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Nutritive Value of Sheep Diets on Coastal California Annual Range

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Diets of sheep on California annual range in the northern Coast Mountains were evaluated at various seasons and stages of plant growth on grass-woodland and improved grassland grazed yearlong at three grazing intensities. Nutritive content of forage samples collected by esophageal-fistulated ewes, including organic matter digestibility, digestible energy, crude protein, ether extract, fiber constituents and minerals, was compared with nutritive content of herbage from both range (vegetative cover) types and with nutrient requirements of sheep. Diets from grassland improved by seeding to subterranean clover were more digestible and had more crude protein and digestible energy than diets from woodland range. There were differences in contents of various nutrients among seasons and phenological stages (e.g., more protein and energy in fall and winter than in summer) but not among grazing intensities. Based on nutrient concentrations, diets were generally adequate for brood ewes except at plant maturity on woodland range when protein and energy could be deficient. Grazing selectivity occurred for some nutrients but not consistently. Associations among nutritional variables suggested that acid detergent fiber was a good indicator of forage nutritional value. Acid detergent lignin and cellulose were the best predictive variables for organic matter digestibility.

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INTRODUCTION

CALIFORNIA HAS A large sheep industry with over 1 million sheep produced annually on 5,000 sheep operations (McGregor and Tucker 1981). Many ewe-lamb operators rely on forage from annual ranges as the basis of their enterprises. There have been numerous investigations of commercial sheep management and production on California's annual range, but studies of sheep diets from this type of grazing land have been limited to a summer study (Van Dyne and Lofgreen 1964; Van Dyne and Heady 1965) or have been based on extrapolation from herbage analyses (Gordon and Sampson 1939; Van Dyne 1965). Knowledge of nutritive aspects of range animal diets is basic to formulating ranch plans and implementing many management practices (e.g., feeding, breeding, marketing, range planning, and improvement). Such information is especially useful if related to seasonal and phenological stages of forage plants or nutrient needs and physiological status of grazing animals. Full appraisal of dietary nutrients should be further interpreted relative to stocking rate, an important element of range management and one shown to influence chemical composition (Cook, Taylor, and Harris 1962) and digestibility of range sheep diets (Langlands and Bennett 1973).

The following trial was conducted to quantify nutritive composition of ewe diets at various stages of herbage development and sheep production cycles on annual ranges. Three grazing intensities were studied (yearlong moderate grazing, moderately heavy grazing, and heavy grazing) so that ranch operations could be developed to increase efficiency of range use, enhance flock productivity, and economize on such costly practices as supplementation.

EXPERIMENTAL PROCEDURE

The investigation was conducted during 1980 and 1981 at the Hopland Field Station, Mendocino County, California, located 50 km inland and within the northern Pacific Coast Mountain Range. Climate is subtropical (humid mesothermal) or mediterranean (Aschmann 1973), with mild moist winters and hot summers devoid of precipitation. Snow falls infrequently and only at higher elevations. Rainfall occurs periodically from September or October through June and averages 89 cms annually. Total precipitation of 1980 and 1981 feed years (July-June) was 112 and 69 cms, respectively (Univ. California 1980, 1981).

Two annual range types were evaluated: (1) improved grassland range and (2) grass-woodland range. The first included seasonal swards of naturalized European annual grasses and forbs overseeded to subterranean clover *(Trifolium subterraneum)*.[2] The second was

[1]Accepted for publication October 10, 1984.

[2]Plant nomenclature from Munz and Keck (1973).

TABLE 1. SPECIES COMPOSITION (%) OF THREE ANNUAL GRASS-WOODLAND AND THREE IMPROVED ANNUAL GRASSLAND PASTURES GRAZED AT THREE STOCKING RATES IN 1980 AND 1981 ON HOPLAND FIELD STATION, CALIFORNIA

	Improved grassland range pasture (stocking rate)*					
Species	**LM 1 1980**	**(100) 1981**	**LM 3 1980**	**(150) 1981**	**LM 2 1980**	**(200) 1981**
Bromus mollis	29	51	21	47	17	43
Elymus caput-medusae		1				T
Festuca spp.	1	10	3	15	8	7
Hordeum spp.	3	20	9	15	8	14
Other annual grasses			1		T	
Erodium spp.	2	4	7	9	2	11
Trifolium subterraneum	64	14	57	14	62	25
Trifolium spp.	T	T	T		2	T
Misc. forbs	T		1		T	T

	Grass-woodland range pasture (stocking rate)*					
	S 3 1980	**(100) 1981**	**S 1 1980**	**(150) 1981**	**D 1 1980**	**(200) 1981**
Aira caryophyllea	4	5	10	18	6	7
Avena barbata/fatua	10	13	5	2	3	4
Bromus mollis	36	38	40	37	62	60
Bromus rigidus	14	7	10	2	4	1
Bromus rubens	1	2	4	8	T	
Elymus caput-medusae	2	4		T		
Festuca spp.	2	1	1	T	2	13
Hordeum spp.	T	1	T	T	5	2
Other annual grasses	T	5	T	3	2	1
Stipa pulchra	T	T				
Erodium spp.	6	12	7	17	T	2
Trifolium spp.	3	2	12	2	T	2
Misc. forbs	22	10	11	11	16	7

SOURCE: Rosiere and Torell (1982). Measured at peak standing crop using step-point procedure.
*% of moderate use; T = trace.

a mosaic of annual grassland and savannah of blue oak *(Quercus douglasii),* interior live oak *(Q. wislizenii),* and madrone *(Arbutus menziesii)* trees with an understory of annual grasses and forbs, and scattered sclerophyllus shrubs such as manzanita *(Arctostaphylos* spp.) and chamise *(Adenostoma fasciculatum).* Botanical composition (herbaceous species) of study pastures (table 1) was determined by step-point procedure (Evans and Love 1957) at the time of peak standing crop. Because of drier conditions in 1981, subclover decreased and soft chess *(Bromus mollis)* increased. Otherwise, botanical composition was similar in both years. Soils of woodland range were Josephine (Typic Haploxerult),[3] Sutherlin (Aquic Haploxeralf), Laughlin (Ultic Haploxeroll), and Los Gatos (Typic Argixeroll) series, while that of grassland range was Soquel (Cumulic Haploxeroll) and Pleasanton (Mollic Haploxeralf).

