Feeding Behavior of Pen Reared Mule Deer Under Winter Range Conditions

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FEEDING BEHAVIOR OF PEN REARED MULE DEER
UNDER WINTER RANGE CONDITIONS

by

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ABSTRACT

Feeding Behavior of Pen Reared Mule Deer Under

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by

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Department: Range Science

This study examined the feeding responses of mule deer to a system of spring livestock grazing. The specific purposes were 1) to determine botanical composition of diets selected by mule deer on a winter range subjected to previous spring grazing by sheep compared to one with no sheep grazing and 2) to develop a basis for predicting selection of individual plants by deer, based on physical characteristics of the plants and the species and physical proximity of associated plants.

The study was conducted within the framework of a completely randomized experimental design with two treatments. Variables controlled for each unit of observation were grazing treatment (prior sheep grazing and no sheep grazing), sampling periods within the winter (early winter and late winter), weeks (four within each period), days (four within each week), sampling times (four each day), age of animal (fawns and adults) and identity of observer.

Two adjacent 2.4 ha pastures were fenced. A sheep grazing treatment of 150 sheep days per ha was applied in late May, 1974, to one pasture. Five hand-reared mule deer were placed in each pasture for two six-week periods, one in early winter and the other in late winter. Diets were quantified by a mouthful count technique and hand plucking representative mouthfuls of each species consumed. Plant physical characteristics were measured while following grazing deer. For each plant encountered by the deer, the following variables were measured: species name, distance from the deer, height and width, degree of prior utilization, proportion of current live plant material present, species of and distance to nearest neighboring plant, and consumption or non-consumption of the plant by the deer.

Differences were found between treatments in forage availability and abundance, and in botanical composition of diets selected by mule deer. The dietary differences were attributed to a greater proportion of current year's bitterbrush forage being available in the sheep grazed treatment and to reduced interference there from standing dead grass in selection of preferred green grasses and forbs. Deer diets in the sheep grazed pasture were higher in herbaceous plant material than in the deer pasture.

Seasonal dietary changes were due to reduced plant availability by deer grazing, snow cover, and plant phenology. Major changes were an increase in shrub consumption through the early winter and well into the late winter periods, and a simultaneous decline in herbaceous species consumption. Snow melt and spring green-up

permitted a sudden shift to forbs and grasses near the end of the late winter period.

Plant attributes capable of predicting consumption of individual plants included 1) degree of prior utilization, 2) amount of current live plant material present, 3) distance of plant from grazing animal, 3) species of nearest plant, and 4) plant height. These characteristics probably exerted their influence indirectly through olfactory and tactile stimuli to the deer. The use of these attributes to place plants in consumed and not-consumed groups indicated that grazing deer probably cue on fairly specific plant characters in selecting plants for consumption.

(85 pages)

INTRODUCTION

The feeding behavior of large herbivores is affected by many abiotic and biotic factors. Among these are factors influencing the animal's location in time and space, plant species available to the animal, physical and nutritional properties of individual plants, and sex and age of animals. Although many other factors are influential in feeding behavior, these mentioned are of particular interest in the improvement of mule deer (*Odocoileus hemionus hemionus*) management in the Intermountain West. These factors are interrelated. Animal location is a major determinant of plant species available. This and others such as recent climatic and grazing history influence physical and nutritional properties of individual plants.

The broad determinant of mule deer location during the year is weather. The onset of winter forces mule deer to move from high elevation summer ranges to lower elevation foothill ranges over much of the Intermountain West. The associated dietary changes are probably quite drastic in terms of botanical composition and nutritional quality, since a move from montane plant communities into sagebrush associations, pinyon-juniper woodlands, or oakbrush is often involved. The botanical composition of foothill plant communities is a function of many factors including topography, climate, and past history of grazing use.

This study attempts to evaluate mule deer dietary botanical composition on a winter range site with respect to previous livestock grazing, the progression of time, age of animals, and physical characteristics of individual plants.

The Problem

Winter range apparently limits mule deer production over much of the mule deer range (Hill, 1956; Aldous, 1945; Doman and Rasmussen, 1944). Of the 7,423,000 ha of mule deer winter range in Utah, 1,140,000 ha are reported to be sagebrush dominated. (David Mann, Utah Division of Wildlife Resources, personal communication). The limitations to production can be viewed in terms of both extent of winter rangeland and quantity of forage (principally shrubs) produced there. Winter deer losses are inversely related to the amount of palatable browse available (Robinette et al., 1952). These ranges also limit production of livestock (Cook and Harris, 1968), as they are a major but limited source of spring forage for the winter livestock industry.

Recent research has indicated that livestock-big game competition can be minimized, and that livestock may be used to manipulate mule deer winter range vegetation to increase quantities of browse available to deer if properly designed grazing systems are employed (Jensen et al., 1972). However, the response of mule deer to such grazing systems is largely unknown. This information gap prompted the present study.

Purpose

The purpose of this study was 1) to determine the plant species present and available to deer on two study sites, 2) to determine the relative proportions of each in the diets of mule deer on winter range sites subjected to previous sheep grazing and no sheep grazing, and 3) to develop a basis for predicting consumption of an individual plant based on physical properties and vegetation surrounding the plant.

Limitations

The applicability of findings of this study to other areas and other mule deer populations should hold generally for the pattern of any dietary changes in deer's winter diets in response to sheep grazing and for plant attributes which are shown to influence deer selection for consumption of individual plants. Direct extrapolation of dietary composition values to other areas would probably be ill-advised. Replication of the study in both time and space would have permitted an evaluation of the effects of climatic variability and of differences in vegetation normally encountered. Resources available did not permit expanding the study beyond one site and winter season.

Definition of Terms

1. Abundance is the proportion of total plant biomass represented by a species in a plant community. It is expressed in the Results and Discussion sections of this thesis as an index based on point hits or contacts from the inclined point frame.

2. Availability is the presence of a species in a condition or position usable by a herbivore in a plant community.

3. Palatability is a plant condition stimulating a selective response by animals (Heady, 1964).

4. Preference is an animal response to plants when confronted by choices (Heady, 1964).

Hypotheses

The null hypotheses tested in this study were: 1) there are no differences in botanical composition of mule deer diets on two winter range study pastures subjected to sheep grazing the previous spring and no sheep grazing, and 2) there are no differences in the physical characteristics of and nearest species to individual plants consumed and not-consumed by mule deer.

LITERATURE REVIEW

The literature on feeding behavior of ungulates is limited. "Food habit" studies, while numerous, have provided little information on availability of forage species or on the physical condition of plants which might influence selection. Information on physical or chemical properties that influence selection is relatively scant.

Forage Selection

Selection of individual plants of a species is known to be influenced by species "availability", "abundance", and time of year (Smith, 1952). Plant spacing may influence the spacing of grazing animals (Bailey, 1958). Taller grasses in high-yielding *Phalaris*-annual grass-clover pastures influenced species selection by interfering with the ability of sheep to select low growing clovers (Arnold, 1964). This depressed availability of preferred plants increased grazing time. Arnold (1969) noted that homeostasis of forage intake with changing pasture conditions is maintained by altering grazing time, bites per minute, and amount of food consumed per bit. Reppert (1960), Cook et al., (1956) and Arnold (1964) found that green plant material was preferred over dry material by cattle and sheep. Arnold (1964), Malechek and Leinweber (1952), and Krueger (1970) found that animals select leaf material in preference to stem material. Bell (1971), studying native east African ungulates, found that initial utilization of the herbaceous community improved its later acceptability to grazing ungulates by removal of the upper strata of vegetation. Longhurst et al. (1968) suggested that associated chemical indicators may give animals cues to nutrient contents such as protein. Arnold (1966a and b) and Krueger et al. (1974) have shown that smell, taste, touch, and sight influence selection. Rice and Church (1974) have found marked differences in preference of doe and buck blacktail deer for particular liquid extracts of forage species and organic acids over a range of concentrations. A preference for extracts of browse species over pure chemicals was observed in both sexes.

Arnold and Hill (1972) in reviewing chemical factors influencing selection of food plants concluded that chemical factors are probably the primary determinants of selection, and that animals can only respond to molecular concentrations of individual compounds in the form that they occur in plants andonly to those compounds acceptable to an animal's chemical receptors. Quantifying the relationship of chemical composition to palatability has not been accomplished.

Food Habits

A larger number of the forage speces found on northern Utah deer winter ranges were tested by Smith and Hubbard (1954) for "preference" by mule deer in a pen situation. They ranked plants in groups based on "palatability" and "productivity of grazing effort." Mountain mahogany (*Cercocarpus ledifolius*, *C. montanus*), cliffrose (*Cowania stansburiana*), and bitterbrush (*Purshia tridentata*) were rated highest. Aldous (1945), Richens (1967), Flook (1955), Smith (1952), Hoskins and Dalke (1955), and McConnell and Dalke (1960) are in broad agreement on the importance of certain plant species if it is recognized that differences in study locality can influence abundance, availability, and palatability; and that different methods of determining preferences were used. Species mentioned by the above authors as being important to wintering mule deer are bitterbrush, big sagebrush (*Artemisia tridentata*), cliffrose, mountain mahogany, rabbitbrush (*Chrysothamnus* spp.) juniper (*Juniperus* sp.), and low sagebrush (*A. arbuscula*). Other shrub species and forbs are of local importance. Grasses (*Poaceae*) although mentioned by several authors (Dasman, 1949; Julander, 1937; Mackie, 1970), have generally not been found to be of great importance in diets of wintering mule deer. Cowan (1945) noted that food preference ratings are applicable only within limited areas.

Livestock Grazing Influence on Sagebrush Range

Mueggler (1950) and Laycock (1967) both indicated that fall livestock grazing will reduce big sagebrush production on sagebrush ranges. Mule deer winter habitat may have originally been modified by range livestock through a reduction of perennial forbs and grasses which increased the competitive advantage of shrubs (Julander, 1962). Jensen et al. (1972) found that late spring and early summer sheep grazing resulted in little or no reduction in forage production by shrubs by the end of the growing season. They implied that such grazing may actually increase quantities of browse available to deer if properly designed grazing strategies are employed.

