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Forage Selection and Nutrition of Sheep And Goats Grazing in the Tunisian Pre-Sahara

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FORAGE SELECTION AND NUTRITION OF SHEEP AND GOATS GRAZING IN THE TUNISIAN PRE-SAHARA

by

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Rudolfo Ricardo Griego

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ABSTRACT

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Nomadic pastoralism has been the traditional method of utilizing grazing resources in arid and semi-arid regions of Africa. However, increased sedentarization accompanied by growing human and animal populations during the past two decades is thought to be accelerating the desertification process, or desert expansion. The specific interactions of the grazing animal with this process has been speculated upon but not studied in detail. A comparative study was initiated during the spring grazing season of 1974 to determine sheep and goat nutritional and production responses, as well as patterns of vegetative selection and utilization under the pastoral system currently employed in the Pre-Saharan region of southern Tunisia.

The study site was located on a sandy soil dominated by the per-

ennial shrub, *Rhanterium suaveolens*. Annual herbs were co-dominants of this community in early spring.

Four grazing treatments were employed during a month-long grazing season. These included: sheep grazing alone, goats grazing alone, sheep grazing with goats, and goats grazing with sheep. Stocking rates (1.9 sheep or goats per hectare per month) were comparable to those locally employed. Dietary composition was determined for randomly selected animals by a modified bite-count method. Forage intake was determined by the equation, I = F/1-D where I represented intake rate, F represented fecal output as determined from collections using standard fecal bags, and D represented digestibility of composite diets as determined by in vitro techniques. Animals were weighed weekly.

Diets of all treatment groups, except goats in the mixed herd, consisted primarily of annuals during the first week. During Week Two there was a gradual shift to perennials and by the third week, all treatment groups selected primarily perennial species for their diets. Perennials comprised over 90% of the diets, except for sheep in the mixed herd, by the end of the fourth week. Also, by Week Four, *Rhanterium* comprised 71-92% of the diets.

Estimates of forage quality indicated a declining trend in nutritional value of the forage over the grazing period. Dry matter consumption, digestibility of the diets, consumption of apparent digestible energy, dietary crude protein and apparent digestible protein all decreased from Week One to Week Four. These changes were probably attributable to a combination of factors including a decrease in plant species availability due to grazing, maturation of the remaining vegetation and a dietary shift

from annuals to perennials.

Young animals gained weight at generally increasing rates throughout the grazing trial. Adult animals gained weight after the initial week but their rate of gain indicated a leveling off or even a decrease by the fourth week, probably in response to declining forage quality.

Animals in the mixed herd traveled farther during daily grazing periods than either of the single species herds. Goats grazing alone traveled farther than sheep grazing alone. Goats in the mixed herd may have influenced the sheep in that herd to travel more than sheep grazing alone.

(91 pages)

INTRODUCTION

Grazing by sheep, goats and other domestic animals has been a significant factor in the ecology of desert ecosystems of North Africa for many hundreds of years. However, the grazing process has received intensified interest recently because of its implied connection with the process of desertification (Caldwell, 1975). Yet, the specific relationships involved are unclear. The purpose of this study was to initiate a fundamental understanding of grazing livestock in the Pre-Sahara in support of future, more complex studies of relationships between livestock and the fragile desert ecosystem.

A large segment of the rural population throughout Northern Africa is dependent upon range livestock for livelihood, but relatively little is known about domestic animal production in the Saharan environment (Love, 1970). Furthermore, the impact of grazing animals on the ecosystem, vegetative response to various intensities of grazing by different classes of livestock, and patterns of utilization of available forage have not been studied in any depth. Also, as in the United States, very little is known about the nutritional qualities of range forage (Cook and Harris, 1968). For example, a survey of Tunisian literature revealed numerous papers dealing with feedlot experiments and controlled grazing on seeded pastures, but very little dealing with forage or grazing animals in the semi-desert ecosystems of the area. This deficiency is attributed mainly to the lack of trained personnel and not a lack of interest or realization of need (Christian Floret, Edouard Le Floc'h, personal conversations).

It is well established that domestic animals are selective grazers (Arnold, 1964; Huss, 1972), and that the relationship between populations of these animals and their food resources is especially complex in an environment where herbage production is highly seasonal (Eadie, 1970). For example, the time and length of the grazing season on a typical southern Tunisian range is highly dependent upon precipitation and available forage. Typically, the major grazing season occurs in early spring and for a short period during the rainy winter season, but the timing and duration can vary greatly from year to year. During the portion of the year when animals are not on the range, they are fed stored fodder and crop residues, the combination of which affords a fluctuating and often inadequate nutritional regimen (Mordant, 1970). This fact, combined with high temperatures during most of the year, low rainfall, and low humidity (Bourges, Floret and Pontanier, 1973), in total, contribute to a high degree of stress on the individual animal. Moreover, the limited amount of range forage sought after by an over-sized animal population has resulted in dramatic alterations of plant communities, and the overall stability of the area is tenuous.

Objectives

An initial study into the relationships involved in forage selection and grazing responses of grazing sheep and goats in the Tunisian Pre-Sahara was conducted during the 1974 spring grazing season. The study was designed with the following objectives:

1. To analyze forage selection by sheep and goats, grazing alone and in combination, in relation to seasonal development and availability

of vegetation on the range.

2. To measure the consumption of forage dry matter, energy, protein, and the utilization of these nutrients for maintenance and production by sheep and goats grazed together and in single species herds.

LITERATURE REVIEW

Forage Selection

Generally, a grazing ruminant has available a wide range of different species from which to select its diet (McClymont, 1964; Neff, 1974). These may vary from grasses and forbs, to shrubs, to trees, or some mixture of the three. Each life form is structurally and chemically different, and within any particular species there exists chemical and structural differences in the various parts that make up the plant. Stems, leaves, seeds, new and old growth have characteristic differences and they present differences in physical accessibility to the grazing animal (Neff, 1974). In addition, the proportions of these change through the plant's life history. Arnold (1964) demonstrated that grazing sheep preferred leaves to stems, and green plant material to dry. He associated these preferences to a complex relationship between chemical and physical characteristics of the plants. Wilson (1957) observed that grazing dwarf goats preferred leaves and succulent stems of trees and bushes to grasses. Studies in Texas indicated that goats preferred leaves over stems, and noted the minor contribution of fruits to the animals' diet (Malechek and Leinweber, 1972).

The particular mix of plant species and plant parts selected by the grazing ruminant is ultimately controlled by the central nervous system (Baile and Mayer, 1966) and is mediated through the senses of taste, smell, touch, and to some extent, sight. Arnold (1964) stated that of these four senses involved in food selection, those of the greatest importance to sheep and other ruminants were the sense of touch,

smell and taste.

Numerous terms have been used to describe characteristics of plants that make them desirable to grazing animals, but probably the commonly used are "palatibility" and "preference." Palatibility is most correctly used to describe a characteristic or condition of a plant that stimulates a selective response by an animal (Heady, 1964). The term preference is best used to express a selective behavioral response exhibited by a grazing animal when confronted by alternative choices. Although broad categories of plant preferences have been established for most ruminant species (Arnold, 1970), no generally applicable theory of feeding behavior has yet been formulated.

Phytochemical stimuli affect olfactory and gustatory responses of grazing ruminants, and are generally accepted as a mode of "communication" between plants and animals (Arnold and Hill, 1972). Chemical content of a plant can have a positive effect, promoting selection, or a negative effect, favoring non-selection. Studies have demonstrated that grazing sheep and cattle show a high degree of selection for forage high in organic acids, sugars, fats, and protein (Cook, 1959; Fontenote and Blaser, 1965; Heady, 1964). Essential oils (aromatics), tannins, coumarins, and nitrates have been shown to have a highly negative effect on selectivity (Heady, 1964; Wilkins et al., 1953). Yet, the acceptance or tolerance level for certain chemical compounds may be higher in one animal species than another. For example, the camel is known to select plants having oxalic acid concentrations high enough to be acutely toxic to sheep or cattle (Schmidt-Nielsen, 1964). Also, goats demonstrate higher thresholds for bitter substances than do sheep (Arnold and Hill, 1972). Animal

responses to the chemical composition of plants are also affected by such environmental factors as temperature and humidity.

Gwynne and Bell (1968) have aptly described how the anatomical structure of an animal's mouth parts contributes to differences in the kind of plants eaten by different animal species. Additionally, Meyer et al. (1957) suggest that sheep, because of their smaller mouths, are more selective than cattle. The selectability of goats has been attributed to their mobile upper lip and prehensile tongue (Huss, 1972; Maher, 1945).

Two motives for selective grazing have been hypothesized and are discussed by McClymont (1964): "euphagia" and "hedyphagia." The former means "food selection directed toward optimal nutrition and avoidance of intoxications while the latter means "food selection directed at minimizing unpleasant, or at maximizing pleasant olfactory, gustatory and other sensations." Certain selection patterns can be interpreted as being primarily innate or learned. Selection for a specific nutrient, such as salt by a sodium-deficient animal, can be termed "specific euphagia."

Animal species interactions

In southern Tunisia, as in other countries whose rangelands border the great Sahara Desert, sheep, goats and frequently cattle and camels may all graze on common areas. Certainly, the opportunity for inter-species interactions are great, both in terms of interactions dealing with the forage resource and social interactions. Baskin (1971) studied the behavioral patterns of sheep and goats grazing together. His findings indicated a difference in preference as to type of areas grazed. Goats

preferred rocky and uneven terrain; whereas, sheep preferred flat terrain. He also stated that goats were more social than sheep, and tended to group together and were more apt to follow a leader. If left alone, he concluded, a mixed herd of sheep and goats would eventually separate. On the other hand, Devendra and Burns (1970) discussed the belief held by people in some countries that goats, because of their selective and inquisitive habits, encouraged other grazing ruminants to widen their optimal habitat.

Although goats are generally blamed for destruction of vegetation, which in turns leads to soil degeneration and erosion (Cloudsley-Thompson, 1970; FAO, 1964; Huss 1972), studies indicate that range deterioration throughout the world has been caused by man and man's overgrazing of livestock (Devendra, 1967; Hornby, 1936; Huss, 1972; Le Houerou, 1971; and others). A report by the FAO (1964) concedes that "practically nothing" is known of the conditions under which range goats are raised in desert and semi-desert zones. Similarly, pastoral sheep production methods in arid regions are relatively unknown (Bhattacharya and Harb, 1973).

Nutrient Requirements

The selection of a diet is only the beginning of the complex process of transfering energy and nutrients through the primary consumer tropic level. Equally important is the efficiency with which this process is conducted in terms of resulting animal products.

Maintenance energy requirements

The energy cost values reported in the literature for maintenance of sheep and goats vary greatly between authors and research conditions.

For example, a difference of 30% exists between the 3723 kcal daily requirement reported by French (1944) and the 5357 kcal recommended by Devendra (1967), for goats grazing under range conditions and pen-fed goats (per 100 kg live weight) respectively. Lindahl (1972) concluded that maintenance requirements for penned sheep and goats are similar. He also concluded that the maintenance energy requirement for a goat under range conditions would be considerably higher than that for penned goats, and also higher than that for grazing sheep. This was based on the assumption that grazing goats, by nature, are more active than sheep. Terrill (1968) stated, "the energy costs of eating, grazing, or walking are about double those of standing or ruminating."

The average basal metabolic rate of mammals is accepted as 70 Kcal/$kg^{.75}$. Mcfarlane (1968) has estimated this value to be between 52 and 58 Kcal/$kg^{.75}$ for adult sheep, and even lower in environments with daily temperatures exceeding $30^{o}C$. In order to derive a total maintenance energy requirement, Crampton and Harris (1969) suggested multiplying the above value by a factor of 2. Therefore, an average of the values given would rest in the expression 2 x 55 Kcal (W $kg^{.75}$) for maintenance energy requirements of adult sheep, presumably equal to requirements of a goat (Lindahl, 1972).

Joyce (1968) estimated that grazing sheep require an average of 80 to 90 percent more feed for maintenance than pen-fed sheep. Therefore, in order to survive, the grazing ruminant is obligated to increase its energy intake. The energy utilized by the animal is the result of a complex relationship between the energy content of the forage and the ability of the animal to digest the material. Ultimately, the amount of forage

comsumed determines the energy intake of the grazing animal. This in turn, is controlled by the vegetation density of the grazed pasture (McClymont, 1964).

Season and intensity of use, in general, determine the abundance and nutritive value of range plants (Morris and Kovner, 1970). Cook (1971) found a decrease in forage nutritive value from a high in late spring to a low in fall and winter. Also, by using clipping methods to simulate varying intensities of grazing, he concluded that increased forage removal resulted in a general decrease of protein, gross energy, phosphorus, and cellulose. In addition, there was a marked decrease in regeneration.

Therefore, in order to determine a nutritionally adequate diet in terms of quantity of dry matter consumed, one must be aware of the complexities of range animal and plant community relationships (Cook Mattox, and Harris, 1961; Halls, 1970; Malechek and Leinweber, 1972; Piper, Cook and Harris, 1959). Nevertheless, guidelines have been established as a basis for meeting the nutritional needs of sheep and goats. The National Research Council (1968) has recommended, for maintenance, a daily dry matter intake level of 2.5 to 3.0 percent live body weight for sheep. Devendra and Burns (1970) recommend similar intake levels for goats, although they stipulate an increase to 8 percent for milk goats.

