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LIVESTOCK BEHAVIOR -- THE NEGLECTED LINK IN UNDERSTANDING THE PLANT-ANIMAL INTERFACE

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SUMMARY

Although multispecies grazing dates from antiquity, ecology and ethology must be understood before the principles that underlie a free-ranging animal's grazing become clear and can be manipulated. Early work on multispecies grazing of cattle and sheep involved studying only the botanical and chemical composition of diets. From this work it has been concluded that cattle and sheep diets generally overlap, depending on several factors besides standing-crop conditions. In general, cattle eat more grass and drink more water than do sheep; sheep prefer both grasses and forbs, but not necessarily in that order. Differences in cattle and sheep selectivity during grazing has been proposed to explain the higher crude protein and in-vitro digestibility of sheep diets compared to cattle diets.

Food consumption by grazing animals is directly influenced by grazing time, eating rate, and bite size. Senses of sight, sound, smell, and taste also influence an animal's behavior. The fact that both cattle and sheep have spectral vision may have management implications. Sound already has been demonstrated to have management possibilities with cattle and sheep. Smell appears important in diet selectivity and in recognition of conspecifics. However, taste may be the key sense in influencing diet selectivity.

Abiotic factors such as temperature and light affect animal behavior. Energy expenditure is reduced when the temperature is either high or low. Light is a major factor in triggering daily grazing in both cattle and sheep.

Age, breed, and physiological factors also influence dominance, travel, and intake in cattle and sheep. The size of cattle and sheep groups is influenced by composition of standing crop and paddock size. Possibly a minimum, stable group size for sheep should be no less than four individuals, but this is greatly influenced by breed and management. Paddock size, forage quality, vegetation type, and physical structures are important factors in where animals will graze.

Multispecies cattle and sheep studies in which nutrition and behavior have been simultaneously observed are rare. A preliminary evaluation of multispecies grazing of cattle and sheep on the Jornada Experimental Range in southcentral New Mexico indicates that diet and behavior occur within a temporal and spatial profile both within and between seasons. To date, diets appear to be complementary rather than competitive with respect to botanical composition. Multispecies grazing on arid rangelands should promote a more uniform use of standing crop.

The use of an electronic field-data logger in the Jornada study has reduced turnaround time between data collection and analysis in addition to reducing transcriptional errors. Temporal documentation of diet and behavior data obtained through visual observation is possible with the data logger because it contains a real-time clock.

Beginning in the 1950s, visual observation was supplemented with automated procedures for documenting behavior of free-ranging livestock. The first tools were mechanical. However, today there is a mix of mechanical and electronic "gadgets" that record data on prehension, biting, swallowing of food boluses, rumination, weighing, and travel. Photographic techniques and remote sensing using telemetry have also been used in livestock studies to remove the direct-observer influence.

As more behavioral studies are conducted using advanced statistical techniques, modeling may play an increasingly important role. Because of the complexity of the plant-animal interface it is essential that a team approach be used when studying the free-ranging animal. Besides the animal and range scientist, team members should include ethologists, engineers, statisticians, and modelers.

INTRODUCTION

Multispecies grazing has been advocated as a range management tool for over 40 years (Stoddart and Smith, 1943), yet it is still being studied (table 1). Research indicates that it contributes to better and more uniform forage use (Bennett et al., 1970; Kautz and Van Dyne, 1978; Parker and Pope, 1983) and higher economic returns from livestock (Hamilton and Bath, 1970).

Multispecies herding in Africa probably represents the oldest system of multiple-resource use. Livestock provide more than 50% of Africa's income and food (Wilson, 1984).

Multispecies grazing is ecologically sound: The coevolution of grasses and herbivores dates from the Eocene epoch, 45 million to 55 million years ago (Stebbins, 1981; Owen and Wiegert, 1981). Yet multispecies grazing of domestic livestock is not widely practiced. The plant-animal (nutrition-behavior) interface is still little understood and remains one of the most complex yet fruitful areas of research. Physical factors control biologic systems; however, the quantitative relationship between 1) the location of animals on the grazing landscape and 2) time remains largely unknown (Low, 1975).

Interest in animal behavior dates from antiquity. Field-oriented behavior studies, termed ethology by Lorenz (1981), have only been recognized as a full-fledged part of animal science since the mid-1950s (Arave and Albright, 1981; Curtis and Houpt, 1983). Anderson (1974) indicated that an early animal-husbandry text written by Stephens in 1851 recognized the need for understanding behavioral patterns relating to an animal's health. The subject of behavior is now given much emphasis in popular livestock-management journals (Fisher, 1979), live-

Table 1. Multispecies grazing research on cattle and sheep in 17 western states, along with numbers.

State	Multispecies research			Livestock numbers[a]	
	Prior to 1983	1983-1985	Proposed	Cattle (thousands)	Stock sheep (thousands)
Arizona	No	No	No	1,000	293
California	Yes	No	No	4,900	920
Colorado	Yes	No	Yes	3,040	450
Idaho	No	No	No	1,950	410
Kansas	No	No	No	5,750	130
Montana	No	Yes	Yes	2,990	540
Nebraska	No	No	No	7,200	120
Nevada	No	No	No	650	102
New Mexico	Yes	Yes	Yes	1,450	565
North Dakota	No	Yes	Yes	2,100	175
Oklahoma	No	Yes	Yes	5,350	95
Oregon	Yes	No	No	1,650	370
South Dakota	No	Yes	Yes	4,060	630
Texas	Yes	Yes	Yes	15,000	2,050
Utah	Yes	Yes	Yes	950	535
Washington	No	No	No	1,570	65
Wyoming	No	No	No	1,475	950

[a]USDA Agricultural Statistics (1983).

stock-management textbooks (Squires, 1981), and texts devoted entirely to the subject of free-ranging domestic-animal behavior (Arnold and Dudzinski, 1978). In an article addressing animal production in the 21st century, Tribe (1980) indicated that the main problem for the future would be to improve the efficiency of animal production from pastures. Understanding behavior of grazing animals is essential to reaching this goal. Early literature on free-ranging cattle (Cory, 1927; Tribe, 1950; Dwyer, 1961; Wagnon, 1963) and sheep (Squires, 1975a) provided the background we now have on free-ranging livestock. Unfortunately, past research efforts have often been fragmented (Curtis and Houpt, 1983) with much of the published work on domestic animal behavior being done by scientists not trained as ethologists (Squires, 1975c). A well-trained ethologist should be conversant in the fields of comparative and experimental psychology, evolutionary behavioral ecology, and sociobiology (D. F. Balph, personal communication). However, ethological terms often intimidate traditionally trained animal or range scientists (Malechek and Provenza, 1984). To remedy this situation, Hulet and Bond (1983/84) state explicitly that multidisciplinary teams are needed in complex livestock research and that the team should include animal-behavior scientists. Tribe (1950) generalized this statement by encouraging scientists from many disciplines to work together more closely.

Squires (1975b) stressed the importance of understanding behavior within the context of grazing, and the role of social organizations and interactions among species as they influence range resource use. Zeeb (1976) reiterated this point by suggesting that, as livestock managers, we do not know enough about an animal's adaptability to human management and, therefore, should integrate both ethological and ecological ideas when studying management systems.

MULTISPECIES GRAZING OF CATTLE AND SHEEP

Nutrition

Early work involving multispecies grazing of cattle and sheep did not address the behavioral component. Multispecies grazing research in the United States began in Texas (Fraps and Cory, 1940). Today, diversified livestock enterprises are particularly common among commercial producers in the Edwards Plateau of Texas and central and southeastern New Mexico (Gee and Magleby, 1976).

Van Dyne and Heady (1965) showed that as herbage became less available on late-summer range in California, selection became limiting, and cattle and sheep diets had similar dietary and chemical constituents. Based on work done by Cook et al. (1967) in Utah, it was concluded that under multispecies grazing by cattle and sheep, intermediate use was made of the herbage compared to use of the herbage where each species grazed alone. On New Mexico pinyon/juniper grasslands, sheep diets were generally higher in forbs and lower in grasses than cattle diets, except during June, July, and August (Thetford et al., 1971). Cattle and sheep diets sampled in eastern New Mexico indicate that grasses were predominantly grazed by cattle and approximately equal (39% and 45%) amounts of grasses and forbs were grazed by sheep (Howard et al., 1983). Using fecal analysis, MacCracken and Hansen (1981) found that domestic sheep and cattle diets obtained in southeastern Colorado overlapped by 53% during late spring. Similar findings in diet overlap have been reported from cattle and sheep diet studies done in Oregon (Vavra and Sneva, 1978). Live-weight changes of sheep and cattle grazing semiarid grassland near Deniliquin, New South Wales, Australia were of the same magnitude and direction, even though cattle diets were consistently lower in nitrogen than sheep diets (Wilson, 1976; Wilson, 1978). From these data Wilson further concluded that diet selectivity differed between the two animal species and that cattle may be less competitive than sheep when the two animal species are grazed in common under drought conditions. Sheep diets in Oregon also had consistently higher crude protein and digestible dry matter (in vitro) when compared to cattle diets (Bedell, 1971). Langlands (1965) found that when sheep diets were sampled throughout the day, the nitrogen content of the samples could be expressed as a quadratic relationship with peak values occurring approximately 8 hours after sunrise. Kothmann (1966) found more total protein in evening sheep diets than morning diets. These studies point out the need for sampling diets at more than one time during a 24-hour period.

Uprooting of herbage resulted in an increase in bare ground in tame pastures grazed by cattle compared to similar pastures grazed only by sheep (Boswell, 1977; Briseno and Wilman, 1981). The uprooting has been attributed to differences in grazing between the two animal species. Sheep have a less vigorous bite/pull during eating compared to the more violent pulling action typical of cattle grazing. However, observations by Brelin (1979) indicated that a better use of the pasture would result under multispecies grazing with cattle and sheep. This was because headed stems of grass, rejected by sheep, were eaten by the cattle; the ungrazed patches around cattle dung were grazed by the sheep. Brelin also observed that sheep move more rapidly and graze more selectively than cattle. Wilson and Graetz (1980) found that cattle and sheep, when grazing a semiarid saltbush *(Atriplex vesicaria)* community, required different amounts of water. They concluded that water needed for cattle grazing these paddocks was 50% more than that required for sheep grazing the same area. Dickson et al. (1981) reported improvement of individual cattle gains from multispecies grazing of cattle and sheep as the proportion of cattle decreased in the mix; however, live-weight gain per hectare was superior under mixed grazing compared to treatments containing cattle only.