[3]Soil classification follows Soil Survey Staff (1975).

Both range types were grazed yearlong at grazing intensities of 100, 150, and 200 percent of moderate use by flocks of dual-purpose ewes, primarily of Targhee breeding. Naturalized woodland ranges were Pastures S1 (21.9 ha), S3 (15.4 ha), and D1 (2.5 ha) stocked with 14, 12, and 9 ewes during 1980 and with 13, 11, and 7 ewes in 1981 for 100, 150, and 200 percent of moderate use rates. Improved grassland range grazed under respective grazing intensities consisted of Paddocks LM1 (1.5 ha), LM3 (1.0 ha), and LM2 (.8 ha), each grazed by eight ewes. Mean stocking rates of woodland and grassland range at 100, 150, and 200 percent treatments were .6, 1.8, and 3.2, and 5.3, 8.0, and 10.0 ewes per grazable ha, respectively, plus their spring-born lambs for 3 months and one ram for 2 months.

Improved grassland range was established in fall 1979, by overseeding Mount Barker and Woogenllup varieties of subterranean clover into annual grass sod (22.4 kg seed/ha) and applying soil sulphur (112 kg/ha) and triple superphosphate (56 kg/ha) with a rangeland drill. In fall 1980, pastures were topdressed with single superphosphate (168 kg/ha). Grass-woodland ranges had been grazed for 20 years prior to present studies under stocking rates essentially the same as current intensities (Pitt and Heady 1979).

Diets representative of those consumed by ewes from the six pastures were sampled, using from three to six esophageal-fistulated middle-aged ewes to collect forage during 2- and 3-day periods (morning collections) throughout the year. Collection periods (table 2) were combinations of season, plant phenological stage, and ewe reproductive status (e.g., summer/dry, mature herbage/breeding; spring/boot stage to flowering/lactation). Range

TABLE 2. SEASONS, STAGES OF PLANT DEVELOPMENT, AND CORRESPONDING STATUS OF SHEEP PRODUCTION AT VARIOUS SAMPLING PERIODS

Date	Season	Plant phenology* *stage of maturity*	Sheep status
Late November—early December	Fall	Seedling (2-4 leaf stage) + leached previous season's herbage; *early leaf.*	Second trimester of pregnancy.
Late January—early February	Winter	Seedling—mid-prebloom†; *immature and prebloom.*	Last trimester of pregnancy.
Late March—mid-April	Early/mid-spring	Boot—early bloom stage†; *early bloom.*	Lambing through first three-fourths of lactation; early lamb growth.
Early—mid-May	Late spring	Full bloom—seed set, (soft, doughey seed)†; *full bloom to milk stage.*	Late lactation; lambs grazing and gaining rapidly.
Mid-June	Early summer	Seed set—seed ripe (hard seed)†; *dough stage.*	Weaning; restoration.‡
Mid-July	Midsummer	Maturity (seed ripe—seed shatter)†; *mature.*	Maintenance; possible weight gain in ewes.
Early—mid-September	Late summer	Straw stage (postmaturity, completely dead, leaf shatter); *overripe.*	Breeding; maintenance (weight loss in ewes on heavily stocked range).

*Annual herbaceous species. *Approximate NAS (1971) stage of maturity.*

†Phenology varied with species. Forbs (e.g., *Erodium, Trifolium)* and smaller grasses (e.g., *Aira*) were at more advanced development than abundant grasses *(Bromus, Festuca, Hordeum). Avena* spp. and *Elymus caput-medusae* were the latest maturing species.

‡Forage approaching maturity but apparently capable of supporting weight gain and replenishment of body stores in ewes.

herbage was sampled each period by clipping plants occurring in .09m² plots at ground level. Vegetation exposed to grazing, as well as that excluded from grazing by cages, was measured using 10 randomly chosen locations. Forage and herbage samples were prepared for analysis by drying (56°C) in a forced-draft oven and then grinding (1-mm screen) in a Wiley mill. Analytical procedures followed those of AOAC (1965) for dry matter, ash, crude protein, and ether extract; Goering and Van Soest (1975) for fiber and lignin; and Tilley and Terry (1963) for organic matter digestibility. Heats of combustion were determined by adiabatic calorimetry (Parr Instrument Company 1981). Digestible energy was estimated by using in vitro organic matter disappearance percentages as digestion coefficients and multiplying these by gross energy values. It was assumed that digestibility of energy-bearing components was approximately equal to that of organic matter. Plant mineral content was determined on nitric-perchloric acid digests with phosphorus determined by vanadate-molybdate yellow color development (AOAC 1965). Calcium, magnesium, and potassium were analyzed by atomic absorption spectrophotometry (Varian Techtron 1972).

Statistical procedures followed Steel and Torrie (1960). The experiment was a factorial with split plot, where range types and grazing intensities were main plots and seasons were subplots. (All factors were fixed effects.) This was analyzed by analysis of variance procedures. When F ratios were significant ($p<.05$), treatment means were separated by Tukey determination. Student's t test was used to compare mean contents of nutritional parameters in sheep diets to those in range herbage. Relationships among nutrient contents, organic matter digestibility, and digestible energy were studied by correlation and multiple regression procedures, using stepwise (backward elimination) and maximum R^2 improvement techniques (SAS 1982).

RESULTS AND DISCUSSION

Nutritive content of ewe diets and that of range herbage is presented as follows: crude protein and ether extract (table 3); fiber (table 4); minerals, herbage only (table 5); and in vitro organic matter digestibility, gross energy, and digestible energy (table 6).