Protein requirements

Protein requirements for maintenance of sheep and goats, based on digestible protein (Majumdar, 1960), are similar: .509 kg/454.5 $kg^{.73}$ or roughly 2 grams per kilogram live weight. However, there is general disagreement as to the reliability of values obtained from nitrogen balance trials. Inherent errors of balance trials were reviewed by

Duncan (1965). Values for protein requirements at a maintenance level for sheep and goats have ranged from .06 to .08 percent of live body weight (Devendra, 1970).

Reproduction energy requirements

Because fetal growth is the process of cell synthesis, successful reproduction is dependent upon the energy intake of the dam (Blaxter, 1962; Gill and Thompson, 1954; Lindahl, 1972; Wallace, 1948). Lindahl (1972) has cited numerous studies that demonstrated the high nutritive requirements essential for multiple births. The value presented by these authors are for different breeds and were obtained under varying conditions. Therefore, as Maynard and Loosli (1969) stated one must be aware of the need to adjust for "condition of the animal and results desired." Presumably, this can be extended to encompass environmental conditions and available forage to predict the needs of pregnant dams. The National Research Council (1968) has established energy requirements for different stages of gestation. Based on a ewe with body weight between 45 and 73 kg, the NRC recommends a daily digestible energy intake of 2.2 Mcal/kg for the first 15 weeks and 2.3 Mcal/kg for the last six weeks of gestation. Similar values were proposed for goats of the same weight by Kalaissakis (1958, 1959).

Lactation energy requirements

As in gestation, the lactating animal requires nutritional intake above that required for maintenance alone. The level of intake is determined by the composition and quantity of the milk produced (Maynard and Loosli, 1969). An increase in the fat content of the milk, consequently, requires an increased nutritional intake (Tyrrell and Reid, 1965).

NRC (1968) energy requirements recommended for lactating ewes are: 2.6 Mcal/kg to 2.4 Mcal/kg during the first 8 to 10 weeks, and 2.3 Mcal/kg during the last 12 to 14 weeks. These values are for ewes weighing from 45 kg to 73 kg, and reflects the decrease in requirements as the body weight increases. Presumably, these values can also apply to lactating goats.

Water requirements

Water requirements for sheep and goats vary among species and within breeds (Macfarlane, 1968; Terrill, 1968). Generally, it is believed that goats drink less water than do sheep (French, 1970: Macfarlane, 1968) and conserve water more efficiently than sheep through a slower rate of panting and less water loss through feces and urine. French (1970) has given the following values for water turnover rate at a temperature of 37°C: goats, 188 ml/kg$^{.82}$/24 hours; and sheep, 197 ml/kg$^{.82}$/24 hours. Obviously, the amount of drinking water required varies with the moisture content of the feed, ambient temperature, and physiological conditions of the grazing ruminant, plus numerous other factors.

Thermoregulation

Although numerous studies have been conducted on the overall effects of solar radiation and adaptations of desert amphibians and reptiles (Atsatt, 1939; Schmidt-Neilsen, 1964; and others), relatively little has been done with large mammals that also have successfully occupied the extremely

demanding desert and semi-desert areas (Bartholomew and Dawson, 1968).

On an average (at a latitude 55°N), a sheep receives 300-400 Kcal/m^2/hour of solar radiation. This includes direct, indirect, and ground-reflected radiation (Lee, 1957) which is approximately five times the normal heat production of a sheep and presumably of a goat (Clapperton et al., 1965). Blaxter (1962) has noted that during the whole daylight period, clear sunshine in hot countries produces a heat load exceeding twice that produced in the tissues. Dissipation of this heat load has been found to be a function of fleece or hair, color, vaporization of water, wind, temperature and combinations thereof (Joyce, Blaxter, and Park, 1966; Priestly, 1957).

Animals in desert climates lose excess heat through two mechanisms: alternations in the blood circulation (through vaso-constriction and vaso-dialation) and evaporative cooling (Blaxter, 1961; Devendra and Burns, 1970; Macfarlane, 1968). Both sheep and goats lose heat by panting and sweating, although that loss through increased respiration rate is considered to be the most important (Macfarlane, 1968).

Minimal water excretion is thought to be the single most important factor to desert adaptation (Macfarlane, 1964). For example, total body water of sheep in desert areas is always high, and is about 20 percent lower in the winter than during the summer.

Clark and Quin (1949) identified an additional adaptive phenomenon that perhaps aids desert ruminants' heat tolerance. They established a direct correlation between the amount of dry matter consumed and the intake of water. The restriction of one led to the reduced intake of the other. Thus, heat stress may lead to a decline in rumination because of decreased intake of water and feed. This theory assumes that

increased temperatures cause decreases in plant moisture content. Conversely, it is known that a high level of feeding decreases the animals' heat tolerance by increasing the digestive processes and subsequently the heat generated in the food breakdown (Appleman and Delouche, 1958; Schmidt-Nielsen, 1964).

Fat storage appears to be an effective adaptation of some desert animals. Camels, Zebu cattle, and fat-tailed sheep store fat deposits that allow them a better chance of survival during periods of sparce feed. In addition to providing energy, these fat deposits produce significant amounts of metabolic water during their breakdown (Schmidt-Nielsen, 1964).

METHODS AND MATERIALS

Study Site

Three grazing sites in the Chaabania area of southeastern Tunisia were chosen on the basis of a uniform stand of vegetation in the important *Rhanterium* type. The area where sheep and goats were grazed in combination was a portion of the original US/IBP Chaabania Validation Site (Wagner, 1971), now known as the Dar es Zaoui Site (Wagner, 1975). The two remaining herds (sheep alone, goats alone) were grazed in adjoining pastures, each approximately 10 hectares in size, on another area five kilometers from the validation site, now known as the Henchir es Siane Site (Wagner, 1975).

Vegetation

Vegetation in this area is dominated by the perennial shrub *Rhanterium suaveolens (Compositeae).* Other perennials are relatively few in number, and include the species *Artemisia campestris, Salsola vermiculata, Retama raetam* and *Linaria aegyptiaca.* Production of annuals is highly seasonal and represents a fluctuating percentage of the biomass, both seasonally and from year to year.

Past grazing practices have probably altered the structure and composition of the community, but the absence of ungrazed control or relic areas makes evaluation of current successional status difficult. The present grazing practice involves intensive grazing by sheep and goats whenever sufficient forage is available. Usually, the grazing

season lasts from early spring into mid-summer, however, during years with late summer and autumn precipitation, some fall and winter grazing is also practiced. Camels and donkeys also graze the area on an irregular basis.

Soils

Southard (1973) classified the soils of the study area as members of the sandy family of Typic Paleorthids. These he described generally as fine, loose sand, layered over a calcium-carbonate-cemented hardpan. The study area is dotted with shifting dunes of varying size, areas of exposed hardpan, and areas somewhat stabilized by a natural crusting.

Livestock

A small herd of locally-obtained, native fat-tailed sheep and black Arab goats was divided into three study herds to determine animal-plant interactions as well as grazing interactions between the two animal classes. Sex and age structure of each herd was designed to closely simulate that of local herds. Local shepherds were employed to manage the animals similarly to other herds in the area. Boundaries of the grazed pastures were delineated with markers; no fencing was used. Grazing treatments employed are illustrated in Table 1.

All animals were marked for identification purposes. Livestock marking paint was used on the sheep and metal ear tags were used on the goats. A complete record of each animal was kept, including sex, age, body weights at weekly intervals, and a notation on relationships between mothers and their young. Incidental to this was a recording of pelage coloring (white, black, spotted). Initial body weights were taken prior

Table 1. Grazing treatments

Treatment	Number of animals		Stocking rate[1/]
	Male	Female	
1. Sheep grazing alone	9	15	5 ha/AUM
2. Goats grazing alone	13	13	6 ha/AUM
3. Sheep and goats grazing together			
Sheep	8	11	9 ha/AUM
Goats	7	12	11 ha/AUM

[1/] Based on 455 kilograms per animal unit (AUM).

to the beginning of grazing in late April, 1974, with subsequent weighings every seven days thereafter until termination of the 4-week grazing trials in late May 1974. Animals were shrunk for 12 hours prior to each weighing. Final weights of the animals were recorded at the end of the last week of observations.

Diet Determination

Diets of the animals were determined by a modification of the bite-count approach (Neff, 1974) according to the sampling schedule outlined in Table 2. Four adult male animals in each herd (two goats + two sheep in the mixed herd) were designated as sample animals and these were used throughout the study. On any sampling day (Table 2) observations were taken on these animals both in the morning and again in the afternoon. In both single-species herds, each animal was observed for 30 minutes of grazing time and then another animal was randomly selected from the group of four. It was therefore possible for one animal to be observed more than once during a particular sampling period. In the mixed herd, animals were chosen randomly for observation, but without replacement. Therefore, all four animals were observed during a particular sampling period. The

basic sample unit can be defined as one animal-day of grazing per week based on one hour of observation per day. Animals to be observed could be approached to within a distance of 1 meter because of their docile nature. Therefore, species and relative amounts of the plant parts eaten were relatively easy to determine.

Table 2. Sample scheme for diet determinations.

	Week one			Week two			Week three			Week four		
Day	1	2	3	1	2	3	1	2	3	1	2	3
Herd[1/]	S	G	S/G	G	S/G	S	S/G	S	G	S	G	S/G

[1/] S = sheep alone; G = goats alone; S/G = sheep and goats together.

For any particular herd, the four hours of total daily observation time represented almost one half of the entire grazing time allotted to that herd on a particular day. Here, the term "grazing time allotted" refers to the actual time spent in the pastures, as animals were penned overnight and again at midday for 2 to 5 hours, according to the local husbandry practices. The remaining time was spent observing the entire herd and recording incident observations.

By counting every bite taken by the observed animal and recording these in terms of species and portions of the plants, it appeared possible to closely duplicate an animal's diet. Numerous grazing sheep and goats were observed prior to the study to acquaint the observer with the technique. For each plant species there was an apparent unique amount

taken at any one bite. Therefore, an adjustment of the size of the "bite" had to be made for almost all species before diets could be calculated on a weight basis. For example, annual forbs would be gathered together with the tongue into groups of three to four stems at a time and bitten off at about mid-length, whereas a perennial such as *Rhanterium* was generally nibbled, with five or six buds or leaf bundles taken at a time. In each of these cases, the amount taken was considered the "bite" for that species and the unit dry weight of that "bite" was determined by hand-plucking a portion of the plant representative of that selected by the animal.

Hand-plucked samples were collected during the last day of field work each week. These samples were analyzed for moisture content and were used for quantifying the "bite" unit of measure used in this study. A minimum of 150 samples per plant species were used in quantifying the "bite" unit for each week of the study. Dried plant matter was then saved for further chemical and calorimetric analyses.

The percentage contribution of any species (i) to the diet of an animal during any particular sampling period was then calculated as:

$$\%_{(i)} = \frac{(B_i \times W_i)}{\sum_{j=1}^{N} (B_i \times W_i)} \times 100$$

Where:

B_i = number of "bites" on species (i) in that sample.

W_i = unit dry weight per bite of species (i).

N = total number of species grazed in that sample.

Behavioral Observations

Additional to the measurements outlined above, general observations were made in an attempt to detect any aberrant behavior with respect to:

1. Climatic conditions, primarily wind and temperature
2. Herd composition.
3. Distance traveled during grazing.

Forage Intake

Daily forage intake (kg dry matter per kg of animal body weight) was determined according to the equation:

$$I = \frac{F}{1 - D},$$

a rearrangement of the standard digestion-balance equation, where I is equal to forage intake, F is equal to fecal output, and D is equal to percentage digestibility. Estimates of fecal output were achieved by fitting four adult male animals in each treatment with standard fecal collection bags (Harris, 1968).

Feces for each herd were collected three times every twenty-four hours. Each collection from an individual animal was weighed fresh and then sub-sampled for moisture determinations. This procedure was followed daily over the entire grazing period. Within each herd, daily fecal sub-samples from each animal were pooled. These daily composite samples from each herd were then oven-dried at 60°C and sealed in metal containers in preparation for chemical and calorimetric analyses in Logan, Utah.

Estimates of digestibility were derived by *in vitro* procedures

(Tilley and Terry, 1963). These procedures employed a two-stage digestion technique. The first stage included a 48-hour incubation by rumen organisms. A second 48-hour incubation in acid-pepsin completed the digestion of the plant matter. This procedure has been demonstrated to give *in vitro* dry matter digestibility estimates that are in close agreement with *in vivo* values (Tilley and Terry, 1963).

In vitro trials were conducted at Utah State University College of Natural Resources laboratory facilities. Vegetative samples collected in Tunisia were oven-dried at 60°C for a minimum of 24 hours and sealed in metal containers in preparation for shipment to the United States. Rumen fluid was obtained from two ruminally fistulated sheep and two goats which were fitted with rumen fistulas and maintained on baled alfalfa hay.

Apparent digestibility coefficients for protein were determined as the quantitative difference between grams of protein in the daily diet and grams of protein intake. Nitrogen content of both diets and feces was determined by micro-kjeldahl procedures, and crude protein was then calculated as N x 6.25. Energy content (kcal/gm) of both diets and feces was determined by bomb calorimetry (Maynard and Loosli 1969). The difference in energy content of the total daily food intake and total daily fecal output yielded estimates of daily consumption of digestible energy (Maynard and Loosli, 1969).