Forage Availability and Abundance

As noted by Smith (1952), forage availability and abundance are important factors influencing herbivore diets. They may be expressed in such ways as species cover, species density, and species biomass compared to total herbage biomass (Brown, 1954). Leaf area index (LAI), foliage area or cover as a proportion of ground cover, can be used as an index to dry matter production, gross photosynthesis and respiration rate (Takeda, 1961). An inclined point frame can be used to objectively measure leaf area (Warren-Wilson, 1960, 1965) and by inference can be used to determine the stem area. Foliar density change through time can be measured with inclined point frames (Brown et al., 1966; Loomis and Williams, 1969). Point frame techniques as opposed to traditional harvest methods permit non-destructive measurements of vegetation. Such a method is desirable where repeated measurements on permanent quadrats are of interest.

METHODS

This study was conducted within the framework of a completely randomized experimental design with two treatments: grazing by sheep in spring and no sheep grazing, applied to two adjacent pastures. Mule deer were grazed during two periods the following winter on each pasture. Observations of diets and plant consumption were made utilizing the deer as basic sampling units. Additional factors which were recorded for each observation included winter period, week within period, day within week, time of day, deer age, and observer.

Experimental Area and Material

Study area

The study was conducted at Hardware Ranch, Cache County, Utah, about 48 km southeast of Logan. The elevation is about 1768 m with southerly and southeasterly slopes. The area is similar in physiography and vegetation to much of the northern Utah deer winter range.

Soils of this area have been classified by the Soil Conservation Service into the Ant Flat and Yeates Hollow series, derived from quartzite and quartzite-calcareous sandstone parent materials (Doell, 1966). Soil texture is loam to extra stony silty clay loam. Soils are deep, well drained, and have slow permeability and medium runoff potential.

The vegetation on the study site was a shrub-forb-grass community with bitterbrush and big sagebrush as codominants. A small area in each pasture was dominated by low sagebrush. Serviceberry (*Amelanchier alnifolia*), green rabbitbrush (*Chrysothamnus vicidiflorus*), and Wood's rose (*Rosa woodsii*) were common but with a low density. Chokecherry (*Prunus virginiana*) and a few juniper trees (*Juniperus* spp.) were widely scattered in the area.

Important herbaceous species of abundance were bluegrass (*Poa pratensis*, *P. secunda*), Pacific aster (*Aster chilensis* var. *adcendens*), and mule ear dock (*Wyethia amplexicaulis*). Lupine (*Lupinus caudatus*), yarrow (*Achillea lanulosa*), Great Basin wildrye (*Elymus cinereus*), junegrass (*Koeleria cristata*), beardless wheatgrass (*Agropyron inerme*), and timothy (*Phelum pratense*) were common on the site.

Pastures

The two adjacent pastures were located along a northeast-southwest axis. Each was about 2.4 ha in area. Vegetation types in each pasture were delineated on the basis of aspect dominant species. The bitterbrush-big sagebrush type comprised 80 percent or more of both pastures. Areas of predominantly low sagebrush, creek bed dominated by bluegrasses, and open grassy areas dominated by Great Basin wildrye, bluegrasses and bastard toad flax (*Comandra umbellata*) occupied 10 to 20 percent of both pastures. The area had not been used by livestock in over 20 years.

Although the two pastures were located in an area previously selected for uniformity of both topography and vegetative cover, slight differences became apparent during the course of the study. The sheep-grazed pasture supported a larger area of low sagebrush and a greater ground cover of big sagebrush than the other pasture. The pasture with no sheep grazing (deer pasture) had a larger open grassy area, more area in creek bed, and greater ground cover of bitterbrush (Appendix, Table 15) than the sheep-grazed pasture.

The pastures were enclosed in 1973 with a 2.4 m fence of net wire.

Deer

The mule deer used in the study were pen reared at Utah Division of Wildlife Resources (UDWR) facilities in North Logan, Utah. They were obtained as fawns from does at the facility and from UDWR early each summer during the years 1973-1975. Fawns born at the facility were taken from the does at 24-36 hours post-partum and were fed fresh goat's milk on a schedule similar to that described by Reichert (1972). Fawns from UDWR were animals that had been picked up in the wild at unknown ages, although within a few days of birth. An early removal from natural mothers and a feeding schedule insuring frequent handling was necessary for the fawns to imprint on their handlers. Those that did not imprint were difficult to feed and were eliminated from the herd.

Frequent handling or petting to insure that tractability was maintained was the major training effort. Training to lead and to enter a vehicle, as done by Neff (1974), was not necessary since my deer were transported only four times yearly and were allowed to range freely throughout the winter sampling periods in their respective pastures. Transportation, when necessary, was accomplished by placing the deer in individual crates which were then hauled in a truck to the study site. The use of crates facilitated weighing the deer at the beginning and end of grazing periods, and permitted easy transfer to a horse-drawn sleigh when required by deep snow.

The mule deer used on the study site for sampling were does and fawns except during the winter, 1973-1974, when only fawns were available for preliminary studies.

Sheep

The sheep used for the livestock grazing treatment were range ewes and lambs secured from a local rancher, Mr. Leland Peterson. They were returned to his flock at the end of the grazing period.

Apparatus

An aluminum, electrically driven, inclined point frame was used as the device for vegetation sampling. The unit was powered by a 12 volt wet-cell battery and stood on tubular legs that permitted repeated placement over permanent stakes on each quadrat. A rheostat was used to regulate the flow of power to the motor to slow the pin when moving it through the vegetation.

Casette tape recorders were used to record field observations of diet composition and plant characteristics. Data were later transcribed to coding forms in preparation for key-punching and computer analysis.

Procedures

The sheep-grazing treatment was applied to one of the pastures in late May, 1974. The number of sheep and length of grazing period were designed to achieve 150 sheep days per ha of grazing use or removal of approximately 70 percent of the herbaceous vegetation. Sheep grazing at this time and of this intensity greatly reduces the herbaceous vegetation but removes only limited amounts of shrubby vegetation (Iskander, 1973).

Vegetational analysis

Permanent quadrats, 1.0 m^2 by 1.2 m high, were randomly located in each vegetation type in both pastures. The number of quadrats in the bitterbrush-big sagebrush type of each pasture was based on pre-determinations of the variability in total hits on bitterbrush. There were 46 such quadrats in the sheep-grazed pasture and 62 in the nongrazed pasture. Sampling in the other vegetation types was for descriptive purposes and was not used in statistical analysis. The quadrats were sampled with an inclined point frame (Warren-Wilson, 1963) before and after deer grazing periods. The point frame was systematically oriented in the four cardinal directions on successive quadrats. The bar height of the point frame was 80 cm for each quadrat. If a shrub taller than 80 cm occurred in the quadrat, the bar height was raised to shrub height and the qaudrat was sampled again. During the course of measuring each quadrat, the pin was moved through the length of its travel 20 times at 4 cm intervals across the point frame bar. All hits encountered by the sharpened pin tip were recorded. Information recorded for each hit included plant species, plant part (leaf or stem), whether from current or prior years' growing seasons, whether alive or dead, and distance down the pin from the bar.

In processing the raw data, the distance above the soil surface of each hit was calculated (by the method of similar triangles) and each was assigned to one of six 20-cm horizontal strata (measured from the soil surface upward) for each quadrat. Hits were then categorized by plant species and plant part within each stratum and summed. Data records for each plant part category within a stratum were prepared which identified plant part sums by plant species, pasture, vegetation type, quadrat number, collection date, stratum, and plant part. Where quadrats were sampled at two heights the quadrat summary values were the mean of the two samples. Values presented in Tables 1 and 2 for "all parts" are the means of all quadrats in a pasture across plant parts and strata. Values for age and livelihood (dead or alive) categories (Tables 1 and 2) represent quadrat means for both plant parts (leaves and stems) averaged across all strata. Part category means therefore do not sum to all part means.

Litter was treated as a species with only one possible plant part category. Hits on soil or rock were not recorded. Cover for each species, in percentage of total ground surface, was calculated from the number of first hits on each species per quadrat. The following equation describes this calculation:

Total number of first hits per species/total number of quadrats x 200 pins per quadrat x 100 = percent cover

Species not occuring in a quadrat received a zero value.

Deer grazing

Five mule deer were placed in each pasture for a 6-week period beginning about 1 November 1974 (early winter) and again near the end of March, 1975 (late winter). Three fawns and two adult does were used in each pasture for the two 6-week periods with the goal of achieving 100 deer days per ha use during the entire winter. This degree of utilization is considered typical for mule deer winter ranges in northern Utah (C. Jensen, UDWR, personal communication).

During the 1973-1974 winter, prior to any sheep grazing use, four fawns were placed on the pastures for two short periods for use in developing procedures for deer diet composition sampling and sampling plant characteristics influencing consumption.

Sampling schedule

The first week of each winter period was an adjustment period for the mule deer and was used for calibrating techniques by the observers. The next four weeks were occupied by continuous diet composition and plant selection sampling. The final week was reserved for adjustment of the desired grazing pressure and for removal of the deer from the pastures.

During the four weeks of active sampling, measurements were conducted for 4 consecutive days each week. Four deer, two fawns and two adults, were sampled daily on a rotating time schedule so that no deer was sampled twice at the same time of day during any week. Two observers rotated between pastures on a daily basis. Daily sampling was initiated at 0800, 1000, 1300 and 1500 MST. Diet composition sampling was conducted for 30 min of actual grazing time and was followed immediately by collection of representative mouthfuls of each plant species just eaten. Observations of plant characteristics influencing plant consumption were then made.

Sampling techniques

Diet. The botanical composition of mule deers' diets was sampled by a mouthful-count technique quantified by hand plucking representative mouthfuls of each species taken. The deer were observed for 30 min of actual grazing time. Time spent in walking unrelated to feeding and other activities was excluded. The numbers of mouthfuls of each plant species consumed were tallied on a tape recorder. Observers could stay within a distance of 1 m from most deer if necessary. A mouthful was defined as the amount of forage taken into the mouth between acts of swallowing. A slight ripple of the throat muscles was used as an indicator of swallowing. Immediately following the 30 minute of sampling several representative mouthfuls of each species eaten were hand plucked and placed in individual paper sacks for later drying and weighing. Samples were marked as to species, pasture, week collected, deer represented, and observer. The number of mouthfuls and oven dry weights of mouthfuls were used to compute the percentage contribution, by weight, of each species consumed to the total forage consumed during the 30 min sample period. Mouthful numbers and forage samples for each 30 min period were identified by winter period (early or late), pasture (sheep grazed or ungrazed), week within period, day within week, time of day, deer age, and observer.

This method of quantifying diets of intact animals is a modification of the approaches of Mattox (1971) and Reppert (1960). It is similar to that of Neff (1974) except that Neff used bites rather than mouthfuls as the forage unit.

