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Sheep Diets and Feeding Behavior in Single and Common Use Grazing Trials on Southwestern Utah Summer Range

George B. Ruyle
Utah State University

SHEEP DIETS AND FEEDING BEHAVIOR IN SINGLE AND COMMON USE GRAZING TRIALS ON SOUTHWESTERN UTAH SUMMER RANGE

by

George B. Ruyle

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ABSTRACT

Sheep Diets and Feeding Behavior in Single and Common Use Grazing Trials on Southwestern Utah Summer Range

by

George B. Ruyle, Doctor of Philosophy

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Major Professor: Dr. Don D. Dwyer
Department: Range Science

A series of grazing trials were conducted on high elevation summer range near Cedar City, Utah. Cattle and sheep were stocked alone and in common in .4 hectare (ha) paddocks. Stocking rates were .76 ha/AUM in 1981 and .60 ha/AUM in 1982. Vegetation measurements were taken before and after grazing treatments to quantify vegetation disappearance. Diet samples were collected from esophageally fistulated sheep in the paddocks before grazing treatments were applied. After a predetermined level of forage utilization was achieved, the paddocks were re-sampled by the esophageally fistulated sheep to examine diets consumed from the forage-reduced vegetation. Behavioral observations were made throughout the trials on sheep grazing alone and with cattle. The length of time sheep spent at a feeding station, feeding station interval, was measured.

Sheep ate less grass and more forbs and shrubs than cattle.

Cattle showed a strong reluctance to browse snowberry (*Symphoricarpos oreophilus*) even when the herbaceous vegetation was greatly reduced. Utilization of grasses, forbs and shrubs in the common use paddocks did not represent an average of the utilization by cattle and sheep each grazing alone. Cattle and sheep grazing together used more forage, especially snowberry, than calculated from single use averages.

The diets of esophageally fistulated sheep were altered by the various grazing treatments. Diets consumed from previously ungrazed paddocks were higher in forbs, *in vitro* organic matter digestibility (IVOMD) and crude protein (CP) and lower in fiber than those diets consumed after paddocks had been grazed. Sheep consumed diets higher in IVOMD but lower in CP in paddocks previously grazed by sheep than where cattle had grazed alone or in commonly grazed paddocks. Sheep selected diets from the remaining herbaceous layer when grazing after sheep but ate mostly snowberry when grazing after cattle. Diets of sheep consumed subsequent to common use grazing were intermediate containing both snowberry and grasses.

Sheep adjusted their feeding behavior as the grazing trials progressed by increasing the number of brief feeding station intervals. This trend was consistent regardless of whether sheep grazed alone or in common with cattle. However, when sheep grazed with cattle, longer feeding station station intervals persisted further into the grazing trials indicating that amounts of acceptable forage per feeding station were not reduced as quickly as when sheep grazed alone.

(124 pages)

INTRODUCTION

Management of grazing animals has been the most important management practice applied to rangelands (Kothmann 1980a, Morley 1981). Range livestock production is generally an extensive operation where relatively few animals graze on large tracts of land with little input beyond seasonal round-ups. But more attention will be paid to rangelands for livestock production in the future. In the past research has concentrated on the vegetation with perhaps some animal-response information. Increasingly the focus of grazing research has become the plant-animal interface. Better knowledge of how grazing livestock interact with their forage resource will become more and more useful as rangeland management becomes more complex.

To study range-animal and range-plant response under various grazing management options, the Utah Agricultural Experiment Station leased approximately 1300 hectares (ha) of high elevation summer range on the border of Iron and Washington Counties in southwestern Utah (UAES Project 089 Outline, Figure 1). Much of the surrounding land is in private ownership and supports livestock grazing during the summer months.

These summer ranges, an integral part of the local livestock production system, have been grazed almost exclusively by domestic sheep for decades. Extensive and heavy sheep grazing has induced a general shift in the herbaceous vegetation from what was probably a

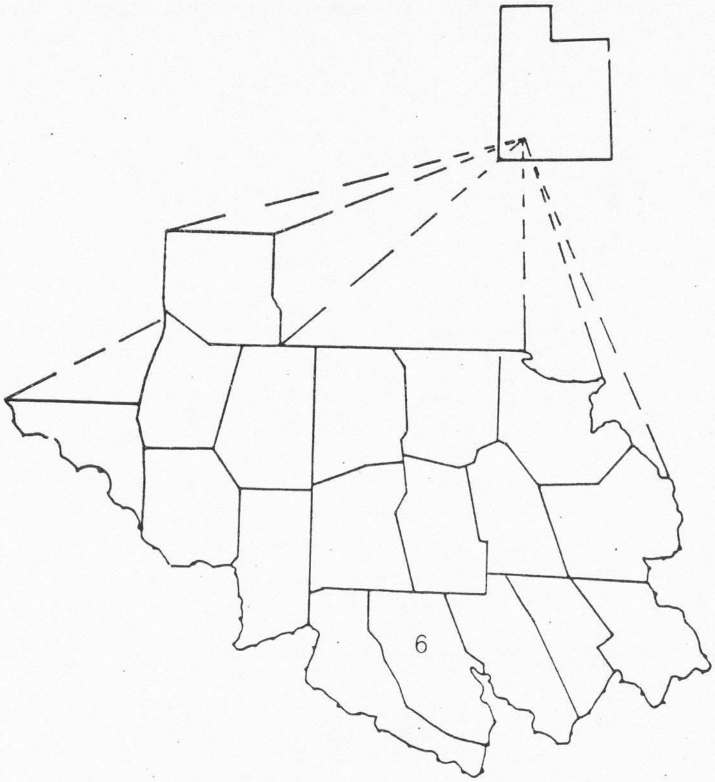

Figure 1. Location of the Utah Agricultural Experiment Station Project 089 study area. The experiments reported here took place in pasture 6, located at the bottom of the figure.

tall forb-grass community to a grass dominant community (Bowns 1983). In much of the area, Letterman needlegrass (Stipa lettermanii), considered a less preferred forage species by sheep, is the current herbaceous dominant while more palatable forbs have nearly disappeared (Bowns 1983). Despite these vegetation modifications, sheep continue as the major livestock species on Cedar Mountain, the location of the study area. The ability of sheep to adjust to changing forage resources by shifting diet selection, combined with the important presence of the palatable shrub snowberry (Symphoricarpos oreophilus) may enable sheep to better use the entire forage resource as reported by Schlundt (1980) and maintain high production levels (Bowns and Matthews 1983, Whittier 1981) while traditional range management theory would predict a vegetation shift to favor cattle (Stoddart et al. 1975).

Although grazing itself affects forage quality, most research has concentrated on or been confounded by the seasonal effect on forage quality. With the coming of more sophisticated grazing management, especially short duration grazing programs, the impacts of grazing as it alters forage quality and feeding behavior need further investigation.

In this study, the flexibility in feeding behavior and diet selection of sheep when the quantity of forage resources is reduced by grazing were investigated during short, intense grazing trials using sheep and cattle stocked separately and together. Behavioral adjustments made by sheep to abundant versus reduced forage were quantified through ocular observations and dietary analysis. Various changes in the plant community were also measured and described. More specifically, the research was designed to quantify how the grazing treatments altered the following:

1. Vegetation structure (standing crop, leaf to stem ratios (L:S), green to dead ratios (G:D))

2. Sheep diets

    a. botanical composition

    b. nutritive quality

3. Sheep grazing behavior

In this dissertation three discrete methods and results sections are presented. These are vegetation use, sheep diets and grazing behavior. Some overlap between sections occurs. This work was a part of and supported by Utah Agricultural Experiment Station Project 089 titled "Response of Animals and Vegetation Under Various Grazing Systems on Forested Rangelands."

LITERATURE REVIEW

Feeding Behavior of Domestic Sheep on Rangelands

As grazing management systems become increasingly complex more information will be needed on how and why range livestock select the food they do. However, most range management practices have focused on the forage plant with less consideration given to livestock production. This failure may be partly responsible for the generally low livestock performance seen in specially designed grazing systems (Heady 1961, Gammon 1978, Kothmann 1980a, Malechek 1981). Understanding relationships between feeding behavior and forage availability should help bridge the gap between better management of rangelands and increased livestock production.

Flexibility in grazing behavior

The flexibility an animal may have in various behaviors differs widely (Alcock 1979). Many behaviors are relatively inflexible allowing the organism little choice of action. There are many examples of an innate mechanism offering no real behavioral choice (Alcock 1979). Animals confined to narrow niches are often genetically molded to fit. Most mating behaviors are likely to be relatively inflexible, for example the choice of a partner. There are more general circumstances, however, that allow for a broad range of choices where narrowly defined, innate behaviors would not be appropriate. In many species, feeding behavior is such a process and may be one of the most flexible of behaviors. Large herbivores fall into this category and perhaps largely due to man's influences large domesticated grazing animals may be one of the best examples of animals with flexible feeding behavior.

Range livestock select their diets from the various plants available in the vegetation. Complex plant communities offer more choices to the grazing animal than tame pastures consisting of relatively few plant species and as this complexity increases so does the complexity of feeding behavior (Arnold and Dudzinski 1978, Van Soest 1982). Large herbivores can be classified according to such feeding habits. Van Soest (1982), after reviewing these classification schemes, labeled domestic sheep as intermediate feeders preferring grass, forbs or browse. Sheep are able to change their diets in concert with forage availability and quality. This flexibility in feeding behavior may enable sheep to more fully use mixed vegetation types than could animals with more limited food selection flexibility and, additionally, sheep may continue to forage successfully when the vegetation is being altered by grazing. Feeding flexibility of sheep may best be expressed when they graze in common with or subsequent to less selective bulk eaters such as cattle (Van Soest 1982).

As grazing progresses, previously rejected plant species may be eaten when preferred foods become scarce (McClymont 1967). However, according to Arnold and Dudzinski (1978), sheep will often continue to graze on preferred species even when their availability is low.

A major behavioral adjustment is made as preferred forage becomes less available. Sheep particularly seem to have a characteristic grazing habit of going over and over an area, each time consuming less-preferred dietary items (Van Dyne et al. 1980). Animals reduce their rate of food consumption and increase grazing time as available forage decreases, up to a point (Allden and Whittaker 1970, Arnold and Dudzinski 1967), indicating there are upper limits to grazing flexibility where food intake is reduced (Freer 1981). There is thought to be a threshold of forage availability where animals minimize their feeding effort (Kothmann 1980b, McClymont 1967). The problem of determining at what level of forage availability sheep are forced to generalize their intake remains unsolved (Iskander 1973).

Many other factors interact in the feeding process to partly determine the degree of flexibility an animal will express in diet selection. These include the physiological condition, physical state, previous experience, morphology, and other genetic expressions in the animal (Arnold and Dudzinski 1978, Malechek and Provenza 1981, Provenza 1981 and others). But the fact remains that domestic sheep, often referred to as selective feeders (Heady 1975) express a wide range of dietary choices demonstrating large feeding flexibility.

Behavior while grazing

In the past, most research on behavior of free-ranging livestock concentrated on patterns of distribution, daily movement and activity budgets (for example; Bowns 1971, Bueno and Ruckebush 1979, Cory 1927, Cook 1966, Dwyer 1961, Herbel et al. 1967, Mueggler 1965). Recent efforts to better understand livestock grazing behavior have focused on intricacies of the grazing activity itself.

Rather than monitoring total daily activity patterns, some researchers have concentrated on the grazing periods, trying to define indices of foraging behavior that relate to the quality and quantity of available food. Major foraging periods usually occur in the morning and evening (Arnold and Dudzinski 1978, Bowns 1971, Dwyer 1961, Moorefield and Hopkins 1951, Wagnon 1963, and others), and it is during these times that researchers are concentrating their efforts. Many factors operate during the grazing activity which can only be examined by carefully monitoring feeding periods.

Gluesing and Balph (1980) studied the amount of time sheep spent walking while grazing and found that they walked more in pastures with limited amounts of alfalfa after they were rotated from pastures with abundant alfalfa (Medicago sativa), evidently searching for the preferred species. This apparent "overshoot" effect, where the animal spends a disproportionate amount of effort seaching for a preferred food item, was described by Cowie (1979) in an experiment using great tits (Parus major) (Cowie 1979 as reported by Krebs et al. 1981). This phenomenon, although recognized in ecological theory, has only recently been considered in the context of range livestock. Under more controlled circumstances, Razmi

(1978) demonstrated that sheep reduced intake of a less preferred food (grass hay) when their preferred food item (pelleted alfalfa) was removed. From this it might be inferred that differences in the availability of preferred forage among pastures may play an important role regarding animal diets in rotational grazing schemes. Because grazing reduces the relative amounts of preferred food items, the degree of forage use may also influence current and subsequent grazing behavior when animals are rotated to fresh paddocks.

Food searching behavior was examined by Razmi (1978) and by controlling food related cues he simulated the choice situation for sheep in so called patchy environments where resources occur in clumps or patches. He found that sheep exhibited an apparent form of exploratory behavior and required two days to learn to discriminate between shape and location of containers offering varying food values. Iskander (1973) found that sheep moved towards conspicuous objects while feeding, using shrubs for example, apparently to orient themselves in the paddock. This behavior would certainly influence patterns of vegetation use. These examples of behavioral patterns are likely modified by rapidly changing forage supplies. Such feeding behavior changes may influence the ways animals handle the stress associated with grazing systems as explained by Kothmann (1980a).

Methods to quantify changes in foraging behavior as available food is reduced have often been tested. To investigate how cattle exploited a forage resource, Scarnecchia (1980) monitored time spent grazing and bites per minute as available forage decreased. He showed that cattle spent more time grazing and increased biting rate as the standing crop of crested wheatgrass (Agropyron cristatum) decreased to around 240 kg/ha. Further decreases in the forage had little affect on these indices of cattle grazing behavior. On the same site, Havstad et al. (1983) found no difference in voluntary intake of heifers as the availability of crested wheatgrass declined from 880 to 280 kg/ha. He also reported no change in energy expenditure as the animals foraged over this range of available forage (Havstad and Malechek 1982) even though feeding behavior was likely adjusted.

Chacon and Stobbs (1976) identified behavioral changes during the process of defoliation of tropical pastures by cattle. As grazing progressed, grazing time and biting rate increased and then decreased while bite size continuously decreased. They concluded that the complexity of conditions caused the low correlation they obtained between feeding behavior and what was measured as forage conditions. However, modification of behavioral variables results as animals compensate to changes in forage conditions (Hodgson 1982a).

Two excellent recent examples of attempts to better understand large herbivore foraging behavior were reported by Novellie (1978) and Owen-Smith (1979). Novellie (1978) studied feeding-moving sequences of Blesbok (Damaliscus dorcas phillipsi) and Springbok

(Antidorcus marsupialis) monitoring feeding behavior rather than actual amounts of food material consumed. Foraging behavior was quantified by recording feeding station intervals (in seconds) alternated with number of step-sets defined as number steps between feeding stations (Goddard 1968). The grazing area accessible to a foraging animal with its fore feet stationary was called a feeding station. The approach detected that seasonal changes in foraging behavior were correlated with chemical and structural changes in the vegetation.

Recognizing that there is an apparent surfeit of food for large herbivores but great variability in nutrient quantities and qualities, Owen-Smith (1979) reported on the development and testing of behavioral measures to detect changes in food abundance as experienced by the kudu (Tragelaphus strepsiceros), a large African herbivore. Two indices of what he called foraging efficiency were used: 1) accepted food abundance, i.e., the feeding seconds achieved per predetermined number of steps while foraging and 2) food ingestion rate, i.e., the proportion of time spent actually feeding during recorded segments of foraging activity. Kudu were observed during their main feeding sessions. The abundance of food accepted by kudu was found to be most sensitive to non-obvious differences in forage quality. The major influence on forage quality was due to seasonal changes. The effects of forage quality reduction as affected by the grazing process was not studied.

More recently, Flores (1983) combined some of these concepts and tested which ones were most sensitive to changes in food supply hoping to gain an indication of forage conditions. He monitored feeding stations (Goddard 1968) and set-steps (Novellie 1978) as well as biting rate (Chacon and Stobbs 1976) and total foraging time (Arnold and Dudzinski 1978) of Angus heifers and related these variables to forage availability and phenology of crested wheatgrass. He concluded that the number of bites per feeding station and total daily foraging time were the variables most sensitive to chaning forage conditions. However, feeding station intervals (FSI) also showed statistical significance in the regression analysis where total foraging time and FSI were the only significant correlations with forage availability. Bites per feeding station were well related to the green to dead proportions of forage. Further, stocking densities increased during the study although grazing pressure was kept constant in all three trials. It is not known how stocking densities or very low levels of available forage would alter these relationships.

Forage perception

The obvious discrepancy between potential food and accepted food, discussed by Owen-Smith (1979) and Owen-Smith and Novellie (1982), introduces the idea of "forage perception" by large herbivores. It has long been recognized that domestic grazing animals select a diet higher in nutrient quality than the average available in the plant community (Heady and Torell 1959, Weir and Torell 1959, and others). It follows then that the methods traditionally used to estimate forage availability to compare with diet selection are likely poor representations of what the grazing animals perceive as food. Variation in forage quantity and quality confounds many field studies (Freer 1981). Owen-Smith (1979) stated that direct measurements on the vegetation may be an inadequate reflection of food availability as experienced by the animals. Recent research supports this idea (Hodgson 1982b).

Variation in diets has not been well explained on the basis of forage availability in the paddock as a whole (Iskander 1973). Most plant species are not eaten in proportion to their availability indicating broad selection on the part of the herbivore. But this broad comparison is not enough.

For example, evidence available shows that high forage yields alone do not necessarily result in improved animal performance (Beaty and Engle 1980). Benefits from high forage yields may be reduced if there was a correlated increase in factors causing a reduction in intake, for example leaf fiber content (Hodgson 1982a). So, botanical composition based on standing crop may not be the best comparison for diet selection indices. Chacon and Stobbs (1976) reported that estimated animal intake was especially well correlated with leaf yield and leaf to stem ratio of the forage, providing a better expression of forage supply than grazing pressure. Management to maintain green to dead ratios or L:S may meet animal nutritional needs better and reduce the accumulation of undesirable plant parts (Beaty and Engle 1980). Iskander (1973) suggested that the real need is to measure forage availability and consumption with every bite the animal takes. He further claimed that feeding behavior may limit diet selection and intake more than forage availability in the traditional sense. Forage may be available but left ungrazed. In accordance, Gammon and Roberts (1980) reported that cattle left favored grazing areas long before herbage levels were reduced to limiting quantities, further stating that quality rather than quantity may have dictated grazing times. However, the differences in behavior observed between continuously grazed paddocks and paddocks grazed for periods of short duration were not well explained by measured herbage characteristics or patterns of defoliation.

The apparent discrepancy between man's and animal's perception of forage availability could be partly responsible for the reduced animal performance seen in many grazing systems. Any paddock deferment that allows forage to mature may restrict the nutrient intake by grazing livestock (Kothmann 1980b). Grazing pressure may also have an effect on nutrient intake (Hart 1978). As L:S and G:D ratios are reduced, "animal sensitivity" to grazing pressure increases up to the point when all forage is dormant and then levels out (Kothmann 1980b). So the degree of variation in forage quality within the standing crop (e.g. L:S, G:D) may best indicate periods when animal performance will be most sensitive to grazing pressure (Kothmann 1980b). By being aware of this variation managers may be able to better predict animal perception of and response to available forage.

Selective grazing greatly affects forage quality. When designing grazing systems this impact should be considered. Gammon and Roberts (1980) suggested that grazing periods of less than 14 days appeared unnecessary as a means of reducing repeated defoliation but that shorter grazing periods might restrict the animals forage selection less and improve their performance. On most ranges successful animal production hinges on selective grazing (Kothmann 1980a).

Diet selection

Diet selection by range livestock is a major management concern. Under most rangeland conditions livestock graze plants selectively. Through the selective defoliation of plant communities animals may alter the competitive interaction favoring certain, less palatable plant species (Heady 1975, Kothmann 1981, Stoddart et al. 1975). But selective grazing allows the animals to choose diets higher in nutrient quality than that available in the vegetation as a whole thus increasing the productive potential from the livestock (Kothmann 1980b). Animal performance would be expected to be higher where grazing can be selective than where non-selective grazing is imposed (Kothmann 1980b).

Diet selection is a relative phenomenon which depends on the array of choices available to the grazing animal (Heady 1964). Because domesticated animals have been selectively bred to meet man's needs they probably do not forage in an optimal sense (Westoby 1974, Emlen 1966, Arnold and Dudzinski 1978). But foraging behavior still allows domestic animals to select diets which at least meet their maintenance requirements in most situations, even when forage quality as a whole is low (Arnold and Dudzinski 1978, McClymont 1967, Provenza 1981).

Very few generalizations can be drawn from the extensive literature on range livestock diet selection. Green plant material is preferred over dead and leaf is preferred to stem by both cattle and sheep (Arnold 1964, Arnold and Dudzinski 1978, Kothmann 1980b). However, accessibility of green material may affect selectivity (Freer 1981, Norton et al. 1982). The forage selected is usually higher in nitrogen, phosphate and gross energy, but lower in fiber (Arnold 1981, Van Dyne et al. 1980). Whether diet selection stems from innate euphagia, hedyphagia or a combination of both is still open to debate (Arnold and Dudzinski 1978).