Water consumption by each of the three herds was also recorded. Sheep and goats in the mixed herd were watered separately. WAter consumed at each watering was estimated by a "dip-stick" method where the water level in troughs was measured before and after drinking. The

difference between the two readings was measured before and after drinking. The difference between the two readings was converted to liters and was considered as the amount consumed by the herd.

Weather conditions were recorded throughout the grazing season. Daily recordings included temperature, humidity, and precipitation. Temperature and humidity were recorded on a standard hygrothermograph. Precipitation was measured using a standard rain gauge. In addition to these, hourly wind speeds were recorded during the animal observation periods. Because the anemometer used gave a continuous reading in accumulated kilometers of wind, hourly readings were made in order to provide a better estimate of the diurnal variation in wind speed.

RESULTS AND DISCUSSION

Available Forage and Selected Species

Vegetation available to the grazing animal consisted of approximately 30 species of annuals and 14 species of perennials (Table 3). These values were obtained from unpublished Desert Biome data for the 1974 spring season and have not been statistically analyzed. Of the annuals, 19 species were eaten to some extent during the season, but only five species, not including annual grasses, contributed more than 10 percent to a given diet for either sheep or goats. Data on botanical composition of diets consumed by sheep and goats during the four-week grazing season are presented in Tables 4 and 5. Some species grazed by the animals were not detected in the vegetative analysis, but of the species not detected, only two comprised over one percent of either the sheeps' or goats' diets during any particular week (Tables 3, 4, and 5).

Annual plants in the pastures grazed by single species herds represented only 6.7 percent of the total vegetational biomass available. Yet, they comprised 39.6 and 42.3 percent of the average seasonal diets of sheep and goats respectively. In contrast, annual plants in the pasture grazed by the mixed herd represented 14.7 percent of the

Table 3. Available forage on pastures grazed by single species herds (Henchir es Siane) and mixed herd (Dar es Zaoui).

Identification	Henchir es Siane		Dar es Zaoui	
	Kg·ha^{-1}	% Total Vegetation	Kg·ha^{-1}	% Total Vegetation
ANNUALS				
Diplotaxis muralis	NS[1/]	---	NS	
Matthiola longipetala	1.7	<1.0	1.3	<1.0
Daucus syriticus	9.9	1.0	3.3	<1.0
Ifloga spicata	13.3	1.4	44.3	4.2
Cutandia divaricata	8.5	<1.0	28.3	2.8
Plantago albicans	3.3	<1.0	41.7	3.9
Hippocrepis multisiliquosa	4.1	<1.0	1.2	<1.0
Zollikoferia resedifolia	3.9	<1.0	1.9	<1.0
Gooza [2/]	NS	---	NS	---
Asphodelus refractus	5.9	<1.0	8.3	<1.0
Atractylis candida	1.1	<1.0	NS	---
Fagonia cretica	NS	---	NS	---
Astragalus sp.	NS	---	NS	---
Filago spathulata	10.5	1.1	9.6	<1.0
Senecio delphinifolius	1.2	<1.0	.7	<1.0
Inula sp.	.1	<1.0	.9	<1.0
Cleome arabica	NS	---	NS	---
Gramineae	.2	<1.0	9.6	<1.0
SUB-TOTAL	63.7	6.6	151.9	14.5
OTHER [3/]	1.2	<1.0	1.9	1.0
TOTAL ANNUALS	65.0	6.7	152.9	14.7
PERENNIALS				
Rhanterium suaveolens	511.3	52.7	658.3	63.1
Echiochilon fruticosum	.9	<1.0	5.2	<1.0
Artemisia campestris	368.1	37.9	6.8	<1.0
Linaria aegyptiaca	20.6	2.1	5.4	<1.0
Helianthemum lippii	2.2	<1.0	9.1	<1.0
Genista uniflora	NS	---	NS	---
Salsola vermiculata var. *brevifolia*	.7	<1.0	14.5	1.4
Retama raetam	00		179.7	17.2
SUB-TOTAL	903.7	93.1	879.0	84.3
OTHER	1.6	<1.0	10.7	1.0
TOTAL PERENNIALS	905.3	93.3	889.7	85.3

[1/] Not sampled: species was not detected at sampling intensity employed.
[2/] Local common name. Determination of generic name was not possible.
[3/] Species not eaten by either sheep or goats.

Table 4. Botanical composition of diets of sheep grazing alone and with goats.[1/]

Identification	Percent of Diet									
	Week 1		Week 2		Week 3		Week 4		Treatment Average	
	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
ANNUALS										
Diplotaxis muralis	14.4	<1.0	<1.0	0	<1.0	0	<1.0	0	3.5	<1.0
Matthiola longipetala	12.4	14.7	<1.0	<1.0	<1.0	<1.0	0	<1.0	3.1	3.7
Daucus syrticus	29.4	13.0	26.7	2.1	3.8	<1.0	1.1	0	15.3	3.8
Ifloga spicata	<1.0	0	0	0	<1.0	0	0	0	<1.0	0
Cutandia divaricata	14.2	9.6	<1.0	2.9	3.3	3.1	2.1	4.9	4.9	5.1
Plantago albicans	4.4	9.4	3.0	4.2	<1.0	<1.0	0	0	1.9	3.4
Hippocrepis multisiliquosa	2.3	0	<1.0	0	0	0	0	0	<1.0	0
Zollikoferia resedifolia	15.0	18.1	2.2	2.9	<1.0	1.6	0	0	4.3	5.7
Gooza [2/]	<1.0	0	<1.0	0	0	<1.0	<1.0	4.1	<1.0	<1.0
Asphodelus refractus	0	1.5	<1.0	8.6	<1.0	<1.0	<1.0	0	<1.0	2.5
Atractylis candida	0	0	1.8	0	4.5	0	0	0	1.1	0
Fagonia cretica	0	0	1.6	0	<1.0	0	0	0	0	0
Astragalus sp.	<1.0	<1.0	0	0	<1.0	0	0	0	<1.0	<1.0
Filago spathulata	0	0	0	0	0	0	0	0	0	0
Senecio delphinifolius	0	<1.0	0	<1.0	0	<1.0	0	0	0	<1.0
Inula sp.	0	3.2	0	4.3	0	6.9	0	0	0	3.6
Cleome arabica	0	0	0	0	0	0	0	0	0	0
Gramineae	<1.0	2.5	<1.0	<1.0	<1.0	<1.0	1.1	16.6	<1.0	4.8
TOTAL ANNUALS	93.44	73.30	40.08	27.09	16.38	18.36	6.82	26.56	39.6	36.4
PERENNIALS										
Rhanterium suaveolens	2.6	2.9	54.9	56.2	80.5	69.63	86.8	71.0	56.2	49.9
Echiochilon fruticosum	<1.0	<1.0	<1.0	<1.0	0	<1.0	0	0	<1.0	<1.0
Artemisia campestris	<1.0	<1.0	2.4	<1.0	3.0	3.9	6.1	<1.0	2.9	<1.0
Linaria aegyptiaca	<1.0	<1.0	<1.0	3.7	<1.0	2.4	<1.0	<1.0	<1.0	1.5
Helianthemum lippi	<1.0	1.1	<1.0	<1.0	0	<1.0	0	0	0	<1.0
Genista uniflora	1.7	18.2	1.0	3.6	0	2.1	0	0	<1.0	5.9
Salsola vermiculata var. *brevifolia*	2.2	1.7	1.7	5.4	1.0	3.2	<1.0	<1.0	<1.0	2.6
Retama raetam	0	2.8	0	3.1	0	0	0	2.1	0	2.0
TOTAL PERENNIALS	6.56	26.70	59.92	72.91	83.62	81.64	93.18	73.44	60.4	63.6

[1/] Percentages are based on hand-plucked samples representative of diets.

[2/] Local common name

Table 5. Botanical composition of diets of goats grazing alone and with sheep.[1/]

Identification	Percent of Diet									
	Week 1		Week 2		Week 3		Week 4		Treatment Average	
	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
ANNUALS										
Diplotaxis muralis	2.8	<1.0	1.5	<1.0	<1.0	0	<1.0	0	1.1	<1.0
Matthoila longipetala	5.4	4.6	1.4	<1.0	2.0	0	0	0	2.2	1.2
Daucus syrticus	14.3	1.2	43.7	2.5	3.9	0	0	0	15.5	<1.0
Ifloga spicata	0	0	0	-	0	0	0	0	0	0
Cutandia divaricata	34.7	3.4	6.7	7.6	4.6	6.4	1.6	2.2	11.9	4.9
Plantago albicans	<1.0	<1.0	5.2	<1.0	<1.0	0	0	0	1.3	<1.0
Hippocrepis multisiliquosa	<1.0	0	<1.0	0	0	0	0	0	<1.0	0
Zollikoferia resedifolia	6.7	14.3	3.3	2.4	<1.0	<1.0	<1.0	0	2.8	4.2
Gooza [2/]	0	0	0	0	<1.0	0	0	0	<1.0	0
Asphodelus refractus	3.3	1.8	2.9	<1.0	6.6	<1.0	3.5	<1.0	4.1	<1.0
Atractylis candida	5.3	0	0	0	<1.0	4.0	0	0	1.3	<1.0
Fagonia cretica	0	0	1.4	0	<1.0	0	0	0	<1.0	0
Astragalus	<1.0	<1.0	<1.0	0	0	0	0	0	<1.0	<1.0
Filago spathulata	0	0	0	0	0	0	<1.0	0	<1.0	0
Senecio delphinifolius	0	<1.0	0	0	0	0	0	0	0	<1.0
Inula sp.	0	3.1	0	2.0	0	<1.0	0	0	<1.0	0
Cleome arabica	0	0	0	<1.0	0	0	0	0	0	<1.0
Gramineae	<1.0	0	<1.0	<1.0	0	0	0	3.6	<1.0	<1.0
TOTAL ANNUALS	73.66	31.57	67.99	19.25	21.91	10.62	5.5	5.94	42.3	16.8
PERENNIALS										
Rhanterium suaveolens	25.6	19.2	29.9	36.5	77.1	68.6	92.8	74.8	56.4	50.1
Echiochilon fruticosum	<1.0	6.5	<1.0	<1.0	0	0	0	0	<1.0	1.6
Artemisia campestris	<1.0	3.0	<1.0	1.9	<1.0	3.2	1.2	0	<1.0	2.0
Linaria aegyptiaca	<1.0	2.3	<1.0	<1.0	<1.0	<1.0	<1.0	0	<1.0	<1.0
Helianthemum lipii	0	<1.0	0	0	0	0	0	0	0	<1.0
Genista uniflora	0	6.1	<1.0	1.5	0	<1.0	0	0	<1.0	1.9
Salsola vermiculata var. *brevifolia*	<1.0	2.1	1.3	7.8	<1.0	2.4	<1.0	3.1	<1.0	3.9
Retama raetam	0	28.7	0	32.4	0	14.6	0	15.1	0	23.0
TOTAL PERENNIALS	26.34	68.43	32.01	80.75	78.09	89.38	94.50	94.06	57.7	83.2

[1/] Percentages are based on hand plucked samples representative of the diets.

[2/] Local common name.

total vegetational biomass and contributed 36.4 and 16.8 percent to the average seasonal diets of sheep and goats respectively.

Perennial plants in the pastures grazed by sheep and goats alone comprised 93.1 percent of the total vegetation available on a weight basis, but they contributed only 60.4 percent to the sheep's and 57.7 percent to the goats' month-long average diets. Two of the plants grazed, *Rhanterium* and *Artemisia*, collectively represented approximately 90 percent of the total available biomass. While *Rhanterium* contributed about 56 percent to the average diets for sheep and goats grazing alone, *Artemisia* was relatively unimportant in the diets of either sheep or goats in this treatment.

Perennials were somewhat less abundant in the pasture grazed by the mixed herd where they comprised about 85 percent of the total vegetation but their contribution to the diets of the animals in the mixed herd was slightly higher than that for animals grazing alone. Perennials contributed about 64 percent of the sheep's and 83 percent of the goats' average seasonal diet in the mixed herd.

