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Common Use Grazing Studies on Southern Utah Summer Range

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COMMON USE GRAZING STUDIES ON

SOUTHERN UTAH SUMMER RANGE

by

Al F. Schlundt

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of

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to Terri Lynn and the "folks"

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Al F. Schlundt

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure | Page

ABSTRACT

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by

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Two common use grazing trials were conducted during two summer grazing seasons (1978-1979) on a typical shrubby grassland site on the Kolob Terrace, about 20 miles (32 km) southeast of Cedar City, Utah, at an elevation of about 8500 feet (2600 m). Two animal units of ewes with lambs, or cows with calves, or both were stocked in each of six, one-acre (0.39 ha) pastures. A five to one substitution ratio provided two single-species and one mixed (five ewes with lambs and one cow with calf) livestock treatments replicated twice. The pastures were grazed for nine days during which time two major experiments were performed.

In the first experiment, livestock forage preferences were quantified so that precise single-species and common use grazing capacities could be determined. Disappearance of the current season's production of herbaceous vegetation was measured using clipped plots (a modified, "paired plot" procedure) and step-point transects (with grazed plant heights and percent of plants grazed). A predictive regression (r^2=0.90)

of the stem diameters of snowberry (Symphoricarpos vaccinioides), the dominant shrub on the site, with the cubed roots of the combined dry matter of its stems plus leaves was used for estimating browse utilization. Rates of utilization in kilograms per day of the grass, forb and shrub components were computed from the data in terms of increasing herbage use (disappearance). Simple stocking rate relationships, using the rates and proper use considerations, were employed to predict sheep to cattle substitution ratios and optimum mixes of the two species for sites similar to that studied. Results indicated a decrease in the substitution ratio as the relative snowberry density of sites decresed because of the higher rate of browse use by sheep. Proper use of the shrub constrained sheep grazing capacity under these conditions causing a significant, but small, gain in total grazing capacity under common use. Levels of utilization of selected forage components recorded in mixed livestock treatments were significantly different from levels predicted for mixed herds based on single-species treatments. This indicated an effect of mixing cattle with sheep, a social facilitation of forage preferences.

The second experiment, studies of sheep and cattle behavior, provided additional information about the effects of common use on livestock. The pasture layout was such that the behavior of sheep, cattle and mixed groups could be observed in both an isolated situation and in pastures with common fences. Locations and activities for all animals within each pasture were mapped every hour during four days of each grazing trial. Average distances between animals, among groups of animals and between them and key pasture features (fencelines, watering areas) and associated animal activities were determined by livestock species, hour

of day, trial day (herbage quantity) and pasture arrangement. Cattle influenced the morning distribution and activities of sheep in isolated pastures. As the trials progressed, and herbaceous forage became limiting, browsing activity increased in both sheep and cattle. No major differences in distribution or activity patterns were recorded which clearly distinguished mothers from offspring of either livestock species.

The research approach (small scale, intense data collection) presented was appropriate, informative and economic for studying this site and should apply as well to other sites. A discussion of the study methodology was included.

(122 pages)

INTRODUCTION

The concept of carrying capacity is the one most frequently applied by range scientists when determining optimum land use planning. Capacity relates range site size (hectares, acres, sections) and duration of use (days, months, seasons) to numbers of users (livestock, wildlife, hikers, ORV's). Traditionally, much range research has been oriented toward the the determination of correct stocking rates for single livestock species' use of single range sites. Grazing capacities, usually expressed in units of area required per animal unit month of use (AUM) or in AUM's per pasture, were determined for seasons of livestock use by the manager's perceptions of average range condition and long term trends in condition change. Because of the many environmental variables involved in ecosystem dynamics, an accurate determination of a site to sustain a single species of grazing animal has been, at best, an educated approximation often adjusted downward to prevent site deterioration. Capacity determinations become much more difficult as any of the factors in the determinations increase (e.g. multiple range sites). Wildlife grazing has often been considered in livestock grazing capacity determinations (Smith and Julander 1953, Jensen et al. 1972) but few experiments have been conducted which accurately account for the dietary overlaps of two or more ruminant species grazing the same site (McMahan 1964, Smith 1965). Similarly, information for exchanging one ruminant species for another is restricted to simple plant communities or improved pastures (Hull et al. 1957, Meyer et al. 1957, Hamilton 1975, Nolan and

Connally 1976).

The relative ease of managing sheep, goats and cattle makes these species the traditional focus of range livestock production and, therefore, of most grazing research. Specific data regarding these species' forage preferences in single and common use systems of management on a variety of sites will allow an evaluation of their production potential within appropriate proper use constraints. Offshoots of this kind of research are evaluations of field techniques which should also apply to range wildlife studies. Further, the same optimization economics used to evaluate common use studies will apply to most other competing range uses. The experiments presented here were conducted in carefully planned common use grazing trials. Even the simplest research in range ecosystems is a step in complexity beyond most agronomic pasture and animal production research. Sites involved in range research are the next thing to wild ecosystems, albeit with domestic livestock displacing native ungulates, where the forage bases consist of distinct communities of native plants.

RESEARCH SETTING

The traditional use of mountain ranges in southern Utah has been, and still remains, summer sheep grazing (Goodsell and Belfield 1973). Most of the productive sites are in private ownership dating back to Mormon homesteads established nearly a century ago (Nelson 1927). Highlands with easiest access to nearby settlements and corridors of passage to those areas received very heavy use causing substantial stream cutting, sheet erosion, a reduction in palatable shrub cover and a general decline in range condition. Sheep ranching is still strong in this part of the state but, in spite of many economic incentives, the industry is not growing. Predation problems aggravated by recent emotional environmental activism and complicated by a lack of experienced shepherds are contributing to the decline.

Miner's Peak (9243 ft, 2817 m)(Figure 1) lies on the southern end of the Kolob Terrace between the O'Neil and Crystal drainages. The range surrounding the peak (Figure 2) has received comparatively less heavy grazing through the years than have sites closer to Cedar City. As a result, the area has higher shrub cover, less meadow erosion and is in comparatively better range condition. The location was chosen for implementation of a ten year common use grazing study by the Utah Agricultural Experiment Station (U.A.E.S. 1977). Approximately 3200 acres (1300 ha) were leased and fenced into 18 pastures (Appendix Figure 54). The goals of the U.A.E.S. study are to investigate animal and vegetation responses resulting from grazing sheep alone, cattle alone, and sheep and sheep and cattle together, each under simple rotation and continuous

Figure 1. Miner's Peak, northwest of the study site, June, 1977. The area is a mosaic of aspen, oak and open meadows.

Figure 2. Typical shrubby hillside with shallow soils, August, 1977. The dominant shrub is snowberry (Symphoricarpos vaccinioides) in mixtures with gambel oak (Quercus gambeli).

summer use.

The research presented in the following pages was a substudy within the long term U.A.E.S. study at Miner's Peak. A single site within study Pasture 6 (Appendix Figure 54) was chosen as representing much of the range there under investigation (Figures 3 and 4). There, a short-duration grazing trial was implemented to perform experiments on single and dual animal species grazing preferences and patterns of use related to forage availability (Figures 5 and 6). These data are to be used to predict livestock stocking rates within proper use constraints and to serve as a guide to adjust the initial stocking for the entire U.A.E.S. project. Observations of animal distribution and associated activity patterns provided means to quantify degrees of affinity among members of the same species as well as between species of livestock. The scope of the data collection, using various techniques for estimating herbage utilization, had the additional attractive feature of allowing an evaluation of the applicability of the techniques to this and similar situations. This may influence approaches to subsequent substudies associated with the U.A.E.S. study at Miner's Peak.

Figure 3. The study site looking east. The dominant shrub is snowberry (Symphoricarpos vaccinioides) with quaking aspen (Populus tremuloides), the dominant tree.

Figure 4. Pasture arrangement into an isolated block (Pastures 1, 2 and 3) and a contiguous group (4, 5 and 6) with an attached exclosure (E). Dashed line indicates the path of the observer for the behavior data collection.


1
2
3
4
5
E
B

Livestock Treatment	Block 1	Block 2
Sheep	Pasture 3	Pasture 6
Cattle	Pasture 1	Pasture 4
Mixed	Pasture 2	Pasture 5
	1978 1979	1978 1979

Figure 5. Pasture allocation for Experiment 1, a vegetation utilization study, in two grazing trials.

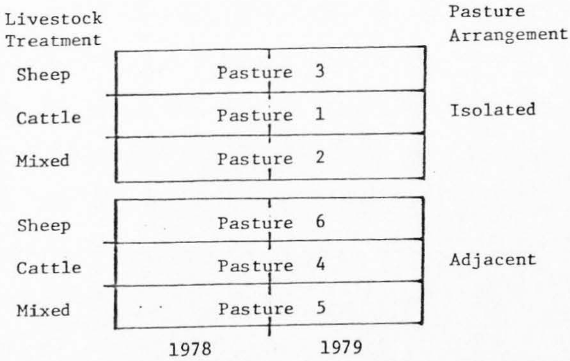

Figure 6 . Pasture allocation for Experiment 2, a livestock behavior study, including six pastures in six treatment combinations repeated in 1978 and 1979. All animals were observed every daylight hour during four days of each trial.

REVIEW OF LITERATURE

Common Use Grazing

Nolan and Connally (1976) reviewed the literature concerning common use grazing by sheep and steers and listed three main concepts included in most mixed-grazing research designs (Connally and Nolan 1976):

1. Equal levels of use of the forage base.
2. Equal stocking rates according to predetermined animal substitution rates.
3. Stocking in different ratios to fix an optimum.

These authors found fault with all of these approaches because of widespread inconsistent interpretation of results. They suggested that economic criteria be used to organize and evaluate future mixed grazing research. Although advice concerning the economics of common use grazing was offered over 25 years ago by Hopkin (1954) few studies have considered livestock market values in determining optimum stocking mixtures.

Indeed, the literature on the subject is diverse and difficult to relate to Utah summer range research. Most researchers have descibed the qualitative differences in diets between livestock species grazing similar sites. Van Dyne and Heady (1965 a,b,c) have gone into great detail, quantifying sheep and cattle diets on annual grass ranges in California. Analyses of samples from fistulated animals gave them a variety of results. Sheep diets, though more variable in botanical composition than cattle diets, were higher in nutritive value. Diet quality decreased as the summer grazing season progressed and as herbage decreased. Linear correlations among plant components of the diets and between the components and their respective nutritive qualities were also presented. More correlations between components and qualities of sheep diets were significant, indicating a greater consistency in sheep forage preferences during the grazing period. Similar research by Cowlishaw and Alder (1959) on cattle and sheep preferences of English meadow vegetation could not separate microclimatic effects from herbage palatability so forages were ranked for comparisons. Cook's work (1954) on common use of summer range in the Wasatch mountains of northern Utah also included a ranking system of "forage factors" for sheep and cattle forage preferences. Starting with the premise that ranges can be more efficiently utilized when cattle are stocked with sheep, he calculated that common use would increase stocking rates by 16 percent over cattle alone by 113 percent over sheep alone. Although his results should bear directly on work at Miner's Peak, the basis for his common use stocking rate calculations is not clear. In subsequent research, Cook and coworkers (1967) demonstrated clear distinctions in sheep and cattle preferences for forages grouped into three classes. Cattle preferred grasses and forbs while sheep rejected stemmy grasses and showed a greater preference for browse.

In the last decade Australians have made great progress in researching mixed livestock performance. Hamilton (1975) reported cattle production per hectare optima at lower stocking rates than for sheep. On those ranges, mixed stocking provided no production increases. In earlier experiments (Hamilton and Bath 1970), however, wool production and weight gain increased in sheep when cattle and sheep were grazed in common. Hamilton (1976) also reported improved lamb performance in mixed herds when sheep to cattle stocking ratios were about one to one. Fewer sheep meant less competition between sheep for a higher quality of forage apparently unavailable to cattle. The recent work of Dudzinski and Arnold (1973) approached comparisons of sheep and cattle diets using a principal components analysis which sorted effects of intercorrelated variables. Diet differences were attributed to the mechanical differences in sheep versus cattle grazing. Sheep grazed closer to the ground and so had a larger soil component in their diets until forage became limiting when the less selective grazing of cattle caused them to pick up more soil than sheep. Working in semi-arid grasslands, Wilson (1976) reported that the suitability of a sparse, Danthonia-Stipa vegetation type was the same for both cattle and sheep. Although sheep diets on these ranges were consistently higher in crude protein than cattle diets, cattle digested their diets as readily as sheep did theirs. Relative weight gains were similar in both species when stocked alone, however, when forage was in short supply common use showed superior weight gains in sheep over cattle.

The grazing of western mountain ranges by sheep and cattle has been studied extensively (Forsling and Storm 1929, Cook and Harris 1950, Cook et al. 1965, Malechek 1966, Matthews et al. 1967, Conrad and Laycock 1968, Buchanan et al. 1972, Cook and Harris 1977) and many animal production data have been collected. A useful approach for determining common use grazing capacities for sheep and deer from single species use data was described by Smith (1965) clarifying the discrepancies of Cook's (1954) calculations. Smith took Standing's (1938) key species concept and derived simple substitution relationships for the two ruminants.

Recent advances in computer technology allowed Peden and Rice (1971) to develop a linear program which made use of single species utilization and production data to manage mixed ungulate populations on mixed vegetation. Drought season probabilities were incorporated in a more recent forage allocation program by Hunter and coprogrammers (1976). Although big game have been studied with regard to their potential competition with livestock on rangelands (e.g. Jensen et al. 1972), small mammalian herbivore impacts are generally overlooked. The importance of insects and other invertebrates as factors when considering plant biomass turnover rates is beginning to be appreciated. Using sensitivity analyses on the whole system grassland model, factors such as these which have been previously considered inconsequential in predicting system dynamics (i.e. common use optima) have become more obviously important and worthy of larger research efforts (Innis 1978). For example, extremely little is known about the impacts of soil organisms on plant root survival, yet this may be a confounding effect of surprising proportions in all studies of livestock production.

Herbage Production and Utilization Estimation

Clipping of small sample plots is a commonly used procedure to estimate the availability of individual forage species as well as total forage on an area basis. Modifications of this technique include longer and narrower rectangular plots to improve availability estimates of plant species in lesser abundance (Cristidis 1931). Plot size (area) is most often determined by convenience both in terms of frame portability and ease of translation of estimated forage availability into conventional units of measure such as kilograms per hectare (Stoddart et al.

1975). In general, clipped plot procedures are only applied to herbaceous vegetation because of the difficulty of estimating actual browse availability from the rather complex shrub canopy (Kinsinger et al. 1960). A "paired plot" procedure is recommended commonly using exclosure cages (Klingman et al. 1943), to reduce the number of plots required for statistical purposes and to estimate productivity during a season. Though there is some controversy surrounding the inherent bias due to cage effects (Michalk and McFarlane 1977), the paired sample procedure is a standard statistical approach (Steel and Torrie 1960) and has a valuable place in Range Science. Minimum plot sizes and numbers required relative to specific plant or plant category variability and desired precision have been established for mountain grasslands (Mueggler 1976).

Modern modifications of the plot concept take plot dimensions and sizes to their natural extremes. Thus, the line intercept (a long, extremely narrow plot) and single point (a very small plot) techniques of vegetation analysis have evolved (Canfield 1941, Evans and Love 1957). These are important examples of rapid,nondestructive approaches having particular application where repeated measures are desirable. Using simple variations and combinations of these, accurate estimates of useful vegetation parameters can be made, including species composition and frequency, ground cover percentage and canopy structure (Whitman and Siggeirsson 1954). Development of height to weight relationships for key forage species in the form of mathematical models (Crafts 1938), simple tables (Laycock 1970) or photographic series (Schmutz et al. 1963) have made estimating utilization with step-point information a straight-forward task.

Occasionally, permanent plots are used to record changes in botanical composition and relative dominance of plant species through mapping of plant basal or canopy area (Anderson 1942). This technique, including maps of large plots, whole pastures and aerial photographs, can provide useful plant ground cover estimates. Because of the variability from plot to plot, strong technician biases, and small sample sizes, mapped plots are not successfully used for range trend analysis. Only where vegetation is homogeneous and many permanent plots are frequently remapped (e.g. Mott et al. 1978) can significant trend analysis be performed.

Universal nondestructive techniques which estimate shrub availability are desirable but unavailable (Ferguson and Marsden 1977). Because shrubs vary considerable in growth habit within and between species there is no single relationship, such as height/weight ratio, which can be used for this purpose. A variety of geometrical relationships between whole plants or plant parts and dry weight measurements does exist, however, among which satisfactory predictive models can be formulated. The twig length to twig dry weight ratio has been used where average twig length is recorded before and after browsing to estimate by difference the percent of browse removed (Jensen and Scotter 1977). Bitterbrush utilization has been estimated using a relationship involving twig diameters, lengths, and weights (Ferguson and Marsden 1977). Repeated measurements of whole shrub geometry (height, diameter) for solitary shrubs on arid sites serve as useful indicators of changes in shrub dominance (Mueller-Dombois and Ellenburg 1974).