The management of free-ranging livestock is complex. Cook (1966) and McDaniel and Tiedeman (1981) concluded that use of mountain slopes by cattle and sheep involves the interrelation of a multifaceted set of factors. The economic implications of free-ranging livestock behavior demands much more research. It has been said for sheep (Scott and Sutherland, 1981), and it can also be said for cattle, that knowledge of behavioral patterns is as much a requirement for their successful management as is knowledge of their feed requirements.

Behavior

Animal behavior encompasses many facets. Fraser (1978) listed feeding, exploration, kinesis, association, territorialism, reproduction, and body-care behavior as seven activities involved in the maintenance of domesticated animals. Arave and Albright (1981) discussed cattle behavior in terms of feeding, social, resting, and sexual behavior, as well as behaviors evoked due to adaptation to new environments. Schein and Fohrman (1955) pointed out that group behavior is fully as complex as the behavior of the individuals comprising the group, and little has been reported on the social behavior of ruminants. In addition, Price and Tomlinson (1979) and Fraser (1981) pointed out that intragroup sympathetic pairings and interspecies alliances may exist; therefore, in addition to natural behaviors, we must accurately know an animal's capabilities, adaptabilities, and limitations within the context of domestication, especially the collective management of animals as groups rather than individuals. Chacon et al. (1976) stressed the importance of behavior to range-animal nutrition by demonstrating that feed consumption of Jersey cows was equal to the number of bites times the bite size. Bite size, in addition to being influenced by other characteristics of the sward, appears to be largest at the commencement of morning grazing if preceeded by overnight fasting (Chacon and Stobbs, 1977). Arnold (1960) reported that the time sheep spent grazing increased linearly as standing crop availability decreased. Scarnecchia et al. (1985) showed that, as standing crop decreased, grazing time and biting rate of Angus heifers increased. Gammon and Roberts (1980) concluded that, of all behaviors, grazing time may have the most variability among animals. In temperate swards, the height of the herbage horizon from the soil surface exerts a much greater influence upon intake rates than does herbage density or the proportion of live material in that horizon (Hodgson, 1981).

The Senses

Krueger et al. (1974) concluded that taste had the greatest effect on forage preference for sheep, while smell was of least importance. However, work by Johnstone-Wallace (1937) indicated that smell was of considerable importance in influencing herbage selection under grazing. Odell et al. (1977) noted that cattle do not prefer grasses high in volatile essential oils, and concluded that smell ranks above taste in influencing their eating behavior.

As a stimulus to intake, Arnold et al. (1980) found that sheep reacted favorably to butyric acid and amyl acetate. As a management tool, the influence of odors on the movement of sheep along a race was studied (Franklin and Hutson, 1982a). It was concluded that olfactory stimuli do not change movement patterns of sheep. The odor of amniotic fluid may play an important role in the ewe-lamb bond. This odor is most important during the 12 hours following birth (Poindron et al., 1984). Urine is the easiest odor for sheep to use in identifying conspecifics (Baldwin and Meese, 1977). In sheep housed indoors, neither daily intake nor meal size was altered by removal of their olfactory bulbs (Baldwin et al., 1977).

Under field conditions livestock possess excellent vision and readily respond to visual stimuli. Until recently it was assumed that cattle did not have spectral vision (Doane's Agricultural Report, 1979). However, Gruber (1979) contended that color vision is represented to a greater or lesser degree in all orders of vertebrates. Thines and Soffie (1977) reported that Friesian heifers could discriminate between green and red but not between blue and purple, and were often confused in differentiating between orange and yellow. Sheep likewise have some sort of spectral vision, at least for colors in the longer wavelengths (Alexander and Stevens, 1979). Certain colors may actually induce negative or positive behaviorial responses in livestock (Mebes, 1979). Both cattle and sheep are able to discriminate between a variety of similar shapes (Baldwin, 1981). In a study designed to evaluate factors that would influence sheep movement, Franklin and Hutson (1982c) determined that conspecific decoys and photographs or film would cause sheep to move through a race.

Based on several studies in which different experimental methods were used, cattle and sheep responded differently to sound. Cattle can be conditioned to come to the sound of a loud alarm or car horn (Kiley-Worthington and Savage, 1978; Entsu et al., 1980). This has been known for many years by most ranchers who supplement range cattle from a vehicle. Sheep, however, showed no preference for moving toward either a sheep call or silence when tested in a Y-maze (Franklin and Hutson, 1982b). In a study to evaluate the basis of ewe-lamb recognition, Walser and Hague (1980) were unable to document that any one particular character of the ewe's bleat is used by the lamb to identify the voice of its dam. However, it is obvious to shepherds that lambs and their dams recognize each other's voices. Sheep also respond immediately to the rattle of a feed bucket and the bleating of a few sheep who notice the approach of the feed wagon.

The Animal

Age, breed, and physiological state affect grazing. Arnold and Maller (1977) found that adult sheep took longer to adjust to a new environment than did lambs. Time and frequency of lying and moving and the number of urinations and defecations apparently are very similar within a single breed of cattle (Czako, 1975). However, behaviors such as walking in cattle differ significantly between species within the same genus. Apparently, *Bos indicus* genotypes walk more on a daily basis than *Bos taurus* cattle (Herbel and Nelson, 1966).

Lactating cows ate 43% to 76% more herbage than did nonlactating cattle of similar weight (Hodgson and Jamieson, 1981). Digestible-organic-matter intakes were greater in pregnant or lactating ewes than in dry ewes (Arnold, 1975). Dominant cows are seldom herd leaders when the herd moves (Cole, 1975). Age had more importance in establishing rank than did live weight in German Spotted and Holstein-Friesian cattle (Sambraus, 1977). However, Sambraus et al. (1978/79) reported in a later study a significant relationship between live weight and social rank, while age, wither height, and girth were of no consequence. Arnold (1976) documented that grazing time of sheep could be reduced following shearing, but that organic matter intake per hour increased regardless of stocking rate and amount of available feed. Arnold and Birrell (1977) found that shorn sheep achieved a higher digestible-organic-matter intake rate under both abundant and scant herbage compared to wooled sheep by increasing intake per hour of grazing (Arnold and Birrell, 1977).

The Abiotic Environment

Cows become less active during periods of cold-weather stress, apparently as a means of conserving energy (Malechek and Smith, 1976). Daily grazing time appeared to be related to deviations from a 12-day continuous mean temperature (Rittenhouse and Senft, 1982). Larkin and McFarland (1978) suggested that temporal organization of behavior may be based on energy expenditure, because changing activities influence energy expenditures. High ambient air temperatures reduce grazing in cattle (Shaw and Dodd, 1979) and reduce spatial distribution of sheep grazing (Daws and Squires, 1974). Rectal temperatures were lower for shaded than for nonshaded cows (Baccari et al., 1982). However, Asiedu (1978) found no relationship between sheep behavior and either temperature or rainfall.

Light appears to influence animal behavior. Cattle activities change greatly from day to night (Low et al., 1981b). Occasional midnight grazing has been documented throughout the year for some breeds of cattle (Winter et al., 1980), but Sinkovic and Bures (1982) found practically no grazing by cattle between 2200 and 0400. Low et al. (1981a) and Ishii et al. (1983) found a positive correlation between the onset of grazing in cattle and sunrise. However, night grazing of cattle has not been positively related to moonlight (Low et al., 1981c). The initiation of eating in sheep also is probably triggered by light (Hunsaker and Wolynetz, 1979; Bueno and Ruckebusch, 1979). However, cessation of sheep grazing does not appear to be related to sunset (Squires, 1974). Cattle breeds may show more behavioral difference during a humid and hot season compared to a cooler, drier winter season (Winter et al., 1980).

The Grazing Location and Animal Numbers

Livestock distribution under free-ranging conditions is influenced by social factors, forage availability, water distribution, wind direction and velocity, shade and shelter availability, or the complex interaction of some or all of these factors (Squires, 1978). Group size is not a constant under free-ranging conditions. Under grassland grazing subgroups with as few as four sheep have been found, while on saltbush paddocks, 200- to 300-head flocks were observed (Squires, 1975b). Squires concluded that the presence or absence of shade was the major factor influencing these two grazing patterns. McIlvain and Shoop (1971) suggest that shade can be used to manipulate distribution and improve pasture use. However, Wilson (1974) concluded that with wooled sheep, shade was of little importance in influencing grazing location. A study by Muller et al. (1976) also indicated that vegetation was important in determining subgroup size. Dudzinski et al. (1982) found that cattle aggregated into larger mobs in open (i.e., treeless) communities compared to wooded communities. They also found that, as forage conditions improved, aggregation increased. Although not studied or confirmed for free-ranging animals, Clark and Mangel (1984) propose that group foraging can increase individual feeding rates as a result of information sharing among group members. McNaughton (1984) has proposed that group foraging, which produced a grazing lawn, is beneficial to the grazing animal's forage intake.

Although most studies indicated that forage conditions affect behavior of grazing animals, Low et al. (1981c) did not find this to be true with grazing Shorthorn cows in central Australia. However, Sato and Hayashi (1976) found that cattle dispersion or aggregation was related to paddock size; the smaller the paddock, the more dispersed were the animals, and conversely, the larger the paddock, the more the cattle were aggregated.

Lynch and Hedges (1979) found no difference during the summer in grazing behavior of groups of two sheep compared to four or five. These researchers concluded that grazing patterns were most affected by day length, lack of grass, and rate at which animals lost weight. Baldry (1979) concluded that because sheep are strongly social animals, a stable unit requires the presence of at least four or five individuals.

This finding should be considered in designing research studies involving grazing sheep. Murphey et al. (1981) stated that cattle behave differently in groups than they do in isolation. The development of group relationships in cattle probably occurs before 6 months of age and is probably limited by dominance relationships (Bouissou and Andrieu, 1978).

Some areas within a pasture may never be used by a grazing animal (Squires, 1974). Low et al. (1981a) found that the location of a cow at daybreak was a good indicator of the plant community in which the day's grazing would occur. Gluesing and Balph (1980) found that if sheep are moved to a new paddock not containing a plant species previously of major importance in their diet, searching will occupy a large portion of the initial time in the new paddock. Gammon and Roberts (1980) found that the time cattle spent grazing in a particular area was positively correlated with the area of veld types. However, grazing time per unit area differed between veld types, with the relationships being seasonal. Based on data from four plant communities in Florida, Tanner et al. (1984) concluded that grazing time of crossbred cattle was not in proportion to the size of the communities but rather related to the quality of forage available. Van Rees and Hutson (1983) indicated that the main influence on cattle distribution was their preference for particular vegetation communities.