Grazing Intensity Influences

Nutrients and nutrient properties were not affected by grazing intensities, except possibly for crude protein ($P<.1$). Seasons, by contrast, had a large influence on nutritional parameters—hemicellulose ($P<.1$), ether extract ($P<.05$), and others ($P<.005$). Range type had a limited effect on nutrient content. Crude protein was higher ($P<.005$) on subterranean clover seeded grassland range than on woodland range (15.6 percent versus 9.3 percent). Organic matter digestibility was greater ($P<.05$) for diets from grassland range than for those from woodland range (63 percent versus 56 percent). Digestible energy contents were higher ($P<.025$) on grassland than on woodland range (3.08 Mcal/kg versus 2.70 Mcal/kg organic matter). Mean differences in acid detergent fiber and lignin between woodland and grassland range (36.3 percent versus 33.3 percent and 8 percent versus 4.8 percent, respectively) approached significance ($P<.1$). There were significant interactions only between grazing intensity and range type for lignin and between season and range type for crude protein and digestible energy. A season X grazing intensity

TABLE 3. CRUDE PROTEIN AND ETHER EXTRACT CONTENT (%)*† OF EWE DIETS AND OF HERBAGE FROM ANNUAL GRASS-WOODLAND AND IMPROVED ANNUAL GRASSLAND RANGE IN NORTHERN CALIFORNIA DURING VARIOUS SEASONS UNDER YEARLONG USE

	Season							
Nutrient	Fall	Winter	Early/ mid- spring	Late spring	Early summer	Mid- summer	Late summer 1980	Late summer 1981
			Woodland range‡					
Crude protein								
Diet	12.8±.9	10.7±.5	11.3±.8	10.8±.3	8.2±.3	6.8±.3	6.9±.3	6.8±.4
Herbage	8.2±1.5	8.6±.5	8.3±1.3	8.0±.7	4.9±.3	5.1±.3	5.6±.3	5.2±.2
Ether extract								
Diet	2.1±.2	2.1±.3	2.0±.1	1.8±.1	1.9±.2	1.2±.3	1.3±.1	1.1±.1
Herbage	1.3±.2	1.5±.1	2.6±.2	1.7±.3	1.3±.2	1.2±.3	.7±.2	2.3±.8
			Grassland range‡					
Crude protein								
Diet	25.4±1.4	21.9±.6	23.3±.4	14.4±.4	13.3±.3	8.7±.2	10.1±.3	8.1±.4
Herbage	12.5±.7	18.8±2.0	18.8±.5	10.0±.5	8.7±1.1	6.1±.5	8.4±.4	5.2±.2
Ether extract								
Diet	2.3±.2	2.1±.1	2.7±.1	2.4±.1	1.4±.1	1.2±.1	1.1±.1	.9±.1
Herbage	1.7±.1	2.1±.3	3.3±.5	3.2±.2	1.8±.2	1.5±.0	1.3±.1	1.1±.0

*Mean ± SE.

†DM basis; to convert to OM basis, divide values by corresponding organic matter percent in Table 4 (100 − Ash).

‡Values are shown as means of three stocking rates because they did not differ statistically.

interaction in crude protein levels and another for season X range type in cellulose content approached significance.

The limited effect of grazing intensity on quality of sheep diets may be a feature unique to or more pronounced on annual range than on other range types. Cook, Taylor, and Harris (1962) found that degree of use and plant species present were the major factors affecting nutritional value of sheep diets on desert ranges in different condition classes. Heavier grazing intensities generally decreased nutrient content and digestibility, but this was sometimes offset by dietary shifts among the various categories of forage and browse. In another study of sheep diets from desert range, Pieper, Cook, and Harris (1959) reported a more straightforward relationship, with nutrient concentration and digestibility usually decreasing with increasing levels of utilization. The greater herbage production on the annual type and, on annual grass-woodland ranges, more diverse species composition of plant communities may explain why grazing intensity failed to influence the nutritive value of sheep diets. Abundance of sclerophyllus browse, which was visibly less affected than herbaceous plants by grazing intensity and was eaten copiously by fistulated sheep, may have been a factor in negating stocking treatments on woodland range.

This concept is consistent with findings from Australian rangelands having major shrub components. There, stocking rates either had no effect or significant but infrequent and minor impact on dry matter digestibility and nitrogen content of sheep diets (Leigh, Wilson, and Mulham 1968; Wilson, Leigh, and Mulham 1969). A companion study (Rosiere and Vaughn, in review) compared grass-woodland range sites to a serpentine barrens site and found significant differences in nutritional contents of sheep diets among the woodland

TABLE 4. FIBER COMPOSITION (%)*† AND ASH (%)* OF EWE DIETS AND OF HERBAGE FROM ANNUAL GRASS-WOODLAND AND IMPROVED ANNUAL GRASSLAND RANGE IN NORTHERN CALIFORNIA DURING VARIOUS SEASONS UNDER YEARLONG USE