Forage Intake Estimation

The use of the term, "utilization", in range literature has been misleading. A distinction between utilization and forage intake should be made because range livestock trample and destroy herbage they do not consume. Nonforage species may be as susceptible as preferred forages to trampling damage so dietary composition and quantity as estimated by forage removal is inaccurate (Laycock et al. 1972). Yet, forage intake information is largely irrelevant to carrying capacity, because correct stocking rates are determined by average overall animal impacts on the range resource. Animal weight gains are important to the livestock producer so the means to predict optimum animal production are necessary to develop. Knowing the quantity and quality of the forage in the diets selected by livestock during the year serves to indicate the limiting factors of the production cycle.

Free-Ranging Livestock Behavior and Distribution

Although whole texts have been written on animal behavior in the feedlot or barnyard (Hafez 1962, Fraser 1974, Kiley-Worthington 1977) few were available which dealt with livestock on rangelands until quite recently (Arnold and Dudzinski 1978). Range livestock are generally free roaming within large expanses so feedlot behavior information applies only in the most general of terms to rangelands. The behavior of most importance to range managers is that of patterns of animal distribution because of its more or less direct relationship with where and how much forage is utilized. The factors which determine animal distribution and, ultimately, forage selection and intake have been discussed in detail by Squires (1975) and Arnold (1964) but no models were developed. Some of the more important categories of effects included environmental considerations such as size and shape of pastures, location of water, range site and time of day. Livestock sociology determined animal spacing and was in turn influenced by species, breed and size of group. Intrinsic charateristics of individual animals, such as age, health and previous experience, ultimately determined forage selection at a given time and location. On Montana mountain ranges, Mueggler (1965) demonstrated the importance of slope steepness to cattle use of forages on the slope. Cook (1966) offered an evaluation of 21 independent environmental variables of which eight were important in a linear prediction model but he could not explain which determined cattle utilization of mountain slopes. He also dismissed cow chip counts (Julander 1955) as unreliable indices of forage utilization related to animal distribution. The best way to relate herbage utilization to animal distribution is to conduct vegetation studies in areas where animals have been actively grazing, though, by doing this, little is added to the understanding of why the animal selects that site or forage.

Cory's range livestock observations (1927) on sheep, cattle and goats form the basis of many subsequent field studies on livestock activities. His observations were restricted to daylight hours so he made no conclusions about the relative importance of night grazing. On the basis of many observations on the grazing habits of sheep, Tribe (1949, 1950) recommended direct and continuous observations as the best means to quantify behavior. Making observations during selected days with typical weather for each month of the year, he showed that sheep doubled their night time grazing during the late summer months as compared to the rest of the year. Following Tribe's lead, England (1954) studied the effect of breed of sheep on behavior during summer grazing. In this study four breeds were observed during two 24-hour periods and their times spent in various activities were recorded. No clear-cut differences between black and white-faced breeds were demonstrated. Hunter's research (1954) on the behavior of black-faced sheep on the hilly ranges of Scotland indicated the importance of previous experience on sheep acclimatization to the sites. With respect to the locations of grazing impacts during the seasons of the year, he implicated weather conditions, learned behavior and the presence of lambs as contributing factors. Pearson Hughes and Reid (1951) also emphasized the importance of night observations for a more accurate assessment of overall forage utilization. In studies with sheep and cattle, they stressed that many animals be observed over many representative time periods to report meaningful information. Recording of livestock activities at time intervals was found to be a satisfactory alternative to continuous in this research. Dwyer (1961) included night observations in his studies of the behavior of Hereford cows and calves on excellent range in Oklahoma. His report indicated that when calves reached the age of four to five months they began to graze quite similarly to their mothers. The animals traveled over three miles per day, a long distance considering the high quality of the forage available. Similar studies in New Mexico compared patterns of distribution of Hereford and Santa Gertrudis cattle (Herbel et al. 1967) and their activities (Herbel et al. 1966). Corbett (1952) found cyclic, diurnal and annual behavior patterns in six pairs of monozygotic calves grazing on New Zealand pastures. Cresswell's studies (1960) established differences between two sheep breeds related to their suitability for hilly sites also in New Zealand. Mileages traveled by individual sheep were measured by a unique harness device which trailed a wheel connected to an odometer. In the British Isles, Hunter and Milner (1963) continued researching sheep behavior including observations on related groups of sheep. They found that the sheep divided their hill pasture along matrilineal lines. This indicated that fences were not the only factors determining sheep distribution. Replacement ewes apparently learned, as lambs, their mothers' preferred grazing areas and perpetuated the subterritories. On mountainous summer range in southern Utah, Bowns (1971) performed a similar study with three white-faced breeds of range sheep where subterritories were not established. Rambouillet sheep traveled about a mile farther during the day and rested more often than either Columbias or Targhees. Valley bottoms and bedgrounds were the preferred locations of all breeds and overuse of these areas occurred without grazing management. Recently, in Australia, Squires (1974) determined summer grazing distributions and associated activities of Merino sheep on saltbush (Atriplex) sites. A flat, 1400 ha pasture was mapped by vegetation type and observations were made from a centrally located ten meter tower. Heaviest use of forage occurred within 1.2 km of water sources with perennial grasses receiving the heaviest use.

Groupings of animals as units of experimentation were considered by Arnold and Pahl (1974). Social attachments among sheep were studied which showed their tendency to pair up in grazing and bedding distributions. Sheep also subdivided their groupings along breed lines even after two years in flocks which combined two breeds. New analysis techniques for the aggregative behavior of flocks were outlined by Pahl (1968,1970) and, more recently, by Grassia (1978) who applied methods used in genetic research. The mathematics which describe group movements and changes in distributions through time, however, have not been widely developed (e.g. Altmann 1980). For this, range livestock behaviorists must rely on ecologists who deal with questions of plant distributions within plant communities (Cottam and Curtis 1956, Goodall and West 1979) and apply those principles to dynamic situations.

Models of range forage allocation cannot take into account livestock patterns of movement until animal distribution can be related to environmental factors, therefore, present predictions of forage utilization on mountainous rangelands are inherently inaccurate. Through a better understanding of the distribution and activities related to the sociology and environment of wild ruminants, a clearer model of range livestock patterns of activities can be built. Literature exists which puts the activities of bighorn sheep in a wide perspective (Irvine 1969, Woolf et al. 1970). Deer (Rue 1978), elk (Altmann 1952,1956) and antelope (Jarman 1974) have also been studied in natural settings. Hypotheses and speculations regarding the evolutionary advantages of flocking (and schooling) behavior have been presented (Wynne-Edwards 1962, Hamilton 1971, Vine 1971, Morse 1977). The roles of predators, such as wolves and coyotes , as important forces in flock behavior evolution have also been described (Pimlott 1967, Fox 1969, Treisman 1975a, b). Studies on the overlaps of wild mammal territories (Burt 1940, Gysel 1960) have indicated the unlikelihood of conflicts between livestock species grazing in common because of shifts in grazing preferences and habitat subdivisions.

STUDY AREA

Kolob Terrace

The geology of the Canyonlands of the "Four Corners" area has been well documented for some time (Barnes 1978). The horizontal Kolob terrace (Figure 7) strata lie exposed south and below the pink cliffs of the younger Wasatch deposits which form a colorful panorama viewed from Miner's Peak area (Figure 3). These flats are undifferentiated Kaiparowitts and Straight Cliffs formations which were deposited 60 to 100 million years ago during the Cretaceous period of the late Mesozoic. The area was once an ocean bottom (shell outcroppings are frequently encountered) but was uplifted to about 8,000 feet (2500 m) when the Laramide revolution formed the Rocky Mountains and the Andes. Signs of vulcanism are also seen on the terrace but soils are generally derived from the sedimentary parent materials. The flowing water of earlier, wetter climates shaped the dominant features of the region leaving the steep cliffs which border the southern and eastern extremes of the terrace. Recent grazing impacts have caused substantial stream cutting and sheet erosion adding additional color and texture to the countryside. Bench slumping, the slippage of hundreds of cubic meters of intact soil strata, is also common and related to the unique geology of the sedimentation (Southard 1977).

Figure 7. Summer view of the Kolob Terrace looking south toward Zion National Park. Note the white cliffs of the Straight Cliffs formation. Arrow indicates study site near Miner's Peak.

Climate

No specific climatic data are available for the study site before 1977. The region receives the greater part of its annual precipitation during the winter as snow (Figure 8). An accumulation of eight to ten feet (2 to 3 m) of snow has not been unusual (Bowns 1978). Some winters are drier than others so herbage production can be greatly influenced by the quantity and temporal distribution of summer rains. In the last four to five years infrequent summer precipitation has come from southerly storms blown north from the Sea of Cortez. The precipitation is spotty causing a potentially large variability in effective rainfall between sites farther than one kilometer apart. Summer air temperatures recorded on the study site ranged from the mid 50's (10°C) at night to about 80°F (27°C) during the day in the shade. Freezing night temperatures have been recorded in late June and as early as mid-September with freezing rain or hail occurring at any time during the summer. The site was usually breezy but without the wind flies became an important environmental feature affecting researchers and livestock alike.

Soils and Range Sites

The soils which have been described for the area (Wilson et al. 1975) form two major associations depending upon average annual precipitation and mean summer soil temperature. The great soil groups involved are all rich mollisols, mostly Cryborolls and Argiborolls. Range sites, listed in Table 1 with soil associations and climax vegetation, include soil textures and horizon thicknesses. Sites such as high mountain loam and stoney loam, mountain stoney and shallow loam, with rock

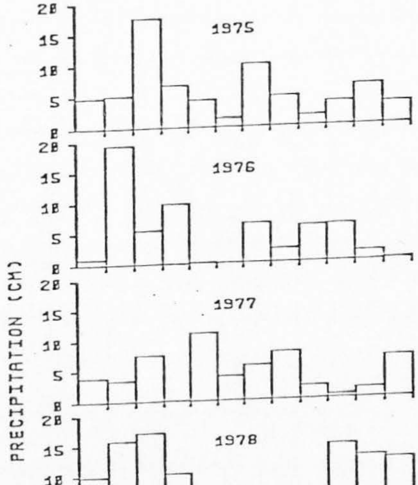

Figure 8. Precipitation data recorded at the Southern Utah State College ranch in Cedar Canyon at 8135 ft. (2500 m), 20 miles (32 km) from the study site. This regime was considered representative of that on the Kolob Terrace (after Bowns 1980).

Table 1. Soil associations, dominant range sites, potential biomass yields and dominant species in the climax vegetation for the area surrounding Miner's Peak on the Kolob Terrace in Southern Utah (after Wilson et al. 1975)

Soils	Range Sites	Potential Yields Favorable	Potential Yields Unfavorable	Dominant Species in Climax Vegetation
		-------lb/acre--------		
Argic Cryoborolls-Pachic Cryoborolls-Cryic Paleborolls Association	High Mountain Loam (Aspen)	5300	2000	blue wildrye, mountain brome, edible valerian, bearded wheat, aspen
	High Mountain Stony Loam (Aspen)	2800	1300	aspen, blue wildrye, bearded wheat, slender wheat, mallow ninebark
	High Mountain Loam	3000	1400	slender wheat, basin wildrye, oak, mountain brome, bitterbrush
	High Mountain Loam (Shrub)	2600	1200	maple, blue wildrye, oak, mallow ninebark, chokecherry
Typic Argiborolls-Lithic Argiborolls-Typic Haploborolls Association	Mountain Stony Loam (Summer Precipitation)	2000	1200	mountain brome, Nevada bluegrass, bitterbrush, oak, muttongrass
	Mountain Shallow Loam (Summer Precipitation)	1200	600	oak, Nevada bluegrass, slender wheat, bitterbrush, mountainmahogany
	Mountain Loam (Summer Precipitation)	1600	825	needleandthread, Nevada bluegrass, big sagebrush, western wheat, black sagebrush

outcrops interspersed or exposed in stream beds are encountered around Miner's Peak. The study site was surrounded by both quaking aspen and gambel oak (Figure 3) putting it in the high mountain site category. However, it should be classified as a high mountain loam by virtue of its climate (Wilson et al. 1975). In Wyoming, Severson and Thilenius (1976) clustered aspen stands into nine functional groups. This approach may be useful for developing a more precise classification of the sites on the Kolob Terrace.

MATERIALS, METHODS AND PROCEDURES

Two experiments were conducted on an open shrubby site in six one-acre pastures near Miner's Peak. The experiments were performed in two nine-day grazing trials one each in the summers of 1978 and 1979. The main emphasis was to determine sheep and cattle forage preferences and levels of utilization when stocked separately and together. In addition, an effort was made to gain behavior information through comprehensive recordings of the locations and activities of the livestock during the trials. These two experiments, hereafter referred to as Experiment 1 (Figure 5, the grazing study) and Experiment 2 (Figure 6, the behavior study), tested the following hypotheses.

Hypotheses

Experiment 1

1. Five ewes with lambs utilize the herbage on the site to the same extent as one cow with calf. Based upon the comparative surface areas of sheep to cows and the required caloric intake to maintain homeostasis, the"metabolic" ratio of five sheep to one cow was expected to apply to the recorded disappearance of forage within treatment combinations.
2. On site estimates of herbaceous forage utilization using clipped plots are comparable to those using step-point transects and height to weight ratios.
3. Levels of forage utilization caused by mixtures of cattle and

sheep can be predicted from levels recorded in single species treatments. Differences between predicted levels and levels actually observed indicate social facilitation between the two livestock species.

4. Both species of livestock waste forage in proportion to expected levels of intake. Based upon actual intake recorded by Cook (1970) for sheep and cattle on Utah summer range, herbage wastage can be estimated by difference from total utilization estimated in the study.

Experiment 2

1. The dispersion patterns of sheep and cattle within small pastures are similar for both species.
2. Effects of isolation on distribution are similar for both species.
3. The effect of one species on the distribution of the other when stocked together is the same for both sheep and cattle.
4. No dispersion differences result from animal age. Ewes and lambs or cows and calves are similar in their patterns of distribution.
5. Sheep and cattle activity patterns are alike. The relative proportions of either species group participating in specific behaviors are similar for both groups.
6. The influence of livestock age on observed activity is negligible.
7. Mixing sheep and cattle has no effect on the activity patterns of either species.

Pastures

The six one-acre (0.30 ha) pastures (Figures 4 and 9) were fenced early in the summer of 1978 on a single range site. They were as similar as possible in forage productivity, aspect and shape. They were constructed to be as near square as possible while meeting all other requirements for uniform botanical composition and desired arrangement. Pastures sloped from five to ten percent to the east. To meet the requirements of Experiment 2 (Figure 6) three individual pastures were isolated from all of the others, while the other three were fenced as a block with an attached half-acre (0.19 ha) exclosure. Treatments were randomized within these blocks of three with the exception of the center pasture of the three fenced together which, because of Experiment 2, required a mixed grouping of livestock as a treatment.

Livestock

To achieve heavy utilization of pastures during a short time period, a stocking rate of ten ewes with lambs per acre (0.39 ha) was used (Bowns and Dwyer 1978). The typical five sheep to one cow conversion (Garret et al. 1959) was applied to set cattle stocking at two cows with calves per acre (0.39 ha) and mixed stocking at one cow with calf and five ewes with lambs. In total, 30 ewes with lambs and six cows with calves were stocked in the six one-acre pastures (Table 2). In 1978, cattle were purebreds and crosses of Hereford and Charolais with previous experience on similar summer range. Sheep were a mixed-bred flock borrowed from an operator who did not restrict his flock's breeding season so lambs ranged from new-born to about three months of age. The

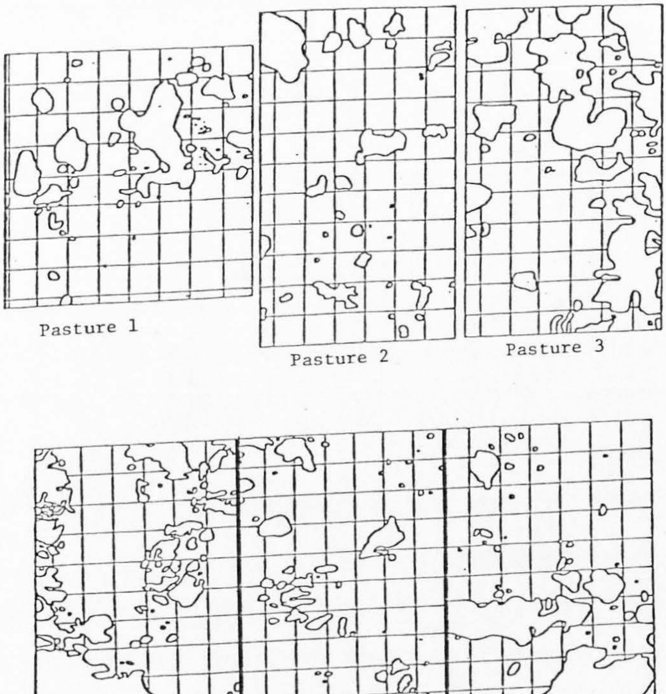

Figure 9. Shrub outlines within six, one-acre (0.39 ha) pastures. Grid system was established on 25 ft. (7.6 m) centers. 1cm = 12.8 m.

Table 2. Numbers of livestock in six small pastures during two summer grazing trials conducted 1978 and 1979.