Physical structures such as fences and corrals may also affect the grazing location of cattle and sheep (Dean and Rice, 1974). All of these studies and many others can be summed up in a statement by Skiles (1984) that a good understanding of site selection by large herbivores does not exist.

NUTRITION PLUS BEHAVIOR STUDIES

The dearth of multispecies (cattle and sheep) grazing studies in which behavior was an integral part of the study is apparent once the literature has been perused. Lofgreen et al. (1957) claimed to have published the first behavioral study involving cattle and sheep grazing pastures differing in composition of standing crop. Their conclusion was that the differences in behavior patterns between the two species were related to the animals' ability to graze selectively. An integrated nutrition-behavior study conducted by Harrington (1978) used visual observation. He concluded that diet studies alone provide a poor basis for drawing far-reaching conclusions. He further indicated that, by observing animals, information on both diet and feeding behavior could be obtained. However, ideal nutrition-behavior studies probably should involve both visual and esophageal-fistula information on diets because fistula data provide our most quantitatively reliable information on the free-ranging animal's diet (Holechek et al., 1984).

THE JORNADA -- A CASE STUDY

Since the early 1900s, the Jornada Experimental Range has been a cow-calf operation that carries yearlings only when forage and market situations are favorable. However, in 1984, combination stocking research of cattle and sheep was begun for the first time. The objective of introducing multispecies grazing on this arid rangeland was to evaluate the biological and economic feasibility of grazing both cattle and sheep. Data from the first year of the study will illustrate the importance of obtaining behavior data while simultaneously obtaining diet information to be used in developing grazing strategies. A rigorous analysis of the data discussed here and the live-weight data obtained from both animal species will follow the third year of data collection.

Climate

The Jornada's weather pattern can be characterized into three distinct seasons. 1) Dormancy includes the months of November, December, January, and February when mid-range air temperatures average near 42°F (5.6°C). 2) Ephemeral growth depends on adequate soil moisture during the months of March, April, May, and June. 3) Perennial growth occurs in July, August, September, and October. During this period 52% of the average annual 9.2 inches (230 mm) of precipitation is received. Details concerning the Jornada's climate, geography, and major forage species have previously been described by Paulsen and Ares (1962). Data were collected once within each of these three seasons on this combination stocking project. Total standing-crop production during 1984 in the experimental paddock was consistent with long-term records (R. P. Gibbens, personal communication).

Methods

From a herd of mature 7- to 9-year-old Hereford and Hereford-Santa Gertrudis crossbred cattle, 15 cows and(or) cow-calf pairs, representing various physiological stages of the breeding herd, were weighed immediately upon being gathered. The 15 animals were then released into the 1,625-acre (650-ha) experimental paddock. Likewise a herd of 40 ± 5 dry, pregnant Rambouillet ewes, 2 to 5 years old, were gathered, weighed, and released into the same paddock with the cows. This stocking resulted in a cattle-to-sheep ratio of between 1:2.3 to 1:3.

Although similar in herbage composition to the paddocks in which the experimental animals had previously been grazing, an adjustment period of approximately 5 days was allowed before diet and behavior data collection was begun. All diet and behavior data were entered into an electronic field-data logger. As each entry was made, a temporal profile of activities was accumulated because a date and time were automatically assigned to each entry. For convenience, date-time frames were kept on Mountain Standard Time during all seasons. Initially collected field information consisted of diet and behavior data. The technique used has been described by Bjugstad et al. (1970) as the feeding-minutes method. In our technique, each animal was observed for 30 minutes. Every minute during the 30-minute period the plant species being grazed or the activity in which the animal was engaged was recorded into the electronic field-data logger as a numerical code.

Approximately 11 to 14 hours of both cattle and sheep data were collected between sunrise and sunset for each species group during the three seasons in 1984. Observational periods were broken into mornings (AM) and afternoons (PM), with data collection beginning either at sunrise and lasting until noon or beginning at noon and lasting until sunset. Due to extraneous factors, such as weather, it took between 6 and 8 days to collect a complete data set. It was usually not possible for an individual to observe both cattle and sheep within a single morning or afternoon since the herds found within the paddock were either composed of cattle or sheep but normally not both. Usually the herds were not close, thus making it difficult to switch between observing cattle and sheep. Each of the 6 to 7 animals within the two animal groups was observed for a total of 2 hours per season. The 2 hours were composed of four 30-minute intervals with two randomly assigned to AM observations and two randomly assigned to PM observations. The sheep flock and individuals within the cow herd were not the same each season; therefore, a new set of animals was chosen for observation each season.

During periods of observation, the general flock or herd location was recorded on a map. Following the collection of diet and behavior data, standing crop was sampled within each of the delineated locations (figure 1). The step-point method of sampling vegetation described by Evans and Love (1957) was used to determine standing-crop composition by species. Approximately 1,200 points, within each area sampled, were taken as a series of 100-point lines arranged in a serpentine pattern. Each line was parallel and separated by 50 to 100 paces from the line just traversed. The spacing of the parallel lines was dependent on the size of the area being sampled. Once the animal diets and standing-crop data were collected, each animal was again weighed (using the same procedure as that used initially) and then removed from the paddock. Although informative, neither the live-weight data obtained from the cattle and sheep nor the detailed information on the standing crop and species composition of the cattle and sheep diets will be addressed in this discussion.

Results and Discussion of Behaviors

Spatially, the paddock was not used uniformally throughout 1984 (figure 1). The cross-hatched locations in the paddock depict areas of use rather than specific soil and(or) vegetation associations. Locations of use within the paddock represent minimal overlap between the two animal species. Except for locations 4 and 5 during dormancy (figure 1, table 2) and location 2 during ephemeral growth (figure 1, table 3) there was no overlap in the use of the 1,625-acre (650-ha) paddock by cattle and sheep during periods of observation in 1984. Location 2 (table 3) during ephemeral growth was the only location in which a major spatial overlap of the two animal species occurred. Approximately 40% and 58% of the grazing time for cattle and sheep, respectively, was recorded in this location.

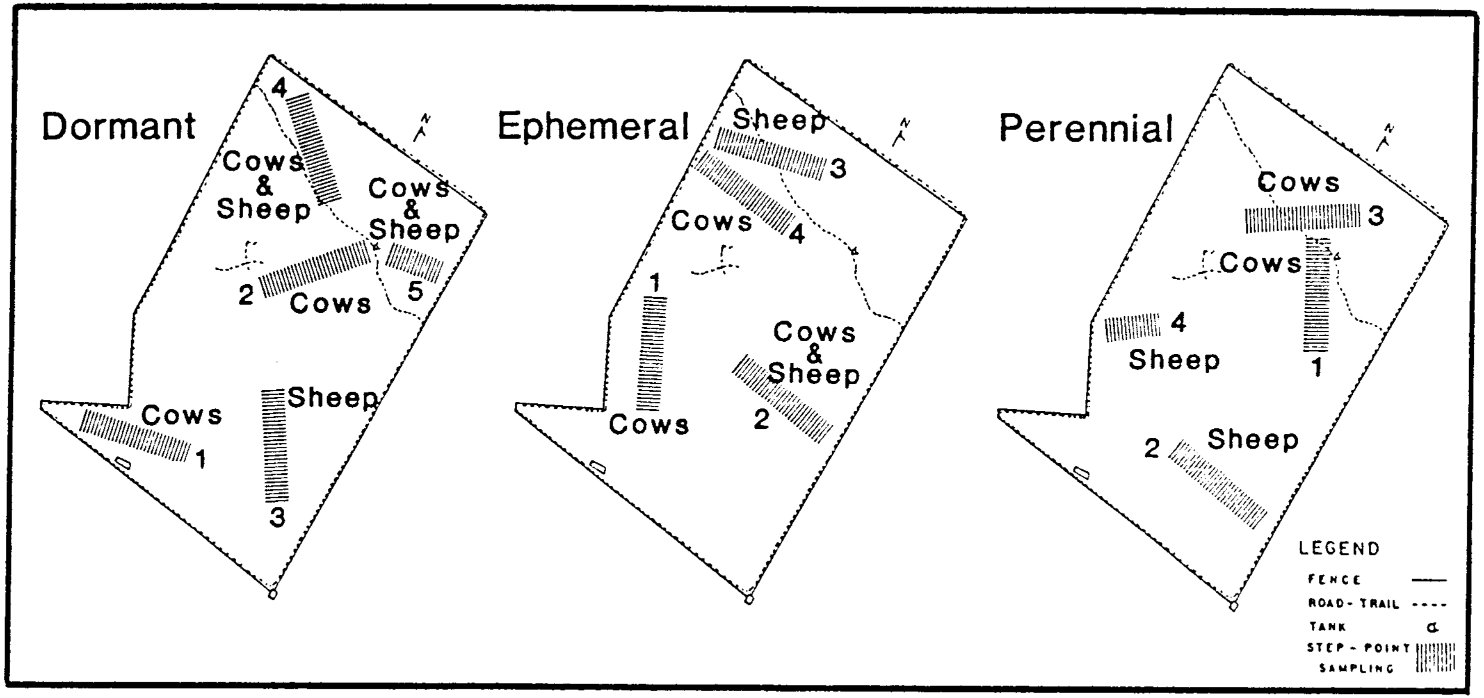

Figure 1. Spatial distribution of cows and sheep in a 650-ha arid rangeland paddock during the dormant (November-February), ephemeral (March-June), and perennial (July-October) seasons, 1984.

Table 2. Time budget (percentage) of cattle and sheep observed between 0645 and 1805 (Mountain Standard Time) during dormancy of the standing crop for the interval 01-21-84 to 02-24-84, with both kinds of livestock managed together under continuous stocking of an arid rangeland paddock.

