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MOUNTAIN RANGELANDS
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Several aspects of cattle grazing behavior and distribution were studied on mountain rangeland dominated by ponderosa pine-Douglas fir, mixed conifer, and white fir forest communities in northeastern Oregon.

The association between upland distribution, determined by forage utilization and by direct cattle observation, and several habitat factors was studied through correlation and regression analysis. Cattle use of small riparian meadows was monitored by periodic utilization sampling and time-lapse photography. Individual cattle were marked to study the occurrence of home range behavior.

Riparian meadows were the most heavily used plant communities averaging about 75% forage utilization over all sites and years. Utilization levels were similar under continuous grazing and the early and late grazing periods of a two pasture deferred-rotation system. Late grazing increased the frequency of cattle presence on the riparian meadows as compared to early grazing. Large quantities of forage, a dependable source of water, and gentle

topography combined to make riparian meadows the major influence on cattle distribution. Afternoon temperature and relative humidity were similar in riparian meadow versus upland plant communities.

Upland forage use averaged 8-12% and the highest estimated utilization on a single site was 36%. When available, clearcut forest sites were the most highly preferred upland plant community, especially when introduced pasture grasses were present. Late grazing decreased use on the clearcut sites by 1/3 because of the advanced maturity of the herbage. Cattle use appeared to shift to the riparian meadows in this situation.

A large percentage of cattle were observed within the ponderosa pine-Douglas fir communities although these were not preferred range areas. The grassland, mixed conifer forest, and white fir forest communities were all lightly used by cattle.

Slope gradient was the physical habitat factor most consistently associated with cattle distribution. Salt distribution also appeared to be important. Water distribution did not limit cattle grazing behavior.

Cattle restricted their activities to home ranges averaging 343 ha. Home range size was similar between purebred and crossbred cattle.

GRAZING BEHAVIOR AND DISTRIBUTION OF CATTLE ON MOUNTAIN RANGELANDS

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INTRODUCTION

Proper animal distribution is an integral part of effective range management. Through proper distribution the range manager attempts to gain maximum safe use over as wide an area as possible without causing serious damage to any portion within it. Mountain rangelands often exhibit complex combinations of topography, vegetative communities, successional stages, and water distribution which create especially difficult grazing distribution problems. For instance, utilization may reach 75 to 80% on gently sloping drainages while steep slopes 150 m away receive 5% use or less (Phillips 1965). On a relatively small range unit of 690 ha, as much as 62% of the area received no use by cattle in northern Utah (Gonzalez 1964). Livestock behavior, as influenced by natural habitat factors as well as imposed managerial factors, must be thoroughly understood as an aid in developing more effective methods of livestock distribution.

This study was conducted as a portion of the Oregon Range Evaluation Project under the direction of the U.S. Forest Service. It was an attempt to characterize and quantify a portion of the many relationships between cattle distribution and the mountain range environment. The major objectives of the study were to determine for a mountain rangeland grazing allotment:

1. The effects of several physical, biological, and managerial factors on the upland grazing distribution of cattle;

2. The patterns of habitat use and preference of cattle on mountain rangelands;

3. The intensity and pattern of cattle use of small riparian meadows and the effects of grazing management systems on these patterns;

4. The aerial temperature and moisture regimes of different vegetation types in relation to cattle grazing distribution;

5. The possible existence and nature of home range behavior of cattle.

LITERATURE REVIEW

Grazing Distribution on Mountain Rangelands

The distribution of grazing over a rangeland area is influenced by many factors. These can be divided for discussion into two broad classes, natural or inherent factors and managerial or imposed factors. The effects of the more common factors such as slope gradient and water distribution are fairly well established and generally considered to be common knowledge. Other factors such as behavioral psychology of the grazing animal and the effects of microclimate are less well defined. The next several paragraphs will focus on natural factors of the environment which influence cattle grazing distribution.

Plant Community. Vegetation type or plant community is a major factor influencing the use of space by cattle. The great majority of research indicates cattle seldom, if ever, use plant communities in proportion to their occurrence. Instead, they exhibit marked preference for some while avoiding others. A classic example is the disproportionate use of riparian zones relative to upland areas (Phillips 1965, Roath 1980, Pinchak et al. in press). The main factors contributing to the phenomenon of plant community preference appear to be plant species composition and total forage production.

In general, cattle prefer to graze those areas in which the proportion of palatable and preferred species is greatest (Julander and Jeffery 1964, Patton 1971, Miller and Krueger 1976, Pinchak el al. in press). In the case of cattle, preferred species would most often be grasses or grasslike plants. Plant preference often changes seasonally and so habitat preference can be expected to shift also (Bjugstad and Dalrymple 1968, Bryant 1979, Skovlin 1961). However, while Cook (1966) found the proportion of palatable species had a positive effect on cattle utilization, other factors appeared to be more important. Van Vuren (1982) found the influence of the amount of palatable herbage on a site was completely outweighed by physical factors.

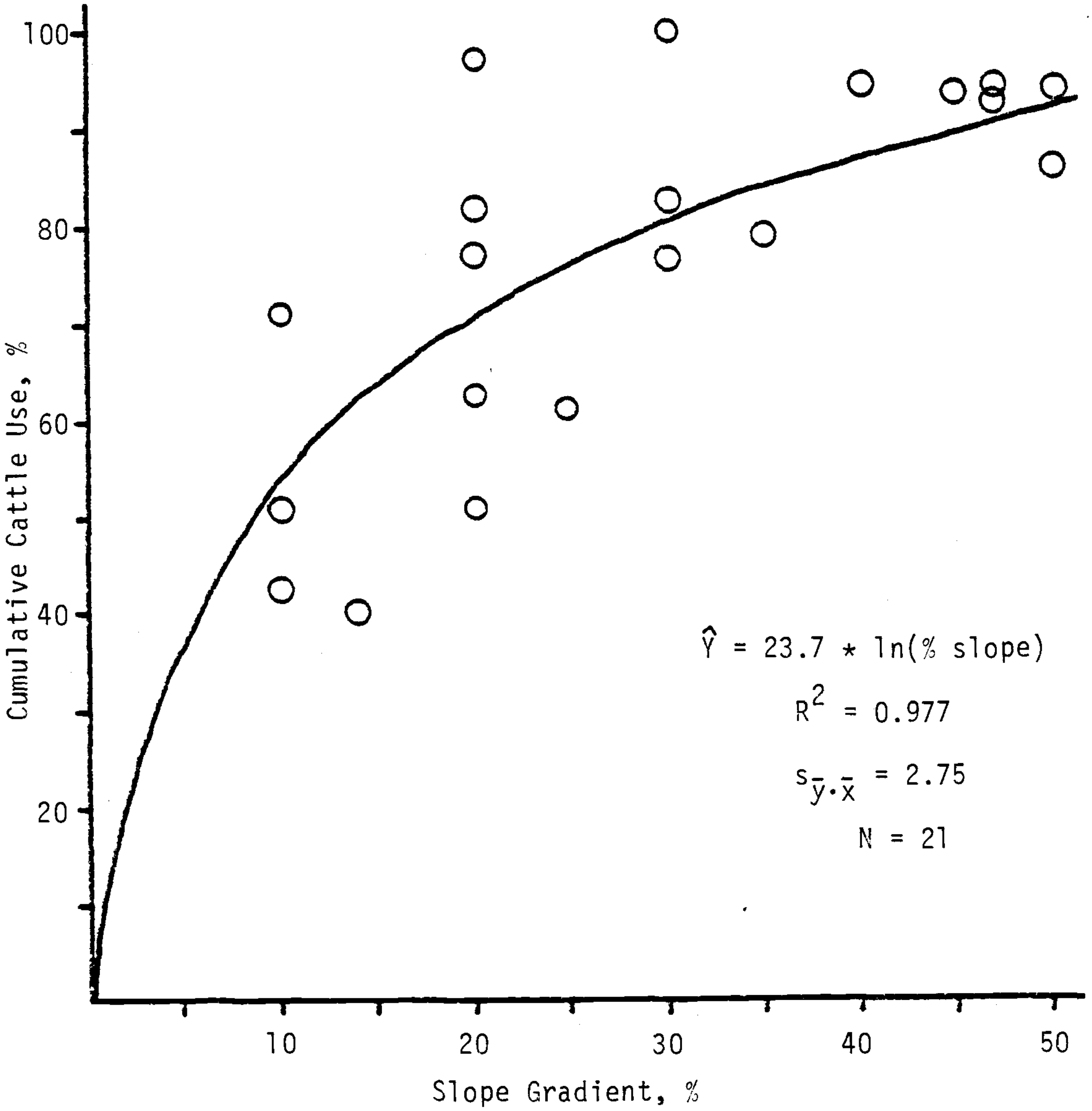
The quantity of forest tree canopy cover or basal area is another example of the species composition effect. There appears to be general uniformity in the selection of grass or shrub communities over forest by cattle (Julander and Jeffery 1964, Reynolds 1966, Berg and Hudson 1982, Long and Irwin 1982). Within the forest, cattle use declines as crown cover or basal area increases (Hedrick et al. 1968). Clary et al. (1978) found a combination of tree crown cover and basal area could explain 72% of the variation in observed cattle use with a negative logarithmic relation. This effect is probably more a response to herbage production than tree cover itself since a similar relation exists between tree crown cover or basal area and understory production (Clary et al. 1975, Krueger 1980). This is supported by Reynolds (1969) who found 70% more cattle use in aspen stands than conifer stands. Because of the unique characteristics of aspen communities, this type had slightly more basal area but four times as much understory production as the conifer type. Another effect pointed out by Glendening (1944) is that heavy needle litter in overmature timber stands may restrict plant accessibility for grazing and result in cattle avoidance of these situations.

Herbage production differences among plant communities appear to influence cattle distribution. However, it is difficult to separate this effect from species composition and canopy cover effects since all three are interrelated. For instance, Miller and Krueger (1976) found a high correlation between forage production and animal use but the various plant communities also had greatly different species compositions. Studies from an aspen (*Populus tremuloides*) community (Kranz and Linder 1973) and an annual grassland (Wagnon 1968) in which species composition was held relatively constant reported correlation coefficients associating animal use and herbage production of greater than 0.90. Similar results reported by Reynolds (1969) were discussed in the previous paragraph.

A final component of plant communities which is known to influence cattle use is the presence of excessive amounts of down timber. The nature of this effect is certainly obvious to anyone who has seen a thinned or logged timber stand which has not undergone slash disposal. Reductions in forage utilization of 30% have been documented for modest slash accumulations (Glendening 1944, Reynolds 1969) and heavier accumulations could certainly result in almost total cattle exclusion. Hedrick et al. (1968) emphasized the importance of properly disposing of logging slash and keeping skid trails free of down timber.

Physiography. Slope gradient is often considered the overriding influence on cattle use of mountain ranges. Cattle tend to favor relatively level drainage bottoms, ridge tops, and benches, lower slopes, and areas adjacent to trails on steeper slopes (Glendening 1944, Julander and Jeffery 1964, Phillips 1965, Patton 1971). Information from several studies is combined in Figure 1 to illustrate the relationship between cumulative percent cattle use and percent slope. Even though the availability of various slope classes and community types was certainly different among studies, a logarithmic relationship is clearly present. Slopes of 30-40% appear to be the upper limit of extensive cattle use. Patton (1971) reached the same conclusion regarding maximum slope limits. Six of eleven factors which significantly affected cattle distribution on Utah foothill ranges involved some measure of slope steepness (Cook 1966). Van Vuren (1982) calculated a correlation of -0.85 between the square root of slope (in degrees) and percent cattle use. This would indicate a relation similar to Figure 1.

On the other hand, Miller and Krueger (1976) and Clary et al. (1978) indicated little or no relation between degree of use and slope steepness. Slopes averaged less than 15% in both studies so steepness was not a limiting factor in either case. The location of preferred communities on steeper areas may at least partially override the influence of slope gradient (Gonzalez 1964, Bryant 1979).



References: Julander and Robinette 1950, Gonzalez 1964, Julander and Jeffery 1964, Mackie 1970, Knowles 1975, Wittinger 1978, Bryant 1979, Berg and Hudson 1982.

Figure 1. Relationship between cumulative cattle use and slope gradient on mountain rangeland composited from published research.

Actually, distance upslope and slope steepness have been shown to interact, and so the two should be discussed in combination. For example, Mueggler (1965) found cattle use would extend 1275 m upslope on a 10% gradient but only 550 m upslope on a 40% gradient. By combining a negative exponential function of distance upslope and a linear function of slope steepness, he could account for 81% of the variation in cumulative cattle use. All other habitat factors were held relatively constant in this study on mountain grasslands. Phillips (1965), working in roughly similar conditions in Idaho and Nevada, found relationships very similar to Mueggler's. Glendening (1944) also noted the interaction between slope length and gradient even though slope gradients were generally not excessive on his study area.

Slope orientation or aspect is not usually considered to be a direct factor in cattle distribution (Wagnon 1968, Mackie 1970, Wittinger 1978, Van Vuren 1982). Aspect may operate in an indirect fashion by influencing plant community distribution and microclimate (Glendening 1944). Gonzalez (1964) found cattle preferred north and east slopes and avoided west aspects while Phillips (1965) reported substantially less use on north exposures. No explanations were given for these observations. Knowles (1975) indicated cattle were little affected by aspect in general but showed a tendency to avoid north aspects in the fall of the year.

Cattle have been observed to avoid areas with excessive surface rock when less rocky areas are available (Culley 1938). Surface rock covering of greater than 40% reduced utilization of key forage species by 50-75% in northern Arizona (Glendening 1944). Mueggler (1965) could determine no relation between surface rock and cattle use but it could well be that the amount of surface rock did not reach limiting levels on the mountain grassland sites used in that study.