	Season							
Component	Fall	Winter	Early/ mid-spring	Late spring	Early summer	Midsummer	Late summer 1980	Late summer 1981
				Woodland range‡				
NDF§								
Diet	45.9±1.5	53.0±1.9	41.7±.8	43.1±1.2	49.8±1.7	51.7±1.4	50.8±1.6	52.3±1.9
Herbage	60.4±2.2	60.4±1.6	52.5±.8	57.3±1.1	67.7±1.3	62.7±2.2	61.1±1.5	60.1±1.8
ADF								
Diet	34.4±1.6	39.3±1.7	29.2±.5	32.0±.7	38.7±1.1	37.9±1.0	39.5±1.4	39.3±.7
Herbage	53.6±2.4	47.7±.8	40.7±1.1	36.6±1.9	46.7±.6	44.4±1.0	48.3±.4	43.8±1.4
ADL								
Diet	6.5±1.2	9.8±1.8	5.4±.4	6.6±.5	12.1±.6	8.3±.6	8.7±.5	7.6±.9
Herbage	13.4±2.4	9.9±1.0	10.7±1.1	5.8±1.0	7.6±.1	8.5±1.6	9.7±.9	8.3±2.1
AIA								
Diet	4.0±.6	3.7±.1	2.8±.5	1.6±.2	1.0±.4	1.7±.3	2.3±.4	2.9±.4
Herbage	18.1±.59	7.6±2.8	5.4±1.6	2.7±.8	3.4±1.1	3.7±.7	7.0±.9	3.2±.7
Ash								
Diet	13.6±.6	13.7±1.3	13.2±.5	11.4±.3	10.2±.3	9.9±.3	10.8±.5	11.0±.4
Herbage	25.8±.3	16.2±3.4	13.0±2.8	27.1±3.9	8.3±.8	8.4±.7	13.7±1.1	8.2±.9
Hemicellulose								
Diet	11.5±1.3	14.9±1.2	12.7±.7	11.1±1.2	11.7±1.3	13.8±1.3	11.3±.8	13.0±1.3
Herbage	10.7±1.6	12.7±2.4	11.8±.5	20.7±2.2	21.0±1.8	18.2±3.2	12.7±1.7	16.2±2.5
Cellulose								
Diet	23.9±.8	25.7±1.2	24.5±2.2	23.8±.7	25.8±.8	27.5±.8	28.1±1.3	28.8±1.5
Herbage	21.9±1.5	30.2±2.7	24.5±2.2	28.1±1.6	34.9±.4	32.2±1.2	31.7±.9	32.3±1.1

TABLE 4. CONTINUED

Component	Season							
	Fall	Winter	Early/ mid-spring	Late spring	Early summer	Midsummer	Late summer 1980	Late summer 1981
				Grassland range‡				
NDF								
Diet	42.6±2.0	44.2±2.2	40.0±1.9	39.0±.6	58.1±.9	58.6±.7	58.4±.7	61.4±1.0
Herbage	65.7±1.1	46.7±4.8	44.3±3.9	52.8±2.1	65.9±.7	65.1±.6	58.6±1.1	65.7±1.1
ADF								
Diet	27.9±1.4	26.8±.9	21.7±.3	29.1±.4	41.0±.4	40.0±.4	40.1±.3	40.0±.3
Herbage	43.9±.7	32.8±2.2	24.2±.8	30.1±.9	40.0±.4	41.6±.4	41.9±.5	43.9±.7
ADL								
Diet	3.4±1.2	4.2±.3	2.9±.1	3.9±.1	8.9±.2	4.7±.1	6.2±.2	4.0±.1
Herbage	3.7±.2	6.4±.7	3.1±.2	3.4±.2	6.9±.3	4.3±.2	5.9±.5	3.7±.2
AIA								
Diet	3.2±.3	1.8±.2	.7±.1	.7±.2	.3±.1	1.2±.1	1.0±.3	1.3±.2
Herbage	12.0±4.4	8.7±.1	1.0±.3	.5±.3	.2±.1	2.1±.2	3.1±.1	2.9±1.3
Ash								
Diet	14.9±.4	12.6±.6	11.4±.1	12.0±.3	12.5±.2	10.0±.4	11.1±.3	11.0±.5
Herbage	33.6±5.1	27.1±3.9	10.3±.6	6.74±.2	7.8±.3	7.2±.5	11.0±.8	8.4±1.9
Hemicellulose								
Diet	14.7±.8	18.5±1.6	17.7±1.5	9.8±.8	17.5±.9	18.5±.6	18.5±.7	21.4±1.1
Herbage	21.8±1.1	13.9±2.4	20.1±3.2	22.7±1.7	25.9±.8	23.6±.9	16.7±1.6	21.8±1.1
Cellulose								
Diet	21.4±1.0	20.4±.5	18.2±.3	24.4±.5	32.3±.3	34.0±.3	33.0±.4	34.7±.6
Herbage	38.2±.7	14.3±4.5	20.6±1.1	26.3±.5	32.8±.4	35.2±.3	32.9±.3	38.2±.7

*Mean ± SE.

†DM basis; to convert to OM basis, divide values by corresponding organic matter percent in table 4 (100 − Ash).

‡Values are shown as means of three stocking rates because they did not differ statistically.

§Neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and acid insoluble ash (AIA).

TABLE 5. MINERAL CONTENT (%)*† OF HERBAGE FROM ANNUAL GRASS-WOODLAND AND IMPROVED ANNUAL GRASSLAND RANGE IN NORTHERN CALIFORNIA DURING VARIOUS SEASONS UNDER YEARLONG USE

	Season							
Nutrient	Fall	Winter	Early/ mid-spring	Late spring	Early summer	Midsummer	Late summer 1980	Late summer 1981
				Woodland range‡				
Calcium	.75±.19	.34±.03	.76±.18	.48±.15	.88±.29	.71±.19	.37±.2	.67±.23
Phosphorus	.24±.08	.17±.01	.27±.04	.26±.02	.14±.01	.13±.01	.11±.00	.12±.01
Potassium	.82±.08	.58±.02	1.33±.10	1.23±.03	.42±.04	.60±.08	.39±.06	.59±.09
Magnesium	.46±.25	.32±.19	.32±.18	.19±.06	.15±.05	.24±.10	.24±.11	.24±.10
				Grassland range‡				
Calcium	.52±.08	.32±.03	.84±.09	.54±.05	1.12±.03	.57±.04	.40±.04	.46±.04
Phosphorus	.28±.01	.41±.06	.44±.01	.31±.01	.22±.01	.18±.02	.22±.01	.17±.02
Potassium	1.38±.13	1.77±.25	2.74±.25	1.88±.02	1.00±.03	1.12±.09	.98±.08	1.03±.09
Magnesium	.43±.06	.32±.04	.24±.02	.17±.01	.20±.01	.19±.01	.19±.00	.20±.03

*Mean ± SE.

†DM basis.

‡Values are shown as means of three stocking rates because they did not differ statistically.