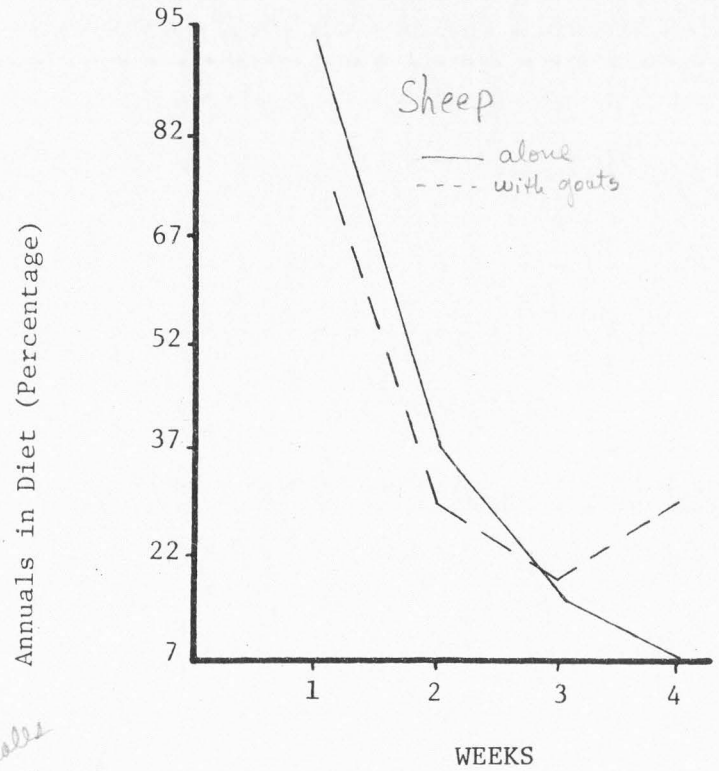
Field notes recorded during the grazing season indicated the annual component of the available forage rapidly decreased during the first two weeks. This rapid decrease was probably due in large part to the selective grazing by the animals. In a study with sheep and cattle on a California annual range, Van Dyne and Heady (1965a) suggested that selective grazing on forbs contributed to their disappearance during the first part of a summer grazing season. In addition, the increasing temperatures and decreasing humidity during this part of the study may also have contributed to rapid drying and shattering of

the annual component, thus speeding its depletion. Climatic records for the study period are presented in Appendix 1.

Grazing ruminants generally prefer the more palatable annual species over woody perennial browse species (Van Dyne and Heady 1965b). Accordingly, animals in all treatments except for goats in the mixed herd initially selected a much higher proportion of annuals than perennials in their diets. As long as the preferred annuals were available, the animals continued to utilize them in a considerably larger proportion than that represented in available forage (Tables 3, 4 and 5). Data were not summarized on the basis of selection for plant parts; however, in almost all instances, sheep and goats in the study were observed to graze flowers, leaves, and stems of annuals in that order of preference. Most perennials were grazed in a manner that would suggest a similar sequence of preference except that very few stems were taken.

The general trend in composition of diets over time for all treatments, except goats in the mixed herd, was a marked change from predominantly annuals at the beginning of the grazing season to predominantly perennials at the end (Figures 1 and 2). This trend was also evident for goats in the mixed herd, but the change was much less pronounced due to the higher initial consumption of perennials by that herd. Individual species of annuals varied in their contributions from less than one percent to 44 percent of the average weekly diet for either sheep or goats.

No statistical differences ($P \leq .10$) were found between treatments for the percentage of perennials (and consequently annuals) in the diets of sheep (Table 6), although sheep in the mixed herd appeared to have a slightly larger proportion of perennials in their average, season-long



change scales to begin at zero, change to decades

Figure 1. Percentage annuals in the forage consumed by sheep grazing alone (——) and with goats (- - -).

diet than did sheep grazing alone (Table 4). Statistical differences were found over time ($P \leq .01$) and there occurred an interaction of treatments with time ($P \leq .10$). Also, there was no treatment difference ($P \leq .10$) for the proportion of *Rhanterium* in the diets of sheep in the two treatments (Table 6).

Table 6. Analysis of variance for percent perennials and percent *Rhanterium* in diets of sheep grazing alone and with goats.

Source of variation	Degrees of freedom	Perennials		*Rhanterium*	
		Mean Squares	F	Mean Squares	F
Treatment	1	43.06	0.32	207.74	1.48
Week	3	5,261.00	39.74**	6,557.89	46.83**
Treatment x Week	3	415.26	3.13*	94.52	0.67
Error	16	132.38		140.00	
Total	23				

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

Sheep in both treatments grazed 11 species of annuals during the first week. The individual species selected by each herd differed to some extent, but an apparent preference for certain species was exhibited. The major annual species selected (approximately 90 percent contribution to the first week's diet) by sheep grazing alone were *Daucus syrticus*, *Zollikoferia resedifolia*, *Cutandia divaricata*, *Matthiola longipetala*, and *Diplotaxis muralis*. The first four species mentioned also contributed the major portion of annuals for sheep in the mixed herd.

During Week 4, sheep's diets in the mixed herd reflected a regeneration of annual grass species. The contribution of these

grasses probably accounted for the divergence from the general trend detected by the significant interaction in the analysis of variance (Table 6).

Genista uniflora, a low-growing perennial shrub, contributed about six percent to the season-long diet for sheep in the mixed herd, as compared to the less than one percent in all other treatments (Table 4). Based on occular observations, *Genista* was limited in abundance and was quickly depleted during the first week of grazing. Because of its rarity, the species was not detected in the organized vegetation sampling. The selection of *Genista* appeared to be the result of a forage preference exhibited by the sheep in the mixed herd. *Rhanterium*, in contrast, was not a preferred perennial to sheep during the initial week, considering that it contributed only 3 percent to the diet while representing approximately 53 percent of the available forage.

Goats grazing alone exhibited dietary trends generally similar to those observed in sheep, but the magnitude of change from annuals to perennials was smaller than for sheep primarily because goats consumed a larger proportion of perennials at the outset than did sheep (Figure 2). Goats in the mixed herd also exhibited a trend characterized by a change from annuals to perennials, but the magnitude of change was markedly smaller than for goats alone. The perennial component selected by goats grazing alone ranged from about 26 percent during the first week to 95 percent during the final week, while the proportions of perennials eaten by goats in the mixed herd ranged from about 68 percent during the first week to 94 percent during the final week (Table 5).

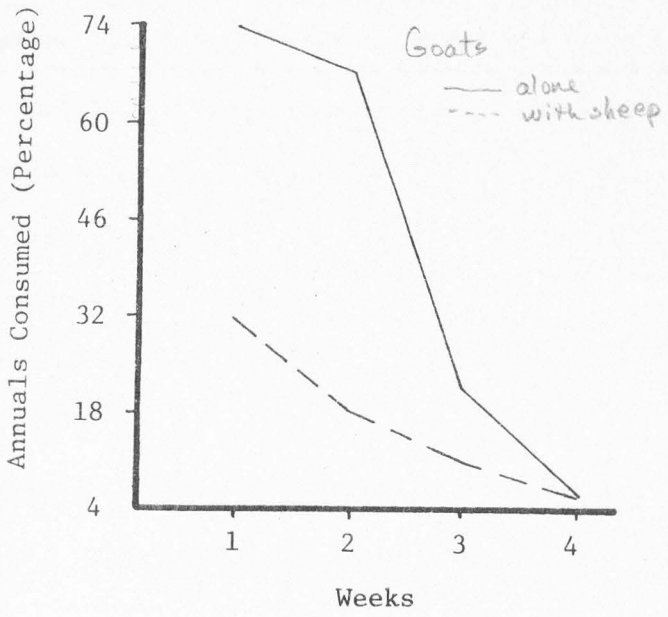


Figure 2. Percentage annuals in the forage consumed by goats grazing alone (——) and with sheep (- - -).

Unlike the sheep, statistical differences ($P \leq .01$) were found between treatments for perennials in the goats' diets (Table 7). Goats grazing in the mixed herd consumed almost 30 percent more perennials on the average than did goats grazing alone. There were also statistical differences found over time ($P \leq .01$), and a significant ($P \leq .10$) interaction was detected for treatments over time. As with sheep, there was

no treatment difference ($P \leq .10$) for the proportions of *Rhanterium* in the diets (Table 7). The perennial *Retama raetam* that was consumed avidly by goats in the mixed herd was responsible for the statistical difference in the perennial (and consequently, annual) component.

When all sheep were compared to all goats, irrespective of treatments, a significant difference ($P \leq .10$) was found for percentage perennials (and annuals) in the diets. Perennials comprised a larger proportion of the goats' diets than they did the sheep's diets. Yet the proportion of *Rhanterium* in the diets did not differ ($P \leq .10$) between sheep and goats.

Table 7. Analysis of variance for percent perennials and percent *Rhanterium* in diets of goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Perennials		*Rhanterium*	
		Mean Square	F	Mean Square	F
Treatment	1	3,599.82	24.84**	206.26	1.23
Week	3	2,436.12	16.81**	4,730,41	28.20**
Treatment x Week	3	661.23	4.56	126.26	.75
Error	15	144.90		167.68	
Total	22				

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

The annual component in the diet of goats grazing alone was dominated by five species. *Cutandia divaricata* and *Daucus syrticus* collectively represented 49 percent of the weekly diets during the first week. Goats in the mixed herd concentrated on the annual forb *Zollikoferia*

resedifolia to the extent that it represented almost 50 percent of the annual component in their diets during the first week. The three species that dominated the annual component of the goats' diets were also preferred by sheep.

Perennials in the diet of goats grazing alone were dominated by *Rhanterium* from Week 1 through Week 4 (Table 5). The increase in the percentage contribution of perennials throughout the season is principally a reflection of increasing amounts of *Rhanterium* in the diet. Although *Artemisia campestris* comprised about 38 percent of the available forage for the goats grazing alone, the species contributed less than one percent of the season-long diet. Although *Artemisia* did not represent a significant contribution to the diets, field observations indicated the species was seemingly a preferred one. Sheep and goats "stripped" the small leaves off the stems and the actual dry weight per bite of leaves proved to be relatively small. But, on a bite count basis, data not herein presented, the grazing animals tended to favor *Artemisia* more than is indicated.

Perennials dominated the diet of goats in the mixed herd and were chiefly the result of two selections, *Rhanterium* and *Retama raetam*. *Retama*, a perennial shrub, was found only in the pasture grazed by sheep and goats together, and therefore did not contribute to the diets of animals grazing in the single-species herds. As mentioned previously, selection for this species most likely led to the statistical difference between treatments for percentage perennials in goats' diets. A preference for *Retama* by goats in the mixed herd was indicated during Week 1. Although it represented but 17 percent of the total biomass

(as compared to 63 percent for *Rhanterium*), the species represented almost 29 percent contribution to the first week's diet. This value increased slightly during Week 2, and the subsequent decrease during the remaining two weeks reflected a decrease in availability of *Retama*. On a season-long basis, the species contributed about 23 percent of the diet.

The decrease in availability of *Retama* was not due to grazing alone. This rather tall browse species was used mainly by goats as a source of forage and also in what appeared to be mischievous amusement. Young goats frequently climbed into the brush and either grazed while within or, more often than not, cavorted around with each other. The reason for this play can only be speculated, but it is important to note the destruction of relatively large quantities of available forage by the practice. Utilizing occular appraisals, I estimated that over 50 percent of the forage of *Retama* was rendered unuseable by the young goats. The fastideous grazing habits of the goat precluded the use of the forage that had either been trampled or soiled by animal waste (Lindahl 1972).

From data presented on relative availability, diet composition and recorded visual observations, one can conclude that animals in all treatments tended to select forage comprised of species other than *Rhanterium* as long as those species remained available. Sheep in both treatments tended to prefer annuals to perennials. Sheep in mixed herd selectively grazed for the perennial *Genista uniflora* in preference to *Rhanterium* as long as the *Genista* was available. Goats grazing alone tended to prefer annuals to perennials, as long as they remained available, and selected *Rhanterium* thereafter. Goats

in the mixed herd, however, appeared to show a definite preference for the perennial *Retama* over *Rhanterium*, or annuals.

As is shown in this study, *Rhanterium* initially contributed a relatively small percentage to the sheep and goat diets. But, the consumption level of this species increased throughout the grazing season. It is interesting to note that during the entire grazing season, when either sheep or goats grazed on *Rhanterium*, they almost exclusively selected the leaves of mature plants or mature parts of the plants. Only rarely were the animals observed to graze even lightly on the leaves of relatively young *Rhanterium* plants. In contrast, young plants of all other species grazed were invariably chosen over the more mature plants and plant parts of the respective species. Possibly contributing to the present density of *Rhanterium* in the ecosystem (over 50 percent of the biomass) is the fact that very young plants are almost totally ungrazed by sheep or goats.

Analysis of botanical data and forage selection processes tend to support the hypothesis that *Rhanterium suaveolens* is an increaser in the arid ecosystem studied. Furthermore, given alternative choices of other plants in sufficient abundance, it is believed that sheep and goats will select one or more of the choices over *Rhanterium*.

Nutrition

Nutritional parameters of the diets were analyzed and calculated on the basis of weekly average diets for each treatment (Figures 3 and 4). One must, therefore, assume that the results reflect nutritional properties of both the annual and perennial components of the diets. In addition, quantitative data presented are based

on adult male sheep and goats. Consequently, without further adjustments, estimates of intake of dry matter and digestible energy may not be directly applicable to other sex or age classes. However, estimates of qualitative parameters such as percent digestibility, percent crude protein in diets and percent digestibility of protein would seem to be more easily accepted. In general, they reflect basic properties of the vegetation and compositional changes in the diets rather than animal-influenced factors.

Consumption of dry matter

Figures 3 and 4 describe the trends in nutritional parameters of diets for sheep and goats in all treatments. Sheep grazing alone as well as sheep in the mixed herd consumed forage dry matter at a considerably higher rate during the first week than during the remainder of the season. These rates ranged from 2.9 kg/day during Week 1 to 1.5 kg/day during Weeks 3 and 4 for sheep alone, as compared to a range of 2.6 kg/day during Week 1 to 1.8 kg/day during Weeks 3 and 4 for sheep in the mixed herd (Figure 3). While there appears to be a difference between treatments for rates of consumption by sheep, no statistical differences ($P \leq .10$) were found between herds nor was there a herd x time interaction. The variation in consumption rates over time were highly significant ($P \leq .01$), however (Table 8).