Water Distribution. Since water is essential for life, water availability and distribution is expected to have a major impact on the use of space by cattle. Patton (1971) reported a linear decrease totaling about 60% in cattle use from 0 to 1200 m from water followed by a rapid drop to no use at 1600 m. Linear decreases with distance were also found by Van Vuren (1982), Glendening (1944), and Miller and Krueger (1976). Other workers (Mackie 1970, Phillips 1966, Roath 1980) have indicated a curvilinear negative relation between distance from water and use with the steepest decreases in use occurring within 400 m from water. Maximum limits of cattle use have ranged from 660 m (Pinchak et al. in press) to 8000 m from water (Glendening, 1944).

Some studies have indicated a stronger influence for vertical rather than horizontal distance from water (Roath 1980). Van Vuren (1982) reported the correlation of cattle use and the square root of the vertical distance to water as -0.96. He indicated this effect was apparently independent of slope.

At least three research reports (Julander and Jeffery 1964, Cook 1966, Clary et al. 1978), have indicated little or no effect of water distribution on cattle use on well watered ranges.

Microclimate. The timing and duration of certain cattle activities such as grazing and ruminating have been related to daily weather patterns (Dwyer 1961, Ehrenreich and Bjugstad 1966, Shaw and Dodd 1979). However, cattle response to the differential microclimates which almost always occur on a large range area has not been demonstrated other than on a casual basis. Weaver and Tomanek (1951) indicated cattle preferred windy areas of a pasture to increase summer cooling and to avoid insects. Holscher and Woolfolk (1953) reported a reversed situation in winter in which cattle preferred areas protected from wind. Bryant (1979) demonstrated temperature and relative humidity differences between upland and riparian communities as well as differential cattle use. He felt cattle responded more to relative humidity than to temperature and communities with average relative humidities in the range of 60-70% would be preferred.

Annual Precipitation Variations. Below or above average precipitation has been shown to influence animal distribution. Gonzalez (1965) reported large decreases in the amounts of both unused and severely overused range in a favorable precipitation year as compared to a year deficient in moisture. Data from Mackie (1970) suggest the same trend. Increased dispersion of cattle was attributed to an increase of water availability in temporary water developments. Knowles (1975) stated cattle dispersion across large pastures appeared to be less rapid when forage conditions were above average but effects on final dispersion patterns were not mentioned. No differences in cattle distribution for average, dry, or wet years were noted by Wagnon (1968) working in relatively small pastures (less than 220 ha).

Summary of Natural Habitat Factors. It appears plant community characteristics, slope gradient and length, and water distribution are the major determinants of cattle distribution on mountain ranges. Although each was discussed by itself, all of the factors undoubtedly interact in many complicated ways. For instance, meadow vegetation types, the most preferred plant communities on mountain ranges, almost invariably occur on gentle or level slopes with water closely available. Vegetative and physical factors often cannot be separated. Situations were discussed in which each of the three major factors was dominant and in which each was overridden by the others. This illustrates that in evaluating cattle distribution, basic principles must be reapplied in each situation of interest while the use of rigid formulas will almost certainly be unsuccessful.

The next several paragraphs will review the influence of various managerial factors on cattle grazing distribution.

Water Development. Because of the significant influence of water distribution as discussed above, water development is often considered one of the best tools for improving cattle distribution (Skovlin 1965, Cook 1967). Hooper and Workman (1970) reported an increase of 80-150 animal unit months (AUM) of grazing capacity per water development on Utah foothill range. However, Goebel (1956) aptly pointed out new developments may simply alleviate local overuse problems with no gain of additional animals.

Gonzalez (1964) and Goebel (1956) also indicated the value of many small temporary developments in promoting even utilization. On the other hand, Bryant (1979) found in steep pastures with water available in drainage bottoms, upland water developments may have limited value in improving upland grazing use.

Fencing. Distribution problems often increase in larger pastures due to the increased heterogeneity of plant communities and topographic situations (Williams 1954). Intensive fencing would seem to be the ultimate solution for gaining control of complex distribution problems. However, it is the most expensive method of influencing distribution on mountain ranges with high initial construction and annual maintenance costs (Skovlin 1965).

Cook and Jeffries (1963) found fencing foothill ranges into 280-400 ha pastures increased use very slightly on slope gradients greater than 45% with no change in use patterns on slopes of lesser gradients. Cross-fencing added only about 5.6 additional AUM's per pasture in this situation (Hooper and Workman 1970). Yearly cattle distribution was little affected by cross-fencing on rough range in central New Mexico (Hickey and Garcia 1964). The real value of cross-fencing may be that it allows the implementation of special grazing plans as discussed below.

Grazing Management. Stocking rate and grazing plan (including season of use) may have considerable effect on cattle distribution. Williams (1954) pointed out distribution problems often increase as stocking rate decreases because animals are allowed to be more selective. As more animals are added, the quantity of resources available per individual decreases so a more complete and even utilization pattern results as observed by Peterson and Woolfolk (1955). However, while achieving proper use on less preferred sites, increasing stocking rate alone may result in the total destruction of preferred sites.

While specialized grazing plans such as deferred-rotation and rest-rotation were designed to promote plant response, one of the major values of such systems is claimed to be improved animal distribution (Stoddart et al. 1975). This is due to the confinement of roughly the same animal numbers to a smaller area with results similar to those discussed above. However, a combination of shorter grazing periods and periods of deferment or rest prevent the degradation of preferred sites.

The effects of special grazing plans on cattle distribution are seldom reported. Johnson (1965) found a four pasture rotation system promoted more even forage use than continuous grazing but that a four pasture rest-rotation system had no influence on distribution in northwestern Wyoming. Little (1971) observed light use on slopes greater than 30% on a mountain allotment under continuous grazing. Under rest-rotation grazing on the same allotment, substantial use was obtained on gradients of up to 45%. On sagebrush-grass range, a three pasture rotation reduced the area of heavy and light use and increased the area of proper use by 44% over continuous grazing (Hyder and Sawyer 1951). These results are at least partially confounded with water development and fencing since the latter two practices must be put in place before a special grazing plan can be implemented.

Trail Construction. Roads and trails connecting preferred grazing areas are readily used by cattle. Patton (1971) found most grazing on steep slopes was confined to bands about 80 m in width and centered on a contour trail. In northern Arizona, forage utilization decreased seven percentage units for each 200 m of distance from a major trail (Glendening 1944). The use of logging skid trails and roads as access routes for cattle was noted by Hedrick et al. (1968) and Roath (1980). This use was improved if the trails had been seeded to introduced pasture grasses. Cook (1967) considered trail construction to be the most neglected distribution tool while Hooper and Workman (1970) estimated an increase of 70-100 AUM's per $100 spent on trail construction.

Vegetative Manipulation. Practices such as fertilization, herbicide application, seeding, and prescribed burning often change plant species composition and palatability which may then alter cattle distribution. Seeding of palatable introduced grasses in forest clearcuts created a highly preferred and heavily used community type in northeastern Oregon (Miller and Krueger 1976). Studies from mountain rangelands in Wyoming (Smith and Lang 1958) and Utah (Cook and Jeffries 1963) have shown utilization increases of 25-100% on steep slopes when nitrogen fertilizer is applied on 5-15 ha areas. Increased returns from this practice include more available forage on fertilized areas, heavier utilization of this increased forage resource, and heavier utilization of surrounding unfertilized areas (Hooper et al. 1969). Considering all three effects, Hooper and Workman (1970) calculated a return of 10.8 AUM's per fertilized hectare. Carryover effects lasted for up to three years. They recommended treating a minimum of 10-20 ha to avoid excessive animal concentration on smaller areas.

Cook and Jeffries (1963) also applied 2,4-D for big sagebrush (*Artemisia tridentata*) control alone and in combination with fertilizer on steep slopes. Herbicide application appeared to be the major factor influencing cattle use. Herbicide alone increased utilization 74% while the combination treatment yielded an 85% increase. This compared with a 24% increase for fertilizer alone. The authors stated that while cattle did not seek out the treated areas, they tended to remain longer on treated plots when herded onto the slopes. In contrast, Long and Irwin (1982) reported cattle on Wyoming foothills avoided areas on which sagebrush had been controlled by herbicides while using unsprayed areas about in proportion to their availability. No explanation was given for this result.

Class of Animal. It has often been suggested younger animals will make more even use of rough ranges than older age classes. Hedrick et al. (1968) ranked different animal classes in order of most even distribution as: yearling steers, yearling heifers, 2-3 year old cows, older dry cows, and older cows with calves. In central New Mexico, yearling heifers were clearly superior for achieving even range use, followed by yearling steers (Hickey and Garcia 1964). Cows with calves were closely tied to water and protected calving areas which resulted in poor distribution compared to yearlings.

Bryant (1979) reported different results from northeastern Oregon. He found cows with calves made more even use of steep slopes than yearling heifers during most of the summer season. This was attributed to the fact that the cows had grazed the area in previous years and were familiar with the locations of preferred sites. However, the pastures were relatively small, less than 200 ha, and it seems that the yearlings would have had adequate opportunity to explore the entire area in a three month grazing season.

From a slightly different perspective, Skovlin (1957) observed cattle reared on rough home ranches and winter fed on the range made better use of mountain summer ranges than cattle with less vigorous backgrounds. Claims are often made that one breed of cattle or another makes better use of rough terrain but this possibility has not been substantiated on mountain rangelands.

Salting. Manipulating cattle distribution by strategically locating salting stations is a classic range management tool (Chapline and Talbot 1926). Salt must be placed at least 400 m from water to achieve a positive effect (Skovlin 1965). It has also been emphasized that on rough topography cattle may have to be herded to salt grounds several times before they will make proper use of the location (Chapline and Talbot 1926, Skovlin 1957).

On Utah foothills, Cook (1967) found proper salting increased grazing capacity by 19%. Patton (1971) reported relatively uniform use out to 1000 m from salt with a rapid drop to no use at 1100 m. A significant correlation of 0.80 between utilization and the square root of the distance from salt was calculated by Roath (1980). At distances less than 1200 m from water, salt increased utilization by 12 percentage units within a 100-200 m radius (Phillips 1965). Farther out from water, salt was able to slow the normal rate of utilization decline. Bjugstad and Dalrymple (1968) observed a yearling heifer walk from an empty salt ground completely across a 500 ha pasture to look for salt at another location.

Salt is probably not a primary determinant of utilization patterns but rather a secondary practice (Hedrick et al. 1968). Salt distribution was not useful in predicting utilization patterns on foothill range (Cook 1966). Placement of salt in "inconvenient" sites (not directly adjacent to trails) depressed salt consumption by 50% and had no effect on utilization patterns on California foothill range even though all pastures were less than 220 ha in size (Wagnon 1968). Bryant (1979) found no useful effect of salt on rough pastures as cattle did not alter normal behavioral patterns to seek it.

Herding. Gathering groups of animals and moving them to unused portions of the range on a regular basis may improve cattle distribution. Phillips (1965) took measurements on twelve range allotments in Idaho and Nevada, six of which employed full-time riders while the other six did not. On areas with slope gradients below 30% and within 600 m from water, allotments with riders had utilization levels 8-10 percentage units below allotments without riders. Beyond these limits, no differences in utilization were noted. On slope gradients less than 35%, Cook (1967) found utilization increased from 7% initially up to 27% with riding 2-4 times per week. This resulted in an increase in grazing capacity of 1200 AUM's. On the same area, riding was found to be more effective after July 1 (Cook and Jeffries 1963). This probably occurred because less forage was available on bottomland sites at that time due to earlier animal concentrations.

Skovlin (1957) pointed out the range rider is the key element in determining the success of a range management plan because he/she is in close touch with actual forage and animal conditions on the ground. The same author also stated riding is a supplementary practice which brings other more important practices to their full potential (Skovlin 1965). This same view was expressed by Hedrick et al. (1968).

Summary of Managerial Factors. Water development, vegetative manipulation, trail construction, and changing class of animal appear to be the major practical distribution tools. Grazing management can also be a major influence but it usually depends on increased fencing. Salting and herding are seen more as secondary practices.

Hooper and Workman (1970) calculated the economic feasibility of various distribution practices. Under the conditions of their study, fencing was the only economically infeasible practice while water development, fertilization, trail construction, salting, and herding produced returns higher than costs. They also indicated that unless the extra forage made available was actually used, none of the practices were economical. However, these practices may also be justified in cases where, because of local overuse, a reduction in animal numbers would be required unless improved distribution is achieved.

Gaining the best possible distribution is more art than science. Each local situation is different and combinations of practices must be tailored to specific needs (Williams 1954, Skovlin 1965). Distribution patterns have yet to be predicted by mathematical means. They can only be accurately determined by applying good management and observing the results (Cook 1966). Finally, achieving good cattle distribution is a continuous and dynamic task. Success can only be achieved by making adjustments as weather patterns, water supplies, forage conditions, and palatabilities change throughout the grazing season.

Cattle Use of Riparian Meadows

Riparian meadows are narrow, highly productive plant communities occurring along stream courses. These meadows are usually dominated by grasses and grasslike plants but shrubs are often a major vegetative component. Differential use of these riparian meadows compared to adjacent upland areas is a special case of the distribution problems discussed in the previous section. Extreme cattle preference for riparian meadows is the major influence on overall grazing distribution on mountain rangelands.

Riparian meadows possess many features which make them attractive to cattle. First, they are highly productive with herbage production 2-20 times greater than nearby forest and grassland communities (Reid and Pickford 1946, Hall 1973, Roath 1980). Second, the herbaceous production is generally dominated by grasses and grasslike plants which are a preferred forage class for cattle (Reid and Pickford 1946, Roath 1980, Kauffman 1982). Third, these communities maintain green palatable herbage for a longer period than adjacent upland communities (Reid and Pickford 1946). Fourth, meadow herbage apparently differs from forest herbage in having lower levels of crude fiber, a forage component negatively correlated with palatability (McLean et al. 1963, McEwen and Dietz 1965). Fifth, because they lie along drainage channels, these communities usually have a readily available source of drinking water and have considerably lower slope gradients than the uplands. Finally, microclimatic differences have been demonstrated between upland and riparian zones which may increase the attractiveness of the meadows to cattle (Bryant 1979).