Other factors are known to contribute to diet selection. Animal morphology influences the extent to which animals may choose their diets. Size of mouth parts and the methods of grazing used may limit the animals ability to bite off preferred items. For example, Van Dyne et al. (1980) reported that cattle seldom graze closer than 12 mm from the soil. Because cattle use their tongues to help grasp and shear the forage as the vegetation is grazed down, the forage becomes less easily available. Sheep on the other hand have a hard upper palate (Arnold 1981) enabling them to use their smaller mouths to bite off selected food items even where availability is low.

No attempt will be made here to synthesize the literature on diet selection of grazing animals. Recently Van Dyne et al. (1980) summarized over 855 estimates of diet characteristics of large herbivores and discussed factors influencing large herbivore diet selection. These factors included botanical composition of the stand, grazing intensity, seasonal variability, topography, age and herding influences. Data are summarized from rangeland studies and presented on the basis of the grass, forb and shrub composition in the diet. Overall, on a yearlong basis sheep diets included 50 percent grass, 30 percent forbs and 20 percent shrubs whereas cattle consumed about 70 percent grass, 15 percent forbs and 15 percent shrubs. The common generalization that sheep are forb eaters is only true in the broadest sense and has resulted in much confusion. On a seasonal basis, sheep diets demonstrate great variability with grasses and shrubs being consumed more than forbs during autumn and winter and summer diets vary widely in reported grass, forb and shrub composition.

Few conclusions are drawn from the Van Dyne et al. (1980) extensive literature review. Much variation is seen among individual animals, seasons and places. Cattle and sheep express diet selection differently during the four seasons. Sheep are much more selective than cattle in early and late summer but this difference narrows during autumn and winter. Grazing intensity alters this relationship. Heavy grazing reduces the selectivity of sheep for plants in summer but cattle seem to become more selective. The management implications of this are not clear. It appears to suggest that cattle are less able to adapt to heavy grazing than are sheep. Evidence supporting this includes Hamilton (1976) who reported that cattle production is lower than sheep production over a range of stocking rates. Further, sheep may be better adapted to common use grazing management than cattle because of their apparent ability to reduce selectivity as forage availability declines. Available research does not address this possibility.

Common use by cattle and sheep

Niche separation of grazing ungulates in grazing ecosystems runs from distinct to subtle, allowing a combination of animal and plant species to exist together in relative harmony (Bell 1971, Janis 1976, McNaughton 1979). This phenomenon is especially obvious and particularly well-studied on the African Savannah (see Sinclair and Norton-Griffiths 1979). The mix of grazing animals in many ecosystems is such that forage use and animal biomass supported are increased within the constraints of system stability (Hirst 1975). The sequence of animals grazing is very important to the system as one animal species may "prepare" the area for another (Bell 1971). This has rarely been considered when planning common use grazing.

The rangelands of North America are no exception to the idea that combinations of animal species generally use the total land resource more efficiently than a single species. Management practices developed from these theories can seek to increase red meat production from a given area through the practice of common use grazing. Common use is generally defined as the grazing of two or more species of domestic animals together or separately on the same range in a single growing season (Heady 1975, Stoddart et al. 1975).

There are two main principles that help explain why more efficient range use may be accomplished with a mix of animal species such as cattle and sheep. Cattle and sheep may select different types of food and also may separate themselves on a topographic basis. In order to realize increased production from common use grazing, the range should have mixed vegetation and varied topography.

Several studies have been conducted comparing the diets of cattle and sheep when grazed in common on a single range type. Cook et al. (1967) compared the diets of sheep and cattle grazing together and separately on typical mountainous summer range in northern Utah. Sheep grazing alone consumed significantly more forbs and browse than cattle grazing alone or when cattle and sheep grazed together. Grass use was a little higher where cattle grazed alone. The study concluded that commmon use grazing with sheep and cattle was complementary since the percentage of plant species consumed varied from one kind of livestock to the other.

Schlundt (1980) reported similar results from a study in southern Utah. He found that grasses disappeared from pastures grazed by sheep and cattle alone at a similar rate to that from pastures grazed in common by cattle and sheep. Forbs were less preferred by cattle than grasses and the shrubs were used to a much greater degree by sheep than cattle. Additionally, shrub use in the common use pasture was higher than predicted from single use stocking rates.

On mature annual range in California, Van Dyne and Heady (1965) determined botanical and chemical composition of diets of steers and ewes grazed in common from July to September. Cattle and sheep diets differed in plant species, plant parts and live versus dead plant material throughout the summer. These differences were minimal by the end of the sampling period indicating decreased selectivity with a reduced forage supply.

More recently, researchers in Australia have reported similar results showing varying degrees of diet separation between cattle and sheep grazed in common on several range sites (Wilson 1976, Wilson and Graetz 1980). Other studies have been conducted in a variety of vegetation types supporting this principle (Bedell 1968, Bennett et al. 1970, McMahan 1964, Pearson-Hughes and Reid 1951).

Although mixed rangeland vegetation and differences in diet selection by cattle and sheep may allow for increases in animal-days with common use grazing, other characteristics are important to increase efficiency of range use. The number of livestock that can be grazed on an area of rangeland is partly a function of the degree of use that can be attained on the rougher portions of the range (Cook 1966). Cattle tend to heavily graze valley bottoms and level terrain in preference to steep slopes (Cook 1966). Percent slope and distance to water greatly influence range use by cattle (Cook 1966, Mueggler 1965). But sheep make better use of rough topography and grazing capacity can be increased through better distribution (Cook 1966, Stoddart et al. 1975). With sheep and cattle grazing together it is more likely that there will be increased use of rough topography and of all forage species leading to increased grazing capacity within the constraints of proper use (Cook 1954, Heady 1975).

Several studies have concluded that common use grazing can increase the carrying capacity of a particular rangeland. Cook (1954) conducted a study on summer range in northern Utah and reported that under common use the grazing capacity of the ranges was substantially increased. Wilson (1976) and Wilson and Graetz (1980) also estimated increased grazing capacities with a mix of cattle and sheep on semi-arid grasslands and salt desert shrub communities.

Merrill and Miller (1961) showed that grazing cattle and sheep, sheep and goats, or all three species together proved more profitable on ranges with mixed vegetation than did grazing of any one animal species alone. Hamilton and Bath (1970) found that combined production from wool and weight gains increased when sheep and cattle were grazed in common. Hamilton (1976) also reported increased production in mixed herds. He found improved lamb performance when sheep and cattle were grazed together at low substitution ratios (around 1:1).

The commonly recommended substitution ratio of 5 sheep to 1 cow presumably represents energy requirements of average sized animals. It also is thought to express the amount of forage use by sheep compared with cattle. And, in fact, Schlundt et al. (no date) reported that sheep and cattle substitution ratios of 5:1 were approximately correct for a mountainous range site in southern Utah, basing their conclusion on forage disappearance. But as Hamilton (1976) showed, lower substitution ratios may improve sheep performance.

Smith (1965), using Standing's (1938) key species concept determined theoretical substitution curves under common use grazing. While not all common use situations would increase grazing capacities, maximum stocking rates can very often be achieved by grazing more than one kind of livestock.

Yet there are certain assumptions basic to sheep and cattle substitution curves for common use stocking rates. Cook (1954) considered animal behavior an important aspect of common use grazing. Common use, he believed, was based on the assumption that livestock behavior would not be different regardless of whether cattle and sheep grazed alone or in common. Further, Cook et al. (1967) reported that average utilization of available herbage in common use pastures was intermediate between sheep and cattle use when grazing as a single species. Common use stocking rates are often calculated on the basis of intermediate levels of forage utilization.

In general terms, a potential increase in the grazing capacity of an area may be possible by mixing the animal units of grazing between two or more species of livestock. Common use does not assure increased grazing capacity however, and the mixture of grasses, forbs and shrubs available plays an important role in the system (Heady 1975). Many other factors also contribute to the success or failure of common use grazing management. Animal behavior, topography, predation problems, poisonous plants, availability of livestock water and personal preference of the manager are but a few of these.

STUDY AREA

Floristically, the study area consisted of interspersed stands of oak and aspen woodland with large open areas of grassland and grass-shrub mixtures. Major forage species on the study site included letterman needlegrass, Kentucky bluegrass (Poa pratensis), snowberry, herbaceous sage (Artemisia ludoviciana), yarrow (Achillea millifolium), vetch or cowpea (Vicia americana) and a daisy fleabane (Erigeron flagellaris) (Appendix Table 14). The site is typical of many of the mountainous rangelands on the southeastern fringe of the Great Basin. Climate, geology and soils of the site were described by Schlundt (1980).

For the study reported here eight 0.4 ha paddocks were selected as being as similar as possible in herbaceous productivity, slope, and aspect. The paddocks were representative of much of the mountain ranges in the area, a vegetation mixture of grasses, forbs and snowberry.

METHODS

Study Design

Grazing treatments

The purpose of the grazing treatments was to determine how grazing by sheep and cattle alone and together would affect the structure and composition of the vegetation, changing the relative availability of the various plant species, individual plants, plant parts and chemical and physical (fiber) characteristics of the sward and what the subsequent affect these vegetation changes would have on the diet of esophageally fistulated sheep. Vegetation measurements were taken before and after grazing to compare grazing effects of cattle and sheep grazing alone and together. Livestock grazing can cause both long term and short term changes in the plant community. Here, grazing was used as the vegetation treatment and also as a means to sample the vegetation. The "treatment animals" were the sheep and cattle used for grazing the paddocks. The grazing treatments included sheep grazing alone, cattle grazing alone, and sheep and cattle grazing in common (Figure 2). Measurements of the vegetation were made to compare these three grazing treatments. Of major interest were effects of the grazing on the diet selection of sheep.

How does prior grazing by sheep, grazing by cattle and common use grazing affect the subsequent diet of sheep? To help answer

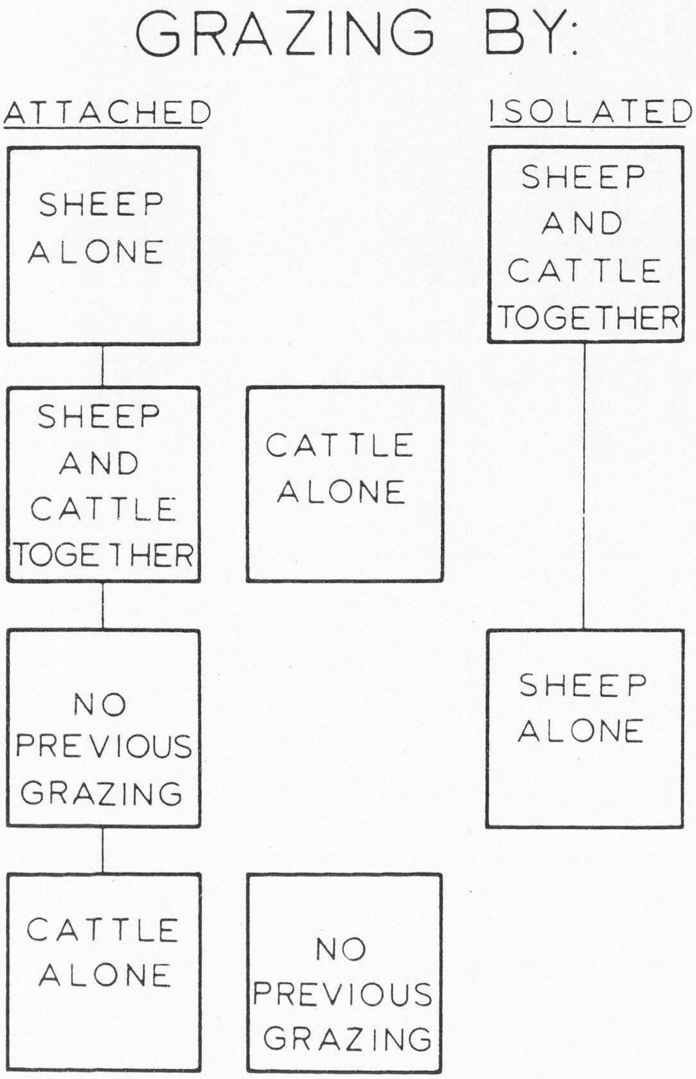

Figure 2. Paddock treatment combinations. Four pastures on the left were contiguous while the four on the right were each separate and not visible from one another.

this question esophageally fistulated sheep were used to obtain diet samples from each paddock both before and after the grazing treatments were applied. It was expected that diets would not differ among paddocks prior to grazing treatments. Additionally, two control paddocks were sampled for sheep diets but then left ungrazed (untreated) while the various combinations of treatment animals grazed in the other paddocks. Following the grazing treatments, all paddocks were sampled again by esophageally fistulated sheep. Any differences observed in these diets were considered to be due to the grazing treatment and normal plant development. Other vegetation sampling generally followed this before and after grazing treatment pattern.

For the purposes of this study, grazing levels were considered moderate to heavy, and defined as the degree of grazing necessary to produce at least 60 percent grazed plants among Kentucky bluegrass and Letterman needlegrass. During the 1981 trials, grazing treatments were applied to the .4 ha (1 acre) paddocks with 20 ewes and 40 lambs or 4 cows with calves for the single use treatment; or 10 ewes and 2 cows with offspring (5:1 sheep:cow substitution ratio) for the common use treatment. Grazing trials lasted 4 full days(96 hours). The 1982 grazing trials were identically stocked but lasted 5 days resulting in stocking rates equivalent to .76 ha/AUM in 1981 and .60 ha/AUM in 1982. Stocking density was 4 animal units per .4 ha (9.9 animal units/ha). Dates of the grazing trials and the data collection sequences are listed in Table 1.

Table 1. Sampling sequence for the 1981 and 1982 grazing trails.

Year	Activity	Dates
1981	Standing crop estimates (Pre-grazing treatment)	
	Diet sampling (Fresh paddocks)	
	Grazing treatment animals in rep. 1 paddocks	7/6-7/10
	Behavior monitoring	
	Grazing treatment animals in rep. 2 paddocks	7/10-7/14
	Behavior monitoring	
	Standing crop estimates (Post-grazing treatment)	
	Diet samples (Post-grazing treatments)	
	Height/weight utilization estimates	
	Snowberry utilization estimates	
	Regrowth standing crop estimates	
	Diet sampling (regrowth)	9/1-9/15
1982	Standing crop estimates (Pre-grazing treatment)	
	Point frame data collection (Pre-treatment)	
	Diet sampling (fresh paddocks)	
	Grazing treatment animals in rep. 1 paddocks	7/14-7/19
	Behavior monitoring	
	Grazing treatment animals in rep. 2 paddocks	7/19-7/24
	Behavior monitoring	
	Point frame data collection (Post-grazing treatment)	
	Standing crop estimates (post-treatment)	
	Diet sampling (Post-treatment)	
	Height/weight utilization estimates	
	Snowberry utilization estimates	

Treatments were assigned in a randomized block design (Figure 2). Blocking criteria were the locations of the paddocks in relation to one another. Four paddocks were contiguous whereas four others were each isolated from one another. Blocking in this manner was to reduce any error resulting from different utilization patterns due to social facilitation and tendency to group behaviors among adjacent livestock (Arnold 1981).

Grazing treatments were off-set in time in an attempt to reduce the confounding effects of vegetation quantity and quality including regrowth (Freer 1981). Contiguous paddocks were grazed first followed by the isolated paddocks. Vegetation and diet sampling were confined to pre- and post-grazing treatment conditions. Behavioral data were collected while the grazing treatments were being applied. Vegetation in the ungrazed paddocks was also sampled before and after the grazing treatments to provide a check on the effects of vegetation development.

The statistical design of the experiments was a factorial arranged in randomized blocks with four grazing treatments and trials replicated twice. Major data analysis involved a split-plot procedure with three sampling dates, before and after grazing treatments and during the regrowth period (Neter and Wasserman 1974). Significant F-statistics were tested for interaction and main effect significance using Least Significant Difference statistic (LSD)(Steel and Torrie 1980). Regression analysis, T-tests, and Chi-square analysis (X^2) were also applied where appropriate. Data reduction and manipulation were achieved using Minitab (Ryan et al. 1981), Rummage (Bryce 1980), and STATPAC (Hurst, Utah State University, unpublished) statistical packages.

Livestock and experimental animals

Cattle used to graze the paddocks were mature (3-7 year old) grade Hereford cows with calves 4 to 5 months of age. The ewes were straightbred Targhee, Suffolk X Targhee cross and Finnsheep X Targhee cross, each having 2 lambs born in April. All animals were randomly selected from larger herds.

The surgically prepared sheep used for esophageal fistula extrusa diet collections were standard Targhee-cross range ewes purchased in Lyman, Wyoming in April, 1981. When purchased the animals were two years old. They had been culled from a rancher's band because they failed to conceive.

General Objectives and Research Hypotheses

Major objectives followed by research hypotheses were:

1. To compare the grazing pressures of cattle alone, sheep alone and common use through diet sampling with esophageally fistulated sheep grazing before and immediately after grazing treatments.

H1. Grazing by the treatment animals in single and common use grazing treatments does not significantly alter the diet selection of esophageally fistulated sheep.

H1a. There are no differences among the grazing treatments in their effects on the ability of esophageally fistulated sheep to select nutrients from the remaining vegetation.

H1b. Forage quality in esophageally fistulated sheep diets is not different before, after and among grazing treatments.

2. To determine how standing crop, leaf to stem ratio (L:S) and green to dead ratio (G:D) of the herbaceous vegetation are altered by cattle and sheep each grazing alone and in common.

H2. Stand-wide L:S, and G:D are not significantly altered by and among the grazing treatments, indicating that differences and similarities among cattle, sheep and common grazing occur primarily at the plant species level.

3. To monitor vegetation utilization based on three measurement techniques (percentage of grazed plants; utilization based on a comparison of grazed and ungrazed plant heights; and standing crop disappearance measured before and after grazing) comparing grazing treatments and techniques.

H3a. There are no significant differences in vegetation utilization by cattle and sheep grazing alone or when grazing together.

H3b. The degree of use per grazed plant is not statistically different among all grazing treatments.

H3c. Cattle and sheep use snowberry alike in terms of forage reliance and mechanics of harvest.

4. To monitor sheep grazing patterns as the amount of available forage declines by recording overt feeding behaviors (testing the

feeding station concept (Goddard 1968) with domestic sheep).

H4a. The average time a sheep spends at a feeding station does not change as grazing progresses regardless of the amount of forage on offer.

H4b. Sheep grazing alone exhibit the same pattern of behavior at feeding stations as do sheep grazing with cattle in terms of time spent per feeding station and numbers of browse and herb layer feeding stations.

Forage Use by Cattle and Sheep Grazing Separately and Together

In each grazed paddock, utilization of herbaceous and shrubby vegetation was estimated using different techniques. Because snowberry was by far the most abundant shrub on the site, shrub sampling focused on this species and browsing use was estimated separately from that of herbaceous vegetation by stratifying the shrub cover. Additionally, stand-wide leaf-to-stem (L:S) and green-to-dead (G:D) ratios were estimated before and after treatments with sheep and cattle grazing alone.

Utilization estimates

Herbaceous vegetation. Three sampling techniques were used to estimate utilization of herbaceous vegetation; 1) standing crop before and after grazing, 2) percentage of grazed plants, and 3) average heights of grazed and ungrazed plants with utilization being based on the weight of the difference between the grazed and ungrazed heights as determined from height-weight relationships. Where height-weight relationships were unavailable (mostly small forbs) use was ocularly estimated.

Standing crop measurements before and after grazing described vegetation disappearance (utilization). A double sampling procedure was employed using a 1:4 ratio of clipped to estimated .2 m^2 plots (Meuggler 1976, Mueggler and Stewart 1981). Twenty to 30 plots were sampled in each paddock (Mueggler 1976). Plants were weighed by species in the field with hand-held spring scales (2 gram precision). Regression analysis of estimated and observed weights appear in Appendix Table 15 (Ahmed et al. 1983). These weights were later converted to an air-dried basis (Appendix Table 16).

In a separate sampling procedure, the percentage of grazed plants for each species was determined by counting grazed and ungrazed plants in every plot. Average grazed and ungrazed height of each plant species encountered was then measured. Height-weight relationships for the most important forage species were developed by Bowns (1980) and used in a manner similar to that described by Dwyer (1961). This sampling method allows for stand-wide as well as grazed plant utilization estimates for each species where height-to-weight relationships have been developed. Regression models were available to predict utilization values. Sampling was done in a series of ten randomly placed transects which comprised 10, .03 m^2, rectangular plots (15 x 20 cm), that were lumped by transect for data analysis.

Shrubs. Shrub sampling concentrated on snowberry, the major browse species. Utilization was determined by the method developed by Ruyle et al. (1983) in which caliper measurements of the last intact internode on browsed stems was used to predict biomass removed by browsing. Two models were used to predict the quantity of biomass removed distinguishing between two kinds of browsing--leaf only and entire stem removal. Sheep usually stripped only the leaves from the stems while cattle generally consumed the entire stem. It was noted in the field where entire stems were removed and the intact twig model was applied only on those measurements.

