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Factors Affecting Feeding Habits of Sheep Grazing Foothill Ranges of Northern Utah

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FACTORS AFFECTING FEEDING HABITS OF SHEEP GRAZING FOOTHILL RANGES OF NORTHERN UTAH

by

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Farid D. Iskander

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ABSTRACT

Factors affecting feeding habits of sheep grazing foothill ranges of northern Utah.

by

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Utah State University, 1973

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An experiment was designed to study the effects of forage availability, season and intensity of grazing, and distribution and behavior of sheep on their forage preferences. Three grazing periods of 15 days each were used to study the effect of season. Each grazing period included a heavy and a moderate stocking intensity. Pastures were divided by a grid into 30.48 m x 30.48 m compartments. Each compartment was sampled for botanical composition of available herbage prior to and after grazing. Esophageally fistulated sheep were allowed to graze freely and positions of individual sheep with respect to compartments were recorded at 5-minute intervals during the daily forage sample collection period. Immediately following collection of fistula samples, daily measurements were taken on leaf area index and height for all plant species. Estimates of herbage yield and forage utilization were derived from height-leaf area measurements by regressions. Botanical composition of the diet was determined through microscopic analysis of plant cuticle fragments on dried, ground esophageal samples.

Analysis of the dietary data indicated that season had no effect on the botanical composition of diets of sheep. However, grazing intensity significantly ($P \leq 0.20$) affected diets of sheep. Significant differences ($P \leq 0.01$) were also found in proportion of plant species that comprised the diet at any particular time. Individual sheep were significantly ($P \leq 0.01$) different in their forage preferences. There were no significant changes in botanical composition of the compartments due to grazing. However, bare ground increased significantly ($P \leq 0.10$) more under heavy stocking than under moderate stocking.

Herbage yield was found to be highly correlated with leaf area index and height ($r^2 = 0.85$) in the ungrazed control pasture. Forage yield in the grazed pastures was also correlated with leaf area index and height ($r^2 = 0.79$). Utilization was estimated as the difference between the two parameters.

Sheep were observed to graze more heavily around the periphery of shrubs than in the interspaces. The heavily grazed areas around shrubs were found to be significantly larger in heavily stocked pastures ($P \leq 0.10$). Observations of grazing behavior showed that sheep tended to orient themselves toward conspicuous objects. In so doing, they grazed a strip leading from one conspicuous object to another (ex. shrubs).

In an experiment designed to determine the role of such conspicuous objects in animal distribution and feeding behavior, sheep distribution, in relation to randomly-placed cardboard boxes, was found to be non-random and significantly ($P \leq 0.05$) related to the

position of the boxes. It was also found that sheep grazed the herbaceous species to a certain height below which the plants became inaccessible to grazing.

Micro-associations of plant species greatly influenced preferences. Sagebrush (Artemisia tridentata) plants exerted a negative effect on use of adjacent bitterbrush (Purshia tridentata) plants. This negative effect was determined by the distance between the two shrubs. This "critical distance" was found to be 56.1 ± 23.7 cm and was not affected either by season or stocking intensity.

An equation was developed by multiple regression to predict diets of grazing sheep. This equation explained 52% of the variation in botanical composition of the diet. Visual orientation of individual sheep, while grazing, modified to a large extent their forage preferences.

(82 pages)

INTRODUCTION

Herbivores occupy a central position in all ecological systems of the world as an important link in food chains between the producers and secondary consumers. The efficiency of any ecosystem is evaluated by the efficiency of its users, mainly herbivores, to utilize the available resources in a way that is beneficial to both.

As with all living organisms, herbivores have evolved optimization processes to provide the greatest quantity of life-sustaining material with the least expenditure of effort, as for example, in selecting habitats that best provide for their specific requirements. Within a given habitat, herbivores have the opportunity to practice this optimization in gathering their food, hence, the well documented phenomenon of selective grazing. Where a choice exists, herbivores will prefer certain plant species and are capable, as well, to select certain palatable portions of the preferred plant species.

Selective grazing by herbivores provides an evolutionary advantage for the coexistance and sharing of the same habitat by different animal species. Needless to say, such coexistance will require that the use of certain plant species by one animal compliment the use of others. When the food resource becomes scarce, competition between the users will favor the survival of those animal species that are capable of altering their feeding strategies to best fit the new situation. Consequently we expect that plant-animal relationships will be ever changing and complex.

The capability of herbivores to graze selectively and their ability to alter their feeding habits presents a great challenge to resource managers. These people are usually required to develop management plans that will enhance the production of both the grazing animals and the resource they utilize. The point of equilibrium between the demands of both the animals and the food resource can only be reached by evaluating the most important factors that govern the plant-animal relationships. The ability to predict these relationships through time will certainly improve management decisions.

Range researchers have long treated grazing animals as "black boxes". The responses of the grazing animals to a given set of conditions are fairly well known, but little has been done to determine the stimuli involved. The determination of species composition in the diet of grazing animals has usually represented the ultimate and final result of plant-animal relationship investigations. Such studies do not offer an explanation of the processes that take place when the animal encounters a certain plant species. Plant species will always fall in broad categories of rejection and acceptance as long as the factors controlling the ingestion of food by the animals are unknown. Every grazing situation has its unique problems and complexities. Variations between individual animals and the erratic changes in their dietary habits might complicate the grazing situation and give it its own individuality.

Conflicting reports on forage preferences of grazing animals abound in the literature. There is no agreement on forage preferences, not even for the same animal species grazing similar plant communities.

These discrepancies suggest that unknown factors cause the inconsistency in research data. Investigation of the dietary habits of grazing animals is centered around predicting diets of a specific animal species grazing a given plant community. So far, all information on dietary habits of grazing animals has failed to have any predictive values. Attempts to isolate and investigate single factors affecting forage preferences are probably responsible for the present discrepancies in the literature. Animal and plant factors should be integrated and manipulated in any study dealing with forage preferences of herbivores. Animal factors are difficult to quantify. Developing methods of investigation that quantify animal factors will improve studies on animal preferences.

In this study, sheep distribution in the pasture, as a behavioral process, was investigated in connection to availability of forage species and plant association. The specific objectives of this study were:

1. To determine the effect of season and intensity of use on dietary habits of sheep.
2. To determine availability of forage species and its effect on the botanical composition of sheep diets.
3. To investigate sheep distribution patterns as related to sheep diets.

LITERATURE REVIEW

Heady (1964) stated that palatability and preference have been used synonymously in the literature to describe two different concepts. He maintained that palatability is related to plant characteristics while preference is associated with animal characteristics. Marten (1969, p. 2) defined palatability as:

> A plant characteristic(s) eliciting a proportional choice among two or more forages conditioned by plant and environmental factors which stimulate a selective intake response by the animal; this characteristic(s) may also be described in terms of acceptability, preference, selective grazing and relish conditioned by sensory impulse, and while it may influence voluntary intake properly measured.

Plant species vary in their palatabilities, and specific palatability ratings cannot be designated to cover all conditions in which they might be presented to the animal (Tribe, 1950; Heady, 1964). Marten (1969) reported that some plant species are found generally to be unpalatable and that there are conflicting reports for many species.

The feature of palatability in plants has been attributed to several factors including "intrinsic qualities" (Stapledon, 1947; Balch and Campling, 1962), intraspecific differences due to plant strains (Leigh, 1961; Bland and Dent, 1962; Reid, Jung and Thomas, 1968), chemical composition (Foutenot and Blaser, 1965; Reid, Jung and Kinsey, 1967), morphological features (Heady, 1964), succulence (Arnold, 1964; Buckner et al., 1967), availability (Arnold, 1964;

Van Dyne and Heady, 1965; Malechek and Leinweber, 1972), and associated species (Cook and Harris, 1950; Heady, 1964; Hyder and Bement, 1964).

There is a general agreement that animals select leaf in preference to stem (Arnold, 1962; Krueger, 1970; Malechek and Leinweber, 1972), and green material in preference to dry material (Cook, Stoddart and Harris, 1956; Arnold, 1962).

Halls (1954) reported that the actual plant part selected was of more importance than the species consumed. Hubbard (1952) concluded that availability and not palatability was a primary factor governing species intake.

Reppert (1960) reported that forage species selected by grazing animals were not necessarily in proportions coinciding with the abundance of those species in the pasture. He further commented that relative availability of the species is one important factor influencing preference.

Availability can be expressed in a variety of ways: species cover, species density and forage production compared to the total herbage production (Brown, 1954; Phillips, 1959). One useful technique that has been employed in agronomic work is to express foliage area or cover as a proportion of ground area. This can be termed "leaf area index (LAI)". Leaf area index can be used as an index to dry matter production, gross photosynthesis and rate of respiration (Takeda, 1961). Black (1963) reported that leaf area index is related to growth rate per area per day (G/M^2/day). Leaf area as a measure of availability of plant tissue has the inherent advantage that it can be objectively measured with inclined point frames (Warren-Wilson, 1960, 1965). Several researchers (Booysen, 1966; Brown, Blaser and Dunton, 1966; Loomis and Williams, 1969) have reported that inclined point frames can measure change of foliar density through time. In contrast to the traditionally employed harvest methods, the use of point frames enables non-destructive measurements of vegetation.

Preference, in contrast to palatability has been explained on the basis of senses (Arnold, 1966; Waldo, 1967; Krueger, 1970), aversive stimuli (Revusky and Garcia, 1970), learning (Rozin, 1969), and optimization of diet (Schoener, 1971). Previous grazing experience of animals has been reported to have profound effects on subsequent preferences either positively influencing selection of a plant (Tribe, 1950; Jones, 1952) or negatively influencing selection (Garner, 1963; Bruns et al., 1969).

The role of the senses in forage selection was studied in detail by Arnold (1964), and Krueger (1970). In these studies sight was reported to be of minor importance in forage selection. Color of the forage, as affected by nitrogen content, was reported by Dwyer, Sims and Pope (1964) to affect selection of forage plants while Tribe and Gordon (1949) reported that color was not important.

Different species of animals have different preferences for forage (Kare and Ficken, 1963; Bedell, 1958). Hancock (1950) found grazing differences between sets of twins in dairy cattle. Reid, Jung and Murray (1966), and Simkins, Pensack and Gilbert (1969) found considerable differences in forage preference of individual animals within the same breed. In a similar connection, Arnold and Hull (1972) reported that individual animals vary in their responses to unit flavors and textures.

Evaluating 21 factors that affect utilization of mountainous rangelands by cattle, Cook (1966) found that only 11 were significantly related to utilization. He concluded that utilization on a given part of the range could not be predicted from the relationships studied. He attributed the large unexplained variability in his data to "animal psychology".

Arnold (1964) reported that parts of the pasture used by grazing animals were not grazed and animals preferred to lower their intake rather than graze the highly productive parts of the pasture. He commented that "ungrazed areas became less and less attractive to grazing animals".

Galt et al. (1969) reported that botanical composition of steers' diets varied qualitatively and quantitatively over a four-month collection period. Van Dyne and Meyer (1964) observed that during a month grazing trial with sheep, there were three successive periods of generally rising feed intake which were terminated by an abrupt decrease in feed intake. They reported that reasons for these responses were not clear. Other unexplainable and seemingly aberrant plant-animal interactions abound in the literature. For example, Sharafeldin and Shafie (1965) in a study of four breeds of sheep in Egypt reported that sheep were indifferent as to what they grazed, sometimes cropping straw and dry weeds while "better plants" were within their reach.

Through all these studies, researchers have expressed the need for more information on plant-animal interactions (Martin, 1970). One type of effort to better explain plant-animal interactions has evolved as "grazing behavior" studies. "Behavioral patterns" usually studied by range researchers have resulted in little more than a cataloguing of activities during a particular grazing period (Lofgreen, Meyer and Hull, 1957; Allden, 1962; Arnold, 1962, 1964). As such, they provide little inferential insight into plant-animal problems.

Very little work has been done to quantify the spatial distribution of grazing animals. Work by Dudzinski, Pahl and Arnold (1969) constitutes the major contribution in this area. Lange (1969) reported that changes in vegetation were accompanied by changes in track pattern of sheep in Australia. In an earlier study, Crofton (1958) reported that there was a non-random scatter of individuals in the pasture and that there was no relationship between mean distance between sheep and size of pasture. Dudzinski and Arnold (1967) reported that behavioral patterns are dynamic and cannot be described from random sampling. They further observed that closeness of sheep to one another decreases as feed availability decreases.

The role of learning in feeding systems of animals has been emphasized by Rozin (1969) and Revusky and Garcia (1970). Krueger (1970) showed that learning was important in modifying dietary habits of sheep because of the tendency of the animals to graze those plants that they were familiar with. Nevertheless, most of the work that has been done to demonstrate the role of learning in feeding systems was done on laboratory animals and under highly controlled experimental conditions.

McClymont (1967, p. 129) summarized the complexity of plant-animal interactions by the following statement:

> A grazing ruminant commonly has available to it a wide range of potential food in the form of different plant species each with its young and old leaves, stems, reeds, and other components, each with particular physical, chemical and so nutritional, characteristics and each with different densities and physical accessibility.

McClymont (1967) also mentioned that describing the qualities of forage as differences in palatability or acceptability is not preferable as these terms do not differentiate between the relative and absolute situations and are interpretative.

The study of dietary habits of animals was promoted by the techniques of esophageal fisulation (Van Dyne and Torell, 1964), the use of microscopic-point technique for plant identification (Heady and Torell, 1959), and estimation of percent composition by dry weight as related to frequency of occurrence of plant fragments (Sparks and Malechek, 1968).

Van Dyne and Torell (1964) reported that indicated variation between sheep was much higher than variation within sheep and although sampling from fistulated animals may not be highly precise there was no advantage in multiple sampling during a given period of the day.

DESCRIPTION OF STUDY AREA

The experiment was conducted at Hardware Ranch, Blacksmith Fork Canyon, Cache County, Utah. Hardware Ranch is the major winter range for elk in northern Utah and the topography and vegetation are similar to much of the deer winter range throughout the state.

Elevation is approximately 5700 - 6200 ft. above sea level with slopes facing south and southeast.

Soils of this area are typed by the Soil Conservation Service as belonging to the Ant Flat and Yeates Hollow series, which were derived from quartzite and quartzite-calcareous sandstone parent material, respectively (Doell, 1966). The soils range in texture from a loam to an extra stony silty clay loam that are deep, well drained and have slow permeability and medium runoff.

The vegetation on the study site is a sagebrush-grass type which is representative of the foothill ranges in much of Utah and southern Idaho. The dominant shrub is big sagebrush (*Artemisia tridentata* subsp. *typica* H. & C.). Several limited areas are solely occupied by low sagebrush (*Artemisia tridentata* subsp. *arbuscula* (Nutt.). H. & C.). The most abundant shrub is bitterbrush (*Purshia tridentata* (Pursh) DC.). Service berry (*Amelanchier alnifolia* Nutt.) is scattered in the area with a very low density. Rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.) and wild rose (*Rosa woodsii* Lindl.) occupy limited areas. The least common shrub is chokecherry (*Prunus virginiana* L., var. *melanocarpa* (A. Nels.) Sarg.). Few juniper trees (*Juniperus spp*. L.) are found widely scattered in the area.

The most dominant herbaceous species is aster (*Aster chilensis* Nees, subsp. *adscendeus* (Lindl.) Cronquist.). Mule ear (*Wyethia amplexicaulis* Nutt.) occupies large areas. Lupine (*Lupinus sericeus* Pursh.) is quite common in the less stony areas in the pastures. Yarrow (*Achillea millifolium* L.) is also common all over the area. There are also 39 other forbs which are considered of less importance than those previously mentioned.

The most common grasses are Kentucky bluebrass (*Poa pratensis* L.), cheatgrass (*Bromus tectorum* L.), junegrass (*Koeleria cristata* L.), bluestem (*Agropyron smithii* Rydb.), beardless wheatgrass (*Agropyron inerme* (Scribn. & Smith) Rydb.), and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith). There are 11 other grasses that are found in the area.