With the combination of characteristics in riparian meadows listed above, the resulting cattle use patterns can be striking. When forage utilization on meadows reached 75% on Utah foothill range, forage use on upland slopes averaged only 20% (Cook and Jeffries 1963). Phillips (1965) reported almost identical results from southern Idaho. Johnson (1965) and McEwen and Dietz (1965) found the intensity of utilization 3-5 times higher on riparian meadows versus forested communities although meadow use did not exceed 50% in either study. In northeastern Oregon, Roath and Krueger (1982) estimated that 80% of the forage consumed on a mountain allotment came from the riparian meadows which made up 1.9% of the total area. Pinchak et al. (in press) reported 63% of their cattle observations were on meadows comprising 28% of the study area. Long and Irwin (1982) observed 25% of the cattle on the 6% of their study area covered by meadows. Finally, Bryant (1979) made 66% of his cattle observations on riparian meadows or communities directly adjacent to meadows from late July to early September. The meadows and adjacent communities comprised 5.1% of the study pastures. However, in late September, only 12% of the observations were made in the same communities. This shift in habitat use was attributed to thundershowers, which stimulated new forage growth on the uplands; complete utilization of forage in the riparian zone; and a microclimatic shift to more favorable conditions in the uplands.

The same factors which attract cattle to the riparian meadows also attract other animals. Over the last decade, an increasing amount of attention has been given to the idea that excessive cattle use has reduced the usefulness of the riparian zone for wildlife species, especially fish (Ames 1977, Platts 1979, Thomas et al. 1979). Bowers et al. (1979) summarized five studies which indicated an average 200% increase in trout biomass when improper grazing was controlled and streams were managed for optimum trout habitat. Platts (1980) stated streams impacted by cattle overuse are wider, shallower, warmer, have less overhead cover, and have more fine sediment than unimpacted streams. He further stated (1982) livestock impacts are usually small cumulative changes that occur over several years.

The classification of the condition (or health) of an ecosystem as acceptable or unacceptable depends to a large extent on the use that is to be made of the ecosystem. Given this viewpoint, it seems apparent that there will be increasing pressure applied to alter the pattern of livestock use in riparian ecosystems to improve habitat conditions for fish and other wildlife species. There has been some suggestion a reduction in the intensity of use could benefit livestock production as well (Roath 1980). Adequate knowledge of possible techniques to modify cattle grazing habits in relation to riparian zones and the relative efficiency of these techniques then becomes important in achieving management goals.

First, it has been pointed out riparian meadows are greatly different from the surrounding plant communities and this difference must be recognized in management planning (Platts 1979). The special features of these zones should not be overlooked because the importance of the riparian system generally outweighs the small area it occupies.

Fencing and complete exclusion of grazing from riparian ecosystems has often been recommended as a solution to the problem (Armour 1979, Behnke and Raleigh 1979, Bowers et al. 1979). While this would certainly alleviate some aspects of the problem it does not seem practically feasible on a broad scale and also implies that any level of cattle use would be detrimental. Fencing riparian zones to allow strict control of intensity and season of use seems to be a more reasonable approach. Light to moderate late season grazing has been most often advocated (Bowers et al. 1979, Platts 1981) and has shown good results in practice (Claire and Storch 1977, Kauffman 1982). However, the use of fencing will probably be limited economically to the larger and more important riparian ecosystems (Platts 1979). Small riparian meadows along primary drainages may only range from 5 to 30 m in width but may total several miles in length in a single mountain range pasture. These meadows are also the riparian types most susceptible to alteration by cattle grazing (May and Davis 1982). Fencing such areas seems practically infeasible on a large scale. If it is deemed necessary to alter cattle grazing patterns on these small riparian systems, some combination of the practices discussed in the previous section must be employed.

While all of the usual distribution tools have been suggested as at least partial solutions, the implementation of grazing systems has been given the most attention. Continuous season-long or year-long grazing is generally considered to be a detrimental and unacceptable management scheme for riparian meadows (Reid and

Pickford 1946; Pond 1961; Platts 1981, 1982) so some type of specialized plan appears necessary. Platts (1981) rated most standard grazing plans as to their ability to maintain quality in-stream habitat; no system was rated better than fair. He stated none of the present grazing strategies would be satisfactory in this aspect. However, as more data have become available, Platts (1982) has indicated the situation may be somewhat better than first thought.

Few studies have been conducted on the tolerance of riparian meadow plants to various intensities and patterns of defoliation. Pond (1961) clipped meadow plants to simulate heavy continuous (2.5 cm height), moderate continuous (7.5 cm height), and heavy late (2.5 cm height in September) grazing periods. Kentucky bluegrass maintained itself or increased in all treatments. Tufted hairgrass (Deschampsia caespitosa) decreased under heavy continuous use but remained static or increased under the other treatments. Sedges (Carex spp.) generally decreased under continuous use. Production was decreased 10-60% on continuously clipped plots as compared to a single late season clipping. McLean et al. (1963) clipped a sedge meadow at a 5 cm height at intervals ranging from two to eight weeks. Plots clipped at two or four week intervals showed yield reductions of 20-30% over plots clipped at six or eight week intervals. Also, plots which were allowed four to six weeks of regrowth before fall frosts always had the greatest herbage production the following year.

Johnson (1965) reported a four pasture rotation system reduced the intensity of meadow use over a four pasture rest-rotation system or continuous grazing. However, meadow utilization averaged less than 50% under all systems. In northern California, meadows under rest-rotation management for 18 years had significantly larger proportions of sedges and rushes, significantly smaller proportions of forbs, and significantly greater herbage production than meadows under continuous grazing (Ratliff 1972).

Virtually no information is available on the tolerance of the major riparian shrub species to growing season defoliation. However, it appears the intensity of shrub use is related to the season of grazing and the condition of the herbaceous forage. Martin (1979) reported shrub use increased rapidly as the condition of upland forage and water supplies deteriorated. Roath and Krueger (1982) observed shrub use seemed to depend on the condition and availability of other forage for a July-August grazing period. In a dry year shrubs were used immediately while in a normal year shrub use was delayed about four weeks and was more selective. These workers also reported when grazing was delayed until fall, shrub use increased even though herbaceous forage use was low. It was speculated some change may have taken place in the shrubs themselves to alter their palatability. Davis (1982) observed large increases (2500% and 4700%) in riparian shrub and tree stems after two years of rest-rotation grazing in central Arizona.

Physical impacts of cattle on riparian meadows may include soil compaction and streambank erosion. Orr (1960) compared soil physical characteristics between grazed Kentucky bluegrass meadows and exclosures ranging from 5 to 17 years of age. Three of the four experimental sites exhibited an increase in bulk density and a decrease in large pore space in the surface soil under grazing which indicated that soil compaction had occurred. The degree of compaction was related to soil texture but not years of rest and was confined to the surface 10 cm of soil. Overwinter recovery was not determined. Bryant et al. (1972) reported an average production decline for Kentucky bluegrass of 33% under heavy trampling and 20% under moderate trampling as compared to untrampled plots. Overwinter recovery from soil compaction was rather large but not complete. After one year of treatment, several different grazing periods showed no influence on water infiltration rates on lightly grazed meadows in northeastern Oregon (Knight 1978). Orr (1960) noted soils are most susceptible to compaction when the water content is midway between wilting point and field capacity. He felt this would usually occur in early to mid summer on riparian meadow soils. At an earlier time the soils would be too wet to compact easily and later in the summer the soils would become dry enough to resist compaction.

Considering streambank erosion, Buckhouse et al. (1981) reported no clear differences among 19 treatments involving various grazing schedules after two years of study. Continuous grazing tended to result in the largest streambank losses. The overwinter run-off period resulted in more bank loss than the grazing treatments. Hayes (1978) observed no difference in bank loss for a July-August grazing period compared to no grazing after one year. He also found the overwinter period to be the major factor in streambank erosion. After two years, there were no significant differences in stream habitat conditions between rest-rotation grazing and complete protection in central Idaho although there was some trend for decreased bank stability with grazing (Platts 1982). Several authors (Armour 1979, Behnke and Raleigh 1979, Platts 1981) have indicated concern that damage done during the period of concentrated grazing under a rest-rotation system would not be repaired in the ensuing rest period.

Rest-rotation grazing has received the majority of attention to date. Several more years of data will need to be collected before firm conclusions can be drawn concerning the effects of various intensities and seasons of cattle use on riparian ecosystems.

Cattle Home Range Behavior

Home range has been defined as that area which an animal or group of animals travels in the course of its daily activities (Hayne 1949). The idea that cattle exhibit home range behavior was mentioned by Culley (1938) and has often been noted observationally by stockmen.

Elliott (1976) found distinct group home ranges on two mountainous pastures in northeastern Oregon. Each group home range contained a source of water and there was little or no interchange between cattle groups inhabiting each area. The same general group home ranges were formed in both years of the study even though total cattle numbers varied. Group home ranges appeared to be more distinct on the rougher of the two pastures indicating that topographic and visual barriers may be important in formation of the home ranges.

In the same geographic area, Roath (1980) also noted the formation of home ranges. He observed three distinct group home ranges, one encompassing only uplands, one only riparian meadows, and one including portions of both types. Overlap of areas and interchange of individuals among areas was more prevalent than in Elliot's study. Roath suggested cattle entering a range new to them could be behaviorally bonded to certain areas and that this idea could be used to improve cattle distribution.

In the mountains of Arizona, Martin (1979) used radio-telemetry to follow cattle movements. He found well defined home ranges measuring about 1.6 km in width and 2.1-5.6 km in length. These home ranges were generally oriented parallel to ridges and drainages.

Available research indicates cattle do exhibit home range behavior on mountain rangelands. The occurrence of home range behavior could have real effects on cattle distribution and could determine the success of management practices designed to alter distribution patterns.

STUDY AREA

Location

The study was conducted on the Upper Middle Fork Grazing Allotment in the Long Creek Ranger District of the Malheur National Forest. The allotment lies on either side of the Middle Fork of the John Day River approximately 22.5 km northeast of Prairie City in northeastern Grant County, Oregon (Figures 2, 3). The boundaries begin near the town of Bates on the Middle Fork and extend downstream about 16 km to the confluence of the Middle Fork and Ragged Creek. The allotment extends from the Middle Fork to the major watershed boundaries formed by Vinegar Hill on the north and Dixie Butte on the south. The allotment encompasses about 21,800 ha of mountain range and timberland.

Physiography and Soils

Elevations along the Middle Fork range from 1280 m at the eastern boundary to 1160 m on the west. Elevation rises to a maximum of 2480 m on the north and 2315 m on the south. The Middle Fork of the John Day River actually flows from southeast to northwest as it traverses the allotment. This results in a general south-southwesterly aspect for the northern portions of the allotment and a north-northeasterly aspect for the southern portions.

Topography is mountainous and often complex. Both the north and south portions are drained by eight small stream systems. Two

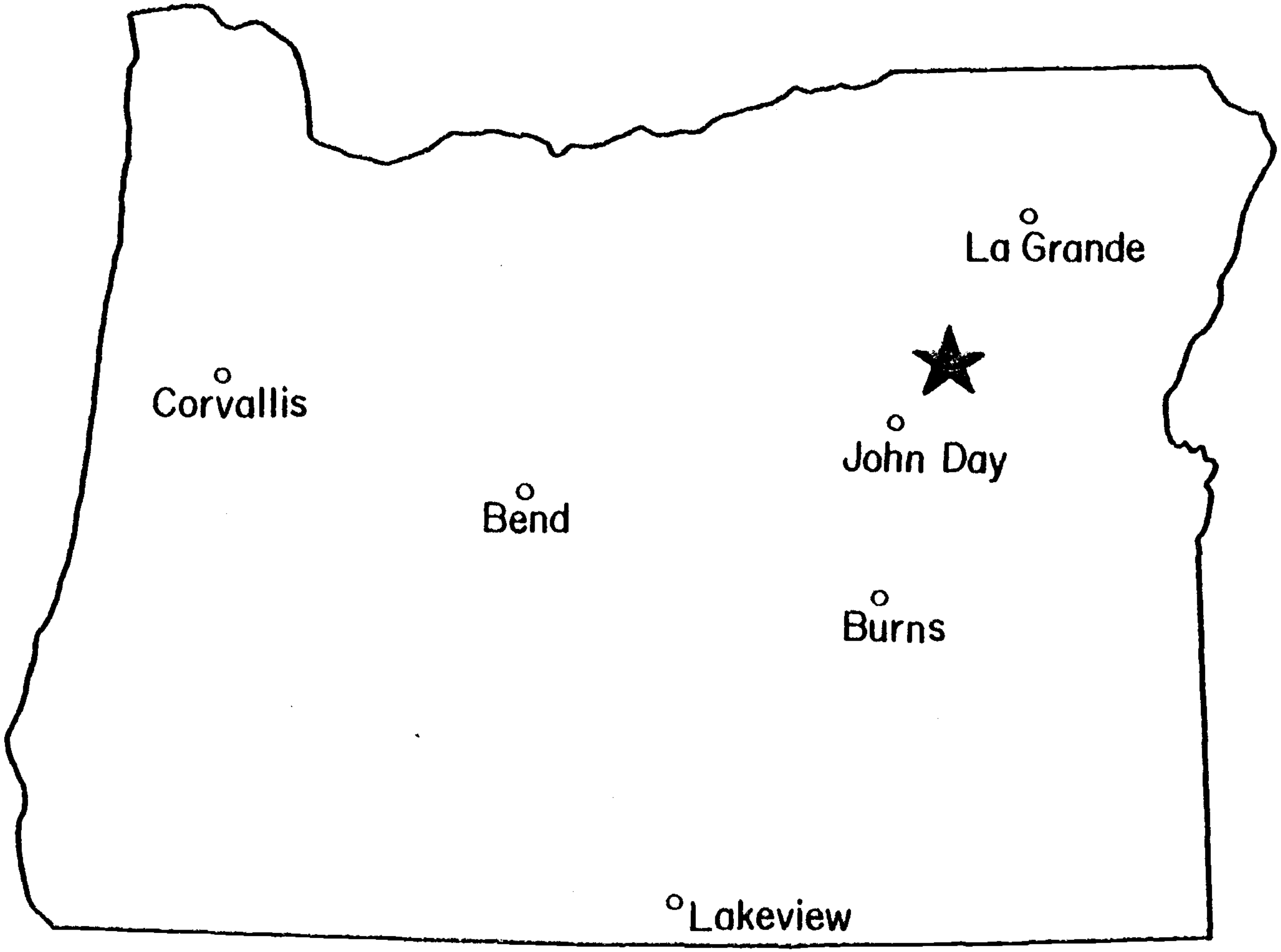


Figure 2. Geographic location of Upper Middle Fork Grazing Allotment in northeastern Oregon.

of these streams on the north side are intermittent while all others exhibit perennial flow. Slope gradient averages 25-30%. Slope gradients range from 0% up to greater than 100% but are generally less than 75%.

