by sheep and cattle for plant groups. Ratings shown on the central axis are ratios of dietary composition to range composition and suggest that those parts of the diet near the top of the scale are highly preferred while those near the bottom are rejected.

praisal estimates have commonly indicated include *Cerastium, Madia,* and *Anagallis* for sheep and *Hypochaeris* for cattle. All the "head" categories (fig. 12), *Avena, Festuca* spp., and *Poa* were unexpectedly rejected, although they are believed to be preferred.

Grasses were grazed by cattle to about the same extent as they were found on the range, but sheep grazed slightly less grass than was found in available herbage (fig. 12). Forbs were only 0.8 as great in cattle and sheep diets as in available herbage. Legumes and perennials were selected both by cattle and sheep, but the greater selectivity was by sheep. Sheep grazed proportionally fewer stems and heads but more leaves than did cattle, but sheep grazed more forb stems than did cattle. Grass stems were higher in both cattle and sheep diets than in the available herbage. Selectivity of forb leaves by sheep was three times as great as by cattle.

Cattle and sheep obtained most of their diets from the abundant species, and appeared to employ selection and rejection for the many species which occurred infrequently.

DISCUSSION

The general development and use of the esophageal fistula has been reviewed elsewhere (Van Dyne and Torell, 1964). The researches discussed here are only those concerning measurement of dietary botanical composition as sampled with fistulated animals.

Heady and Torell (1959) collected 12 fistula samples from sheep at monthly intervals on annual vegetation, one month of which was during the dry summer period, and these samples were grazed from 30- by 30-foot plots. The sheep were not subjected to flock competition, were not allowed to graze freely, and were fasted prior to sample collection. Differences in forage preferences were found to be related to growing season but no analysis of variability was made. The most useful conclusion of their work, with regard to this study, was that both field and laboratory point-analysis overestimated percentage weight of grasses. This led to the development of equations for converting per cent data to per cent weight.

Lusk *et al.* (1961) grazed sheep in 10- by 40-foot plots on annual range; half of each plot had been fertilized and half was unfertilized. They hand-separated clipped samples and used the laboratory-point method on diet samples to determine the proportion of *Elymus caput-medusae*. Their sheep were fasted before sample collection, were not subjected to flock competition, were grazed for only 10 to 15 minutes for sampling, and no estimate of animal variability was made. This study showed that *Elymus* was grazed at certain times of the year.

Lesperance *et al.* (1960) used ruminal-fistulated steers to sample diets grazed from irrigated pastures of Kentucky bluegrass-white clover or of tall fescue-ladino clover. They analyzed their samples with a microscopic-point technique. They found high variations in botanical composition of the diets with highly significant differences among grazing periods, days, and a pasture × animal interaction in some periods. Similarly, Ridley *et al.* (1963) evaluated botanical composition of samples obtained from two ruminal-fistulated steers on orchard grass and tall fescue pastures. On this simple herbage mixture, five rumen samples would be required for the tall fescue mixture and 11 samples for the orchard grass mixture for any one day to sample per cent grass in the diet within a 20 per cent confidence interval at 90 per cent probability. These data indicate greater uniformity among samples than in the current study which is a result probably due to the uniform mixture of a few species.

Arnold *et al.* (1964) recently have used esophageal-fistulated ewes and wethers in Australian grazing studies. By pooling data from various experiments they investigated per cent of grass content of the diet, with variance being separated into sheep, day, time of day, and sheep × day components. Generally, variation between sheep was greater than that within days or between days. Per cent of dietary grass content was relatively constant in their study. They suggested that pre-fasting affected the dietary selection by the animals, but they do not specify the number of animals used, dates of collection, most botanical components or amounts of herbage available.

Cook *et al.* (1963) used esophageal-fistulated cattle and sheep to sample summer mountain ranges in northern Utah. One group of animals was penned overnight and samples from them were collected in the morning; a second group was penned in the morning and samples were collected in late afternoon. Thus, in contrast to our study, animals were subjected to fasting prior to sample collection. Eight sheep and two steers were used, but because of the division of animals for sampling, only four sheep and one steer yielded samples at a given time. Although fistula samples were not analyzed botanically, observations made while the animals were grazing indicated that sheep grazed less grass, more forbs, and about the same amount of browse as did cattle. Animal variability and estimates of error were not given.

The esophageal-fistula technique holds considerable promise in studies of forage intake and selectivity, yet this and cited studies leave unanswered questions. One such unknown is the hypothesis that fasted animals yield different results from those which are grazing within their normal daily habits (Arnold *et al.*, 1964). Hungry animals are likely to yield good samples because they graze vigorously and seldom contaminate the sample with regurgitated material—however, they may not select forage in their usual manner. Although the present study did not investigate this question specifically, it assumed the hypothesis to be correct. Fistulated animals grazed in the pasture throughout the present study without being disturbed other than by handling necessary to the experiment.