Sheep

Body wts (adult males)

	Initial	Week 1	W-2	W-3	W-4	
Alone	47.1	47.5	49.4	52.1	50.0	
Mixed	51.0	49.3	54.0	57.0	57.3	
		Intake (% of BW)				
Alone		6.1	3.9	2.9	3.0	
Mixed		5.2	3.1	3.1	3.1	3.6
		Intake g/kg BW				X
Alone						
Mixed		53	31.5	31.6	31.4	36.9

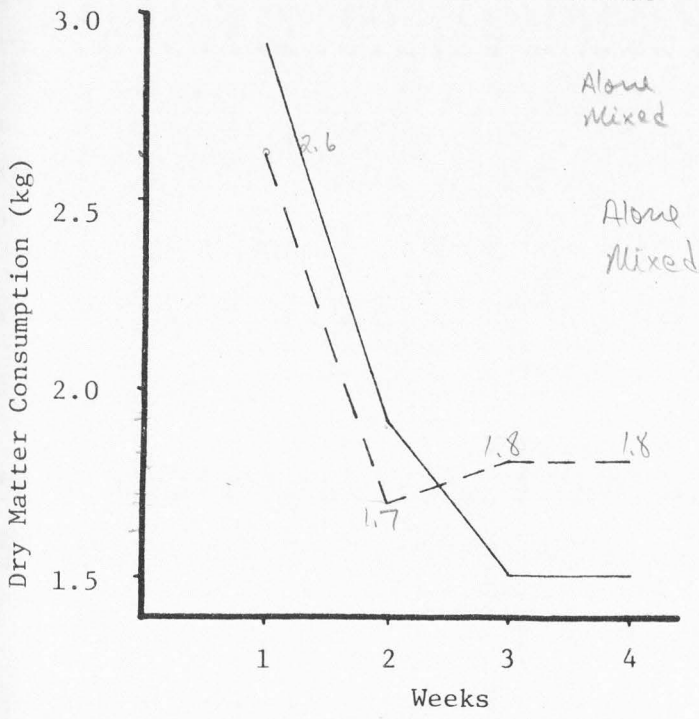


Figure 3. Consumption of dry matter by sheep grazing alone (——) and with goats (- - -).

The decrease in dry matter consumption level exhibited by sheep in both treatments seemed to correspond well to the decline in their selection of annuals (Table 4). A possible explanation for this decline in consumption might be the suggested adaptation to desert environments (McClymont, 1964). As temperature increases (which was the case), animals consume less possibly to minimize heat production from metabolism, and consequently reduce the need to eliminate excess heat. A second possible explanation might be the suggested association

Table 8. Analysis of variance for dry matter consumption by sheep grazing alone and with goats.

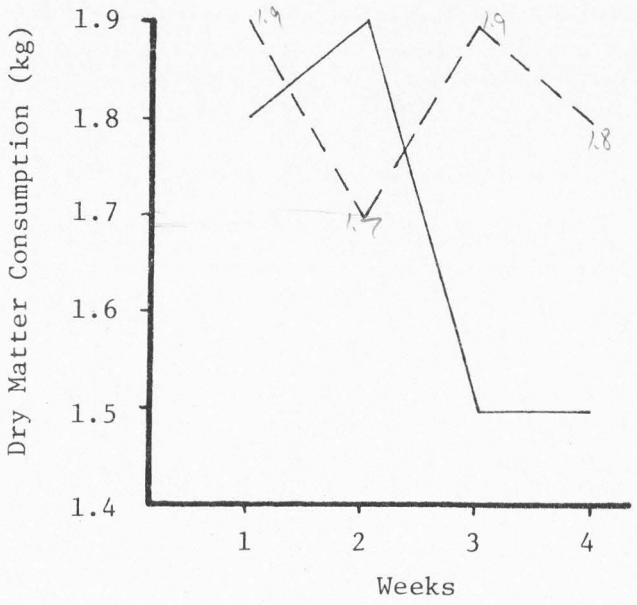
Source of variation	Degree of freedom	Mean square	F
Treatment	1	0.001	0.01
Week	3	1.49	20.56**
Treatment x Week	3	0.17	2.37
Error	16	0.07	
Total	23		

**$P \leq .01$

between availability of palatable species and forage intake (Arnold 1970).

Goats grazing alone appeared to exhibit a relatively high rate of dry matter consumption during the first two weeks (average of 1.85 kg/day) followed by a decrease during the final two weeks (average of 1.50 kg/day) (Figure 4). In contrast, goats in the mixed herd demonstrated no consistent trends in rates of consumption over the four weeks of the study. Their consumption rates fluctuated between 1.7 and 1.9 kg/day (Figure 4). As with sheep, no statistical differences ($P \leq .10$) were found in rates of consumption between treatments nor was there a treatment x time interaction (Table 9). Figure 4 suggests that differences between treatments did indeed exist, probably during Week 3 and 4; however, such differences were statistically undetectable because of variable consumption rates by goats in the mixed herd.

Earlier discussion identified differences in species composition of the diets for goats in both treatments. In order to maintain a relatively even rate of consumption as the annual component of the vege-



Goats

Body wts (adult males)

	weeks 1	2	3	4
alone	39	40.3	43.3	41.6
mixed	41	44.3	45.8	45.5

Intake (% of BW)

	1	2	3	4	$\bar{X}$
alone	4.6	4.7	3.5	3.6	
mixed	4.6	3.8	4.1	4.0	4.1
g/kg BW	46.3	38.4	41.5	39.6	41.5

Figure 4. Consumption of dry matter by goats grazing alone (——) and with sheep (- - -).

tation disappeared, the goats had to increase their intake of perennials. The goats grazing alone experienced a greater change in species selected than did goats in the mixed herd. Literature already cited (Arnold, 1970; Wilson, 1957) has pointed out the goat's preference for browse.

When all sheep were compared with all goats, statistical differences ($P \leq .10$) were found for rates of consumption. Sheep consumed about 8 percent more dry matter per animal per day than did goats. Sheep in this study were slightly larger animals, on the average, than were the goats. Therefore, higher rates of consumption per animal would be

Table 9. Analysis of variance for dry matter consumption of goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	0.06	0.59
Week	3	0.05	0.42
Treatment x Week	3	0.08	0.78
Error	15	0.11	
Total	22		

expected.

Digestibility of the diets

Digestibility of all diets selected by either sheep or goats generally decreased through the study (Figures 5 and 6). This change closely corresponded to the increase in percentage contribution of perennials as the grazing season progressed.

Cook (1971), Ghadaki, et al. (1974), Van Dyne and Heady (1965b), and others have concluded that the nutritive value (e.g., digestibility, protein content) of range forage decreases with advancing maturity. Furthermore, studies with sheep have associated such decreases with decreases in intake (Campling, 1970). With limited success, Arnold and Hill (1972) have attempted to correlate intake to olfactory and gustatory chemical stimuli given off by plants. They, nevertheless, do not discount the importance of plant chemical influence in the selection and consumption processes.

Statistical analysis of digestibility data for sheep (Table 10) showed significant differences ($P \leq .01$) between herds and over time, as well as a significant treatment x time interaction. A comparison of the two treatments on a week-by-week basis showed a rather consistent difference of about 5 percent during Weeks 1 and 2 in favor of sheep grazing alone.

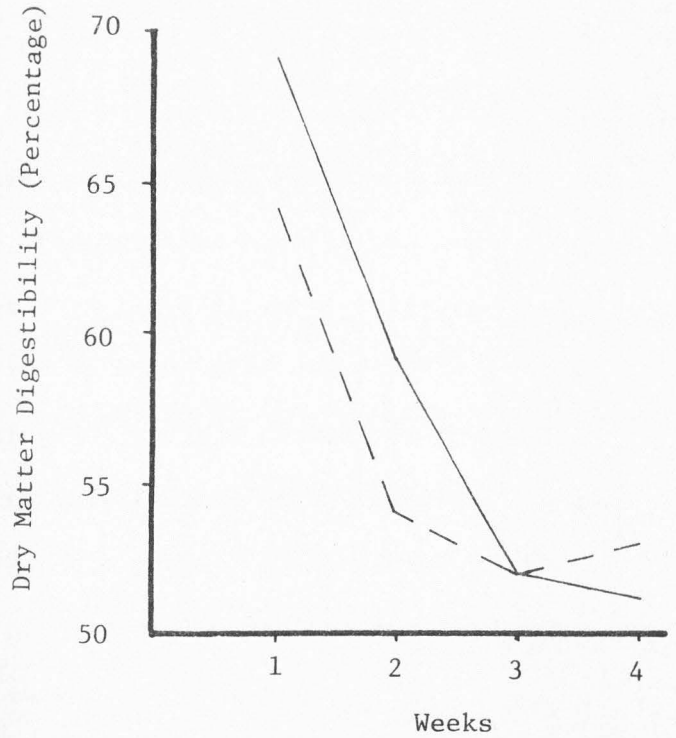


Figure 5. Dry matter digestibility of forage consumed by sheep grazing alone (——) and with goats (- - -).

Based on nutritional data thus far presented, there appears to be a positive association between level of consumption and digest-

Table 10. Analysis of variance for percentage dry matter digestibility of diets of sheep grazing alone and with goats.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	19.78	36.50**
Week	3	280.04	517.10**
Treatment x Week	3	17.11	31.59**
Error	16	154	
Total	23		

**$P \leq .01$

ibility of the diets for sheep in both treatments (Figures 3 and 5). Also, the positive association between digestibility and quantity of annuals in the diet seems evident. Therefore, differences in digestibility between herds can possibly be attributed to the selective grazing for certain perennials by sheep in the mixed herd. An important factor to consider in the overall decrease in digestibility is the increased maturity of the forage consumed over time. The increased use of perennials, and the increased lignification of the species as the season progressed (Cook, Mattox, and Harris, 1961; Van Dyne and Heady, 1965c) lend support to this thought. Also, the interaction of herds and time (Table 10) appears to have been caused by the increased intake of fresh annual grasses during Week 4 by sheep in the mixed herd (Table 4).

As with sheep, statistical analysis for digestibility of goats' diets (Table 11) showed highly significant differences ($P \leq .01$) between

herds, over time, and a treatment x week interaction. Also similar to sheep treatments, goats grazing alone exhibited higher digestibilities during the first two weeks than did goats in the mixed herd (Figure 6).

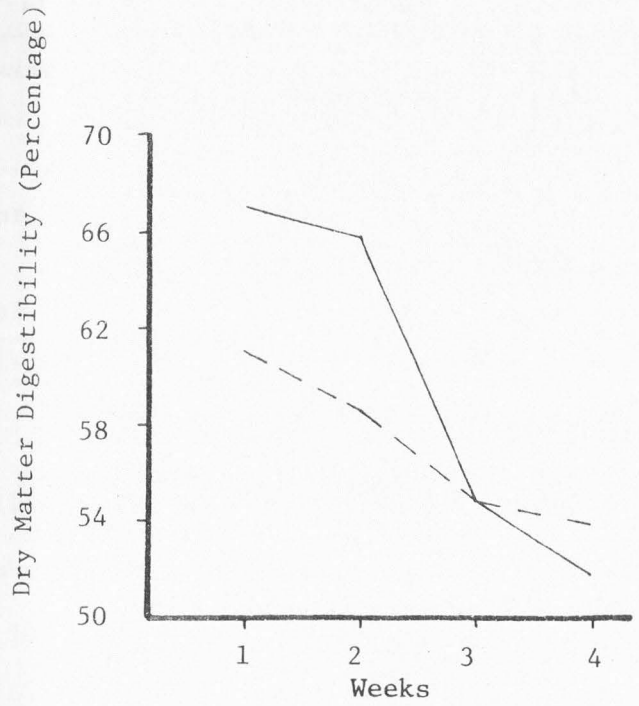


Figure 6. Dry matter digestibility of forage consumed by goats grazing alone (———) and with sheep (- - -).

Goats in both herds exhibited a decrease in digestibility over time, although the overall change for goats in the mixed herd was apparently lesser in magnitude. Differences in digestibility between goat treatments appears to have occurred during Weeks 1 and 2 (Figure 6) and probably reflected changes in the intake of annuals (Table 5).

Table 11. Analysis of variance for percentage dry matter digestibility of diets of goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	53.04	154.45**
Week	3	180.06	524.45**
Treatment x week	3	35.47	103.31**
Error	16	0.34	
Total	23		

**P≤.01

Unlike sheep, however, there did not appear to be an association between intake and percent annuals in the diet and level of consumption. The initial differences between treatments and subsequent changes throughout the grazing season in both treatments largely reflects structural and chemical changes in maturing browse species. Cook and Harris (1968) discussed the lignification of plant tissue over time and related this factor to declining digestibility values. As with sheep in the mixed herd, the increased intake of fresh annual grasses during Weeks 3 and 4 by goats in the mixed herd conceivably caused the treatment x week interaction.