The bedrock types under the allotment reflect the volcanic origins of the area (Carlson 1974, Carlson and Rother 1974). The major bedrock type is basalt, a common product of lava flows. A second major rock type is pyroclastic material ejected from volcanoes and later consolidated into rocks or mixed with mudflows and solidified. These two types underlie the entire eastern portion of the area and extend along the length of the Middle Fork. Argillite, a metamorphosed rock of sedimentary origins, is common at higher elevations in the western portion of the allotment. Finally, a large area of intrusive diorite and gabbro is present northwest of Dixie Butte.

Non-forested soils of the allotment are shallow, 10 cm to 38 cm in depth, with loam, clay loam, or clay surface horizons (Carlson 1974, Carlson and Rother 1974). Most are classified as mollisols. These soils are droughty and soil moisture restricts plant growth by June 1 of most years.

The great majority of the forested soils have silt loam surface horizons formed in 25-40 cm of volcanic ash (Carlson 1974, Carlson and Rother 1974). The depth of ash horizons generally increases toward northerly exposures and higher elevations. The depth of ash influence has a great effect on vegetation because of the high waterholding capacity of the ash. Subsoils are generally stony or cobbly loams to clay loams. Total soil depth ranges from 30 cm to 245 cm which also influences the resulting vegetation. These soils are usually classified as inceptisols.

Small amounts of non-ash forested soils are present. These soils have clay loam surface horizons and range from 30 cm to 122 cm in depth. They are found on southerly exposures and are the most xeric forested sites on the allotment. These soils are classified as mollisols.

Climate

The nearest weather station with long term measurements available is located east of Austin, Oregon. This station is about 2 km east of the eastern boundary and 10 km east-southeast of the center of the allotment. The elevation of the Austin station is 1285 m. Weather data from this station have been recorded since 1912 (U.S. Environmental Data and Information Service 1978-1981).

Long term averages of temperature and precipitation and data for the three study years are presented in Table 1. Average annual precipitation at Austin is 508 mm. Precipitation on the allotment, as predicted from isohyetal maps (Carlson 1974), averages 500 mm annually along the Middle Fork of the John Day River and increases at a relatively constant rate up to 1020 mm at the highest elevations. Most of the precipitation falls as snow from November through April. Showers occur in May, June, and

Table 1. Climatic conditions at Austin, Oregon (long term averages, 1912-1981).

	Temperature (°C)			
Month	Average	1978-1979	1979-1980	1980-1981
Oct	6.3	6.8	7.8	6.2
Nov	-0.2	-2.8	-2.1	1.0
Dec	-4.1	-7.9	-2.3	-2.2
Jan	-6.4	-11.4	-5.8	-0.9
Feb	-3.6	-2.4	-0.3	-1.8
Mar	0.4	0.8	0.4	1.9
Apr	5.3	4.2	6.2	-
May	8.9	8.6	8.2	7.8
Jun	12.6	12.4	10.4	11.1
Jul	16.6	15.8	15.6	14.4
Aug	15.2	15.4	12.5	17.0
Sep	11.3	12.6	10.7	10.4
Oct-Mar	-1.3	-2.8	-0.4	0.7
Apr-Sep	11.7	11.5	10.6	11.0
Annual	5.2	4.4	5.1	5.9

Table 1. (cont.) Climatic conditions at Austin, Oregon (long term averages, 1912-1981).

	Precipitation (mm)			
Month	Average	1978-1979	1979-1980	1980-1981
Oct	40	4	55	19
Nov	60	59	62	44
Dec	72	53	23	107
Jan	70	51	74	25
Feb	51	78	51	63
Mar	47	35	50	45
Apr	32	49	21	18
May	45	27	54	66
Jun	43	4	79	61
Jul	12	1	28	29
Aug	18	55	6	13
Sep	20	26	45	33
Oct-Mar	338	280	315	304
Apr-Sep	170	163	232	219
Annual	508	443	547	523

October. Little precipitation is expected in July, August, and early September.

Average monthly temperatures at Austin range from -6.4°C in January to 16.6°C in July. Summer maximum temperatures reach 20-30°C but frost may occur in any month. Temperatures would be expected to decrease with increasing altitude.

In all three study years, winter precipitation was below average, especially in 1978-79. That year also had below average growing season precipitation, particularly in May and June. Rain which occurred in August was useful only in promoting late summer regrowth. The second and third year had increased growing season precipitation especially during the important months of May and June.

The mid-winter months of 1978-79 were colder than normal while the remaining months were close to average conditions. The second winter was relatively warm and was followed by a cool summer. The year 1980-81 also had a warm winter and a cool summer with the exception of August. Precipitation and temperature conditions combined to make 1978-79 a relatively poor year for plant growth while 1979-80 and 1980-81 were above average forage years.

Vegetation

Plant communities of the Blue Mountain region, including the study area, have been described by Hall (1973). Table 2 depicts the percentage of area contributed by several broad groupings of

Table 2. Plant Community Groups of the Upper Middle Fork Grazing Allotment (% composition).

Plant Community Group	Allotment	Pasture Butte	Caribou	Deerhorn
meadow	1.0	1.1	0.5	1.2
grassland	1.0	2.6	0.6	0.5
juniper	1.2	2.1	2.8	trace
ponderosa pine	6.1	5.1	10.0	7.5
ponderosa pine-Douglas fir	18.8	9.0	37.0	6.0
mixed conifer	15.6	14.6	15.2	5.0
white fir	51.5	65.0	34.1	70.5
alpine	6.0	0.8	-	9.0
Total Area (ha)	21800	4675	3610	5735

plant community types on the allotment as a whole and on the three main study pastures which comprise 64% of the total allotment.

The meadow communities are found along streams and in small moist openings in the forest. They are dominated by grasses and sedges with a variable composition depending on range condition and moisture relations. Major dominants include Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis alba*), Nebraska sedge (*Carex nebraskensis*), sheep sedge (*Carex illota*), and Baltic rush (*Juncus balticus*). Prominent forbs include white clover (*Trifolium repens*), springbank clover (*Trifolium wormskjoldii*), and western yarrow (*Achillea lanulosa*). While meadows comprise only 1-1.5% of the study area, they have a much larger influence on animal distribution and habitat use.

Grassland communities occupy sites with shallow soils and limited water storage capacity. Sandberg's bluegrass (*Poa sandbergii*) and one-spike danthonia (*Danthonia unispicata*) are always present and are dominants on sites of low potential or in poor range condition. Bluebunch wheatgrass (*Agropyron spicatum*) and/or Idaho fescue (*Festuca idahoensis*) become dominant as site potential or range condition improves. Major forbs are western yarrow, yellow fleabane (*Erigeron chrysopsidis*), and wormleaf stonecrop (*Sedum stenopetalum*). This community group also includes a few minor areas dominated by stiff sagebrush (*Artemisia rigida*) with Sandberg's bluegrass and one-spike danthonia. The grassland group covers a minor portion of the allotment.

The juniper community group is similar in composition to the grassland group with the addition of an overstory of western juniper (Juniperus occidentalis). This type also covers a minor portion of the study area.

The ponderosa pine (Pinus ponderosa) community group consists of an overstory of ponderosa pine and some western juniper with an understory of bluebunch wheatgrass, Idaho fescue, and Sandberg's bluegrass. Major forbs include western yarrow, yellow fleabane, and wormleaf stonecrop. This group covers 6-10% of the allotment area. Soil water content on this group and the previously mentioned shallow soil vegetation groups begins to limit plant growth by early June of most years and plant growth is completed by July 1 (Carlson 1974). If August and September rains occur, these sites will produce late summer regrowth.

The ponderosa pine-Douglas fir (Psuedotsuga menziesii) community group is the driest commercial timber site on the study area. It consists of a variable overstory mixture of ponderosa pine and Douglas fir with an understory dominated by elk sedge (Carex geyeri). Pinegrass (Calamagrostis rubescens) may be nearly co-dominant with elk sedge on the more productive sites. Common forbs include tailcup lupine (Lupinus caudatus), western yarrow, hawkweed (Hieracium albertinum), and peavine (Lathyrus nevadensis). This group covers from 6% to 30% of the study pastures and is a major grazing area on the allotment.

The mixed conifer community group is similar to the ponderosa pine-Douglas fir community group but occurs on more productive sites. Grand fir (*Abies grandis*) is a major overstory component along with ponderosa pine and Douglas fir. Western larch (*Larix occidentalis*) may also be present. Pinegrass and elk sedge dominate the understory with pinegrass generally contributing the larger component. Prominent forbs are heartleaf arnica (*Arnica cordifolia*), hawkweed, peavine, and bigleaved lupine (*Lupinus polyphyllous*). This group comprises 5% to 16% of the study area.

The white fir community group occurs on the most mesic forest sites at the higher elevations. Dominated by white fir, the overstory also includes varying amounts of Douglas fir, larch, ponderosa pine, and Engelmann spruce (*Picea engelmannii*). Several discrete types of understory occur depending on soils, topographic position, and elevation. Understory dominants may be twinflower (*Linnaea borealis*), big huckleberry (*Vaccinium membranaceum*), or grouse huckleberry (*Vaccinium scoparium*). Associated understory species include pinegrass, northwestern sedge (*Carex concinnoides*), heartleaf arnica, and mitrewort (*Mitella stauropetala*). This community group is by far the major vegetation type on the allotment. Because of high overstory canopy coverage and resulting low understory production, the white fir group is generally classified as non-range. Some livestock use does occur in early successional stages created by logging, fire, or other similar events.

The alpine communities occur at the highest elevations on the allotment. Several distinct communities are included in this grouping. Examples include a subalpine fir (*Abies lasiocarpa*) - whitebark pine (*Pinus albicaulis*) - elk sedge community, a sagebrush (Artemisia tridentata ssp. vaseyana) - elk sedge community, and an alpine elk sedge community. Alpine areas are not used in calculating livestock forage allowances and receive minimal livestock use.

Management Activities

The area now included within the Upper Middle Fork Grazing Allotment has been grazed by domestic livestock since at least the 1880's (U.S. Forest Service 1967). Much of the area was originally grazed by large sheep bands under Forest Service permit but only cattle have been present since about 1950. A division of the large Middle Fork Grazing Allotment in 1962 into two smaller parcels defined the Upper Middle Fork Grazing Allotment with roughly the same boundaries it possesses at present. Since that time, permitted animal numbers have remained constant at 400 animal units (AU) for the June 1 - October 15 grazing season.

Before 1967, little or no internal or boundary fencing was present. Sufficient fencing had been completed by 1972 to implement a three pasture rest-rotation grazing system. This system operated until 1979 when, in cooperation with the Oregon Range Evaluation Project, additional cross-fencing was added as well as one new pasture, the Austin Pasture (Grant Conservation District 1978). This allowed implementation of three separate grazing plans to be run simultaneously on the allotment in an effort to determine the effects of different management strategies on multiple use outputs. Figure 3 depicts the present pasture layout

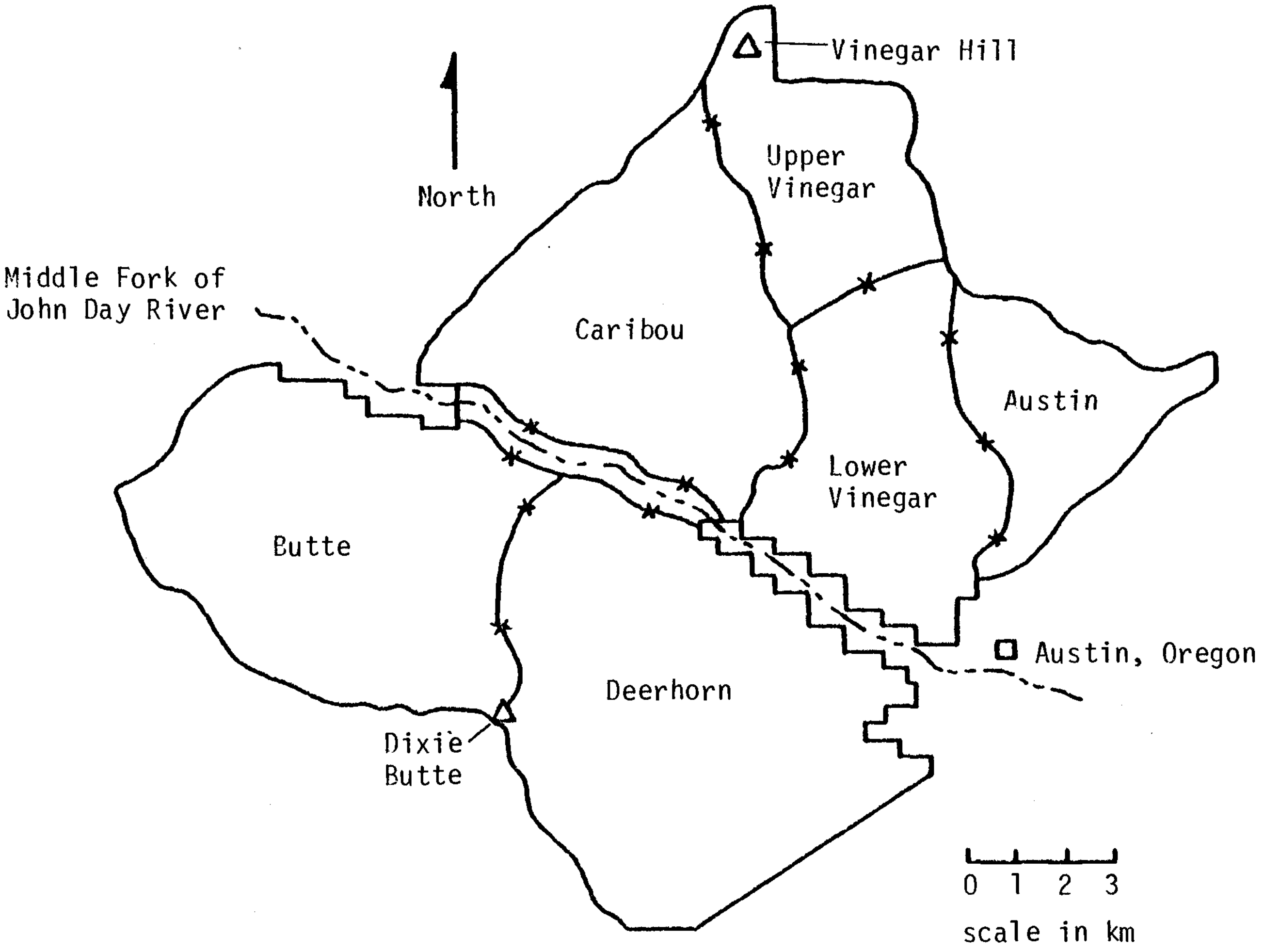


Figure 3. Pasture layout of Upper Middle Fork Grazing Allotment.

while Table 3 presents the grazing schedule during 1979-1981. Major research activities took place in the Butte, Caribou, and Deerhorn Pastures.