Plant characteristics. Plant physical attributes and proximity of adjacent plants affecting consumption of a particular plant or contiguous plant group were accompanied by following a deer closely. The characteristics of plants that were consumed and of neighboring plants that were not consumed but were in close enough proximity to the deer to be consumed were measured.

All plants within an arc of about 180° in the direction the animals was facing and not farther than about 1.5 m away from the deer were measured when animals were grazing in shrubby areas. Plants masked from view of the deer by other plants were not measured. In more open situations where only herbaceous plants were within 1.5 m, plants farther away than 1 m from the deer were not described.

For any sequence of observations on an animal, winter period, pasture, week, and age were recorded. For each plant encountered by the deer and measured, the species name, distance from the deer, plant height, plant width, degree of plant use prior to the animal's arrival, an index to the proportion of current live plant material comprising the plant, the species of the nearest neighboring plant, distance to the nearest neighboring plant, and whether the plant being measured was eaten or not were recorded vocally on tape. The degree of prior utilization was one of three categories: light, moderate, and heavy. The categories were based on the extremes encountered in plants of any particular species. The index to proportion of current live plant material was derived in essentially the same fashion having three categories also. This approach was designed to best fit the species most commonly used, bitterbrush and bluegrasses. It did not fit other species as well, particularly those which were dead when consumed such as Pacific aster, mule ear dock, or lupine.

Data analysis

A general least squares analysis with multiple regression methodology (Draper and Smith, 1966) was used in an analysis of variance on the vegetation data and diet composition data. The plant selection data were analyzed using a discriminant function analysis (Cooley and Lohnes, 1962). Although Steele and Torrie (1960) suggest that an arc sin transformation may be appropriate for small percentage values, as are found in the dietary composition data for some plant species, transformations were not used. Therefore, statistical differences demonstrated between small percentage values may be of dubious validity unless the differences are proportionately quite large.

RESULTS

Vegetation

Big sagebrush, bitterbrush, and bluegrasses were evaluated for the bitterbrush-big sagebrush vegetation type. These three species and litter were the only components that occurred in sufficient numbers of quadrats to justify statistical analysis. The bitterbrush-big sagebrush vegetation type was used exclusively in the analysis because of its dominance in both pastures.

Big sagebrush, for all plant part categories, was 77 percent more abundant in the sheep-deer pasture than in the pasture grazed only by deer (Table 1). Bitterbrush, on the other hand, was 70 percent more abundant in the pasture used only by deer than in the sheep-deer pasture. However, there was no difference between pastures in the amount of current year's bitterbrush (Table 1). Evidently, the difference in the total availability was due to old plant parts. Old live parts were 61 percent more abundant in the deer pasture. This indicates that current bitterbrush was proportionately more abundant in the sheep-deer pasture.

Bluegrasses in the sheep-deer pasture were only 39 percent as abundant as in the deer pasture. However, the amounts of current green material were about the same in both pastures (Table 1). Dead leaves and stems of bluegrasses in the sheep-deer pasture

Table 1. Mean number of hits per quadrat for plant species evaluated in two grazing regimes.

Plant species and parts	Grazing Regime: Sheep and Deer	Grazing Regime: Deer only	Standard Error
Big sagebrush			
All parts[1/]	.19	.11***	.01
Bitterbrush			
All parts[1/]	.10	.18***	.01
Current year's parts[2/]	.05	.05	.01
Old live parts[2/]	.21	.35***	.03
Bluegrasses			
All parts[1/]	.09	.24***	.02
Live parts[2/]	.12	.15	.03
Dead Parts[2/]	.11	.41***	.04
Litter	9.71	9.32	.50

***P≤.01

1/ Values are quadrat means for each plant part occurring in all strata considered.

2/ Values are quadrat means of the sum of leaves and stems in all strata considered.

were only 28 percent as abundant as in the deer pasture. Litter amounts were not different between pastures.

Temporal changes were not evident in big sagebrush, old live parts of bitterbrush or in litter (Table 2). However, significant reductions over time were evident in bitterbrush when all parts were considered jointly or when current parts only were considered. Most of the change in "all parts" was associated with the large change in current year's parts. Bluegrasses were much reduced because of snow compaction over the winter.

Dietary Botanical Composition

The major plant species or species groups in the winter diets of mule deer were bitterbrush, grasses (primarily bluegrasses), Oregon grape (*Mahonia repens*), low sagebrush and mule ear dock. Deer in the pasture grazed previously by sheep selected less total bitterbrush than deer in the deer pasture with the differences being due to consumption of less old bitterbrush (Table 3). These deer also used more low sagebrush and more of the miscellaneous forb category than deer in the deer pasture. Oregon grape use was somewhat greater by deer where sheep had previously grazed than where sheep had not grazed.

In the early winter period deer selected somewhat more grass and total herbaceous material but less bitterbrush and total shrub material in the sheep-grazed pasture than in the deer-only pasture (Table 4). Grazing use of old bitterbrush was again less in late winter in the sheep-deer pasture than in the deer pasture but

Table 2. Mean number of hits per quadrat for plant species evaluated before and after deer grazing.

Species	Time of Measurement		Standard Error
	October 1974 (before deer grazing)	May 1975 (after deer grazing)	
Big sagebrush			
All parts[1/]	.16	.14	.01
Bitterbrush			
All parts[1/]	.17	.11***	.01
Current parts[2/]	.08	.02***	.01
Old live parts[2/]	.32	.24	.03
Bluegrasses			
All parts[1/]	.29	.05***	.02
Live parts[2/]	.18	.09***	.03
Dead parts[2/]	.52	.00***	.04
Litter	9.93	9.09	.50

***$P \leq .01$

1/ Values are quadrat means for each plant part occurring in all strata considered.

2/ Values are quadrat means of the sum of leaves and stems in all strata considered.

Table 3. Diets (% botanical composition) of mule deer in winter on two grazing regimes.

Species	Grazing Regime: Sheep and Deer	Grazing Regime: Deer Only	Standard Error
All shrubs	54.3	58.8	2.7
All bitterbrush	38.7	48.8**	2.0
Current bitterbrush	30.4	29.9	1.8
Old bitterbrush	8.3	18.9***	1.4
Oregon grape	9.2	6.7*	1.0
Low sagebrush	4.1	1.7***	0.6
Miscellaneous shrubs	2.3	1.7	0.5
All herbaceous	45.7	41.2	2.1
Grasses	32.9	28.7	2.0
All forbs	12.8	12.5	1.1
Pacific aster	2.8	3.5	0.6
Mule ear dock	3.3	4.5	0.5
Miscellaneous forbs	6.7	4.5**	0.8

***$P \leq .01$
**$P \leq .05$
*$P \leq .10$

Table 4. Diets (% botanical composition) of mule deer in early winter.

Species	Grazing Regime: Sheep and Deer	Grazing Regime: Deer Only	Standard Error
All shrubs	43.1	52.0**	2.7
All bitterbrush	27.8	42.0***	2.7
Current bitterbrush	27.8	33.1	2.5
Old bitterbrush	0.6	8.9***	1.3
Oregon grape	9.0	8.0	1.3
Low sagebrush	2.7	1.1	0.7
Miscellaneous shrubs	3.5	0.9*	0.9
All herbaceous	56.9	48.0**	2.7
Grasses	39.2	32.4*	2.6
All forbs	17.7	15.6	1.6
Pacific aster	4.8	5.9	1.1
Mule ear dock	6.3	4.7	0.9
Miscellaneous forbs	6.7	5.2	0.9
All herbaceous	56.9	48.0**	2.7

***$P \leq .01$
**$P \leq .05$
*$P \leq .10$

consumption of current bitterbrush was slightly higher during that period (Table 5). Oregon grape and low sagebrush use was higher but miscellaneous shrub and mule ear dock use was lower in the sheep-grazed pasture than in the other.

The relationship of some species and plant categories in diets changed between pastures from early to late winter (Figure 1). The relationships depicted are those indicated as statistically significant through tests of interactions in the analysis of variance. In the sheep-deer pasture, current bitterbrush in diets increased from early to late winter while miscellaneous shrubs and mule ear dock declined. In contrast, current bitterbrush in the deer pasture declined in dietary importance through the winter while miscellaneous shrubs increased and mule ear dock declined slightly.

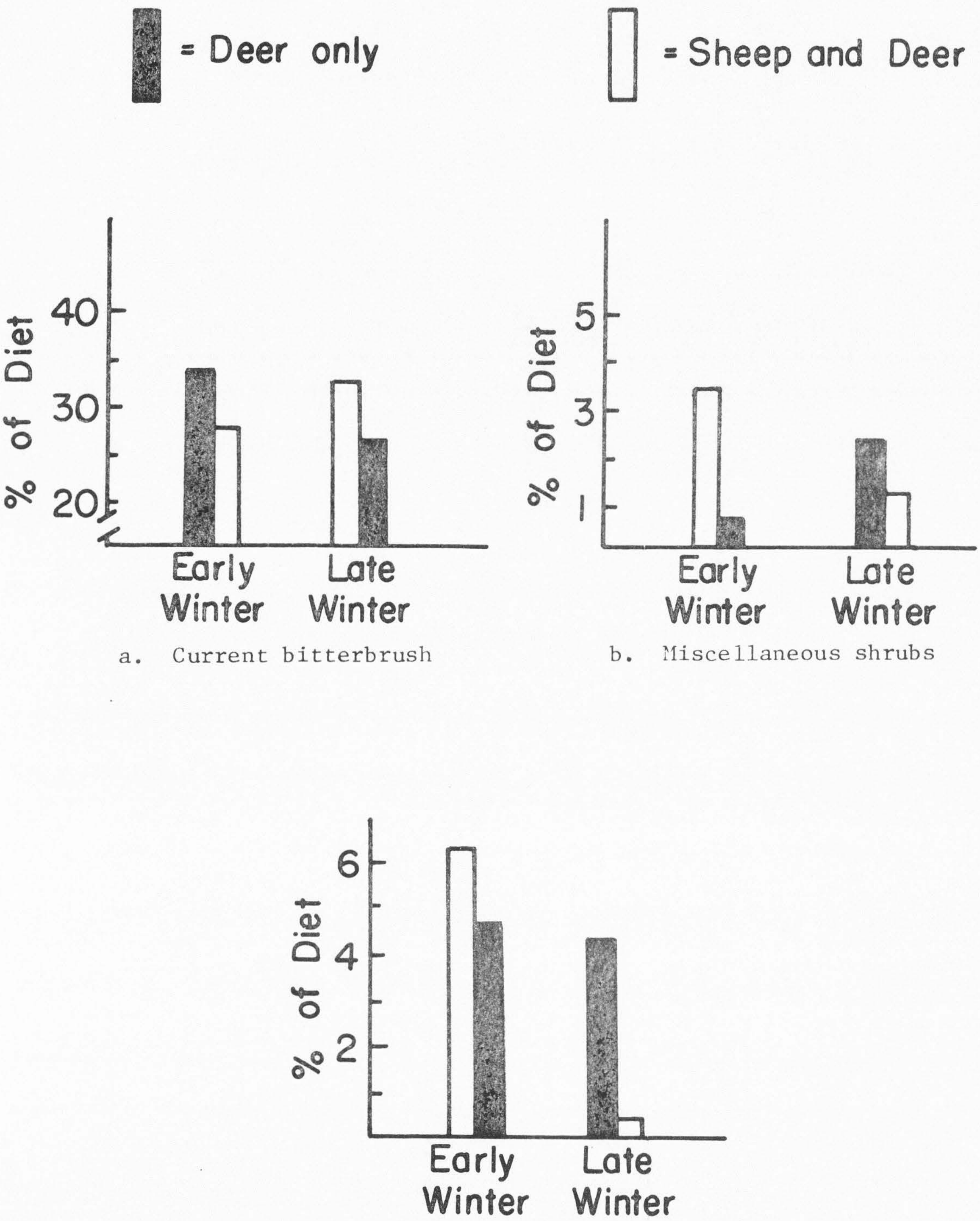
Averaged across both treatments, dietary changes reflecting winter periods occurred in several species and categories (Table 6). Of the shrubs, old bitterbrush, total bitterbrush, and all shrub utilization increased dramatically in late winter while all classes of herbaceous plants declined in utilization.