The three pairsof pastures studied in this experiment show a heterogenous and highly diverse vegetative composition, even though these pastures were selected and located on the basis of uniformity. Density of major shrubs was variable ranging from zero to 1306 per acre.

MATERIAL AND METHODS

Six grazing treatments were designed to study the effect of season and intensity of forage removal on dietary habits of sheep. Table 1 summarizes grazing periods and stocking intensities:

Table 1. Grazing period and stocking intensity.

GRAZING PERIOD	STOCKING INTENSITY	DURATION (Days)	SHEEP DAYS PER HECTARE*
Early (E)	Moderate (M)	15	73.88
5/18 - 6/1	Heavy (H)		150.00
Intermediate (I)	Moderate (M)	15	99.00
6/2 - 6/16	Heavy (H)		198.00
Late (L)	Moderate (M)	15	123.75
6/17 - 7/1	Heavy (H)		247.50

* Calculated on basis of metabolic body size.

A total of 14 sheep were oesophageally fistulated and fitted with either plexiglass cannulae or rubber plubs of the type described by Van Dyne and Torell (1964). Of the 14 fistulated sheep, six were randomly selected to form two groups of three sheep each. The composition of both groups remained constant throughout the experiment. Each group was initially assigned to a grazing intensity, but the two groups were alternated among the two intensities at each of the two succeeding periods.

Each pasture was stocked with eight ewes and 11 lambs in addition to the fistulated sheep to exert the desired grazing pressure.

Pastures were divided by a grid into compartments 30.48 m x 30.48 m in dimension and each compartment was identified by a letter and a number according to its position in the pasture (Fig. 1). These compartments were regarded as the basic experimental units. A discussion of the parameters measured in each compartment follows.

Botanical composition of available herbage

In every 30.48 m x 30.48 m compartment, a permanent line transect was established and marked. Botanical composition of the compartment was then estimated by frequency measurements along the transect employing a vertical point frame. Only the first hit by each pin was recorded. The rationale behind this approach was to measure the species composition as seen by grazing sheep. In any particular pasture, measurements were taken prior to grazing in all compartments and after grazing only in the compartments grazed by the fistulated sheep.

Leaf area index (LAI) and plant height

Measurements were taken daily in those compartments that were subject to grazing activity by fisulated sheep in that day. An inclined point frame was used to measure leaf area indices and heights (Warren-Wilson, 1963).

Initially, the point frame was read in two random locations in each compartment. Later, five locations were positioned randomly in every compartment to enhance our sampling technique. No statistical differences were found between the two sampling techniques, nevertheless, we adopted the latter.

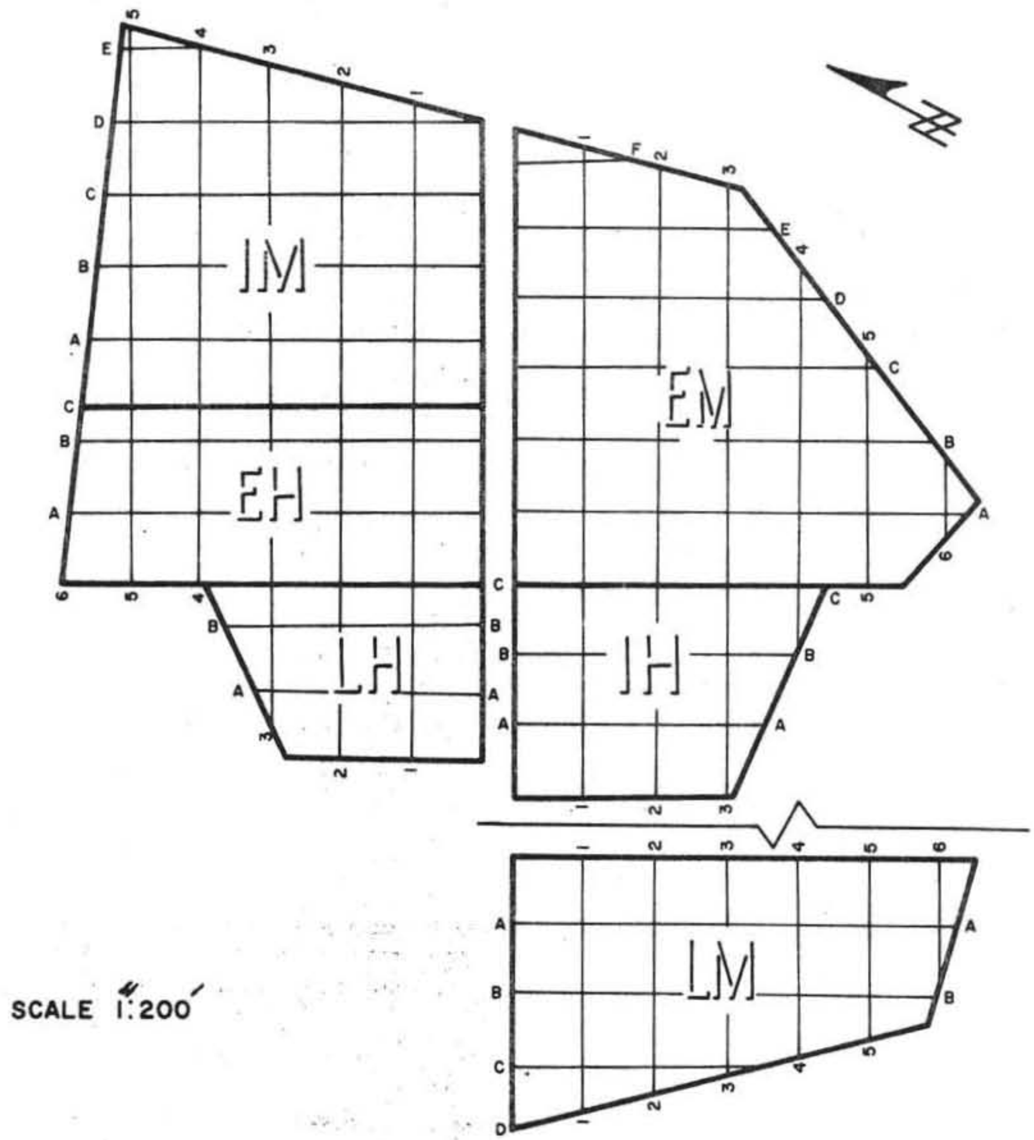

Figure 1. Diagram showing treatments and compartments.

The estimation of the leaf area indices for every species as a function of position in the canopy (Warren-Wilson, 1960; 1963) was made for herbaceous species and shrubs separately by positioning the inclined point frame at two different heights. A height of 25.5 cm. was used for herbaceous vegetation and 84.5 cm. for shrubs.

In addition to the five frame placements read on herbaceous vegetation, two shrubs of every species were selected randomly in every compartment and readings were taken from the same position prior to and after grazing.

In every inclined point frame (quadrat), 47 pins (each 2 mm. in diameter) were placed at horizontal intervals of 2 cm. and passed through the canopy at an inclination of 32.5°. Movement of the pin through the canopy was regulated by a small battery-operated motor.

For each pin contact, six values were recorded: pin number, distance from pin point to top of frame, name of species contacted, whether living or dead, type of structure contacted (leaf, stem, flower or fruit), and current phenophase of all species. Height at every hit was calculated from a simple formula based on similar triangles.

Production and utilization

Leaf area index, in the strict sense, is an indicator of productivity. Successive determinations of leaf area index reveal removal by grazing as well as growth if data are available from similar plants in protected areas. Assuming that we were dealing with a uniform plant community, a control area (with no grazing) was selected for measuring leaf area index and height of individual plant species at 15-day intervals. Ten randomly selected point frame quadrats were read at each interval. Additionally, production was also estimated for every species in the control pasture over the 15-day intervals by harvesting and weighing separately every species that occurred in the 10 randomly located 0.89 m quadrats.

Each species in the 0.89 m quadrats was clipped at heights of 5 cm. each and dried and weighed separately. From the information available from these measurements on ungrazed plant species, a relationship was developed between relative leaf area index to production at different heights. By comparing these measurements to the measurements on grazed plants, an estimation of utilization can be calculated.

Collection of esophageal samples

Fistulated sheep were allowed a period of five days to acclimatize before ccllection of esophageal samples started. Early each morning, the fistulated sheep were separated from the main herd and driven slowly out of the pasture into an adjacent "catch pen". After a training period of approximately one week, this procedure was accomplished with little or no disturbance to either the fistulated sheep or the main herd of ewes and lambs. Cannulae were opened or rubber plugs were removed from the fistulae and numbered canvas collection bags were secured around the necks of the sheep. The fistulated sheep were then returned to their respective pastures and allowed to graze freely.

Observations were made at five-minute intervals regarding the individual activities and position of each fistulated sheep in the pasture. Sample collection periods ranged from 20 to 40 minutes and this depended largely on whether the sheep immediately began grazing upon being returned to the pasture.

At the end of the sample collection period, the fistulated sheep were again herded out of the pasture and fistulae samples were then removed. Samples contaminated with regurgitated rumen material were disregarded. Esophageal samples were then individually emptied in a tray and thoroughly mixed by hand. Each sample was then placed in a polyethelene bag, and labelled by a tag bearing information on grazing period, stocking intensity, sheep number and date of collection. The bags were then stored in a freezer for further analysis.

Esophageal samples from the sheep were collected during a period of five consecutive days in each week.

Botanical analysis of the diet

Frozen esophageal samples were chopped and freeze-dried. These dry samples were then ground in a Wiley mill to pass through a 40-mesh screen. A small quantity was then transferred to a test tube containing a mixture of 10% nitric acid and 10% chromic acid solution and was boiled for one minute.[1] The sample was then quantitatively transferred to a 200-mesh screen and washed thoroughly under running warm water. The sample was then stained by

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[1] C.H. Jensen, personal contact.

immersing in a solution of Safranin-O dye for 30 seconds followed by washing in warm water and then staining again in crystal violet dye for the same length of time.[2] After again washing thoroughly, a small amount of the sample was transferred to a microscope slide, dispersed by a few drops of water and then dried by passing gently over a small flame. A few drops of "Karo syrup" were then added as a mounting medium and the sample was covered by a 55 mm. slide cover. The slide was then labelled and allowed to dry for 24 hours.

Examination of the plant fragments was done under the microscope using 40X power. Plant fragments were identified and counted in 100 microscopic fields on each slide. Epidermal characteristics were matched to similarly prepared slides of reference material obtained from the species occurring in the experimental pastures. Density and frequency of every identifiable plant species were then recorded. Species composition of the samples was then predicted according to the procedure outlined by Sparks and Malechek (1968).

As a check to the validity of this procedure, mixtures of the most important plant species were prepared in proportions (by weight) and were unknown to the author. No statistical differences were found between the actual composition by weight of these artifically prepared mixtures and that estimated by frequency. Therefore, the technique was assumed to be a valid prediction of species composition of the diet for the plant species encountered in this study.

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[2] L. Shandruk, personal correspondance.

Behavioral patterns of grazing

During the course of the study, it became obvious that there was a pattern of grazing related in some way to objects conspicuous to the sheep (ex. shrubs and fence posts). To test this hypothesis, another experiment was then suggested in an open area of one hectare. The distances between boxes were measured as well as the angles between the nearest two boxes (Fig. 2). The selected area had never been subject before to any grazing activity by the study sheep. The 14 fistulated sheep were then dirve to the area and the distribution and angle of deflection from each box by every individual sheep was plotted on a scale diagram.

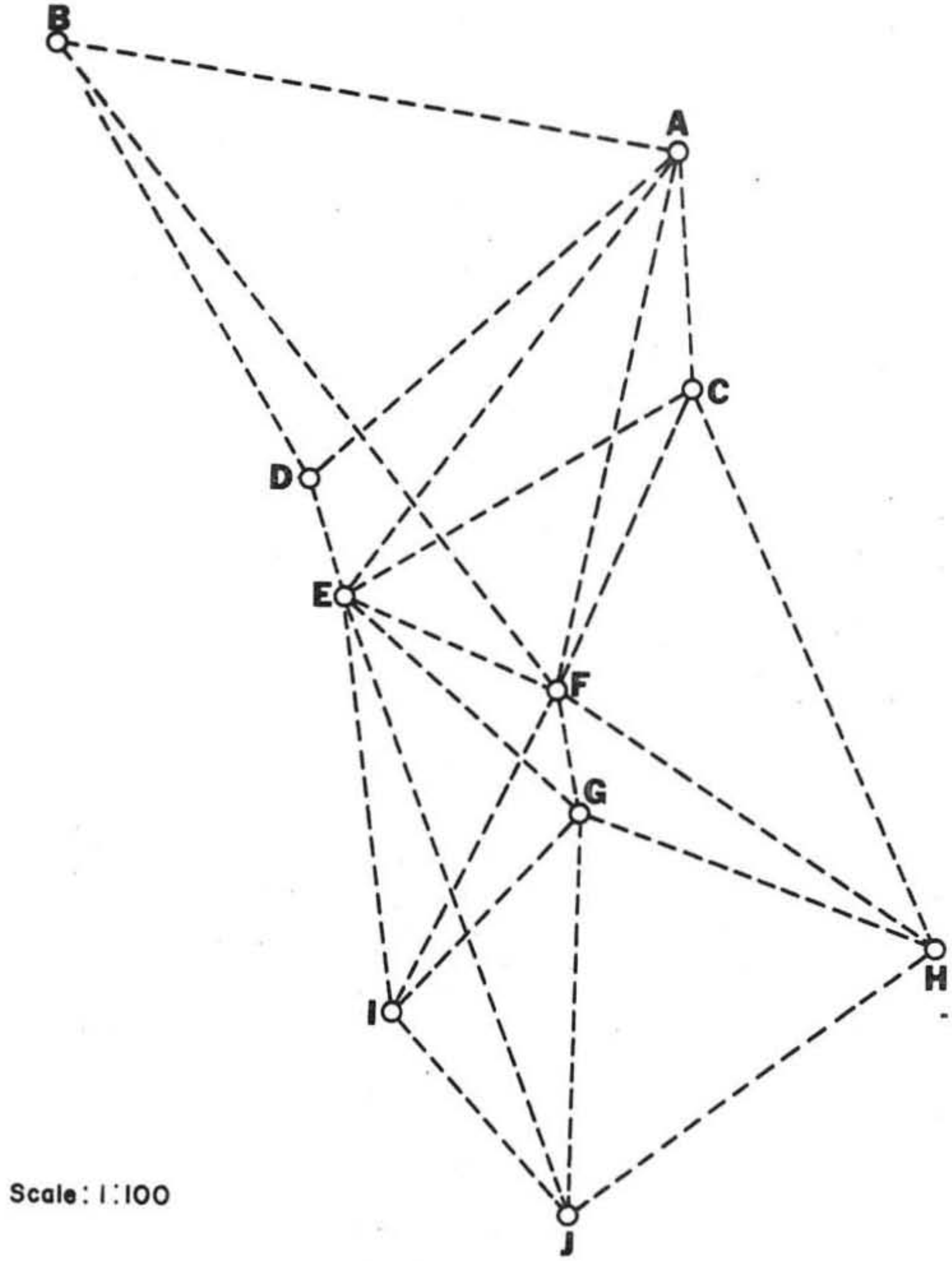

Figure 2. Diagram showing location, distances and angles subtended among randomly located cardboard boxes.

RESULTS

Availability of Forage

Leaf area index and height as related to production

Leaf area index (LAI) and height (HT) of every plant species were related by multiple regression to production on the control area. The relationship studied indicated that there is a highly significant correlation ($r^2 = 0.85$) between leaf area index and height, and production (Table 2).

Table 2. Regression analysis of the dependent variable Production on control area.

SV	DF	MS	F ratio	Level of significance
S (Season)	1	2014.07	3.77	0.10
LAI	1	8070.75	15.11	0.005
HT	1	147.06	0.28	NS
LAI . HT	1	709.01	1.33	NS
Error	10	534.30		

NS = Not significant

The predictive equation for production (lb/acre) on the control area is as follows:

Production (lb/acre) $= b_o + b_1 \cdot S + b_2 \cdot LAI + b_3 \cdot HT + b_4 \cdot LAI \cdot HT$ where; $b_o = -53.16$, $b_1 = 15.34$, $b_2 = 850.09$, $b_3 = 1.97$, and $b_4 = -52.51$.