Vegetation structure. In order to compare stand-wide L:S and G:D changes resulting from grazing by sheep and cattle a fiber-optic point quadrat system developed by Caldwell et al. (1983) was used. Although point sampling has long been recognized in the ecological literature (Warren-Wilson 1960), the plant-tissue-sensing, fiber optic tip allows greatly increased precision over the standard point frame procedures (Caldwell et al. 1983). For sampling, the inclined point frame was placed at five randomly selected, permanently marked locations. The degree of inclination used was 33.5 (Warren-Wilson 1960). At each location, 30 pin travels were sampled and a record of each hit on grass and forb plant parts was made before and after cattle and sheep grazing treatments.

Statistical analysis

Main effects for statistical analysis were grazing treatment and date of sampling period (before and after). Where analysis of variance showed significant F-statistics, means were separated using the L.S.D. test (Steel and Torrie 1980). Significance levels of p=.10 were generally accepted but where biological interpretation seemed important lower levels were discussed.

Nutritional Quality and Botanical Composition of Domestic Sheep Diets on Forage-Abundant Versus Forage-Reduced (by grazing) Mountain Range

Diet sample collection

Dietary samples were collected from four esophageally fistulated sheep in each paddock before and immediately after the grazing treatment period. In 1981, samples were also taken during the fall regrowth period in early September. It was observed that both cattle and sheep on the rangeland surrounding the study site fed primarily on fall regrowth of grass developed in response to August rains. Sampling with esophageally fistulated sheep during one year was considered adequate to describe the nutritive value of diets consisting exclusively of grass regrowth.

Prior to all diet collections, fistulated sheep were grazing on sites adjacent to the research paddocks for several weeks and were familiar with the vegetation. To avoid fasting the animals prior to sampling, the sheep were penned at daybreak directly before collections were made. In this way natural daily grazing patterns were simulated (Bowns 1971, unreported data). Later in the study, however, the animals were penned at dusk the previous evening when they normally began to bed down, and sampling continued to be at daybreak. The animals were allowed to forage for 30 to 45 minutes with their fistula plugs removed and screen-bottom collection bags attached. Fistula extrusa samples were hand mixed, sub-sampled into two parts, placed in plastic bags and frozen in a slurry of dry ice and methyl alcohol.

Since the early development of the esophageal fistula techniques in domestic sheep by Torell (1954) it has become the recommended procedure for range animal diet studies (Holechek et al. 1982a, Holechek et al. 1982b, McManus 1981).

Laboratory analyses

Botanical analysis. The microscope-point technique of Harker et al. (1964) was used for the botanical anaysis. Each extrusa sample was spread uniformly over a tray and sampling was done through a variable-powered binocular microscope. Two hundred points in a grid were observed for presence of the various species categories and percent frequency of each species and category was calculated. These categories included recognizable grass, forb, and shrub species, miscellaneous (unrecognizable) grasses, forbs, and shrubs, leaves and stems, green and dead material, and unknowns.

Chemical analysis. Prior to chemical analysis, samples were freeze-dried and ground through a Wiley mill equipped with a 40 mesh screen. *In vitro* organic matter digestibility (IVOMD) was determined by the two-stage method described by Tilley and Terry (1963). Rumen innocula were obtained from rumen-fistulated sheep fed an alfalfa hay diet.

Crude protein was analyzed by the macro-Kjeldahl method (Bremner 1965, Harris 1970). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin (PML) were sequentially analyzed by the methods of Goering and Van Soest (1970).

Statistical analysis

A factorial analysis was used with grazing treatments and sampling periods (before, after and regrowth) as the main effects. Treatments were replicated twice and animals within treatments used as subsamples. The least significant different (LSD) test was used to compare treatment, date and interaction means (Steel and Torrie 1980). The p=.10 level was considered adequate unless otherwise stated. Additionally, recognizable plant species in the diet samples were ranked in importance, based on frequency of occurrence (Marshall and Squires 1979, Vavra et al. 1978). Ranks were then compared among treatments and dates.

Foraging Behavior of Domestic Sheep Grazing Alone and In Common With Cattle

Behavioral analysis

The problem of forage assessment and selection faced by domestic sheep is not unlike that of wild herbivores. In general, there is more forage supply than demand at any one time for each sheep, but the nutrient contents available in a particular vegetation type (or habitat) are constantly changing, both seasonally (short term), and yearly (long term range condition), and also, perhaps, daily or hourly with changing grazing pressures. This changing nutrient supply becomes acute where stocking densities are high. Traditionally, the range manager makes the decision of how long to graze animals in a particular paddock, a decision often based on the amount of forage remaining. Yet through expressed grazing behavior the animal may be a more sensitive indicator, not just of forage remaining, but of remaining nutrients. The manager, then, may be able to use certain behavioral cues expressed by the grazing animal to help decide when a paddock is properly defoliated from the animal's perspective. Ideally, these cues must be easy to monitor in terms of knowing what the cues are and what they mean.

In order to test a field method capable of determining by direct observation of the animals the amount of forage remaining at a given time, a technique originally described by Goddard (1968) and more recently published in the wildlife literature by Novellie (1978) was used. The method involved analysis of the feeding-moving series separating this sequence into feeding station intervals (FSI). A feeding station is defined as forage available in a half cylinder-shaped area in front of and to each side of the animal with it's front feet stationary (Figure 3).

For the research reported here, sheep behavior was monitored at

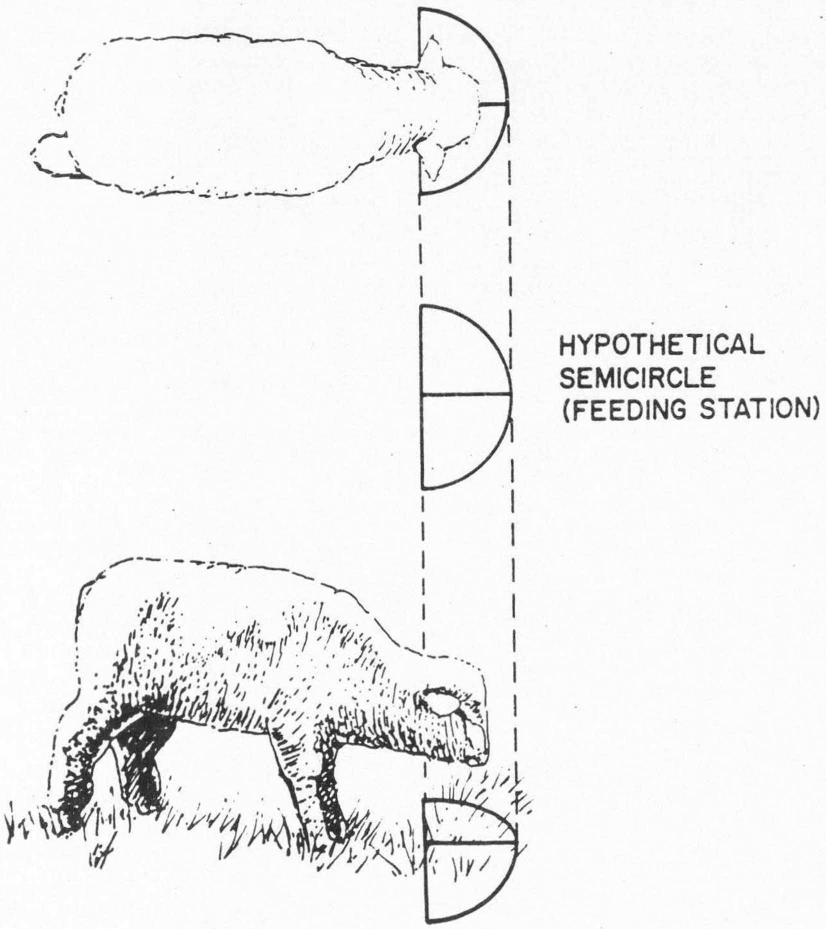

Figure 3. The amount of forage available to a grazing animal when the forefeet are stationary is termed a feeding station (after Goddard 1968).

several periods during grazing trials in 1981 and 1982. Sheep were placed in small (.4 ha) paddocks and allowed to graze for 4 days in 1981 and 5 days in 1982. Twenty ewes and 40 lambs were stocked in the sheep alone treatment and 10 ewes and 20 lambs were grazed in common with 2 cows with calves (5:1 substitution ratio). Stocking rates were .76 ha/AUM and .60 ha/AUM in 1981 and 1982, respectively. Stocking densities were 4 animal units/.4 ha (9.9 AUs/ha). The experiments were replicated twice.

Feeding stations

During the morning grazing period (6 a.m.-10 a.m.) FSIs were monitored for three to four hours, alternating between the sheep grazing alone and the sheep grazing in the common use treatments. The paddocks were visually divided into four approximately equal sections. To decide which individual to study, a section was chosen at random and the nearest moving sheep was selected as the focal animal (Altmann 1974) to observe for 5 to 10 minutes and then the process was repeated, selecting a different sheep. Timing of each FSI (to the nearest .1 second) was done with a stop-watch having memory capabilities. Observations began the morning after the animals entered a paddock (after the animals had been in the paddocks for about 18 hours). In 1981, only days one (after 18 hours in the paddock) and four were monitored. In 1982 FSI's were monitored on days one through five.

Single versus common use. Because of the hypothesized differential removal of nutrients between the single livestock species and common use grazing treatments, FSIs of sheep grazing alone and with cattle were monitored. It was expected that the average FSI would change less during a grazing period when sheep were grazed with cattle because of the known dietary separation of the two animal species.

Herbaceous versus browse feeding stations. Observations during pilot studies indicated that sheep spent more time standing at a feeding station when they were feeding in snowberry than when they were feeding on the herbaceous layer. Thus, FSIs were recorded as either browse or herbaceous feeding stations during the grazing trials.

Statistical analysis

Data are presented as average FSIs for each day. Further presentation is after Novellie (1978). Histograms of FSIs of 0-10, 10-20, 20-30, 30-60, and >120 seconds are plotted for each day, treatment, and treatment totals. The Chi-square test was used to test the significance of differences between days and treatments.

RESULTS

Forage Use by Cattle and Sheep Stocked Separately and Together

Utilization estimates

Herbaceous vegetation. Utilization estimates of herbaceous vegetation followed similar trends for each sampling method during both years of the study (Table 2). Grasses were used to a greater degree by cattle than by sheep, while sheep used more forbs than cattle did. Only *Poa pratensis*, *Stipa lettermanii*, and *Artemisia ludoviciana* occurred consistently enough among treatments and plots to make acceptably precise height-weight and grazed plant estimates of grazing use. Because of grazing or infrequent occurrence, other plant species were not adequately sampled by these methods. Sampling only once after grazing does not account for those very palatable plants which disappear early from the vegetation when it is grazed. This is especially true where no height-weight relationships were developed. In cases where there were no height-weight relationships utilization was ocularly estimated.

During 1981 there was less use of *Poa pratensis* by sheep than by cattle or common use but this difference disappeared with the 27 percent heavier stocking levels of 1982 (.60 ha/AUM versus .76 ha/AUM in 1981) (Table 2). *Stipa lettermanii* showed less use by sheep than cattle in 1981 while *Artemisia ludoviciana* was used heavier by sheep than cattle both years. With the exception of

Table 2. Comparison of utilization estimates by percentage of grazed plants or grazed stems (G), height-weight (H/W), and standing crop (SC) disappearance for the three grazing treatments, both years of the study.

Grazing Treatment	Grasses			Forbs			Syor[1]			Popr[2]			Stle[3]			Arlu[4]		
	G	H/W	SC	G	H/W	SC	G	H/W	SC	G	H/W	SC	G	H/W	SC	G	H/W	SC
1981																		
Sheep	51a[5]	19a	33a	73a	47a	68a	71a	--	36a	66a	36a	40a	62a	17a	22a	39a	11a	41a
Cattle	81b	30b	66b	24b	14b	31b	9b	--	3b	75a	33a	58b	81b	27b	48b	10a	16a	20b
Common	71b	31b	62b	63a	39a	61a	52a	--	23c	81a	39a	62b	81b	32b	60c	16a	17a	22b
1982																		
Sheep	80a	39a	39a	86a	48a	77a	87a	--	45a	97a	61a	45a	81a	45a	27a	79a	21a	62a
Cattle	95b	53a	70b	7b	7b	52b	8b	--	12b	98a	65a	64b	90b	42a	60b	11b	5b	24b
Common	88ab	44a	71b	76c	50a	66a	87a	--	41a	95a	53a	73c	93b	39a	68b	27c	9b	7c

1 *Symphoricarpos oreophilus*

2 *Poa pratensis*

3 *Stipa lettermanii*

4 *Artemisia ludoviciana*

5 Means in the same column within years followed by a different letter are significantly different at P=0.10.

Artemisia ludoviciana utilization under common-use grazing approximated that of the single animal species treatment with the highest use in each forage category. Utilization levels for forbs and grasses under common use did not represent the average use of the grazing use of sheep and cattle grazing alone (Table 2). This is generally not in accordance with Cook's (1954) assumption that if cattle or sheep grazing separately normally utilize a given species to 60 percent by the end of the grazing season they will utilize that species to the same degree when grazing in common. Schlundt et al. (no date) reported that substitution ratios should not be calculated directly from single species stocking is supported by this work. Forage utilization levels of cattle or sheep grazing alone were not linearly related to levels in common use treatments in several categories. In general, more total grasses, Poa pratensis and Stipa lettermanii disappeared from the pastures grazed by sheep and cattle together than when standing crop utilization was averaged during the single use treatments (Table 3).

Utilization estimates were made for three forbs, Achillea millifolium, Erigeron flagellaris and Vicea americana (Table 3). Achillea millifolium was grazed most under common use in both 1981 and 1982 (60 and 96 percent) while sheep alone grazed Achillia to the same degree as cattle alone in 1981 but to a greater degree in 1982 (Table 3). Utilization of Achillea was highest in the common use paddocks. Erigeron flagellaris and Vicia americana were grazed to similar degrees in all three grazing treatments. Vicea, a highly

Table 3. Percent utilization of standing crop by grazing treatment for stocking levels of .76 ha/AUM in 1981 and .62 ha/AUM in 1982.

	Percent Utilization															
	Grasses		Forbs		Popr[1]		Stle[2]		Arlu[3]		Acmi[4]		Erfl[5]		Viam[6]	
Grazing Treatments	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
Sheep alone	32a[7]	39a	68a	77a	40a	45a	23a	27a	41a	62a	48a	67a	58a	69a	99a	99a
Cattle alone	66b	70b	31b	52b	58b	64b	48b	60b	20b	24b	40a	42b	53a	67a	95b	93a
Common use	62b	71b	61a	66b	62b	73c	60c	68b	22b	7c	60b	96c	61a	65a	98a	96a

[1] _Poa pratensis_

[2] _Stipa lettermanii_

[3] _Artemisia ludoviciana_

[4] _Achillea millifolium_

[5] _Erigeron flagellaris_

[6] _Vicea americana_

[7] Means in a column followed by a different letter are significantly different at P=0.10.

palatable forb, was used heavily (96 percent average) in both years for all treatments. The high desirability of this species to both cattle and sheep make it unsuitable to one-time sampling after grazing since the remnant stems are exceedingly difficult to see and are often overlooked.

An advantage of height-weight data compared to the other methods is that percent utilization on grazed plants and stubble height can be calculated and this provides additional comparisons among treatments (Table 4). Interestingly, only a few differences were found among treatments in grazed plant utilization or stubble height at the stocking rates applied. During both years, sheep grazing alone used *Stipa lettermanii*, a very coarse, stemmy grass, to stubble heights of 10.9 cm in 1981 and 6.2. in 1982. This compared to 6.3 cm and 4.5 cm stubble heights left by cattle grazing alone but only in 1981 were these differences significant. Average stubble heights for all grasses were lower in the cattle only treatments but this difference was not reflected in the use estimates (Table 4).

Shrubs. Differences in snowberry utilization among grazing treatments were larger than any other forage class (Table 5). Cattle made little use of the shrub, even at the 27 percent higher stocking levels of 1982. Sheep used snowberry heavily, browsing 71 percent of the stems in 1981 and 87 percent in 1982, with estimated use being 36 and 45 percent, respectively. However, 45 percent utilization (calculated in the traditional manner of the current

Table 4. Average percent use and average stubble height of grazed plants in sheep, cattle and common use grazing treatments. Stocking rate was .76 ha/AUM in 1981 and .62 ha/AUM in 1982.

Grazing Treatment	*Poa pratensis* 1981	*Poa pratensis* 1982	*Stipa lettermanii* 1981	*Stipa lettermanii* 1982	*Artemisia ludoviciana* 1981	*Artemisia ludoviciana* 1982	Total All Grasses 1981	Total All Grasses 1982
				Percent Use Grazed Plants				
Sheep alone	56a[1]	62a	26a	54a	26a	26a	31a	58a
Cattle alone	45a	66a	34b	46a	41a	34a	38a	56a
Common use	49a	56a	39b	42a	39a	34a	38a	50a
							34.5	54.7
				Stubble Height of Grazed Plants (cm)				
Sheep alone	5.3a	5.2a	10.9a	6.2a	11.5a	6.5a	11.1a	6.6a
Cattle alone	5.7a	4.2a	6.3b	4.5a	8.2a	5.7a	6.5b	4.7b
Common use	5.5a	4.5a	6.5b	5.1a	8.6a	7.0a	7.3b	5.9a

$\bar{x} = 44.6$ ~45

[1] Means in a column followed by a different letter are significantly different at p=.05.

Table 5. Percent utilization of snowberry for sheep, cattle and common use grazing treatments during 1981 and 1982.

	1981 (.76 ha/AUM)			1982 (.62 ha/AUM)		
	Sheep	Cattle	Common	Sheep	Cattle	Common
% Grazed stems	71a[1]	9b	52a	87a	8b	87a
Utilization	36a	3b	23c	45a	12b	41a
$\bar{x}$ Snowberry cover in treatment	24	18	12	24	18	12
Adjusted use[2]	49	3	16	61	12	27

[1] Means in a row, within years, followed by the same letter are significantly different at p=.01, except 1981 utilization (p=.10).

[2] Adjusted use accounts for the variable snowberry cover in each treatment by dividing the treatment percent by the average percent cover and multiplying by the utilization value (e.g., sheep adjusted use = 36 * 24/17.7).

year's biomass removed divided by total current year's standing crop) represented an upper level of use of total current year's growth on this shrub because of the way sheep strip the leaves and leave the stems essentially intact (Figure 4). This was different from cattle browsing where entire stems were bitten off (Figure 4). Under common use most of the stems were stripped of leaves similar to paddocks grazed only by sheep (Figure 4). This indicates that most of the snowberry use in these treatments was by sheep. During both years of the study, common use resulted in higher than expected snowberry use, based on the average of utilization values of sheep and cattle grazing alone. Schlundt et al. (no date) in similar trials also found this to be the case. Cattle seemed to influence the sheep to rely more heavily on this forage source by somehow displacing them from the larger areas of herbaceous vegetation preferred by the cattle.

Further analysis of the snowberry data showed a good relationship between numbers of grazed stems and utilization levels (Table 6). The discrepancy between years in the regression equations may be partly due to the calculation of snowberry use. In 1982 stem measurements where entire stems were removed were coded in the field and both the leaf only and whole stem models were used (Ruyle et al. 1983). The leaf only regression model was used exclusively in 1981. Unsuitably low correlations were found between percentage of grazed plants and utilization of herbaceous species even though F-statistics were generally significant.

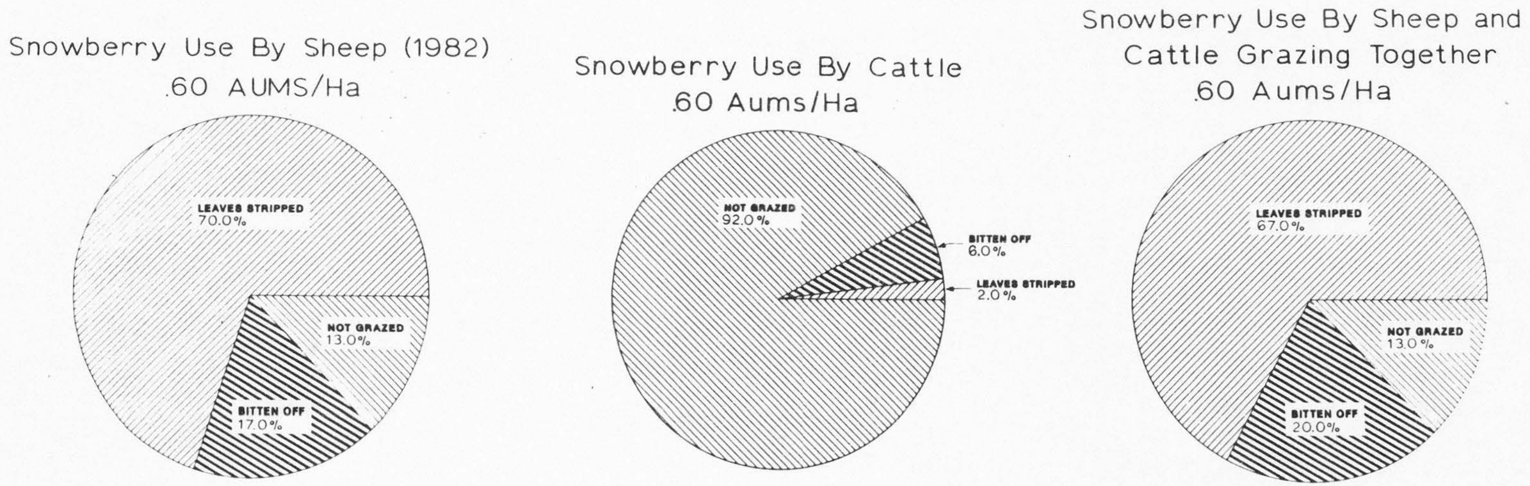

Figure 4. Snowberry use by sheep, cattle and mixed species depicting the browsing methods. Sheep stripped the leaves from the stems whereas cattle bit off entire stems. Common use resulted in most of the browsed stems stripped of leaves, similar to those in sheep treatments.