A reconnaisance range survey was conducted by the U.S. Forest Service in 1978. Excluding grand fir communities which are not given range condition ratings, 3% of the allotment was in good condition, 60% rated fair, 37% was considered to be in poor condition, and no portions of the area were in very poor condition (good condition was the top rating in this system). On a large proportion of the area, it is difficult to determine whether past overgrazing or overly dense tree reproduction has resulted in a poor condition rating.

The major range management problem on the allotment appears to be chronic overuse of riparian vegetation. This problem was pointed out in the 1967 Management Plan (U.S. Forest Service 1967) and again in 1978 (Grant Conservation District 1978). It has undoubtedly been a problem for some time longer. The riparian meadow along the main stem of the Middle Fork was excluded from the rest of the allotment by fencing in 1978. Cattle use of the small riparian meadows along the primary drainages was a major topic of the research work.

Timber harvest activities have been and continue to be major factors on the Upper Middle Fork Allotment. Approximately 80% of the merchantable timber was removed during the 1930's and 1940's by railroad logging methods. This has resulted in large areas of second growth timber, much of which is overstocked with trees to

Table 3. Planned grazing schedule, Upper Middle Fork Grazing Allotment, 1979-1981.

Pasture	Grazing Management	1979		1980		1981	
		Grazed Period	No. of Cattle	Grazed Period	No. of Cattle	Grazed Period	No. of Cattle
Butte	continuous	6/1-10/15	85	6/1-10/15	85	6/1-10/15	85
Caribou	deferred-rotation	6/1- 7/31	200	8/1-10/15	200	6/1- 7/31	200
Deerhorn	deferred-rotation	8/1-10/15	200	6/1- 7/31	200	8/1-10/15	200
Austin	rest-rotation	rested		6/1- 8/15	131	rested	
Lower Vinegar	rest-rotation	6/1- 8/15	131	rested		6/1- 8/15	131
Upper Vinegar	rest-rotation	8/16-10/15	131	8/16-10/15	131	8/16-10/15	131

the point that both tree and forage growth is detrimentally affected. A second result of railroad logging is a network of abandoned railroad grades which make excellent travel lanes for cattle and are generally well used for this purpose. However, these trails are gradually becoming overgrown by trees and there is no active maintenance program to keep the main grades open.

Timber harvesting has taken place in the last decade across the lower portions of the Caribou Pasture. These operations generally removed mature ponderosa pine leaving small clearcuts interspersed with patches of younger pine and Douglas fir. Road shoulders, skid trails, and areas of high soil disturbance were seeded with common pasture grasses. Orchardgrass (*Dactylis glomerata*) and intermediate wheatgrass (*Agropyron intermedium*) are the major introduced grasses on these areas.

A relatively small salvage operation for standing dead lodgepole pine (*Pinus contorta*) took place in the northeastern portion of the Deerhorn Pasture in late summer, 1981. This operation had minimal effect on research activities.

Mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) are important big game species on the Upper Middle Fork Allotment as both species use the area for production and rearing habitat (Grant Conservation District 1978). Elk generally spend the summer at the higher elevations while deer are present throughout the area. The allotment is heavily used by hunters during the fall harvest seasons. Forage allocation for big game is set at 10% of estimated grazing capacity. The small primary drainages as well as the main stem of the Middle Fork are considered to be important spawning and rearing areas for anadramous steelhead trout (*Salmo gaidneri*).

STUDY METHODS

Upland Grazing Distribution

Studies of possible factors affecting upland grazing distribution of cattle were conducted in the Butte and Caribou Pastures in 1979, 1980, and 1981. For each pasture, 50 sampling sites were located by a stratified random procedure to represent the range of plant community types and topographic situations. Sampling sites were confined to the lower two-thirds of both pastures because the higher elevations were occupied predominantly by dense grand fir forests. While some use was made of these areas by cattle, it was felt the great majority of stock use was included within the sampling area. Because of time constraints, all sites could not be established in 1979. For that year, 25 sites were sampled in the Butte Pasture and 40 sites were sampled in the Caribou Pasture. All sites were established for the 1980 field season.

Each site was marked for the life of the study by placing plastic flagging on trees. Utilization sampling was conducted at the end of the respective grazing period in each pasture. The sampling arrangement consisted of a randomly located transect approximately 60 m in length oriented perpendicular to the slope gradient. Twenty evenly spaced 0.5 m^2 circular plots were placed along each transect. Utilization was estimated by the ocular-estimate-by-plot technique (Pechanec and Pickford 1937a) for all species occurring within a plot.

When each site was established, it was initially classified to plant community type using the criterion of Hall (1973). After plant frequency data became available from utilization and production sampling (discussed below), the initial classifications were checked and modified when necessary. Community types were further stratified by timber stand condition (sapling, pole, timber, clearcut) and overstory canopy cover classes (less than 60%, 60-79%, greater than 79%). Overstory canopy was estimated with a spherical densiometer (Lemmon 1957). The number of study sites within a particular community type ranged from one site in a few rare types up to nineteen in the most common type.

Time constraints allowed herbaceous production sampling on only about one-half of the study sites. The number of production sampling sites allocated to each community type was roughly proportional to the total number of sites within that type and ranged from one to ten. Production sampling sites were then chosen randomly within community types. Production measurements were collected on one transect per site. These transects ran parallel to and were within 10 m of the utilization transects. Ten evenly spaced 0.5 m^2 circular plots were measured per transect. Major species including pinegrass, elk sedge, and bluebunch wheatgrass were clipped and weighed for each plot. All other species were estimated by the weight-estimate-per-plot method (Pechanec and Pickford 1937b). Samples of all species were collected and dried at 50°C to a constant weight to express production estimates on an oven-dry basis. Production transects were then pooled within community types for estimates of annual herbage production and species composition within types.

Several other attributes were estimated for all utilization sites. These included slope gradient; slope length to road, trail, or drainage bottom; slope aspect to nearest 45°; distance to water and salt along a straight line and probable trailing route; absolute value of elevation change along probable trailing route to salt and water; elevation; and % composition of pinegrass and elk sedge (forested and logged sites only). All distance and slope measurements were taken from U.S. Geological Survey topographic maps. Percent composition of pinegrass and elk sedge was calculated from production data.

Utilization was expressed in two ways. First, a weighted percentage estimate of grass utilization for each site was calculated by summing the products of percent utilization and percent composition by weight over all grass species. This expression indicated which sites were receiving the greatest cattle impact. Second, an estimate of the weight of grass removed per hectare was obtained by multiplying the weighted percent utilization estimate by the estimate of grass production per hectare. This expression indicated which sites were most important to the cattle in terms of relative forage consumption. Upland sedges (Carex spp.) were included within the grass component. Grasses contributed 70-90% of the herbaceous production in most community types and made up 80-90% of the cattle diet. For these reasons, grass utilization alone was considered to be an adequate index of grazing intensity on a given site.

The dependent variables of observed utilization and the quantitative independent variables of various site factors were subjected to correlation and multiple regression analyses to determine which site factors were most highly associated with grass utilization. The data were stratified by pasture, year, and forage types for the analyses. Forage types were based on the major forage species and the general characteristics of the site and consisted of three groups. The grassland forage type consisted of shallow soil sites producing combinations of bluebunch wheatgrass, Sandberg's bluegrass, and one-spike danthonia. A few sites with sparse stands of ponderosa pine and the same understory species were included within this group. The elk sedge-pinegrass forage type consisted of all relatively undisturbed forest sites with those species as understory dominants. The logged forest forage type included forest sites which had received 90-100% reductions in tree crown cover in the previous 15 years. These sites supported various mixtures of understory species ranging from mainly pinegrass and elk sedge up to high proportions of introduced pasture grasses.

Several transformations of site characteristics suggested from the literature review were included in the correlation analyses. These included the natural logarithms of all distance, slope, and canopy cover variables, the square root of all distance and slope variables, and the product of slope gradient and slope length. These transformations did not measureably improve the correlation of any site characteristic and were not considered in further analyses.

Stepwise and backstep procedures were used in building the regression models (Neter and Wasserman 1974, Rowe and Brenne 1981). Models were selected on the basis of the additional contribution to the R^2 value, the additional reduction in residual error, and the statistical significance of the various regression coefficients at each step. After a simple model had been built, all two-way interactions of variables already included in the model were screened to determine if inclusion of any of the interactions would improve the model fit. Only those models with R^2 values significant at the 10% probability level were reported.

Utilization with respect to the qualitative variables of plant community group and slope aspect was analyzed within years by completely randomized analysis of variance with unequal replications. For plant community groups, the categories were the same as the forage types used in the regression analyses. One modification was that the elk sedge-pinegrass forage type was split into three community groups based on tree species composition. These were the ponderosa pine-Douglas fir, mixed conifer, and white fir forest community groups.

Finally, an effort was made to compare the relative palatability of elk sedge and pinegrass, the two major upland forage species. All utilization sites on which both species had a frequency of at least 25% were included as single observations.

The estimates of % utilization were used to make paired t-tests of the null hypothesis of equal utilization on the two species. Tests were made within year, pasture, and forage type.

Habitat Utilization

Cattle habitat utilization and activities were determined by actual observations in 1979, 1980, and 1981. Vehicle routes were established along existing roads in the Butte and Caribou Pastures. These routes totaled 19.7 km in the Butte Pasture and 28 km in the Caribou Pasture. As with the upland utilization sites, the observation routes were concentrated in the lower portions of the pastures where the majority of animal use occurred.

Observation routes were divided into subsegments. The order in which subsegments were traversed and starting times for the observation routes were allocated in a stratified random manner. Observations took place during all time periods from dawn until dusk. Routes were traversed an average of once every three days while cattle were actually present in a pasture. Whenever a group of cattle was seen, the time of day, number of animals, type of activity, plant community occupied, and map location was recorded. Additional information for each cattle sighting was later taken from U.S. Geological Survey topographic maps. This included slope gradient and aspect, elevation, trail distance to salt and water, and the absolute value of elevational change along the trailing route to salt and water.

Vegetation along the observation routes was mapped by community type following the classification of Hall (1973). Vegetation mapping extended out to the approximate limit of cattle visibility which varied among communities. The availability of all habitat factors used to describe cattle location, as discussed in the previous paragraph, was estimated by placing a random sample of 100 points within the observation boundaries of each route and determining the habitat characteristics of each sample point.

In analyzing the effect of plant community group and slope aspect on cattle distribution, the category definitions for the independent variables were the same as those used in the analysis of upland grazing distribution. Cattle observations were totaled within categories of the independent variables and the resulting distributions were compared between years and also with the distribution of available habitat within pastures by chi-square analysis. When the hypothesis of equality among distributions was rejected, pairs of proportions were tested within categories through the use of the normal approximation to the binomial distribution (Snedecor and Cochran 1967) to determine which categories were responsible for the significant chi-square value. The simultaneous probability level used for these sets of pairwise comparisons was 10%. Using the Bonferroni approach to simultaneous testing, this resulted in a pairwise probability level of 1-3% depending on the number of pairs tested (Marcum and Loftsgaarden 1980).

For the analysis of quantitative habitat variables, the continuous independent variables were divided into discrete classes. For slope gradient these classes were 0-5%, 6-10%, 11-15%, 16-20%, 21-30%, 31-45% and greater than 45%. Trail distances to water and salt were divided into 100 m increments from 0 to 1000 m and a class of greater than 1000 m. Vertical distances to water and salt were divided into 10 m increments from 0 to 100 m plus a class of greater than 100 m. Elevation was divided into 50 m increments between 1150 m and 1650 m.

Since each class of the independent variables did not contain an equal proportion of the observation area, a habitat preference index (HPI) was used. This was defined as the ratio of the percentage of total animals observed within a particular class divided by the percentage of the total observation area within that class. Values of the index greater than one indicated that more cattle were observed within that habitat class than would have been expected by chance and were considered to imply positive animal preference for that habitat class. Values less than one implied a particular habitat class was not preferred.

Correlation analysis was used to determine the association between the habitat preference index and the slope gradient, distance, and elevation classes of the independent variables. The forms of the possible relationships were examined by observing scatter plots of the data. Several functions were tested to determine which best described the observations. Two functions were adequate for describing all important associations. The first was the simple linear function:

$$Y = bX + a$$

where, Y = HPI
X = independent habitat factor
a, b = constants.