Weekly changes within winter periods occurred in many species and categories of the deers' diets. For example, in the early winter, dietary use of all shrubs increased through the 4-week period except for some decline in consumption of current bitter brush (Table 7). All herbaceous species declined in importance during the early-winter period except for grasses which remained relatively stable. Trends in relative importance of dietary items

Table 5. Diets (% botanical composition) of mule deer in late winter.

Species	Grazing Regime: Sheep and Deer	Grazing Regime: Deer Only	Standard Error
All shrubs	65.5	65.6	3.1
All bitterbrush	49.5	55.5	3.0
Current bitterbrush	32.9	26.7*	2.6
Old bitterbrush	16.6	28.8***	2.4
Oregon grape	9.3	5.4*	1.6
Low sagebrush	5.5	2.2**	1.3
Miscellaneous shrubs	1.2	2.5*	0.5
All herbaceous	34.4	34.4	3.1
Grasses	26.5	25.0	2.9
All forbs	7.9	9.4	1.4
Pacific aster	0.8	1.2	0.4
Mule ear dock	0.4	4.3***	0.9
Miscellaneous forbs	6.7	3.9	1.2

***$P \leq .01$
**$P \leq .05$
*$P \leq .10$



a. Current bitterbrush

b. Miscellaneous shrubs

c. Mule ear dock

Figure 1. Temporal changes in the three dietary components as influenced by grazing treatment.

Table 6. Diets (% botanical composition) of mule deer for two winter periods.

Species	Winter Period Early	Winter Period Late	Standard Error
All shrubs	47.5	65.6***	2.1
All bitterbrush	34.9	52.5***	2.0
Current bitterbrush	30.5	29.8	1.7
Old bitterbrush	4.4	22.7***	1.3
Oregon grape	8.5	7.4	1.0
Low sagebrush	1.9	3.9**	0.6
Miscellaneous shrubs	2.2	1.8	0.5
All herbaceous	52.5	34.4***	2.1
Grasses	35.8	25.8***	2.0
All forbs	16.7	8.6***	1.1
Pacific aster	5.3	1.0***	0.6
Mule ear dock	5.5	2.3***	0.5
Miscellaneous forbs	5.8	5.3	0.8

***$P \leq .01$
**$P \leq .05$

Table 7. Diets (% botanical composition) of mule deer by weeks during the early winter period.

Species	Weeks 1	2	3	4	Standard Error
All shrubs	39.5a[1/]	39.4a	57.4b	53.8b	3.9
All bitterbrush	30.1	29.7	38.7	41.2	3.9
Current bitterbrush	30.1a	29.7a	38.7b	23.4a	3.6
Old bitterbrush	0.0a	0.0a	0.0a	17.8b	1.9
Oregon grape	7.1	5.6	12.2	9.1	1.9
Low sagebrush	0.0a	1.1a	4.7b	2.0a	1.0
Miscellaneous shrubs	2.4	3.0	1.9	1.5	1.3
All herbaceous	60.5a	60.6a	42.6b	46.2b	3.9
Grasses	38.8	32.9	32.2	39.2	3.8
All forbs	21.6a	27.7b	10.3c	7.0c	2.3
Pacific aster	10.8a	7.7b	1.4c	1.5c	1.5
Mule ear dock	4.7a	11.1b	3.5ac	2.5c	1.3
Miscellaneous forbs	6.1ab	8.9a	5.4b	3.0b	1.3

[1/] Means within rows followed by a common letter are not significantly ($P \leq .05$) different.

in the late winter period were generally opposite to those of the early winter (Table 8). All shrubs except old bitterbrush and low sagebrush declined in importance while all herbaceous species except mule ear dock became increasingly important as the period progressed.

Some dietary components followed different trends in the two pastures as the winter periods progressed (Figure 2) as indicated by significant interaction tests in the analysis of variance. Consumption of all bitterbrush in the sheep-deer pasture fluctuated much more than it did in the deer pasture. Consumption levels of all bitterbrush in the sheep-deer pasture equaled or exceeded the levels in the deer pasture during one week in early winter and two weeks in late winter. Old bitterbrush (Figure 3) was consumed avidly late in the early winter period by deer in the deer pasture, in contrast to animals in the sheep-deer pasture that did not begin consuming it until the late winter period. All forb use (Figure 4), similar in the two pastures throughout the early winter, alternated positions of relative importance in late winter.

The variables, day of week, time of day of sampling, and deer age influenced botanical composition of the deers' diet. Species and species groups varying in the diets with sampling days within weeks were bitterbrush and low sagebrush (Table 9). Means are for days across all weeks, periods, and pastures. Variation among days had no apparent explanation. The trend seemed to be a random cycle. Observer effects were not significant for any major component of the diets of deer.

Table 8. Diets (% botanical composition) of mule deer by weeks during late winter period.

Species	Weeks 1	2	3	4	Standard Error
All shrubs	78.2a[1/]	69.8b	72.0ab	42.4c	4.4
All bitterbrush	61.5a	59.5a	57.0a	32.1b	4.2
Current bitterbrush	38.1a	38.3a	31.9a	10.9b	3.6
Old bitterbrush	23.4	21.2	25.1	21.9	3.4
Oregon grape	11.0a	8.3a	7.7a	2.3b	2.2
Low sagebrush	0.8a	1.2a	5.5b	7.9b	1.4
Miscellaneous shrubs	4.8a	0.7b	1.8b	0.0b	0.7
All herbaceous	21.8a	30.2b	27.9ab	57.6c	4.4
Grasses	19.9a	24.0a	20.9a	38.1b	4.2
All forbs	1.9a	6.2b	7.0b	17.4c	2.0
Pacific aster	0.0a	0.0a	0.5a	3.4b	0.5
Mule ear dock	1.3a	5.3b	2.2a	0.5a	0.8
Miscellaneous forbs	0.6a	0.9a	4.4b	15.4c	1.8

[1/] Means within rows followed by a common letter are not significantly ($P \leq .05$) different.

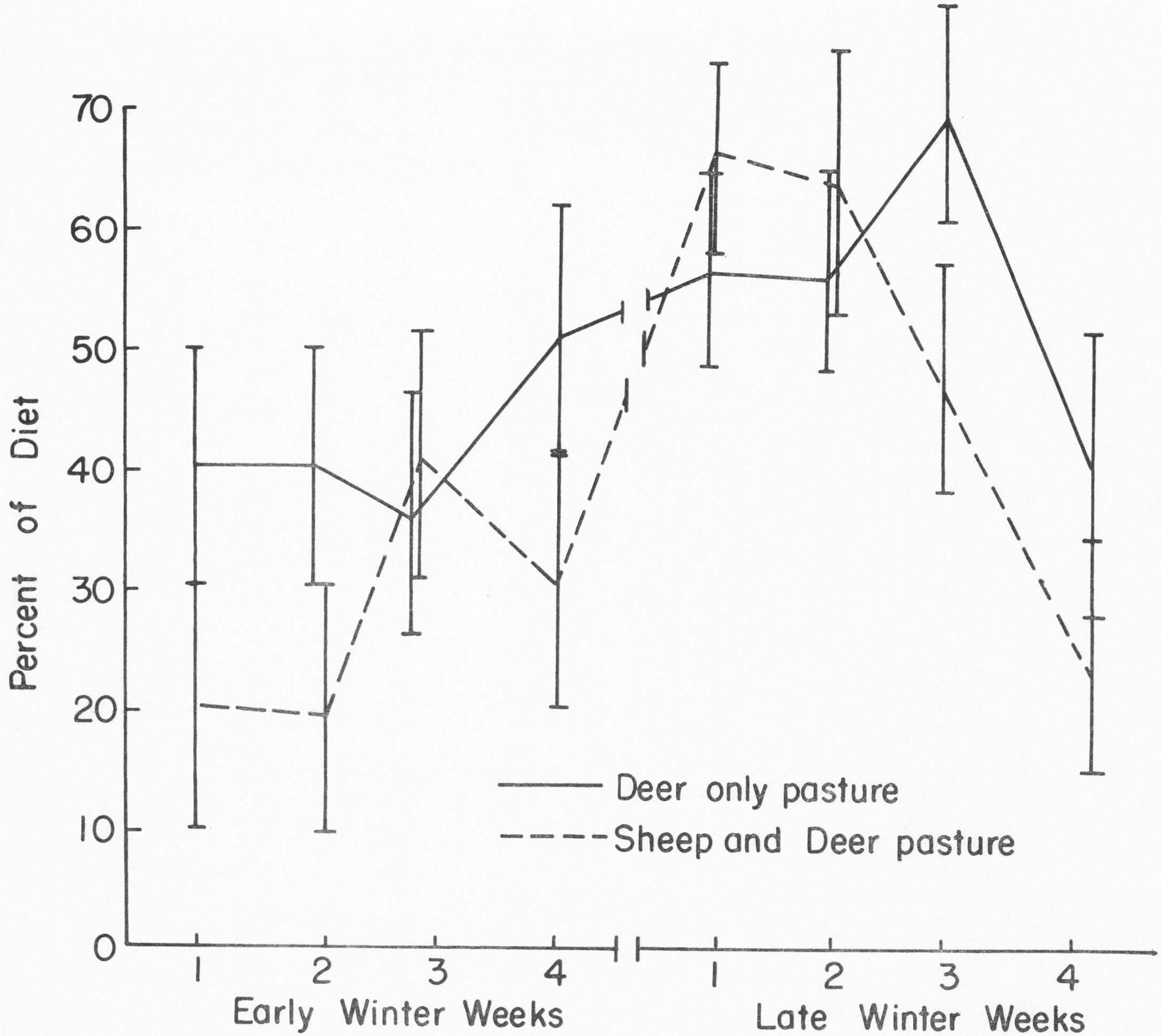


Figure 2. The relationship of total bitterbrush in diets of mule deer grazing in two regimes. Vertical bars represent 95 percent confidence limits.