TABLE 6. IN VITRO ORGANIC MATTER DIGESTIBILITY (%), GROSS ENERGY, AND DIGESTIBLE ENERGY (MCAL/KG)*† OF EWE DIETS AND OF HERBAGE FROM ANNUAL GRASS-WOODLAND AND IMPROVED ANNUAL GRASSLAND RANGE IN NORTHERN CALIFORNIA DURING VARIOUS SEASONS UNDER YEARLONG GRAZING

Property	Season							
	Fall	Winter	Early/ mid-spring	Late spring	Early summer	Midsummer	Late summer 1980	Late summer 1981
				Woodland range‡				
IVOMD								
Diet	61.4±3.2	54.1±2.7	72.2±1.1	55.2±1.1	42.5±1.4	53.6±1.0	54.3±1.2	57.1±1.6
Herbage	36.3±2.4	51.5±3.8	60.7±2.6	69.9±3.2	43.4±3.7	51.5±1.8	48.6±2.7	58.7±.7
GE								
Diet	4.35±.05	4.16±.05	4.14±.03	4.16±.04	4.45±.04	4.18±.03	4.23±.02	4.23±.02
Herbage	3.59±.06	3.91±.20	4.19±.10	4.09±.04	4.34±.05	4.24±.03	4.08±.05	4.22±.08
DE								
Diet	2.82±.13	2.45±.10	3.20±.04	2.48±.05	1.88±.06	2.38±.03	2.38±.05	2.52±.07
Herbage	1.64±.13	2.28±.18	2.73±.10	3.06±.11	1.89±.14	2.26±.06	2.18±.09	2.54±.04
				Grassland range‡				
IVOMD								
Diet	65.3±1.3	69.3±.5	72.3±.6	72.1±1.6	44.6±1.0	61.6±1.1	54.1±1.8	63.1±1.1
Herbage	35.2±4.7	52.4±3.0	73.6±.7	77.5±.6	53.5±1.5	58.2±.6	54.4±1.7	63.5±.6
GE								
Diet	4.42±.03	4.42±.05	4.64±.02	4.17±.02	4.31±.01	4.08±.02	4.19±.01	4.17±.02
Herbage	3.40±.19	3.66±.20	4.42±.08	4.28±.03	4.41±.01	4.18±.03	4.22±.04	4.21±.09
DE								
Diet	3.06±.08	3.26±.03	3.38±.05	3.30±.07	1.98±.04	2.71±.05	2.34±.08	2.72±.04
Herbage	1.68±.18	2.48±.14	3.34±.04	3.32±.05	2.34±.06	2.55±.04	2.40±.06	2.75±.02

*Mean ± SE.

†DM basis; to convert to OM basis divide values by corresponding organic matter percent in table 4 (100 − Ash).

‡Values are shown as means of three stocking rates because they did not differ statistically.

ranges discussed here. Inability of grazing intensity to alter composition of diets from grassland range defied explanation and was inconsistent with results of sheep diet research on annual grass-subclover pasture in Australia (Arnold et al. 1966) and with findings from cattle trials on perennial grass ranges (Vavra, Rice, and Bement 1973; Allison and Kothmann 1979; Lewis et al. 1982).

Season Influences

Differences in nutritional characters among seasons (table 7) were least numerous for gross energy with levels lower in late spring and midsummer diets than in those during early/mid-spring diets. The most numerous seasonal differences were in digestible energy, which was highest in early/mid-spring and lowest in early summer. Summer diets had significantly less digestible energy than did diets during other seasons, except that energy in late summer 1981 did not differ from that in winter and late spring.

Seasonal differences were most pronounced for protein. There was roughly two and three times more crude protein in fall and winter diets than in mid to late summer diets on the respective woodland and grassland ranges (table 3). Countless other studies have documented effects of the season/climate/plant maturity complex on nutrient content and forage quality (Van Soest 1982). Changes in protein content have been among the most dramatic and most commonly reported, but it is not obvious whether levels of this nutrient are more dynamic than are other nutrients or whether protein determination is simply more widespread and traditional than are such more recently developed analyses as forage fiber evaluation.

Seasonal fluctuations in fiber components (tables 4 and 7) were less than in protein but greater than in ether extract. Lipid content concentrations, like those for hemicellulose, were statistically inconsistent as analysis of variance indicated significant effects due to season, but such effects were not detected in pair-wise comparisons. This may reflect rigor of the Tukey procedure (Steel and Torrie 1960).

Lignin was the most seasonally variable fiber constituent with fluctuations of more than 250 percent on grassland range between young forage (fall, winter, spring) and mature forage (summer). Variability in lignin among seasons was less on woodland range than on grassland range. This may have resulted from greater botanical variety of diets on woodland where there were summer forbs and sclerophyllus shrubs as well as cool season herbs. By comparison, grassland had only cool season herbaceous species. Variation within seasons among individual fistulated sheep grazing various pastures on different days was similar for lignin and hemicellulose (coefficient of variability of 25 percent) which were more variable than other components (table 4).

Although cellulose varied significantly among seasons, contents essentially occurred within a range of 20 to 30 percent (table 7) and biological significance of small differences seemed slight. Of more importance, perhaps, was the relatively narrow range of cellulose values when compared to that for organic matter digestibility. This narrow range, coupled with proportionately greater fluctuation in lignin, suggested that lignin or the lignincellulose unit had more influence on digestibility than did cellulose or hemicellulose (see section on relations among nutrients and properties).

Significant differences in organic matter digestibility (table 7) were limited. Early summer diets were less digestible than were those in fall, winter, spring, and late summer 1981.