Activity	Location 1			Location 2			Location 3			Location 4			Location 5			Paddock[a]		
	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total
Cattle																		
Lying	---	---	---	36.4[b]	63.6[c]	66.4[d]	---	---	---	---	100.0	19.0	100	---	14.7	38.9	61.1	28.8
Standing	---	---	---	36.9	63.1	91.2	---	---	---	---	100.0	8.8	---	---	---	29.7	70.3	15.4
Walking	---	---	---	17.6	82.4	100.0	---	---	---	---	---	---	---	---	---	26.9	73.1	4.6
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	100	---	100.0	100.0	---	1.9
Grazing	---	100	9.8	51.4	48.6	66.1	---	---	---	---	100.0	10.4	100	---	13.8	47.7	52.3	44.7
grass	---	100	3.8	54.9	45.1	78.8	---	---	---	---	100.0	11.1	100	---	6.3	49.5	50.5	63.6
forb	---	100	32.0	15.8	84.2	25.3	---	---	---	---	---	---	100	---	42.7	46.7	53.3	22.9
shrub	---	---	---	54.6	45.5	75.0	---	---	---	---	100.0	25.0	---	---	---	40.9	59.1	13.5
Other[e]																		4.6
Sheep																		
Lying	---	---	---	---	---	---	---	---	---	47.9	52.1	100.0	---	---	---	47.9	52.1	49.4
Standing	---	---	---	---	---	---	---	---	---	40.0	60.0	48.1	100	---	51.9	71.2	28.9	15.2
Walking	---	---	---	---	---	---	---	100	18.8	37.7	62.3	52.5	---	100	28.7	49.5	50.5	14.8
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grazing	---	---	---	---	---	---	---	100	48.9	---	100.0	49.6	100	---	1.5	1.5	98.5	19.7
grass	---	---	---	---	---	---	---	---	---	---	100.0	100.0	---	---	---	---	100.0	4.4
forb	---	---	---	---	---	---	---	100	55.0	---	100.0	45.0	---	---	---	---	100.0	88.9
shrub	---	---	---	---	---	---	---	---	---	---	100.0	77.8	100	---	22.2	22.2	77.8	6.7
Other[e]																		0.9

[a]Paddock equals the sum of all locations.
[b]Percentage of total activity recorded between sunrise and noon in a specific location.
[c]Percentage of total activity recorded between noon and sunset in a specific location.
[d]Percentage of total activity recorded between sunrise and sunset in a specific location.
[e]Activities other than grazing that occur in less than 5 consecutive minutes.

Table 3. Time budget (percentage) of cattle and sheep observed between 0500 and 1859 (Mountain Standard Time) during ephemeral growth of the standing crop for the interval 05-10-84 to 06-08-84, with both kinds of livestock managed together under continuous stocking of an arid rangeland paddock.

	Location 1			Location 2			Location 3			Location 4			Paddock[a]		
Activity	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total
Cattle															
Lying	25.4[b]	74.6[c]	34.2[d]	100.0	---	35.2	---	---	---	100	---	30.6	74.5	25.5	32.2
Standing	85.7	14.3	61.8	100.0	---	25.0	---	---	---	100	---	13.2	91.2	8.8	11.2
Walking	---	100.0	50.0	100.0	---	50.0	---	---	---	---	---	---	50.0	50.0	1.6
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grazing	20.6	79.4	45.3	100.0	---	39.3	---	---	---	100	---	15.4	24.0	36.0	49.3
grass	24.8	75.2	49.5	100.0	---	35.3	---	---	---	100	---	15.2	62.7	37.3	68.0
forb	8.8	91.2	38.2	100.0	---	47.2	---	---	---	100	---	14.6	65.2	34.8	29.7
shrub	---	100.0	14.3	100.0	---	57.1	---	---	---	100	---	28.6	85.7	14.3	2.3
Other[e]															5.6
Sheep															
Lying	---	---	---	87.4	12.6	71.7	---	100	28.3	---	---	---	62.7	37.3	35.8
Standing	---	---	---	32.6	67.4	70.9	8.5	91.5	29.1	---	---	---	25.6	74.4	24.2
Walking	---	---	---	55.7	44.3	70.5	39.4	60.6	29.5	---	---	---	50.9	49.1	13.3
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grazing	---	---	---	61.3	38.7	59.2	50.0	50.0	40.8	---	---	---	56.7	43.3	24.0
grass	---	---	---	83.3	16.7	75.0	100.0	---	25.0	---	---	---	87.5	12.5	4.0
forb	---	---	---	58.0	42.0	60.9	52.8	47.2	39.1	---	---	---	57.1	42.9	91.5
shrub	---	---	---	100.0	---	11.1	12.5	87.5	88.9	---	---	---	22.2	77.8	4.5
Other[e]															2.7

[a]Paddock equals the sum of all locations.
[b]Percentage of total activity recorded between sunrise and noon in a specific location.
[c]Percentage of total activity recorded between noon and sunset in a specific location.
[d]Percentage of total activity recorded between sunrise and sunset in a specific location.
[e]Activities other than grazing that occur in less than 5 consecutive minutes.

Temporal use of the paddock also differed between cattle and sheep. This helped to confirm that the time of the day during which data are collected can influence conclusions. Grazing time was split almost equally between morning and afternoon intervals for cattle regardless of season (tables 2, 3, and 4). However, this same pattern existed only during ephemeral growth for sheep (table 3). Sheep grazed predominantly in the afternoon during dormancy (table 2) while morning grazing was characteristic of perennial growth (table 4).

Those plant species that were grazed only in the morning or afternoon but not during both intervals are indicated in table 5. During dormancy sheep grazed deer's tongue *(Cryptantha crassisepala)* and wooly paperflower *(Psilostrophe tagetinae)* in the afternoon more than 4% of the time. The other thirty-five plant species were not grazed throughout the day (that is, they were grazed only in the morning or only in the afternoon) in 1984. Approximately half of these plants would have been missed if both AM and PM observations had not been conducted. Likewise, the aberrent behavior of one cow chewing on bones between sunrise and noon during dormancy (table 2) would not have been documented if only PM observations had been conducted.

Lying, standing, and walking also reflected temporal distribution (tables 2, 3, 4). Cattle and sheep spent the least percentage of time walking between sunrise and noon during dormancy.

Tentative Conclusions

Observations on multispecies grazing of cattle and sheep on the Jornada have shown that their diets throughout the year enhance the use of standing crop and are complementary rather than competitive. Competition between cattle and sheep for wooly paperflower during ephemeral growth may be put to a management advantage. Death of sheep during the season of ephemeral growth has been attributed to this species. The genus *Psilostrophe* affects the central nervous system (Bailey, 1978). Thus sheep should not graze paddocks containing wooly paperflower during ephemeral growth. These paddocks can be grazed by cattle since no loss of cattle on the Jornada has been attributed to wooly paperflower.

Cattle and sheep did not uniformly graze the paddock during observation periods. Areas used in common by both species were minimal and hence more of the available area was grazed using multispecies grazing. The AM and PM observations made it possible to document more conclusively all species in the standing crop that actually contributed to cattle and sheep diets, and to observe aberrant behavior. Without day-long observations in 1984 to record diet selection, only about one-half of the 37 grazed species not grazed throughout the day would have been documented. These species involved less than 6% of the grazing time; therefore, it is doubtful they were important dietary components on a weight basis. Because the above information is inconclusive, esophageally fistulated cattle and sheep will be used in conjunction with visual observations throughout the remainder of the study.

Table 4. Time budget (percentage) of cattle and sheep observed between 0528 and 1759 (Mountain Standard Time) during perennial growth of the standing crop for the interval 09-01-84 to 10-02-84, with both kinds of livestock managed together under continuous stocking of an arid rangeland paddock.

	Location 1			Location 2			Location 3			Location 4			Paddock[a]		
Activity	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total	AM	PM	Total
Cattle															
Lying	83.0[b]	17.1[c]	93.6[d]	---	---	---	100	---	6.4	---	---	---	84.0	16.0	13.7
Standing	57.4	42.6	90.4	---	---	---	100	---	9.6	---	---	---	61.5	38.5	31.9
Walking	51.4	48.6	100.0	---	---	---	---	---	---	---	---	---	51.4	48.6	5.1
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grazing	41.3	58.7	99.3	---	---	---	100	---	0.7	---	---	---	41.7	58.3	44.2
grass	41.8	58.2	99.7	---	---	---	100	---	0.3	---	---	---	42.0	58.0	95.4
forb	30.8	69.2	92.9	---	---	---	100	---	7.1	---	---	---	35.7	64.3	4.6
shrub	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Other[e]															5.1
Sheep															
Lying	---	---	---	54.2	45.8	100.0	---	---	---	---	---	---	54.2	45.8	23.2
Standing	---	---	---	35.7	64.3	65.1	---	---	---	---	100	34.9	23.3	76.7	28.1
Walking	---	---	---	80.6	19.4	42.9	---	---	---	---	100	57.1	34.5	65.5	13.7
Eating bone	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grazing	---	---	---	96.9	3.1	75.4	---	---	---	---	100	24.6	72.9	27.1	27.9
grass	---	---	---	100.0	---	100.0	---	---	---	---	---	---	100.0	---	0.6
forb	---	---	---	96.8	3.2	75.9	---	---	---	---	100	24.1	73.5	26.5	97.6
shrub	---	---	---	100.0	---	33.3	---	---	---	---	100	66.7	33.3	66.7	1.8
Other[e]															7.1

[a]Paddock equals the sum of all locations.
[b]Percentage of total activity recorded between sunrise and noon in a specific location.
[c]Percentage of total activity recorded between noon and sunset in a specific location.
[d]Percentage of total activity recorded between sunrise and sunset in a specific location.
[e]Activities other than grazing that occur in less than 5 consecutive minutes.

Table 5. Cattle and sheep diets (percentage of time) and the standing-crop composition (percentage) of an arid rangeland paddock during dormancy, ephemeral growth, and perennial growth in 1984.