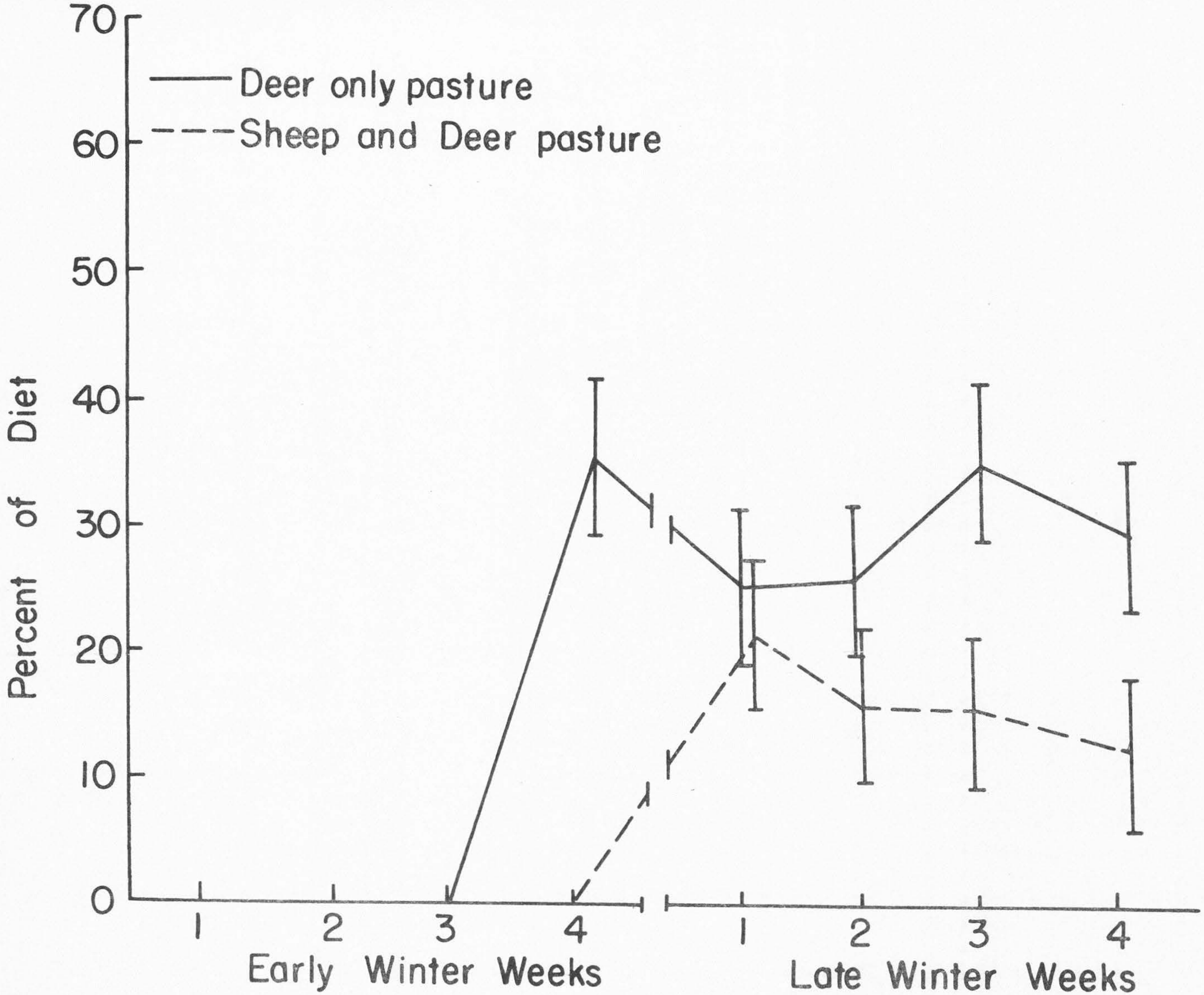


Figure 3. The relationship of old bitterbrush in diets of mule deer grazing in two regimes. Vertical bars represent 95 percent confidence limits.

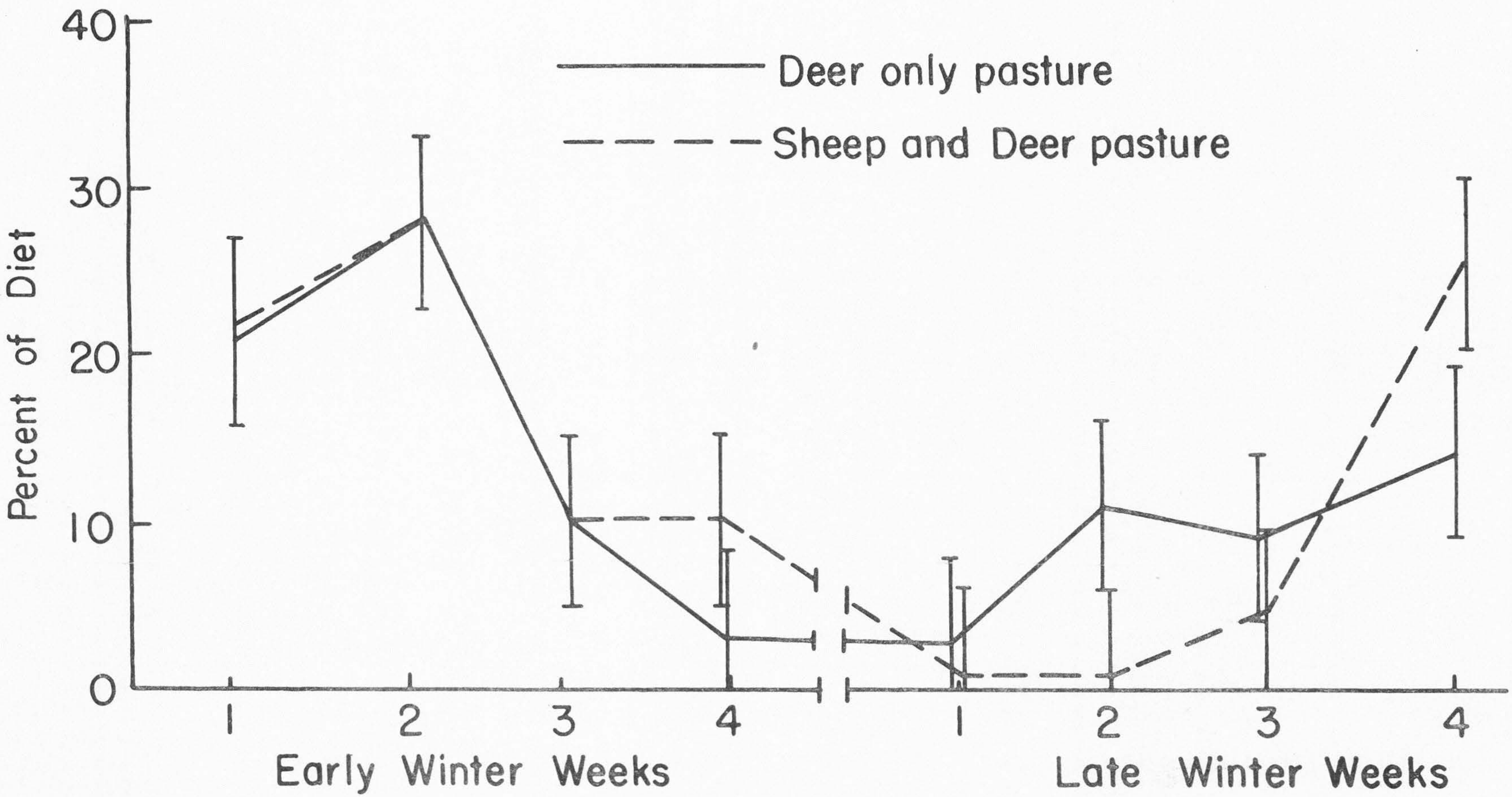


Figure 4. The relationship of all forbs in diets of mule deer grazing in two regimes. Vertical bars represent 95 percent confidence limits.

Table 9. Diets (percent botanical composition) of mule deer on four consecutive sampling days.

Species[1/]	Sampling Days Within Weeks 1	2	3	4	Standard Error
All bitterbrush	41.6ab[2/]	49.6b	44.2ab	39.4a*	2.8
Current bitterbrush	30.9ab	34.4b	31.0ab	24.2a**	2.5
Low sagebrush	2.2ab	1.6a	3.0ba	4.8b*	0.9

[1/] Only species with statistically significant differences (**≤.05, *P≤.10) are listed.

[2/] Means within rows followed by a common letter are not significantly different.

Species and plant groups in the diet varying with time of day were Oregon grape, grasses, all bitterbrush, all herbaceous plants, miscellaneous shrubs, and all shrubs (Table 10). Shrubs seemed to received greater use early in the day, while herbaceous and low growing species such as the Oregon grape received less use in early morning. Mean air temperatures at sampling times (Table 11) followed the same trend as herbaceous species and Oregon grape in deer diets. Temperatures were low in the morning and increased through the day.

Table 10. Diets (percent botanical composition) of mule deer at daily sampling times.