Estimation of utilization from point-frame data

Production (lb/acre) on grazed pastures was related to LAI and height (HT) by multiple regression analysis (Table 3).

Table 3. Regression analysis of the dependent variable Production on grazed pastures.

SV	DF	MS	F ratio	Level of significance
LAI	1	25486.38	39.96	0.005
HT	1	236.79	0.37	NS
Error	12	637.80		

NS = Not significant

The predictive equation is as follows:

Production (lb/acre) = $b_o + b_1 \cdot LAI + b_2 \cdot HT$ ($r^2 = 0.79$) where $b_o = -11.93$, $b_1 = 637.79$, and $b_2 = -1.03$.

Utilization is estimated as the difference between predicted production on the control area and predicted production on the grazed pastures for every plant species.

Species composition in the compartments

Species composition of the range varied widely between compartments within the same pastures. The largest variation was in the shrub component both in respect to density and contribution to the total species composition in the compartments. The herbaceous species were also variable among compartments. It was quite common to find some species totally absent from some of the compartments. The coefficient of variation ranged from 13.7% to 68.5%.

Measurements taken prior to and after grazing indicated that species composition in the compartments did not change appreciably during a grazing trial. The largest change in species composition prior to and after grazing was in those compartments that were used as bedding areas. Trampling and removal by grazing were the major factors that brought a significant change ($P \leq 0.20$) in bedding areas.

There was a significantly greater increase in bare areas in the heavily stocked pastures than the moderately stocked ones ($P \leq 0.10$). In rocky compartments, the bare areas did not increase significantly under the two grazing intensities.

Botanical Composition of the Diet

Analysis of the diet samples showed that all plant species present in the pastures were consumed to some extent by the fistulated sheep. However, in all treatments 10 plant species (Appendix; Tables 1-6) appeared to be the most important food items by virtue of their higher frequency of occurrence in approximately 74% of the diet samples. These ten species were: aster, lupine, mule ears, bitterbrush, rabbitbrush, service berry, bluebunch wheatgrass, June grass, Kentucky bluegrass, and oniongrass.

Six of these ten plant species were selected for intensive analysis because their proportions in the diet exceeded 10% in approximately 80% of the diet samples and because of their continuous presence in the diet throughout the experiment. These six plant species were: aster, lupine, mule ears, bitterbrush, Kentucky bluegrass, and June grass.

A total of 82 dietary samples were obtained from 29 days of sampling on the lightly grazed pastures, as opposed to 59 samples on the heavily grazed pastures for the same collection period. There was a tendency for the fisulated sheep on heavily grazed pastures to stand idle and ruminate during the daily sample collection period, hence a smaller total number of usable samples were obtained.

Every plant species in the diet exhibited a wide variation from day to day regardless of date or stocking intensity (Appendix; Tables 7-12). There is a strong indication that sheep increased their ingestion of a certain plant species for a period of 1-2 days followed by another 1-2 day period of decrease (Figs. 3-8). This cyclic change was clearly pronounced in all treatments.

Variation in the ingestion of each of the six major plant species studied was significant at the level $P \leq 0.01$ for all sheep and treatments. This indicates a variation in the selectivity within the different plant species.

Variation among individual sheep was also highly significant ($P \leq 0.01$), indicating that individual sheep differed widely in their preferences for a certain plant species (Table 4).

Grazing intensity was also significant at the level of $P \leq 0.20$. In terms of overall variation due to stocking intensity, the contribution due to heavy treatments was much greater than that due to moderate treatments.

Season of grazing did not affect significantly the diet of the grazing sheep.

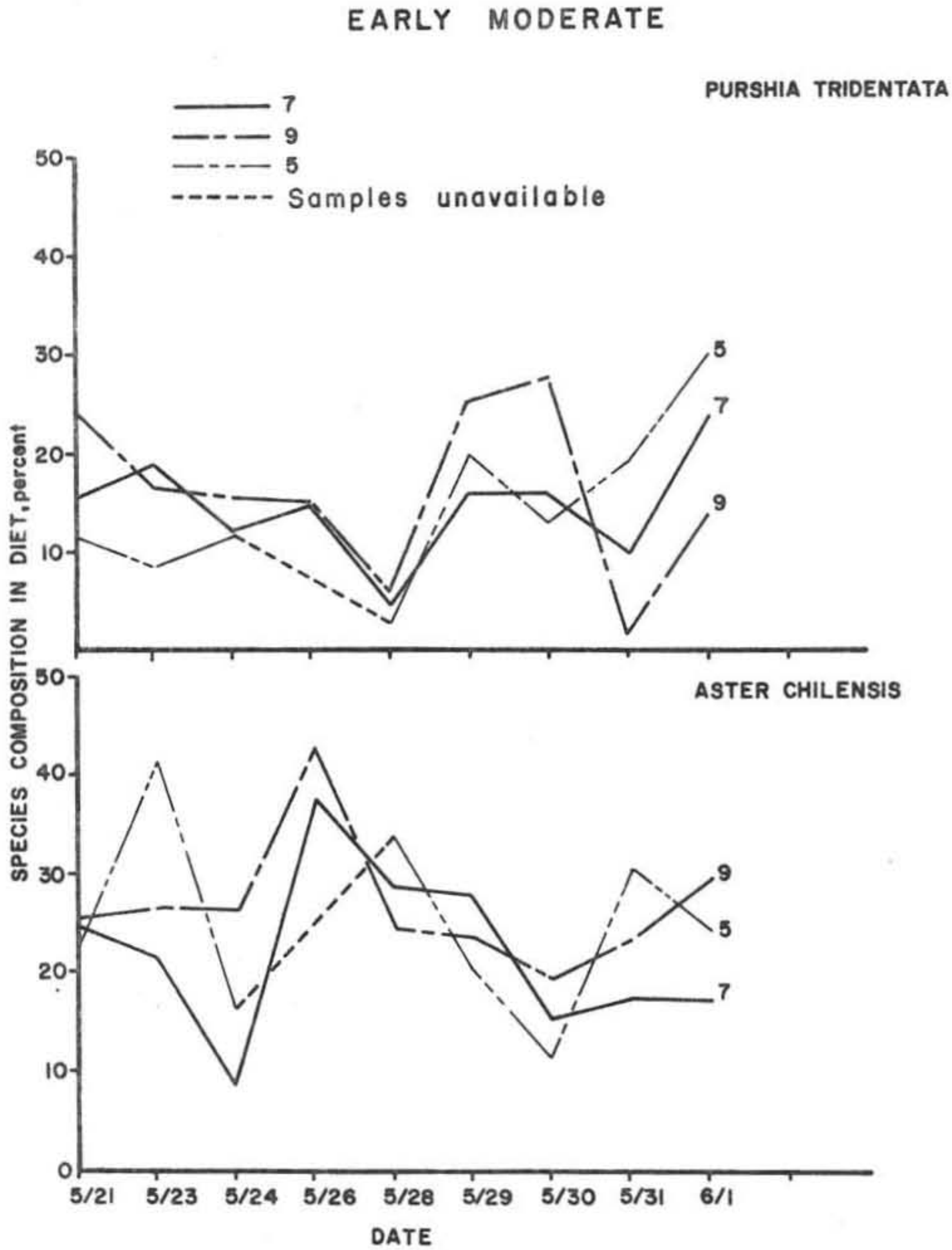

Figure 3. Diet content of bitterbrush and aster for sheep grazing an early moderate pasture. Numbers by curves refer to individual sheep.

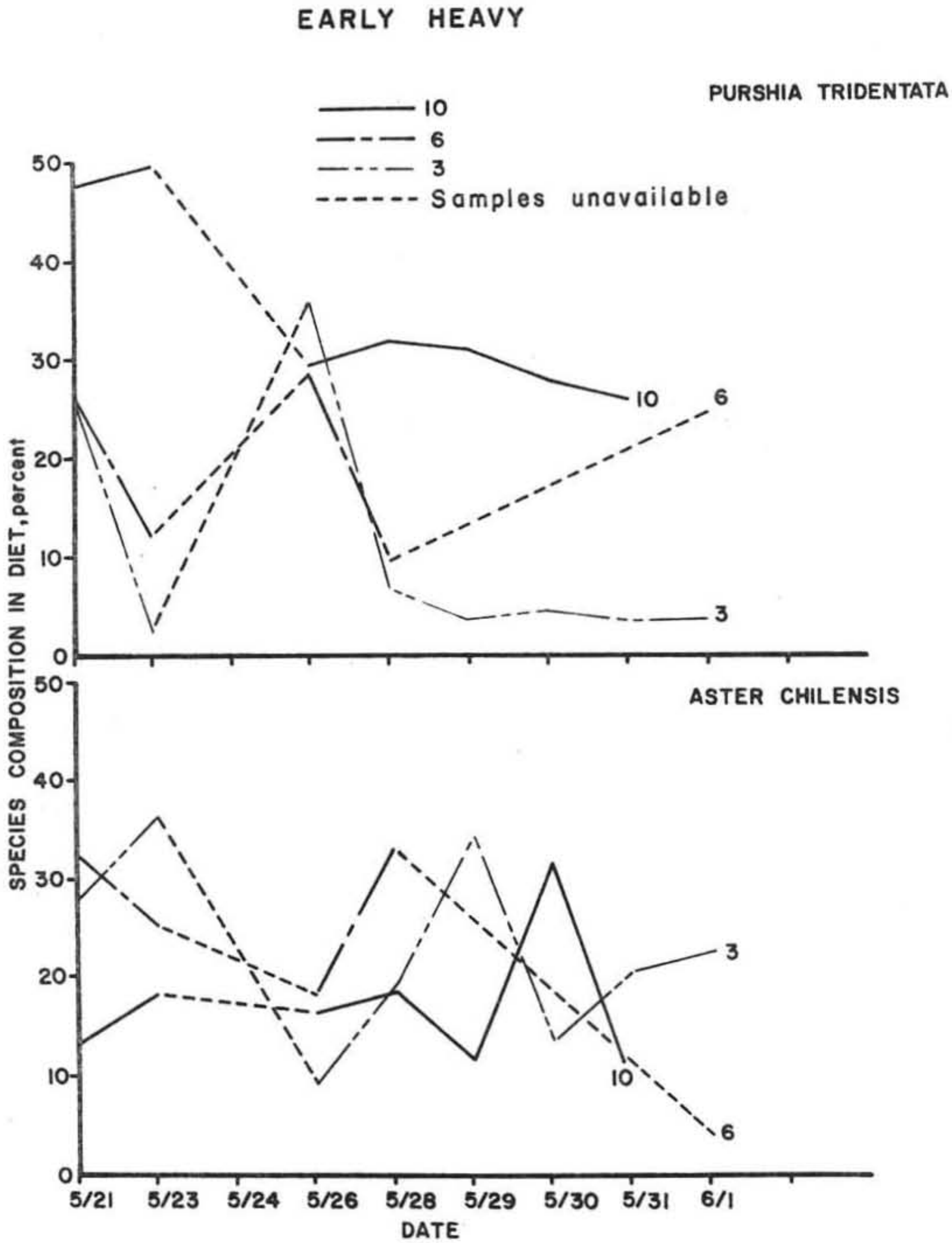

Figure 4. Diet content of bitterbrush and aster for sheep grazing an early heavy pasture. Numbers by curves refer to individual sheep.

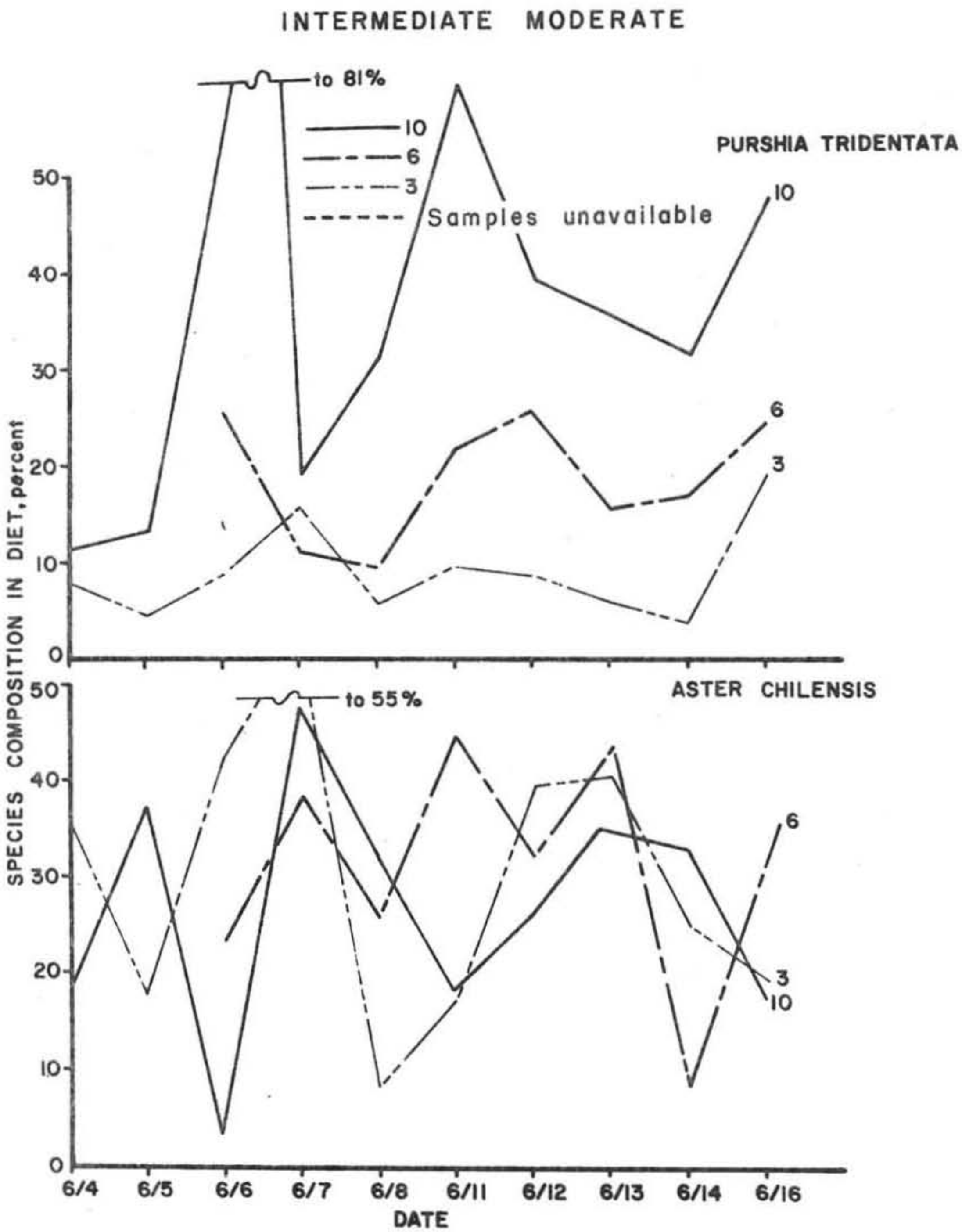

Figure 5. Diet content of bitterbrush and aster for sheep grazing an intermediate moderate pasture. Number by curves refer to individual sheep.