Livestock Species	Pasture Number 1	2	3	4	5	6
	-----numbers of animals-----					
Sheep						
ewes	0	5	10	0	5	10
lambs (1978)[1]	0	5	10	0	5	10
(1979)	0	9	15	0	8	14
Cattle						
cows	2	1	0	2	1	0
calves	2	1	0	2	1	0

1. The numbers of lambs included with five or ten ewes varied between years.

livestock for the 1979 trial were much more uniform. Cattle were all Hereford or Hereford-Angus crosses, however, their previous grazing experience was restricted to lower elevations on desert ranges. The sheep were randomized selections from the productive, white-faced flocks (Targhee, Rambouillet and Columbia) of the Southern Utah State College ranch. Animals were either weighed immediately before or after the trials. If this was not possible data gathered for the large U.A.E.S. study were used. A data summary for the livestock in the 1978 and 1979 grazing trials is presented in Table 3.

Experiment 1: Production and Utilization

Herbaceous vegetation

Two methods were used to record changes in herbaceous forage resulting from grazing: clipped plots and step-points transects. In 1978, ten plot locations (15 in 1979) were marked in homogeneous spots of the open vegetation of each pasture where four similar plots could be clipped (Figure 10). One random plot from each of the ten groupings of four was clipped before, one during (after five days of grazing) and one after the trial. Flexibility in choosing the third plot from the two remaining after the trial eliminated cow chip problems. Wet weights of each plant species encountered within each plot were recorded and later converted to dry weight. A small spring scale, accurate to the nearest gram, was used for field records. Weights of species in very low quantity were visually estimated. An additional set of 15 locations of four plots was also identified outside of the pastures. All 60 of these plots were clipped before grazing to test the variability of plots within homogeneous grouping.

Table 3. Mean livestock weights and variances during two summer grazing trials. Weights were recorded immediately before or after the trial (1978) or interpolated from Utah Agricultural Experiment Station project data.

	Year	
Livestock	1978	1979
	lb(kg)	
Ewes	141(64)	142(64)
variance	15 (7)	14 (6)
Lambs	77(35)	62(28)
variance	19 (9)	9 (4)
Cows	1129(512)	941(427)
variance	78(35)	87(39)
Calves	333(151)	298(135)
variance	86(39)	36(16)

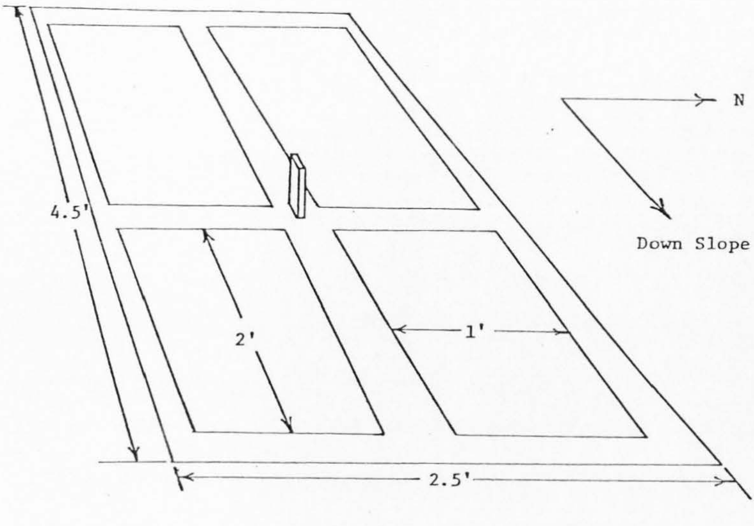

Figure 10. Approximate orientation and arrangement of four, one-by-two ft (30 by 60 cm) plot locations within a homogeneous patch of herbaceous vegetation.

Plot locations for the 1979 trial were selected disregarding the 1978 locations.

The "notched toe" method (Evans and Love 1957) was also used to gather information about the herbaceous vegetation. Sixteen, 25-point transects were recorded in each pasture after each grazing trial where data on canopy cover, basal "hits", nearest plants, occurrence of grazed plants and average grazed height were observed for each point. The transects were parallel, approximately 25 m long, spaced four m apart and perpendicular to the slope of the pastures. The heights of ungrazed plants were recorded in the attached exclosure. Height to weight relationships were established from plant specimens gathered in the immediate vicinity of the study pastures (Bowns 1979).

Snowberry

The current year's growth within 10, 1 by 2-foot (30 by 60 cm) plots placed over dense snowberry stands (Figure 11) was clipped and weighed to estimate snowberry production on an area basis. Numbers of new stems were counted for each clipped plot to estimate numbers of stems produced per unit area. Diameters of 150 randomly selected stems were measured to describe the distribution of diameters in a large sample population. A similar population was dried, weighed accurately, plant parts separated, stem lengths recorded, leaves weighed and measured to sort out useful geometrical relationships with which to predict levels of snowberry utilization. Because of the conical shape of stems, a satisfactory predictor of stem plus leaf biomass related to stem diameter was determined. Ten locations were selected along the diagonals of the study pastures where groups of 20 stem diameters (Figures 12 and 13) were systematically re-

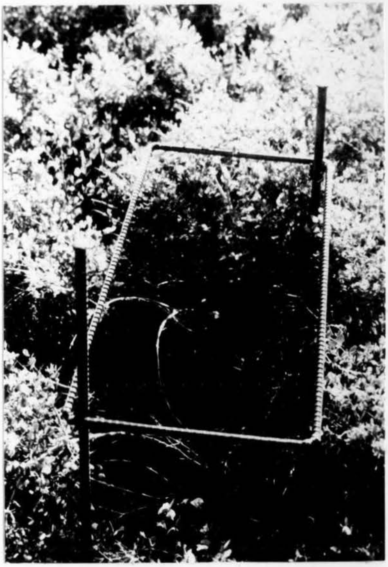

Figure 11. Clipped snowberry plot.

Figure 12. Plot frame and dial caliper used to estimate average diameter of browsed snowberry stems. Frame is in place over moderately browsed shrub patch.

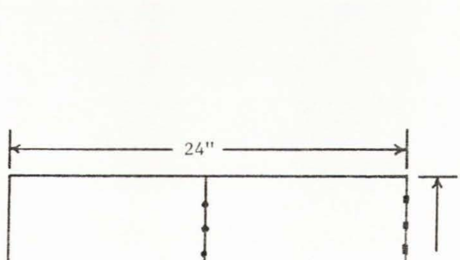

Figure 13. A one by two foot (30 x 60 cm) frame was used to collect 20 stem diameters of snowberry.

corded during and after each grazing trial. An intact (unbrowsed) stem was recorded as a zero while browsed stems were measured by caliper (0.02 mm) at the center of the internode remaining after browsing. So actual utilization by weight was determined by multiplying percent of stems browsed times the total number of stems available times the predicted weight of the average browsed stem.

Experiment 2: Animal Distribution and Activity Patterns

The fences of the six, one-acre pastures were color-flagged at 25 foot (7.6 m) intervals. This provided coordinates for a grid system imposed over the pastures (Figure 9). Fluorescent pink pegs were set within each pasture on 25 foot (7.6 m) centers wherever they could be seen from outside of the perimeter fence. A scale map of each pasture was drawn, carefully outlining the shrub components. These were later reproduced in large quantities for use as permanent records of animal locations and activities through time. For four days during each trial (day 2, 4, 7, 9) the location and activity of each animal was mapped every daylight hour. The observer walked a one mile circuit (Figure 4) hourly from dawn to dusk, observing and recording data for each animal. Data included distinctions between adult and juvenile livestock and their behaviors including lying down, standing while resting, ruminating, active grazing, active browsing, drinking, suckling, and salt licking. Binoculars aided in determining locations and distinguishing activities, especially for sheep in shrubs. Observations on night activities and distribution of livestock were also recorded.

RESULTS AND DISCUSSION

Grazing Trials

The trials lasted only 9 days. The factor which decided the 1978 termination time was the refusal of the cattle in Pasture 1 to remain confined. By the ninth day nearly all of the herbaceous vegetation had been utilized in that pasture (Figure 18). The urge of the Pasture 1 cattle to leave may have been intensified by an earlier "escape" by the cow in Pasture 2 on the eighth day. In 1979 the 1978 trial was duplicated as closely as possible with the planned exceptions of an earlier starting date and more clipped plots (Table 4). Species lists for comparing each pasture based upon plot and point information were prepared (Table 5). These also served as base line data for subsequent trend studies. The pregrazing clipping averages served as appropriate estimates of pasture and site productivity and approximate forage availability for both summers. Little herbage growth occurred after these data were collected until fall rains came or until the following spring when soil moisture deficits had been recharged.

Experiment 1

Clipped plots

The analysis of the variability of plots associated with location showed there was no significant effect of plot within each four-plot grouping when grasses or forbs were considered collectively. This means that production of individual species, however, varied significantly

Table 4. Timing of the 1978 and 1979 grazing trials.

Item	1978	1979
Preliminary	Clipped 10 plots per pasture (7/27-31).	15 plots were clipped per pasture (7/9-10).
Initiation	8/2 all animals in 3:00 p.m.	7/12 (cattle were weighed before release into pastures).
Day 1	Animals grazed.	Corrected mistaken calf assignment.
Day 2	Recorded behavior observations.	Same.
Day 3	Dry weight samples, snowberry support data.	Animals grazed.
Day 4	Recorded behavior observations.	Same.
Day 5	Clipped plots in pastures 1, 4-6.	Clipped plots in pastures 1-4.
Day 6	Clipped plots in pastures 2,3. Snowberry utilization data collected	Clipped plots in pastures 5,6. Pace transects.
Day 7	Recorded behavior observations.	Same, snowberry utilization data collected.
Day 8	Recorded behavior observations.	Same.
Day 9	Clipped all plots.	Animals out at 4:30.
Follow up	Weighed all animals. Ran pace transects, last snowberry data collected.	Clipped all plots, ran pace transects, dry weight estimates, snowberry data collected.

Table 5. The species lists of six study pastures on a single range site near Miner's Peak on the Kolob Terrace recorded by clipped plots (C), step-point transects (T) and general visual surveys (O). Names after Welsh and Moore (1973).

	Pasture Number					
Species	1	2	3	4	5	6
Grasses:						
Agropyron riparium	CT	CT	CT	CT	CT	CT
A. trachycaulum	CT	CT	CT	CT	CT	CT
Bromus marginatus	O	O	O	O		
Hordeum brachyantherum		C				
Koeleria nitida			C	C	CT	CT
Muhlenbergia richardsonis						CT
Poa pratensis	CT	CT	CT	CT	CT	CT
Stipa comata	CT	T				
S. lettermanni	CT	CT	CT	CT	CT	CT
Sitanion hystrix		T				
Grasslikes:						
Juncus sp.						CT
Carex sp.						CT
Forbs:						
Achillea millefolium	O	T	CT	CT	CT	CT
Agastache urticifolia			O			
Agoseris glauca		O	O	C	C	O
Artemisia ludoviciana	CT	CT	CT	CT	CT	CT
Aster integrifolius	C	CT	CT	C	CT	
Astragalus sp.	C	C		C	CT	
Calochortus nuttallii	O	O	O	O	O	O
Collomia sp.			C			
Cirsium sp.	C					
Crepis intermedia	C	CT	O	CT	C	C
Delphinium nelsonii	C	C	C	C	C	C
Erigeron flagellaris	CT	CT	CT	CT	CT	CT
Eriogonum racemosum	O				O	O
Hydrophyllum occidentalis			O			
Madia glomerata			CT	C		CT
Mertensia arizonica		O			O	
Navarretia breweri	C			C		C
Penstemon leiophyllus			O			
P. rydbergii			CT		O	O
Senecio integerrimus	C	O	O	T	T	CT
Stellaria jamesiana	CT	CT	CT	CT	C	T
Taraxacum officinale	C	C	C	CT	C	C

Table 5. (Continued)

Species	Pasture Number					
	1	2	3	4	5	6
Forbs (continued)						
Tragopogon dubius	C			C		
Trifolium longipes	O		CT	CT	CT	CT
Vicia americana	CT	C	C	CT	C	C
Wyethia arizonica		T	T		T	T
Shrubs:						
Artemisia arbuscula	T	T				
A. dracunculoides		T		O		
Chrysothamnus nauseosus	T	CT	T	T	CT	T
Hymenopappus filifolius	O					
Populus tremuloides			O			
Potentilla gracilis			O			
Prunus virginiana	O		O	O	O	
Ribes cereum	O		T			
Symphoricarpos vaccinioides	T	T	T	T	T	T
Xanthocephalum sarothrae	T			O	O	

among the four plots within groupings. The impact of spotty grazing on the variation of these measurements was untested but it was assumed that the relationship was consistent with herbage decline.

Clipped plot data were collected and converted by forage type into kilograms per hectare of dry matter-on-offer using herbage dry weight determination (Appendix, Table 21). The correct paired sample procedure made use of differences between paired plots among the trio of plots clipped for analysis (Steel and Torrie 1960). If differences were greater than zero, then the sample means were different, thus for the analysis of herbage decline (Table 6) the differences were used. This corresponded to analyzing the levels of herbage utilized after the fifth and ninth days of the trials. Because the pastures were somewhat dissimilar, herbage availability analyses were also done on a "corrected" pasture basis (Table 6). For this correction the average pasture snowberry canopy cover percentages (Table 7) were used as common denominators with which to linearly adjust herbage availabilities. There were no differences however, between the analyses so pasture dissimilarities were inconsequential insofar as herbage analyses were concerned. Treatment effects on grass or for utilization revealed no main effect of sheep or cattle. In other words, five sheep impacted these forage components to the same extent as one cow. The effect of trial day was highly significant, however, and is presented graphically in Figures 14 and 15 and photographically in Figures 16 through 18 for the two forage components. The slopes of the simple linear increases in forage disappearance corresponded to livestock rates of utilization (Table 8). These data are similar to those reported by Cook and Harris (1977) for cattle and sheep use of aspen sites in late summer. A single cow with calf caused

Table 6. Effects of treatments on herbaceous forages measured in the six experimental pastures.[1]

Forage Quantity Index	Livestock	Forage Type	Year	Trial Day	Interactions
Actual[2] (kg/ha)	NS	NS	*[6]	**[7]	NS
Corrected[3] (kg/ha)	NS	NS	*	**	NS
Relative[4] (kg/kg)	*	NS	*	**	NS
Relative[5] ($kg/kg^{.75}$)	NS	NS	**	**	NS

1. As estimated using paired, clipped plots. The analysis was based on differences between a pregrazing clipping and subsequent clippings after five and nine days of grazing.

2. Based on actual forage encountered in the pastures.

3. Based on values corrected to an aversge pasture shrub canopy cover.

4. Forage measured per kg of livestock grazing in pastures.

5. Forage measured per $kg^{.75}$ of livestock grazing in pastures.

6. * significant at the 0.05 level.

7. ** significant at the 0.01 level.

Table 7. Percent canopy cover of snowberry in the six pastures and factors used to correct to average cover percentage.

	Pasture Number						
Estimate	1	2	3	4	5	6	average
	percent						
Step-points[1]							
1978	19.8	12.0	27.8	20.0	12.8	24.0	19.4
1979	27.0	16.5	34.0	26.3	15.8	30.2	25.0
average	23.4	14.3	30.9	23.2	14.3	27.1	22.2
Planimetered Map[2]	16.2	12.0	34.9	22.5	10.2	32.0	21.3
Correction Factors[3]							
Shrub	1.31	1.78	0.61	0.95	2.09	0.67	
Herb	0.94	0.89	1.21	1.02	0.88	1.16	

1. 400 points were collected per pasture per year.

2. Includes all shrubs encountered wothin pastures, July 1978.

3. Used to adjust pasture herbage up or down to an average shrub canopy cover basis. For example, the correction factors used to adjust Pasture 1 browse availability:

$$CF_s = \frac{21.3}{16.2} = 1.31$$

and herbaceous vegetation:

$$CF_h = \frac{100.0 - 21.3}{100.0 - 16.2} = 0.94$$

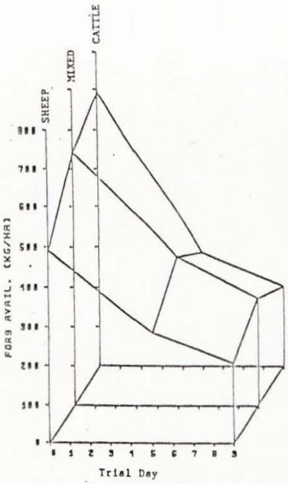

Figure 14. Decline in grass component as estimated by clipping plots for three livestock treatment combinations. 1978 and 1979 averages.

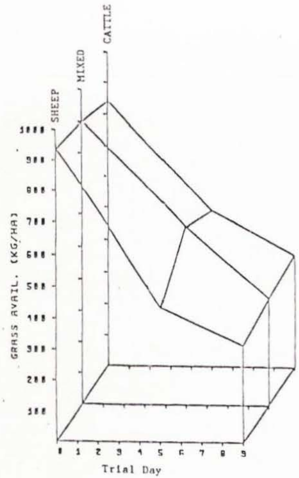

Figure 15. Decline in forb component as estimated from clipped plots. Averages from two grazing trials in three livestock treatment combinations, 1978 and 1979.

Figure 16. Herbage within Pasture 3 (below) and Pasture 1 (above) prior to grazing trials, July, 1978.

Figure 17. Herbage remaining after six days of grazing by 10 ewes with lambs (Pasture 3, below) and two cows with calves (Pasture 1, above), July 1978.