Species[1/]	Sampling Time Within Days 0800	1000	1300	1500	Standard Error
All shrubs	62.4a[2/]	54.0ab	57.7ab	52.1b*	2.9
All bitterbrush	50.2a	42.0ab	41.4ab	40.6b*	2.8
Oregon grape	5.7a	5.8ab	12.0b	7.3ab**	1.4
Misc. shrubs	3.7a	1.8ba	1.3b	1.2b*	0.7
All herbaceous	37.6a	46.0ab	42.3ab	47.8b*	2.7
Grasses	24.5a	34.0ab	29.3ab	35.3b**	2.8

[1/] Only species with statistically significant differences (**P≤.05, *P≤.10) are listed.

[2/] Means within rows followed by a common letter are not significantly different.

Table 11. Mean air temperature (°C) at daily sampling times.[1/]

	0800	1000	1300	1500
Early winter	-3.5	-0.5	4.0	5.0
Late winter	2.0	2.0	5.0	4.5

1/ Data not statistically analyzed

Deer age influenced consumption of old bitterbrush, mule ear dock, and miscellaneous forbs and shrubs (Table 12). Fawns appeared to have selected less than the other deer of the more fibrous plant materials, particularly old bitterbrush and miscellaneous shrubs.

Table 12. Diets (percent botanical composition) of fawn and adult mule deer across grazing regimes and winter periods.

Species[1/]	Fawns	Adults	Standard Error
Old bitterbrush	11.2	16.0**	1.4
Miscellaneous shrubs	4.3	6.8*	0.8
Mule ear dock	4.8	3.0**	0.5
Miscellaneous forbs	4.3	6.8**	0.8

1/ Only species with statistically significant differences (**$P \leq .05$, *$P \leq .10$) are listed.

Plant Selection

Several plant characteristics in addition to the plants' locations in the treatments (pastures) and in time (winter period and week within period) appeared to have predictive capabilities when applied to the selection of individual plants by deer. Degree of prior utilization, amount of current live plant material, and distance of the plant from the grazing deer seemed to be the most important characteristics for all species. The species of the nearest neighboring plant and the height of the plant considered also appeared important for some plant species (Table 13).

When all plant species are considered together, the characteristics in order of importance for predictive ability were degree of prior use, amount of current green plant material, distance of the plant from the grazing deer, species of nearest neighboring plant, and plant height. Ranking of plant characteristics was determined by a stepwise deletion process (Miller, 1960) in which each characteristic was evaluated as to its individual contribution to the predictive ability of the collection of characteristics being considered for a species or species grouping.

Physical characteristics of importance for individual species were ranked differently, depending upon the species under consideration (Table 13). For example, with bitterbrush the order of importance was amount of current green material, distance from deer, species of nearest plant, and degree of prior use. For grasses, the ranking was amount of current green plant material, plant height, distance from deer, and degree of prior utilization. For mule ear dock, the order was pasture (i.e. previously grazed or not grazed by sheep) and degree of prior use. With allium (Allium spp.) the ranking was distance to deer and species of nearest plant. The ranking of characteristics for low sage was weeks within periods, winter periods, prior use, and distance from grazing animal.

Table 13. Plant characteristics (including grazing treatment and time factors) statistically different ($P \leq .05$) between plants consumed and those not consumed by grazing mule deer on winter ranges.

Characteristic	Plant Species and Groups Considered					
	All Species (12 species)	Bitterbrush	Grass	Mule ear dock	Allium	Low Sagebrush
Degree of prior use	1 [1/]	4	4	2		3
Amount of current green plant material	2	1	1			
Distance from grazing deer	3	2	3		1	4
Species of nearest neighboring plant	4	3			2	
Plant height	5		2			
Pasture				1		
Winter period						2
Week within winter period						1

1/ Numbers (in columns) denote importance rank (decreasing scale) of plant characteristics to the selection of various species and species groups by mule deer. Absence of a number indicates the relationship was not statistically significant.

A discriminant function (Cooley and Lohnes, 1962) was calculated from the relative positions of the selected and rejected groups of plants when plotted in a multidimensional hyperspace where the characteristics were axes. This permitted evaluation of individuals as to their probably membership in one of the groups. Upon computing the discriminant function, all individual plants from each group (selected and rejected by grazing deer) were evaluated according to their characteristics and without consideration for their previous consumption or non-consumption by deer. They were then grouped solely on the basis of their physical characteristics into selected or rejected plants (Table 14). A measure of the performance of the discriminant function would be the correct placement of individual plants back into the groups from which they originated. Correct placement into the selected group varied from 69 to 81 percent of the cases depending on the species or species group. Successful placement into the non-consumed group was much lower, from 53 to 61 percent except for allium and low sage with success of 78 percent and 84 percent, respectively.

Table 14. Placement by the discriminant function of individual plants from groups of plants consumed and not-consumed by grazing mule deer.

Species	Group placement by deer (numbers of plants) Totals	Group placement by discriminant function (numbers of plants) Consumed	Not consumed	% Placed correctly
All species				
Consumed	1078	776	302	72
Not consumed	1597	751	846	53
Bitterbrush				
Consumed	357	271	86	76
Not consumed	360	173	187	52
Grass				
Consumed	332	269	63	81
Not consumed	306	119	187	61
Mule ear dock				
Consumed	82	64	18	78
Not consumed	50	21	29	57
Allium				
Consumed	83	66	17	79
Not consumed	55	12	43	78
Low sagebrush				
Consumed	47	32	15	69
Not consumed	133	21	112	84

DISCUSSION

The results of this study indicate that the null hypotheses being tested are to be rejected. There were differences in diets of mule deer on two winter range situations: one subjected to heavy grazing by sheep the preceeding spring and the other not grazed by sheep. Some of these differences are explainable in terms of the sheep grazing effects. There were also differences in physical characteristics, nearest neighboring plant species, location in grazing treatment, and time of selection of individual plants consumed versus those not consumed by grazing mule deer.

Vegetation

The greater abundance of big sagebrush in the sheep-deer pasture is largely attributable to inherent features of the site. Sheep grazing could have enhanced the amount of current growth by releasing moisture and nutrients to the big sagebrush. Evidence of sheep grazing of big sagebrush was absent. No current growth had any apparent consumption by deer. Reduction in litter cover has been used as an indicator of heavy grazing (Stoddart et al., 1975) but litter was not reduced by the one season of sheep grazing applied in this study. A litter reduction due to heavy sheep grazing over the long term would be expected.

The greater natural abundance of bitterbrush in the deer pasture is evident from the difference in old live parts between the two pastures. However, the apparent effect of sheep grazing, the release of moisture and nutrients from herbaceous plant use to shrub use, is evident from the greater proportion of current bitterbrush to old live bitterbrush (plant material largely consisting of growth from previous seasons) in the sheep-deer pasture. This supports earlier work by Smith and Doell (1968) and Jensen et al. (1972) who suggested the favorable effects of regulated livestock grazing on subsequent shrub production.

The reduction in the total amount of bluegrassses, and in particular dead leaves and stems, in the sheep-deer pasture is directly attributable to sheep grazing. However, the absence of a difference in the amount of current green growth of bluegrasses in the fall indicates that fall precipitation had an equal effect on the two pastures in providing sufficient soil moisture for grass regrowth. The important difference in the nature of the bluegrasses was that in the sheep-deer pasture the fall regrowth was relatively free of dry, cured leaves and stems from growth the previous spring and summer. Cured grasses could offer some mechanical intereference but more likely changed the olfactory and gustatory stimuli offered by grasses and other species to deer. Moreover, forbs and other low growing plants (e.g. Oregon grape) were not obstructed by the cured grasses. Arnold (1962) stated that tall grasses reduced consumption by sheep of low growing clover in Phalaris-annual grass-clover pasture.

Temporal changes in plant material were of two causes: deer grazing, and weathering and breakage due to snow cover during the winter. As expected, the old live parts of shrubs were little affected by combined grazing and weathering and breakage, but current bitterbrush parts were appreciably reduced. As current twigs on bitterbrush are pliable and resistant to breakage, most of the reduction of that forage category over time is likely due to deer grazing. However, the unknown reduction in current bitterbrush due to winter effects precludes attempting to quantify mule deer consumption on the basis of forage disappearance without a suitable control not subjected to grazing.

The measured reduction in blue grass from prior-to-deer-grazing to post-deer-grazing must largely be assessed in terms of phenological changes. Disappearance of plant material due to deer grazing could not be distinguished from other changes. The weathering and crushing effects of snow effectively changed the status of most leaf and stem material from standing live and dead to litter, although some green material persisted under the snow cover. Most green leaf and stem material found in the spring was due to initiation of spring growth in exposed locations.

Dietary Botanical Composition

The relative amounts of various plant species available obviously influenced the amounts consumed. Although not central to this study, it is interesting to note that with two obvious exceptions, the plant species most abundant in the pastures were consumed in the largest quantity by deer. Big sagebrush, although very abundant and available, received little dietary use while the rare Oregon grape, not found in any vegetation sample quadrat, was consumed in significant amounts. Consumption of large proportions of more abundant species like bitterbrush and bluegrass would seem to be beneficial to deer. Absence of big sagebrush consumption probably indicates that other more palatable species were of sufficient abundance that an adequate diet could be obtained without big sagebrush use.

The relationship of bitterbrush and low sage consumption in winter long diets between the two pastures was similar to the relationship of amounts available. The deer-pasture contained more bitterbrush and less low sage than did the sheep-deer pasture. The differences were reflected in animal diets in the two pastures. Consumption of grass and all herbaceous species in the sheep-deer pasture was slightly, although not significantly, greater in the other pasture for winter long diets. Significant differences between pastures existed in the early winter period. The greater abundance of Oregon grape and miscellaneous forbs in the diet from the sheep-deer pasture could be attributed to the lesser amount of standing dead grasses covering and interfering with consumption of these low growing species.

In late winter, herbaceous species eaten by deer were less influenced by previous sheep grazing than by phenological changes due to seasonal progression. An exception was mule ear dock, a species used more in the deer-use-only pasture. As the snow melted in late winter and growth of herbaceous species was initiated, their contributions to deer diets correspondingly increased as more plant material became available. Mule ear dock, however, did not initiate growth until after deer grazing had ceased. Thus the only mule ear dock available in late winter was from the previous growing season and subjected to both sheep and deer grazing in the pasture with that treatment. The differences between treatments in selection of old bitterbrush became more pronounced in this period when animals in the sheep-deer pasture consumed lesser quantities of this material than did animals in the deer pasture. This strongly suggests an improvement in deer dietary quality due to sheep grazing. Short (1971) and Cowan et al. (1970) have demonstrated the higher nutritional quality (digestibility, protein content) of current year's twigs as compared to one-year-old and older twig material.