Category	Dormancy			Ephemeral			Perennial		
	Diet		Standing crop	Diet		Standing crop	Diet		Standing crop
	Cow	Sheep		Cow	Sheep		Cow	Sheep	
Grasses									
Mesa dropseed	43.1	0.0	9.9	35.3	2.5	8.5	0.0	0.6[a]	7.0
Alkali sacaton				0.3[a]	1.5[a]	4.5	10.9	0.0	2.7
Red threeawn	15.9	0.0	6.2	25.7	0.0	3.4			
Poverty threeawn				1.7[b]	0.0	1.3			
Black grama	0.6	2.2	2.7						
Sideoats grama							8.6	0.0	0.8
Silver bluestem							6.0	0.0	----[c]
Burrograss	0.9	1.5	17.9	4.7[a]	0.0	17.4	32.1	0.0	20.3
Tobosa	1.5	0.0	0.7	0.3[a]	0.0	0.1	11.3	0.0	2.9
Vine mesquite							26.5	0.0	1.3
Fluffgrass	0.0	0.7[b]	1.9						
Bush muhly	1.5[a]	0.0	0.2						
Species not grazed			4.1			4.0			14.2
Subtotal	63.5	4.4	43.6	68.0	4.0	39.2	95.4	0.6	49.2
Forbs									
Flameflower	0.0	0.7[b]	0.7				0.0	7.7	1.3
Wislizenus spectaclepod	22.6	0.0	4.0	0.0	1.0[b]	1.5			
Deer's tongue	0.0	48.2[b]	24.2	0.0	1.0	---			
Wooly paperflower	0.0	40.0[b]	2.3	22.7	44.3	5.7	0.0	69.4	4.1
Globemallow				0.0	0.5[b]	1.0			
Leatherweed croton				0.3	16.4	11.1	1.0	0.0	10.1
Tumbling Russian thistle							0.0	0.6[a]	---
Fendler bladderpod				3.7	7.5	4.1	0.0	0.6[a]	4.5
Whitestem stickleaf							0.0	2.9[a]	<0.1
Roundleaf broomsnakeweed				1.3	13.4	8.5	0.3[b]	2.9[b]	4.5
Sawtooth spurge				1.0[a]	0.0	---			
Faint crown							0.0	1.2[b]	---
White wildbuckwheat							0.0	0.6[a]	0.2
Purslane portulaca							0.0	0.6[a]	<0.1
Desertholly perezia							2.0[b]	0.0	2.2
Desert baileya				0.3	0.0	0.1	0.3[b]	0.0	0.5
Fineleaved wildbuckwheat							0.7	2.9	<0.1
Woolly sumpweed							0.0	0.6[b]	0.4
Purple roll leaf				0.0	0.5[b]	4.0			
Morning glory							0.3[a]	0.0	<0.1
Babywhite aster				0.3	6.5	0.8			
Hairy evolvulus							0.0	0.6[a]	---
Dwarf dalea				0.0	0.5[a]	0.1			
Yellow flax							0.0	1.2[a]	<0.1
Green falsenightshade							0.0	0.6[a]	<0.1
Slender gaillardia							0.0	5.3[a]	0.1
Hymenopappus	0.3[b]	0.0	---						
Species not grazed			5.1			9.5			9.3
Subtotal	22.9	88.9	36.3	29.3	91.6	46.4	4.6	97.7	37.2
Shrubs									
Broomsnakeweed	0.0	1.5	17.1						
Longleaf ephedra	0.0	4.4	0.6	0.7	4.6	0.5	0.0	0.6[a]	0.5
Trailing ratany	0.0	0.7[b]	---			---	0.0	0.6[b]	---
Soaptree yucca	13.5	0.0	0.4	1.7	0.0	0.2			
Mesquite beans			---				0.0	0.6[b]	---
Species not grazed			2.0			13.6			12.9
Subtotal	13.5	6.6	20.1	2.4	4.6	14.3	0.0	1.8	13.4
TOTAL	99.9	99.9	100.0	99.7	100.2	99.9	100.0	100.1	99.8

[a]Only in sunrise-to-noon diets.
[b]Only in noon-to-sunset diets.
[c]Species not encountered in step-point transects.

TOOLS AND TECHNIQUES

The earliest animal-behavior studies involved documenting observations (Cory, 1927). Because of the great amount of diligence and labor this required, few behavior studies were undertaken. As technology advanced beyond field glasses and a watch, automated data acquisition began. At first the equipment was bulky and not adapted to free-ranging livestock. Balch et al. (1951) used lightly inflated toy balloons to record gastric movements in ruminally fistulated cows confined to a cowshed. Tambours were placed in a recorder to give ink records on ruled white paper. Later Balch (1958) expanded his interest to include studies of jaw movements, a behavior of prime importance in studying free-ranging livestock. From this work he documented that jaw-movement patterns for concentrate diets, roughage diets, and drinking were unique. He attributes these pattern differences to the degree to which the mouth was opened.

Monitoring of free-ranging animal behavior came with the advent of self-contained equipment packages. Grazing was one of the earliest behaviors of free-ranging animals to be studied. Allden (1962) adapted the Vibracorder (developed by the Germans to monitor motor vehicles) to measure sheep grazing. Stobbs (1970), using Vibracorders on cattle, concluded that the instruments could be used successfully to monitor both time and diurnal patterns of grazing. However, Castle et al. (1950) used infrared equipment to aid in night observation 20 years earlier. The same conclusions concerning Vibracorders discussed by Stobbs were substantiated several years later by Castle et al. (1975). As with most tools, changes and improvements are inevitable. Ruckebusch and Bueno (1978) attempted to improve Vibracorder accuracy by attaching a syringe to the pendulum portion of the instrument. A more accurate estimate of grazing time was recorded via a tube attached to a balloon placed in the submandibular space of the cow's jaw. They concluded that an unaltered Vibracorder may overestimate grazing time, especially in paddocks where herbage intake is restricted. Even with their limitations, Vibracorders are still being used to quantify the animal's behavior during grazing (Lathrop et al., 1985).

With the advent of electronics and its application to sensing information from animals and man (Mackay, 1970) it was inevitable that animal-behavior studies would never be the same. Canaway et al. (1955) described an automated system for use with free-ranging animals. It used various switches for monitoring walking, lying or standing, jaw movements, and head position. O'shea (1969) monitored grazing time (jaw movements) of a free-ranging cow using power supplied from a backpack-attached battery with a mercury switch attached to the side of the animal's halter. He concluded the instrument was cheap and satisfactory for measuring grazing time; however, the sensor did not provide information on grazing patterns.

The idea of electronically recording jaw movements was carried further by Stobbs and Cowper (1972). They developed an instrument that could differentiate total bites from grazing bites. In an attempt to miniaturize the equipment package developed by O'shea (1969), a more energy-efficient unit was developed by Jones and Cowper (1975). In testing their unit with Vibracorders, they determined that their unit consistently gave lower grazing-time measurements than the Vibracorder. They concluded that resolution from their electronic sensor was greater than that possible from the mechanical Vibracorder. It has been concluded that the grazing clock developed by Jones and Cowper (1975) is the best equipment that has been developed to measure time spent grazing. However, ambient air temperature and battery life may affect readings (Pattinson et al., 1981).

A bite meter was developed by Chambers et al. (1981), not only to monitor jaw activities, but also head movements in order to provide information on the processes of prehension and severance of herbage. Their findings indicated that jaw and head movements not only differ between cattle and sheep, but are influenced by height of herbage grazed. These findings may have influenced Penning (1983) to develop an electronic unit capable of recording not only jaw movements, but grazing, ruminating, and idling times. Penning's transducer does not require careful placement and adjustment on the animal. With this equipment, head position no longer is used to differentiate between grazing and ruminating. In addition the data can be processed and analyzed automatically by a microprocessor.

The ultimate tool would sense the food bolus as it passes through the esophagus. Stoner et al. (1979) reported on the successful use of titanium electrodes implanted into the serosal layer of the esophagus to detect waveforms associated with various digestive events. Work on this methodology to study the grazing behavior of free-ranging animals is continuing at an ever-increasing pace (J. Stuth, personnel communication).

Frequent weighing represents another area where automation has had to wait for adaptation of electronic technology. Martin et al. (1967) described the first use of electronics to automate weighing free-ranging livestock. Water consumption patterns (Anderson et al., 1981) and minute changes in weight during grazing (Horn, 1981) have been monitored with the advent of frequent weighing of free-ranging cattle.

Animal travel has always been of interest when documenting behavior of free-ranging livestock (Cory, 1927). Range meters were used by Van Dyne and Van Horn (1974) to monitor travel by sheep. However, digital pedometers provided a major breakthrough to monitoring cattle travel on brush-infested rangeland (Anderson and Kothmann, 1977). Prior to this, visual observation followed by mapping of movements was frequently used (Dwyer, 1961). Today electronic pedometers (Rossing et al., 1984) are being used in the dairy industry to detect estrus, largely as a result of behavior research by Kiddy (1977).

It is desirable that the observer not influence observations (Hurd and Blaser, 1962). During the 1960s, photography was used to aid visual observation of animal behavior. Dudzinski and Arnold (1967) used aerial photography and a digital computer to evaluate patterns of animal behavior precisely, rapidly, and quantitatively. Photographic recorders operated by the animals themselves were used successfully by Squires et al. (1969) to produce unbiased records of temporal patterns in sheep, especially their walking activity. Use of SP8 cinematographic recording of grooming behavior in cattle has been reported by Simonsen (1979).

Biotelemetry systems may be the next step in automating electronically obtained behavior data from free-ranging livestock. However, radio carrier waves are only a "convenient substitute" for a wired connection between free-ranging animals and the recording system, to quote Bligh and Heal (1974). The high costs involved in developing the systems have usually not been justified. Such a system was developed in Australia and has not yet been fully used (V. R. Squires, personnel communication). A description of the system is given by Petrusevics and Davidson (1975), who used low-power CMOS integrated circuits in transponders worn by animals in order to locate their positions within a 165-km^2 paddock.

Using similar electronic components, Stermer and Smith (1978) developed a telemetry system for monitoring the physiological responses of temperature, heart rate, and respiration in cattle prior to and during shipping. Using radiotelemetry, Kam et al. (1980) attached transmitters to the tympanic membrane to sense temperature changes in dairy cattle. By combining other sciences, such as neuroscience and ethology, fresh new concepts should result (Fraser and Herchen, 1979).

The future also presents a unique opportunity to applied statisticians and modelers. As part of a research team they need to be involved from the inception of nutrition-behavior research. How behavior data should be analyzed to provide the most accurate and precise answers has not been resolved. The lack of simple yet suitable analysis techniques appears to be the major limitation to studies involving dispersion and aggregation of free-ranging animals (Grassia, 1978). Recently, models have been used to provide internal validation of observed patterns (Rice et al., 1982; Senft et al., 1985).

Computer systems are now available to analyze animal vocalizations (Zoloth et al., 1980), spacing behavior of animals in pens (Gonyou and Stricklin, 1978; Stricklin and Crow, 1978), and spacing behavior of free-ranging animals within their home range (Murai et al., 1979; Rice et al., 1982). Models have provided management options. For cattle to use pen space effectively, the ratio of perimeter to area should be maximized; therefore, circular pens are preferred to triangular pens (Stricklin et al., 1979). Findings such as these provide useful information in the design and construction of livestock facilities (Grandin, 1980; Anderson, 1981; Scott, 1984).

Nelson and Furr (1966) determined that major periods of grazing and ruminating can be documented adequately from 30-minute observation intervals. Mullen et al. (1980) state that our intuition is correct if we sample less often those activities that occur most frequently. According to Altmann (1974), there are seven major statistical sampling methods for observational studies, and using more than one of the methods in any one study can increase efficient use of research time.