Consumption of apparent digestible energy

Sheep alone and sheep in the mixed herd followed similar trends in consumption of digestible energy (Figure 7). Although sheep alone consumed about 7 percent more digestible energy per animal per day

than did sheep in the mixed herd, averaged over the entire study (Table 12), no differences ($P<.10$) were detected between treatments (Table 12). However, there was a highly significant ($P<.01$) variation over time. This time effect seems mainly due to the changes between weeks 1 and 3. These changes reflected both a decrease in dry matter intake and a decrease in digestibility of the diet.

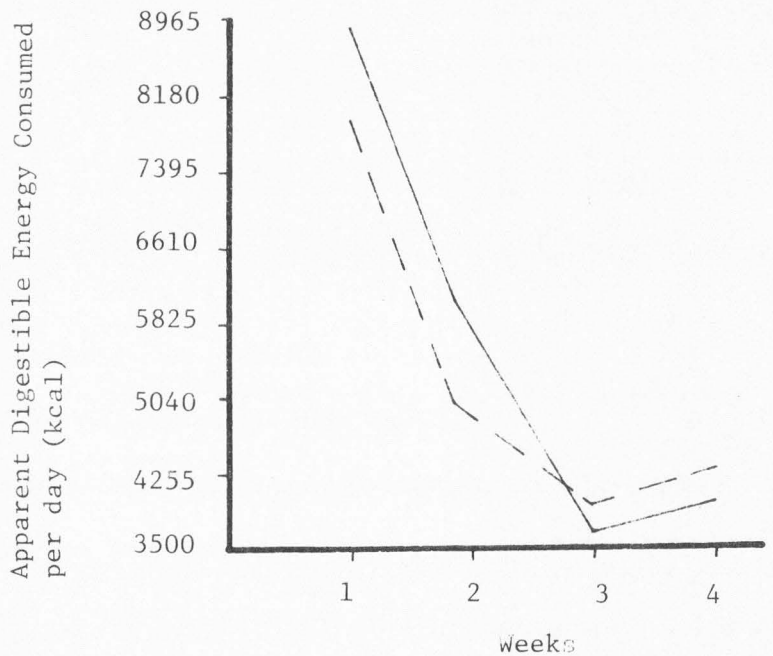


Figure 7. Consumption of apparent digestible energy by sheep grazing alone (——) and with goats (- - -).

Table 12. Analysis of variance for apparent digestible energy consumed by sheep grazing alone and with goats.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	813,750.7	1.49
Week	3	23,235,600.0	42.58**
Treatment x Week	3	789,451.3	1.45
Error	16	545,714.4	
Total	23		

**$P \leq .01$

Moir (1961) has demonstrated a close positive relationship between digestible dry matter and apparent digestible energy in the diet. These declines can probably be related to the changes in species composition of the diet from annuals to perennials. The slight increase in apparent digestible energy consumption from Week 3 to Week 4 for sheep in the mixed herd was probably the result of the increased intake of annual grasses discussed earlier. A similar increase by sheep in the single species treatment is not easily explained but could have resulted from a more selective grazing for certain plant parts. Cook, Mattox, and Harris (1961) discussed this selective behavior by grazing ruminants.

Goats in both treatments followed generally decreasing trends in consumption of digestible energy (Figure 8). The only difference ($P \leq .05$) detected was in the "week" or time component of the analysis (Table 13).

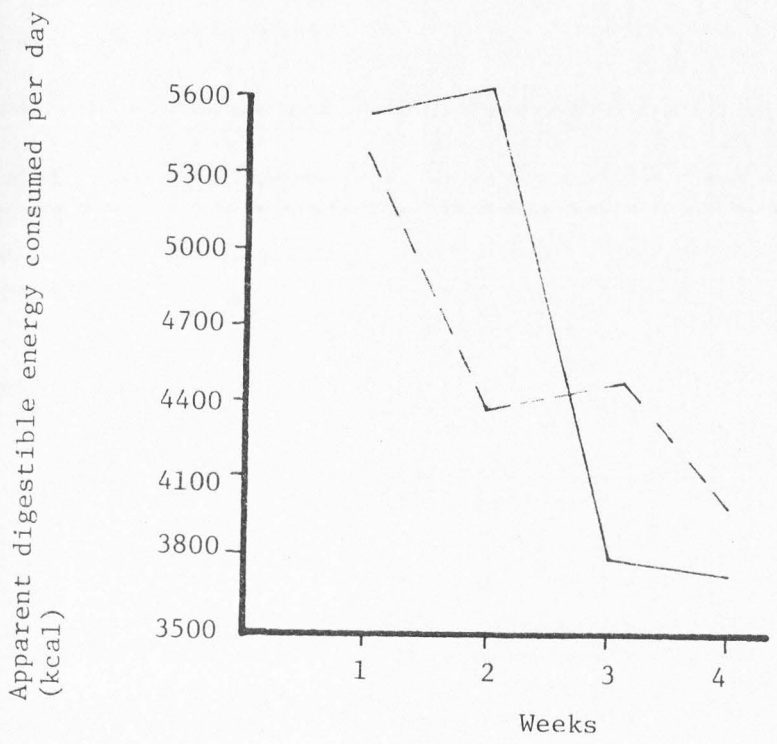


Figure 8. Consumption of apparent digestible energy by goats grazing alone (——) and with sheep (- - -).

These trends appeared to be associated with declines in diet digestibility and changes in diet composition. Unlike sheep though, this association apparently did not relate as closely to levels of dry matter consumption.

When all sheep were compared with all goats, it became evident that sheep consumed about 16 percent more digestible energy per animal per day than did goats ($P \leq .10$) but as with dry matter, this difference does not consider size differences between sheep and goats.

Table 13. Analysis of variance for apparent digestible energy consumed by goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	54,935.95	0.07
Week	3	2,935,041.00	3.49*
Treatment x Week	3	194,204.90	1.09
Error	15	841,343.20	
Total	22		

*P≤.05

Dietary crude protein

Percentage crude protein in the diets of animals in all treatments averaged higher during the first two weeks of the study than during the last two. However, the magnitude of this percentage varied from treatment to treatment (Figures 9 and 10).

Diets of sheep grazing alone steadily decreased in crude protein content from a high of about 14 percent during Week 1 to a low of 9 percent in Week 4 (Figure 9). Sheep grazing in the mixed herd experienced a change from about 13 to 11 percent during the same period. In spite of the variations, diets for sheep in both treatments averaged approximately 11 percent crude protein on a season-long basis, and showed no statistical differences (P≤.10) (Table 14). Highly significant differences (P≤.01) were detected over time, and there was a treatment x week interaction (Table 14).

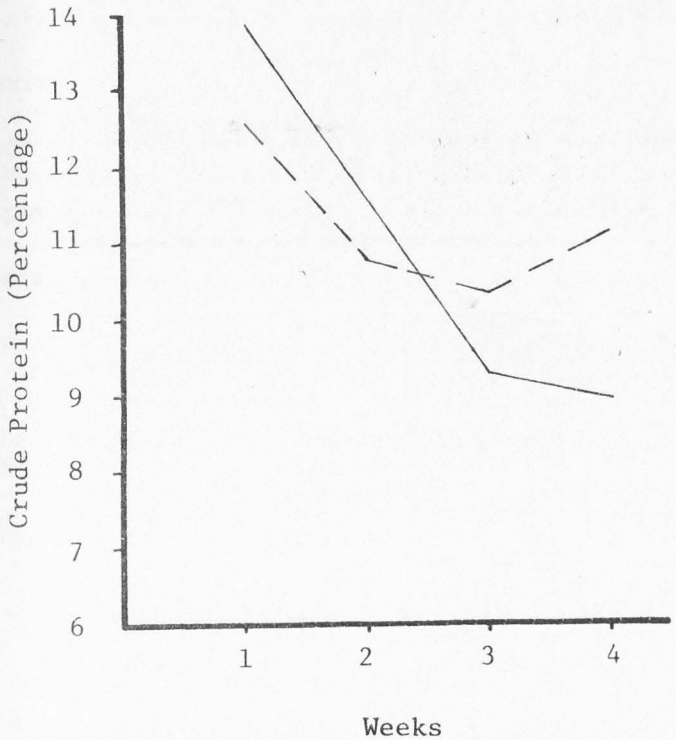


Figure 9. Percentage crude protein in forage consumed by sheep grazing alone (——) and with goats (- - -).

Table 14. Analysis of variance for crude protein in forage consumed by sheep grazing alone and with goats.

Source of variation	Degree of freedom	Mean square	F
Treatment	1	1.14	0.12
Week	3	461.44	47.68**
Treatment x Week	3	76.67	7.92
Error	16	9.67	
Total	23		

**$P \leq .01$

From Week 1 to Week 4, crude protein content of diets of goats grazing alone decreased from about 13 percent to 9 percent (Figure 10). Crude protein in the diets of goats in the mixed herd decreased from 12 percent to 10 percent during this same period. Comparable to sheep treatments, season-long crude protein averages for both goat treatments were approximately 11 percent, and there were no statistical differences ($P \leq .01$) between treatments (Table 15). Also, similar to sheep treatments, differences ($P \leq .05$) in dietary crude protein content were detected over time, but no treatment x week interaction was detected (Table 15).

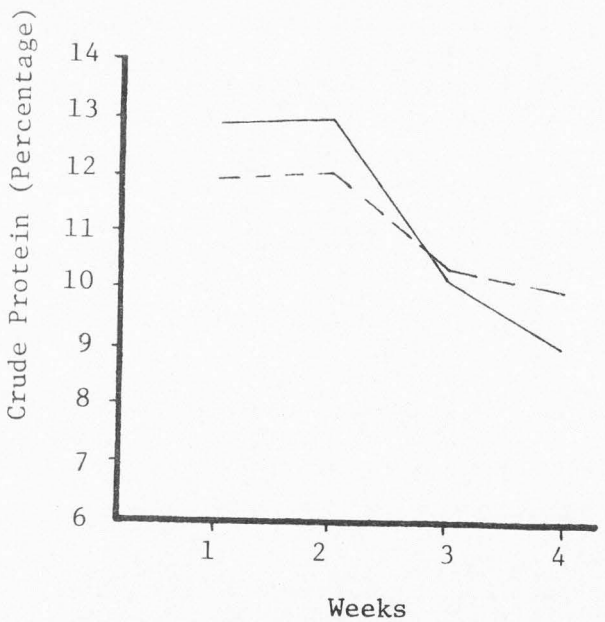


Figure 10. Percentage crude protein consumed by goats grazing alone (——) and with sheep (- - -).

Table 15. Analysis of variance for crude protein in forage consumed by goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	2.04	0.13
Week	3	68.31	4.42*
Treatment x Week	3	31.50	1.39
Error	15	15.45	
Total	22		

*$P \leq .05$

Apparent digestible protein

The general trends and patterns of differences for apparent digestible protein content of diets for all treatments corresponded to those for crude protein content. Apparent digestible protein in the diet of sheep in both treatments decreased from Week 1 to Week 4 (Figure 11). Season-long diets for sheep grazing alone averaged 9.4 percent as compared to 8.7 percent for sheep in the mixed herd but these differences were not significant (Table 16). Both the weeks and the treatment x week components were highly significant (Table 16).

Goats grazing alone experienced a greater season-long decrease in apparent digestible protein in the diet than did goats in the mixed herd. From Week 1 to Week 4 there was a decrease from approximately 11 percent to a low of 7 percent for goats alone as compared to a change from a high of 9 percent to a low of about 8 percent for goats in the mixed herd (Figure 12). Similar to sheep, no detectable differ-

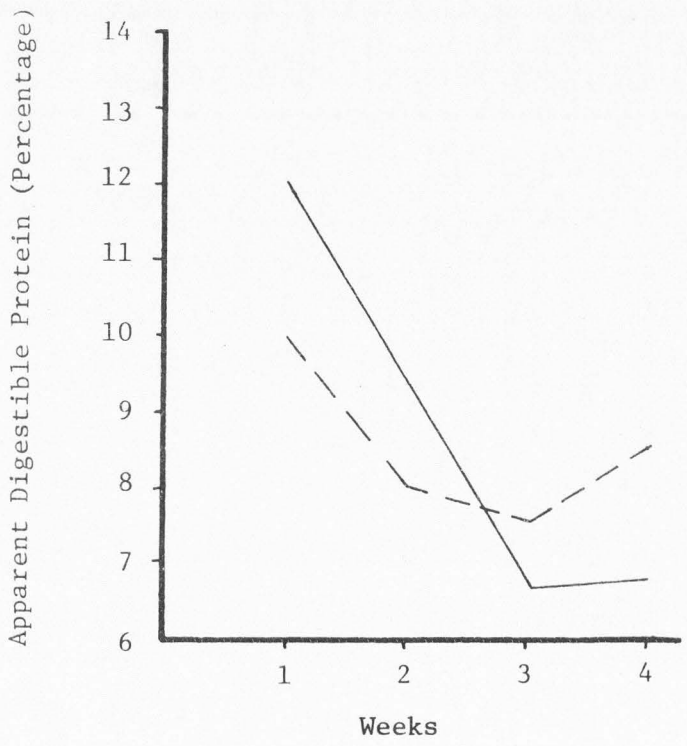


Figure 11. Apparent digestible protein content of forage consumed by sheep grazing alone (——) and with goats (- - -).