The decline through the winter in current year's bitterbrush consumed by animals in the deer pasture may indicate a decline in availability due to consumption. In contrast, the increased consumption of this material during the same time in the sheep-deer pasture suggests that its availability was maintained in the early winter, probably as an indirect result of greater use of alternative forages. This suggestion assumes no great change in palatability of current bitterbrush in either pasture during the winter. Miscellaneous shrubs, including serviceberry and green rabbitbrush, may have received increased use in late winter in the deer pasture in response to a shortage of more palatable forages. The decline in dietary importance of miscellaneous shrubs during the same period in the sheep-deer pasture can be attributed to no other cause than reduced availability due to consumption although greater consumption of this food category in this pasture in early winter is unexplained by abundance. Mule ear dock may have been more accessible to the grazing deer during early winter in the sheep-deer pasture, although less abundant because of previous sheep use. Iskander (1973) indicated appreciable consumption of this species by sheep in spring. By late winter consumption and lack of initial abundance greatly reduced its presence in the diet of deer in contrast to the deer-use-only pasture where only a slight decline was noted.

Snow cover during most of the late winter period reduced the availability of all herbaceous plant species. This is reflected in the greater dietary importance of most shrubs in both pastures during this period. The reduction in importance of current bitterbrush relative to old bitterbrush seems to be reflective of its reduced availability due to consumption. Reduced availability of forbs due to deer consumption would seem to account for their decline in importance through the early winter period and the simultaneous increase in shrub utilization there, as there was only one snowfall during the third week, and it melted rapidly. Snow melt followed immediately by the beginning of spring growth accounted for the sudden increase in importance of all herbaceous species with a corresponding decline in shrub use in the fourth week of the late winter period.

Although plants were reduced in availability by prior deer use, snow cover and plant phenology seem to account for the general trends in plant species present in diets through the winter. Prior sheep grazing may be responsible for some of the dissimilarity in trends through the winter for bitterbrush consumption. The much lower level of bitterbrush use in the sheep-deer pasture at the beginning of the winter probably indicates a greater accessibility of preferred herbaceous plant material, particularly green grass regrowth. The steep increase in bitterbrush use in the third week of fall followed by a drop in the fourth week coincided with a short duration snow cover. This obviously reduced accessibility of low growing plants. Interestingly, bitterbrush use in the deer pasture did not respond similarly, indicating that those deer were able to cope with the soft uncompacted snow cover and maintain the same level of grass use. Taller grass and forbs seemed to break the continuity of the snow cover leaving more exposed plant material. The earlier use of old bitterbrush in the deer pasture is probably indicative of the lesser accessibility of perferred herbaceous plant material because of the larger amount of cured grasses.

In late winter consumption of forbs in the deer pasture was higher than in the other pasture, especially during the first three weeks. There were more of the taller forbs, especially mule ear dock from the previous growing season, still accessible, even with crusty compacted snow cover. The reversal of this trend in the fourth week corresponded to earlier spring greenup in the sheep-deer pasture. Greenup in the deer pasture began approximately 4-7 days later and was retarded in part by the greater herbaceous ground cover there slowing soil warming (Geiger, 1965).

Dietary variations among sampling days in bitterbrush and low sagebrush probably involved nothing more than chance variation. No observed change in climatic condition or forage condition coincided with these apparent cycles. Bitterbrush use was greatest when low sage use was at its lowest level.

Air temperature variations and frost conditions provide the best explanation for the greater utilization of tall shrubs in the early morning hours and the correspondingly lesser use of herbaceous plants and Oregon grape at that time. The species used least in early morning are all low growing and tended to be distributed as discrete units widely scattered in space. Cold temperatures and the presence of frost during early morning hours reduce molecular activity of volatile chemical compounds of plants (Arnold and Hill, 1972). As olfaction is probably of primary importance in food selection by deer (Longhurst et al., 1968) the depressed molecular activity would reduce the ability of animals to locate discrete and scattered plants like Oregon grape or even short frost-covered grass. Tactile responses of the deer could be implicated also, as bitterbrush twigs appeared to be more brittle and more easily broken off at sub-freezing temperatures. No objective tests were made to confirm this point, however. As the early morning was observed to be a somewhat more concentrated feeding period than any time later in the day, an increased attention to the easily obtainable shrubs might have been possible, even without involvement of temperature-related factors.

The apparently smaller digestive capacity of fawns to process fibrous plant material was indicated by the greater consumption by adult deer of old bitterbrush and miscellaneous shrubs. Fawns require a higher quality diet than adults to compensate for the smaller rumen capacity relative to body size and for growth requirements (Moen, 1973).

Plant Selection

The physical characteristics of an individual plant that were found to influence consumption by a mule deer are probably indicators of other plant factors eliciting olfactory, gustatory, or tactile responses in the deer. Deer frequently would reach under shrubs for plants (e.g. Oregon grape) that were not visible to the observer. A thin soft snow cover was not a serious deterant to selection of species under it when air temperatures were above 35°F. Colder temperatures seemed to decrease consumption of the harder-to-locate plants. Olfaction, therefore, seemed to be the most important sense used by deer in selecting plants for feeding. Some testing of woody twigs before biting them off was noted. Animals would pull at twigs with their mouth. More frequently a twig once pulled at with the incisors was rejected without further action if it did not immediately break.

Evaluation of all species together in the discriminant function was done primarily to determine which characteristics would be of use with individual species evaluations. From this evaluation the results as noted in Table 13 were extracted.

Degree of prior utilization could be relayed to the deer as either olfactory or tactile stimuli. Heavy prior use could reduce the amount of plant material available to provide the volatile molecules providing the olfactory stimulus in most species and leave plant material relatively more fibrous. In grasses, however, prior utilization particularly by sheep may have enchanced consumption by removing dead stems and leaves which would later interfere with consumption by the deer. Prior utilization of some species may leave only coarse woody plant material that increases the likelihood of non-consumption by the grazing deer because the material is harder to bite and chew. The importance of plant height is in its relation to prior utilization. Taller plants within a species usually had received less utilization.

The amount of current green plant material may also determine the extent of olfactory and tactile stimuli. Greater proportions of green material should increase the level of olfactory stimulus provided by a plant by providing more leaf area from which volatile compounds may eminate. Current green material should also be easier to bite off and chew thus requiring lower energy expenditure in foraging.

The distance away from the deer that a plant is found should influence the strength of olfactory stimuli reaching the animal. The farther away the plant may be, the greater the dilution and the mixing of odors from all other species in the vicinity. Distant plants would be less likely to be located by the grazing animal. Arnold and Hill (1972) suggest that ruminants can discriminate odors only at short range. The increased energy expenditure involved with selecting a palatable but distant plant over a close but less palatable once should also influence the deer to select the closer one, if indeed deer are capable of such optimization decisions as is hypothesized for other mammalian species (Schoener, 1971). Extensive use of rare plants by deer in this study did not seem to be the result of the animal seeking out the plant but rather his taking of every rare plant encountered.

The presence of some plant species apparently enhanced selection of others while the presence of other species in the vicinity increased the likelihood of non-consumption of a particular species. For all species, the presence of bitterbrush and Pacific aster probably enhanced consumption while the presence of big sagebrush was negatively related. Whether this effect is due to the odor of the species or to some other factor such as association of some other species with bitterbrush would be difficult to speculate upon at this point. Iskander (1973) found that bitterbrush plants growing close to big sagebrush received less utilization by sheep than bitterbrush plants not in close proximity to big sagebrush. Low sagebrush and big sagebrush are associated with allium selection possibly because allium is more frequently found growing around the sagebrushes.

Pasture or grazing treatment was a significant factor for only one species, mule ear dock, probably because there was a strong relationship between grazing treatment and prior utilization of this species. Plants in the deer pasture would have received no prior use until the deer were introduced there in contrast to the other pasture where grazing by sheep in spring had appreciably reduced the quantity of this species.

Winter period and weeks within period are important variables because low sagebrush was used more in late than in early winter and more in the last two weeks of either period than during the first two weeks. The importance of these factors is probably largely indicative of the relatively low palatability of low sagebrush and the diminishing abundance of other species as winter progressed.

The implications of the relatively high success of the disciminate function in placing selected plants back into their respective groups (Table 14) are that mule deer seem to be fairly specific in the characteristics they use to select a plant for consumption and that these characteristics should be of some usefulness in evaluating a range area for suitability and quality. The low success achieved in placing rejected plants into their respective groups suggest that there is a significant amount of background noise associated with selection, and that the deer were capable of filtering it out, but observers were not. A refinement of the present definition of material within a deer's scope of attention would probably be of great value. Deer appeared to not consume plants that were similar to the ones they consumed when in reality what may have happened was that many of the plants recorded by observers as rejected may never have been considered by the animal. If, as seems likely, olfaction is the primary sense initiating consumption, then a working definition of distance to a plant for recognition of desirable qualities would have to be established under the environmental conditions prevailing at the time of any future study. Factors such as volatility of plant chemicals, size of plants, wind speed, and wind direction would have to be considered.

SUMMARY AND CONCLUSIONS

Lower elevation foothill ranges in the Intermountain West serve as mule deer winter ranges and as spring range for much of the range livestock industry. These ranges are usually limited both in extent and in carrying capacity relative to other seasonal ranges, and thus effectively limit production of both mule deer and livestock. Considering the high potential for competition between domestic and game animals on these ranges, previous researchers have developed livestock management systems directed at better integrating the two types of grazing use. This study examined the response of mule deer to one such system.

The specific purposes of this study were to determine botanical composition of diets selected by mule deer on winter range subjected to two intensities of previous spring grazing by sheep and to develop a basis for predicting grazing selection of individual plants based on their physical characteristics and the species and physical proximity of associated plants.

The study was conducted within the framework of a completely random experimental design with two treatments. Variables noted for each unit observed included treatment (previously grazed or not grazed by sheep), winter period (early winter vs late winter), weeks within periods (four weeks per period), days within weeks (four days per week), daily sampling time (four times per day), and age of animal (fawns vs adults), and identity of observer. The study site was located at Hardware Ranch, Cache County, Utah. The vegetation on the site was a shrub-grass-forb community with bitterbrush and sagebrush as codominants.