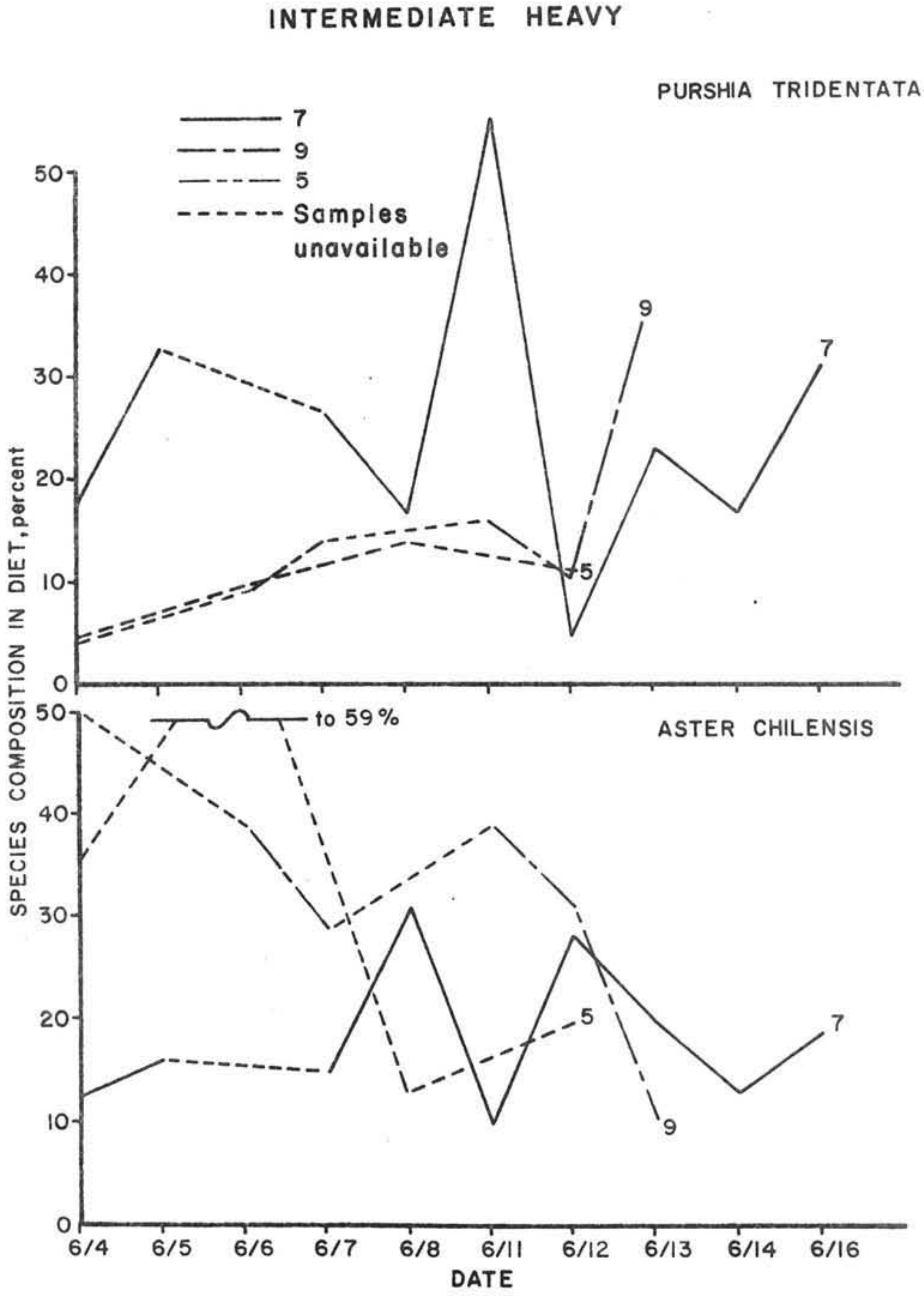

Figure 6. Diet content of bitterbrush and aster for sheep grazing an intermediate heavy pasture. Numbers by curves refer to individual sheep.

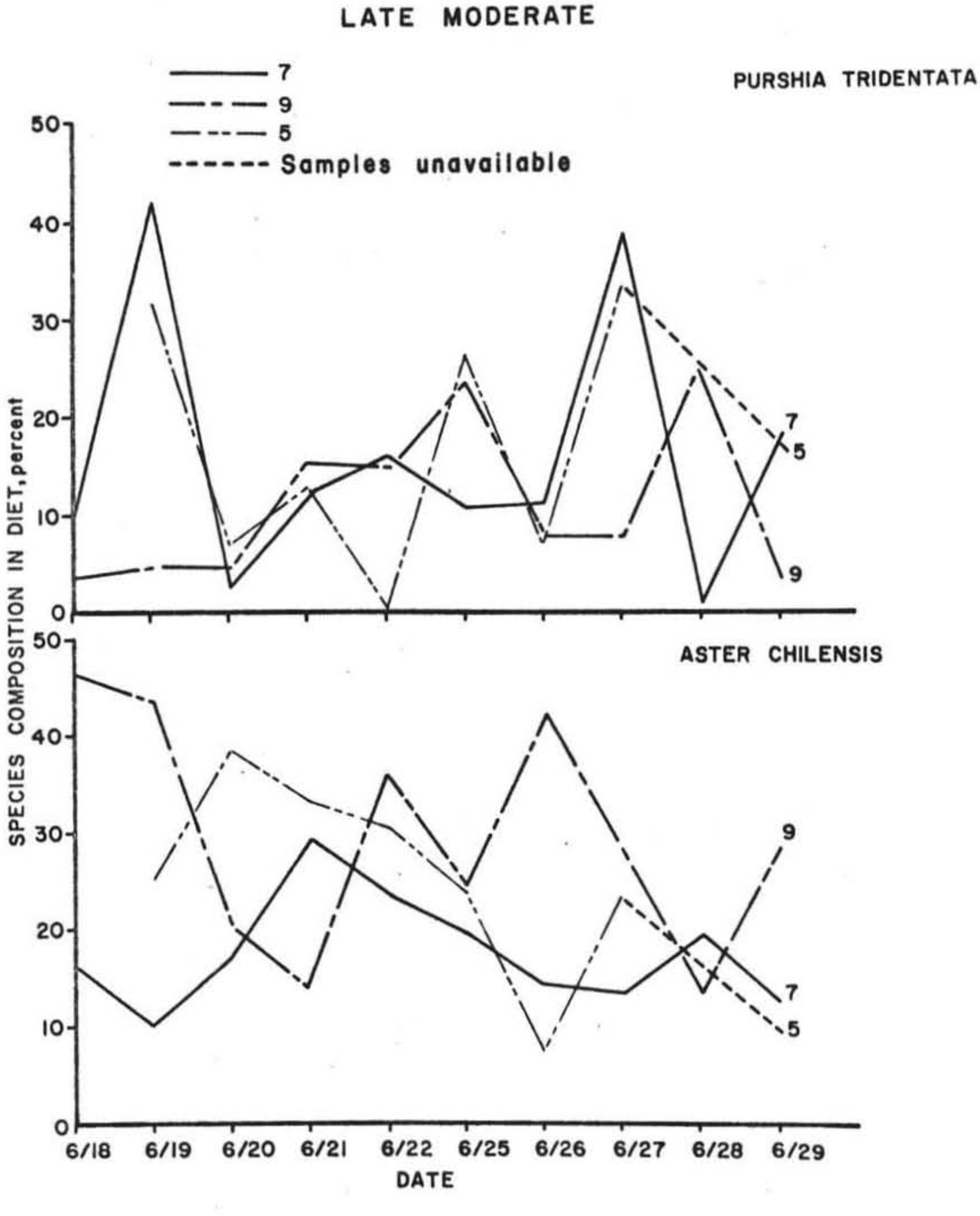

Figure 7. Diet content of bitterbrush and aster for sheep grazing a later moderate pasture. Numbers by curves refer to individual sheep.

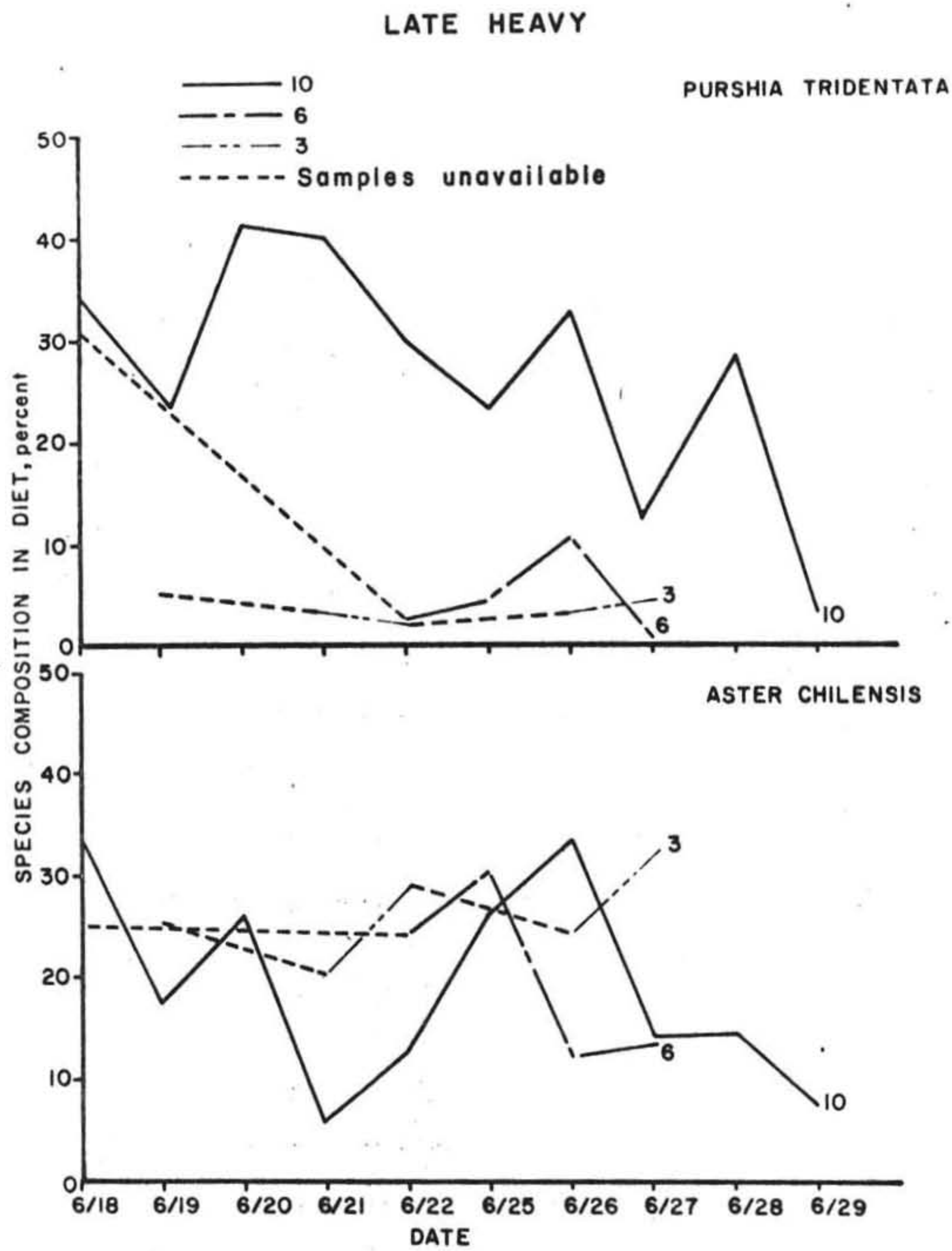

Figure 8. Diet control of bitterbrush and aster for sheep grazing a late heavy pasture. Numbers by curves refer to individual sheep.

Table 4. Analysis of variance for the independent variables.

SV	DF	MS	F ratio	Level of significance
Plant Species	5	0.104	15.06	0.01
Sheep	5	0.025	3.57	0.01
Grazing Intensity	1	0.019	2.70	0.20
Season	2	0.002	0.22	NS
Error	415	0.007		

NS = Not significant

Botanical composition of the diet as correlated to leaf area index, height, species composition of the range, production and utilization

Table 5 shows the correlation between botanical composition of the diet and each of the independent variables measured in this study.

Table 5. Correlation matrix relating botanical composition of the diet to LAI, HT, species composition of the range, production, and utilization.

Variables	Pearson Product Moment Correlation
Leaf area index (LAI)	0.41
Height (HT)	-0.21
Species composition of the range (SPCR)	0.24
Production (PROD)	0.43
Utilization (UTIL)	0.07

These correlation coefficients indicate that each variable alone is a poor estimator of botanical composition of the diet.

The botanical composition of the diet was then related by multiple regression to all five variables. The analysis of variance for the independent variables and the possible interactions is presented in Table 6 .

Table 6 . Analysis of variance for the dependent variable (botanical composition of diet) as related to the independent variables (leaf area index, height, species composition of the range, production, utilization, plant species, grazing intensity, season of use, and individual sheep).

SV	DF	MS	F ratio	Level of significance
LAI	1	0.0220	3.12	0.10
HT	1	0.0009	0.13	NS
SPCR	1	0.0081	1.15	NS
PROD	1	0.0020	0.27	NS
UTIL	1	0.0104	1.47	NS
PLANT	5	0.1029	14.58	0.005
GRAZING	1	****	****	NS
SEASON	2	****	****	NS
SHEEP	5	0.0239	3.39	0.005
GRAZING/SEASON	2	****	****	NS
GRAZING/SHEEP	5	0.0036	0.52	NS
DAYS/SEASON	27	0.0063	0.89	NS
Error	381	0.0071		

**** very small values (E-19).

where; LAI leaf area index, HT height (cm), SPCR species composition of the range, PROD production (lb/acre), UTIL utilization (lb/acre), PLANT plant species, GRAZING stocking intensity, and SEASON season of use.

The predictive equation for any one plant species in the diet is as follows:

$$Y_{ijkl} = b_o + P_i + G_j + S_k + SH_L + b_1X_1 + b_2X_2 + B_3X_3 + b_4X_4 + b_5X_5 \quad (r^2 = 0.52).$$

where: P_i plant species, G_j grazing intensity, S_k season of grazing, SH_L sheep, X_1 Leaf area index, X_2 height, X_3 species composition of the range, X_4 production, and X_5 utilization.

Factors of the Plant Association Related to Grazing Behavior

Grazing behavior

Sheep inspected and grazed a swath averaging approximately 60 cm in width and 30 cm in depth with every step. They did this with stereotypic head movements. A sheep started by thrusting its head forward until it made contact with the vegetation. Then it pulled its head back towards its chest while grabbing the plants. With the third movement it thrusted its head forward and pulled the vegetation loose while at the same time investigating the next bunch of plants. There were two movements of the neck, one to the right and one to the left (Fig. 9). Each sheep utilized part of the area it maintained for itself, in that the swath it covered was smaller in width than the individual distance between sheep.