LITERATURE CITED

Alexander, G. and D. Stevens. 1979. Discrimination of colours and grey shades by merino ewes: Tests using coloured lambs. Appl. Anim. Ethol. 5:215-231.

Allden, W. G. 1962. Rate of herbage intake and grazing time in relation to herbage availability. Proc. Australian Soc. Anim. Prod. 4:163-171.

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behaviour. 49:227-265.

Anderson, D. M. 1981. Manipulating rangeland forage quality with the grazing animal. In: J. L. Wheeler and R. D. Mochrie (eds.). Forage Evaluation: Concepts and Techniques. CSIRO and American Forage and Grassland Council, Melbourne, Australia. pp. 313-328.

Anderson, D. M. and M. M. Kothmann. 1977. Monitoring animal travel with digital pedometers. J. Range Manage. 30:316-317.

Anderson, D. M., J. A. Landt, and P. H. Salazar. 1981. Electronic weighing, identification and subdermal body temperature sensing of range livestock. In: J. L. Wheeler and R. D. Mochrie (eds.). Forage Evaluation: Concepts and Techniques. CSIRO and American Forage and Grassland Council, Melbourne, Australia. pp. 373-382.

Anderson, G. C. 1974. Old wine in a new skin or animal behavior in the modern animal science curriculum. J. Anim. Sci. 39:441-445.

Arave, C. W. and J. L. Albright. 1981. Cattle behavior. J. Dairy Sci. 64:1318-1329.

Arnold, G. W. 1960. The effect of the quantity and quality of pasture available to sheep on their grazing behavior. Australian J. Agr. Res. 2:1034-1043.

Arnold, G. W. 1975. Herbage intake and grazing behaviour in ewes of four breeds at different physiological states. Australian J. Agr. Res. 26:1017-1024.

Arnold, G. W. 1976. A note on changes in ingestive behaviour of sheep following shearing. Appl. Anim. Ethol. 2:175-179.

Arnold, G. W. and H. A. Birrell. 1977. Food intake and grazing behaviour of sheep varying in body condition. Anim. Prod. 24:343-353.

Arnold, G. W., E. S. de Boer, and C. A. P. Boundy. 1980. The influence of odour and taste on the food preferences and food intake of sheep. Australian J. Agr. Res. 31:571-587.

Arnold, G. W. and M. L. Dudzinski. 1978. Ethology of free-ranging domestic animals. Elsevier Scientific Publishing Co., New York.

Arnold, G. W. and R. A. Maller. 1977. Effects of nutritional experience in early and adult life on the performance and dietary habits of sheep. Appl. Anim. Ethol. 3:5-26.

Asiedu, F. H. K. 1978. Grazing behavior of sheep under three crops in Ghana. Trop. Agr. 55:181-188.

Baccari, F., Jr., P. S. Assis, R. Polastre, and C. A. Fre. 1982. Shade management in tropical environment for milk production in crossbred cows. Proc. West. Sec. American Soc. Anim. Sci. 33:209-210.

Bailey, E. M., Jr. 1978. Physiologic responses of livestock to toxic plants. J. Range Manage. 31:343-347.

Balch, C. C. 1958. Observations on the act of eating in cattle. J. Nutr. 12:330-345.

Balch, C. C., A. Kelly, and G. Heim. 1951. Factors affecting the utilization of food by dairy cows. British J. Nutr. 5:207-216.

Baldry, A. F. 1979. Sheep behavior and welfare. Appl. Anim. Ethol. 5:289-300.

Baldwin, B. A. 1981. Shape discrimination in sheep and calves. Anim. Behav. 29:830-834.

Baldwin, B. A., C. L. McLaughlin, and C. A. Baile. 1977. The effect of ablation of the olfactory bulbs on feeding behavior in sheep. Appl. Anim. Ethol. 3:151-161.

Baldwin, B. A. and G. B. Meese. 1977. The ability of sheep to distinguish between conspecifics by means of olfaction. Physiol. Behav. 18:803-808.

Bedell, T. E. 1971. Nutritive value of forage and diets of sheep and cattle from Oregon subclover-grass mixtures. J. Range Manage. 24:125-133.

Bennett, D., F. H. W. Morley, K. W. Clark, and M. L. Dudzinski. 1970. The effect of grazing cattle and sheep together. Australian J. Exp. Agr. Anim. Husb. 10:694-709.

Bjugstad, A. J., H. S. Crawford, and D. L. Neal. 1970. Determining forage consumption by direct observation of domestic grazing animals. In: Range and Wildlife Habitat Evaluation, A Research Symposium. U.S. For. Serv. Misc. Pub. 1147. U.S. Government Printing Office, Washington, D.C. pp. 101-104.

Bligh, J. and J. W. Heal. 1974. The use of radio-telemetry in the study of animal physiology. Proc. Nutr. Soc. 33:173-181.

Boswell, C. C. 1977. Comparisons of cattle grazing and sheep grazing. Proc. New Zealand Grassland Assoc. 38:56-65.

Bouissou, M. F. and S. Andrieu. 1978. Establissement des relations preferentielles chez les bovins domestiques. Behaviour. 64:148-157.

Brelin, B. 1979. Mixed grazing with sheep and cattle compared with single grazing. Swedish J. Agr. Res. 9:113-120.

Briseno de la Hoz, V. M. and D. Wilman. 1981. Effects of cattle grazing, sheep grazing, cutting and sward height on a grass-white clover sward. J. Agr. Sci. Cambridge 97:699-706.

Bueno, L. and Y. Ruckebusch. 1979. Ingestive behaviour in sheep under field conditions. Appl. Anim. Ethol. 5:179-187.

Canaway, R. J., W. F. Raymond, and J. C. Tayler. 1955. The automatic recording of animal behaviour in the field. Elect. Eng. 27:102-105.

Castle, M. E., A. S. Foot, and R. J. Halley. 1950. Some observations on the behaviour of dairy cattle with particular reference to grazing. J. Dairy Res. 17:215-232.

Castle, M. E., E. Macdaid, and J. N. Watson. 1975. The automatic recording of the grazing behaviour of dairy cows. J. British Grasslands Soc. 30:161-163.

Chacon, E. and T. H. Stobbs. 1977. The effects of fasting prior to sampling and diurnal variation on certain aspects of grazing behaviour in cattle. Appl. Anim. Ethol. 3:163-171.

Chacon, E., T. H. Stobbs, and R. L. Sandland. 1976. Estimation of herbage consumption by grazing cattle using measurements of eating behaviour. J. British Grasslands Soc. 31:81-87.

Chambers, A. R. M., J. Hodgson, and J. A. Milne. 1981. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. Grass and Forage Sci. 36:97-105.

Clark, C. W. and M. Mangel. 1984. Foraging and flocking strategies: Information in an uncertain environment. American Nat. 123:626-641.

Cole, P. H. 1975. Why cows behave the way they do. Agridynamics 16:17-21.

Cook, C. W. 1966. Factors affecting utilization of mountain slopes by cattle. J. Range Manage. 19:200-204.

Cook, C. W., L. E. Harris, and M. C. Young. 1967. Botanical and nutritive content of diets of cattle and sheep under single and common use on mountain range. J. Anim. Sci. 26:1169-1174.

Cory, V. L. 1927. Activities of livestock on the range. Texas Agr. Exp. Sta. Bull. 367. Texas A&M Univ., College Station. 47 pp.

Curtis, S. E. and K. A. Houpt. 1983. Animal ethology: Its emergence in animal science. J. Anim. Sci. 57(Suppl. 2):234-247.

Czako, J. 1975. Determination of behaviour norms in cattle of various age and purpose. Acta. Agron. Acad. Sci. Hungary 24:343-358.

Daws, G. T. and V. R. Squires. 1974. Observations on the effects of temperature and distance to water on the behavior of Merino and Border Leicester Sheep. J. Agr. Sci. Cambridge 82:383-390.

Dean, R. E. and R. W. Rice. 1974. Effects of fences and corrals on grazing behavior. Proc. W. Sec. American Soc. Anim. Sci. 25:56-58.

Dickson, I. A., J. Frame, and D. P. Arnot. 1981. Mixed grazing of cattle and sheep versus cattle only in an intensive grassland system. Anim. Prod. 33:265-272.

Doane's Agricultural Report. 1979. Cow psychology. Doane's Agr. Rep. 41(19):271-272.

Dudzinski, M. L. and G. W. Arnold. 1967. Aerial photography and statistical analysis for studying behaviour patterns of grazing animals. J. Range Manage. 29:77-83.

Dudzinski, M. L., W. J. Muller, W. A. Low, and H. J. Schuh. 1982. Relationship between dispersion behaviour of free-ranging cattle and forage conditions. Appl. Anim. Ethol. 8:225-241.

Dwyer, D. D. 1961. Activities and grazing preferences of cows with calves in northern Osage County, Oklahoma. Oklahoma Agr. Exp. Sta. Bull. 588. 61 pp. Oklahoma State Univ., Stillwater.

Entsu, S., F. Ando, and K. Morozumi. 1980. Control of behaviour of young cattle under restricted grazing with night kraaling. III. Improvement of method for recalling cattle by conditioned sound. Bull. Nat. Grassld. Res. Inst. 16:128-142.

Evans, R. A. and R. M. Love. 1957. The steppoint method of sampling -- a practical tool in range research. J. Range Manage. 10:208-212.

Fisher, H. 1979. Nutrition and animal behavior...A new frontier in animal production. Feedstuffs 51(26):17-18.

Franklin, J. R. and G. D. Hutson. 1982a. Experiments on attracting sheep to move along a laneway. I. Olfactory stimuli. Appl. Anim. Ethol. 8:439-446.

Franklin, J. R. and G. D. Hutson. 1982b. Experiments on attracting sheep to move along a laneway. II. Auditory stimuli. Appl. Anim. Ethol. 8:447-456.

Franklin, J. R. and G. D. Hutson. 1982c. Experiments on attracting sheep to move along a laneway. III. Visual stimuli. Appl. Anim. Ethol. 8:457-478.

Fraps, G. S. and V. L. Cory. 1940. Composition and utilization of range vegetation of Sutton and Edwards counties. Texas Exp. Sta. Bull. 586. Texas A&M Univ., College Station. 39 pp.

Fraser, A. F. 1978. The behavior of maintenance. Appl. Anim. Ethol. 4:299-300.

Fraser, A. F. 1981. Animal togetherness. Appl. Anim. Ethol. 7:303-305.

Fraser, A. F. and H. Herchen. 1979. The behaviour of liberated livestock. Appl. Anim. Ethol. 5:95-101.