Figure 18. Levels of forage use by 10 ewes with lambs (Pasture 3, below) and two cows with calves (Pasture 1, above) after nine days of grazing, August, 1978.

Table 8. Sheep and cattle utilization rates[1] of herbage components as determined by clipped plots and step-point transects.

	LIVESTOCK TREATMENT															
Herbage Component	Sheep unit[2] actual			Five sheep units actual			Cattle unit actual			C:S[3]	Mixed unit[4] actual			Mixed unit[4] predicted[5]		
	kg/d	%/d	%/d'	kg/d	%/d	%/d	kg/d	%/d	%/d		kg/d	%/d	%/d	kg/d	%/d	%/d
Poa pratensis	0.9	0.9	0.8	4.5	4.5	4.0	1.5	2.1	3.1	1.6:1	2.4	3.6	4.3	3.0	4.6	3.5
Stipa lettermannii	0.8	0.4	0.4	4.0	2.0	2.0	14.7	4.2	3.6	17.9:1	8.3	3.0	3.0	9.3	3.4	2.8
Total grass	2.6	0.7		13.0	3.5		15.8	4.1		6.0:1	11.5	3.5		14.5	4.4	
Artemisia ludoviciana	0.2	0.7	0.5	1.0	3.5	2.5	1.5	0.4	0.8	2.1:1	4.3	2.2	1.3	2.6	1.3	1.6
Total forb	2.6	0.9		13.0	4.5		6.5	3.2		2.5:1	7.6	3.2		9.8	4.1	
Total herb	5.3	0.8		26.5	4.0		22.3	3.8		4.2:1	19.1	3.4		24.3	4.3	
Symphoricarpos vaccinioides	2.5	0.8		12.5	4.0		2.3	0.7		0.9:1	13.5	4.5		7.5	2.5	
Total	7.8	0.8		39.0	4.0		24.6	2.8		3.2:1	32.6	3.5		31.8	3.6	

1. Rates, determined by measuring herbage disappearance from clipped plots, are expressed first in kilograms per day (kg/d) followed by rates expressed in percent disappearance of total production per day (%/d). These are followed by rates of key species disappearance estimated from step-point transect data expressed also in percent disappearance per day (%/d).

2. Rates for a single ewe with an average of 1.4 lambs.

3. Ratio of utilization rates based on the rates of herbage disappearance corresponding to a sheep unit and a cattle unit. The ratio would be 5:1 if cattle and sheep grazed similarly according to metabolic weight prediction.

4. The mixed animal unit was based on approximately half of a cattle unit plus 2.5 sheep units.

5. The predicted values for the mixed livestock treatment were based on rates determined for single species utilization.

grasses to disappear at about six times the rate caused by a ewe with lamb. About 2.5 ewes with 3.5 lambs caused the same impact on forbs as a cow with calf, indicating a much stronger preference in sheep for forbs than in cattle. Based on total disappearance of herbaceous forage from the study pastures, 4.2 ewes with 5.9 lambs (about ten animals) caused the same impacts as one cow with calf.

Although the forage production for 1979 was significantly higher than 1978, the differences of over 50 percent (Figure 19) were exaggerated due to the confounding effect of year with the selections of plot locations. the lack of significant interactions of livestock with other main treatments indicated that both sheep and cattle acted consistently between years. The effect of livestock breed and previous grazing experience on overall perferences of herbaceous vegetation was probably unimportant.

The effects of treatments on the disappearance of individual plant species were also analyzed (Table 9). No main effect of livestock treatments were demonstrated but the effect of year and livestock-by-trial day interactions were significant for Kentucky bluegrass and for two species of Stipa (Figures 20 and 21). From these, strong differences in specific forage preferences between sheep and cattle could be inferred. Stipa lettermanni was much more preferred by cattle than by sheep while sheep utilized Poa pratensis to a much greater extent than cattle. This high use of Poa by sheep supports the observations of Bowns (1971) and other researchers on similar sites. Artemisia ludoviciana, the forb with highest production on the site, was utilized by a ewe with lamb at over twice the rate by a cow with calf. Some of these differences are illustrated in Figures 22 and 23. A strong preference of sheep for Achillea mille-

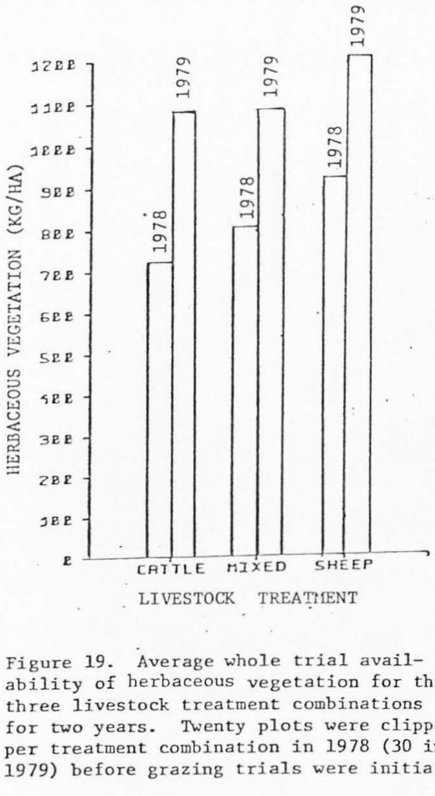

Figure 19. Average whole trial availability of herbaceous vegetation for the three livestock treatment combinations for two years. Twenty plots were clipped per treatment combination in 1978 (30 in 1979) before grazing trials were initiated.

Table 9. Effects of treatments on individual herbaceous forage species on an average snowberry canopy cover basis.[1]

	Treatments			Interactions		
Species	Livestock	Year	Trial Day	LxY	LxTD	YxTD
Agropyron spp.	NS	NS	**[2]	NS	NS	NS
Artemisia ludoviciana	NS	NS	**	NS	NS	*[3]
Poa pratensis	NS	**	**	NS	*	**
Stipa spp.	NS	*	**	NS	*	NS

1. See footnotes, Table 6.
2. ** significant at the 0.01 level.
3. * significant at the 0.05 level.

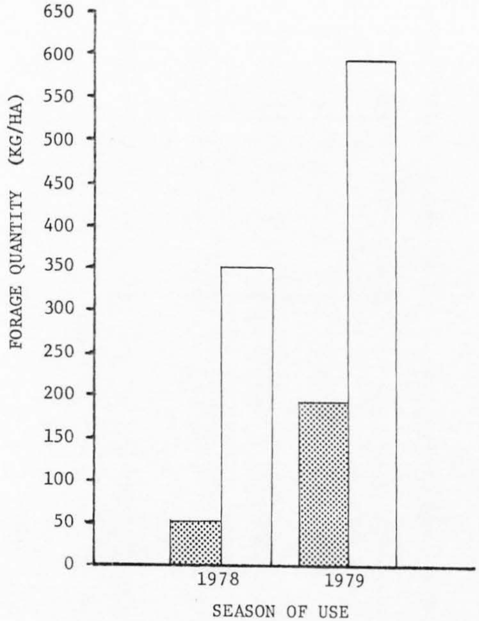

Figure 20. Average production of two grasses for the 1978 and 1979 grazing trials. Stippled bars represent <u>Poa pratensis</u> and the others, <u>Stipa</u> species.

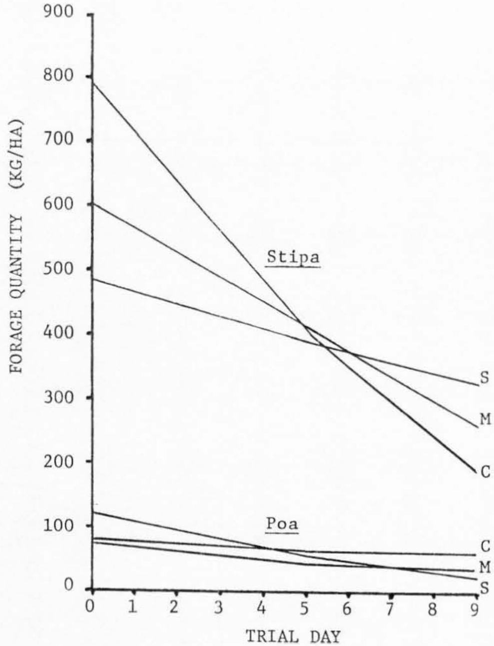

Figure 21. Disappearance of <u>Stipa</u> species and <u>Poa pratensis</u> through the grazing trials in three livestock treatments, sheep (S), cattle (C) and mixed herds (M).

Figure 22. Differential use of forages. Cattle pasture (right) shows heavier use of grasses than mixed livestock treatment (left) after nine days of grazing.

Figure 23. Differential use of forages. Heavier use of Grasses occurred in mixed livestock treatment (right) than in sheep pasture (left). See Figure 22 for additional comparisons. The mixed pasture was the same in both cases.

folium was also observed (Figure 24) but data were not sufficient to test this effect. Year-by-trial day interactions for bluegrass (Figure 25) and Artemisia ludoviciana (Figure 26) were also significant (Table 9). These interactions may have been artifacts of the effect of plot location which changed between years. Because of the large qualitative differences in forages between years (e.g., moisture content, Appendix, Table 21), this was more likely an example of relative forage palatability. The main effect of year (Table 9) on bluegrass and Stipa species, which made up the bulk of all available grasses, helped to explain the year effect on total available herbaceous vegetation (Table 6). This was also related to differences in plot site selections. Also, above and beyond the possibility of more favorable climatic conditions for growth during 1979, the intense pasture grazing of 1978 may have stimulated herbaceous forage production for 1979 by reducing accumulated dead material in the grass canopy.

Step-point transects

Data collected within the herbaceous component of the pasture vegetation were quite consistent between years (Table 10). Average utilization percentages compared well to those estimated by the clipped plot procedure (Table 8) although confidence limits on estimates determined by step-points were not computed. Data were expressed for key species in percents of the original production of plants utilized per day. These were useful values for calculating grazing capacities but they could not indicate relative forage preferences or rates of utilization in kg per day without including plant density data or correlations to clipped plot information. Point frequency (Table 10) gave some indication of the relative abundance of the plant species. Key species were

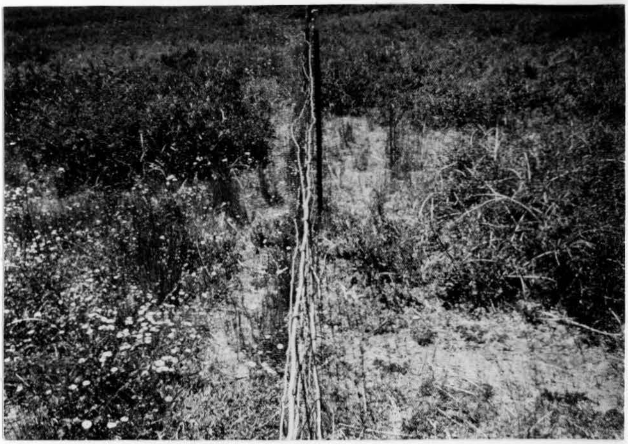

Figure 24. Strong preferences of sheep for Achillea millefolium (white flower) were seen along the south fenceline of Pasture 6. Left of fence was ungrazed.

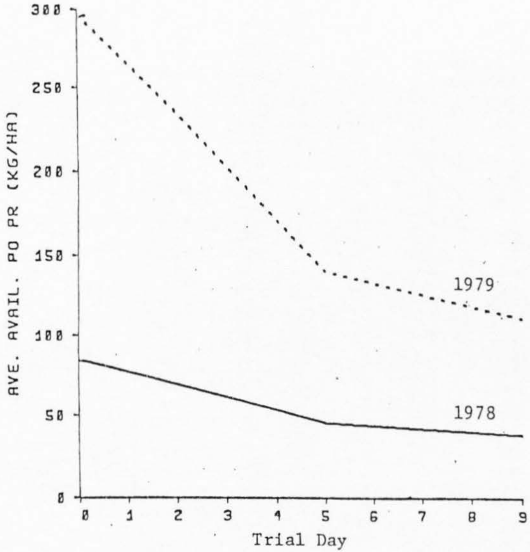

Figure 25. Year by trial day interaction of Poa pratensis averaged over all treatments by trial day.

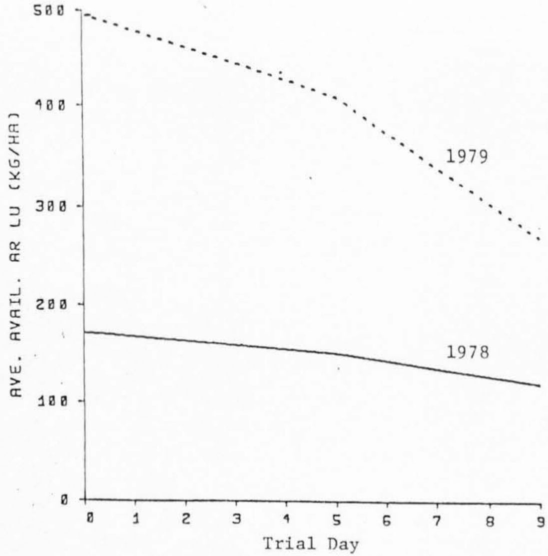

Figure 26. Year by trial day interaction of Artemisia ludoviciana availability averaged over all teatments by trial day.

Table 10. Percent basal ground cover and point-frequency of herbaceous plants encountered within six experimental pastures on an average pasture basis. These were determined using 400 points in parallel step-point transects repeated in 1978 and 1979.

	PASTURE NUMBER																							
	1				2				3				4				5				6			
	G.C.		Freq.		G.C.		Freq.		G.C.		Freq.		G.C.		Freq.		G.C.		Freq.		G.C.		Freq.	
Forage Species	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
	percent																							
Grasses:																								
Agropyron riparium	0.6		3	2			1	1			3	4	0.6		6	8	0.3	0.3	9	5	1.0	0.7	9	6
A. trachycaulum								1			3	3		1.0	2	2	0.6	0.9	2	6	0.7	1.1	4	5
Koeleria nitida																7		0.3	1	1			1	2
Poa pratensis	0.9	0.7	24	25	0.6	2.1	20	27	2.1	2.7	41	45	3.8	2.7	36	34	2.6	3.3	36	36	0.3	1.8	30	36
Stipa comata	8.1	1.0	30	12																				
S. lettermanni	3.1	6.4	28	37	5.4	2.4	32	26	4.2	4.9	24	20	6.9	4.4	30	23	8.3	6.2	31	21	3.3	2.9	15	9
Other grasses			1				1														0.7	1.4	6	3
Total grass	12.1	8.1	86	76	6.0	4.5	54	55	6.3	7.6	71	72	11.3	8.1	74	74	11.8	11.0	79	69	6.0	7.9	65	61
Forbs:																								
Achillea millefolium											1		0.3	0.3	2					1	1.3	0.4	13	10
Artemisia ludoviciana		1.0	6	5	2.0	3.3	33	25	0.7	0.4	13	8	1.2	1.4	12	7	0.6	0.3	9	8	0.3	0.4	11	4
Erigeron flagellaris			3	3		0.2	8	5	0.4		5	2	0.3		8	8	0.3	0.6	8	6	0.7		5	1
Madia glomerata																							2	2
Penstemon rydbergii									0.4	0.8	3	3												
Polygonum aviculare				3			2	4			3	3								1		0.4	2	1
Stellaria jamesiana			4	4			1	4			2	3	0.3		2	5								1
Trifolium longipes										0.4									1	2		0.4	3	9
Vicia americana			1					1							1	1								
Other forbs			1	9			1	6			1	5			1	7			3	11				7
Total forbs	0	1.0	15	24	2.0	3.5	45	45	1.5	1.6	28	24	2.1	1.7	26	28	0.9	0.9	21	29	2.3	1.2	36	35
Total Herbaceous	12.1	9.1	101	100	8.0	8.0	99	100	7.8	9.3	99	96	13.4	9.8	100	102	12.7	11.9	100	98	8.3	9.1	101	96

easily chosen using these and other qualitative observations and a rudimentary knowledge of forage decline under normal stocking conditions.

The use of percent of plants grazed as an indicator of the level of key species utilization has much potential on this site. The data showed close relationships between estimated levels of utilization and percent of plants grazed (Table 11) which would allow utilization to be accurately estimated using percent of plants grazed. The trials produced heavily grazed pastures so, with the exception of herbaceous sage, the relationships may not apply to lower levels of utilization. The high correlations between the two variable (r^2=0.83 to 0.99) reflects the dependence of utilization estimates on percent of plants grazed.

Snowberry utilization

A weak link in the determination of snowberry utilization was the estimation of the production of the shrub on an area basis (Table 12). Both the weight of the current year's growth and numbers of new stems were recorded to give this estimate but the process was so tedious that only ten plots could be clipped per season. Variability was reasonably low, however, so predictions of whole stand utilization were accurate. The effect of the apparently better 1979 season also affected snowberry production (Figure 27). Most snowberry stems examined were between 0.5 mm and 2.5 mm in diameter (Figure 28) so samples of stems in this size category were measured in detail and analyzed for useful browse utilization relationships. Of two promising relationships which used stem diameter to predict total dry weights of stems with leaves (Figures 29 and 30), the conical relationship which correlated the cubed root of the weight to the diameter gave the superior fit (r^2=0.90). The predicted total weight of the average clipped plot as determined by appliying this

Table 11. Average end-of-trial utilization estimates as determined by pace transect data. Estimates of key species utilization compared with percents of plants grazed relating the two by livestock treatment combinations.