Body orientation

Sheep always moved toward a near conspicuous object while they grazed. To invesigate this phenomenon, randomly distributed cardboard

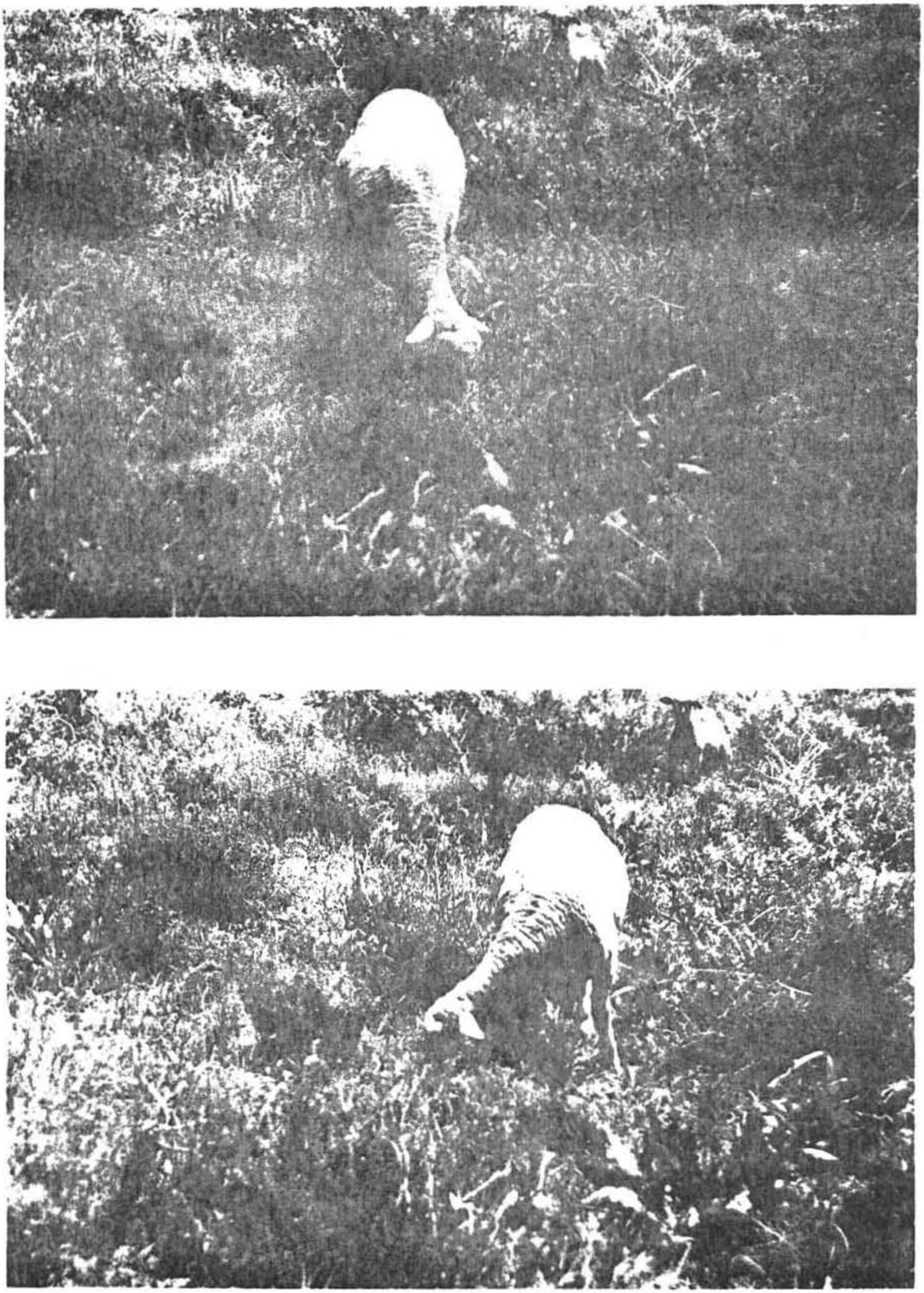

Figure 9. Sequence photographs illustrating stereotypic feeding behavior of sheep.

boxes were placed in an area of one hectare. The probability of an individual sheep encountering a box within its grazing swath, on the basis of chance, was 0.0002. The path of every sheep was plotted on a map (Figs. 10 and 11), and the angle of deflection from each box was recorded. Fig. 12 shows a histogram of angles of deflection indicating that the grazing pattern observed was far from random. The pattern was significantly related to the position of the cardboard boxes at the level of $P \leq 0.05$.

When the cardboard boxes were removed from the area, sheep swept through the area and started grazing along the fence (Fig. 13).

Use of sequential areas

Sheep grazed the pasture in sequential segments. They spent about two days in a particular portion of the pasture, then they moved to an adjacent portion for the next two days, and so on. Apparently, this pattern can be broken by driving the sheep to a new area and keeping them there for about two days. If this is done, sheep will not return to the old area, but will move to an adjacent segment of the pasture at the new location. Sheep did not change their bedding area by changing the location of their grazing activities.

It seems that familiarity with specific portions of the pasture plays a role in this behavior. I do not know what happens when the sheep have covered all parts of the pasture.

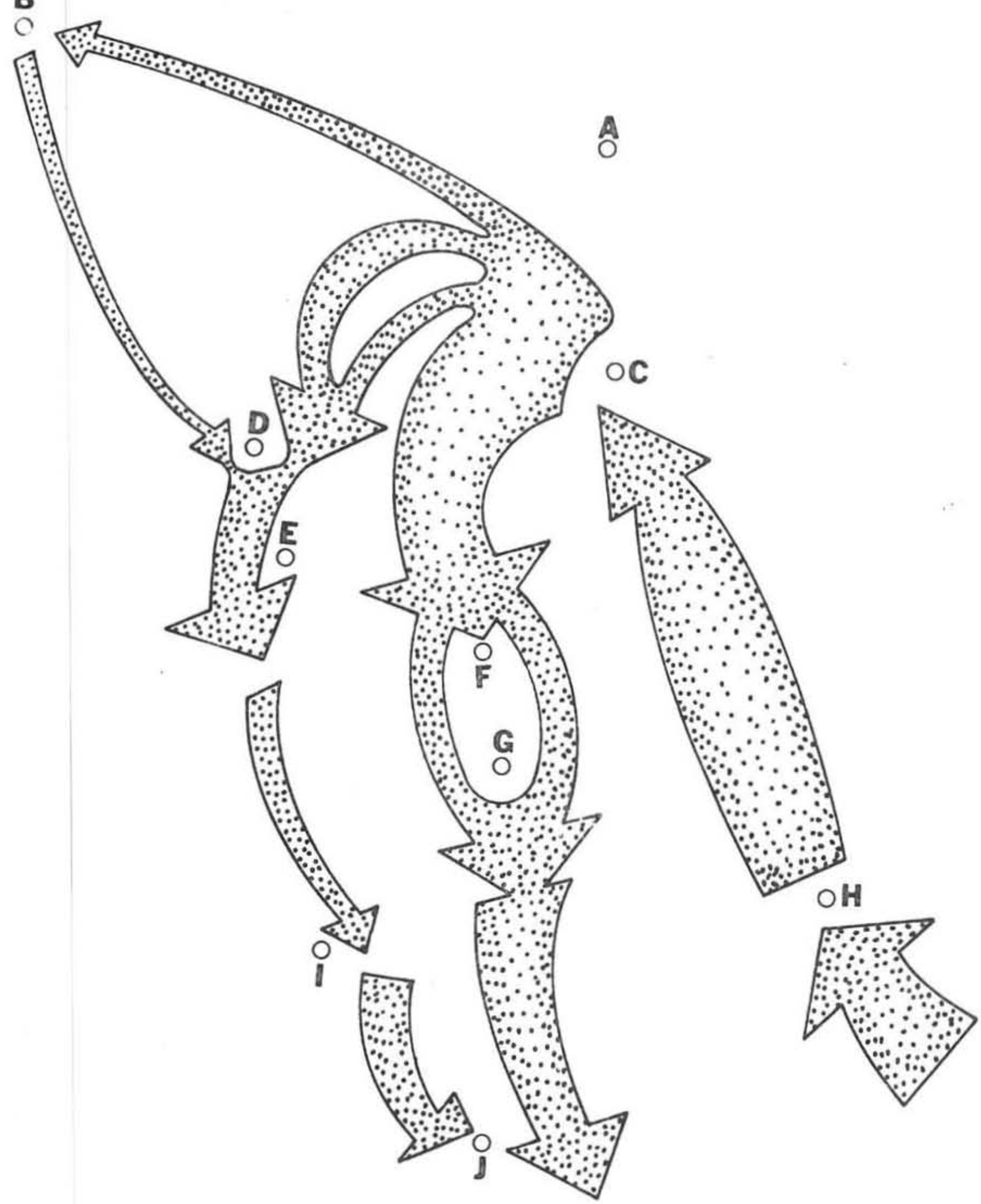

Figure 10. Distribution and movement of sheep in relation to the cardboard boxes (first day). Width of arrows indicates approximate numbers of sheep. (Scale not exact).

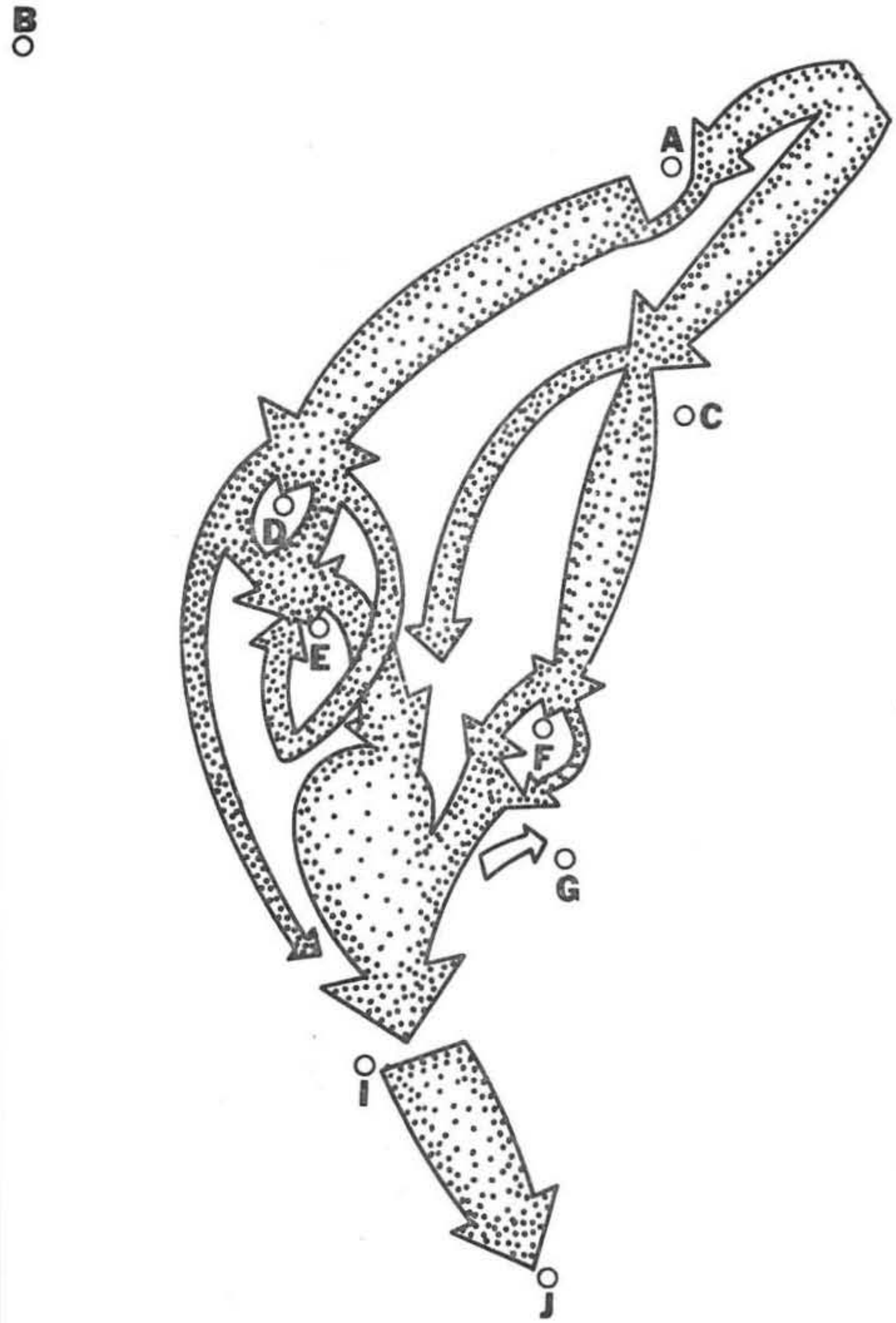

Figure 11. Distribution and movement of sheep in relation to the cardboard boxes (second day). Width of arrows indicates approximate numbers of sheep. (Scale not exact).

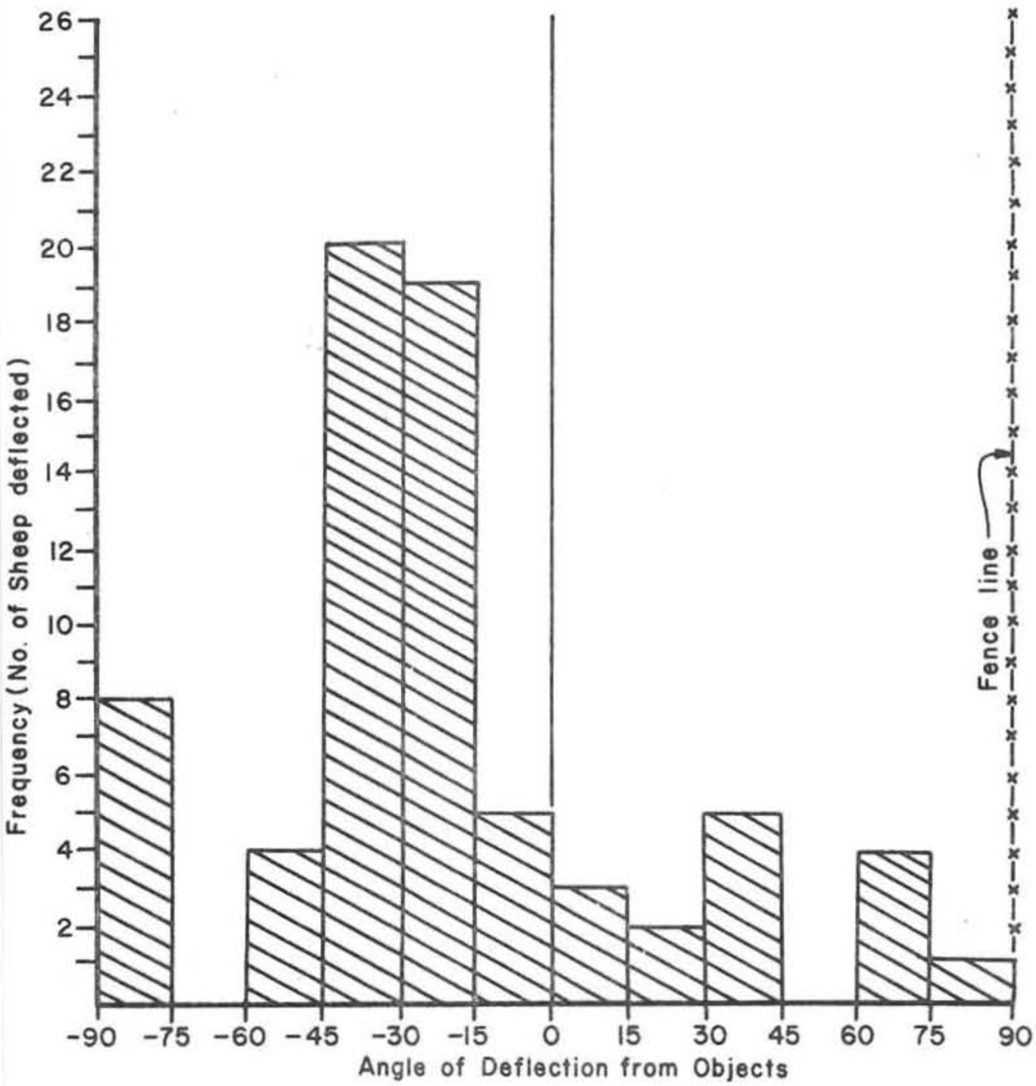

Figure 12. Histogram showing angles of deflection from objects by grazing sheep.