Gammon, D. M. and B. R. Roberts. 1980. Grazing behaviour of cattle during continuous and rotational grazing of the matopos sandveld of Zimbabwe. Zimbabwe J. Agr. Res. 18:13-27.

Gee, C. K. and R. S. Magleby. 1976. Characteristics of sheep production in the western United States. Nat. Resources Econ. Div., USDA, Econ. Res. Serv., Agr. Econ. Rep. 345. U.S. Government Printing Office, Washington, D.C. 47 pp.

Gluesing, E. A. and D. F. Balph. 1980. An aspect of feeding behavior and its importance to grazing systems. J. Range Manage. 33:426-427.

Gonyou, H. W. and W. R. Stricklin. 1978. Spatial behavior of feedlot cattle: Diurnal patterns and meteorological effects. Canadian J. Anim. Sci. 59:837. (Abstr.)

Grandin, T. 1980. Observations of cattle behavior applied to the design of cattle-handling facilities. Appl. Anim. Ethol. 6:19-31.

Grassia, A. 1978. A technique in the study of aggregative behaviour of sheep. Appl. Anim. Ethol. 4:369-377.

Gruber, S. H. 1979. Mechanism of color vision: An ethologist's primer. In: E. Burtt (ed.). The behavioral significance of color. Garland Press Inc., New York. pp. 185-236.

Hamilton, D. and J. G. Bath. 1970. Performance of sheep and cattle grazed separately and together. Australian J. Exp. Agr. and Anim. Husb. 10:19-26.

Harrington, G. 1978. The implications of goat, sheep and cattle diet to the management of an Australian semi-arid woodland. In: D. N. Hyder (ed.). Proc. 1st Int. Rangeland Congress. Soc. Range Manage., Denver, CO. pp. 447-450.

Herbel, C. H. and A. B. Nelson. 1966. Activities of Hereford and Santa Gertrudis cattle on a southern New Mexico range. J. Range Manage. 19:173-176.

Hodgson, J. 1981. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. Grass and Forage Sci. 36:49-57.

Hodgson, J. and W. S. Jamieson. 1981. Variations in herbage mass and digestibility, and the grazing behaviour and herbage intake of adult cattle and weaned calves. Grass and Forage Sci. 36:39-48.

Holechek, J. L., M. Vavra, and R. D. Pieper. 1984. Methods for determining the botanical composition, similarity, and overlap of range herbivore diets. In: Developing Strategies for Rangeland Management. Westview Press, Boulder, CO. pp. 425-471.

Horn, F. P. 1981. Direct measurement of voluntary intake of grazing livestock by telemetry. In: J. L. Wheeler and R. D. Mochrie (eds.). Forage Evaluation: Concepts and Techniques. CSIRO and American Forage and Grassland Council, Melbourne, Australia. pp. 367-372.

Howard, V. W., J. L. Holechek, R. D. Pieper, S. L. Beasom, and K. Green-Hammond. 1983. Roswell pronghorn study. New Mexico State Univ., Las Cruces. 115 pp.

Hulet, C. V. and J. Bond. 1983/84. Some observations on the role of behavior in sheep production and future research needs. Appl. Anim. Ethol. 11:407-411.

Hunsaker, W. G. and M. S. Wolynetz. 1979. A study of free-running rhythms in sheep. Inter. J. Chronobiology 6:219-230.

Hurd, R. M. and R. E. Blaser. 1962. Palatability of Herbage: Pasture and Range Research Technique. Comstock Publishing Assn., Ithaca, NY. pp. 65-69.

Ishii, T., M. Namiki, F. Watanabe, Y. Kubota, N. Abe, H. Tokasaki, and M. Omiya. 1983. Grazing behaviour of dairy beef steers. Japanese J. Livestock Manage. 18:73-80.

Johnstone-Wallace, D. B. 1937. The influence of grazing management and plant associations on the chemical composition of pasture plants. J. American Soc. Agron. 29:441-455.

Jones, R. J. and L. J. Cowper. 1975. A lightweight electronic device for measurement of grazing time of cattle. Trop. Grasslands 9:235-241.

Kam, L. W. G., R. M. Nakamura, and N. L. Clarke. 1980. The use of radiotelemetry as a means of monitoring body temperatures of dairy cattle in Hawaii. Proc. West. Sec. American Soc. Anim. Sci. 31:44-46.

Kautz, J. E. and G. M. Van Dyne. 1978. Comparative analyses of diets of bison, cattle, sheep, and pronghorn antelope on shortgrass prairie in northeastern Colorado, U.S.A. In: D. N. Hyder (ed.). Proc. 1st Int. Rangeland Congress. Soc. Range Manage., Denver, CO. pp. 438-443.

Kiddy, C. A. 1977. Variation in physical activity as an indication of oestrus in dairy cows. J. Dairy Sci. 60:235-243.

Kiley-Worthington, M. and P. Savage. 1978. Learning in dairy cattle using a device for economical management of behaviour. Appl. Anim. Ethol. 4:119-124.

Kothmann, M. M. 1966. Nutrient content of forage ingested in the morning compared to evenings. J. Range Manage. 19:95-96.

Krueger, W. C., W. A. Laycock, and D. A. Price. 1974. Relationship of taste, smell, sight, and touch to forage selection. J. Range Manage. 27:258-262.

Langlands, J. P. 1965. Diurnal variation in the diet selected by free-grazing sheep. Nature 207:666-667.

Larkin, S. and D. McFarland. 1978. The cost of changing from one activity to another. Anim. Behav. 26:1237-1246.

Lathrop, W. J., K. M. Havstad, D. D. Kress, D. E. Doornbos, and E. L. Ayers. 1985. Grazing behavior of rangeland beef cows differing in milk production. Soc. Range Manage. Abstracts 38:263. Soc. Range Manage., Denver, CO.

Lofgreen, G. P., J. H. Meyer, and J. L. Hull. 1957. Behavior patterns of sheep and cattle being fed pasture or silage. J. Anim. Sci. 16:773-780.

Lorenz, K. Z. 1981. The Foundations of Ethology. Springer-Verlag, New York.

Low, W. A. 1979. Spatial and temporal distribution and behavior. In: D. W. Goodall, R. A. Perry and K. M. W. Howes (eds.). Arid-land Ecosystems: Structure, Functioning, and Management. Cambridge Univ. Press, Melbourne, Australia. pp. 769-795.

Low, W. A., R. L. Tweedie, C. B. H. Edwards, R. M. Hodder, K. W. J. Malafant, and R. B. Cunningham. 1981a. The influence of environment on daily maintenance behaviour of free-ranging Shorthorn cows in Central Australia. I. General introduction and descriptive analysis of day-long activities. Appl. Anim. Ethol. 7:11-26.

Low, W. A., R. L. Tweedie, C. B. H. Edwards, R. M. Hodder, K. W. J. Malafant, and R. B. Cunningham. 1981b. The influence of environment on daily maintenance behaviour of free-ranging Shorthorn cows in Central Australia. II. Multivariate analysis of duration and incidence of activities. Appl. Anim. Ethol. 7:27-38.

Low, W. A., R. L. Tweedie, C. B. H. Edwards, R. M. Hodder, K. W. J. Malafant, and R. B. Cunningham. 1981c. The influence of environment on daily maintenance behaviour of free-ranging Shorthorn cows in Central Australia. III. Detailed analysis of sequential behaviour patterns and integrated discussion. Appl. Anim. Ethol. 7:39-56.

Lynch, J. J. and D. A. Hedges. 1979. The influence of shape of paddock, type of fence and stocking rate on grazing behaviour and social facilitation in Merino sheep. Appl. Anim. Ethol. 5:321-331.

MacCracken, J. G. and R. M. Hansen. 1981. Diets of domestic sheep and other large herbivores in southcentral Colorado. J. Range Manage. 34:242-243.

Mackay, R. S. 1970. Bio-medical Telemetry. John Wiley and Sons, Inc., New York.

Malechek, J. C. and F. D. Provenza. 1984. Analysis of feeding behavior in grazing trials and production studies on small ruminants. Working papers, 2nd Intl. Rangeland Congress, Adelaide, Australia.

Malechek, J. C. and B. M. Smith. 1976. Behavior of range cows in response to winter weather. J. Range Manage. 29:9-12.

McDaniel, K. C. and J. A. Tiedemann. 1981. Sheep use on mountain winter range in New Mexico. J. Range Manage. 34:102-104.

McIlvain, E. H. and M. C. Shoop. 1971. Shade for improving cattle gains and rangeland use. J. Range Manage. 24:181-184.

McNaughton, S. J. 1984. Grazing lawns: Animals in herds, plant form, and coevolution. American Nat. 124:863-886.

Martin, S. C., K. K. Barnes, and L. Bashford. 1967. A step toward automatic weighing of range cattle. J. Range Manage. 20:91-94.

Mebes, H. D. 1979. Do colours affect "normal" behaviour of laboratory and farm animals? Instantaneous change of behaviour by presentation of red in the peach-faced lovebird (*Agapornis roseicollis* (PSITTAFORMES). J. South African Vet. Assn. 50:97-99.

Mullen, K., J. F. Hurnik, and K. M. Ralph. 1980. Note on the effect of recording frequency on the precision of behavioural experiments. Appl. Anim. Ethol. 6:83-86.

Muller, W. J., W. A. Low, C. Lendon, and M. L. Dudzinski. 1976. Variation in grazing patterns of free-ranging cattle in a semi-arid area. Proc. Australian Soc. Anim. Prod. 11:461-464.

Murai, M., W. A. Thompson, and W. G. Wellington. 1979. A simple computer model of animal spacing. Res. Pop. Ecol. 20:165-178.

Murphey, R. M., F. A. M. Duarte, W. C. Novaes, and M. C. T. Penedo. 1981. Age group differences in bovine investigatory behavior. Developmental Psychobiology 14:117-125.

Nelson, A. B. and R. D. Furr. 1966. Interval of observation of grazing habits of range beef cows. J. Range Manage. 19:26-29.

Odell, G. V., J. E. Hall, and W. E. McMurphy. 1977. Biochemical and physiological aspects of animal behavior: Taste and smell. In: R. W. Bullard (ed.). Flavor Chemistry of Animal Foods Symp. American Chem. Soc. 174th Mtg. Washington, D.C. pp. 92-101.

O'shea, J. 1969. Evaluation of a simple device for measuring the time animals spend grazing. J. Agr. Res. 8:329-335.

Owen, D. F. and R. G. Wiegert. 1981. Mutualism between grasses and grazers: An evolutionary hypothesis. Oikos 36:376-378.