Table 16. Analysis of variance for apparent digestible protein content of forage consumed by sheep grazing alone and with goats.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	7.13	1.17
Week	3	398.15	65.32**
Treatment x Week	3	65.46	10.74**
Error	16	6.09	
Total	23		

**$P \leq .01$

ences ($P \leq .10$) were found between treatment (Table 17). Diets for goats grazing alone averaged 9.2 percent apparent digestible protein compared to 8.4 percent for goats in the mixed herd. Again, as with sheep, the differences in apparent digestible protein intake were highly significant ($P \leq .10$) over time (Table 17).

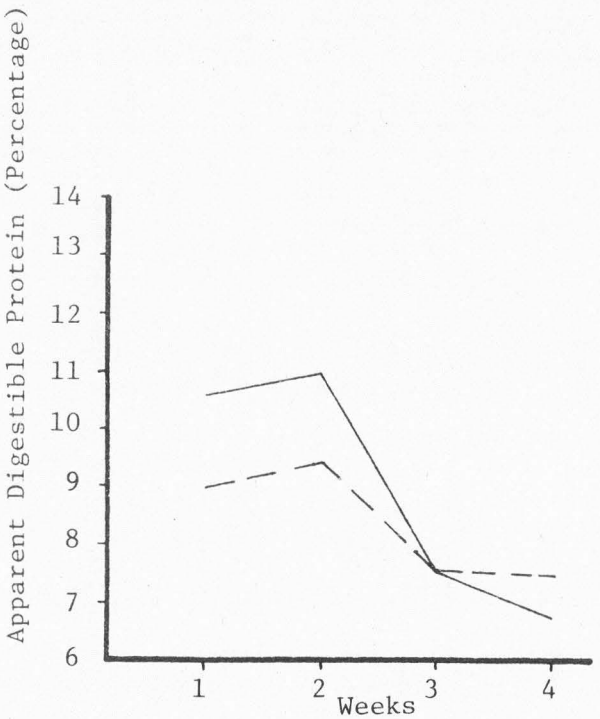


Figure 12. Apparent digestible protein content of forage consumed by goats grazing alone (——) and with sheep (- - -).

Table 17. Analysis of variance for apparent digestible protein content of forage consumed by goats grazing alone and with goats.

Source of variation	Degrees of freedom	Mean square	F
Treatment	1	.41	0.04
Week	3	65.91	6.49**
Treatment x Week	3	22.59	2.22
Error	15	10.16	
Total	22		

**P $\leq$.01

The positive association between crude protein and apparent digestible protein content as a grazing season progresses, is discussed by Cook and Harris (1968) and is evident from comparisons of Figures 9 and 10 to Figures 11 and 12. This general decrease in protein values for maturing forage is consistent with a recent rangeland study in Iran by Ghadaki, et al. (1974). The decline in crude protein content, as affected by the maturing process of the vegetation, consequently lowers the digestible protein available to the grazing animal. The relationship is curvilinear, however, due to the interaction of true protein digestibility and metabolic fecal protein excretion, and at relatively low (<5%) crude protein levels, the concentration of apparent digestible protein decreases at an increasing rate (Robbins, et al. 1975).

Herd interaction for crude protein and apparent digestible protein was detected in the sheep treatments, during Weeks 2 and 3 (Tables 14 and 16). This appears to correspond to the increased intake of grasses

by animals in the mixed herd during the same period of time. It is known that protein content for fresh grasses is generally higher than that found in more mature browse species (Huston, Shelton, and Ellis, 1971).

Animal Weight Responses

In analyzing weight responses, initial weights of animals in each treatment were used as a covariate to compensate for the disparity in sizes of animals in each herd. Essentially, this procedure adjusted all animals to an equal starting weight, from which subsequent weight responses in each of the following sex and age categories were compared over the grazing season: 1) adult males, 2) adult females with young, 3) adult females without young, and 4) young animals, both male and female.

When seasonal weight changes of all sheep grazing alone were compared to those for all sheep in the mixed herd, no significant differences ($P<.10$) were found between herds (Table 18). All sheep grazing alone averaged 2.17 kg/animal seasonal gain while all sheep in the mixed herd averaged 2.14 kg/animal. Weight responses of individual categories are presented in Figure 13 and weights of individual animals for each weigh date are tabulated in Appendix 2. There were, however, true differences ($P<.01$) among weeks and sex-and-age categories, as well as significant herd-by-week, and week-by-sex-and-age interactions (Table 18). The differences found in the "weeks" component of the analysis appear to have been a reflection of the changes in animal weights (Figure 13) as the grazing season progressed from

conditions of relatively high availability and nutritious forage to limited availability of relatively poor quality forage. The significance of the sex-and-age component of the analysis appears to have resulted from the seemingly greater weight changes that occurred in the adult male class (Figure 13). In general, the changes that occurred in the remaining classes were more gradual and these appeared to be similar.

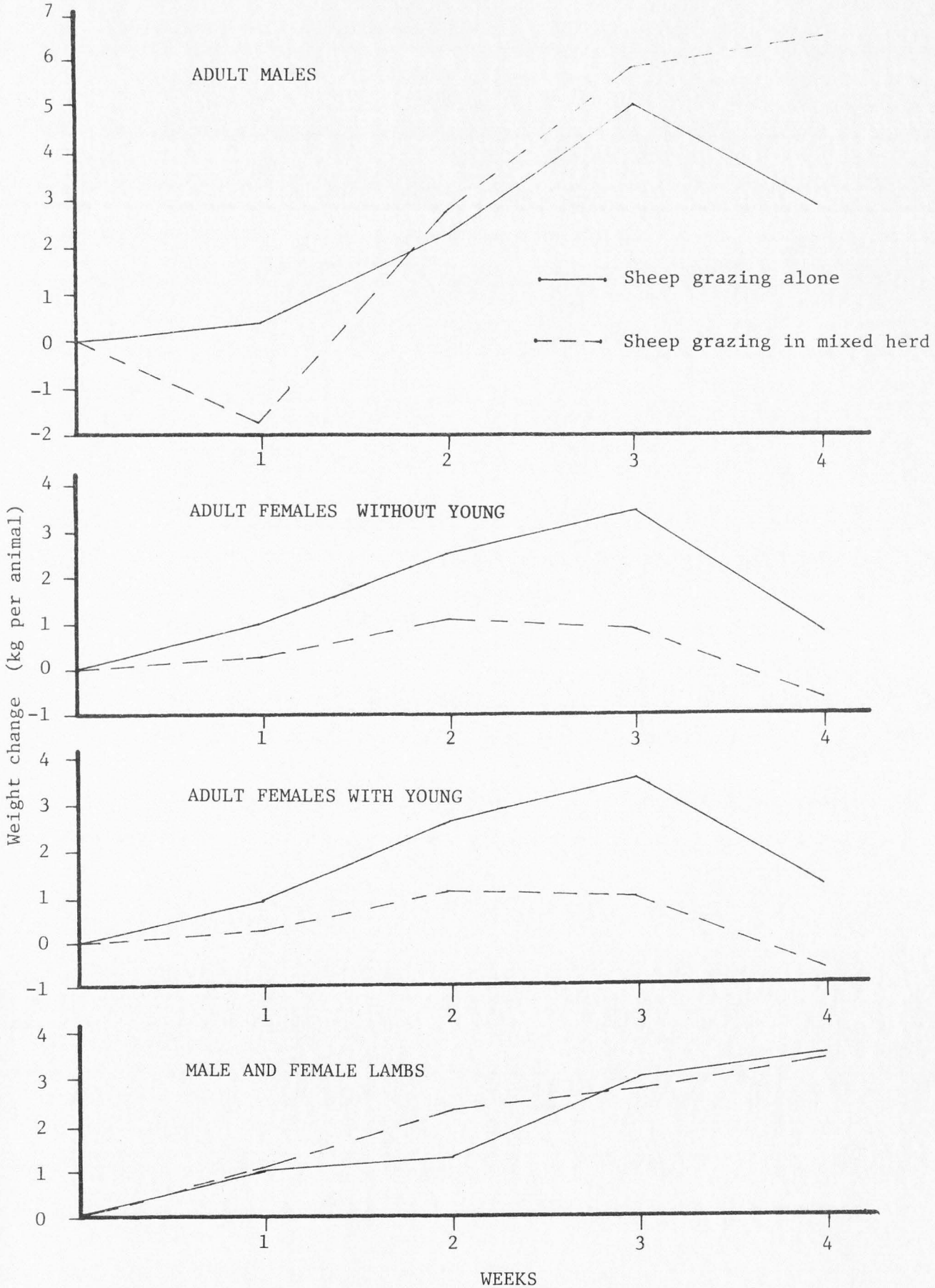
Table 18. Analysis of covariance for weight responses of sheep grazing alone and with goats.

Source of variation	Degrees of freedom	Mean Square	F
Initial weight	1	3697.33	3892.20**
Treatment	1	.03	.03
Week	3	19.81	20.85**
Sex-and-Age classes	4	6.68	7.03**
Treatment x Week	3	9.35	9.84**
Treatment x Sex-and-Age	4	2.06	2.17
Week x Sex-and-Age	12	6.81	7.17**
Treatment x Week x Sex-and-Age	12	2.07	2.13
Error	131	.95	
Total	171		

**$P \leq .01$

Care should be used in making strong interpretations about response of adult males, as the sample size for that category was small, four

Figure 13. Weight responses of four sex and age classes of sheep during the grazing season.


ADULT MALES
Sheep grazing alone
Sheep grazing in mixed herd
ADULT FEMALES WITHOUT YOUNG
ADULT FEMALES WITH YOUNG
MALE AND FEMALE LAMBS
Weight change (kg per animal)
WEEKS

animals in the single-species herd and only two of each species in the mixed herd.

Adult female sheep in both treatments exhibited similar trends in weight responses, that is, a general gain during the first two weeks, a leveling-off during the third week, and a marked decrease during the fourth week. The change appeared somewhat more exaggerated in the single species herd. This response would have been expected for lactating ewes, reflecting declining nutritional value of range forage coupled with the energetic costs of milk production. Inexplicably, dry ewes in both treatments exhibited almost identical responses to the lactating ewes in their respective herds. Cook, Mattox and Harris (1961) discussed the relatively higher intake of wet ewes when compared to dry ewes, and the differences in weight gains favoring the dry ewes. On a season-long basis, both dry and lactating ewes in the species alone treatment showed a tendency for positive gains while those in the mixed herd showed a tendency for slight losses. However, these apparent differences were not large enough to be detected in the statistical analysis.

In both sheep treatments, male and female lambs exhibited almost equal weight gains on a season-long basis. Generally, weight gains for animals in this category showed an increasing trend throughout the grazing season. The animals grazed with their dams throughout the season and had the added nutritional advantage of receiving milk from them during this time. As the nutritional value of the range declined, lambs continued to thrive at the expense of the lactating ewes (Cook, Mattox and Harris, 1961), however, the amount of milk the lambs were able to consume is not known. One can speculate that lambs

would eventually exhibit a decline in weight reflecting the declining condition of the dams and decreasing levels of milk production caused by the increasingly poor range conditions.

As with sheep, goats exhibited no statistical differences ($P<.10$) for weight responses between herds (Table 19). All goats grazing alone averaged 2.2 kg/animal seasonal gain, and all goats in the mixed herd averaged 2.9 kg/animal.

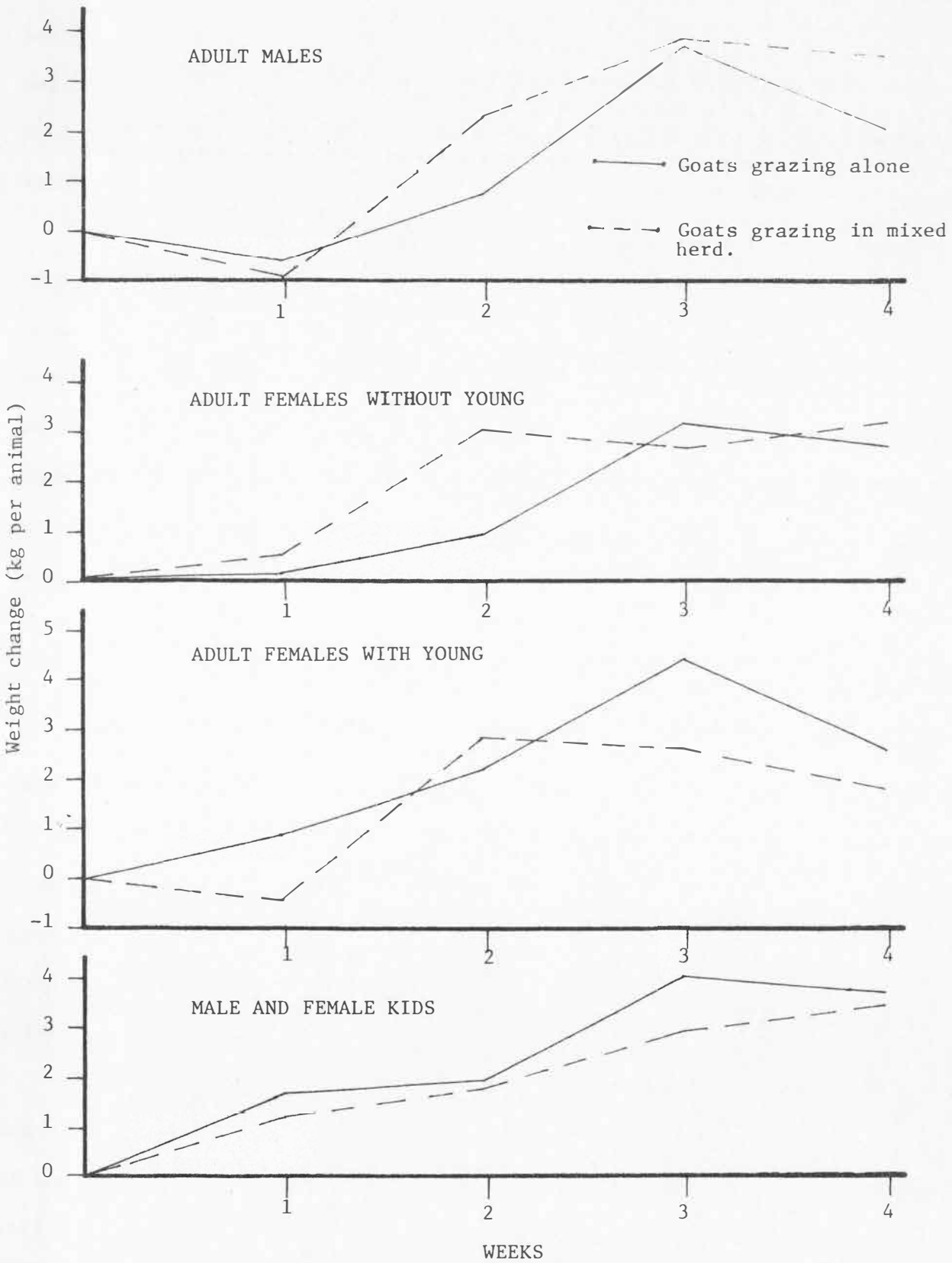
Table 19. Analysis of covariance for weight responses of goats grazing alone and with sheep.