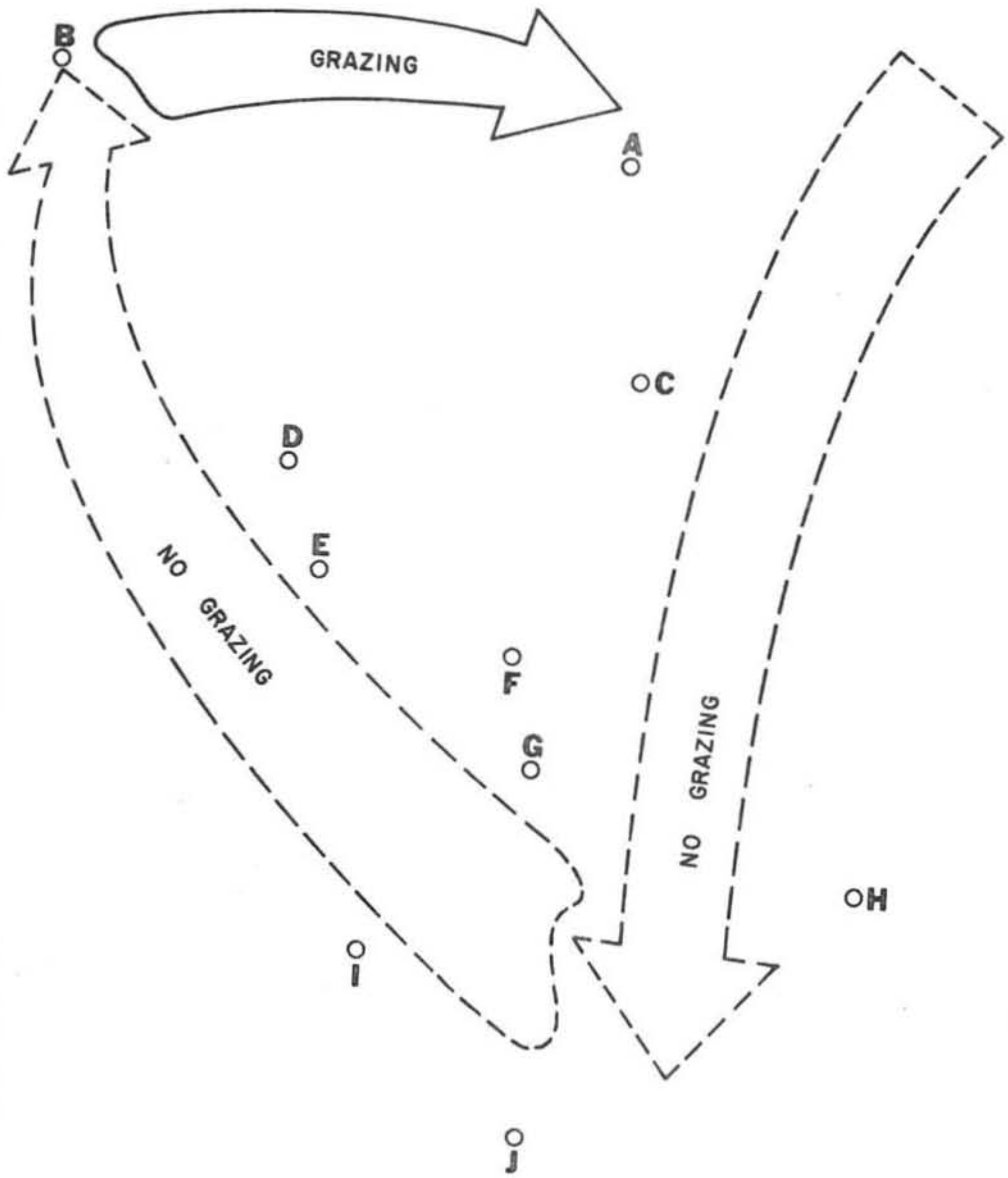

Figure 13. Distribution and movement of sheep after removal of cardboard boxes.

Shrub density as related to the total time spent grazing in each compartment

Total time spent grazing in each compartment was determined for all treatments. We proceeded to investigate if a relationship existed between total time spent grazing in each compartment and density of all shrubs in the compartment. The relationship analyzed explained only 7% of the variation in the moderately stocked pastures and 16% in the heavily stocked pastures.

To account for more of the variation, other variables, such as mean distances of the compartments from the fence line, watering points, and bedding areas, were included in the analysis. Total time spent grazing in each compartment was correlated with the function:

$$e^{-(D + MF + MW + MB)}$$

where: D is shrub density in the compartment, MF mean distance from fence line, MW mean distance from watering point, and MB mean distance from bedding area (Goodall, 1969). The relationships developed explained only 12% of the variation in the moderately stocked pastures and 18% in the heavily stocked pastures.

Effect of sagebrush on utilization of bitterbrush

We observed, during the course of various grazing trials, that the level of utilization on individual bitterbrush shrubs differed widely. The level of use was apparently influenced by the proximity of individual sagebrush plants in such a way that sagebrush plants seemed to exert a negative effect upon the utilization of nearby bitterbrush plants.

We used data generated by measurements with the inclined point frame to determine the existence and extent of a "critical distance" where a sagebrush shrub would exert an effect on the utilization of bitterbrush under the two grazing intensities.

It was found that such a "critical distance" did exist and the average value of this critical distance was 56.1 ± 23.7 cm. It was not significantly different among the two grazing intensities and the three grazing seasons (Fig. 14).

Effect of grazing around shrubs

Sheep tended to graze and trample all the vegetation surrounding the taller shrubs. The width of these "bare areas" around the shrubs (Fig. 15) varied widely in the grazed compartments. There was a significant difference ($P \leq 0.10$) between the two grazing intensities, indicating that the width of the bare area around the shrubs was larger in the heavily stock pastures. The average width of the denuded area around shrubs in the heavily stocked pasture was 138 ± 42.6 cm. and in the moderately stocked pasture the average width was 63.8 ± 31.8 cm.

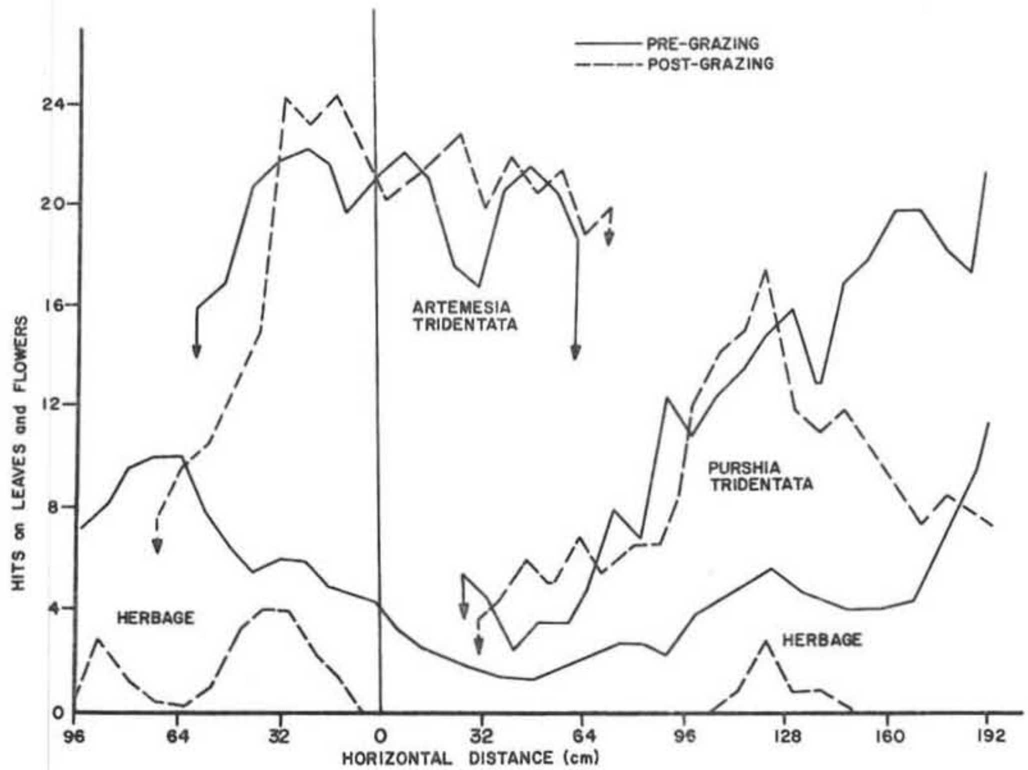

Figure 14. Effect of sagebrush on utilization of bitterbrush and understory by grazing sheep.

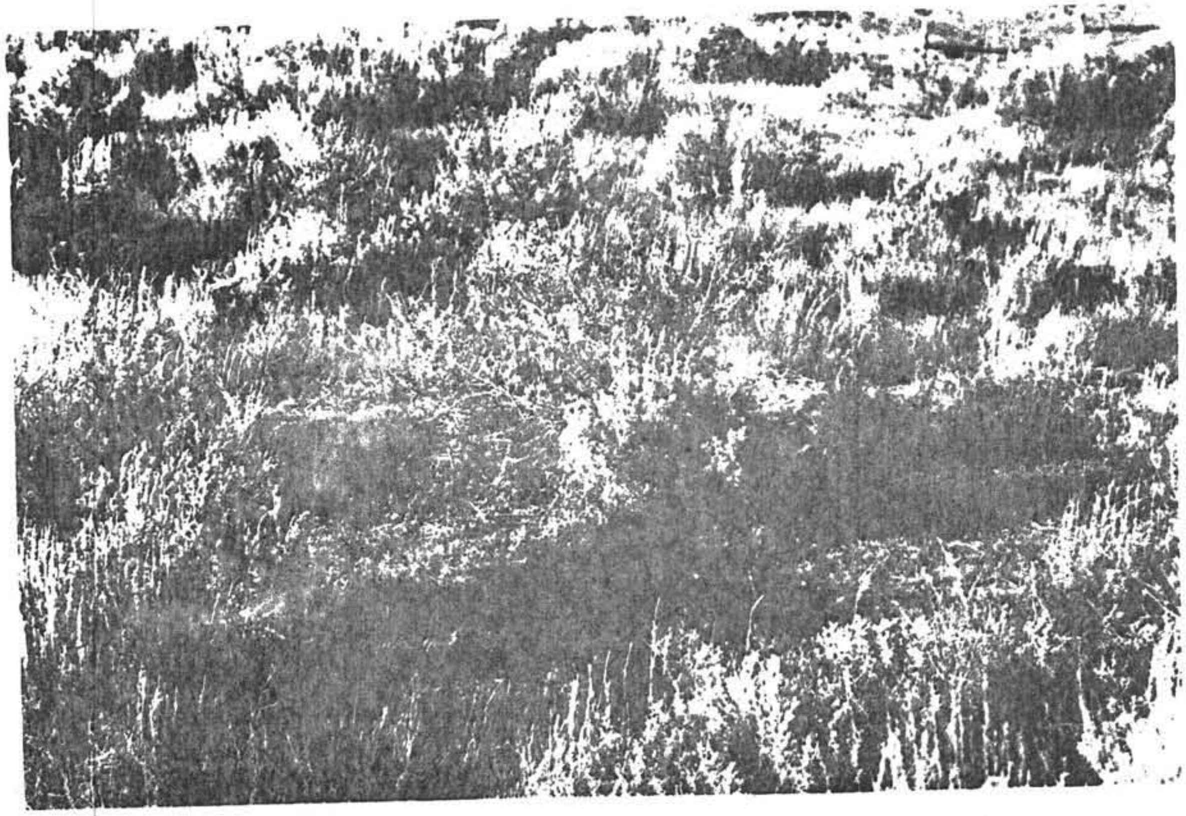

Figure 15. Effect of grazing around shrubs.

DISCUSSION

Theoretically, if grazing animals are positively reinforced for eating specific plants, they will search these plants out and make them more a part of their diet. As the supply of these palatable plants decreases, the animals must increase their effort to locate them. Sheep that discriminate too highly in favor of preferred plant species would be at a disadvantage when the energetic cost of finding the increasingly rare plants exceed the energetic benefit of eating them. Thus evolution and experience may favor a balance between discrimination for a few highly palatable plant species and a willingness to eat other plant species that are far less palatable. The problem here is to determine at what level of availability animals are forced to generalize in their dietary habits due to unavailability of preferred plant species either through physical inaccessability or scarcity (i.e. total absence due to overuse).

Animals should strongly disciminate when preferred plant species are abundant in the pasture such as at the beginning of the grazing period in a particular pasture. The diet would persumably then be composed exclusively of these preferred plant species. This study showed that in the foothill range, sheep preferred aster and bitterbrush more than any of the other 68 plant species. Measurements indicated that these two plant species were at all times sufficiently abundant in the pasture not to have caused the large variations observed in the diet. At the same time, other plant species (example, mules ear) that are usually considered low in palatability (Jensen, Smith, and Scotter, 1972) were detected in the diet from the first day the sheep were introduced to a pasture. Throughout the grazing period, aster and bitterbrush were detectable in the diet of sheep even under heavy grazing intensities (Appendix; Tables 1-6). Accordingly, it can be safely assumed that these variations in the daily use of a particular plant species cannot be explained on the basis of its availability in the pasture as a whole.

Seemingly, there should be a relationship between the availability of any single plant species in the pasture and its proportion in the diet of grazing animals. Such relationships have been incorporated in the various preference indices that have been developed by other researchers (Van Dyne and Heady, 1965; Chamrad and Box, 1968). The relative preference index (RPI) of Van Dyne and Heady (1965) relates consumption (C) of a certain plant species by grazing animals to its availability (A) in the pasture by the equation:

$$RPI_i = \frac{C_i}{A_i}$$

This relative preference index assumes that, for any defined period of time, a constant proportion of a plant species is taken when encountered by a grazing animal.

In this equation consumption (C_i) and availability (A_k) have been reduced to proportions so that

$$\Sigma C = \Sigma A_i = 1$$

If B is the total amount of food examined and R the total taken, at each morsel examined the probability (P_i) it will be taken is:

$$P_i = \frac{R}{B} \ RPI_i$$

In this model RPI values are applied to new sets of availabilities and it is unlikely that the new sets of consumptions predicted will add to one (Westoby, 1973).

The preference index developed by Chamrad and Box (1968) differed from that of Van Dyne and Heady by including frequency of occurrence of a plant species in the diet. This modification suggests that consistency of selecting a plant species is an indication of its preference. In a highly diverse plant community, this index will bias the uniformly distributed plant species in the pasture more than those with irregular distribution. The uniformly distributed plant species have a higher probability of being encountered by a grazing animal than irregularly distributed plant species.

Krueger (1972) compared several preference indices. He assumed that selection of plant species by grazing animals was random. However, in a previous study Krueger (1970) showed that plant selection by grazing sheep was not random. This inconsistency reflects the difficulty of relating food selected by grazing herbivores to the array of choices available and some of the faulty assumptions that form the basis of our current concepts of "preference indices".

Westoby (1973) in a review of preference indices pointed out that the relative preference index varies from zero to plus infinity. He further concluded that it is difficult to statistically relate preference indices by regression to any particular plant characteristic such as chemical composition.

In all cases, preference indices have failed to predict diets of grazing animals. One major problem is the inadequacy of the present measuring and sampling techniques to yield accurate data on availability.

In contrast, techniques to estimate botanical composition of the diet are far more sophisticated and accurate than the present vegetation measurements. Another problem is that preference indices do not incorporate environmental and behavioral variables.

The data from this study indicated that species composition of the pasture compartments (approx. 1/4 acre) varied widely within the same pasture. Had smaller sampling areas been used, it is likely that much large compartment-to-compartment variation would have been observed. If we further reduced our sampling area to equal the area investigated by an individual sheep while grazing, we would undoubtedly have detected even larger variations. Accordingly, every grazing sheep, merely by its position in the pasture, encounters plant associations that vary with every step it takes. If it were possible to measure availability and consumption with every bite, we could certainly develop more useful preference indices in terms of predictive value. Sheep by their position in the pasture, which is strictly a behavioral phenomenon, alter their preferences to match availability of forage species. Arnold (1964b) reported that sheep preferred to lower their forage intake rather than grazing the neglected highly productive parts of the pasture. Availability, considered in the large sense, was not in this case, as limiting as was the behavior of the grazing sheep.

During the ingestion of any particular meal (i.e. a fistula sample) grazing sheep were observed, in this study, to examine and graze swaths that represented a small portion of the pasture. The act of selection by an animal includes an examination of the potential food item closely followed by a decision to ingest or ignore it (Barnett, 1963). The decision to ingest or ignore a potential food item will be based on the summation of all the stimuli detected by the animal's senses (Arnold, 1966; Krueger, 1970). In the case of herbivores grazing a complex plant community, each potential mouth full usually contains more than one plant species, each with its physical and chemical characteristics that contribute to characteristics of the mouth full and the final decision made by the animal. If we visualize that the act of selection takes place on the level of each potential morsel, then we are dealing with a more complex situation that what preference indices deal with. This complexity might explain some of the discrepancies in reporting factors affecting dietary habits of grazing animals.