Table 6. Regression analysis using percentage of grazed stems to predict snowberry utilization.

Year	Number of Observations	Regression Equation	r-squared	Sy·x	F	Probability>F
1981	120	$y = -.679 + .380X$	.82	5.5	524.9	<.001
1982	90	$y = 8.20 + .401X$	.79	8.0	330.1	<.001

In general forage utilization in the treatments compared favorably to levels reported by other researchers on similar sites (Cook and Harris 1950a, Cook 1954, Cook et al. 1967, Schlundt et al. no date). The low levels of snowberry use by cattle at rather high stocking rates indicated a strong reluctance of cattle to eat this plant even when other, more preferred species were no longer available. Sheep, on the other hand, effectively defoliated the shrub to approximately 50 percent of the current year's biomass.

Sheep grazing alone selected less grass and more forbs than did cattle grazing alone, or when both animal species grazed together. When sheep and cattle grazed together there was no difference in the percent utilization of grasses or forbs when compared to cattle grazing alone.

Vegetation structure

Leaf to stem ratios. Leaf to stem (L:S) and green to dead (G:D) ratios of plants on a stand-wide basis were used to compare defoliation patterns of cattle and sheep. Because of time constraints, common use grazing treatments were not sampled.

Cattle and sheep reduced the stand-wide L:S of grasses to similar levels by selective grazing. The analysis showed highly significant differences before and after grazing. L:S in the cattle treatment declined from 4.6 to 1.7 while sheep grazing alone reduced L:S from 3.3 to 1.3 (Figure 5). Sheep reduced the L:S of forbs much more effectively than cattle (Figure 5). A significant interaction between date and treatment highlighted an important difference

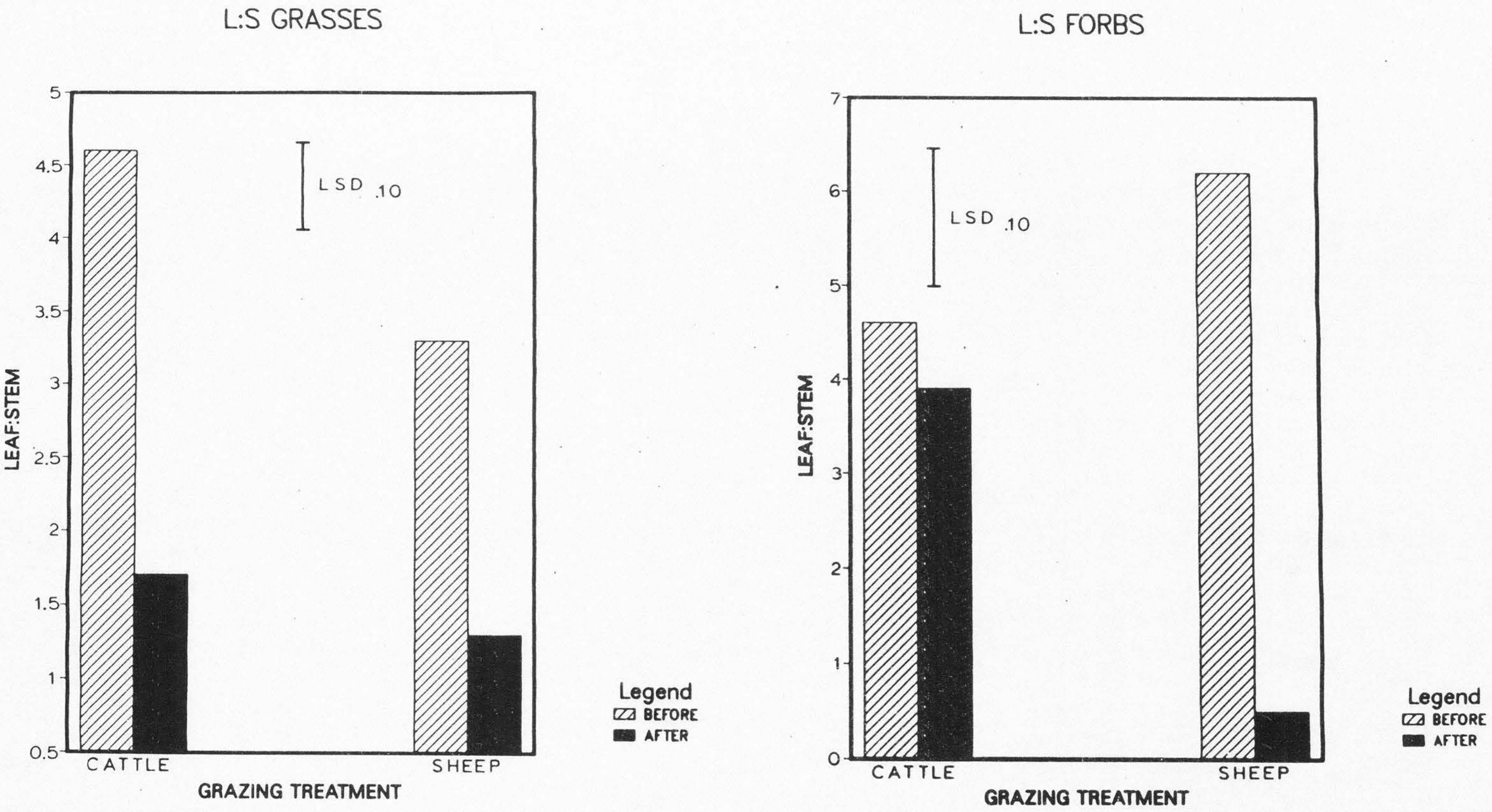

Figure 5. Stand-wide L:S of grasses and forbs before and after cattle and sheep grazing treatments.

between the way cattle and sheep graze forbs. Sheep selectively grazed forb leaves while cattle indiscriminately removed (bit) whole plants. Mouth morphology probably restricts cattle selection of forb parts and their method of grazing by grasping with the tongue does not allow delicate removal of forb leaves. On the other hand, cattle were as effective as sheep in reducing stand-wide G:D (Figure 6).

Nutritional Quality and Botanical Composition of Domestic Sheep Diets on Forage-Abundant versus Forage-Reduced (by grazing) Mountain Range

Botanical composition

Botanical composition of sheep diets is summarized in Table 7. Discussion of results is summarized here and then incorporated into the chemical composition section.

Botanical composition of sheep diets followed the same general pattern both years of the study. The palatable forb *Vicea americana* constituted a major portion of sheep diets consumed previous to paddock grazing treatments (Table 7). Grasses, especially *Poa pratensis* made up most of the remaining diet constituents. Sheep diets consumed after paddock grazing differed among treatments. Sheep diets consumed in paddocks previously grazed by sheep only were mainly composed of grasses whereas sheep diets from paddocks previously defoliated by cattle consisted largely of *Symphoricarpos oreophilus* (Table 7). Sheep diets consumed after the regrowth

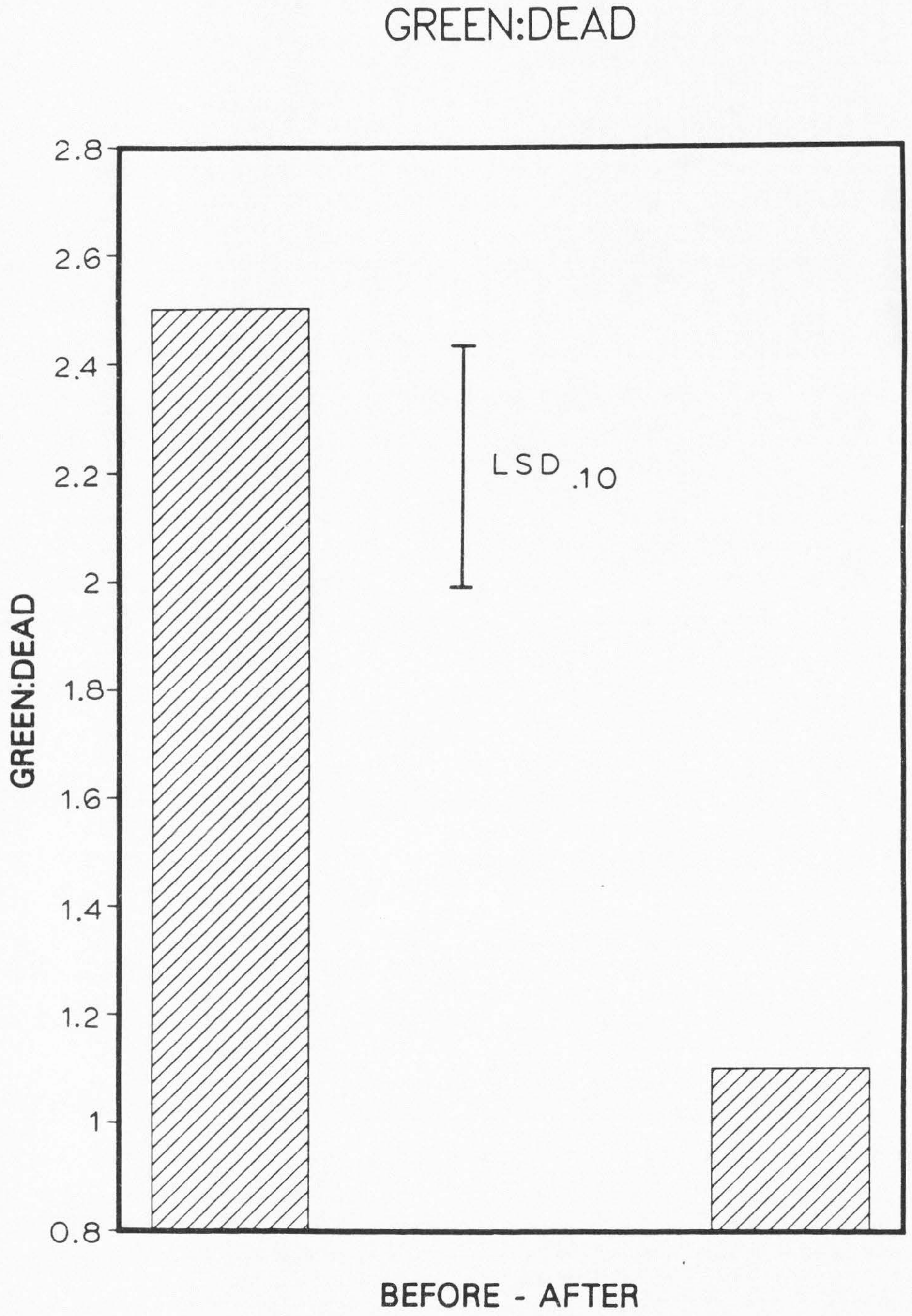

Figure 6. Average of stand-wide G:D before and after cattle and sheep grazing treatments.

Table 7. Botanical composition of sheep diets consumed before and after sheep alone, cattle alone, and common use grazing treatments and after a 30-day regrowth period.

Species	*Poa pratensis*			Total Grasses			*Vicea americana*			Total Forbs			*Symphoricarpos oreophilus*			Total Leaf to Stem Ratios	
Grazing Treatment	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth	Before	After
1981																	
Sheep alone	17.0a[1]	17.6a	58.9d	42.1a	96.5b	97.2b	45.4a	0.0b	0.0b	57.7a	3.2b	0.1b	0.1a	0.3a	0.0a	5.7	2.8
Cattle alone	16.1a	0.0b	55.4d	39.2a	32.2a	95.5b	44.0a	0.0b	0.0b	60.9a	3.0b	4.5b	0.0a	60.5b	0.0a	4.4	2.0
Common use	25.5a	5.1c	54.0d	46.4a	70.2c	98.4b	33.2a	0.0b	0.0b	52.9a	13.8c	1.6b	0.8a	16.0c	0.0a	4.8	1.2
No grazing control	18.3a	14.7	59.6d	33.5a	70.5c	96.4b	45.5a	13.4c	0.0b	60.5a	26.0d	3.6b	4.1a	3.5a	0.0a	3.2	2.5
AVERAGE	19.2	9.4	57.0	40.3	63.5	96.9	42.0	7.9	0.0	58.0	16.1	2.7	1.2	20.1	0.0	4.5a	2.1b
1982																	
Sheep alone	18.0a	0.0b	--	28.7a	93.5b	--	51.3a	0.0b	--	70.5a	0.0b	--	0.7a	5.4b	--	2.7a	2.6a
Cattle alone	20.0a	7.5c	--	34.2a	36.4a	--	48.6a	0.0b	--	65.6a	0.1b	--	0.0a	63.5c	--	2.9a	5.3b
Common use	23.5a	10.6c	--	32.1a	65.8c	--	46.9a	0.0b	--	68.1a	7.1b	--	0.0a	24.5d	--	3.7a	1.5a
No grazing control	15.9a	7.6c	--	23.9a	39.5a	--	51.2a	40.1a	--	74.2a	56.5c	--	0.4a	4.1b	--	2.5a	2.2a
AVERAGE	19.3	6.4	--	29.8	58.8	--	49.5	10.0	--	69.6	15.9	--	28.1	24.4	--	2.9a	2.9a

[1] Mean in a column or row within species and year followed by a different letter are significantly different at p=.10.

period consisted almost entirely of grass leaves. The leaf to stem ratio was lowest in sheep diets consumed after common use grazing.

Chemical composition

Sheep diets consumed before grazing treatments were similar in quality during both years of the grazing trials (Table 8). Major differences were seen before and after grazing treatments but fewer treatment and interaction terms showed significance at the lighter grazing intensities of 1981.

During 1981, in vivo organic matter digestibility (IVOMD) showed the largest decrease (7 percent) in the diets of sheep after grazing by cattle. The smallest drop was in the control pastures but overall the pre-treatment sampling period was higher in IVOMD than either the post-grazing or regrowth diets (Figure 7). The main reason post grazing treatment diets were lower in IVOMD and CP is likely due to the shift from forbs to grasses and shrubs in the diet by the sheep. Due to similarities among treatments, dietary crude protein (CP) differences were also best expressed at the sampling period level in 1981. Grazing the paddocks reduced diet CP 4.8 percent over all treatments. Diet CP increased again during the regrowth period (Figure 7).

Fiber analysis revealed more subtle differences in diet quality. Although fiber is actually a physical property of forage diets, some nutritional inferences can be made (Van Soest 1977, 1982).

Both treatment and diet sampling periods (pre- and post-grazing

Table 8. Average percent values for *in vitro* organic matter digestibility (IVOMD), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin (PML) in the diets of esophageally fistulated sheep before and immediately after grazing by sheep alone, cattle alone, and cattle and sheep together, and after 30 days of regrowth (1981 and 1982).

Treatment	IVOMD			CP			NDF			ADF			PML		
	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth	Before	After	Regrowth
1981															
Sheep alone	62	59	58	16	10	15	40.8	60.6	54.7	29.8	39.1	37.2	8.0a	7.7a	8.2a
Cattle alone	66	59	61	16	10	15	38.1	53.2	51.3	30.0	35.2	33.4	7.6ab	10.1c	6.5b
Common use	60	56	60	14	11	15	43.5	46.9	53.4	30.9	33.5	36.7	8.9a	9.4c	8.9a
No Grazing Control	60	59	60	16	12	14	42.4	48.0	55.4	30.9	32.8	38.1	6.5b	8.6a	9.1a
AVERAGE	62a[1]	58.3b	59.8b	15.5a	10.7b	14.7a	41.2a	52.2b	53.7b	30.4a	35.1b	36.3b			
1982															
Sheep alone	64a	60ab	--	14ad	9b	--	40.5a	65.0b	--	27.8a	39.7b	--	6.7	7.4	--
Cattle alone	65a	56bc	--	17a	11c	--	37.9a	45.3c	--	26.7a	30.4c	--	5.8	8.7	--
Common use	65a	52c	--	15a	11c	--	34.8a	51.3c	--	26.0c	34.0b	--	6.7	8.1	--
No Grazing Control	66a	59b	--	16a	13d	--	38.8a	38.8a	--	28.2a	29.7a	--	6.4	7.9	--
AVERAGE													6.4a	8.0b	

[1] Means within a category within years followed by the same letter are not significantly different at p=.10. Where means are not followed by a letter, F statistics did not allow a separation at p=.10.

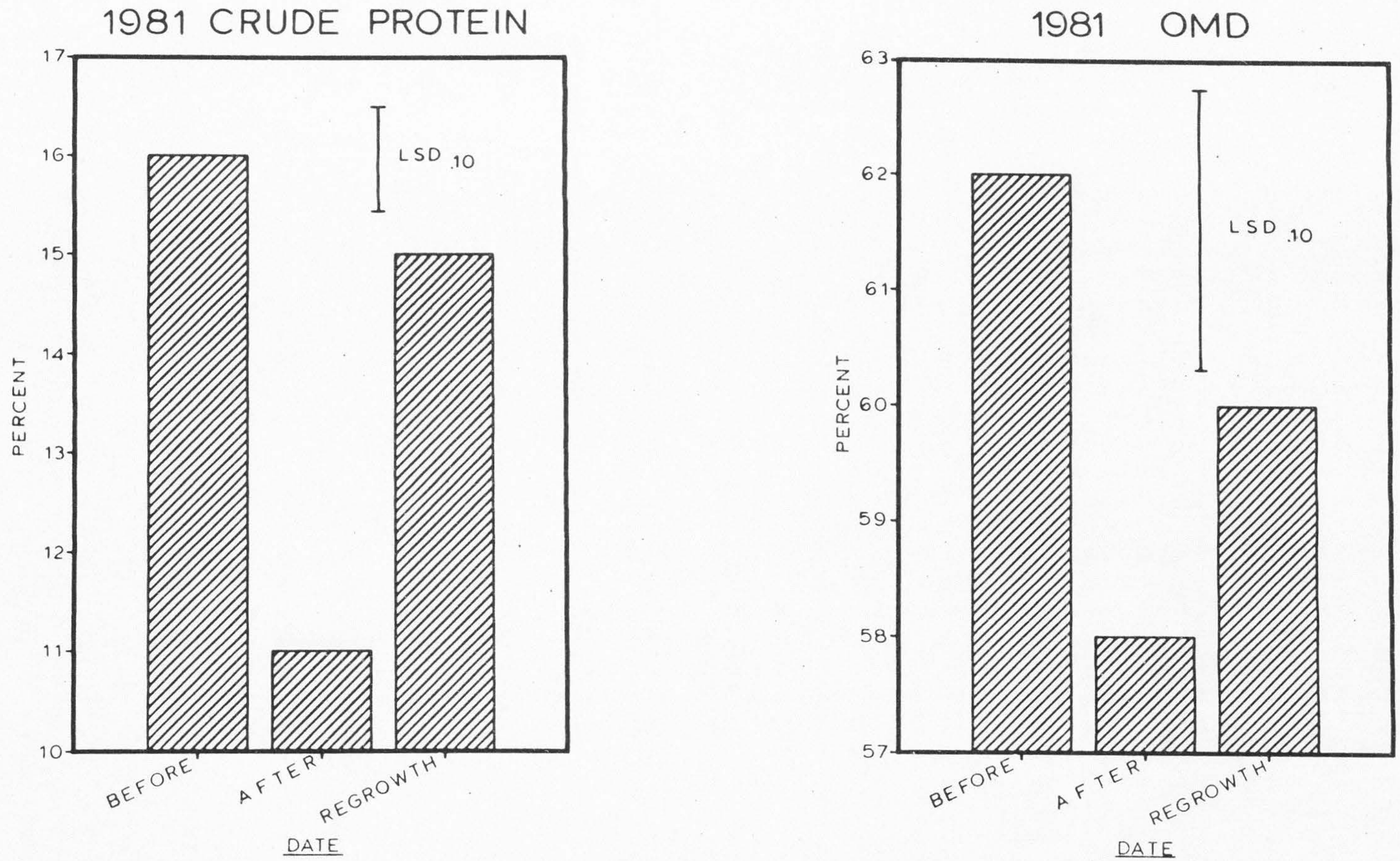

Figure 7. Diet organic matter digestibility and crude protein average before and after grazing and during the regrowth period of the 1981 grazing trials.

treatment and regrowth periods) showed significant differences in neutral detergent fiber (NDF) and acid detergent fiber (ADF) analyses. Paddocks defoliated first by sheep yielded diet samples highest in both NDF and ADF. Sheep diets consumed subsequent to the grazing treatments were higher in grasses which tend to have greater cell wall constituents contents, especially hemicellulose, than forbs or shrubs (Cook 1972, Van Soest 1977). Sheep grazing alone relied on both herbaceous and shrub vegetation, which relaxed use on the grass component compared to common use or cattle only treatments. As a consequence, the esophageally fistulated sheep were able to select a diet high in grasses following the sheep only treatments.