Key Species	Year	Sheep actual	Mixed actual	Mixed predicted	Cattle actual
		percent utilization[1] (percent of plants grazed)			
Agropyron riparium	1978	60(68)	58(64)	70(79)	80(90)
	1979	68(80)	59(76)	67(80)	66(80)
(r^2=0.96)					
Artemisia ludoviciana	1978	32(40)	14(20)	26(31)	19(22)
	1979	56(63)	32(40)	32(36)	8(10)
(r^2=0.99)					
Poa pratensis	1978	76(81)	83(92)	74(84)	73(86)
	1979	68(79)	72(79)	53(62)	38(45)
(r^2=0.98)					
Stipa lettermanni	1978	50(75)	67(87)	62(85)	73(95)
	1979	24(44)	42(86)	40(62)	55(79)
(r^2=0.83)					

[1] Percent Utilization = Percent Utilization of Plants Grazed x Percent of Plants Grazed where height to weight relationships were used to estimate Percent Utilization of Grazed Plants within the treatment combinations.

Table 12. Snowberry (*Symphoricarpos vaccinioides*) weights and stem counts recorded from clipped plots of dense stands.

Estimate	Year 1978	1979
Current Year's Production (DM kg/m^2)	0.291 ± 0.005	0.376 ± 0.004
Number of Stems/m^2	4790 ± 13	5850 ± 47
Predicted Production[1] (DM kg/m^2)	0.317	0.387

1. The average stem diameter (0.054 cm) of 150 randomly selected new stems was used in the equation:

$$DM/m^2 = \text{No. Stems}/m^2 \times (0.25473 + 2.77135 \times \text{Ave. Diam.})^3$$

to predict browse availability.

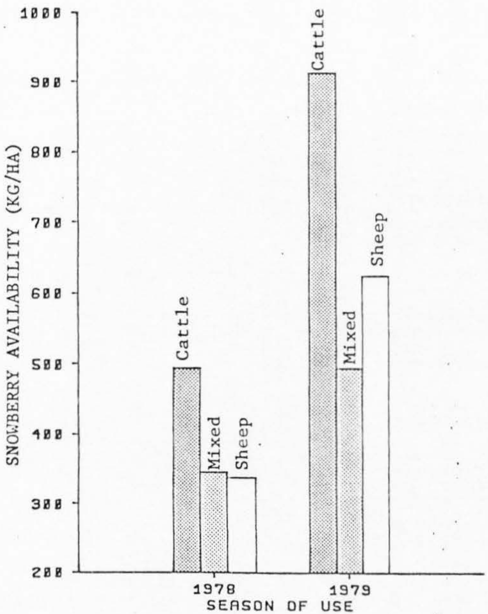

Figure 27. Snowberry production within the three livestock treatment combinations. Estimated using step-point transects for canopy cover and clipped plots for average production per unit area.

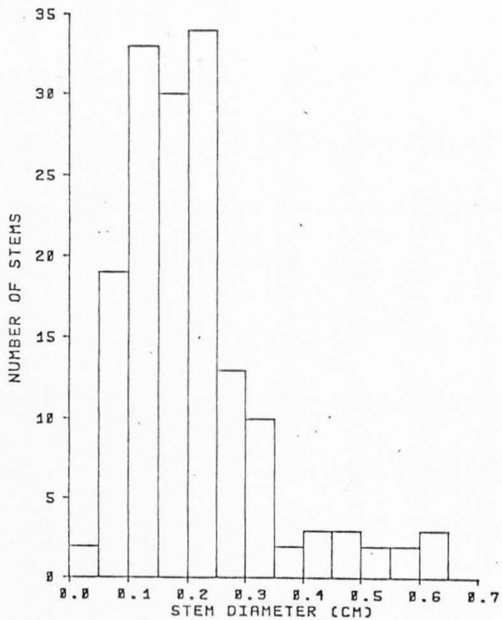

Figure 28. Distribution of snowberry stem diameters from a population of 150 randomly selected stems. Diameters were recorded at the center of the largest internode of each stem sampled.

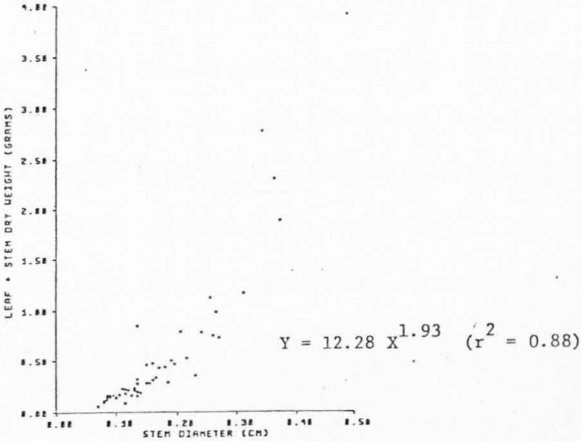

Figure 29. Relationship of snowberry stem diameter to dry weight of stems with leaves.

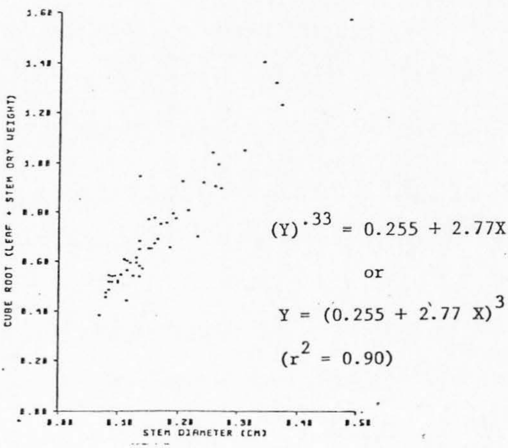

Figure 30. Relationship of snowberry stem diameters to the cubed root of the stem plus leaf dry weight.

relationship to the average stem diameter of the 150 randomly sampled stems gave very reasonable results (Table 12). Predicted production was less than ten percent higher than that actually estimated using clipped plots. Production and utilization of snowberry were determined by the following calculations:

TOTAL BROWSE = CANOPY COVER % x PASTURE AREA x PRODUCTION PER AREA

TOTAL STEMS = CANOPY COVER % x PASTURE AREA x NO. STEMS PER AREA

BROWSE UTILIZATION = % STEMS BROWSED x TOTAL STEMS x AVE. STEM DRY WEIGHT

% BROWSE UTILIZATION = BROWSE UTILIZATION x TOTAL BROWSE^{-1}

where snowberry canopy cover was estimated by planimetered mapping (Table 7). Production and numbers of stems came from clipped plot data (Table 12), while percent of stems browsed and average browsed stem diameter were determined in the field. The weight of the average stem became the utilization indicator using the conical-stem plus leaf relationship (Figure 30). Analyses of these data are difficult to interpret (Table 13). Essentially all possible effects and interactions were significant. Year and livestock-by-year effects have been presented in Figure 27. The final pair of interactions (Table 13) resulted from the fact that snowberry was used differently by the mixed livestock treatment between years, while cattle alone did not browse snowberry much at all. These effects are shown in Figure 31. The heavy browse use which was recorded in the mixed livestock pastures was also due to an overestimation of the average stem diameter resulting from the smaller stems having been completely removed (compare Figure 32 with 33). Livestock, trial day and livestock-by-trial day interaction effects are shown in Figures 34 and 35 along with grass and forb data transformed from Figures 14 and 15.

Table 13. Effects of treatments on snowberry measured in the six experimental pastures.[1]

Forage Quantity Index	Treatmants			Interactions			
	Livestock	Year	Trial Day	LxY	LxTD	YxTD	LxYxTD
Actual (kg/ha)	*[2]	**[3]	**	**	**	*	*
Corrected (kg/ha)	**	**	**	*	**	*	*
Relative (kg/kg)	**	**	**	*	**	**	*
Relative (kg/kg)	**	**	**	**	**	*	*

1. See footnotes, Table 6.

2. * significant at the 0.05 level.

3. ** significant at the 0.01 level.

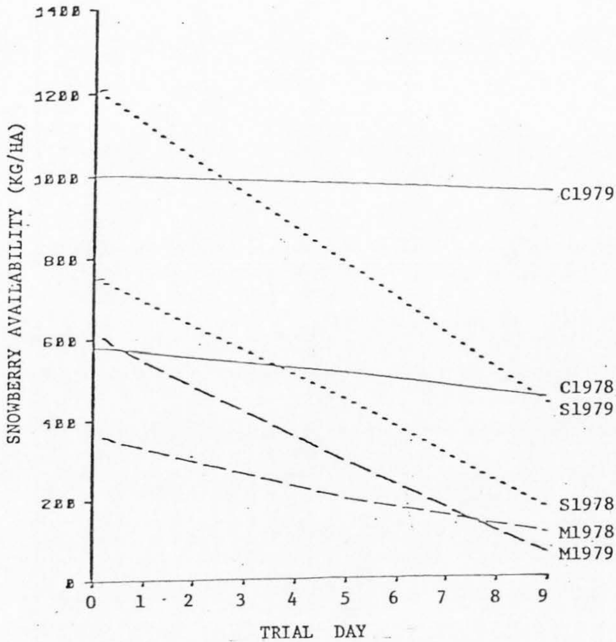

Figure 31. Livestock by trial day by year interaction of the availability of the dominant shrub, snowberry, within livestock treatment combinations. Cattle (C), sheep (S) and mixed herds (M) data are presented for 1978 and 1979 grazing trials.

Figure 32. Example of an unbrowsed snowberry patch.

Figure 33. Heavily browsed snowberry showing complete removal of smaller stems which caused an overestimation of browse utilization.

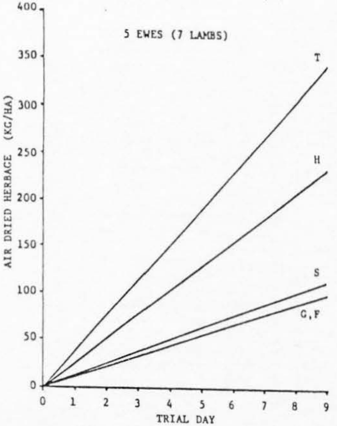

Figure 34. Average increases in herbage utilization through the grazing trial by an Animal Unit of sheep. Herbage components include total herbage (T), herbaceous vegetation (H), snowberry (S). Grass (G) and forb (F) utilization were approximately the same quantities.

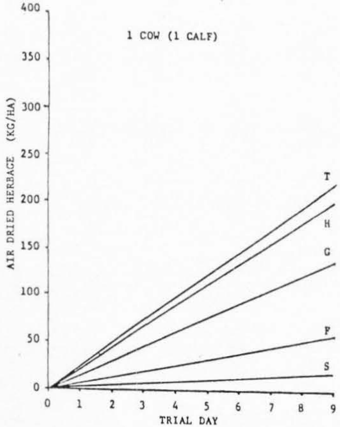

Figure 35. Average increases in herbage utilization through the grazing trial by an Animal Unit of cattle. Herbage components include total herbage (T), herbaceous vegetation (H), grasses (G), forbs (F) and snowberry (S).

These clearly illustrate the utilization of all of the herbage components by a ewe with 1.4 lambs and a cow with a calf. They form the basis of the following grazing capacity determinations.

Rates of utilization and carrying capacities

Herbage utilization determinations included considerations of the weights of animals within treatments and average animals weights (Table 3) as well as herbage disappearance rates. Herbage quantity was expressed in kg per kg of animal stocked and recalculated into levels of utilization per average animal by weight. Lambs and calves were considered as receiving 40 and 30 percent of their diets as herbage, respectively (Cook 1970). Wastage of herbage by lambs or calves was expected to be in proportion to their expected forage intake. Separate analyses of variance for these estimates of relative quantity were done for herbaceous groups of plants (Table 6), snowberry (Table 13) and individual herbaceous forages (Table 14). Carrying capacity calculations followed along two lines of reasoning depending upon the support data used in the calculation.

$$\text{NO. ANIMALS} = \frac{\text{PASTURE AREA x PRODUCTION PER HA x P. U. F.}}{\text{TIME x UTILIZATION RATE}}$$

This equation applied to data recorded as actual weight estimates of herbage utilization, such as the clipped plot data for herbaceous vegetation or the stem diameter data for snowberry. Rates (Table 8) were determined as slopes of increase in herbage utilization (Figures 34 and 35) in units of kg per day. Time was measured in days of grazing. The commonly used 50 percent proper use factor (P.U.F.) (Pearson 1964, Stoddart et al. 1975) was applied as a decimal for herbaceous vegetation. A value of 60 percent (Garrison 1953) was used for calculations which

Table 14. Effects of treatments on the relative quantities of individual forage species on a livestock weight basis (kg forage per kg livestock).[1]

	Treatments			Interactions		
Species	Livestock	Year	Trial Day	LxY	LxTD	YxTD
Agropyron spp.	NS	NS	**	NS	NS	NS
Artemisia ludoviciana	NS	NS	**	NS	NS	*
Poa pratensis	NS	**	**	NS	**	**
Stipa spp.	NS	**	**	NS	*	NS

1. See footnotes, Table 6.

2. ** significant at the 0.01 level.

3. * significant at the 0.05 level.

included snowberry. When herbage use data were in terms of percentages, a conceptually more convenient way to calculate carrying capacity was used.

$$\text{NO. ANIMALS} = \frac{\text{PASTURE AREA x PROPER USE FACTOR}}{\text{TIME x UTILIZATION RATE (percent)}}$$

The same proper use factors could be used as mentioned above. Based upon data collected in step-point transects, the percent utilization of key species recorded at the end of the grazing trials allowed the rates of plant utilization to be calculated. Rates were percentages of the original 100 percent of key species utilized per day (Table 8). Range requirements and substitution ratios for stocking sheep and cattle which were calculated by using these approaches are presented in Table 15. The areas required for a month of use by sheep or cattle are based strictly on their corresponding rates of utilization for a particular herbage component and constrained by the proper use of that component. Levels of use of other components resulting from the proper use of a specific forage can easily be calculated for a month using daily rates of disappearance for those species. The five to one sheep to cattle ratio was accurate for requirements concerning total herbaceous vegetation which constrains stocking in this circumstance. So at proper use of the herbaceous component, five ewes with about seven lambs or one cow with calf either require about six acres (2.5 ha) of range per month. Sheep would cause five times the impact of cattle on snowberry when stocked this way, however. Considerations of total herbage impacts by sheep reduce the relative area required to stock a single cow with calf to about 3.5 times the area required for a ewe with 1.4 lambs. In other words, five sheep require nearly 50 percent more area than a cow with calf.

Table 15. Monthly range requirements for stocking sheep and cattle as determined by proper use of herbage components.

TECHNIQUE: Forage component	ONE SHEEP UNIT actual[3]	FIVE SHEEP UNITS[1] actual	ONE CATTLE UNIT actual	C:S[4]	ONE MIXED UNIT[2] actual	predicted[5]
	------------ acres	(hectares)	-------		--- acres	(hectares) ---
Plots						
Stipa species[6]	0.6 (0.2)	3.0 (1.2)	6.2 (2.5)	10.5:1	4.1 (1.7)	4.9 (2.0)
Poa pratensis	1.4 (0.6)	6.9 (2.8)	3.1 (1.3)	2.2:1	4.9 (2.0)	6.2 (2.5)
Total grasses	1.0 (0.4)	5.2 (2.1)	6.2 (2.5)	6.0:1	4.9 (2.0)	6.2 (2.5)
Artemisia ludoviciana	1.0 (0.4)	5.2 (2.1)	0.6 (0.2)	0.6:1	3.1 (1.2)	1.9 (0.8)
Total forbs	1.4 (0.6)	6.9 (2.8)	4.9 (2.0)	3.6:1	4.9 (2.0)	6.2 (2.5)
Total herbaceous	1.2 (0.5)	6.0 (2.4)	6.2 (2.5)	5.2:1	4.9 (2.0)	6.2 (2.5)
Points						
Stipa lettermanni	0.6 (0.2)	3.0 (1.2)	4.9 (2.0)	8.4:1	4.1 (1.7)	4.1 (1.7)
Poa pratensis	1.2 (0.5)	6.0 (2.4)	4.9 (2.0)	4.2:1	6.2 (2.5)	4.9 (2.0)
Artemisia ludoviciana	0.7 (0.3)	3.7 (1.5)	1.2 (0.5)	1.6:1	1.9 (0.8)	2.7 (1.0)
Stem diameters						
Symphoricarpos vaccinioides	1.0 (0.4)	5.0 (2.0)	0.8 (0.3)	0.9:1	6.2 (2.5)	3.1 (1.2)
Diameters and plots						
Total herbage	1.2 (0.5)	6.0 (2.4)	4.1 (1.7)	3.5:1	4.9 (2.0)	4.9 (2.0)

1. Five sheep units are traditionally considered to equal one cow with calf unit.
2. A mixed livestock unit consisted of half of a cow with calf plus 2.5 sheep units (ewes with lambs).
3. "Actual" data refer to those recorded in grazing trials.
4. The cattle to sheep ratio calculated here was based upon the respective areas required to utilize the component to proper levels by a single cow with calf versus a single ewe with 1.4 lambs.
5. "Predicted" values were determined through calculations using single species' rates of utilization.
6. Areas required for utilizing this key species group to the proper level of 50% at the utilization rates determined by clipping plots are reported in this row of information. Sheep stocked at this rate would utilize other plant species long before 50% use of Stipa would occur. Single key species values serve as indices of relative palatability between the two livestock species.