The second function used was:

$$\ln Y = bX + a$$

where, $\ln Y$ = natural logarithm of HPI
X = independent habitat factor
a, b = constants.

The proportion of total cattle observed in various activities such as grazing or nursing was assumed to reflect the average proportion of time an individual would devote to these same activities. The distribution of time spent in the different activities was compared between years within pastures and between pastures over years using the same procedures as described in the analysis of plant community group effects.

Riparian Meadow Utilization

Production and utilization of small riparian meadows was measured at 12 sites on the study area in 1980 and 1981. Four sampling sites each were located in the Butte, Caribou, and Deerhorn Pastures which comprised the continuous and deferred-rotation grazing plans. The major criteria for selecting sites were that the site be large enough to allow proper sampling and also have relatively uniform vegetative composition.

The meadows were classified into two broad categories following Hall (1973). Dry meadows had soils which were wet in spring but had dried by fall and were not sub-irrigated for the entire growing season. Most dry meadows were dominated by Kentucky bluegrass with western yarrow, northwest cinquefoil (*Potentilla gracilis*), and dandelion (*Taraxacum officinale*) as prominent forbs. Wet meadows had surface soils which were wet in spring but had dried by fall and were sub-irrigated in the rooting zone for the entire growing season. Composition was variable and dominants included redtop, Kentucky bluegrass, Nebraska sedge, sheep sedge, other sedge species, and Baltic rush. Major forbs include white and springbank clover and northwest cinquefoil. The natural non-uniform occurrence of the major meadow types along different drainage systems precluded equal apportionment of meadow types within experimental pastures.

Sampling took place at two week intervals through the period of actual cattle grazing in each pasture. Forage utilization and regrowth were estimated using a movable cage technique (Smith et al. 1963). Cages were constructed of fence wire with a 5.1 cm by 10.2 cm mesh and measured 102 cm square by 122 cm in height. Forage weight sampling consisted of clipping all vegetation to ground level within a rectangular 0.1 m^2 plot. Three plots were randomly sampled on a grid of nine possible plots within each cage. A group of three such plots was referred to as a cluster. Five cages were established per sampling site.

Initial available herbage was estimated by clipping five clusters immediately before cattle entered a pasture. Five cages were then randomly established for future sampling. At each sampling date, five clusters were clipped within the cages and five clusters were clipped in similar areas open to grazing. The cages were then moved to new locations within the meadow. Samples of herbage (100-150 gm fresh weight) from open and caged plots were dried in a forced-air oven to a constant weight to convert herbage estimates to oven-dry weight.

Clipping outside the cages gave an estimate of herbage available for grazing. Comparison of herbage weights in open and caged areas was used to estimate forage removal during the previous two weeks. Finally, comparison of herbage weights from caged plots with herbage weights from open plots from the preceding sample date yielded an estimate of herbage regrowth for the intervening period. Regrowth increments were combined with starting herbage weight to estimate total herbage production under grazing.

Total herbage production without grazing was determined by clipping five clusters which had been caged for the entire grazing period. Vegetative composition was estimated by saving the herbage from one plot chosen at random from each of the five clusters clipped to measure total ungrazed herbage production. This herbage was hand separated into the categories of grass, grasslike, and forb for each plot and averaged over plots for an estimate of composition. The major species within each plant category were also taxonomically identified.

Cattle use of riparian meadows was also monitored on the basis of actual animal presence in 1980 and 1981. This was accomplished through the use of time-lapse photography equipment on six riparian meadows. The Butte, Caribou, and Deerhorn Pastures each contained two study meadows. All monitored meadows were also used for herbaceous production and utilization measurements.

Battery-powered Super 8 mm movie cameras were placed on elevated platforms in trees or snags 5-7 m above the ground. The cameras exposed one frame of film at 5 minute intervals. Light sensors stopped filming when light levels fell below the minimum required for proper film exposure. Cameras operated continuously from the time cattle entered the pastures in June until about September 30 when fall gathering of cattle began.

Film was analyzed one frame at a time using an 8 mm film editor. When cattle appeared in view, the number of animals, their activity, and the time of day was recorded. Only adult cows were counted in the analysis, and 95% or more of the cows on the allotment were nursing calves. The initial unit of measurement was the animal unit frame which was defined as one cow being present in one frame of film. Animal unit frames were then totaled on a daily or seasonal basis and converted to the more familiar expression of animal unit days (AUD) by dividing the total animal unit frames by the average number of camera frames per day. Finally, occupation was expressed as AUD per hectare by dividing AUD by the size of the camera view area. View area size was calculated from the length and width of the view area which had been previously measured with a steel tape.

Modified analysis of variance procedures were used to compare results among grazing periods for final residual herbage levels and total and daily cattle occupation on riparian meadows. This was necessary because the Caribou and Deerhorn Pastures were each grazed once during the early period and once during the late period while the Butte Pasture was grazed continuously both years. This resulted in a non-orthogonal arrangement of treatments. The analyses were made by calculating independent estimates of the error mean square within the deferred-rotation and continuous grazing systems and then pooling these error estimates for comparisons among grazing systems.

The analysis of variance within the deferred-rotation system took the following form:

	degrees of freedom	
source of variation	residual herbage	cattle occupation
Total	15	7
Year	1	1
Pasture	1	1
Year x Pasture (Grazing Period)	1	1
Error	12	4
Sites within Pasture	6	2
Site x Year within Pasture	6	2

The effects of early and late grazing were compared by dividing the mean square for grazing period by the mean square error from the Site x Year x Pasture term. This error term was referred to as MS_{dr} (deferred-rotation).

The analysis of variance for the continuous unit was carried out as follows:

source of variation	degrees of freedom	
	residual herbage	cattle occupation
Total	7	3
Year	1	1
Error	6	2

The error term from this analysis was referred to as MS_c (continuous).

To make comparisons among the means from either the early (x_e) or late (x_l) periods and the continuous period (x_c), a t-test was used:

$$t = \frac{(\bar{x}_e \text{ or } \bar{x}_l) - \bar{x}_c}{\sqrt{\frac{MS_{dr}}{r_{dr}} + \frac{MS_c}{r_c}}}$$

The number of replications (r_{dr} and r_c) equaled eight for the residual herbage analysis and four in the cattle occupation analyses. The approximate degrees of freedom for the t-test were calculated by the method of Satterthwaite (1946).

Regression analysis was used to characterize the relationship between residual meadow herbage, averaged over pasture, and days of grazing. Frequencies of cattle occupation expressed as both the percentage of total camera frames and percentage of total days in which at least one animal was present were compared among grazing periods using the normal approximation to the binomial distribution. Correlation was used to associate profiles of daily and seasonal cattle occupation with daily and seasonal weather and to associate total cattle occupation with total forage removal.

Distributions of cattle allocation of time to various activities were compared among grazing periods using the same methods as described under habitat utilization.

Aerial Microclimate

The aerial microclimate of three contrasting plant communities was measured in 1980 and 1981 in the Caribou Pasture. Two drainages separated by about 3.2 km were chosen for study. Three monitoring stations were established at random in each drainage, one on a small riparian meadow, one on a ponderosa pine-Douglas fir forest site, and one in a small clearcut (1-2 ha) on a ponderosa pine-Douglas fir site. Monitoring stations consisted of hygrothermographs maintained in small wooden louvered shelters placed 1-1.2 m above the ground surface. The instruments recorded temperature and relative humidity continuously from mid-June until late September, irrespective of cattle presence in the pasture. Weather data were recorded from strip charts at two hour intervals for further analysis. The physical characteristics of elevation, slope gradient, and slope aspect for each monitoring site were taken from U.S. Geological Survey topographic maps. Forest canopy cover at each site was measured with a spherical densiometer.

Three main were compared among vegetation types. These included temperature, relative humidity, and the temperature-humidity index (THI). THI integrates temperature and humidity into a single parameter and may be calculated as:

$$\text{THI} = 0.99T_a + 0.36T_d + 41.5, \text{ where}$$

THI = temperature-humidity index

T_a = air temperature, °C

T_d = dew point temperature, °C.

This relation was taken from Thom (1958) with the constants modified for the use of centigrade degrees.

Four variations were calculated for each main parameter. These were daily average, maximum, and minimum, and the average between the hours of 12 noon and 6 p.m. inclusive. These twelve variables were then compared among vegetative types within years using a repeated measures analysis of variance with drainages as blocks. Because of the large amount of data, twenty days from each year were chosen in a stratified random manner for use in the analysis. Sample days were stratified by month with allocation based on the ratio of days in the month to days in the total season. All days in which data were missing from one or more stations were deleted from the analysis.

Cattle Home Range Behavior

Studies were made of individual cattle home ranges and movements in the Caribou Pasture in 1980 and 1981. Immediately before cattle entered the pasture, marking collars were placed on 15 animals. These collars consisted of plastic neck chains with nylon streamers attached. Three chain colors and five streamer colors yielded 15 individual color combinations. Whenever a marked cow was observed in the course of usual observation routes or during other research activities, its position was noted on the pasture map.

Home range size was estimated by connecting the outermost observations in a convex polygon and measuring the enclosed area. A coordinate system was superimposed on the map and the center of activity calculated. The center of activity was the simple average of the X and Y coordinates of the observations (Hayne 1949). The average of the distances from the center of activity to each observation was called the activity radius and was another index to home range size. Finally, the maximum distance between any two sightings was calculated as a third measure of home range size.

Home range area, activity radius, and maximum distance between sightings were compared among years and cattle breed group by analysis of variance.

RESULTS AND DISCUSSION

General

The actual grazing periods for the three main study pastures from 1979 to 1981 are shown in Table 4. All except the initial dates are approximate since removing the bulk of cattle from a pasture requires 7-10 days. A comparison between actual use and planned use (Table 3, p. 43) indicates several deviations. On the Butte Pasture, grazing began about one month later than planned in 1980. Cattle were held on private land for an extended period to facilitate an artificial insemination program in that year. The early grazing period in the Caribou Pasture was extended for an additional 18 days in 1981 due to above average upland forage production. Cattle grazing on the allotment as a whole was delayed about one week in early June because of wet spring conditions in 1980 and 1981. Finally, although a small amount of cattle interchange among pastures and adjoining allotments is normal, at least one major deviation occurred in the Butte Pasture in 1979. About 30% of the cattle escaped through open gates onto the adjoining allotment around mid-August but were not discovered until late in the grazing season. This resulted in lighter than normal use in the Butte Pasture in that year.

As discussed earlier, weather conditions in 1979 produced poor herbage yields while wet spring weather in 1980 and 1981 resulted in above average forage yields in those years. Seventeen sites which were sampled in all three years were used to compare total herbage production on upland sites among years. Total

Table 4. Actual grazing periods on main study pastures, 1979-1981.

Pasture	Grazing Management	Actual Grazing Periods		
		1979	1980	1981
Butte	continuous	6/1-10/15	7/2-10/15	6/6-10/1
Caribou	deferred-rotation	6/1- 7/31	8/1-10/15	6/6-8/17
Deerhorn	deferred-rotation	8/1-10/15	6/7- 7/31	6/6-10/5

production over these sites averaged 208, 367, and 408 kg/ha for 1979, 1980, and 1981, respectively. Production in 1979 was statistically different from 1980 and 1981 ($p < .01$), while the latter two years were similar to each other. Total production over all sites and years averaged 240 kg/ha for the grassland communities, 230 kg/ha for the ponderosa pine-Douglas fir type, 209 kg/ha in the mixed conifer forest, 184 kg/ha in the white fir communities, and 465 kg/ha on logged forest sites.

Upland Grazing Distribution

Butte Pasture

The means and ranges of all quantitative variables used in the analysis of upland grazing distribution for all sites in the Butte Pasture are listed in Table 5. Additional qualitative variables which are not listed include plant community group and slope aspect. The % grass utilization weighted by species composition was low in all years. The average over all sites was less than 12% and the maximum utilization observed on a single site over three years was 33%. Utilization expressed as weight of forage removed was also light. Herbage production followed the pattern discussed in the previous section with production increasing from 1979 to 1981. Average production levels were lower in the Butte Pasture because of a higher proportion of white fir and mixed conifer forest types and a lack of recently logged sites.

Correlations between grass utilization and various site characteristics within the Butte Pasture for the elk sedge-

Table 5. Means and ranges of variables used in regression analysis of grass utilization in relation to site variables, Butte Pasture.

Variables	Unit	Mean	Minimum	Maximum
% utilization	%			
1979		6.1	0	17
1980		11.4	0	33
1981		9.5	0	27
weight utilization	kg/ha			
1979		8	0	35
1980		23	0	69
1981		26	0	80
herbage production	kg/ha			
1979		145	45	235
1980		242	65	325
1981		306	150	370
grass production	kg/ha			
1979		119	30	205
1980		194	55	260
1981		256	115	320
% pinegrass	%	38	0	78
% elk sedge	%	36	0	61
forest canopy cover	%	47	0	81
% slope	%	26	5	75
slope length	m	218	0	1170
elevation	m	1361	1185	1710
horizontal distance to water	m	388	65	1065
trail distance to water	m	543	65	1200
vertical distance to water	m	60	0	180
horizontal distance to salt	m	463	75	830
trail distance to salt	m	572	75	1670
vertical distance to salt	m	45	0	145

pinegrass forage type are listed in Table 6. Only statistically significant correlations are presented ($p < .10$). Although several site factors were correlated with grass utilization, no single factor had a particularly strong association with cattle use. The associations also did not seem to be constant between years. Herbage production, grass production, proportion of elk sedge, and vertical distance to salt were the only site factors correlated with one of the utilization expressions for at least two of the three years. There were fewer significant correlations for % utilization than weight utilization, and the correlations were generally lower. This may have been due to the larger range of values displayed by that expression as compared to % utilization.

For the grassland forage type, grass utilization showed little association with site characteristics. The only significant correlation was between elevation and both utilization measures in 1981 ($r = .843$ and $.809$, respectively; $p < .10$). This result was not surprising since only five grassland sites were monitored in the Butte Pasture compared to 45 sites in the elk sedge-pinegrass forage type.