As expected, NDF and ADF were higher in sheep diets after the grazing treatments than before when diets were collected in fresh (ungrazed by treatment animals) paddocks (Figure 8). Diets from the control paddocks were also somewhat higher in cell wall constituents, likely due to the rapid maturation of the more succulent forbs. This resulted in a small dietary shift to grasses even in the short period of no grazing between sampling dates (7 days). Diets following the regrowth period, which consisted almost entirely of new grass leaves, were also high in both NDF and ADF values.

Differences between sheep diets collected in fresh versus grazed paddocks were very apparent in regard to the lignin comparisons during 1981. Due to the high degree of grass and forb use by

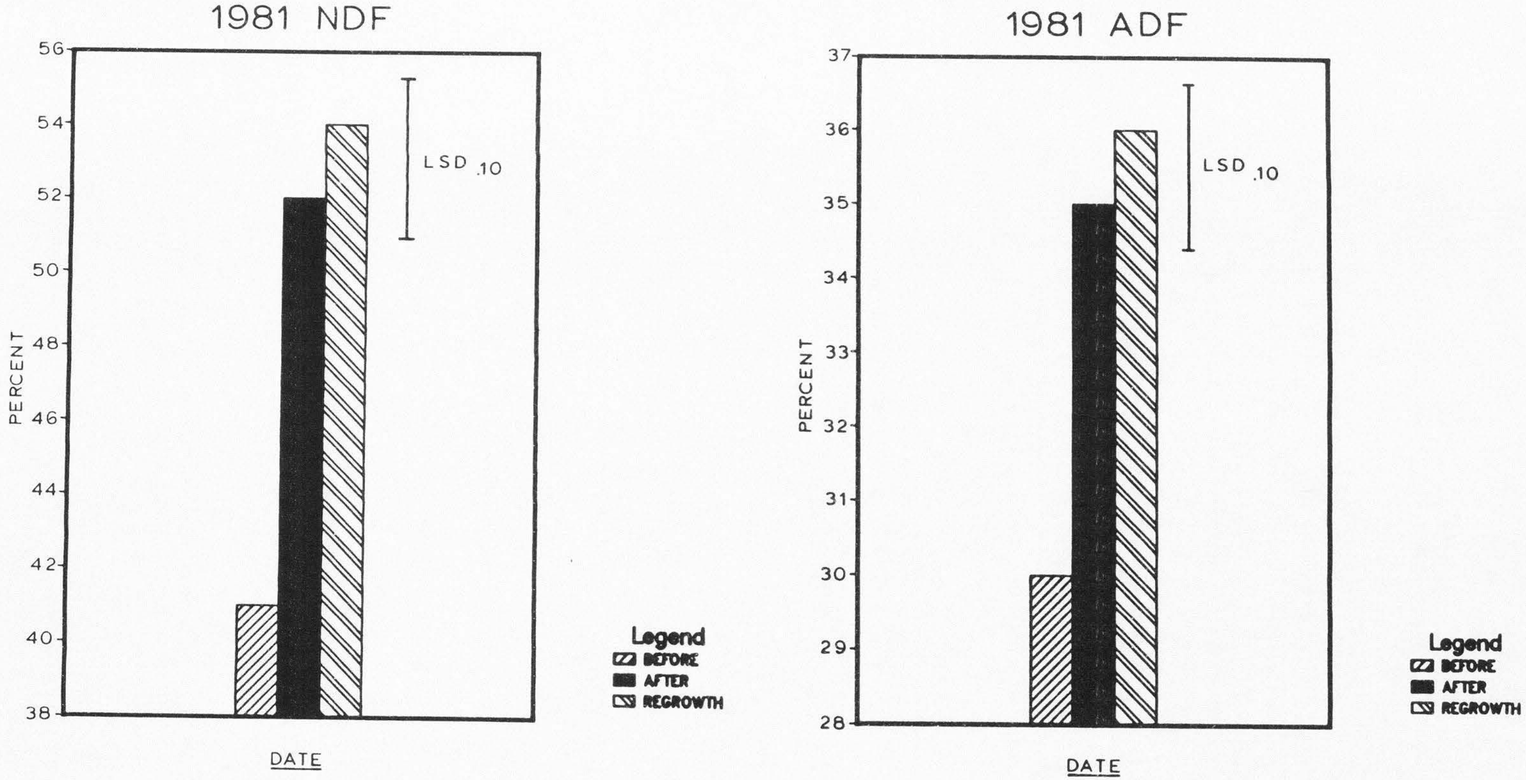

Figure 8. Percentage of neutral and acid detergent fiber in the diets of esophageally fistulated sheep averaged over grazing treatments. These diet samples were collected before and after grazing treatment and after 30 days of regrowth.

cattle, sheep turned their feeding attention to the shrub component and their diets contained large amounts of snowberry when they grazed following cattle. Because shrubs are relatively high in lignin (Cook 1972, Cook and Harris 1950a, Cook and Harris 1950b), sheep diets were consequently higher in this fiber component (Figure 9). Sheep diets obtained from the paddocks previously grazed in common with cattle and sheep were also high in lignin, presumably due to the increased shrub and grass stem content. Under common use all three forage classes were more uniformly reduced. With cattle grazing alone snowberry was essentially untouched and with sheep only the grass component was grazed only lightly. The previously ungrazed paddocks provided diets low in lignin as did the paddocks grazed by sheep. Both the ungrazed and sheep grazed paddocks yielded diets higher in grass leaves than where cattle grazed or under the common-use grazing treatment paddocks.

Differences in the quality of diets the sheep selected in grazed paddocks became more pronounced at the 27 percent higher stocking levels of 1982. Sheep consumed diets lowest in IVOMD in the common-use paddocks (52 percent) while diets from paddocks previously defoliated by sheep were highest in IVOMD (60 percent) (Figure 10). Sheep diets from paddocks previously grazed by cattle were intermediate in IVOMD levels. The date x treatment interaction was less significant when the ungrazed control was included in the analysis, largely because of its similarity to sheep grazing alone. Surprisingly, IVOMD values from diets consumed in the previously

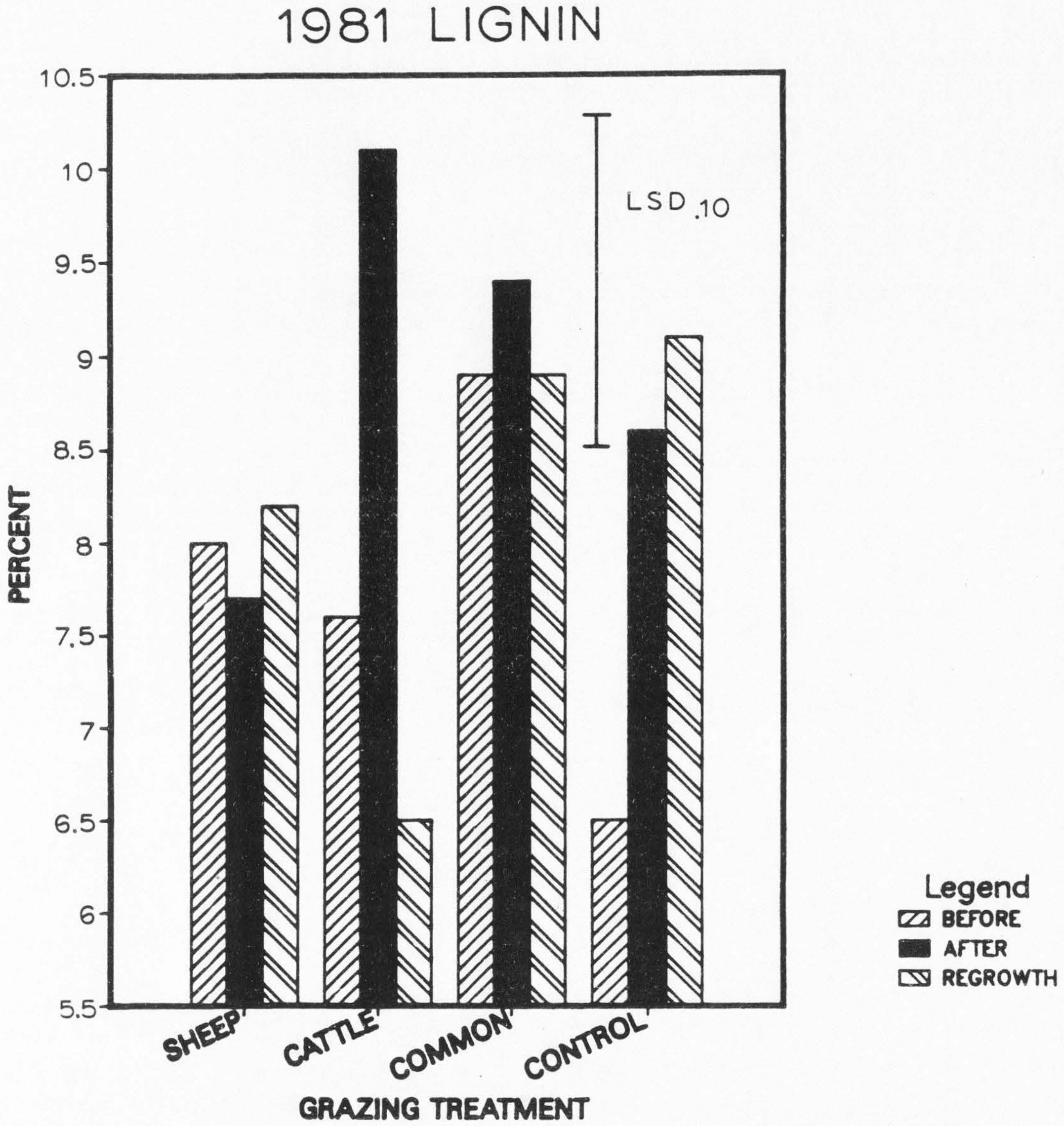

Figure 9. A comparison of percent lignin in the diets of esophageally fistulated sheep before and after each paddock grazing treatment and following regrowth.

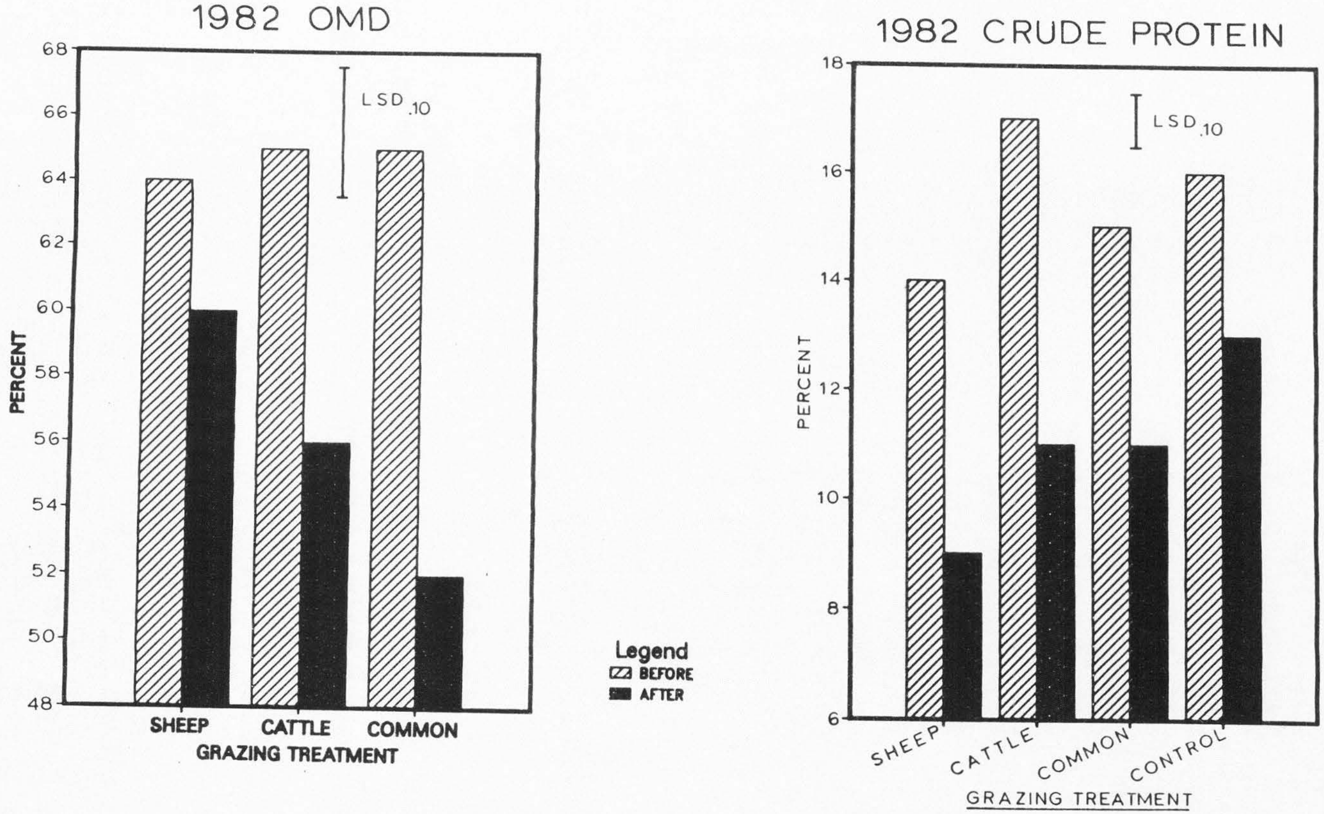

Figure 10. Organic matter digestibility and crude protein in the diets consumed by esophageally fistulated sheep before and after sheep, cattle and common use grazing treatments in 1982.

ungrazed paddocks were lower after only 7 days of vegetation growth. Again, as in 1981, the rapid rate of dessication of the more succulent and palatable forbs, especially Vicea americana may have prompted the dietary shift which corresponded to this reduction. Sheep diets were lower in Vicea during the second sampling period, even in the control paddocks (Table 8). This points out the relative nature of palatability and preference ratios which are affected by rapid morphological changes and daily variation in diet selection even within small enclosures over short time periods.

In contrast to the IVOMD findings, CP was reduced the most in sheep diets consumed in the paddocks previously grazed by sheep (Figure 10). Crude protein was reduced to levels below those recommended for maintenance by the National Academy of Sciences, Nutritional Requirements of Sheep (1975). Sheep were evidently better able to select CP from the available herbage than were cattle or cattle and sheep grazing together. It has been well documented that sheep select diets higher in protein than cattle (Van Dyne and Heady 1965), but their ability to effectively reduce available CP from a plant community has not been discussed.

Sheep diets consumed in paddocks previously grazed by cattle were higher in snowberry leaves which presumably had more protein than the herbaceous component. It is not as clear why common use paddocks were similarly reduced in available CP. Less selective grazing of the herbaceous vegetation by cattle may have left plant parts higher in CP values but only available to the smaller mouths of sheep. Additionally, sheep increased consumption of Symphoricarpos oreophilus when grazing subsequent to common use treatments.

The diet fiber analysis for 1982 was in accordance with 1981 results but significant sampling period (date) x treatment interactions allowed more statistical comparisons in the NDF and ADF fractions.

Both NDF and ADF were highest in sheep diets from the treatments previously grazed by sheep (Figure 11). Again, the grass component in the diet was likely responsible for these differences. Neither NDF nor ADF changed significantly in the control paddocks between sampling periods.

Even though 1982 trends for lignin were similar to 1981, only average before and after treatment differences showed statistical significance. As expected, ligin was higher in post-grazing treatment diets although overall values are rather low (Figure 12).

Sheep diets were reduced in IVOMD and CP due to paddock grazing treatments while fiber values generally increased. Sheep grazing alone apparently reduced CP in the paddocks more than cattle alone or cattle and sheep grazing together. Diet IVOMD was most reduced by cattle grazing alone and common use. Sheep diets contained highest amounts of snowberry and also lignin when they grazed after cattle had previously grazed alone. But total cell wall content was highest in sheep diets consumed after paddocks were previously grazed by sheep alone, presumably due to the higher grass content in

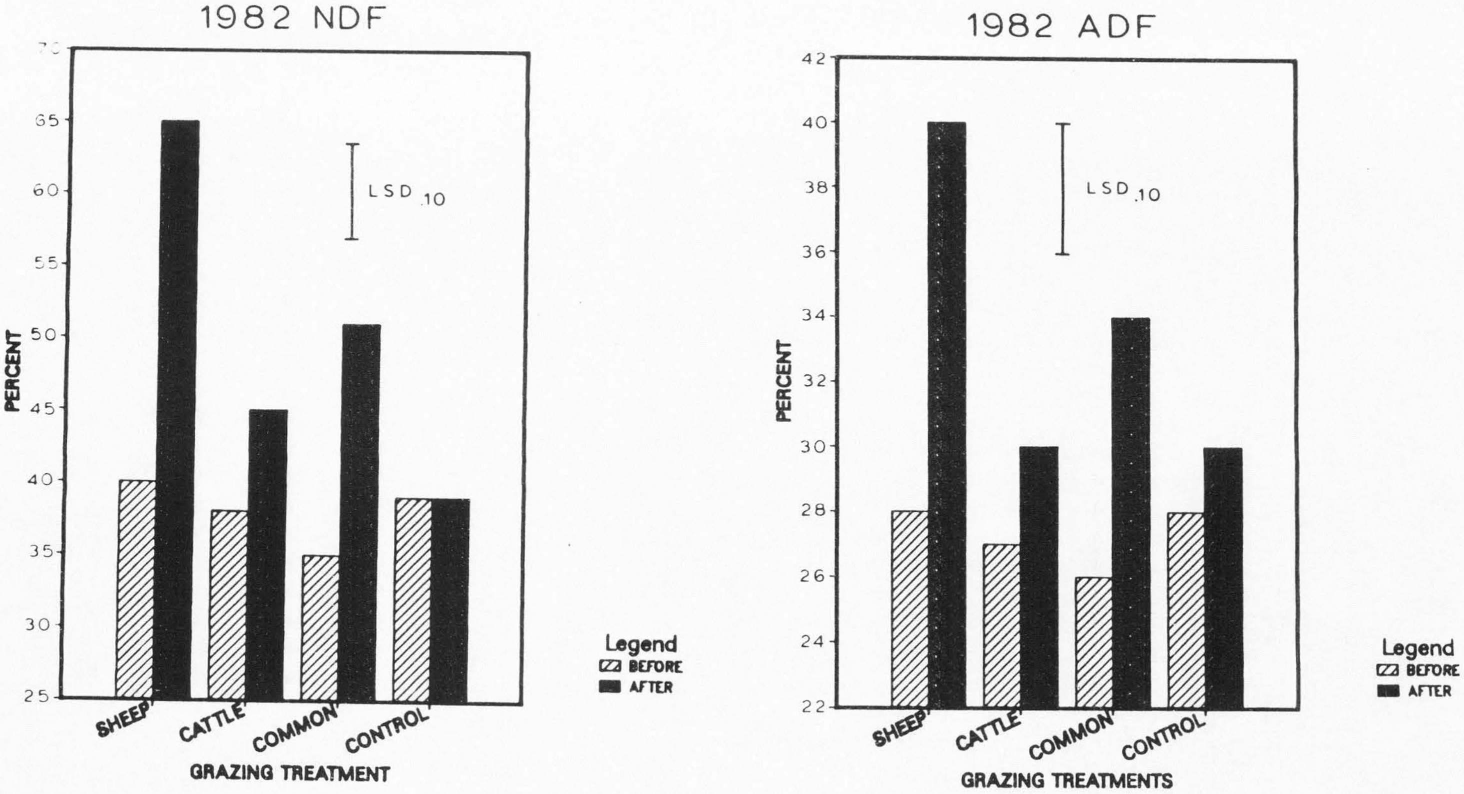

Figure 11. Neutral and acid detergent fiber in sheep diets collected in previously ungrazed paddocks and then again after sheep, cattle and common use grazing.