Using a linear approximation which substituted herbaceous vegetation for snowberry on hypothetical pastures (Figure 36), optimum combinations of the two were calculated where maximum days of sheep or cattle use were available. The linear substitution from all snowberry to 100 percent herbaceous vegetation was determined from clipped plot information recorded for the two main forage components before grazing occurred. Herbaceous vegetation produced at over 1100 kg per ha while the production of dense snowberry exceeded 2600 kg per ha. Using the proper use factors of these components, and the rates cattle and sheep used them, optimum combinations along the substitution line (Figure 36) were calculated where livestock used 50 and 60 percent of the herbaceous and browse components, respectively. A cattle optimum at about 90 kg per ha snowberry and a sheep optimum at about 300 kg per ha snowberry were calculated. Because cattle use of snowberry was not significant, the cattle optimum may be considered at 100 percent herbaceous vegetation. Trampling impacts of cattle on the shrub were recorded, however, so the optimum at eight percent may not be unrealistic. The range of combinations of mixed vegetation between the sheep and cattle optima were where an increase in carrying capacity through common use could be gained (shaded area, Figure 37). Common use stocking rates were calculated by applying the quadratic formula to the following simultaneous equations:

$$S = \frac{0.6B - \left(\frac{0.6B}{r_{bc} \times C}\right)}{r_{bs}}$$

and

$$C = \frac{0.5H - \left(\frac{0.5H}{r_{hs} \times S}\right)}{r_{hc}}$$

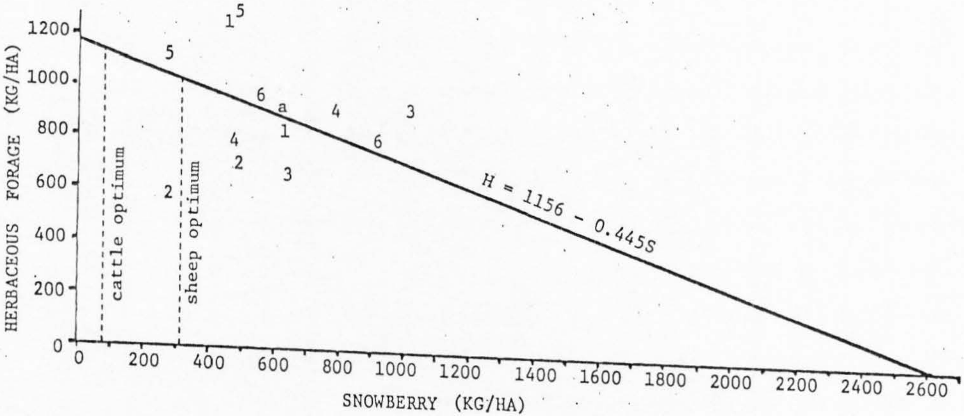

Figure 36. Linear substitution of herbaceous vegetation (H) for snowberry (S) on a hypothetical hectare of shrubby meadow determined from clipped plots of both components. Vertical dashed lines are pasture compositions where proper use of both components would be achieved at the same time by either sheep or cattle. Scattered numbers represent experimental pastures (by pasture number) for the two grazing trials but these compositions were not used to determine the substitution function. The average composition of all pastures for both years (a) falls on the line.

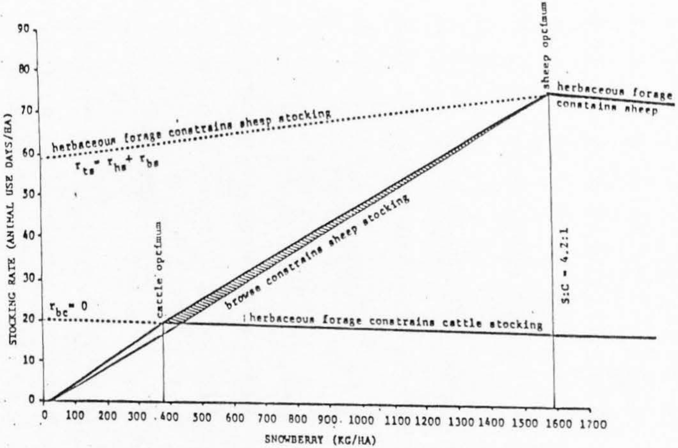

Figure 37. Sheep and cattle stocking rates related to pasture botanical composition. Numbers of animal-use-days per hectare versus the proportion of snowberry in a hypothetical pasture (Figure 36). Zero browsing by cattle represented by $r_{bc} = 0$, total herbage utilization of sheep by $r_{ts} = r_{hs} + r_{bs}$. Peak S:C of 4.2:1 at sheep optimum.

where S and C are numbers of sheep and cattle use days available per hectare. H and B are the herbaceous and browse vegetation in kg per hectare (B is less than 28 percent but greater than 8 percent of the total herbage). Rates of herbage utilization are in kg per animal-use-day expressed for both sheep (subscript s) and cattle (c) use of herbaceous (h) and browse (b) vegetation. Common use stocking rates determined in this manner ranged from all cattle at the cattle optimum (8 percent snowberry) to all sheep at the sheep optimum (28 percent snowberry). Maximum gain in total grazing capacity was realized at mid-point between the optima. This gain was less than one animal unit day of use per hectare. Calculations assumed no effect of mixing the livestock on the forage preferences of one or the other.

A serious test of the predictive powers of these calculated grazing rates and grazing capacities for this site was necessary to fulfill the criteria for achieving "good science" (Romesburg 1978). This was accomplished by conducting a mixed livestock grazing trial concurrently with sheep and cattle trials. Predicted levels of herbaceous and browse forage use by a mixed herd, based on single species treatments, were compared with measurements of actual common use recorded during and after the trial. Predicted values and actual have already been presented (Tables 8 and 11). The most serious discrepancy between predicted values and those estimated was that of the unexpectedly heavy snowberry use by the mixed herd. Although the effect of mixing animal species on their plant preferences has not been extensively studied, a possible explanation for this heavy browsing was that the animals browsed in mixed treatments because the snowberry was relatively low in availability (Table 7). This may also indicate that cattle learn to browse from sheep. The possibility is discussed later with other considerations of livestock behavior.

Additional comparisons

The calculations of grazing capacities used average cattle and sheep herbage utilization estimates. These were derived from transformations of forage quantities on an animal weight basis. When these relative values were analyzed (Tables 6 and 13) they showed significant effects of sheep and cattle on the disappearance of herbaceous and browse vegetation. These effects are illustrated in Figure 38. On a weight per weight basis, sheep had more available forage than cattle. The animals were stocked in the predetermined "metabolic" ratio of five to one, but did that ratio hold true for herbage use on this site? At the metabolic level, sheep and cattle were similar in their uses of herbaceous forages (Table 6 and Figure 39) but dissimilar in their uses of snowberry (Figure 40). The variabilities of the single forage species subsamples were too high to record significant livestock effects on this metabolic basis (Table 16), although fenceline contrasts (Figures 41 and 42) showed evidence for at least qualitative differences in *Stipa* use at mid-trial.

Another important comparison between sheep and cattle use of these ranges can be made based upon daily consumption of similar mountain range forages reported by Cook (1970) in Utah. A ewe with lamb consumed 4.6 percent of her body weight (134 lb, 61 kg) or about 5.5 lb (2.5 kg) dry matter per day while a cow with calf only consumed 3.3 percent of her body weight (956 lb, 434 kg) or about 31.8 lb (14.4 kg) per day. Both the range site and the livestock involved in his studies compare well with those of the study at Miner's Peak (Tables 1 and 3). Based upon Cook's data and the disappearance of herbage measured in the small

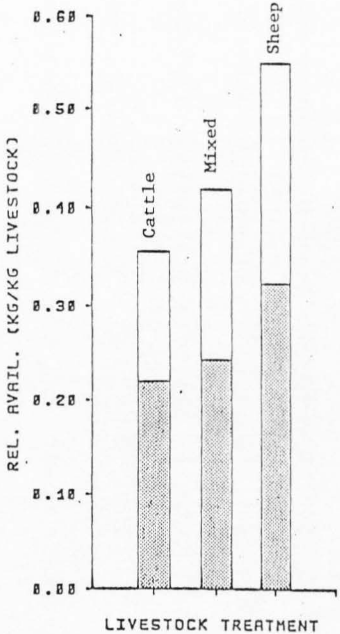

Figure 38. Average relative availability of grass (stippled) and forb (white) components for livestock treatments on a weight available per weight of livestock basis.

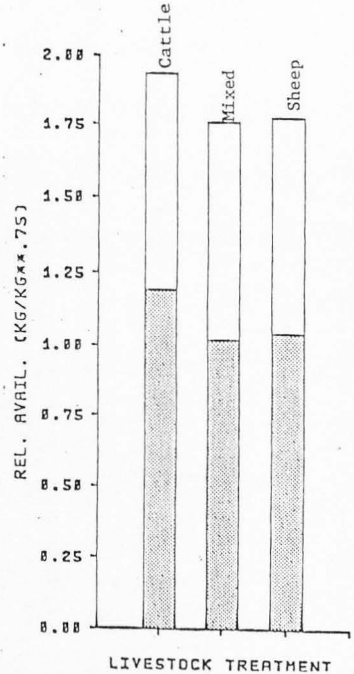

Figure 39. Average relative availability of herbaceous vegetation on a livestock metabolic weight basis. Components are separated into grasses (stippled) and forbs (white).

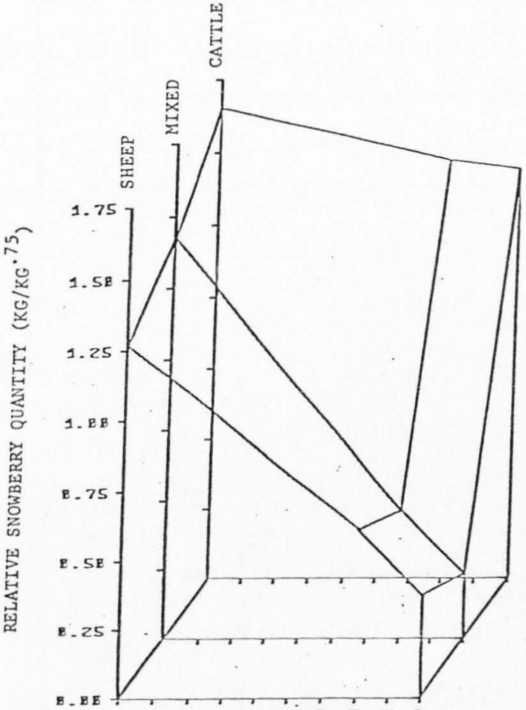

Figure 40. Disappearance of snowberry on a relative basis as estimated using stem diameter relationships. Quantity declined through the grazing trials, however, rate of decline depended on livestock treatment.

Table 16. Effects of treatments on individual herbaceous forage species on a livestock metabolic weight basis (kg forage per $kg^{.75}$ livestock).[1]

	Treatments			Interactions		
Species	Livestock	Year	Trial Day	LxY	LxTD	YxTD
Agropyron spp.	NS	NS	*[2]	NS	NS	NS
Artemisia ludoviciana	NS	*	**[3]	NS	NS	*
Poa pratensis	NS	**	**	NS	*	**
Stipa spp.	NS	**	**	NS	*	NS

1. See footnotes, Table 6.

2. * significant at the 0.05 level.

3. ** significant at the 0.01 level.

Figure 41. Fenceline contrast between cattle use (left) and no use (right) after nine days of grazing at two cows with calves to the acre (0.39 ha). Note relative abundance of herbaceous sage remaining in the grazed pasture.

Figure 42. Mixed livestock treatment (left) after nine days of use by five ewes with lambs and a cow with calf. Compare with level of use by cattle alone in Figure 41.

pasture studies, an estimate of herbage wastage by sheep and cattle can be made. Sheep utilized 7.8 kg of herbage per day while cattle utilized 24.6 kg per day (Table 8). By difference, this indicates that sheep wasted over two times that which they probably consumed while cattle wasted only about 70 percent. This means that in proportion to the total numbers of livestock grazing sheep may waste between two and three times that which cattle waste.

Experiment 2

Livestock distribution

Nearly ten thousand points of paired coordinates were recorded for livestock during the two trials along with time of day and animal activity. Offspring were distinguished from their mothers. A computer program was developed which calculated mean distances of animals from water and salt (one location). Parameters were also computed which described animal distribution with respect to the whole flock or herd center, with respect to each other in terms of mean distances between nearest neighbors and mean distances between all possible pairs of animals. These calculations were not only done for whole species groups, sheep, cattle and separating sheep from cattle in mixed herds, but also for animal subgroups distinguishing between adult and juvenile distribution within but not across species groups. Analyses for these records are presented in Tables 17 and 18.

Although the results of the analyses were a complicated mixture of effects and interactions, they were similar for both whole species and animals subgroups. In other words, ewes and lambs, and cows and calves

Table 17. Effects of treatments on the distribution of whole flocks and herds by species.

	MAIN TREATMENTS					FIRST ORDER INTERACTIONS									
Distribution Parameter	Livestock	Year	Pasture Arrangement	Trial Day	Hour of Day	LxY	LxPA	YxPA	LxTD	YxTD	PAxTD	LxHD	YxHD	PAxHD	TDxHD
Eastern coordinate[1]	**[2]	NS	**	*[3]	*	**	**	NS	**	**	NS	NS	NS	*	*
Southern coordinate	**	NS	**	NS	NS	**	**	NS	NS	NS	NS	**	NS	NS	NS
Distance to water/salt	**	NS	**	NS	*	**	**	NS	**	*	NS	NS	NS	*	NS
All possible pairs	**	**	**	NS	*	**	**	NS	**	*	NS	NS	NS	NS	NS
Nearest neighbor	**	NS	**	*	NS	NS	*	*	**	NS	NS	*	NS	*	NS
Distance from center	**	**	*	NS	*	**	**	NS	**	NS	NS	NS	NS	NS	NS

1. Eastern and southern coordinates were used to locate individual animals. The eastern coordinate also measured distance downslope within pastures.

2. ** significant at the 0.01 level.

3. * significant at the 0.05 level.

Table 18. Effects of treatments on the distribution of flocks and herds by mother-offspring subgroups.

	MAIN TREATMENTS					FIRST ORDER INTERACTIONS									
Distribution Parameter	Livestock	Year	Pasture Arrangement	Trial Day	Hour of Day	LxY	LxPA	YxPA	LxTD	YxTD	PAxTD	LxHD	YxHD	PAxHD	TDxHD
Eastern coordinate	**[1]	NS	**	*[2]	*	**	**	NS	**	**	NS	*	NS	*	*
Southern coordinate	**	NS	*	NS	NS	**	**	NS	*	**	NS	**	NS	NS	NS
Distance to water/salt	**	NS	**	NS	*	**	**	NS	**	**	NS	NS	NS	*	NS
Nearest neighbor	**	*	NS	**	NS	**	**	NS	**	NS	NS	NS	NS	NS	NS
Distance from center	**	NS	*	*	*	**	**	*	**	NS	*	**	NS	NS	NS

1. ** significant at the 0.01 level.

2. * significant at the 0.05 level.

were distributed similarly to sheep and cattle, respectively. The effect of animal species on distribution within these small pastures is illustrated in Figure 43. Individual sheep tended to keep a close distance between themselves and their nearest neighbor. The degree of scattering in the flocks, reflected in all possible pairs of distances and average distances from centers of distribution, generally increased during the course of the day declining toward the end of the day. Cattle distribution patterns were more extensive and more variable than those of sheep. There were no great differences between single species groups versus single species within mixed groups (e.g., sheep alone vs. sheep from mixed herds) although cattle activity in the early morning influenced sheep activity as indicated by relative changes in distribution. Early morning distribution of sheep in mixed livestock treatments was more extensive (α=0.01) than that of sheep stocked alone (Figure 44). Late afternoon distribution of sheep was similar for both sheep treatments (alone, and mixed with cattle) while cattle in mixed treatments had a much tighter distribution than cattle stocked alone (Figure 45). Two influences were recorded which could explain the main effect of the year. Breed difference in sheep, specifically black compared to white-faced breeds, have been shown to affect flock dispersion (England 1954). Because these differences were involved between years in these studies, the breed effect may have influential. Also, during the 1978 trial, a crippled calf was unknowingly included as a study animal. During that trial the calf moved infrequently and so was a second influence which may have affected distribution determinations for that pasture for one year compared to the next. The effect of pasture isolation was confounded with other pasture differences such as shrub distribution,

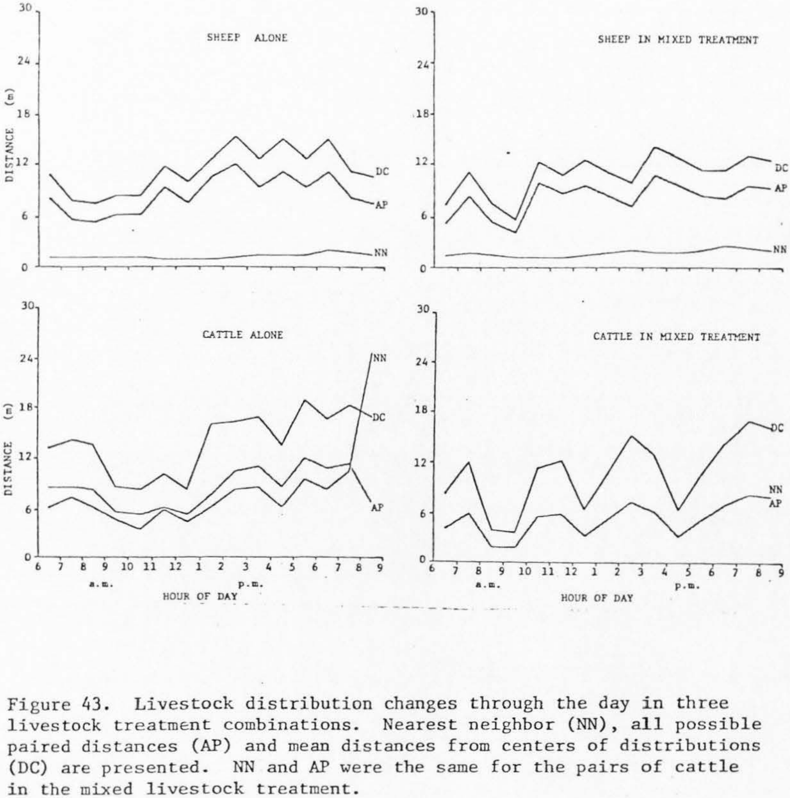

Figure 43. Livestock distribution changes through the day in three livestock treatment combinations. Nearest neighbor (NN), all possible paired distances (AP) and mean distances from centers of distributions (DC) are presented. NN and AP were the same for the pairs of cattle in the mixed livestock treatment.