Results of the multiple regression analysis relating cattle use levels and site factors are shown in Table 7. The set of independent variables used in the model was similar to the set producing significant correlations. Herbage and grass production were closely related to each other and appeared to be about equally associated with grass utilization. Because grass

Table 6. Correlations between grass utilization and site characteristics, elk sedge-pinegrass forage type, Butte Pasture, 1979-1981.[1]

	% Utilization			Weight Utilization		
Site Characteristic	1979	1980	1981	1979	1980	1981
herbage production	.413*		.289	.545**	.331*	.431**
grass production	.353		.286	.515**	.346*	.433**
% elk sedge		.320*	.380**			.474**
% pinegrass			-.324*			-.402**
% slope	-.357		-.321*			-.342*
elevation			-.468**			-.478**
vertical distance to salt		-.402**	-.390**		-.393**	-.395**
N	25	45	45	25	45	45

[1] * denotes significance at the 5% probability level;
** denotes significance at the 1% probability level;
correlation coefficients without superscripts are significant at the 10% probability level.

Table 7. Regression coefficients and associated statistics for predicting grass utilization from site characteristics, elk sedge-pinegrass forage type, Butte Pasture, 1979-1981.[1]

	% Utilization			Weight Utilization		
Site Characteristic	1979	1980	1981	1979	1980	1981
grass production				.10	.12	.12
% elk sedge		.50				
% pinegrass		.36				
% slope	-.99					
elevation			-.24			-.06
vertical distance to salt		-.77	-.75		-.19	-.20
constant (b_o)	8.62	-18.12	46.05	-4.18	8.19	81.88
R^2	.127	.281	.313	.265	.255	.379
$s_{\bar{y}\cdot\bar{x}}$	1.10	1.10	1.07	1.40	2.37	3.02
$\bar{y}$	6.1	11.8	9.6	7.5	23.8	26.6

[1] regression models are of the form $\hat{Y}=b_o+b_1X_1+\ldots+b_iX_i$

production estimates should be easier to obtain than total herbage production estimates, grass production was chosen over herbage production to be included in the regression models. This resulted in a slight reduction in the amount of variation in both dependent variables accounted for by the model in 1979. These reductions were not serious considering the overall lack of fit.

None of the models were particularly successful in predicting either expression of grass utilization in any year. The most successful model was for weight utilization in 1981, yet only 38% of the variation in the dependent variable could be accounted for by the regression model. The models changed from year to year, and grass production, elevation, and vertical distance to salt were the only independent variables occurring in more than one model.

The year to year variation in utilization is also shown in the correlations between the utilization expressions shown in Tables 8 and 9 for the elk sedge-pinegrass and grassland forage types, respectively. For both forage types, the highest correlations were between % utilization and weight utilization within the same year. This was to be expected since % utilization was used to calculate weight utilization. Across years, the correlations decreased markedly although they were often still significant in the elk sedge-pinegrass forage type. At these light utilization levels, cattle use on a site in any one year was not an exceptionally good predictor of use on the same site in another year.

Table 8. Correlation between grass utilization expressions, elk sedge-pinegrass forage type, Butte Pasture, 1979-1981.[1]

		% Utilization		Weight Utilization		
		1980	1981	1979	1980	1981
% Utilization	1979	.636**	.424*	.931**	.626**	.445*
	1980		.602**	.543**	.974**	.623**
	1981			.252	.614**	.977**
Weight Utilization	1979				.499*	.266
	1980					.640**

[1] * denotes significance at the 5% probability level;
** denotes significance at the 1% probability level.

Table 9. Correlations between grass utilization expressions, grassland forage type, Butte Pasture, 1980-1981.[1]

		% Utilization	Weight Utilization	
		1981	1980	1981
% Utilization	1980	.295	.994**	.297
	1981		.199	.998**
Weight Utilization	1980			.203

[1] grassland sites were not sampled in 1979

[2] ** denotes significance at the 1% probability level

For the qualitative variables of plant community group and slope aspect, analysis of variance was used to compare grass utilization among factor categories. Mean grass utilization by plant community group is presented in Table 10. Results were similar for each year individually so only the analysis on utilization averaged over years is presented. For both % utilization and weight utilization, the ponderosa pine-Douglas fir communities were used more heavily than the grassland, mixed conifer, or white fir groups which in turn were all used at about equal intensities. Table 11 contains mean grass utilization estimates by slope aspect. Means for all aspects are statistically equivalent for both % utilization and weight utilization.

The higher intensity of use in the ponderosa pine-Douglas fir plant community group is in general agreement with the correlation analysis for quantitative variables. For instance, this vegetative group had the highest proportion of elk sedge and lowest proportion of pinegrass in the forest communities, and the proportions of these two species had positive and negative respective correlations with utilization. The ponderosa pine-Douglas fir community group was also more prevalent at the lower elevations and elevation had a negative correlation with utilization. The positive correlations with herbage and grass production did not relate specifically to the ponderosa pine-Douglas fir group, since this community did not have a clear advantage over the mixed conifer group in herbage production. It seems logical an animal would prefer areas where food was more abundant, since this should

Table 10. Mean grass utilization within plant community groups averaged over years, Butte Pasture.[1]

Plant Community Group	N	% Utilization	Weight Utilization, kg/ha
grassland	5	8.2^b	14.9^b
ponderosa pine-Douglas fir	18	13.8^a	33.0^a
mixed conifer	20	8.3^b	17.6^b
white fir	7	5.9^b	10.2^b
s^2		40.5	226.1

[1] means with the same superscript within columns are not significantly different at the 10% probability level.

Table 11. Mean grass utilization by slope aspect averaged over years, Butte Pasture.[1]

Aspect	N	% Utilization	Weight Utilization, kg/ha
north	5	12.5	29.4
east	7	10.0	21.2
west	11	10.2	21.6
northeast	9	7.6	17.0
northwest	7	8.4	17.6
southeast	7	11.4	27.0
s^2		52.2	309.0

[1] all means within columns are statistically equivalent at the 10% probability level.

increase the amount of food harvested per unit time spent foraging. This effect has been shown for cattle by several authors (Wagnon 1968, Reynolds 1969, Kranz and Linder 1973). This effect was outweighed on the grasslands, because most of the forage plants on these shallow soil areas were already starting to dry when cattle entered the allotment. This forage was almost totally cured and unpalatable by July 1, and little utilization occurred after that date unless late summer rains stimulated regrowth.

Slope gradient and vertical distance from salt were not closely related to any particular vegetation type. The negative effect of slope on cattle distribution is well documented (Mueggler 1965, Phillips 1965, Cook 1966, Van Vuren 1982). The effect of salt either has been related to utilization by horizontal distance (Phillips 1965, Cook 1967, Roath 1980) or has been found to be of secondary importance in influencing utilization patterns (Cook 1966, Wagnon 1968, Bryant 1979) in other studies. Vertical distance to salt was one of the more highly associated site factors with grass utilization in the Butte Pasture.

Two factors often considered important but which were not associated with utilization patterns were forest canopy cover and water distribution. Canopy cover may have been exerting an indirect influence through its effects on understory production. Apparently the three perennial streams, one intermittent stream, and handful of upland water developments were sufficient to remove water distribution as a major influence on cattle distribution.

This situation has also been reported from other areas (Julander and Jeffery 1964, Cook 1966, Clary et al. 1978).

Caribou Pasture

Means and ranges over all sites for quantitative variables in the Caribou Pasture are displayed in Table 12. Average % grass utilization was again low and did not exceed 10% in the three study years. Maximum observed utilization on a single site was 36%. Utilization expressed as weight of forage removed was also low. Average herbage production was higher than in the Butte Pasture because the Caribou Pasture contained fewer white fir forest sites, which produced the lowest amounts of herbage, and several logged forest sites, which produced the highest amounts of herbage.

Significant correlations between grass utilization and various site characteristics within the Caribou Pasture for the elk sedge-pinegrass forage type are shown in Table 13. Only a few independent variables were associated with either measure of utilization, and no correlation coefficient was greater than 0.63. Slope gradient was the only site factor with a significant correlation in more than one year indicating the variability in distribution patterns from year to year. Within years, the same site factors were usually associated with both dependent variables, and the magnitude of the correlation coefficients did not differ on average for the two cases. Horizontal and trail distance to water were positively associated with cattle use. It would seem these were spurious associations since all previous research has

Table 12. Means and ranges of variables used in regression analysis of grass utilization in relation to site variables, Caribou Pasture.

Variables	Unit	Mean	Minimum	Maximum
% utilization	%			
1979		8.1	0	36
1980		9.2	0	27
1981		9.3	0	28
weight utilization	kg/ha			
1979		14	0	124
1980		24	0	137
1981		32	0	197
herbage production	kg/ha			
1979		182	45	370
1980		316	100	730
1981		369	165	805
grass production	kg/ha			
1979		153	30	345
1980		253	55	640
1981		300	120	715
% pinegrass	%	30	0	55
% elk sedge	%	36	0	61
forest canopy cover	%	42	0	86
% slope	%	24	0	51
slope length	m	100	0	380
elevation	m	1372	1195	1640
horizontal distance to water	m	301	40	835
trail distance to water	m	398	40	1000
vertical distance to water	m	40	0	105
horizontal distance to salt	m	435	30	1310
trail distance to salt	m	519	30	1400
vertical distance to salt	m	36	0	130

Table 13. Correlations between grass utilization and site characteristics, elk sedge-pinegrass forage type, Caribou Pasture, 1979-1981.[1]

	% Utilization			Weight Utilization		
Site Characteristic	1979	1980	1981	1979	1980	1981
herbage production						.424*
grass production			.321			.467*
forest canopy cover						-.365*
% slope		-.523**	-.626**		-.523**	-.590**
horizontal distance to water	.369*			.406*		
trail distance to water				.314		
vertical distance to water			-.356			-.340
N	29	36	36	29	36	36

[1] * denotes significance at the 5% probability level;
** denotes significance at the 1% probability level;
correlation coefficients without superscripts are significant at the 10% probability level.

indicated a negative relation between distance to water and utilization. There was no obvious explanation for such a contradictory result in this study.

Table 14 lists significant utilization-site factor correlations for the logged forest forage type. While fewer site factors showed significant correlations, these correlation coefficients were the highest calculated in the study. Trail distance to salt had the best association with grass utilization followed closely by slope length. No site factors showed a significant association with grass utilization in 1980.

The grassland forage type was seldom used by cattle. The average % grass utilization over all years was only 2.4%. Due to the low utilization levels, correlation and regression analyses was not applied to this forage type.

Results of the multiple regression analysis relating grass utilization and site characteristics for the elk sedge-pinegrass forage type are shown in Table 15. As in the Butte Pasture, grass production was chosen for analysis, and herbage production was excluded from the model. The positive association between utilization and horizontal and trail distance to water could not be logically explained so these two independent variables were also excluded from the regression models.

The sets of independent variables in the models for % utilization and weight utilization within years were identical but there was considerable variation in models between years. As in the Butte Pasture, the proportion of variation in the dependent

Table 14. Correlations between grass utilization and site characteristics, logged forest forage type, Caribou Pasture, 1979-1981.[1]

	% Utilization			Weight Utilization		
Site Characteristic	1979	1980	1981	1979	1980	1981
% elk sedge						-.748
forest canopy cover	-.836			-.904*		
slope length	-.942*		-.808*	-.896*		-.686
horizontal distance to salt	-.965**		-.730	-.920*		-.713
trail distance to salt	-.984**		-.906**	-.942*		-.852*
N	5	7	7	5	7	7

[1] * denotes significance at the 5% probability level;
** denotes significance at the 1% probability level;
correlation coefficients without superscripts are significant at the 10% probability level.

Table 15. Regression coefficients and associated statistics for predicting grass utilization from site characteristics, elk sedge-pinegrass forage type, Caribou Pasture, 1979-1981.[1]

Site Characteristic	% Utilization 1979	% Utilization 1980	% Utilization 1981	Weight Utilization 1979	Weight Utilization 1980	Weight Utilization 1981
forest canopy cover			-.14			-.54
% slope		-.33	-.32		-.70	-.95
vertical distance to water			-.07			-.20
constant (b_o)		17.22	27.79		36.04	87.66
R^2		.273	.546		.274	.554
$s_{\bar{y}\cdot\bar{x}}$		1.11	0.79		2.35	2.42
$\bar{y}$	7.7	9.1	10.1	10.0	19.0	28.3

[1] regression models are of the form $\hat{Y}=b_o+b_1X_1+...+b_iX_i$

variables accounted for by the regression models was not large. Significant models could not be constructed for 1979. Slope gradient was the independent variable most commonly included in the models.

Regression models for the logged forest forage type are listed in Table 16. The only variable included in the models was trail distance to salt. This would be expected since that variable had the highest simple correlations with utilization. In some cases, slope length could have been used in the model rather than trail distance to salt with only a small reduction in model fit. While the R^2 values for these models were the highest calculated, the predictive utility as measured by the standard error of prediction was not appreciably greater than that for the other forage type because of the smaller sample size. The models for 1979 and 1981, the years of early grazing, are similar. For 1980, when grazing occurred in the late period, no significant model could be constructed.

The variability in utilization patterns from year to year was again indicated by correlations among utilization expressions listed in Table 17 for the elk sedge-pinegrass forage type and Table 18 for the logged forest forage type. Correlations were once again largest between forage expressions within the same year. In the elk sedge-pinegrass forage type, correlations were largest between 1979 and 1981 for % utilization and slightly lower between these years and 1980. However, for weight utilization, 1980 and 1981 were most associated. These were the years of

Table 16. Regression coefficients and associated statistics for predicting grass utilization from site characteristics, logged forest forage type, Caribou Pasture, 1979-1981.[1]

	% Utilization			Weight Utilization		
Site Characteristic	1979	1980	1981	1979	1980	1981
trail distance to salt	-.07		-.05	-.23		-.30
constant (b_o)	44.36		30.99	136.82		191.16
R^2	.969		.821	.886		.726
$s_{\bar{y}\cdot\bar{x}}$	1.31		1.53	8.19		13.09
$\bar{y}$	18.0	14.4	14.0	54.0	65.3	80.6

[1] regression models are of the $\hat{Y}=b_o+b_1X_1$

Table 17. Correlations between grass utilization expressions, elk sedge-pinegrass forage type, Caribou Pasture.[1]

		% Utilization		Weight Utilization		
		1980	1981	1979	1980	1981
% Utilization	1979	.688	.819	.949	.760	.769
	1980		.735	.684	.976	.732
	1981			.775	.770	.971
Weight Utilization	1979				.706	.674
	1980					.788

[1] all correlation coefficients are significant at the 1% probability level.