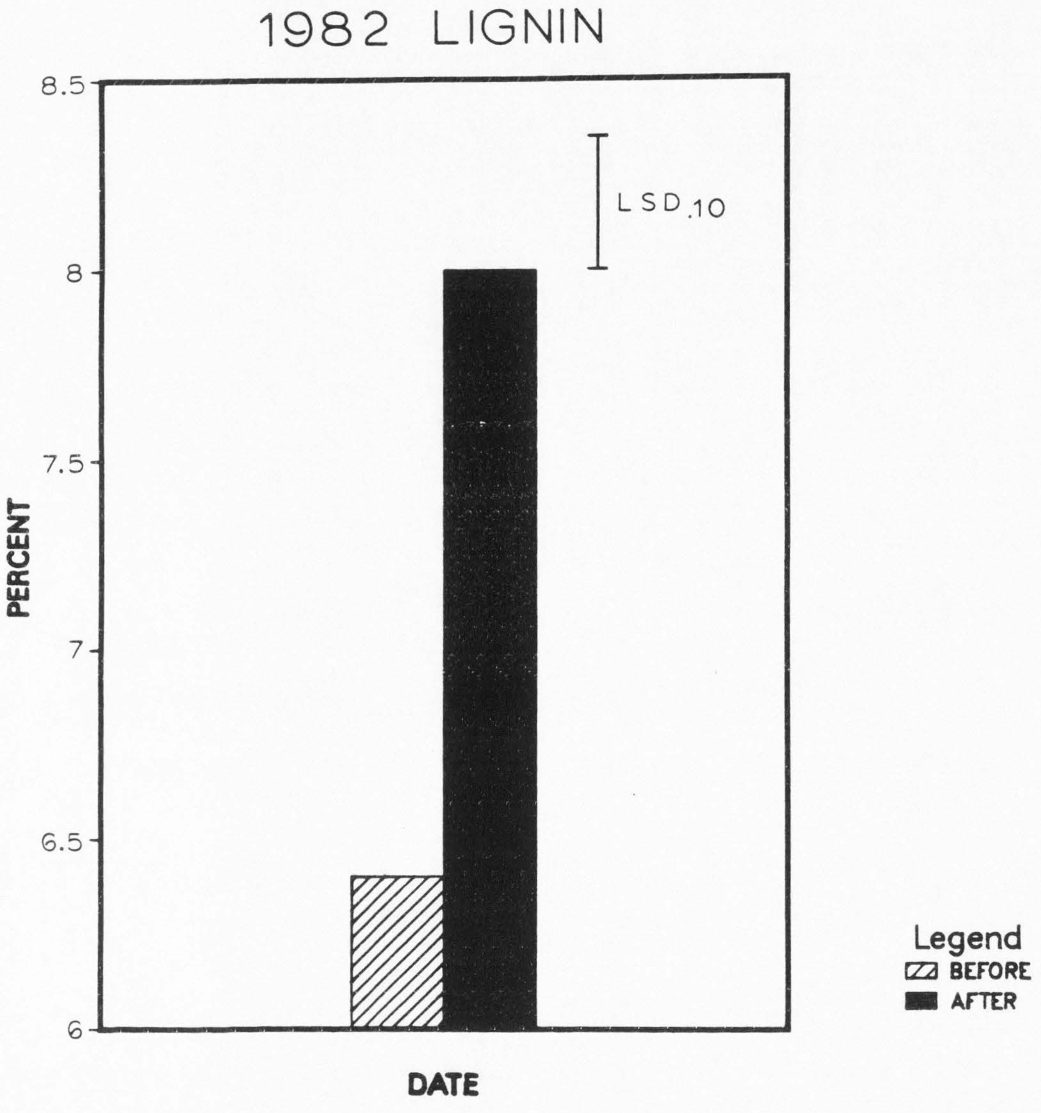

Figure 12. Percent lignin in sheep diets consumed before and after paddock grazing treatments.

post-treatment diets. This was especially true of the hemicellulose fraction (NDF-ADF). Surprisingly, non-grazed paddocks showed trends similar to grazed paddocks, producing diets selected by sheep which were lower in IVOMD and CP after only seven additional days of vegetation maturation. Neutral detergent fiber was largely unchanged during this period, however, while lignin values increased. Sheep diets selected following regrowth were high in CP but somewhat low in IVOMD with correspondingly high fiber components.

Feeding Behavior of Domestic Sheep Grazing Alone and in Common with Cattle

Feeding stations

The actual time sheep spend feeding at a feeding station, the feeding station interval (FSI), may be an indication of how the animals perceive forage availability. The animals used in this study to graze the various paddocks were monitored for FSIs during the trials and although these same animals were not used for the diet sample collections, it is clear that the nutritional quality of the forage on offer was reduced by the prior grazing. Accordingly, FSIs changed during the course of paddock use.

The histograms presented in the following discussion illustrate the percentage of FSIs in the classes 0-10 seconds, 10-20, 20-30, 30-60, 60-120 and greater than 120 seconds following Novellie (1978). These classes were selected to represent the range of FSIs and allow chi-square analysis on the raw data. Chi-square analysis was used to test the significance of differences between days and among the two grazing treatments, sheep grazing alone and sheep grazing in common with cattle. The results of the analysis assume that FSIs follow the chi-square distribution.

The overall trend in FSI during the grazing trials is similar for both years. Average FSI decreased as the grazing trials progressed (Tables 9 to 11). Sheep spent less time per feeding station later in the trial as available forage declined regardless of whether they grazed alone or in common with cattle. However, the reduction in FSI was somewhat modified when sheep grazed with cattle.

Figure 13 shows the percentage of feeding stations in the various class intervals for sheep grazing alone on day 1 (19 hours after turn in) and day 4 (91 hours after turn in) during the 1981 trials. The greatest difference occurred in the 0-10 second FSI category. Sheep adjusted their feeding behavior as the grazing trials progressed by increasing the number of brief FSIs. Chi-square analysis indicated that the probability of a FSI falling into the various time intervals was not independent of trial day. The differences between observed and expected numbers of feeding stations in the various time intervals for the 1981 observations is illustrated in Figure 14. The most obvious shift in feeding behavior occurred in the 0-10 second FSIs. Fewer FSIs were recorded in this class early and more were recorded late than expected by X^2

Table 9. Average feeding station interval of sheep early and late in the grazing trial (1981).

	Sheep Only		Sheep Grazing With Cattle	
	Day of Trial		Day of Trial	
	1	4	1	4
Number of observations	107	112	115	113
$\bar{x}$ seconds per feeding station	20	11	31	18
.90 Confidence interval	(18-22)	(10-13)	(25-37)	(16-20)

Table 10. Average feeding station interval of sheep during the grazing trials of 1982.

	Sheep Only				
	Day of Trial				
	1	2	3	4	5
Number of observations	76	114	84	120	122
$\bar{x}$ seconds per feeding station	46	36	26	22	21
.90 Confidence interval	(36-55)	(26-45)	(18-34)	(15-29)	(10-33)

Table 11. Average feeding station interval of sheep grazing with cattle during the grazing trials of 1982.

	Sheep Grazing With Cattle				
	Day of Trial				
	1	2	3	4	5
Number of observations	68	94	96	86	74
$\bar{x}$ seconds per feeding station	77	53	21	29	25
.90 Confidence interval	(59-96)	(38-68)	(16-26)	(19-39)	(15-34)

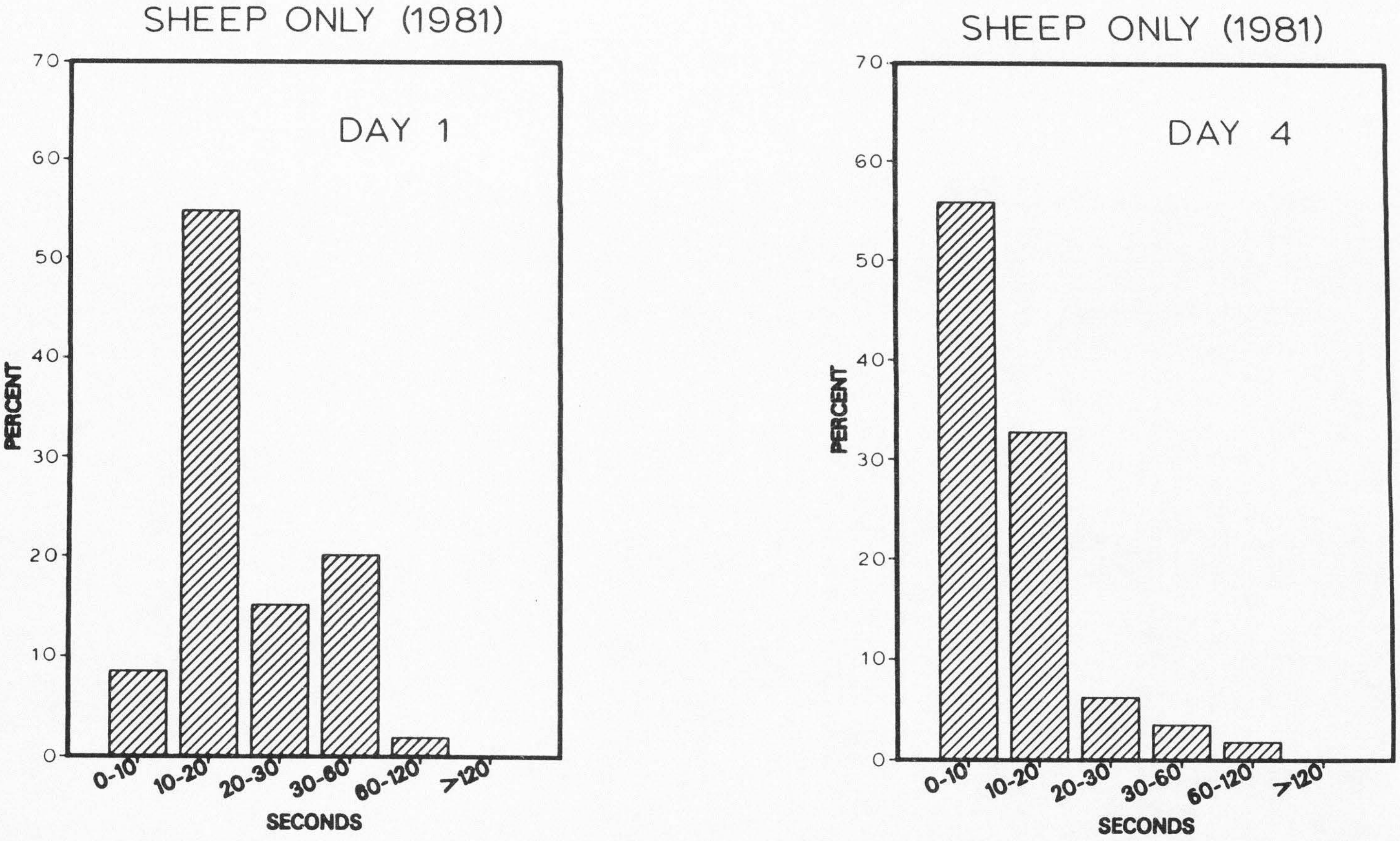

Figure 13. Seconds spent at a feeding station by sheep grazing alone on day 1 and day 4 of the 1981 trials.

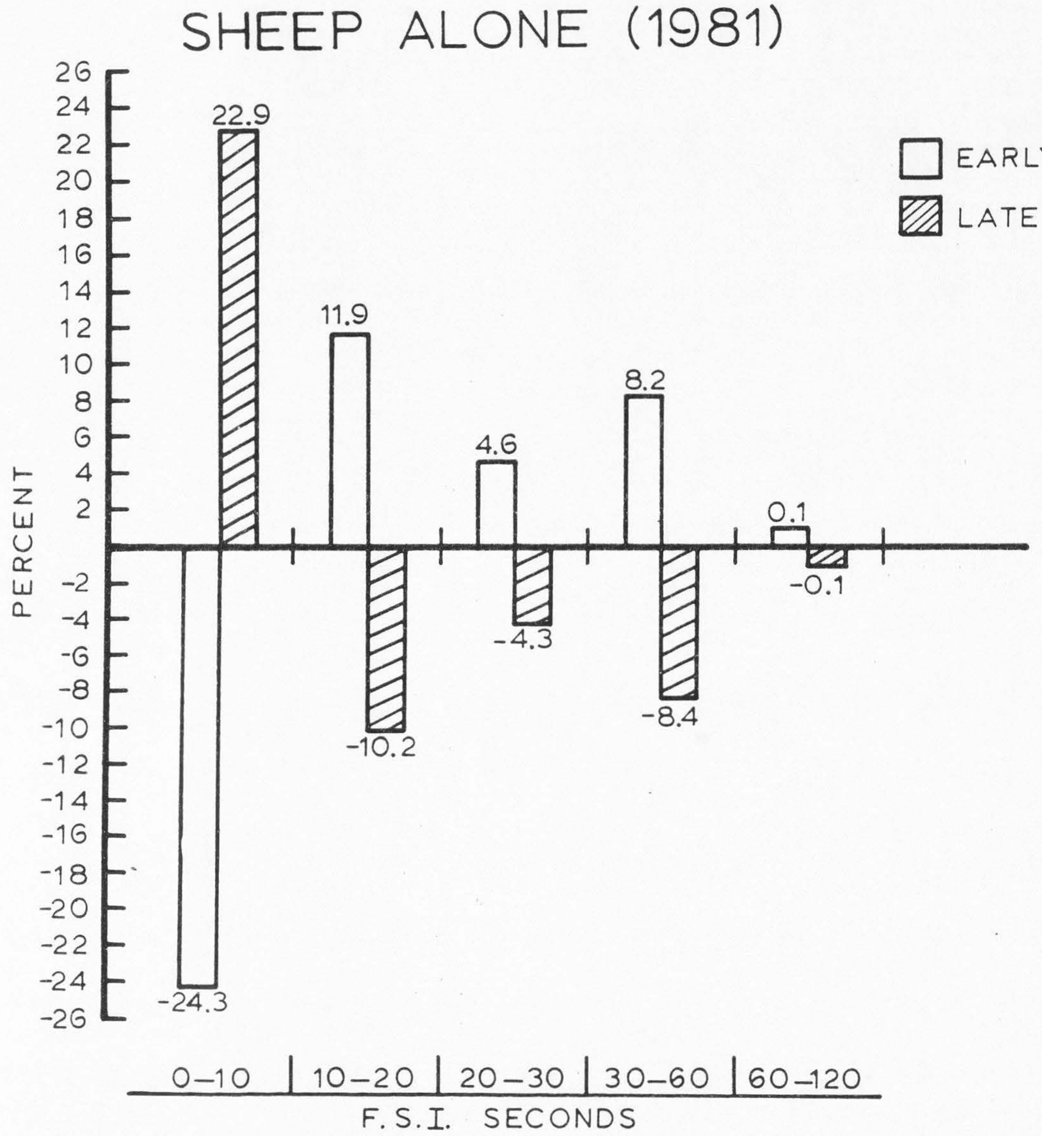

Figure 14. Percent difference between observed and expected time spent at a feeding station.

analysis.

This trend was seen more clearly during 1982 when sheep feeding behavior was monitored every day during the grazing trials. Figure 15 illustrates the histograms for the five consecutive days. Again, day one represents observations made during the morning grazing period, 19 hours into the trials while days two through five are each approximately 24 hours later. The shift toward more short FSIs as the trials progressed is emphasized. Additionally, a reduction in the number of longer FSIs is revealed. Figure 16 illustrates the differences between observed and expected numbers of feeding stations in the various time intervals. Major differences are seen in the 0-10 FSI category over the 5 days of the trial with a consistent increase between the first and last day of grazing (Figure 16). Fewer than expected 0-10 second FSIs were recorded on days 1 through 3 while more than expected were seen on days 4 and 5. Sheep shortened their FSI as grazing progressed. The trend was reversed, however, for the remaining, longer FSI categories (Figure 16). More observations than expected were recorded during the early days of the trials and vice versa for the 5 largest FSI categories. Another category where large deviations were seen was in the 30-60 second intervals. More of these were observed early (days 1 through 3) and fewer were recorded in days 4 and 5 of the grazing trials than chi-square analysis expected.

Single versus common use. Sheep grazing with cattle averaged FSIs somewhat longer than sheep grazing alone (Tables 9 to 11).

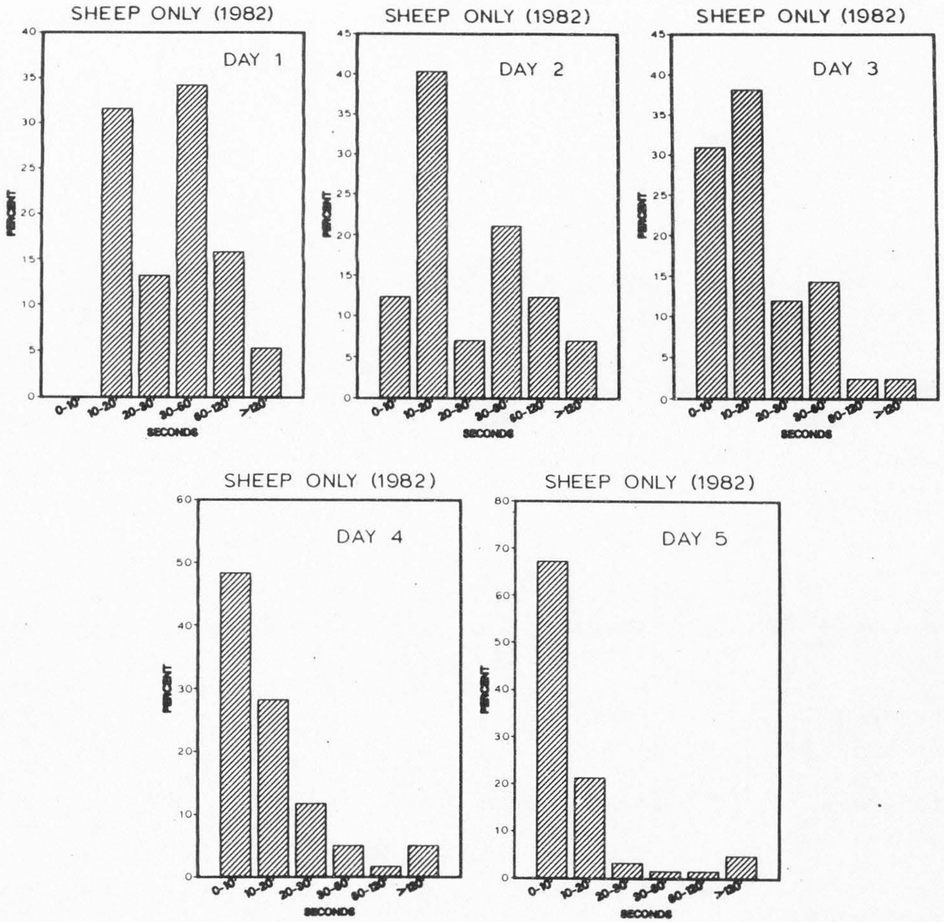

Figure 15. Seconds spent by sheep grazing alone at feeding stations (feeding station intervals) during the 1982 trials.

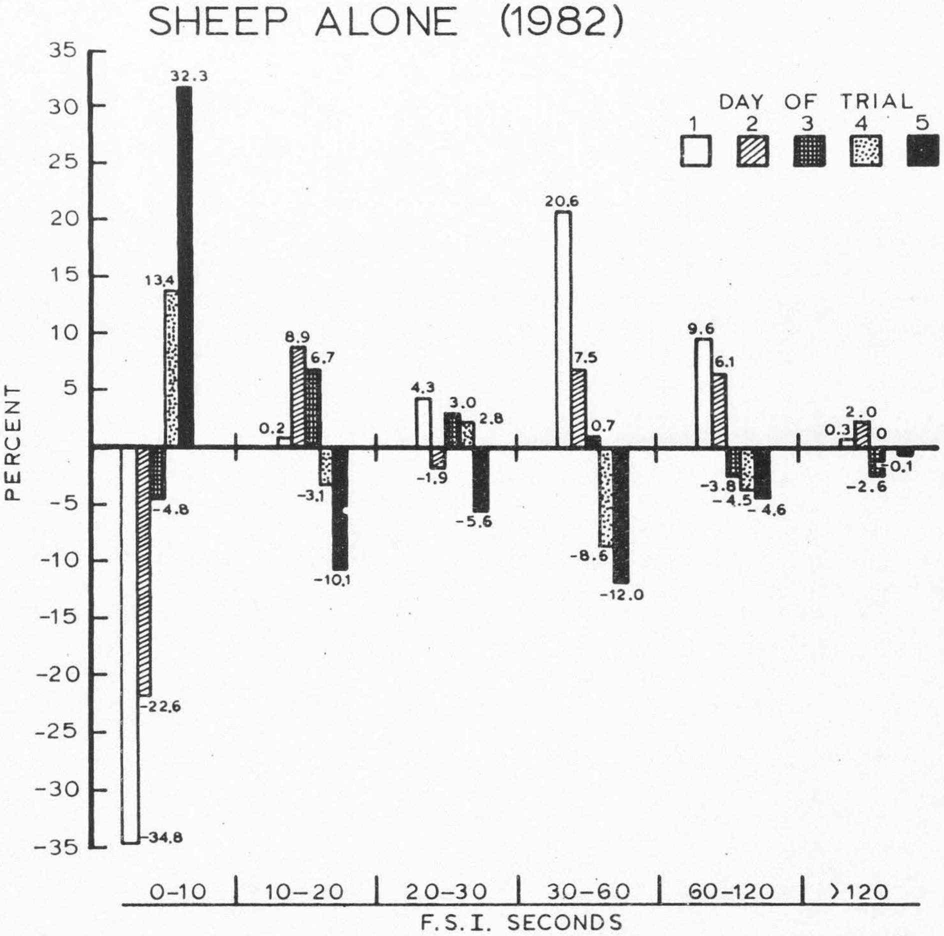

Figure 16. Percent differences between observed and expected time spent at a feeding station.