Parker, C. F. and A. L. Pope. 1983. The U.S. sheep industry: Changes and challenges. J. Anim. Sci. 57(Suppl. 2):75-99.

Pattinson, N. B., D. I. Bransby, N. M. Tainton, M. J. Savage, and R. M. Kloka. 1981. A grazing clock for measurement of time spent grazing by cattle. Unpublished report of the Department of Pasture Science, University of Natal, Pietermaritzburg. 12 pp.

Paulsen, H. A., Jr. and F. N. Ares. 1962. Grazing values and management of black grama and tobosa grasslands and associated shrub ranges of the Southwest. Forest Service Tech. Bull. 1270. U.S. Government Printing Office, Washington, D.C. p. 56.

Penning, P. D. 1983. A technique to record automatically some aspects of grazing and ruminating behaviour in sheep. Grass and Forage Sci. 38:89-96.

Petrusevics, P. M. and T. W. Davidson. 1975. A biotelemetry system for cattle behaviour studies. In: Proc. Iree. pp. 72-76.

Poindron, P., P. LeNeindre, F. Levy, and E. B. Keverne. 1984. Les Mecanismes physiologiques de l acceptation du nouveau-ne chez la brebis. Biol. Behav. 9:65-88.

Price, E. D. and K. A. Tomlinson. 1979. Species affinities in domestic sheep and goats. California Agr. 33:4-6.

Rice, R. W., M. D. MacNeil, T. G. Jenkins, and L. J. Koong. 1982. A simulation model of grazing behavior in cattle. Proc. West. Sec. American Soc. Anim. Sci. 33:301-304.

Rittenhouse, L. R. and R. L. Senft. 1982. Effects of daily weather fluctuations on the grazing behavior of cattle. Proc. West. Sec. American Soc. Anim. Sci. 33:305-307.

Rossing, W., A. H. Ipema, J. A. Kerkhof, H. G. Pluygers, G. J. Garsen, and K. Maatje. 1984. Micro-electronics in dairy herd management. In: Agricultural Electronics -- 1983 and Beyond. Vol. II. Livestock Production Systems. In: Proc. Natl. Conf. Agr. Elec. Appl., ASAE Pub. 9-84. American Soc. Agr. Eng., St. Joseph, MI. pp. 606-613.

Ruckebusch Y. and L. Bueno. 1978. An analysis of ingestive behaviour and activity of cattle under field conditions. Appl. Anim. Ethol. 4:301-313.

Sambraus, V. H. H. 1977. Observations and experiments on social behaviour in a herd of cattle during an eleven year period. Appl. Anim. Ethol. 3:199-200.

Sambraus, V. H. H., B. Fries, and K. Osterkorn. 1978/79. Das sozialgeschehen in einer herde hornloser hochleistungsrinder. Z. Tierz. Zuchtgsbiol. 95:81-88.

Sato, S. I. Ito and K. Hayashi. 1976. Studies on the spatial pattern of grazing cattle. J. Japanese Grasslands Sci. 22:313-318.

Scarnecchia, D. L., A. S. Nastis, and J. C. Malechek. 1985. Effects of forage availability on grazing behavior of heifers. J. Range Manage. 38:177-180.

Schien, M. W. and M. H. Fohrman. 1955. Social dominance relationships in a herd of dairy cattle. British J. Anim. Behav. 3:202-212.

Scott, D. and B. L. Sutherland. 1981. Grazing behaviour of merinos on an undeveloped semi-arid tussock grassland block. J. Exp. Agr. 9:1-9.

Scott, N. R. 1984. Livestock buildings and equipment: A review. J. Agr. Eng. Res. 29:93-114.

Senft, R. L., L. R. Rittenhouse, and R. C. Woodmansee. 1985. Factors influencing patterns of cattle grazing behavior on shortgrass steppe. J. Range Manage. 38:82-87.

Shaw, R. B. and J. D. Dodd. 1979. Cattle activities and preferences following strip application of herbicide. J. Range Manage. 32: 449-452.

Simonsen, H. B. 1979. Grooming behaviour of domestic cattle. Nordisk Vet. Med. 31:1-5.

Sinkovic and F. Bures. 1982. Behaviour and efficiency of animals on intensively and extensively managed pastures. Vyskumny Ustav Luk a Pasienkov, Banska Bystrica, Czechoslovakia. pp. 875-877.

Skiles, J. W. 1984. A review of animal preference. In: Developing Strategies for Rangeland Management. Westview Press, Boulder, CO. pp. 153-213.

Squires, V. R. 1974. Grazing distribution and activity patterns of merino sheep on a saltbrush community in south-east Australia. Appl. Anim. Ethol. 1:17-30.

Squires, V. R. 1975a. Ecology and behaviour of domestic sheep *(Ovis aries):* A review. Mammal Rev. 5:35-37.

Squires, V. R. 1975b. Environmental heterogeneity as a factor in group size determination among grazing sheep. Proc. New Zealand Soc. Anim. Prod. 33:184-190.

Squires, V. R. 1975c. Social behaviour in domestic livestock: The basis for improved animal husbandry. Appl. Anim. Ethol. 1:177-184.

Squires, V. R. 1978. Effects of management and the environment on animal dispersion under free range conditions. In: Proc. 1st World Congress Ethol. Appl. Zootech. Garsi, Madrid. pp. 323-334.

Squires, V. R. 1981. Livestock Management in the Arid Zone. Inkata Press, Melbourne, Australia.

Squires, V. R., G. T. Daws, and R. A. Bawden. 1969. An automatic recording unit for photographic studies of behavior of domestic animals. J. Biol. Photo. Assn. 37(4):188-198.

Stebbins, G. L. 1981. Coevolution of grasses and herbivores. Ann. Missouri Bot. Gard. 68:75-86.

Stermer, R. A. and L. R. Smith. 1978. Telemetry systems for monitoring physiological responses of cattle. ASAE Tech. Paper No. 78-6009. American Soc. Agr. Eng., St. Joseph, MI. 15 pp.

Stobbs, T. H. 1970. Automatic measurement of grazing time by dairy cows on tropical grass and legume pasture. Trop. Grasslands 4:237-244.

Stobbs, T. H. and L. J. Cowper. 1972. Automatic measurement of the jaw movement of dairy cows during grazing and rumination. Trop. Grasslands 6:107-112.

Stoddart, L. A. and A. D. Smith. 1943. Range Management. McGraw-Hill Book Company, Inc., New York.

Stoner, D. L., J. W. Stuth, J. F. Hunter, and H. A. Pearson. 1979. Transduction of changes in esophageal geometry associated with swallowing. Biomed. Sci. Instr. 15:113-116.

Stricklin, W. R. and G. H. Crow. 1978. A computer program to analyze spacing behavior of animals. Canadian J. Anim. Sci. 58:805. (Abstr.)

Stricklin, W. R., H. B. Graves, and L. L. Wilson. 1979. Some theoretical and observed relationships of fixed and portable spacing behavior of animals. Appl. Anim. Ethol. 5:201-214.

Tanner, G. W., L. D. Sandoval, and F. G. Martin. 1984. Cattle behavior on a south Florida range. J. Range Manage. 37:248-251.

Thetford, F. O., R. D. Pieper, and A. B. Nelson. 1971. Botanical and chemical composition of cattle and sheep diets on pinyon-juniper grassland range. J. Range Manage. 24:425-431.

Thines, G. and M. Soffie. 1977. Preliminary experiments on colour vision in cattle. Vet. Ethol. Proc. British Vet. J. 133:97-98. (Abstr.)

Tribe, D. E. 1950. The behaviour of the grazing animal: A critical review of present knowledge. J. British Grasslands Soc. 5:209-224.

Tribe, D. E. 1980. Animal production in the 21st century. J. Australian Inst. Agr. Sci. 46:36-40.

USDA. 1983. Agricultural Statistics. U.S. Government Printing Office, Washington, D.C.

Van Dyne, G. M. and H. F. Heady. 1965. Interrelations of botanical and chemical dietary components of animals grazing dry annual range. J. Anim. Sci. 24:305-312.

Van Dyne, G. M. and J. L. Van Horn. 1974. Distance traveled by sheep on winter range. Proc. West. Sec. American Soc. Anim. Sci. 16:1-6.

Van Rees, H. and G. D. Hutson. 1983. The behaviour of free-ranging cattle on an alpine range in Australia. J. Range Manage. 36:740-743.

Vavra, M. and F. Sneva. 1978. Seasonal diets of five ungulates grazing the cold desert biome. In: D. N. Hyder (ed.). Proc. 1st Intl. Rangeland Congress. Soc. Range Manage., Denver, CO. pp. 435-437.

Wagnon, K. A. 1963. Behavior of beef cows on a California range. California Agr. Exp. Sta. Bull. 799. Davis. 58 pp.

Walser, E. S. and P. Hague. 1980. Variations in the structure of bleats from sheep of four different breeds. Behaviour 75:20-35.

Wilson, A. D. 1974. Water consumption and water turnover of sheep grazing semiarid pasture communities in New South Wales. Australian J. Agr. Res. 25:339-347.

Wilson, A. D. 1976. Comparison of sheep and cattle grazing on a semiarid grassland. Australian J. Agr. Res. 27:155-162.

Wilson, A. D. 1978. The relative production from sheep, cattle, and goats on temperate rangelands in Australia. In: D. N. Hyder (ed.). Proc. 1st Intl. Rangeland Congress. Soc. Range Manage., Denver, CO. pp. 444-446.

Wilson, A. D. and R. D. Graetz. 1980. Cattle and sheep production on an *Atriplex vesicaria* (saltbrush) community. Australian J. Agr. Res. 31:369-378.

Wilson, R. T. 1984. Mixed species stocking and the vital statistics and demography of domestic animals in the arid and semi-arid zones of northern tropical Africa. Working papers, 2nd Intl. Rangeland Congress, Adelaide, Australia.

Winter, V. P., J. H. Weniger, J. E. Huhn, and E. S. Tawfik. 1980. Vergleichende untersuchugen an taurinen und zebuinen rindern und deren kreuzungen bie weide-bzw. Stallhaltung am tropischen standort Bangladesh. Z. Tierzuchtg. Zuchtgsbiol. 97:144-157. (Abstr.)

Zeeb, K. 1976. Systematical principles for animal management in accord with behavioural features and with reference to cattle. Appl. Anim. Ethol. 2:357-369.

Zoloth, S., R. J. Dooling, R. Miller, and S. Peters. 1980. A minicomputer system for the synthesis of animal vocalizations. Z. Tierpsychol. 54:151-162.