TABLE 7. MEAN SEASONAL VALUES[abc] OF NUTRITIONAL PARAMETERS IN DIETS OF EWES GRAZING CALIFORNIA ANNUAL IMPROVED GRASSLAND AND GRASS-WOODLAND RANGE (AVERAGE OF BOTH TYPES)

	Season							
Parameter	Fall	Winter	Early/ mid-spring	Late spring	Early summer	Midsummer	Late summer 1980	Late summer 1981
Neutral-detergent fiber	44.2^{de}	49.1^{de}	40.9^{e}	41.0^{e}	54.3^{de}	55.1^{d}	52.3^{de}	56.8^{d}
Acid-detergent fiber	31.1^{def}	33.0^{def}	25.4^{f}	30.5^{ef}	39.8^{d}	38.9^{de}	39.8^{d}	39.6^{d}
Acid-detergent lignin	4.9^{fg}	6.8^{ef}	3.7^{g}	5.2^{fg}	10.5^{d}	6.5^{ef}	7.4^{e}	5.8^{ef}
Hemicellulose	13.1	16.9	15.3	10.5	14.5	16.2	14.9	17.2
Cellulose	22.6^{ef}	23.1^{ef}	19.8^{f}	24.1^{def}	29.0^{de}	30.7^{de}	30.7^{de}	31.8^{d}
Crude protein	19.1^{d}	16.3^{e}	19.4^{d}	12.6^{f}	10.8^{f}	7.7	8.4	7.4
Ether extract	2.2	2.1	2.4	2.1	1.6	1.2	1.2	1.0
In vitro organic matter digestibility	63.4^{de}	61.9^{de}	72.2^{d}	63.7^{de}	43.5^{f}	57.6^{def}	54.4^{ef}	60.0^{de}
Gross energy	4.39^{de}	4.29^{de}	4.46^{d}	4.17^{e}	4.38^{de}	4.13^{e}	4.21^{de}	4.20^{de}
Digestible energy	2.96^{e}	2.86^{ef}	3.29^{d}	2.89^{ef}	1.94^{h}	2.55^{g}	2.36^{g}	2.62^{f}

[a]Means of diets from three pastures of both improved grassland and naturalized woodland range.

[b]Expressed as percentage except for gross energy and digestible energy (Mcal/kg).

[c]Dry matter basis; to convert to OM basis divide values by corresponding seasonal mean of organic matter percent in table 4 (100 − Ash).

[defgh]Means within rows having different superscripts differ ($P < .05$).

Late summer diets in 1980 were less digestible than were early spring diets. Other comparisons indicated no differences in digestibility. Diets during summer had in vitro digestion coefficients of 60 percent or less; those of other periods were above 60 percent. Absence of pronounced seasonal fluctuations in digestibility of range diets was counter to declines commonly occurring in forages with advancement of growing season and plant maturity (NAS 1971).

Few evaluations of range animal diets on a year-round basis exist for comparison with present findings. Arnold et al. (1966) found declines in digestibility of sheep diets from continuously grazed *Phalaris*-annual grass-subterranean clover pasture in midwinter, late spring, and summer. Rosiere, Wallace, and Beck (1975) reported significant seasonal differences in digestibility of cattle diets sampled year-round on semidesert grassland. On Great Plains grassland Hart et al. (1983) recorded significant decreases in digestibility of cattle diets and major forage species from spring to fall, but previous studies in this region revealed no such decline during three summer months (Jefferies and Rice 1969; Vavra, Rice, and Bement 1973). There might have been greater or more seasonal changes in dietary components on annual range had composition been determined in other years, but there was close agreement between current values and those from a former survey (Van Dyne and Weir 1964).

Mineral composition of sheep diets was not presented, because several elements present in saliva have been shown to contaminate fistula-sampled forage and to result in biased concentration values (Van Dyne and Torell 1964; Wallace, Hyder, and Van Dyne 1972; Lesperance et al. 1974). Contents of calcium, phosphorus, magnesium, and potassium in range herbage were presented (table 5) so that minerals would not be totally ignored.

Selective grazing

The phenomenon of grazing selectivity has been observed in most range types and management systems (see reviews by Van Dyne et al. 1980; Arnold 1981). Ability of sheep grazing annual range in late summer to choose diets more nutritious than the mean of available herbage was shown by Van Dyne and Heady (1965). To characterize selective grazing year-round, this investigation compared nutritional variables in herbage and sheep-selected forage for several seasons and plant development stages. Although sheep tended to graze vegetation that was more nutritious than the average of that on offer, this pattern was inconsistent. Percentage of neutral-detergent fiber, acid-detergent fiber, and hemicellulose (table 4) averaged across all sampling periods differed ($P<.05$) between vegetative material on the range and that in diets (59 percent versus 49 percent, 41 percent versus 35 percent, and 18 percent versus 15 percent, respectively). There was no significant difference in content of acid-detergent lignin or cellulose. Weir and Torell (1959) also found no difference between lignin content of clipped herbage and sheep-grazed forage on annual range. Thus, while sheep selected higher levels of the more digestible fiber portions, they did not avoid or select against the digestibility-depressing lignin, but consumed it indiscriminately. Average organic matter digestibility and digestible energy concentration of sheep diets over all sampling periods did not differ from those of range herbage. Sheep selected forage that was substantially more digestible and energy-rich than the composite of available herbage in fall when, for unknown reasons, ash contents of standing crop were 26 and 34 percent on woodland and grassland range, respectively, while only 14 to 15 percent in diets. These high ash levels probably resulted from concentrations of silica (table 4—acid insoluble ash), which were roughly four times greater in herbage during fall than was the average across all other seasons. Weir and Torell (1959) expressed ash on a silica-free basis to obviate this complication. Current data were presented on a silica-in basis so that they could be compared without conversion to nutrient requirements of sheep (NRC 1975) and to composition of other range feeds (NAS 1971).

Likewise, ether extract content did not differ between feed offered and feed eaten but averaged 1.7 percent in both and was actually measured at smaller quantities in diets from grassland range during six of eight sampling periods (table 3).