Relatively large standard deviations associated with the FSIs reduce the utility of mean comparisons.

The length of FSIs recorded for sheep grazing with cattle diminished with increased grazing time consistent with the trend seen when sheep grazed alone. The frequency histograms in Figure 17 present the 1981 data while Figure 18 contains 1982 data. These data were treated identically to those for sheep alone and similar results were seen.

Sheep grazing with cattle increased the number of 0-10 second FSIs as grazing progressed. Fewer of these short FSIs than expected by chi-square analysis were recorded early and more were recorded late in the 1981 trials (Figure 19). A similar trend was seen in 1982, again consistent over days as with sheep grazing alone (Figure 20). Unlike sheep grazing alone, sheep with cattle displayed fewer feeding stations in both the 0-10 and the 10-20 second categories on day 1 and 2 of the 1982 trials. Then the trend reversed and more of the longer FSIs were recorded during the early days of grazing and fewer longer stations were seen later in the trial.

The combined FSI data, presented in Figures 21 and 22 were further analyzed to detect possible differences when sheep grazed with cattle as opposed to single species use. Percent differences between observed and expected numbers of FSIs recorded for sheep alone and sheep with cattle are presented in Figure 23 for 1981 and Figure 24 for 1982. Major differences were again observed in the 0-10 second category, more of these short FSIs were observed than

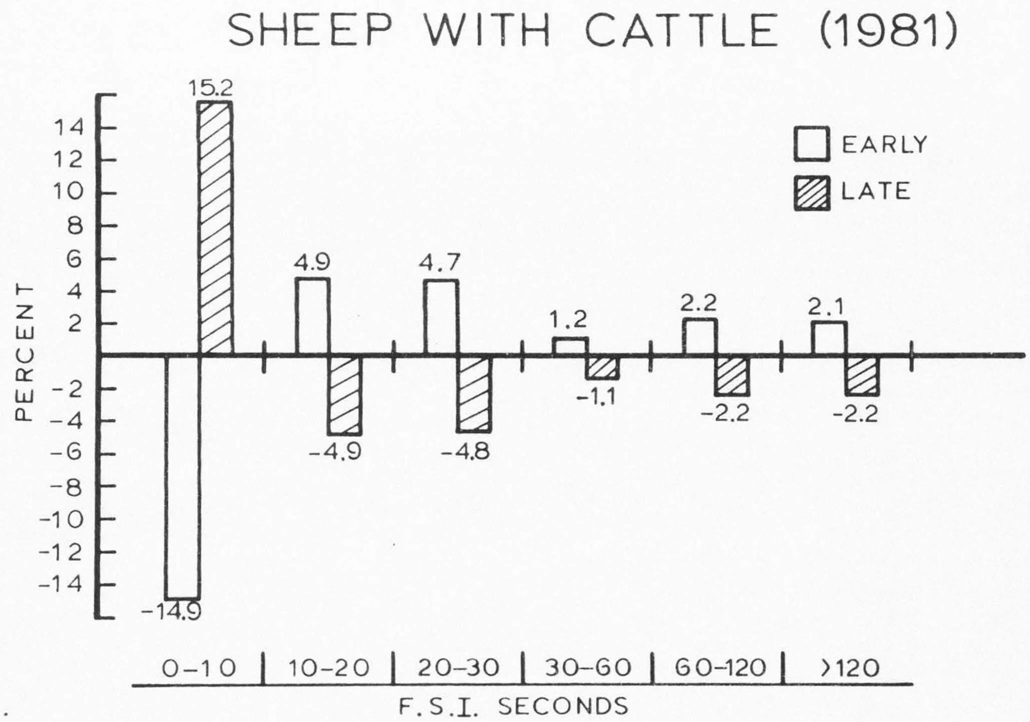

Figure 17. Frequency histograms of seconds spent by sheep at feeding stations while grazing in common with cattle during the 1981 trials.

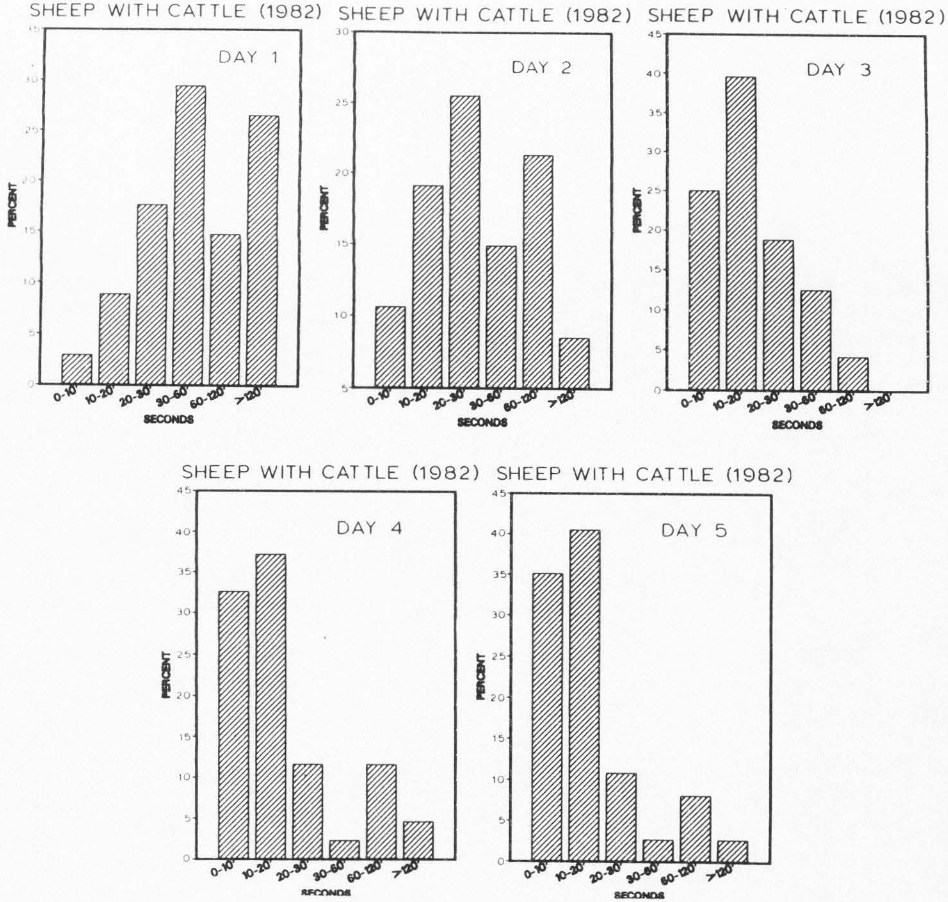

Figure 18. Frequency histograms of seconds spent by sheep at feeding stations while grazing in common with cattle during the 1982 trials.

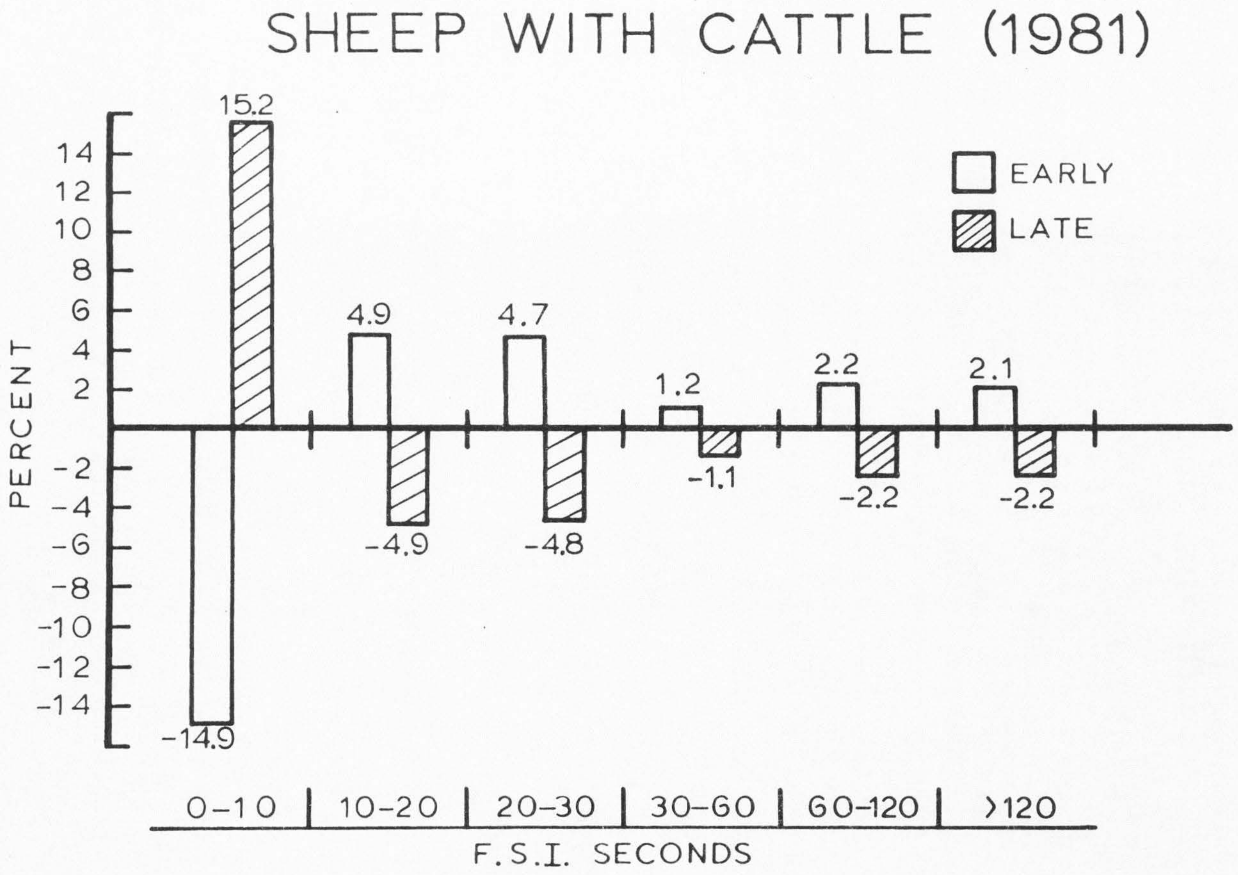

Figure 19. Percent differences between observed and expected time sheep spent at feeding stations while grazing in common with cattle in 1981.

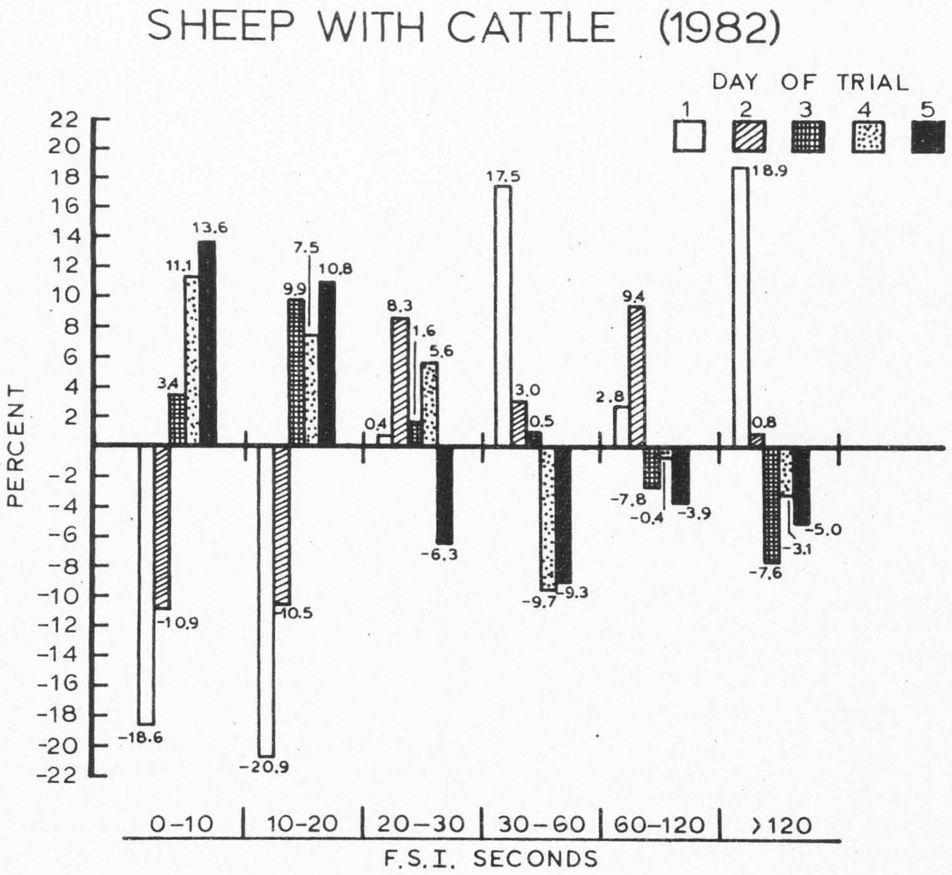

Figure 20. Percent difference between observed and expected time sheep spent at feeding stations while grazing in common with cattle during the 1982 trials.

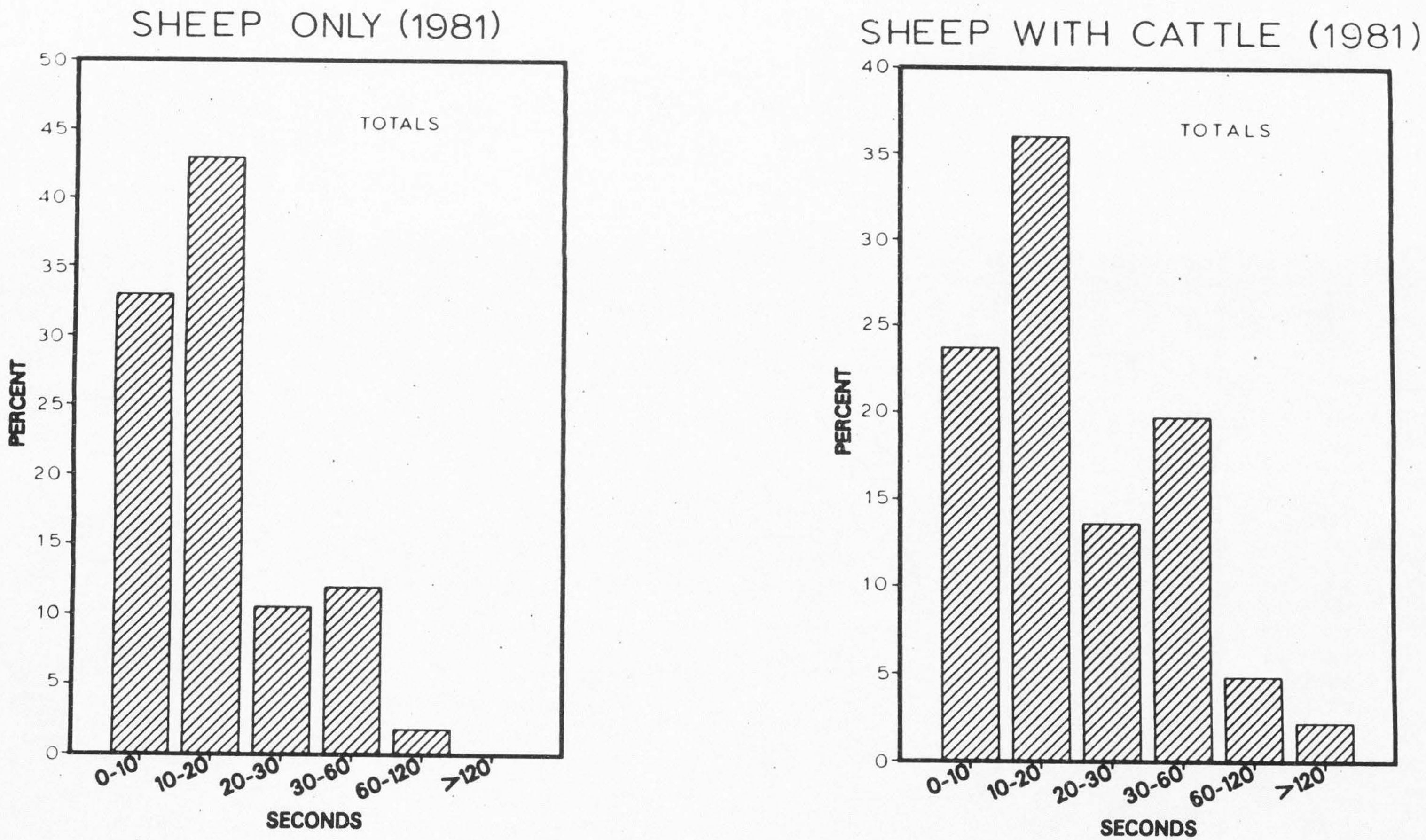

Figure 21. Frequency histograms of total feeding station intervals recorded for sheep grazing alone and with cattle in 1981.

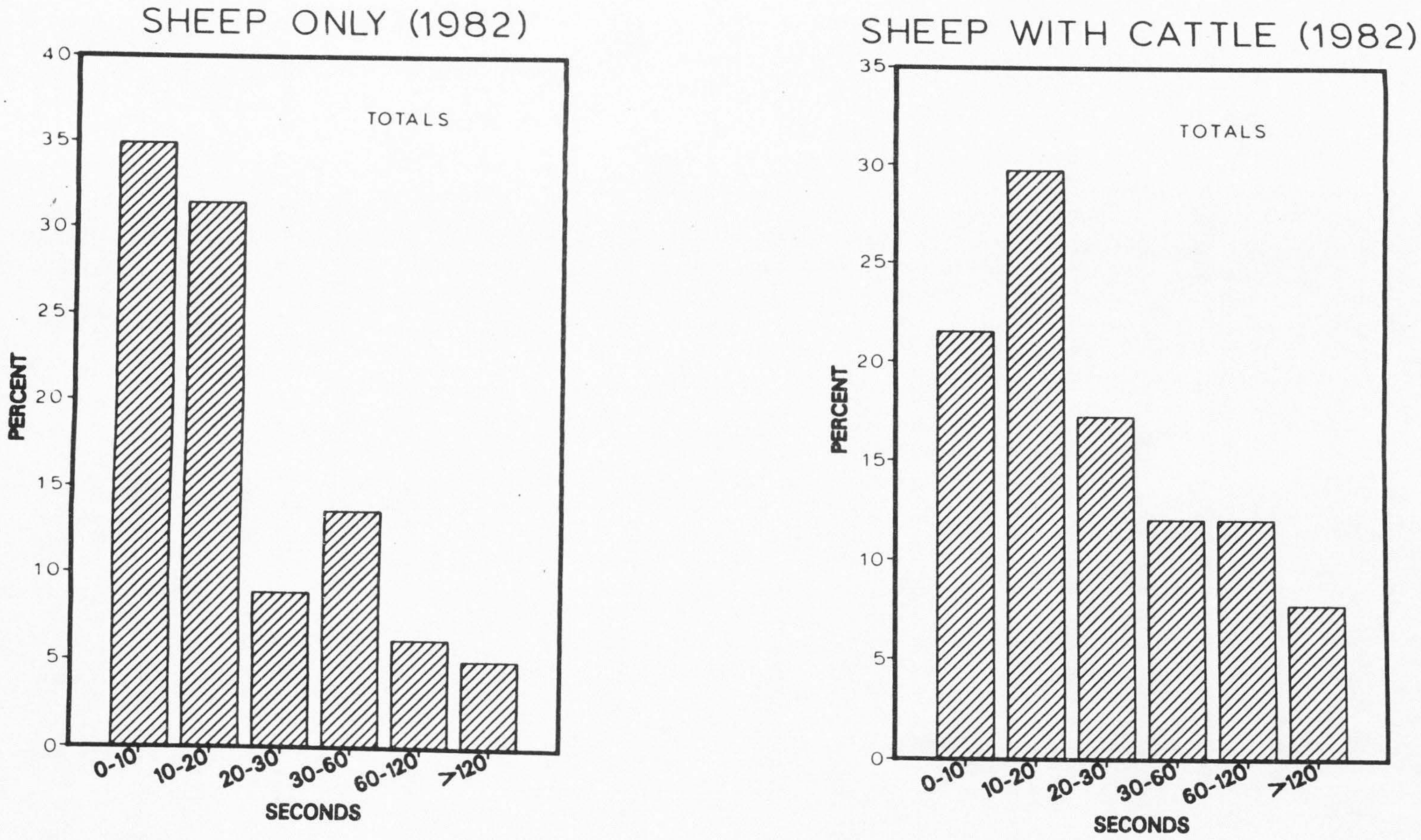

Figure 22. Frequency histograms of total feeding station intervals recorded for sheep grazing alone and with cattle in 1982.