In this study, availability was correlated to leaf area index and height for each plant species. It was also found that leaf area index and height were highly correlated to production of every plant species. An expression of volume was thus generated by multiplying leaf area index by height and was used to predict production at any one point in time. Height alone was not a significant parameter in grazed pastures. This indicates that each plant species was grazed to a certain height below which, in spite of its presence in the pasture, was not available to grazing sheep. This finding presents yet another problem in measuring availability and explains why frequency of plant species in the pasture was a poor estimator of utilization.

Plant volume, as the concept has been developed in this study, greatly affects use of plants by sheep. Plant volume is detected only by vision, which will bring the grazing animal in contact with its potential food. Initially, the position of the individual animal in the pasture is determined by vision. Visualization will be followed by orientation and then movement of the whole body to occupy a certain unique space in the pasture (Linsdale and Tonich, 1953).

According to Arnold (1966) and Krueger (1970), sight was not considered important in forage selection. Arnold, in his experiment, fitted "blinders" on sheep that would prevent them from seeing the immediate area of use (near vision) but allowed far vision. He reported that there were no significant differences between treated and control sheep. Far vision, however, did not prevent the treated sheep from positioning themselves in the pasture similar to the control sheep. In Krueger's experiment sheep were totally blinded and he found that forage selection was not significantly different than in the control sheep. Even when he impaired all four senses (sight, touch, taste, and smell), the sheep did not exhibit a totally random forage selection. His data did not provide any information on the spatial distribution of the sheep in the pasture or degree of heterogenity of the plant association. We suspect that the insignificant differences between treated and control sheep were due to plant species that were abundant and uniformly distributed. We whould point out that vision might not be an important factor at the time of food ingestion but certainly it has an indirect effect on forage selection by virtue of its role in animals distribution in the pasture. The importance of vision is compounded, the greater the diversity of the plant community being grazed.

Data indicated that sheep distribution in the pasture was not random and that it was related to conspicuous objects in the pasture. Similar non-random distribution patterns of sheep have been reported by several researchers (Dudzinski and Arnold, 1967; Dudzinski, Pahl and Arnold, 1969; Lange, 1969). Lange (1969) reported that patterns of sheep tracks changed with changes in vegetation. He observed that sheep tracks in paddocks devoid of obvious "obstacles" exhibited meshed patterns with interstices. He further observed that in paddocks bare except for a few scattered trees, the track patterns of sheep were found to be radiating from the trees. He assumed that this was due to usage of trees for shelter. He did not find similar patterns around watering points.

Crofton (1958), studying nematode infections as related to sheep behavior, also reported that sheep were not randomly positioned in the pasture. He observed that the majority of sheep were oriented so that for any individual, two other sheep subtended an angle of approximately 110° to it. He found that this orientation occurred when two sheep were in front of the individual and never when they were behind it. He suggested that a visual method of orientation may be involved.

Data suggest that sheep orient themselves toward conspicuous objects. In the center of the pasture, shrubs were the most conspicuous objects to a grazing sheep, but at the edges of the pasture other objects such as fence posts or a sign on the fence were used in orientation. If conspicuous shrubs are used continuously in the orientation process of grazing sheep, we would expect to find heavier use around shrubs than in between shrubs. Data support this hypothesis and the bare areas around these shrubs are due to both grazing and trampling. Baily (1970) suggested that heavy use around shrubs was due to the vigorous growth of the plants under shrubs seemingly making such plants more appealing. This explanation would be acceptable if herbaceous species were heavily grazed only around shrubs. Our observations indicated that this heavy use was also detectable around fence posts. In our experiment where cardboard boxes were used to study animal orinetation, heavy use was evident around the boxes after a 2-day grazing period. Certainly we cannot explain this heavy use around the cardboard boxes on the basis of alterations in plant vigor. We recognize the fact that herbaceous species around shrubs may have higher vigor than herbaceous species in shrub interstices. However, the heavy use on them is not due only to their vigor but also to their proximity to a conspicuous object.

There are some questions as to whether the movement toward conspicuous objects involves some exploratory behavior. If this is the case, one would expect sheep to use conspicuous objects less frequently as they become familiar with a pasture. One would also expect that the investigation of the objects would be more intense the first time they were encountered. However, we saw no behavior that could be called exploratory (ex. sniffing) directed toward the object. Thus we conclude that this behavior of moving toward conspicuous objects is simply an orientation mechanism used while feeding. This assumption is supported by the observation that sheep continued grazing while moving from one shrub to another. Sheep are expected, therefore, to graze swaths that lead to conspicuous objects used as foci of orientation. Their forage preferences will then be largely determined by the availability and associations of plant species in those particular swaths and not the pasture as a whole.

In discussing the role of learning in forage selection of herbivores, we face several questions. One is whether or not an herbivore is capable of assessing the nutrient qualify of food. This requires that an animal pair the act of eating a specific food which follows after some considerable time. Although reinforcement theory does not account for this (Garcia, Ervin and Koelling, 1966) rats are able to make this pairing (Revusky and Garcia, 1970). Rozin and Kalat (1971) emphasized that learning is a powerful and adaptive tool in feeding behavior allowing the animals to identify and detect nutritional value of food. Rozin (1969), and Revusky and Garcia (1970) reported that some record of the food which was eaten is stored centrally and compared with the account given by relevant proprioceptors at ingestion time.

There is some reason to think that sheep may differ from rats in the ability to assess the quality of their food. Assessment of food qualities might be more of an advantage to omnivores than herbivores.

In contrast to rates in the above mentioned stuides, free grazing herbivores have options to select among different and highly diverse plant species. We observed that all of the 70 plant species found in our experimental pastures were present in the diet. We found also that on the average, fistulated sheep ingested 19 different plant species in the 40-minute sampling period. Association of aversive stimuli with any specific plant species, such as a poisonous plant, under such complex circumstances would be very difficult. Usually herbivores cannot avoid poisonous plants in a highly diverse plant community. Certainly learning is an important part of animals' feeding behavior, but we doubt that it involves delayed learning with respect to the chemical properties of individual plants. For example, our experiment when sagebrush was associated with bitterbrush, both shrubs were rejected in spite of the fact that bitterbrush was highly preferred by sheep. This rejection was also extended to the associated herbaceous species. This, again, is a phenomenon that is controlled by the animal behavior and not by factors relating to forage availability.

We conclude that an individual sheep will position itself in the pasture in relation to conspicuous objects. It will then investigate and utilize a swath that extends between two conspicuous objects. Its forage preferences are largely determined by availability and plant association in that particular swath. Forage selectivity is based on the level of small microassociations and not individual plant species. There is an indication that sheep would graze an area for a short period of time (1-2 days) before moving to an adjacent area.

SUMMARY AND CONCLUSION

An experiment was designed to study the effects of season, grazing intensity and forage availability upon the dietary habits of sheep grazing foothill ranges in Utah. Three grazing periods of 15 days each were used to study the effect of season. Each grazing period included a heavy and a moderate stocking intensity. Pastures were grazed by three esophageally fistulated wethers, eight intact ewes, and eleven lambs. Differences in stocking rate were obtained by varying the size of the six pastures studied.

For sampling purposes, the pastures were divided by a grid into 30.48 m x 30.48 m compartments and assigned numbers. Each compartment was then sampled for botanical composition of available herbage prior to grazing and again after the 15-day grazing period had ended.

Esophageal samples were collected daily for five successive days in every week by allowing the fistulated sheep to graze freely for a period of 20-40 minutes. During this period, observations were recorded in respect to the position of every fistulated sheep and duration of time spent grazing in each compartment.

Immediately following collection of fistula samples, daily measurements were taken on leaf area index and height of every plant species. Measurements were restricted to the compartments that were subject to grazing activity in that day. Estimates of herbage yield and forage utilization were derived from height-leaf area measurements through regression equations developed by harvesting ungrazed plants in a control area.

Esophageal samples were freeze-dried and ground through a 40-mesh screen. A small portion was taken from each sample, dyed and mounted on a microscope slide. Samples were examined under the microscope for botanical composition on the basis of recognizable epidermal fragments. Botanical composition was then computed on the basis of regressions relating density and frequency of fragments to percent dry weight.

Seventy different plant species were found in the pastures. All of these species appeared in the diet, but only 10 plant species consistantly formed the bulk of the diet. Six of these ten species were chosen for intensive analysis because of their consistantly high proportions in the diet.

Analysis of the dietary data indicated that season had no significant effect on the diets of sheep. On the other hand, grazing intensity did affect the botanical composition of sheep's diet ($P \leq 0.20$). Averaged across all sheep, large and significant differences ($P \leq 0.01$) were found in the proportions of plant species that comprised the diet. Additionally, individual sheep were significantly different in their forage preferences ($P \leq 0.01$).

Measurements taken in the pasture compartments indicated that significant differences in species composition, prior to and after grazing, were found only in those compartments that were part of the bedding areas. However, on the average, bare ground increased significantly ($P \leq 0.10$) more under heavy stocking than under moderate stocking.

Regression relating production to height (Ht) and leaf area index (LAI) in the ungrazed control area were found to be good predicators of herbage yield. The regression equation developed for every plant species is as follows:

$$Y_1 = b_o + b_1 \; . \; LAI + b_2 \; . \; Ht + b_3 \; . \; LAI. \; Ht \; (r^2 = 0.85)$$

where Y_1 is herbage yield. Biomass of the grazed plant species was found also to be correlated with leaf area index and height. To predict biomass of a particular plant species the following equation was developed:

$$Y_2 = b_o^1 + b_1^1 \; . \; LAI + b_2^1 \; . \; Ht \; (r^2 = 0.79)$$

where Y_2 is biomass in grazed pastures. Utilization (U) was then determined by the following equation:

$$U = Y_1 - Y_2$$

In this study, sheep were observed to graze more heavily around the periphery shrubs than in the interspaces. The width of the heavily grazed areas around shrubs was significantly larger in heavily grazed pastures than in moderately grazed pastures ($P \leq 0.10$). The average width was 138.0 ± 32.6 cm in heavily stocked pastures and 63.8 ± 31.8 cm in moderately stocked pastures. Further observations indicated that sheep tended to orient their bodies, while grazing, toward conspicuous objects (ex. shrubs). In so doing, they grazed a strip leading from one object to another.

To test the hypothesis, a second experiment was designed. Ten cardboard boxes were randomly distributed in an ungrazed part of a holding pasture. Distances and angles subtended between boxes were measured and drawn to scale on a map. Fourteen sheep were driven to the area and their responses to the boxes were recorded. During the initial two days, sheep frequented the area on their own. On the third day, sheep abandoned the area to graze in an adjacent part of the pasture. Data on sheep distribution was found to be non-random and significantly ($P \leq 0.05$) related to the positions of the boxes. This distribution pattern was not evident when boxes were removed from the pasture.

Another behavioral aspect investigated in this study was the effect of stocking intensity upon the height of grazing on forage plants by sheep. The average height of any particular grazed plant species was not significantly different among all pastures, suggesting that each plant species is grazed to a certain threshold height. Below this height the plant species must be considered to be unavailable to the grazing animal.

Use on bitterbrush was found to be influenced by its proximity to sagebrush plants. The "critical distance", at which a sagebrush plant would exert a negative effect on the use of bitterbrush plant, was 56.1 ± 23.7 cm. This critical difference was not significantly affected by either season or grazing intensity.

Relating all the measured independent variables by multiple regression to botanical composition of diets of sheep (the dependent variable), an equation was developed that explained 52% of the variation. Data on sheep behavior were not incorporated in the predictive equation, but if included, would have possibly explained additional variability. The difficulty of including such information centered around the fact that sheep paths (swaths) could not have been accurately identified. Moreover, the area of the sampling compartments was fairly large compared to the area examined and grazed by individual sheep.

Results of this experiment lead us to conclude that vision exerts a powerful role in determining the dietary habits of sheep. Visual orientation is a major part of feeding behavior and is not entirely exploratory in nature. The grazing pattern of sheep and their tendency to orient toward conspicuous objects offers an opportunity for manipulating sheep distribution on rangelands. If simuli involved are evaluated and identified, a supernormal stimulus could possibly be developed. This would be useful in directing sheep toward neglected parts of the pasture, thus insuring a more uniform use on all forage species.

Measurements of leaf area index and height by the inclined point frame offer a promising technique in estimating production and utilization. Successive measurements take into account both rate of growth and rate of removal by grazing. The technique also has the advantage of creating a minimum disturbance to the vegetation.

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APPENDIX

Table 7. Percent Species Composition in Diet (Wt.) (Early Moderate)

	May 21	May 23	May 24	May 26	May 28	May 29	May 30	May 31	June 1
Sheep #5									
Aster	22.68	41.14	16.37	-	33.77	20.79	11.51	30.38	24.24
Lupinus	10.31	10.29	4.68	-	32.47	10.67	18.71	21.52	1.82
Wyethia	4.64	13.71	14.62	-	4.55	32.02	33.81	6.33	22.42
Amelanchier	3.09	2.29	1.75	-	0.65	3.93	10.79	0.42	3.64
Chrysothamnus	2.58	1.71	4.09	-	0.65	3.37	5.04	3.80	5.46
Purshia	11.86	8.57	11.11	-	2.60	19.66	12.95	18.57	29.09
Ag. spicat.	4.12	0.57	7.02	-	4.55	0.56	0.72	1.69	0.00
Koeleria	7.22	0.00	4.68	-	1.95	1.12	0.00	1.69	0.00
Melica	6.19	4.00	4.68	-	1.30	0.00	0.00	1.27	0.61
Poa prat.	13.92	4.57	15.21	-	9.09	2.81	5.04	7.17	0.00
Sheep #7									
Aster	24.50	21.34	8.68	37.76	28.80	27.88	15.12	17.86	17.06
Lupinus	4.76	14.63	2.74	16.84	20.42	26.55	23.02	13.78	4.76
Wyethia	9.52	6.71	12.79	14.80	25.13	10.62	8.59	24.49	23.81
Amelanchier	0.00	1.83	3.65	5.10	2.62	1.33	1.38	7.14	2.38
Chrysothamnus	2.38	0.61	13.24	1.53	2.09	3.98	2.41	9.18	2.78
Purshia	15.08	18.90	11.87	14.29	4.71	15.56	15.12	9.59	23.41
Ag. spicat.	6.35	6.71	9.59	0.51	1.05	1.79	9.97	0.51	7.14
Koeleria	9.52	2.44	7.31	0.51	0.00	0.89	1.38	1.02	0.79
Melica	3.18	3.66	5.94	0.00	0.00	0.44	1.03	1.02	1.19
Poa prat.	11.91	15.24	15.53	1.53	1.05	4.43	15.81	8.67	8.33
Sheep #9									
Aster	25.93	26.53	26.09	42.96	24.19	23.59	19.32	23.64	29.95
Lupinus	3.70	5.12	5.98	9.16	31.72	10.90	23.86	43.03	2.67
Wyethia	6.79	7.65	14.67	15.49	11.29	19.23	17.05	4.85	32.62
Amelanchier	4.32	3.57	9.24	3.52	0.00	2.56	2.27	1.21	6.95
Chrysothamnus	4.32	3.06	4.35	1.41	1.61	0.64	3.41	0.00	2.14
Purshia	24.07	16.33	15.22	14.79	5.91	24.00	27.27	1.21	13.90
Ag. spicat.	1.85	5.61	2.17	0.70	2.15	0.64	0.00	3.03	0.00
Koeleria	2.47	2.04	3.80	0.70	2.69	0.64	0.00	2.42	0.00
Melica	5.56	3.06	2.17	0.70	6.99	1.28	0.00	1.82	0.00
Poa prat.	4.94	5.10	5.98	2.82	8.60	1.92	1.14	9.09	1.60

Table 8. Percent Species Composition in Diet (Wt.)(Early Heavy)