Most of the studies cited above sampled animal diets once a day only, generally in the morning. Our study shows many differences in dietary composition between morning and afternoon grazing; thus, biased estimates of daily intake would have been obtained by sampling only in the morning. The differences may be due to hunger after the night's fast, to changes in moisture content of the herbage during the day, to temperature changes, to other conditions, or to a combination of factors. Whatever the cause, time of grazing is an important factor in the study of dietary botanical composition. Differences between samples collected on consecutive days were minor. Therefore in diet studies sampling probably should be conducted throughout the day rather than at the same time daily.

Another matter for study is that of the influence of herd or flock competition on forage selectivity. During our sampling periods not less than 15 sheep and 14 steers were in the pasture—this was considerably more than has been reported in other experiments on dietary botanical composition. Normal herd competition was a condition of the present study, although its influence on forage selectivity was not examined.

Before any new method can be used with confidence, experimental error and inherent variations in the material must be examined. Most of the papers cited do not present variability estimates useful in evaluation of results and in guiding sample size for the next experiment. Large sample sizes may not be needed to sample forage more uniform than annual range vegetation. Mixtures of two or three species in a planted pasture and small plots where the opportunity for selectivity may not be great are examples. Experimental objectives may require only a few samples, but studies of dietary botanical composition under range grazing require more samples than have been taken in most past work.

Studies of range plant selectivity exhibited by freely grazing animals have been done without the same sampling device being used on available herbage and forage consumed. The laboratory point-technique used on clipped and fistula samples in this study permitted development of preference ratios without bias resulting from different methods. The assumption was made, however, that the relations between per cent points and per cent weight are similar for herbage and forage samples. This assumption requires further examination. Since field points and laboratory points gave similar botanical composition of the herbage, preference ratios developed in laboratory analysis are close to field situations.

The need for large sample sizes suggests that the fistula technique is primarily useful for studying abundant and constant elements in the diets of freely grazing range animals. Perhaps more precise determination of botanical composition of fistula forage samples would reduce the numbers of animals required for sampling. Fistulated animals are costly to obtain and maintain, and thus may present an economic factor to consider. One approach to minimizing costs would be to employ experimental designs in which main effects are studied with relatively large numbers of animals and less important factors with fewer animals. The research potential of the fistula technique warrants its expanded use in grazing studies on highly variable vegetation, but sampling designs that permit analysis of the factors contributing to the variability should be used. Regardless of the design, to sample dietary botanical composition the minimum number of animals should be at least 5, and 10 would be better for sampling many dietary constituents. For the same precision, fewer animals are required to sample dietary chemical constituents than botanical constituents (Van Dyne and Heady, 1965).

SUMMARY AND CONCLUSIONS

Five steers and seven sheep with esophageal fistulas were grazed on a mature California annual range for one summer. Early morning and late afternoon dietary samples were taken on five consecutive days in three periods from early July to early September, 1961. Samples were analyzed microscopically for genus or species and plant parts. Statistical analysis for twenty-four dietary components are presented for three periods, five days, two times of day, two classes of stock, individual animal differences, and interactions.

Herbage availability decreased from 1490 to 420 pounds per acre during the three periods. Preference for most of the forage constituents changed significantly as herbage became limited. Heads, forb stems, forb leaves, total grasses, total forbs, *Aira caryophyllea, Avena barbata* and *Bromus* spp. were grazed in the same relative amounts as they occurred on the range throughout the summer. Generally the diets had less stems and more leaves in early than in late summer.

No significant differences were found in botanical constiuents of the average daily diets within a sampling period of 5 days.

One-third of the botanical constituents were eaten in different amounts in the morning than in the late afternoon. When based on differences between clipped and fistula samples, afternoon diets were more selected than were morning diets.

Cattle and sheep diets differed significantly summer-long for about half of the constituents. Sheep selected more total leaves, grass leaves, forb leaves, and legumes than did cattle, whose diets were higher in total stems, grass stems, *Avena barbata, Gastridium ventricosum,* unidentifiable grasses, and *Erodium botrys.*

Cattle and sheep did not respond in the same way to decreased available herbage, as indicated by significant pepiod × class of stock interactions for many dietary components. Decreasing selectivity by sheep suggests that they were more affected by herbage shortage than were cattle. Nevertheless, by the end of summer, sheep continued to be more selective than cattle.

On the average, individual sheep differed in more dietary variables than did individual cattle. Certain sheep had diets similar to those of cattle, but no steer selected a diet similar to the average diet of sheep. Differences in most dietary components among individual cattle and sheep decreased as herbage became limited.

The number of animals required to sample dietary botanical composition within 10 per cent of the mean with 90 per cent confidence would be excessive for most constituents. Fewer animals would be required in late than in early summer and more sheep than cattle would be needed, but by grouping botanical constituents, fewer animals are needed. As many as nine animals would be required to sample the major plant groups in middle and late summer with the precision mentioned above. Most previous studies have not used enough esophogeal-fistulated animals.

The relative preference of cattle and sheep for each plant is given as the ratio of the amount or percentage of the plant in the diet to the amount available on the range. Less abundant species generally were either highly selected or rejected, while abundant ones furnished the bulk of the diets and were neither significantly selected nor rejected.

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