Two adjacent 2.4 ha pastures were fenced. A sheep grazing treatment of 150 sheep days per ha was applied in late May, 1974, to one pasture. This intensity of grazing achieved roughly 70 percent utilization of herbaceous species. The availability of vegetation was determined the following fall and at the end of deer grazing in each pasture with an inclined point technique. Data thus derived included percent cover and hits by plant part for each plant species. Five hand-reared mule deer, two adults and two fawns, were placed in each pasture for two six-week periods, one beginning in early November and the other near the end of March, with the goal of achieving 100 deer days per ha utilization. Sampling for dietary composition and for plant characteristics influencing consumption was conducted on the same four deer daily in each pasture during four weeks of each winter period. Each deer was observed for 30 minutes of actual grazing at a different time each day to determine dietary composition. Diets were quantified by a mouthful-count technique and hand plucking of representative mouthfuls of each species consumed. Plant physical characteristics potentially influencing selection were sampled by following a grazing deer and noting for each plant encountered by the deer, the species name, its distance from the deer, its height, width, and degree of prior utilization, as well as the proportion of current live plant material present, species of nearest plant, the distance to the nearest plant, and whether the subject plant was consumed or not consumed by the deer.

Differences were found between pastures in forage availabilty and abundance, and in mule deer diet botanical composition. Some of these differences are attributable to the effects of sheep grazing, while some reflected inherent differences in the productivity of the two pastures. Sheep grazing increased the proportion of current bitterbrush available and reduced the amount of cured grasses. These vegetational differences resulted in a mule deer diet appreciably higher in herbaceous species and lower in shrubs in the sheep-deer pasture than the deer pasture. The proportion of current bitterbrush to old bitterbrush in diets was also appreciably greater in the sheep-deer pasture. The probable mechanism for these differences is that the absence of an abundance of tall cured grasses where sheep had grazed reduced interference to the deer in selecting preferred green grasses and forbs. The greater accessibility of herbaceous plant material permitted the deer in the sheep-deer pasture to shift utilization pressure away from the shrubs until snow cover precluded herbaceous species use. These dietary differences imply a less fibrous and more nutritious diet where sheep previously grazed. Considering both treatments, major dietary components in order of importance were: bitterbrush, grasses, Oregon grape, low sagebrush, mule ear dock, Pacific aster, and miscellaneous forbs and shrubs.

Seasonal dietary changes were largely explained by changes in availability due to deer consumption, snow cover, and plant phenology. Major changes were an increase in shrub use through the early winter and well into the late winter periods, and a decline in herbaceous species use through the early winter to a low during the first weeks of late winter. Near the end of late winter, snow melt and spring green-up permitted a sudden shift in diets away from shrubs to forbs and grasses.

The physical characteristics of plants determined to have predictive capabilities when applied to the selection of individual plants included degree of prior utilization, amount of current live plant material present, distance of plant from grazing deer, species of the nearest plant, and plant height. These characteristics probably exert their influence indirectly through olfactory and tactile stimuli to the deer. The success of these attributes in placing selected plants into the correct group upon re-analysis of data indicates that grazing deer probably cue on fairly specific characters of selected plants. Poor success, however, in placing non-consumed plants into the correct group indicates that a refinement of the method of determining which plants are being considered by a grazing deer will be necessary. Many plants which had desirable characteristics were not consumed possibly because they were never actually considered by the grazing deer.

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APPENDIX

Table 15. Cover (% of soil surface) on bitterbrush-big sagebrush vegetation type prior to deer grazing.

Species	Grazing Regime	
	Sheep and Deer	Deer Only
Purshia tridentata	11.08	17.18
Poa sp.	5.33	12.30
Artemisia tridentata	12.28	7.30
Wyethia amplexicaulis	0.11	3.10
Chrysothamnus vicidiflorus	3.04	2.30
Amelanchier alnifolia	0.76	0.50
Lupinus caudatus	0.43	0.40
Elymus cinereus	1.08	0.70
Koeleria cristata	0.00	0.60
Aster chilensis	3.15	3.20
Tragapogon pratensis	0.00	0.60
Prunus virginiana	0.00	0.30
Artemisia arbuscula	0.43	1.40
Agropyron inerme	1.84	0.50
Symphoricarpos oreophilus	0.00	0.20
Achillia millifolium	0.54	0.40
Phelum pratense	0.22	0.20
Rosa woodsii	0.11	0.20
Eriogonum sp.	0.00	0.10
Comandra umbellata	0.11	0.60
Orthocarpus tolmeyi	0.11	0.00
Unknown	0.22	0.08
Litter	17.50	29.70

Table 16. Cover (% of soil surface) on creek bed vegetation type prior to deer grazing.

Species	Grazing Regime	
	Sheep and Deer	Deer Only
Purshia tridentata	0.28	
Poa sp.	25.28	21.76
Artemisia tridentata	1.94	
Wyethia amplexicaulis	0.83	6.76
Amelanchier alnifolia	0.28	
Aster chilensis	1.11	2.65
Tragapogon pratensis	0.28	
Artemisia arbuscula	0.28	0.29
Phleum pratense	4.44	2.94
Rosa woodsii	0.83	
Comandra umbellata	0.00	0.29
Orthocarpus tolmeyi	1.11	0.29
Collinsia parviflora	0.00	5.00
Bromus tectorum	0.00	0.29
Gilia aggregata	0.00	1.76
Sitanion hystrix	1.94	0.59
Unknown	0.11	0.88
Litter	30.83	26.47

Table 17. Cover (% of soil surface) on low sagebrush vegetation type prior to deer grazing.

Species	Grazing Regime: Sheep and Deer	Grazing Regime: Deer Only
Purshia tridentata	2.04	0.00
Poa sp.	0.45	0.00
Artemisia tridentata	1.14	0.00
Wyethia amplexicaulis	1.82	4.00
Chrysothamnus vicidiflorus	0.00	2.00
Koeleria cristata	0.91	2.00
Aster chilensis	2.50	11.00
Artemisia arbuscula	25.00	23.00
Agropyron inerme	0.23	0.00
Gutierrezia sarothrae	0.00	8.00
Cordylanthus ramosus	0.45	0.00
Unknown	0.45	0.00
Litter	39.77	14.00

Table 18. Cover (% of soil surface) on grass vegetation type prior to deer grazing in deer use only pasture.

Species	Cover
Poa sp.	9.64
Artemisia tridentata	1.07
Chrysothamnus vicidiflorus	6.42
Elymus cinereus	4.64
Koeleria cristata	2.86
Aster chilensis	5.36
Taragapogon pratensis	0.71
Agropyron inerme	0.71
Achillea millifolium	0.71
Comandra umbellata	20.36
Unknown	3.57
Litter	28.21

Table 19. Discriminant function for all species.

Variable (x_i)[1]		Coefficient (b_i)[1]
Distance to deer		.009
Plant height		.004
Prior utilization	1[2], [4]	.765
	2	-.469
Current growth	1[2], [4]	.318
	2	.307

Group centroides ($\bar{z}$)[3]		Standard deviation (s_z)
Consumed	Not consumed	
.797	1.321	.741

[1] $z = \Sigma \, b_i \, x_i$

[2] Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

[3] Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

[4] Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

Table 20. Discriminant function for bitterbrush.

Variable (x_i)[1]		Coefficient (b_i)[1]
Distance to deer		.007
Plant height		-.007
Winter period[2], [4]		-.043
Prior utilization	1[2], [4]	.176
	2	-.028
Current growth	1[2], [4]	.639
	2	-.152
Species of neighbor plant	1[2], [4]	.561
	2	.310
	3	.114
	4	.219
	5	.090
	6	-.162
	7	-.170

Group centroids ($\bar{z}$)[3]		Standard deviation (s_z)
Consumed	Not consumed	
-.305	.162	.633

[1] $z = \Sigma\, b_i\, x_i$

[2] Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

[3] Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

[4] Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

Table 21. Discriminant function for grass.

Variable (x_i)[1/]		Coefficient (b_i)[1/]
Distance to deer		.006
Plant height		.039
Grazing regime[2/, 4/]		.080
Season[2/, 4/]		-.217
Prior utilization	1[2/, 4/]	-.086
	2	-.022
Current green growth	1[2/, 4/]	.825
	2	-.234
Species of neighbor plant	1[2/, 4/]	-.276
	2	.276
	3	.140
	4	.339
	5	.171

Group centroids ($\bar{z}$)[3/]		Standard deviation (s_z)
Consumed	Not consumed	
.332	1.218	.767

1/ $z = \Sigma\, b_i\, x_i$

2/ Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

3/ Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

4/ Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

Table 22. Discriminant function for mule ear dock.

Variable (x_i)[1/]		Coefficient (b_i)[1/]
Distance to deer		.002
Plant height		-.014
Distance to neighbor		.0
Grazing regime[2/, 4/]		.429
Winter period[2/, 4/]		-.006
Prior utilization	1[2/, 4/]	-.515
	2	.033
Species of neighbor plant	1[2/, 4/]	-.643
	2	.259
	3	.263

Group centroids ($\bar{z}$)[3/]		Standard deviation (s_z)
Consumed	Not consumed	
-.331	.499	.04

1/ $z = \Sigma\, b_i\, x_i$

2/ Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

3/ Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

4/ Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

Table 23. Discriminant function for allium.

Variable (x_i)[1]		Coefficient (b_i)[1]
Distance to deer		.00
Plant height		.00
Distance to neighbor plant		.0
Grazing regime[2, 4]		.0
Week[2, 4]		-.001
Species of neighbor plant	1[2, 4]	.919
	2	-.227
	3	-.241
	4	-.214

Group centroids ($\bar{z}$)[3]		Standard deviation (s_z)
Consumed	Not consumed	
-.212	-.189	0.16

1/ $z = \Sigma\, b_i\, x_i$

2/ Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

3/ Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

4/ Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

Table 24. Discriminant function for low sagebrush.

Variable (x_i)[1/]		Coefficient (b_i)[1/]
Distance to deer		.0
Plant height		.0
Distance to neighbor plant		.0
Winter period[2/, 4/]		-.007
Week	1[2/, 4/]	.061
	2	.040
	3	-.036
Period x week	1[2/, 4/]	-.033
	2	.0
	3	.0
Prior utilization	1[2/, 4/]	.013
	2	-.052
Current growth	1[2/, 4/]	.047
	2	-.007
Species of neighbor plant	1[2/, 4/]	-.895
	2	.317
	3	.290

Group centroids ($\bar{z}$)[3/]		Standard deviation (s_z)
Consumed	Not consumed	
.252	.309	.042

1/ $z = \Sigma\, b_i\, x_i$

2/ Dummy variables as described by Draper and Smith (1966) are used for the levels of qualitative variables.

3/ Decision point for separation into groups is supplied by the user. The point of equal probability of misclassification into the two groups is used here.

4/ Example with three levels:

Level	x_1	x_2
1	1	0
2	0	1
3	-1	-1

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