	May 21	May 23	May 24	May 26	May 28	May 29	May 30	May 31	June 1
Sheep #3									
Aster	28.18	36.67	-	9.55	19.25	34.45	13.02	20.38	22.71
Lupinus	11.60	5.56	-	5.62	1.07	1.06	1.18	0.00	1.93
Wyethia	8.84	18.33	-	11.80	40.64	29.10	27.81	22.93	39.61
Amelanchier	1.66	1.11	-	3.37	1.07	0.53	0.00	0.64	1.93
Chrysothamnus	4.97	1.67	-	7.87	1.60	1.59	1.18	0.00	0.48
Purshia	25.97	2.78	-	35.96	6.95	3.18	4.14	3.19	3.38
Ag. spicat.	1.66	1.67	-	6.74	2.67	2.12	4.73	5.73	5.31
Koeleria	2.21	4.44	-	0.56	5.88	3.70	8.28	16.56	3.38
Melica	0.55	1.67	-	1.69	0.00	0.53	2.96	0.00	0.97
Poa prat.	4.97	8.33	-	10.67	12.30	10.05	20.12	9.55	8.70
Sheep #6									
Aster	32.88	25.85	-	18.97	30.22	-	-	-	4.58
Lupinus	8.11	4.24	-	12.93	1.65	-	-	-	2.61
Whethia	17.12	3.39	-	3.88	39.01	-	-	-	41.18
Amelanchier	3.15	0.42	-	3.88	2.75	-	-	-	2.61
Chrysothamnus	2.70	2.54	-	3.88	2.75	-	-	-	3.27
Purshia	26.58	12.71	-	28.88	9.34	-	-	-	24.18
Ag. spicat.	1.80	2.54	-	3.02	0.00	-	-	-	1.96
Koeleria	1.35	17.80	-	2.16	0.55	-	-	-	2.61
Melica	0.45	0.42	-	0.43	0.55	-	-	-	0.65
Poa prat.	1.80	11.86	-	9.91	3.85	-	-	-	7.84
Sheep #10									
Aster	13.84	18.95	-	16.57	18.46	11.60	31.72	11.31	-
Lupinus	11.32	15.03	-	7.10	2.56	1.66	3.96	3.57	-
Wyethia	12.58	1.96	-	20.71	33.33	34.25	12.33	30.95	-
Amelanchier	3.77	2.61	-	10.06	3.59	6.08	0.00	4.95	-
Chrysothamnus	8.81	2.61	-	2.96	2.05	2.76	2.64	4.76	-
Purshia	47.17	49.67	-	28.99	31.80	30.94	27.31	25.60	-
Ag. spicat.	0.00	0.00	-	2.37	0.00	0.00	0.00	0.00	-
Koeleria	0.00	1.96	-	0.00	0.51	0.55	3.52	1.19	-
Melica	0.00	0.00	-	0.00	0.00	0.55	1.76	0.60	-
Poa prat.	0.00	3.27	-	1.78	2.05	2.76	3.96	3.57	-

Table 9. Percent Species Composition in Diet (Wt.)(Intermediate Moderate)

	June 4	June 5	June 6	June 7	June 8	June 11	June 12	June 13	June 14	June 16
Sheep #3										
Aster	36.31	18.52	42.77	55.42	8.66	17.98	39.88	40.13	25.00	19.36
Lupinus	1.12	1.85	1.81	4.22	1.58	4.83	7.74	12.50	21.23	3.23
Wyethia	17.88	6.02	13.25	9.64	66.14	8.33	7.14	29.61	1.89	24.73
Amelanchier	3.35	1.86	2.41	3.62	0.79	1.32	2.38	2.63	0.00	6.45
Chrysothamnus	0.00	0.00	0.60	0.00	0.00	1.32	0.60	0.00	0.00	2.69
Purshia	7.82	4.17	8.43	15.06	5.51	9.21	8.33	5.92	3.77	18.82
Ag. spicat.	1.12	3.24	1.81	0.60	0.00	6.58	4.17	0.66	5.19	2.15
Koeleria	3.91	18.06	4.82	3.02	3.15	14.47	5.95	1.32	8.02	6.99
Melica	0.56	3.24	3.62	1.21	0.79	3.51	1.19	1.32	2.83	1.08
Poa prat.	5.59	16.20	3.01	1.81	7.09	12.72	11.91	1.32	16.98	9.68
Sheep #6										
Aster	-	-	23.08	38.37	25.95	44.58	32.02	43.26	8.46	35.62
Lupinus	-	-	2.05	6.98	3.17	11.17	3.37	12.36	1.00	10.30
Wyethia	-	-	9.23	14.54	8.86	4.79	8.43	7.87	24.88	14.59
Amelanchier	-	-	3.59	6.98	3.17	2.13	2.81	2.81	3.98	2.15
Chrysotahmnus	-	-	0.48	0.58	1.27	1.06	2.25	0.56	1.99	0.86
Purhsia	-	-	25.64	11.05	9.49	21.28	24.28	15.17	16.92	24.03
Ag. spicat.	-	-	2.56	0.00	0.00	2.13	1.12	1.69	4.48	0.86
Koeleria	-	-	4.10	0.58	12.03	1.06	8.43	1.65	5.47	2.59
Melica	-	-	3.08	1.16	3.80	0.00	1.69	0.56	1.00	0.43
Poa prat.	-	-	8.72	1.16	12.66	5.32	8.43	7.30	13.93	3.43
Sheep #10										
Aster	18.58	37.36	3.51	47.80	32.38	18.18	26.25	35.52	33.01	17.83
Lupinus	1.64	0.58	5.26	3.77	7.62	9.09	5.63	2.73	8.37	21.66
Wyethia	39.34	27.59	4.39	12.58	4.76	2.80	15.63	10.93	5.42	4.46
Amelanchier	3.83	0.58	2.63	5.92	1.43	0.00	1.88	1.64	1.48	1.27
Chrysothamnus	0.55	1.15	1.75	0.00	0.95	4.20	1.25	0.00	2.99	3.82
Purshia	11.48	13.22	80.70	19.50	31.43	50.14	39.38	35.52	31.53	47.13
Ag. spicat.	0.00	0.00	0.00	0.00	2.86	0.00	0.00	1.64	0.99	0.00
Koeleria	0.55	1.72	0.00	0.00	4.29	0.00	1.25	1.64	0.49	0.64
Melica	1.09	1.15	0.00	0.00	1.43	0.70	0.63	1.09	3.00	0.00
Poa prat.	1.09	4.60	0.00	0.63	5.71	0.70	1.25	4.37	4.43	0.64

Table 10. Percent Species Composition in Diet (Wt.)(Intermediate Heavy)

	June 4	June 5	June 6	June 7	June 8	June 11	June 12	June 13	June 14	June 16
<u>Sheep #5</u>										
Aster	35.34	-	58.74	-	12.88	-	19.46	-	-	-
Lupinus	7.23	-	1.40	-	1.14	-	1.81	-	-	-
Wyethia	14.86	-	5.59	-	4.17	-	19.46	-	-	-
Amelanchier	0.40	-	1.41	-	3.03	-	2.26	-	-	-
Chrysothamnus	0.40	-	0.70	-	1.52	-	0.45	-	-	-
Purshia	4.82	-	9.09	-	13.64	-	10.41	-	-	-
Ag. spicat.	1.21	-	0.70	-	8.33	-	5.43	-	-	-
Koeleria	3.21	-	3.50	-	9.47	-	9.05	-	-	-
Melica	2.41	-	0.00	-	1.52	-	2.26	-	-	-
Poa prat.	6.02	-	3.50	-	14.77	-	11.31	-	-	-
<u>Sheep #7</u>										
Aster	12.11	15.96	-	14.92	30.73	9.58	27.95	19.56	12.93	18.10
Lupinus	18.42	11.27	-	4.03	2.60	2.40	1.75	8.00	2.16	10.48
Wyethia	12.11	19.25	-	4.03	0.87	9.58	17.03	6.22	2.59	6.67
Amelanchier	4.21	0.94	-	3.23	3.46	2.40	1.75	2.67	1.29	5.24
Chrysothamnus	2.11	2.35	-	2.02	0.87	1.80	1.31	0.89	0.43	1.91
Purshia	17.90	32.86	-	26.21	16.88	55.09	4.80	22.67	16.38	30.95
Ag. spicat.	4.21	0.94	-	5.65	8.23	0.50	3.49	4.89	9.05	1.91
Koeleria	4.74	1.41	-	6.86	12.55	5.99	8.73	4.89	12.50	1.43
Melica	0.53	0.94	-	3.63	3.90	0.60	1.75	1.33	3.02	0.48
Poa prat.	10.53	4.70	-	13.71	9.52	5.99	8.73	8.00	16.81	6.67
<u>Sheep #9</u>										
Aster	49.33	-	38.34	28.57	-	38.20	30.62	11.91	-	-
Lupinus	4.00	-	2.59	1.97	-	5.06	3.83	6.19	-	-
Wyethia	21.33	-	15.03	5.91	-	10.67	6.22	20.48	-	-
Amelanchier	1.33	-	4.15	3.45	-	5.06	4.31	5.71	-	-
Chrysothamnus	0.00	-	0.52	0.49	-	1.12	1.44	2.38	-	-
Purshia	4.67	-	9.85	13.79	-	15.73	10.05	34.76	-	-
Ag. spicat.	0.00	-	1.55	4.93	-	1.12	2.39	0.48	-	-
Koeleria	0.00	-	2.60	7.88	-	2.25	3.83	3.81	-	-
Melica	2.67	-	1.55	1.97	-	1.69	3.83	1.43	-	-
Poa prat.	2.00	-	3.63	9.85	-	5.06	8.13	3.81	-	-

Table 11. Percent Species Composition in Diet (Wt.)(Late Moderate)

	June 18	June 19	June 20	June 21	June 22	June 25	June 26	June 27	June 28	June 29
Sheep #5										
Aster	-	25.56	38.74	33.03	30.39	23.72	12.26	23.00	-	9.30
Lupinus	-	10.76	29.32	21.72	46.62	18.61	19.61	8.00	-	48.26
Wyethia	-	8.07	9.95	6.79	1.66	6.05	2.45	14.50	-	3.49
Amelanchier	-	5.83	0.00	1.36	0.00	5.58	0.49	3.00	-	2.91
Chrysothamnus	-	2.24	0.52	0.45	0.00	5.58	0.49	1.50	-	1.74
Purshia	-	31.39	6.81	12.67	0.00	26.05	6.86	33.00	-	16.86
Ag. spicat.	-	0.00	0.00	0.45	0.00	0.47	0.49	0.00	-	2.91
Koeleria	-	5.38	2.62	8.60	7.18	0.93	12.26	3.00	-	3.49
Melica	-	2.24	1.05	1.36	1.11	1.86	3.43	2.00	-	0.58
Poa prat.	-	1.35	1.05	3.17	1.66	0.47	10.78	4.50	-	2.33
Sheep #7										
Aster	16.76	10.38	17.13	29.59	23.64	19.36	14.55	13.74	19.29	12.62
Lupinus	48.56	26.89	24.54	7.14	17.83	9.22	9.70	12.32	16.24	6.54
Wyethia	3.47	5.66	7.41	4.59	2.33	14.75	16.97	13.27	2.54	5.14
Amelanchier	0.58	2.83	0.00	2.04	1.16	2.30	1.82	3.79	0.00	0.47
Chrysothamnus	0.00	2.36	0.00	1.53	1.16	1.84	0.00	2.84	0.00	0.47
Purshia	9.83	41.98	2.32	12.25	15.89	10.60	10.91	38.86	0.51	17.29
Ag. spicat.	0.00	0.94	1.39	0.51	1.94	0.92	0.00	0.00	3.05	0.00
Koeleria	5.20	0.94	6.94	4.59	6.59	14.29	20.00	5.11	12.69	19.63
Melica	0.58	0.94	2.78	2.04	2.71	0.46	3.03	0.47	3.05	2.80
Poa prat.	4.05	0.94	8.80	9.18	6.59	8.76	5.46	3.79	5.58	14.49
Sheep #9										
Aster	46.60	43.79	20.90	14.09	35.35	24.48	41.99	27.67	13.58	23.20
Lupinus	35.60	11.77	43.50	13.64	30.70	14.11	14.37	12.62	24.89	26.29
Wyethia	3.67	7.19	19.21	14.55	7.44	8.71	9.95	5.83	3.17	0.52
Amelanchier	0.00	1.31	1.13	3.64	0.93	2.91	1.66	0.97	0.91	0.00
Chrysothamnus	0.00	0.00	0.57	1.36	0.93	0.00	0.55	0.00	1.36	0.00
Purshia	3.14	4.58	4.52	15.00	14.42	23.37	7.18	7.28	24.43	3.09
Ag. spicat.	0.00	0.00	0.57	0.46	0.47	0.00	0.00	0.49	0.45	0.52
Koeleria	1.57	4.58	0.00	6.82	1.86	3.73	2.76	6.31	3.62	6.70
Melica	0.00	3.92	0.57	2.73	0.47	1.66	1.66	2.91	2.72	2.06
Poa prat.	1.05	4.58	1.13	1.82	0.93	2.08	2.21	4.37	6.34	4.12

Table 12. Percent Species Composition in Diet (Wt.)(Late Heavy)

	June 18	June 19	June 20	June 21	June 22	June 25	June 26	June 27	June 28	June 29
Sheep #3										
Aster	-	25.62	-	20.53	29.10	-	24.48	32.70	-	-
Lupinus	-	33.88	-	25.79	7.94	-	17.19	23.27	-	-
Wyethia	-	8.68	-	11.05	30.16	-	13.02	5.66	-	-
Amelanchier	-	0.41	-	0.53	2.12	-	0.00	0.00	-	-
Chrysothamnus	-	0.41	-	1.05	0.53	-	1.56	1.26	-	-
Purshia	-	5.37	-	3.16	2.12	-	3.13	4.40	-	-
Ag. spicat.	-	2.48	-	1.05	1.05	-	2.08	2.52	-	-
Koeleria	-	8.27	-	12.63	7.94	-	7.81	6.92	-	-
Melica	-	0.41	-	2.11	1.59	-	1.04	1.26	-	-
Poa prat.	-	4.13	-	6.32	4.23	-	6.77	6.29	-	-
Sheep #6										
Aster	25.24	-	-	-	24.68	30.19	12.50	13.78	-	-
Lupinus	6.31	-	-	-	7.79	16.23	14.66	6.12	-	-
Wyethia	13.11	-	-	-	8.51	4.15	5.17	15.82	-	-
Amelanchier	6.31	-	-	-	1.28	0.38	0.86	0.00	-	-
Chrysothamnus	9.71	-	-	-	3.40	1.13	0.86	0.00	-	-
Purshia	31.07	-	-	-	2.13	4.15	10.78	0.51	-	-
Ag. spicat.	1.46	-	-	-	6.81	7.55	8.19	4.08	-	-
Koeleria	1.94	-	-	-	9.79	7.17	6.47	8.67	-	-
Melica	0.00	-	-	-	0.85	0.76	2.59	2.04	-	-
Poa prat.	1.46	-	-	-	7.23	11.70	15.52	12.76	-	-
Sheep #10										
Aster	33.87	17.76	26104	5.91	12.61	26.55	33.51	13.92	14.34	7.83
Lupinus	19.36	34.11	17.71	14.29	20.87	7.35	12.97	8.23	13.90	11.74
Wyethia	5.38	17.76	3.65	32.02	4.78	12.99	3.24	19.62	8.52	28.70
Amelanchier	3.23	0.94	1.04	3.45	0.87	4.52	0.54	0.00	2.60	1.30
Chrysothamnus	1.61	2.34	4.59	4.93	2.61	2.83	0.54	3.17	4.04	0.00
Purshia	34.41	23.83	41.15	33.99	30.00	23.16	32.97	12.66	28.25	3.48
Ag. spicat.	0.00	0.47	0.00	0.00	3.48	1.13	0.00	5.70	1.35	6.09
Koeleria	0.54	1.87	0.52	0.00	2.61	5.65	4.87	8.86	7.18	6.25
Melica	0.54	0.00	0.00	0.00	0.87	1.70	0.00	1.27	0.90	1.74
Poa prat.	0.00	0.00	1.04	0.00	3.91	1.70	4.87	6.96	6.73	10.44

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