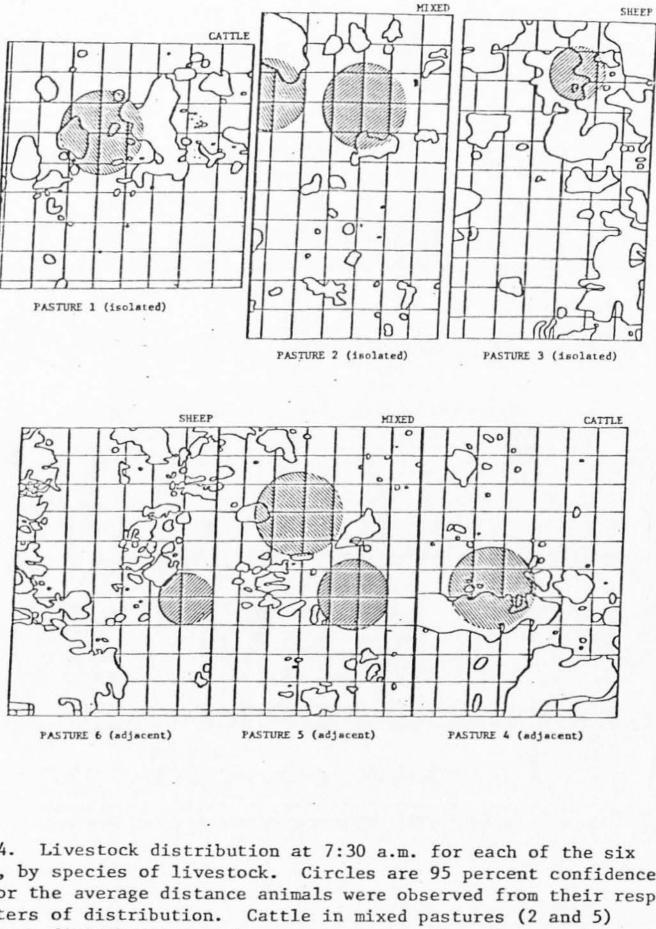

Figure 44. Livestock distribution at 7:30 a.m. for each of the six pastures, by species of livestock. Circles are 95 percent confidence limits for the average distance animals were observed from their respective centers of distribution. Cattle in mixed pastures (2 and 5) caused sheep distributions to be more extensive than when sheep were stocked alone. These data are averages of eight days of observations.

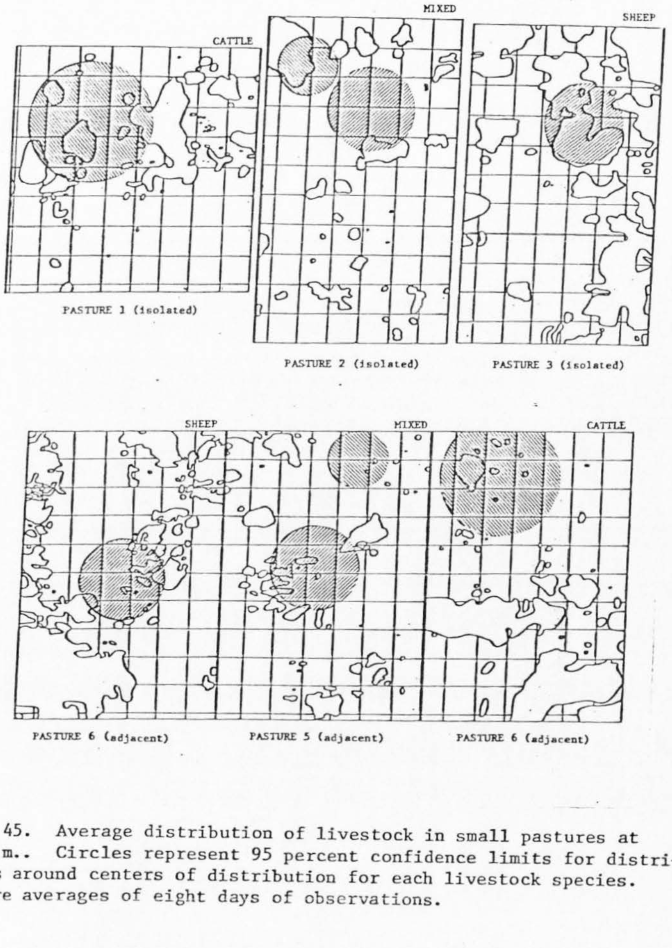

Figure 45. Average distribution of livestock in small pastures at 5:30 p.m.. Circles represent 95 percent confidence limits for distributions around centers of distribution for each livestock species. Data are averages of eight days of observations.

horizontal lines of sight and cover and tree proximity (Figures 3 and 4). However, differences in botanical composition among pastures were not a factor (Tables 7 and 10). The effect of pasture arrangement on the south coordinate of livestock within mixed pastures gave a strong indication of the influence of the proximity of like animal species. Both cattle and sheep congregated along the common fences dividing the mixed treatment from their respective single species treatments (Figure 46). Because all of the study pastures were oriented toward the east and the pastures sloped in that direction the east coordinant of each animal location also measured its distance downslope. The average distances downslope of both whole herd and subfroups were significantly affected by declining forage availability (day of trial), however, this effect did not influence animal distance from water and salt which was closely correlated to the downslope distance. Cattle especially spent more time further downslope as the trials progressed. Livestock-by-trial day and livestock-by-trial day-by-hour of day interactions affected both downslope and distance from water parameters but the results are difficult to sort out. The last main effect, hour of day, had no significant effect on two important distance parameters. First, there was no effect on the south coordinate which indicated that shrub distribution did not influence herd or flock dispersion in that direction so slope was probably the major influence on the east coordinate. Nearest neighbor distances also held constant through the day but differences between sheep and cattle and pasture isolation impacts were demonstrated. These distances did not change, however, as forage became limiting (the nearest neighbor, trial day-by-hour of day interaction was not significant). The discussion on treatment effects on

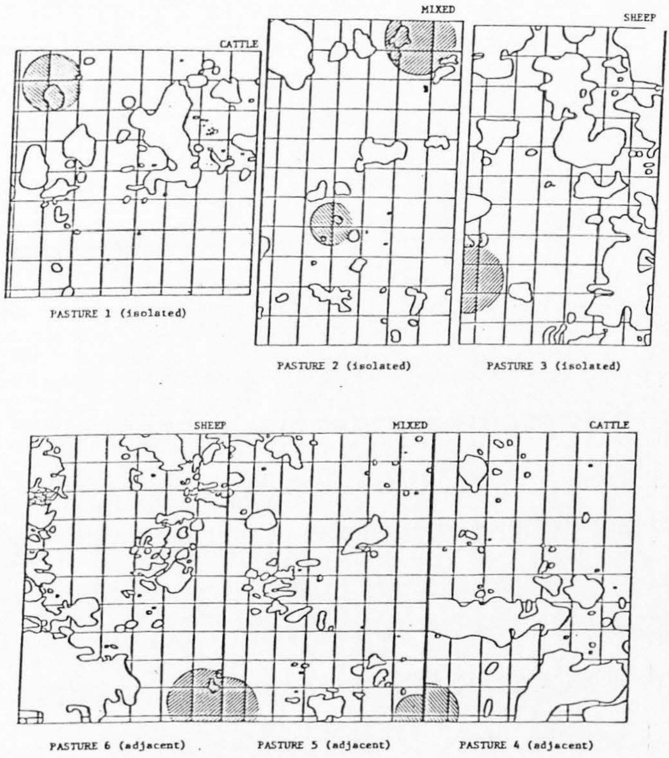

Figure 46. Sheep and cattle distribution at 12:30 p.m. (resting) for each of six experimental pastures. Circles represent clusters of animals around average centers for eight days of observations. Note strong attractions of both species for members of their species along common fences (Pastures 4,5 and 6).

animal distribution ended at this point because, although many treatment interactions still remained unexplained, the interpretations were too subjective to have much meaning.

Livestock activities

The activity patterns of livestock are illustrated in Figures 47, 48, and 49, for sheep flocks, cattle herds and mother-offspring subgroups, respectively. These represent summaries of hourly observations of behavior particularly important with respect to use of the pasture herbage. Behavior categories included active grazing and browsing, standing while rumination, and lying down while ruminating. Additional miscellaneous activities, such as suckling, drinking, and salt licking were lumped into a single "other" category. Analyses of group activities (Tables 19 and 20) were similar for both groups and subgroups with some important exceptions. The effect of the kind of livestock on the percent of flock or herd grazing at a given time was insignificant at the whole group level but highly significant when adults and juveniles were tested separately. In this case, more cows on the average were grazing than calves, ewes, or lambs. An effect of trial day on the average percent of livestock lying down ruminating, while highly significant at the group level, was not significant at the subgroup level and, therefore, was probably a compounded error of combining subgroups. The numbers of livestock standing ruminating did not change significantly through the hours of the day, although more cows (α=0.01) spent more time ruminating while standing than calves and sheep which laid down more frequently.

Air temperature was recorded during the trials (Figure 50). This variable was inversely related to combined browsing and grazing activity

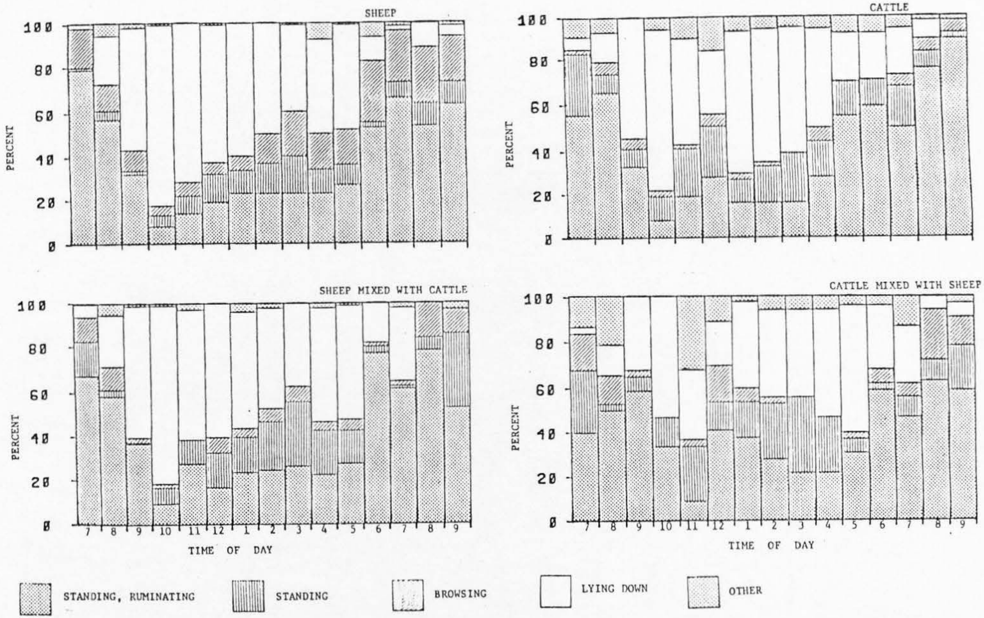

Figure 47. Livestock activities by species for hours of the day in four treatment combinations. Data are averages of 16 days of observations (4 days x 2 years x 2 replications) presented as percentages of whole groups by type of activity.

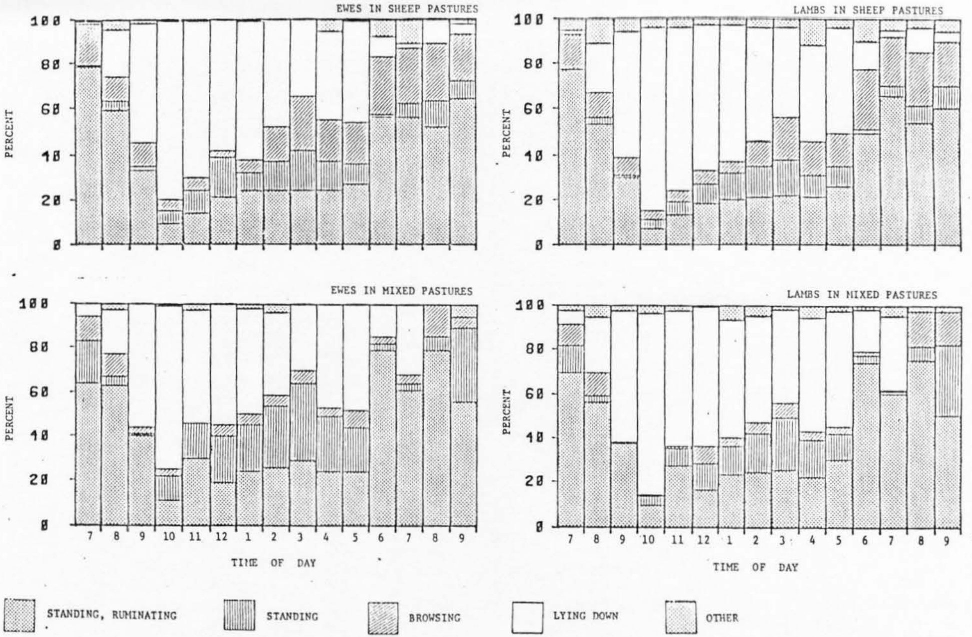

Figure 48. Ewe and lamb activities for hours of the day in two treatment combinations. Data are averages of 16 days of observations (4 days x 2 years x 2 replications) presented as percentages of subgroups by type of activity.

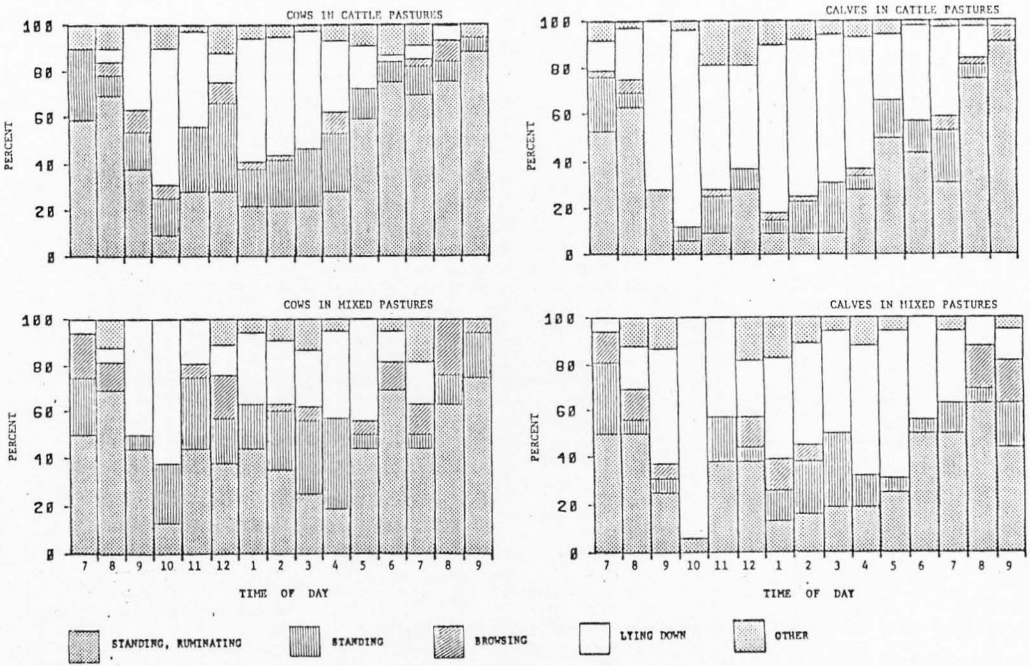

Figure 49. Cow and calf activities for hours of the day in two treatment combinations. Data are averages of 16 days of observations (4 days x 2 years x 2 replications) presented as percentages of subgroups by type of activity.