Source of variation	Degrees of freedom	Mean Square	F
Initial weight	1	1828.26	3301.88*
Treatment	1	.06	.10
Week	3	21.08	38.08*
Sex-and-Age	4	.58	1.06
Treatment x Week	3	16.67	30.11*
Treatment x Sex-and-Age	4	.62	1.12
Week x Sex-and-Age	12	6.28	11.35*
Treatment x Week x Sex-and-Age	12	.86	1.56
Error	139	.55	
Total	179		

* $P \leq .01$

Weight responses of the individual categories are presented in Figure 14 and weights of individual animals are tabulated in Appendices 2 and 3.

Figure 14. Weight responses of four sex and age classes of goats during the grazing season.


ADULT MALES
Goats grazing alone
Goats grazing in mixed herd.
ADULT FEMALES WITHOUT YOUNG
ADULT FEMALES WITH YOUNG
MALE AND FEMALE KIDS
Weight change (kg per animal)
WEEKS

Differences ($P \leq .01$) were found among weeks (Table 19). Unlike sheep, however, no statistical differences were detected among the sex-and-age categories. Significant interactions were indicated for herd-by-week, and week-by-sex-and-age components of the analysis (Table 19).

Again, as with sheep, the differences detected in the "weeks" component tend to reflect the seasonal availability of forage and the consequent change in consumption level. The adult male class was represented by relatively fewer animals; as in the sheep treatments, adult females were in various stages of lactation; and the grazing season was over by the end of Week 4.

When all sheep were compared with all goats, on a season-long basis, no significant differences ($P \leq .10$) were detected for weight response.

Distances traveled

Animal movement data (Table 20) revealed that animals in the mixed herd traveled significantly farther ($P \leq .01$) than either sheep or goats in the single species herds (Table 21). Differences in distances varied from 24 to 40% between the mixed herd and goats grazing alone and sheep grazing alone respectively. No differences ($P \leq .10$) were found within treatments for distances traveled in morning vs afternoon, nor among weeks. Likewise, interaction components were not significant.

Goats grazing alone appear to have traveled farther than sheep grazing alone, indicating that goats possibly influenced the greater mobility of the mixed herd. Devendra and Burns (1970) discussed the apparent influence exerted by goats on other ruminants when grazed together. Findings of this study tend to support this idea.

SUMMARY AND CONCLUSIONS

Demanding use by grazing livestock of the available forage resources has probably contributed greatly to the expansion of arid and semi-arid regions in Africa. The purpose of this study was to establish a basis from which the complex relationships of livestock and the ecosystem can be studied further. Analyses of forage selection by sheep and goats, grazing alone and in combination, and resulting consequences upon the nutritional intake of these animals were considered essential to this goal. The study was conducted during the 1974 spring grazing season.

Diet determinations were established by using the bite-count method, calibrated by hand plucking and weighing representative bites for the major species components. Forage intake was determined through total fecal collections, using animals equipped with fecal collection bags, with estimates of forage digestibility being derived by in vitro procedures. Standard laboratory procedures were used to determine energy and protein values for both forage and feces. Weight responses were calculated from weekly weighings of experimental animals.

When sheep grazing alone were compared to sheep grazing with goats, there was a significant difference only in the percent dry matter digestibility of diets. No detectable treatment differences ($P \leq .10$) were evident for either percent perennials in the diet, *Rhanterium* in the diet, dry matter consumption, apparent digestible energy consumed, crude protein in forage consumed, apparent digestible protein in forage con-

of diets. No detectable treatment differences ($P \leq .10$) were evident for either percent perennials in the diet, *Rhanterium* in the diet, dry matter consumption, apparent digestible energy consumed, crude protein in forage consumed, apparent digestible protein in forage consumed, or in animal weight responses.

A similar comparison for goats revealed treatment differences ($P \leq .01$) for percent perennials in the diet and percent dry matter digestibility, but for none of the other variables tested.

Analysis for temporal effects revealed differences over time in all botanical and nutritional variables except for dry matter consumption by goats. The data suggested, however, that, at least for goats grazing alone, there was a trend for decreasing consumption rate over time. The general tendency exhibited by sheep in both treatments, and presumably by goats grazing alone, was one associating a high consumption level with high nutritive content of forage. Both nutritional level and intake appeared to be positively associated with annuals in the diet. As the annuals disappeared from the range, and consequently from animals' diets, nutritive value of the forage selected decreased and daily intake rates declined. A deviation from this trend was exhibited by goats grazing in the mixed herd, where perennials comprised the greater percentage of the diet throughout the study and consumption rate for any one week did not vary more than 0.1 kg from the season-long average. However, nutritive value of the forage selected by goats in the mixed herd decreased over time as in other treatments.

By the end of the grazing season forage intake rates, as well as the nutritional value of diets consumed, appeared to be approaching a

maintenance situation for female sheep. Presumably, a continued use of the range would have resulted in continued decline in nutrient intake for these animals, and a comparable response in the other sex and age groups of both sheep and goats would have followed.

In comparison of treatments, findings of this study indicate that either sheep or goats grazed alone were most apt to select annual plant species over perennials, and sheep and goats were attracted to many of the same annual species. When sheep and goats are grazed in combination, both classes tended to select a greater variety of both annual and perennial species than when grazed in a single species herd. Yet, when grazed in combination, the sheeps' diets consisted primarily of annuals and the goats' diets were composed primarily of perennial species.

Hours spent grazing by each herd were relatively constant over the season, largely as the result of management influences (Appendix 4). Also, comparisons of herd movements and average distances traveled revealed that the mixed herd traveled 24-40% farther ($P \leq .01$) than either of the single species herds. Although energy expenditure of the different treatments was not quantified, the implication that the mixed herd expended more energy in movement is clear. Also, goats grazing alone appear to have traveled farther than sheep grazing alone, and seem to have influenced the greater distance traveled by the mixed herd.

An analysis of co-variance comparing all sheep with all goats, adjusted for equal starting weight showed no significant weight response differences ($P \leq .10$) between the two classes of livestock.

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APPENDICES

APPENDIX 1

Climatic records for the study period, taken at 1500 hours.

	Day	Temp	Wind Velocity	Relative Humidity
WEEK ONE	1	--	8.1 km/hr.	--
	2	--	21.8	--
	3	19°C	23.9	88%
	4	18°	13.8	58
	5	26°	11.1	27
	6	36°	16.5	18
	7	30°	11.7	23
WEEK TWO	1	34°	29.9 km/hr.	13
	2	23°	31.8	31
	3	23°	12.2	42
	4	28°	20.3	34
	5	31°	19.8	24
	6	34°	19.8	13
	7	21°	8.9	56
WEEK THREE	1	24°	8.1 km/hr.	51
	2	22°	21.3	68
	3	21°	17.7	60
	4	22°	18.3	58
	5	25°	10.5	47
	6	34°	8.5	20
	7	36°	9.4	20
WEEK FOUR	1	32°	9.5 km/hr.	32
	2	32°	13.8	31
	3	37°	13.9	22
	4	34°	22.2	36
	5	--	--	--
	6	--	--	--
	7	--	--	--

Average weights (kg) of individual sheep categories.

Treatment	Initial wt.		Week 1		Week 2		Week 3		Week 4		Average Seasonal Gain per Animal	
Sheep	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
Adult male	47.1	51.0	47.5	49.3	49.4	54.0	52.1	57.0	50.0	57.3	2.88	6.25
Adult female without young	28.0	28.33	28.94	28.65	30.56	29.44	31.56	29.29	29.19	27.79	1.18	-.54
Adult female with young	30.25	30.07	31.18	30.42	32.81	31.21	33.81	31.07	31.43	29.57	1.18	-.50
Young males and females	19.38	18.85	20.48	19.85	20.81	21.13	22.42	21.59	22.81	22.21	3.44	3.35

Average weights (kg) of individual goat categories.

Treatment	Initial wt.		Week 1		Week 2		Week 3		Week 4		Average Seasonal Gain per Animal	
Goats	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
Adult male	39.6	42.0	39.0	41.0	40.3	44.3	43.3	45.8	41.6	45.5	2.0	3.5
Adult female without young	29.5	23.8	29.66	24.3	30.33	26.8	32.66	26.5	32.16	27.0	2.66	3.2
Adult female with young	24.9	22.9	25.77	22.54	27.08	25.61	29.27	25.39	27.46	24.69	2.56	1.79
Young males and females	11.2	10.9	12.88	12.11	13.10	12.75	15.19	13.82	14.83	14.39	3.63	3.49

Average pasture and grazing time (hr/day) for sheep and goats, alone and in mixed herd.

Treatment	Week 1		Week 2		Week 3		Week 4		Average	
Sheep	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
SHEEP										
Allotted-time [1]	8.3	7.9	8.8	8.5	8.6	8.4	9.0	8.9	8.7	8.4
Grazing-time [2]	6.3	7.6	5.7	7.7	8.5	7.9	6.9	8.5	7.1	7.9
GOATS										
Allotted-time	8.3	7.9	8.8	8.5	8.6	8.4	9.0	8.9	8.7	8.4
Grazing-time	8.2	7.3	8.5	8.5	8.6	8.4	9.0	8.9	8.6	8.3

[1] Allotted-time refers to actual time spent in the pasture.
[2] Grazing time refers to actual time spent grazing.

Weekly and daily water consumption (l./animal) by all sheep and all goats in each study herd.

Herd	Weekly Consumption										Daily consumption Average	
	Week 1		Week 2		Week 3		Week 4		Average			
	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed
Sheep[1/]	2.08	3.16	4.58	3.16	7.08	4.74	8.33	5.26	5.52	4.08	.789	.582
Goats[2/]	2.69	3.68	2.88	3.68	5.77	4.21	6.15	6.31	4.37	4.47	.625	.639

1/ Based on adjusted weights tabulated in the analysis of covariance for sheep, 30.3 kilograms.

2/ Based on adjusted weights tabulated in the analysis of coveriance for goats, 23.6 kilograms.

Table 20. Average distances (meters) traveled by sheep and goats grazing alone and in mixed herd.

Treatment	Week 1		Week 2		Week 3		Week 4		Mean	
	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed	Alone	Mixed[1/]
SHEEP										
Total per day	--	8488	4481	8162	4744	9999	5521	6132	4915[a]	8195[b]
Per hour[2/]	--	1116.8	668.9	1060	558.1	1265.7	800.1	721.4	675.7	1040.9
GOATS										
Total per day	--	8488	6478	8162	6680	9999	5562	6132	6240[a]	8195[b]
Per hour	--	1162.7	762.1	960.2	776.7	1190.4	618.0	688.9	718.9	1000.6

[1/] Treatment means for a particular animal species having different superscripts are significantly ($P \leq .01$) different.

[2/] Travel rates based on actual time spent grazing. Rates were not analyzed statistically, but treatment differences can be inferred as hours spent grazing were relatively constant.

Table 21. Analysis of variance for distances traveled by animals grazing alone and in the mixed herd.

Source of variation	Degree of freedom	Mean squares	
		Sheep	Goats
Treatment	1	4,581,605.0*	2,900,145.0*
AM-PM	1	60,103.76	106,577.9
Week	2	92,439.24	9,657.22
Treatment x AM-PM	1	90,202.68	39,090.67
Treatment x Week	2	20,849.03	109,149.6
Error	4	140,103.8	38,410.2
Total	11	500,809.4	312,460.7

*$P \leq .01$

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