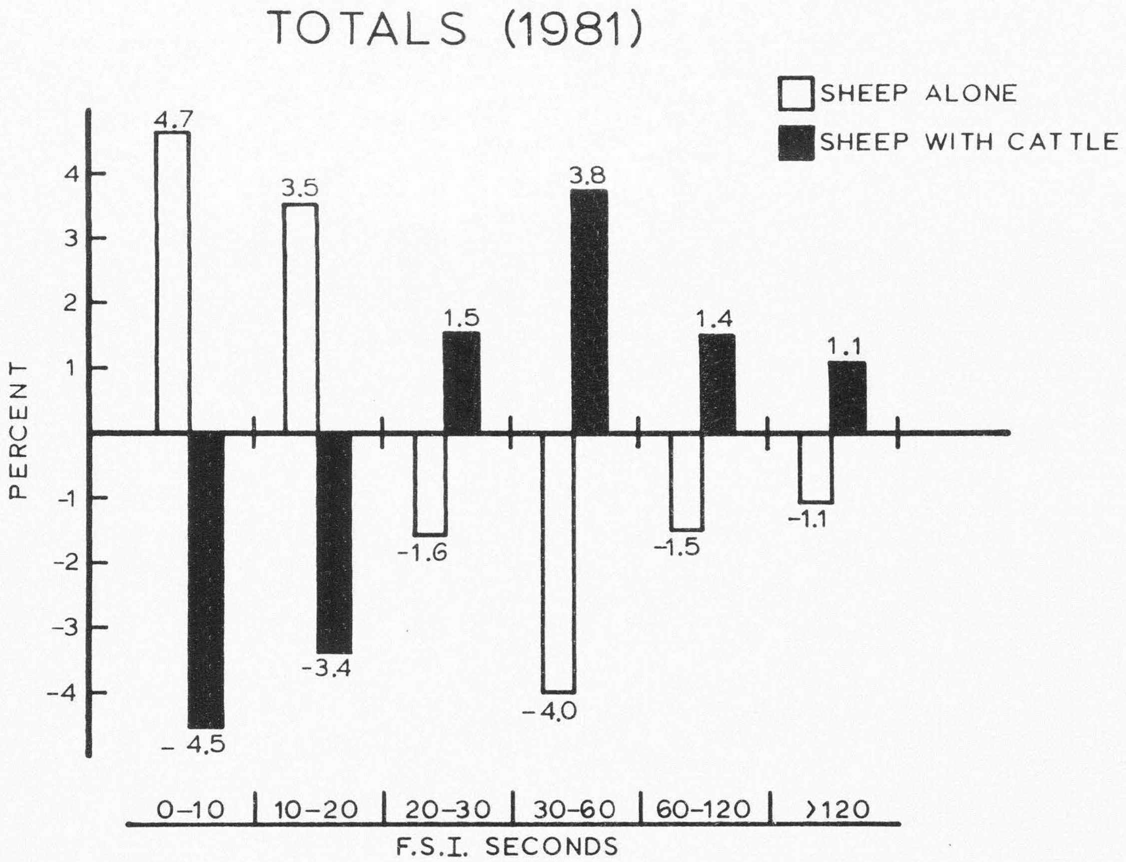

Figure 23. Percent difference between observed and expected time sheep spent at the total number of recorded feeding stations while grazing as a single species and in common with cattle in 1981.

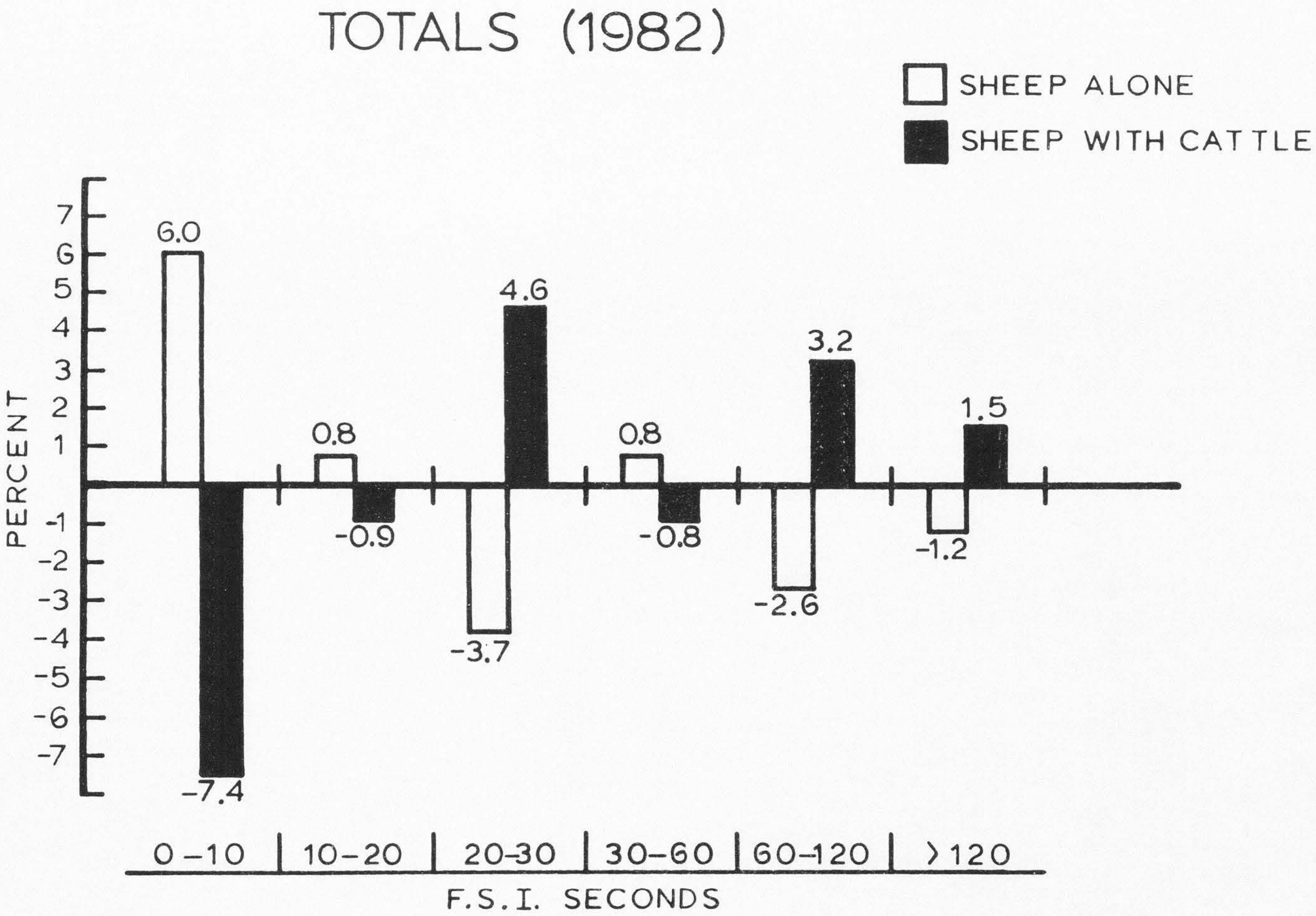

Figure 24. Percent difference between observed and expected time sheep spent at the total number of recorded feeding stations comparing grazing as a single species with grazing in common with cattle in 1982.

values predicted by chi-square when sheep grazed alone. Other differences are consistent between years, especially observations in the 30-60 second category. More of these FSIs were seen when sheep grazed with cattle than would be expected if the data in fact follow a X^2 distribution. These differences were moderated in 1982.

The influence cattle have on sheep feeding behavior is unclear, however one idea deserves discussion. Sheep seemed to spent more time at a feeding station when they were browsing snowberry than when they were grazing herbaceous material. Utilization data and general observations that sheep browsed more when they were stocked in common with cattle. If this was true then the number of browse feeding stations could affect the average FSI and possibly alter the frequency distribution.

There were more browse feeding stations recorded for sheep grazing with cattle than sheep grazing alone but these differences were small and not separated statistically (Table 12). Additionally, numbers of browse feeding stations in proportion to herbaceous feeding stations declined during the trials in both treatments. Averages for browse FSIs are represented in Table 13 and suggest sheep spend more time per browse feeding station than herbaceous feeding station, but there are far fewer browse feeding stations recorded. Variability is also very high.

Table 12. Percentage of total feeding stations where sheep were browsing.

Day	Percentage of Browse Feeding Stations			
	Sheep Only		Sheep with Cattle	
	1981	1982	1981	1982
1	11	19	21	40
2	--	25	--	25
3	--	19	--	17
4	5	17	31	21
5	--	8	--	11

Table 13. Mean and standard deviation of browse feeding station intervals.

	1981	1982
$\bar{x}$ seconds per BFS	48	92
Standard deviation	39	44

DISCUSSION AND CONCLUSIONS

Estimates of generalized forage utilization by sheep and cattle grazing alone and in common generally agreed with the findings of other researchers on similar sites (Cook et al. 1967, Schlundt et al. no date). Sheep ate less grass and more forbs and shrubs than cattle. Cattle showed a strong reluctance to browse snowberry even when herbaceous vegetation was greatly reduced. Cattle grazing left shorter grass stubble heights than either sheep grazing alone or common use under the heavier 1982 stocking rates. These shorter plant heights may have limited forage intake by cattle during the later stages of the grazing trials (Arnold 1981, Hodgson 1982a). Despite limiting herbaceous forage conditions cattle use of snowberry was minimal.

Common use grazing tempered the differences in forage utilization of the single use grazing treatments. All three forage categories, grasses, forbs and shrubs were well grazed. Utilization of grasses, forbs and shrubs in the common use paddocks did not represent an average of the utilization by cattle and sheep grazing alone as reported by Cook et al. (1967). Here, cattle and sheep grazing together used more forage, especially snowberry, than calculated from single use averages in accordance with Schlundt et al. (no date). Because of the number of snowberry stems from which the leaves were stripped but stems not bitten entirely off in the common use treatments, sheep were no doubt responsible for most of the snowberry use seen when grazing with cattle. Interestingly, average use per grazed plant in the herbaceous component was not different among treatments and fluctuated around 40 to 50 percent, an amount generally below recommended management levels.

However where sheep browsed snowberry, up to 100 percent grazed stems were recorded. Despite this high level, traditional calculations of current years use never exceeded 50 percent. But at these utilization levels most of the leaves of current year's growth were browsed and consequently substantial amounts of the shrubs photosynthetic tissue removed. Sheep use of snowberry was greatly reduced when most stems were browsed and the herbaceous component again became the diet mainstay.

There was a good relationship between percentage of grazed stems and utilization levels of snowberry. For management purposes, equations for local conditions should be developed which use only grazed stems to estimate snowberry use.

Even though common use grazing showed little advantage on these sites in terms of increasing stocking rates as calculated by Schlundt et al. (no date) simultaneous grazing by cattle and sheep distribute the grazing pressure more evenly over the three forage classes. The advantage to common use may be that it enables the range site to maintain a stable or upward trend at higher levels of use than single species stocking.

Sheep diets were altered as the various grazing treatments reduced the quantity of forage. Esophageally fistulated sheep diets consumed from paddocks which were previously ungrazed were higher in forbs, IVOMD and CP and lower in fiber than those diets consumed after paddocks had been grazed. Sheep diets consumed in the paddocks previously grazed by sheep only, consisted largely of grasses and were higher in IVOMD but lower in CP than sheep diets from paddocks grazed by cattle or commonly grazed paddocks. Sheep seemingly were better able to select for those plant components higher in CP than were cattle. Grazing by cattle, however, did cause greater IVOMD reduction in subsequent sheep diets. Presumably because esophageally fistulated sheep consumed more grasses after the sheep grazing treatments, these diets were higher in NDF and ADF.

Sheep diets from cattle only and common use paddocks were lower in IVOMD and higher in CP than diets from paddocks previously defoliated by sheep only. These diets were similar in NDF and lignin but ADF was lower in the sheep diets following cattle grazing indicating the diets contained less hemicellulose. This in likely due to the heavy use of grass by cattle and the resulting sheep diets containing large amounts of snowberry while sheep diets consumed following common use treatments contained more grasses.

Sheep diets from previously grazed paddocks were lower in quality than diets from previously ungrazed paddocks but it is not clear which post-grazing treatment diets were superior. On surrounding ranges, lambs gained less where stocking densities were increased and sheep were rotated to another pasture when appropriate levels of forage use were reached. Lambs from pastures grazed continuously and from pastures grazed in common with cattle made consistently higher gains than those where sheep grazed alone under rotational management (George 1983). Perhaps where stocking densities are increased for rotational grazing, ranges become limiting in nutrients (e.g. protein) at lower use levels than the other management combinations even when stocking rates are equal.

Sheep, when grazing alone on these sites make use of both the herbaceous vegetation and the shrub component. Cattle on the other hand use only the grasses and forbs leaving the snowberry. The esophageally fistulated sheep selected diets from the remaining herbaceous layer when grazing after sheep but ate mostly snowberry when grazing after cattle. Sheep diets consumed subsequent to common use grazing were intermediate containing both snowberry and grasses.

Even though sheep diets from paddocks grazed only by sheep were higher in IVOMD, intake is probably more a function of passage rate than total digestibility (Holechek and Vavra 1982, Mertens and Ely 1982). Further, it has been reported that cell wall percentage was highly associated with forage intake by sheep (Mertens 1983, Osbourne et al. 1974) as reported by Holechek and Vavra (1982). The rate of fermentative degradation ultimately controls the intake rate of forages containing a high proportion of cell wall components (VanSoest 1967). Additionally, nutrient selectivity may reduce nutrient intake (Hodgson 1982a). Sheep seldom penetrate into vegetation layers consisting of stems and dead material even when intake is severely limited (Barthran 1980) as reported by Hodgson (1982a).

It appears that shorter grazing periods for rotation grazing might result in increased weight gains of sheep grazing alone and under heavier use nutrient intake would be better for sheep when grazing with cattle. The benefit of shorter grazing periods might be due to less restricted diet selection. Sheep seem to continue selecting high quality diets even at heavy levels of use. It seems probable that nutrient availability may alter intake more than would herbage availability because of the behavioral restrictions of diet selection. Yet sheep are probably better adapted to common use grazing than cattle on these sites because of their ability to shift their diet selection among the three forage components.

A good understanding of livestock feeding behavior appears basic to the development of grazing management systems. Adjusting grazing use or intensity based on some easily recognizable behavioral cue would be a very useful management tool. Livestock adapt their feeding behavior in response to reduced amounts of available forage, but how the animal perceives forage availability can only be hypothesized. The diets selected by grazing livestock may be partly due to the stratified availability of various plant tissues (Hodgson 1982a). Nevertheless, it seems likely that monitoring animal behavior during feeding periods may allow the manager to recognize nutritional limitations in the available forage.

Feeding station intervals (Goddard 1968, Novellie 1978) may be a step towards more consideration of the animals' view of its forage resource. In this study sheep adjusted their feeding behavior as the grazing trials progressed by increasing the number of 0-10 second FSIs. This trend was consistent both years of observation regardless of whether sheep grazed alone of in common with cattle. The behavioral adjustment sheep made was likely due in part to decreased amounts of acceptable forage. Trampling and dunging in combination with grazing probably created an increasingly patchy distribution of acceptable food.

Researchers of livestock feeding behavior must formulate a generalized body of theory before a real understanding of livestock feeding behavior can be reached. Range scientists need to combine the ideas and approaches reviewed by Arnold (1981) and Hodgson (1982a) with those compiled by Kamil and Sargent (1981).

The concept of feeding stations may fit with the ecological theory of optimal foraging. The two-phase process of grazing of site selection and bite selection described by Milne et al. (1979) is similar to the food resource patch selection and search image interpretation of Kamil and Sargent (1981). Feeding stations might be thought of as patches of acceptable food generating a site selection response by the grazing animal. The longer an animal spends at a feeding station might be indicative of the nutrient intake in that food patch. Other predictions could also be tested through basic research and applied management.

The following major findings stem from this research. The hypotheses tested were presented earlier.

--At moderate to heavy stocking rates common use grazing did not represent an average of the forage utilization by sheep and cattle grazing alone. Common use resulted in levels of utilization higher than the average use where sheep and cattle grazed alone, indicating that feeding behavior was altered by mixed species stocking. Sheep ate more snowberry when grazing with cattle than when grazing alone.

--Sheep reduced forb leaf to stem ratio more than cattle but both animal species equally reduced stand-wide grass leaf to stem and green to dead ratios.

--Sheep, known to select diets higher in crude protein than cattle, reduced available crude protein in the forage more than cattle grazing alone did or sheep and cattle grazing together as seen from the diets consumed by fistulated sheep subsequent to grazing treatments.

--Cattle grazing alone and sheep and cattle grazing together reduced available _in vitro_ organic matter digestibility in the vegetation more than did sheep grazing alone.

--As available forage is progressively defoliated by grazing, sheep dramatically increased the number of brief (0-10 second) feeding station intervals indicating that amounts of acceptable food at each feeding station is reduced. These findings suggest that as available forage declines, sheep reduce their intake per feeding station and increase the number of feeding stations visited per grazing period.

--When sheep graze in common with cattle, the trend towards shorter feeding station intervals prevails as grazing progresses but the daily feeding station pattern is not identical compared to sheep grazing alone. Longer feeding station intervals persisted further into the grazing trials when sheep grazed with cattle indicating that amounts of acceptable forage per feeding station were not reduced as quickly as when sheep grazed alone.

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APPENDIX

Table 14. Cedar Mountain study area partial flora (after Welsh and Moore 1973).

Asteraceae

- *Achillea millefolium*
- *Agoseris glauca*
- *Antennaria rosae*
- *Artemisia draculculoides*
- *A. ludoviciana*
- *Aster intergrifolius*
- *Chrysothamnus depressus*
- *C. nauseosus*
- *Cirsium arizonica*
- *Crepis intermedia*
- *Erigeron flagellaris*
- *E. speciosus*
- *Madia glomerata*
- *Senecio intergerrimus*
- *Taraxacum officinale*
- *Tragopogon dubius*
- *Wyethia arizonica*

Boraginaceae

- *Mertensia arizonica*

Caprifoliaceae

- *Symphoricarpos oreophylus*

Caryophyllaceae

- *Stellaria jamesiana*

Chenopodiaceae

- *Chenopodium album*

Fagaceae

- *Quercus gambelii*

Geraniaceae

- *Geranium fremontii*

Labiatae

- *Agastache uticifolia*

Leguminosae

- *Trifolium longipes*
- *Vicia americana*

Liliaceae

- *Allium diehlii*

Poaceae

- *Agropyron riparium*
- *A. trachycaulum*
- *Bromus carinatus*
- *Koeleria nitida*
- *Muhlenbergia richardsonis*
- *Poa pratensis*
- *Stipa comata*
- *S. lettermanii*

Sadifragaceae

- *Ribes cereum*

Scrophulariaceae

- *Collinsia parviflora*

Umbelliferae

- *Ligusticum porteri*
- *Lomatium simplex*

Table 15. Regression equations and r-squared percentage from the standing crop double sampling procedure.

Species	Regression Equations	r-squared
Poa pratensis	y = -0.0571 + 0.925X	95.4
Stipa lettermani	y = 1.79 + 0.804X	83.5
Total Grasses	y = 3.74 + 0.824X	89.1
Artemisia ludoviciana	y = 1.49 + 0.845X	87.9
Achillea millefolium	y = 0.576 + 0.925X	80.9
Erigeron flagellaris	y = 1.28 + 0.877X	95.9
Vicea americana	y = 1.88 + 0.669X	62.6
Total Forbs	y = 316 + 0.787X	85.3

Table 16. Percent dry matter of the major forage species.

Species	1981	1982
	% dry matter on air dry basis	
Grasses:		
Stipa lettermani	55	53
S. comata	53	53
Poa pratensis	54	59
Agropyron trachycaulum	47	49
A. riparium	45	45
Bromus carinatus	51	52
Koleria nitada	40	44
Forbs:		
Vicea americana	37	37
Trifolium longipes	27	33
Erigeron flagellaris	33	33
Artemisia ludoviciana	36	36
Achillea millefolium	22	33
Aster spp.	36	36
Crepis intermedia	36	38
Senecio intergerrimus	86	89
Stellaria jamesiana	38	38
Taraxacum officinale	28	28
Shrubs:		
Chrysothamnus nauseosus	36	39
Symphoricarpos oreophillus	66	55

VITA

George B. Ruyle

Candidate for the Degree of

Doctor of Philosophy

Dissertation: Sheep Diets and Feeding Behavior in Single and Common Use Grazing Trials on Southwestern Utah Summer Range

Major Field: Range Science

Biographical Information:

Personal Data: Born in Columbus, Mississippi, September 5, 1953, son of Asa M. and Betty G. Ruyle; married Jennifer McRae April 12, 1980.

Education: Received Bachelor of Science with a major in Agriculture from Arizona State University in 1977; completed requirements for a Master of Science with a major in Range Management at the University of California, Berkeley in 1980; completed requirements for Doctor of Philosophy with a major in Range Science at Utah State University in 1983.

Professional Experience: 1980-1983, Research Assistant, Department of Range Science, Utah State University, Logan; 1979-1980, Post-graduate Range Ecologist, University of California, Davis; 1977-1979, Reserch Assistant, University of California, Berkeley.