Crude protein was higher ($P<.05$) in diets than in herbage on woodland range (9.3 percent versus 6.7 percent), but there was no significant difference between dietary and herbage protein on grassland range (15.6 percent versus 11.1 percent). This suggested that sheep were more apt to graze discriminately on vegetation from woodland than from grassland. Perhaps protein levels were high enough on subclover-seeded grassland so that ewes could "balance" their diets by foraging at random. There was, as previously noted, however, more seasonal fluctuation in protein content than in other constituents. Trends in dietary protein followed concentration in herbage but less so on woodland ranges. Grazing behavior may have been a factor with sheep likely to feed less selectively on the smaller grassland pastures, which had more uniform vegetation, than on the more extensive woodland pastures with steep slopes and diverse flora. It was also possible that herbage was sampled less precisely on woodland range (coefficients of variation were significantly larger for woodland than for grassland) or that browse was not adequately represented in clipped feed (herbage) samples.

Sampling logistics (always a pitfall when using fistulated animals on diverse range) and seasonal influences notwithstanding, it seems that sheep grazing the California annual type do not choose feed with as much selectivity as do livestock on other types of range and pasture. Hardison et al. (1954) found, for example, that steers grazing introduced species consumed ether extract in significantly greater concentrations than that in pasture herbage. This contrasted with findings here, where there was no difference, and with values reported by Weir and Torell (1959) where ether extract differed between diet and herbage only on annual range that had been ungrazed and only then in 1 of 2 years. Numerous workers (Edlefsen, Cook, and Blake 1960; Lesperance et al. 1960; Coleman and Barth 1973) consistently demonstrated selection by grazing animals for forage with protein concentrations which were greater than mean herbage levels. This was evident on woodland range, but not on grassland range where protein contents of diets did not differ from the herbage average. This was an exception to a general pattern that few other workers (Hart et al. 1983) have failed to demonstrate.

Nutritive value

Total nutritional adequacy of forage from annual range could not be definitively established since forage intake was not measured. Nutrient contents of the ewes' diets can be compared to their nutrient requirements (NRC 1975) and, if viewed relative to stages of the sheep production cycle, may be used as a guide to range feed sufficiency. Crude protein percentage of diets (table 3) in mid and late summer, when ewes were at maintenance, was below the requirement of 8.9 percent total protein on woodland range (6.8 percent), but was marginal to adequate on improved grassland range (8.1 to 10.1 percent). Digestible energy content (table 6) in mid and late summer periods met the maintenance standard of 2.4 mcal/kg of dry matter. During fall (late November and early December) ewes were entering their second trimester of pregnancy and protein levels of approximately 13 and 25 percent on woodland and grassland ranges, respectively, were well above the 9 percent requirement. However, ewes may have been unable to consume adequate amounts of dry matter due to the high moisture content and limited quantity of available herbage. Digestible energy requirements for maintenance were also exceeded (2.8 to 3.0 mcal/kg of diet dry matter). In winter (January to mid-February) ewes were in the final trimester of gestation, while the early/mid-spring period of March and April included roughly the first three-fourths of lactation. Crude protein percentages, which averaged on woodland and grassland pastures 11.0 and 22.6 percent, respectively, were in excess of the 10.4 percent required by ewes suckling singles, but diets on woodland range were below the 11.5 percent standard for ewes with twins. Digestible energy concentrations in winter and early/mid-spring exceeded requirements on grassland range. Diets on woodland range had energy concentrations below requirements in winter but above them in early/mid-spring.

Although protein content in grassland diets dropped dramatically by late spring (May), it still exceeded requirements, as did that in woodland diets. Digestible energy level of woodland diets in late spring fell slightly below the standard. Early summer (June) coincided with weaning and protein was adequate in grassland forage but below requirements for both mature ewes and replacement lambs in woodland forage. Digestible energy was found to be the most deficient in diets during early summer when concentrations were measured below 2 mcal/kg of dry matter on both grassland and woodland range. The lowest ($P<.05$) digestible energy concentrations in early summer, followed by significantly higher values in mid- and late summer, were unexplainable, but they may have been a result of flowering and seed set in annual grasses. Weaning and shipping just before forage energy declined would be important in marketing high-condition lambs and reducing weight loss in ewes prior to the dormant or dry feed season.

It should be emphasized that while ewe diets from dead herbage during summer were marginal (deficient in protein and barely adequate in energy on woodland ranges), they were, when viewed relative to the usual maintenance status of ewes at this season, no lower in nutritional adequacy than some green feed diets. Green feed diets were deficient in energy in winter on woodland range and in early summer on both kinds of range. When compared to nutrient requirements, diets during early summer had the lowest nutritive value. This might have been partially offset by greater intakes of presumably palatable forage at the dough seed stage just after peak standing crop. This seemed unlikely, though, because lignin, a major intake-limiting factor (Van Soest 1982), was highest ($P<.05$) at this stage.

Performance and condition of ewes and their lambs did not indicate any shortages of energy or protein in winter or spring. Despite apparent deficiencies in crude protein over much of the lactation period for ewes suckling twins and in digestible energy for the last third of gestation, several ewes grazing woodland range did raise twins which had weaning weights only slightly lower than those of peer singles. Ewes with twins were in correspondingly good flesh and had weights at weaning and breeding similar to ewes raising singles (Rosiere and Torell, unpublished data). The apparent contradictions between sheep productivity and diet content may have resulted because fistulated ewes selected forage different from that selected by intact ewes. It was possible that ewes regained lost weight and condition during early/mid-spring. Perhaps estimation of digestible energy by in vitro procedure or use of crude protein, instead of digestible protein, was too approximate to evaluate borderline diets which may have contained appreciable nonprotein nitrogen. It should be noted that this assessment was for ewes on a production cycle coordinated with the feed production cycle. If ewes lambed in winter, there would have been a deficiency of digestible energy on woodland range.

Fortunately, and conveniently for discussion, concentrations of calcium, potassium, and magnesium in herbage met or exceeded requirements, with the exception of potassium in woodland herbage which was deficient during late summer 1980. Thus, sheep could graze herbage less selectively and meet their requirements for these elements.