Table 19. Effects of treatments on the activities of whole flocks and herds by species.

Livestock Activity	MAIN TREATMENTS					FIRST ORDER INTERACTIONS									
	Livestock	Year	Pasture Arrangement	Trial Day	Hour of Day	LxY	LxPA	YxPA	LxTD	YxTD	PAxTD	LxHD	YxHD	PAxHD	TDxHD
Shade seeking[1]	**[2]	*[3]	NS	NS	**	**	NS	NS	NS	NS	*	**	*	NS	NS
Open vegetation[4]	**	*	**	NS	NS	**	**	NS	*	NS	NS	NS	NS	NS	NS
Standing, not grazing	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grazing in open	NS	*	NS	NS	**	NS	NS	NS	**	NS	NS	NS	NS	*	NS
Browsing in snowberry	**	NS	NS	**	*	**	*	NS	*	NS	NS	*	NS	NS	**
Lying down	*	NS	NS	**	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

1. Based on animal locations with respect to shade.

2. ** significant at the 0.01 level.

3. * significant at the 0.05 level.

4. Based on animal location with respect to the snowberry canopy within the study pastures.

Table 20. Effects of treatments on the activities of flocks and herds by mother-offspring subgroups.

	MAIN TREATMENTS					FIRST ORDER INTERACTIONS									
Livestock Activity	Livestock	Year	Pasture Arrangement	Trial Day	Hour of Day	LxY	LxPA	YxPA	LxTD	YxTD	PAxTD	LxHD	YxHD	PAxHD	TDxHD
Shade seeking[1]	**[2]	*[3]	NS	NS	**	**	NS	NS	NS	NS	NS	**	*	NS	NS
Open vegetation[4]	**	**	**	NS	NS	**	**	NS	**	NS	*	NS	NS	NS	NS
Standing, not grazing	**	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grazing in open	**	*	NS	NS	**	NS	*	NS	**	NS	NS	NS	NS	*	NS
Browsing in snowberry	**	NS	NS	**	*	**	*	NS	**	NS	NS	**	NS	NS	**
Lying down	**	NS	NS	NS	**	**	NS	NS	NS	NS	NS	**	NS	NS	NS

1. Based on animal locations with respect to shade.

2. ** significant at the 0.01 level.

3. * significant at the 0.05 level.

4. Based on animal locations with respect to the snowberry canopy within the study pastures.

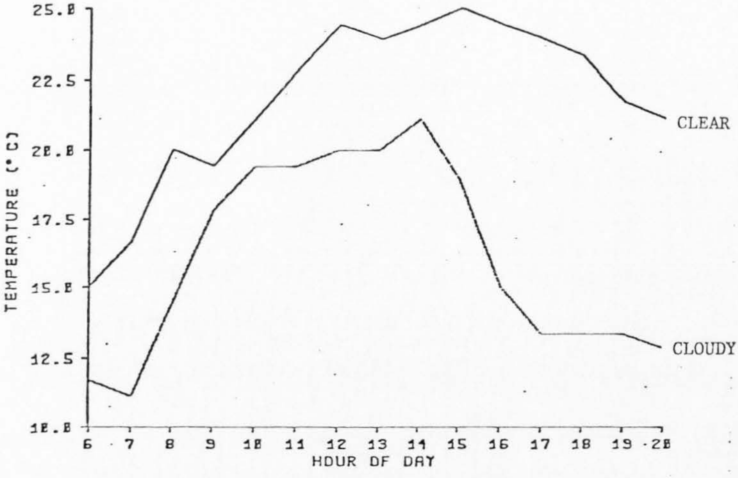

Figure 50. Average air temperatures for clear and cloudy days recorded on the study site during the 1979 trial.

but, because of the confounding of temperature with other environmental variables such as wind, cloud cover, dew fall and intrinsic animal variables, such as gut fill, it was not considered useful for explaining behavior patterns.

How often animals were grazing in snowberry was affected by livestock species, trial day and hour of day. The effects of hour of day, livestock and the livestock-by-hour of day interaction were already illustrated (Figures 47, 48 and 49). Livestock-by-trial day and livestock -by-pasture arrangement treatment interactions are illustrated (Figure 51) to demonstrate that more animals spent more time grazing snowberry than grasses or forbs as herbaceous vegetation declined. This showed a gradual shift of plant preferences from herbaceous forage to browse as more preferred herbaceous plants disappeared. The effect may be explained for cattle as a continued search for herbaceous plants as the more easily obtained and more palatable ones were depleted, however, distinguishing between continued grazing on herbaceous vegetation from new browsing was difficult (Figures 52 and 53). The question of whether cattle especially calves in isolated mixed herds, learned from sheep to brows is interesting. These data indicated that cattly which were grazing in isolation with sheep spend more time "browsing" than cattle grazed alone.

Two further analyses of livestock locations, whether in shrub or opern area and whether in shade or in open sun, were accomplished by a more detailed review of the mapped behavior data. Distinct preferences of animals for shade were recorded as air temperature increased (Figure 51). Factors determining animal preferences for open or shrubby areas were not entirely clear. Neither trial day nor hour of day were signif-

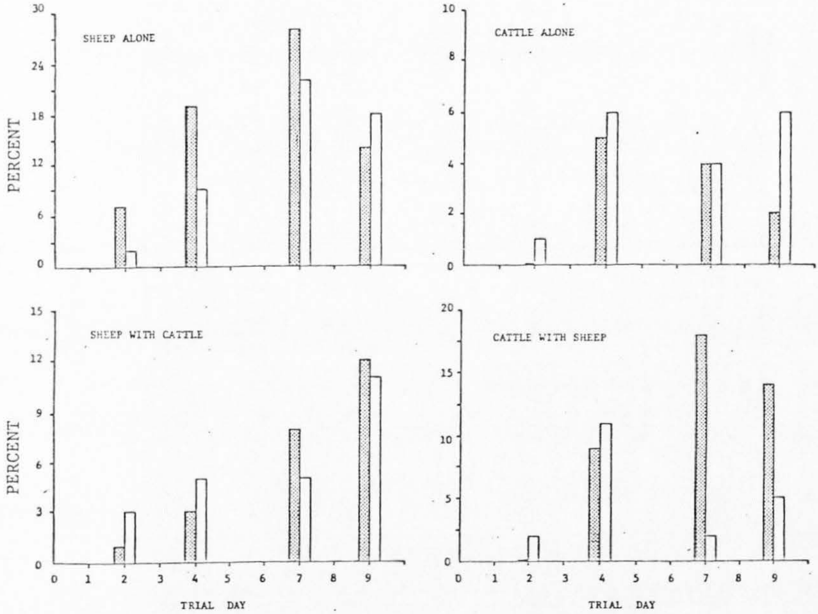

Figure 51. Percent of time each livestock group spent browsing as affected by trial day (feed quantity) and pasture arrangement for four livestock treatment combinations. Data are averages of two years of observations (16 hours per day per year). Pasture isolation treatment (stippled bars) consisted of pastures which had no common fences with other pastures (see Figure 11).

Figure 52. A group of sheep positioned within a snowberry patch in the 1978 grazing trial.

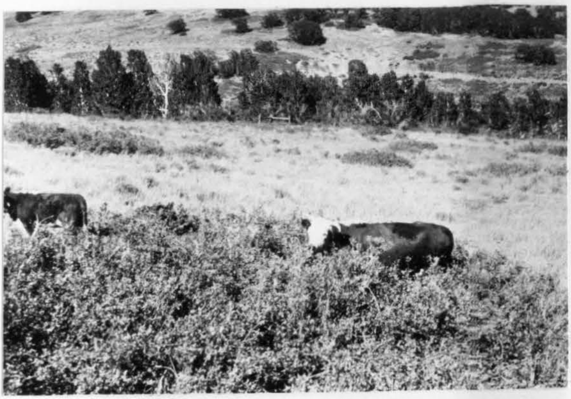

Figure 53. Cattle use of browse in the 1979 grazing trial. Distinguishing between actual browsing by cattle and searching for herbaceous forage in the shrub canopy was difficult.

icant effects on these preferences so no simple explanation exists beyond the obvious differences in livestock species and in breeds between years. The significant effect of pasture isolation was related to the regular distribution patterns chosen by animals in the contiguous block of pastures (Figure 46).

SUMMARY AND CONCLUSIONS

A common use grazing study was conducted on a shrubby mountain site on the Kolob Terrace in southern Utah during the summers of 1978 and 1979. Sheep, cattle and mixtures of both species were stocked and held in small pastures until relatively high levels of herbage use had been achieved. The levels of use were estimated by technicians using a variety of range methods, including clipped plots, step-point transects, pasture mapping and browsed stem relationships. Computer analyses were done during the 1979 through 1980 school year at Utah State University, the results of which are presented in this volume. The following conclusions are supported by the analyses and are presented by research subcategory. The hypotheses tested by the research were presented earlier (page 28).

Pastures and Production

* The experimental pastures were similar in botanical composition and herbage production but varied in proportion of available browse. Browse was predominantly snowberry, *Symphoricarpos vaccinioides*.

* Herbage production was greater during the summer of 1979 than during the summer of 1978. This was due in part to the wetter than average winter of 1978 through 1979.

* Snowberry production on an area basis was higher than that of herbaceous vegetation.

Experiment 1

Utilization

* Grasses disappeared from pastures stocked with either sheep or cattle in the five sheep to one cow substitution ratio at approximately the same rate.

* Forbs were less preferred by cattle than grasses.

* One ewe with 1.4 lambs utilized forbs at about half the rate observed for one cow with calf.

* Four ewes with 5.6 lambs were required to utilize the total herbaceous forage component at the same rate as an average cow with calf.

* The disappearance rates of snowberry were different between sheep and cattle treatments. One ewe with 1.4 lambs utilized the shrub at approximately the same rate as one cow with calf.

* Considering all vegetation used by livestock, the rate of cattle utilization was 3.2 times that of sheep utilization. This means that for this vegetation type 3.2 ewes with 4.5 lambs (8 animals) cause as much vegetation to disappear through consumption, wastage and trampling as one cow with calf.

Herbage wastage implications

* Although not tested directly, herbage wastage for these trials can be inferred from research which estimated actual forage requirements of sheep and cattle on similar mountain ranges. The implication is that on these sites five ewes with seven lambs waste over twice that wasted by one cow with calf. The effect of six times the number of sheep hooves to cattle hooves is likely responsible, but not tested in this research.

Common use

* An important hypothesis tested by this research was that neither livestock species affected the forage preferences of the other. Results indicate that this is not true, although the total amount of herbage utilized in mixed livestock treatments was predicted from levels of use recorded in single species treatments.

* Sheep to cattle substitution ratios changed with hypothetical changes in snowberry versus herbaceous proportions of pastures. Proper use of these forage components and livestock utilization rates determined the ratios.

* A maximum substitution ratio of about four ewes with 1.4 lambs to one cow with calf was reached at the sheep stocking optimum and this ratio did not change as the proportion of snowberry increased in the hypothetical pastures.

* Comparing either species grazing alone and using the average weights of study animals, over 50 percent more kilograms of cattle than sheep could be carried on these experimental pastures.

* Small increases in grazing capacity can be realized for pastures with botanical compositions between that required for sheep and cattle optimum stocking by mixing the two livestock species. Mixtures range from all cattle near the cattle optimum to all sheep at the sheep optimum, substituting nearly linearly in between.

Metabolic comparisons

* There was no difference in the disappearance of herbaceous species caused by sheep and cattle on a "metabolic" weight basis when pastures were stocked using the five to one substitution ratio.

Techniques

* Botanical composition, forage disappearance rates and grazing capacity were similar whether determined by clipped plots or step-point transect techniques.

* Recording step-point information required less than half of the time needed to clip and weigh forage samples.

* The skill required for the step-point technique was substantially higher than for clipping.

* The requirement of establishing clusters of four plots in homogeneous vegetation biased the sampling procedure. As a result plots were not clipped from portions of the pastures which had diverse and often low cover. The large difference between years in herbaceous forage production as estimated by clipped plots was related to plot location as well as climatic variability.

* The correlations of levels of utilization with percents of plants grazed, both computed using step-point information, were quite high (r^2= 0.83 to 0.99). These relationships could be used to further reduce the time required to estimate levels of utilization of key forage species.

* The low variability of information from clipped snowberry plots contributed to accurate estimation of the utilization of the shrub.

* The correlation of snowberry stem diameter to the cubed root of leaf plus stem dry weight (r^2=0.90) allowed average stem diameter to successfully predict levels of shrub utilization.

Livestock Behavior

Distribution

* Sheep and cattle exhibited significantly different distribution patterns within six small pastures.

* Changes in air temperature through the day explain part of the differences observed in diurnal livestock distribution.

* Distances between animals in flocks and herds increased as herbaceous vegetation decreased.

* Cattle distribution in small pastures was influenced by slope and distance from water and salt. As the grazing trials progressed and herbaceous forage availability decreased cattle spent more time down slope away from water and salt.

* Black-faced sheep were widely dispersed more frequently than white-faced.

* Juvenile livestock distribution patterns were very similar to those of adult livestock.

* Livestock in pastures contiguous with other pastures were strongly attracted to members of their species and tended to congregate along common fencelines.

Activities

* The significance of effects of treatments (livestock species, year of trial, pasture arrangement, trial day and hour of day) on livestock activity patterns were similar to the significance of effects on livestock distribution.

* Patterns of sheep activities were similar to those of cattle. Cattle browsed less than sheep and tended to spend more time grazing

herbaceous forage.

* Declining quantity of herbaceous vegetation caused increased browsing for both livestock species, although significant disappearance of snowberry in cattle pastures was not measured.

* Shade seeking behavior was stronger in sheep than in cattle and was closely related to their recorded frequency in shrubby vegetation.

* As groups, lambs and calves behaved much like ewes and cows, respectively.

* Most mixed herd activity and distribution patterns were accurately predicted based upon patterns observed in single species herds. The early morning distributuon of sheep was influenced by cattle, causing a longer period of activity followed by a longer period of clustering than was observed in sheep stocked alone in isolated pastures.

Value of Research and Recommendations

* The approach of using small pastures to study the commmon use of a single range site near Miner's Peak was appropriate, economic and efficient.

* The need to conduct similar, complementary studies on other sites is apparent if a complete investigation of the common use of this general region is desired. These studies should include combinations of the livestock species to account for interspecific influences.

* Range livestock behavior should be studied in large pastures stocked in common with different mixtures of sheep and cattle.

* Simulation models should be developed to focus the whole research effort at Miner's Peak so that a clearer understanding of how common use management can influence range condition and be used to cause desirable

trends. Given a strong and concerted effort, models could be built and tested using the information available within the wide scope of the planned research.

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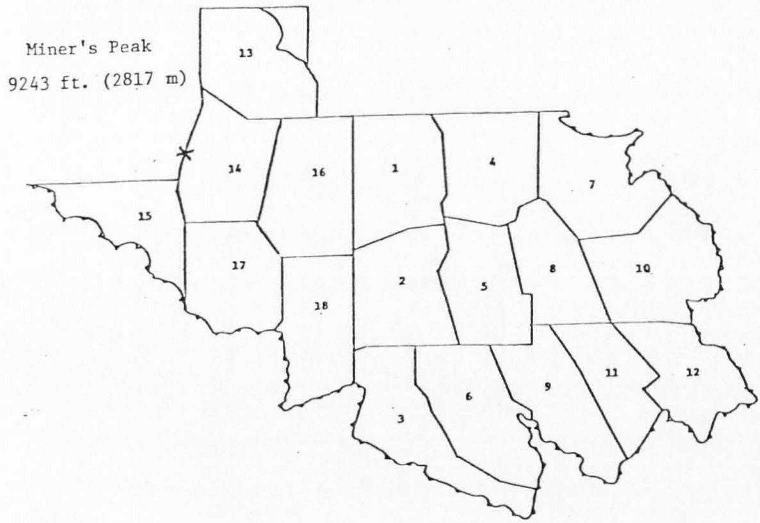
APPENDICES



1" = 4000 ft. 1 cm = 479 m

Figure 54. Pasture layout for the Utah A.E.S. 089 project. The study presented in this book was conducted in Pasture 6.

Table 21. Dry matter percentages of major plant species collected on the study site during the 1978 and 1979 grazing trials.

Species	Summer Season 1978	1979
	-- % Dry Matter (air dried basis) --	
Grasses:		
Agropyron riparium	52.4	38.1
A. trachycaulum		49.8
Koeleria nitida		48.5
Poa pratensis	77.3	46.0
Stipa comata	55.8	50.3
S. lettermanni	57.9	47.2
Forbs:		
Achillea millefolium	45.0	37.2
Artemisia ludoviciana	35.6	37.3
Aster sp.		37.4
Crepis intermedia	40.4	29.3
Erigeron flagellaris		33.0
Madia glomerata		28.9
Penstemon rydbergii		31.7
Senecio integerrimus		100.0
Stellaria jamesiana		38.1
Taraxacum officinale		27.6
Trifolium longipes	47.8	32.6
Vicia americana		36.7
Shrubs:		
Chrysothamnus nauseosus		34.0
Symphoricarpos vaccinioides	47.9	52.3

VITA

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