Relations among nutrients and properties

Relationships between nutrients, digestible energy, and digestibility, as tested by simple correlation (table 8), were similar to those usually reported for forages. Organic matter digestibility was, as Van Soest (1982) explained, more closely associated with acid detergent fiber and lignin than with neutral detergent fiber. In the current study, digestibility was significantly and inversely related to content of cellulose. Contrastingly, hemicellulose was not significantly associated with digestibility or cellulose, and it was, overall, the least correlated component. Digestible energy was closely related to acid detergent fiber and lignin. Crude protein was also associated with digestible energy and with acid detergent fiber which, because of its high association with so many characters, was one of the most useful factors for indicating general nutritive value.

Close association among nutritional variables allowed prediction by regression of in vitro organic matter digestibility and digestible energy. These equations (table 9) were developed to expedite future studies of sheep diets on annual range when in vitro determinations are not possible or feasible. Acid detergent lignin was the single best predictor ($r^2 = .74$) of digestibility and had slight but significant predictive power for digestible energy. Cellulose and crude protein were also useful in estimating organic matter disappearance. The finding that lignin was more useful than protein for this prediction contrasted with other findings where, as discussed by Rosiere, Wallace, and Beck (1975), protein was superior to lignin. Both lignin and protein have been highly associated with and predictive of forage digestibility on numerous range types.

TABLE 8. LINEAR CORRELATION COEFFICIENTS AMONG NUTRIENT CONTENTS AND DIGESTIBILITY OF SHEEP DIETS FROM CALIFORNIA ANNUAL RANGE OVER DIFFERENT SEASONS AND STAGES OF PLANT DEVELOPMENT*

	EE	NDF	ADF	ADL	C	HC	IVOMD	DE
CP	.62††	−.57††	−.83††	−.60††	−.71††	.25†	.59††	.75††
EE		−.58††	−.60††	−.10	−.69††	−.13	.36§	.51††
NDF			.81††	.33‡	.85††	.51††	−.52††	−.57††
ADF				.66††	.88††	−.07	−.77††	−.85††
ADL					.30‡	−.41§	−.86††	−.82††
C						.17	−.53††	−.65††
HC							.22	.25
IVOMD								.96††
DE								

*Values for crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (C), hemicellulose (HC), in vitro organic matter digestibility (IVOMD), and digestible energy (DE) are means of eight sampling periods, shown in table 2, on woodland and grassland range grazed yearlong at three stocking rates.

†$P < .1$.

‡$P < .05$.

§$P < .01$.

††$P < .001$.

TABLE 9. REGRESSION EQUATIONS FOR PREDICTION OF IN VITRO ORGANIC MATTER DIGESTIBILITY (IVOMD) AND DIGESTIBLE ENERGY (DE) OF SHEEP DIETS ON CALIFORNIA ANNUAL RANGE FROM VARIOUS NUTRITIONAL CHARACTERS*

	r^2
$OMD = 97.33 - 3.31x_1 - 0.59x_2 - 0.69x_3 + 4.55x_4$	.88
$OMD = 105.59 - 2.93x_1 - 0.83x_2 - 0.42x_3$	.84
$OMD = 90.27 - 2.55x_1 - 0.54x_2$	.82
$OMD = 77.97 - 2.85x_1$	.74
x_1, x_2, x_3, and x_4 = acid detergent lignin, cellulose, crude protein and ether extract, respectively; neutral detergent fiber, acid detergent fiber, and hemicellulose were nonsignificant.	
$DE = -0.498 + 0.048x_1 + 0.022x_2 + 0.008x_3 + 0.006x_4 + 0.034x_5 - 0.014x_6 + 0.012x_7$	.99
$DE = -0.281 + 0.053x_1$	.93
x_1, x_2, x_3, x_4, x_5, x_6 and x_7 = in vitro organic matter digestibility, crude protein, acid detergent lignin, hemicellulose, ether extract, cellulose, and acid detergent fiber, respectively; neutral detergent fiber was nonsignificant.	

*Data are from ewe diets on grass-woodland and improved grassland range during eight sampling periods which were combinations of season and plant development stage.

As with digestibility, total protein and, to a lesser extent, lignin were useful in predicting digestible energy. Though strongly correlated linearly with these predicted properties, acid detergent fiber had no significant predictive ability for organic matter disappearance and little value for predicting digestible energy.

Range nutritionists frequently rely on prediction equations developed from data on forage different from that which they are investigating. Rittenhouse, Streeter, and Clanton (1971) formulated a regression equation based on diets of cattle grazing prairie to predict digestible energy from organic matter digestibility (DE, mcal/kg = .039 × OM dig. − .10). Other experimentors have used this formula not only to view seasonal or pasture differences but also to compare energy values to nutrient requirements (e.g., Rosiere, Wallace, and Beck (1975) adopted it for diets on desert grassland). Holechek, Vavra, and Pieper (1982) reviewed range nutrition methods and endorsed this equation and comparison of predicted values to NRC requirements. In the current study, digestible energy values predicted by the Rittenhouse, Streeter, and Clanton (1971) equation averaged 23 percent lower ($P<.001$) than values determined with in vitro digestion coefficients and gross energy contents. Although the latter estimations were founded on an assumption of similar digestibilities for organic matter and energy contents, they should be considered more accurate than estimates which did not directly consider caloric contents. This comparison illustrated a hazard in extending use of a prediction formula beyond the kind of range for which it was developed.

CONCLUSIONS

Grazing intensity has little impact on nutritive quality of sheep diets from annual range grazed at levels practicable under yearlong use.

Season or stage of plant development has substantial effect on nutritional value of forage from annual range although perhaps less than expected with annual plants and a long dormant season.

Fertilization and seeding of subterranean clover on annual range results in sheep diets that are more digestible and higher in crude protein and digestible energy.

Diets of ewes grazing grass-woodland range may be protein-deficient in mid- and late summer and energy-deficient in late spring and early summer. Diets from subclover-seeded range could be energy-deficient in early summer.

Selective grazing by sheep is not as important a factor in sustaining adequate levels of nutrition on annual range as on other grazing types.

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