Table 18. Correlations between grass utilization expressions, logged forest forage type, Caribou Pasture.[1]

		% Utilization		Weight Utilization		
		1980	1981	1979	1980	1981
% Utilization	1979	.200	.941*	.973*	.462	.918*
	1980		-.024	.002	.923**	-.080
	1981			.921*	.394	.960**
Weight Utilization	1980				.252	.955**
	1981					.128

[1] * denotes significance at the 5% probability level;
** denotes significance at the 1% probability level.

highest herbage production. In the logged forest forage type, 1979 and 1981 were highly correlated for both utilization expressions. In turn, these years were uncorrelated with 1980 for both utilization expressions. Season of grazing apparently had a large impact on the pattern of cattle use on logged forest sites.

Mean grass utilization by plant community group is shown in Table 19. The results were not consistent over time, so all years are presented. For % utilization, the logged forest was used at the highest intensity in all years but this use was different from the ponderosa pine-Douglas fir type only in 1979. The grassland communities always had the lowest utilization but were never stastistically different from the mixed conifer sites. Overall, the logged forest sites were used most intensively, the forested communities were intermediate, and the grasslands were used least. On the basis of forage removal, the logged forest communities were easily the most important because of the higher herbage production on these sites. Since the other three community types were similar in herbage production, their general ranking for weight removal was the same as their ranking for % utilization. Mean grass utilization by slope aspect is listed in Table 20. No statistical differences for either utilization expression were found among the various slope aspects.

Higher cattle use levels for logged forest sites have been noted by other workers in this region (Miller and Krueger 1976). This was probably a result of higher production and lower forest canopy cover plus the presence of palatable introduced grasses in

Table 19. Mean grass utilization within plant community groups, Caribou Pasture, 1979-1981.[1]

Plant Community Group	N	% Utilization				Weight Utilization			
		1979	1980	1981	Average	1979	1980	1981	Average
grassland	7	2.0^{a}	4.1^{a}	0.7^{a}	2.4^{a}	2.3^{a}	10.3^{a}	1.4^{a}	4.9^{a}
ponderosa pine-Douglas fir	13	8.0^{a}	10.5^{bc}	11.4^{bc}	10.1^{b}	9.6^{a}	22.5^{a}	34.3^{b}	23.4^{b}
mixed conifer	23	7.1^{a}	6.8^{ab}	7.9^{ab}	7.3^{ab}	10.6^{a}	12.8^{a}	17.7^{a}	13.9^{ab}
logged forest	7	18.0^{b}	14.4^{c}	14.0^{c}	15.5^{c}	54.0^{b}	65.3^{b}	80.6^{c}	68.6^{c}
s^2		56.3	57.2	41.9	39.6	308.4	474.5	754.5	354.8

[1] means with the same superscript within columns are not significantly different at the 10% probability level.

Table 20. Mean grass utilization by slope aspect averaged over years, Caribou Pasture.[1]

Aspect	N	% Utilization	Weight Utilization
south	13	11.2	27.5
west	11	6.8	17.1
southeast	6	4.8	16.3
southwest	13	9.3	28.8
s^2		47.3	753.2

[1] all means within columns are statistically equivalent at the 10% probability level.

the logged areas. The grasslands were seldom used for the same reasons as discussed earlier for the Butte Pasture. The problem of early curing of herbage is even more pronounced on this southerly facing pasture.

Within forage types, physical habitat factors appeared to be more consistently associated with grass utilization than vegetation factors. Slope gradient was present in four regression models in the elk sedge-pinegrass forage type. For the logged forest forage type, trail distance to salt and slope length were the major site factors associated with cattle use. While other research supports the importance of slope length in determining utilization patterns (Mueggler 1965, Phillips 1965), salt distribution has not usually been considered to be a primary factor influencing distribution (Phillips 1965, Cook 1966, Wagnon 1968, Bryant 1979). The high association of trail distance to salt and utilization may be due in part to the fact trail distance to salt was also significantly correlated with slope length ($r = .823$, $p < .05$).

Seasonal Palatability and Utilization Patterns

The season of use, either early or late, was seen to have large effects on distribution patterns in the Caribou Pasture. This may have been related to shifting palatability of major forage species. During June and July, pinegrass is in the early stages of growth and has a higher crude protein content than elk sedge (Skovlin 1967, McLean et al. 1969). The forage quality of pinegrass decreases rapidly after mid-July, and the crude protein content falls below that of elk sedge by early August. The decline in nutrient content along with an increase in silica content makes pinegrass a generally inferior late season forage with low palatability (Skovlin 1967). In contrast, elk sedge maintains relatively high crude protein levels for almost a month longer than associated forage species and is also subject to less within-season variation in crude protein content (Skovlin 1967). It might be expected then that the palatability of pinegrass and elk sedge would reverse from early to late season grazing with a possible influence on grazing distribution.

The results of paired comparisons of % utilization between these species using sites on which pinegrass and elk sedge occurred together are shown in Table 21. On a season-long basis, tests from the Butte Pasture indicated the two species were utilized at about equal intensities. The slightly higher pinegrass use in 1979 may have been due in part to a reduction in late season grazing pressure when about 30% of the cattle escaped from the pasture. In forested communities on the Caribou Pasture, pinegrass was preferred over elk sedge in the early grazing period (1979, 1981) while the species were used at equal intensities in the late period (1980). Results were different on logged forest sites with equal use in the early period and higher utilization on elk sedge in the late period.

On sites with a forest canopy to provide shade and delay senescence, pinegrass apparently maintained its palatability under late season grazing. Pinegrass was definitely preferred over elk sedge in the early growth period. This may have been due to the

Table 21. Paired comparisons of % utilization of pinegrass and elk sedge on sites where both occurred, 1979-1981.[1]

	% Utilization								
	Butte Pasture			Caribou Pasture					
	elk sedge-pinegrass forage type			elk sedge-pinegrass forage type			logged forest forage type		
Year	N	pinegrass	elk sedge	N	pinegrass	elk sedge	N	pinegrass	elk sedge
1979	15	10.1	7.5+	25	16.2	5.6**	5	11.0	12.1
1980	36	15.0	15.8	29	12.4	11.1	5	7.2	28.0*
1981	36	13.0	13.3	32	16.0	9.2**	7	9.7	14.1

[1] + denotes that means within year and forage type are different at the 10% probability level;

* denotes that means within year and forage type are different at the 5% probability level;

** denotes that means within year and forage type are different at the 1% probability level.

rough texture of the evergreen elk sedge. When the tree canopy was removed, full solar radiation reached the ground causing increased soil temperatures, an accelerated growth cycle, and a more rapid depletion of soil moisture. Pinegrass matured rapidly in this situation and was fully cured by mid-August (70-80% dry matter content in foliage) while elk sedge remained green (55-60% dry matter content in foliage). Pinegrass and elk sedge both had a foliage dry matter content of 45-55% on forested sites in August. This could explain the differential results from forest and logged communities. Elk sedge became the preferred forage plant on logged sites under late season use while equal use was made of pinegrass and elk sedge during the early period.

This same idea of different stages of maturity between grasses and elk sedge could explain the lack of correlation of grazing use on logged sites from the early to the late grazing period. Utilization on logged sites which were not seeded to introduced pasture grasses was generally twice as great in the late period as compared to the early period. Most of the forage on these sites was supplied by pinegrass, elk sedge, mountain brome (Bromus marginatus), and cheatgrass (Bromus tectorum). All of these species except elk sedge were well cured by mid-August. Since elk sedge was the only green forage available, its use increased dramatically.

Sites on which intermediate wheatgrass had been successfully established experienced moderate to relatively high use in the early period but dropped to almost no use in the late period.

Intermediate wheatgrass produced large amounts of forage and accounted for most of the utilization in the early period. When this grass was deferred until August, it produced many seedheads and became stemmy and harsh. This made the grass unpalatable to cattle and little utilization occurred. As a result, utilization for the entire site decreased to as little as 10-25% of early period use levels.

A third situation existed on sites where appreciable amounts of orchardgrass or timothy (*Phleum pratense*) had been established. These two grasses were highly palatable to cattle and maintained this palatability for the entire grazing season. These sites showed little variation in grass utilization from the early to the late grazing period. Decreases in use on some sites, increases on others, no changes on still others allowed utilization levels on logged sites as a group to remain fairly stable over years. This resulted in a lack of correlation of grass utilization on these sites between the early and late grazing periods.

Late season grazing also resulted in the loss of large amounts of intermediate wheatgrass forage since this grass was lightly used at that time. This shifted more grazing pressure onto the other upland forage plants, especially elk sedge.

Discussion

Most of the analyses gave similar results whether the dependent variable was % utilization or weight utilization. The variation in herbage production was not extremely large among upland plant communities, and % utilization tended to follow herbage production. Additionally, % utilization was used to calculate weight utilization. The result was that % utilization and weight utilization were highly correlated and therefore produced essentially the same results.

The range of R^2 values achieved for the regression models in the elk sedge-pinegrass forage type was 0.13-0.55. Significant individual correlations between site factors and utilization ranged from 0.30 to 0.45 with only a few above 0.50. No single site factor had a dominant association with grass utilization, and the ability to predict cattle distribution patterns from site characteristics was limited under the conditions of this study. Correlations were higher and model fits considerably better for the logged forest forage type. However, predictive ability was not increased because of the lower number of sites used to develop the models.

Forage utilization levels were light over the allotment with an average of approximately 10% over all sites and a maximum of 36% on a single site. As utilization levels decrease, the relative variation of utilization estimates often increases. This additional sampling variation makes the task of outlining utilization patterns more difficult. Even though cattle would be expected to exhibit grazing preferences most clearly under light stocking levels, practical sampling limitations may prevent a clear delineation of these grazing preferences. This is one reason for the general lack of fit in the mathematical models describing upland grazing distribution.

Cattle sign, including fecal droppings and hoof prints, was noted in virtually every part of the pastures, but there were seldom large amounts on any single upland site. At the overall light use levels observed on this allotment, upland grazing distribution was certainly not a problem.

Several other researchers have developed regression models relating forage utilization and various site factors. Cook (1966) obtained R^2 values of 0.56 for a single year and 0.38 for three years of pooled data on Utah foothill range. The decrease in model fit for pooled data suggests that the relationships were not constant between years. In the current study, year to year variation seemed large and data were not pooled over years for this reason. McDaniel and Tiedeman (1981) reported slightly higher R^2 values of .38-.63 in a study of sheep distribution on mountain range. Forage utilization ranged from 3% to 65%. With forage utilization of 0-84%, Clary et al. (1978) reported an R^2 value of 0.79 for a cattle distribution model in northern Arizona. It would appear that as the range in utilization increased, the proportion of explained variation increased, possibly because distribution patterns could be sampled with greater precision.

The ability to predict cattle distribution also increases as the number of major habitat factors influencing distribution decreases and interactions become less complex. Mueggler controlled all but two site factors and achieved an R^2 value of 0.81 for cattle use on mountain grasslands. In a relatively small mountain pasture of 144 ha, Miller and Krueger (1976) developed a model accounting for 99% of the observed variation in cattle use patterns.

While the correlation and regression analyses could not yield models useful in predicting cattle distribution patterns precisely, they did point out habitat factors which may have major influences on grazing distribution. In the Butte Pasture, both vegetational and physical factors were important. Herbage or grass production and elk sedge composition had positive associations with utilization while slope gradient and vertical distance to salt were negatively associated. Water distribution did not seem to be a limiting factor in determining utilization patterns. Within forage types, physical factors were most prominent in the Caribou Pasture. Slope gradient and length and trail distance to salt all had consistent correlations with forage utilization.

Significant differences in utilization were found between broad plant community groups. This indicated that overall vegetation structure and composition were major factors influencing upland cattle distribution in this study even though vegetational and physical factors were not totally independent. Logged forest sites in the Caribou Pasture were used more intensively than the other upland community types and were clearly superior in terms of the relative amount of forage supplied to the cattle. The ponderosa pine-Douglas fir communities ranked second in use in the Caribou Pasture and first in use in the Butte Pasture. Cattle made the heaviest use in the more open forest types (including clearcuts) which agreed with other reports from this region

(Hedrick et al. 1968, Miller and Krueger 1976). Cattle use on the grasslands was restricted because of the earlier forage growth cycle on these sites, especially in the southerly facing pasture. Late summer showers which stimulate green regrowth have been shown to materially increase use on grassland sites (Bryant 1979).

Habitat Utilization

Descriptive statistics for the observation routes in the Butte and Caribou Pastures are shown in Table 22. Observations in the Butte Pasture for 1979 were not included in this table or in the following discussion. After cattle escaped from the pasture in August of 1979, observation routes had to be discontinued because of low numbers of sightings. Only 180 cattle had been observed up to that point and it was felt that this number of sightings was not sufficient for meaningful analysis.

The number of routes in the Butte Pasture was higher than in the Caribou Pasture because cattle were present for a longer period of time in the former pasture. However, more individual cattle observations were made in the Caribou Pasture. This was probably a result of a higher proportion of more open preferred habitats on the Caribou observation routes compared to the Butte routes as well as a longer route length, 28 km versus 19.7 km, respectively. The Butte Pasture also contained 43% as many cattle in a pasture which was 30% larger than the Caribou Pasture. The mean number of sightings per route varied among years with cattle apparently more dispersed in 1981 in the Butte Pasture and 1980 in

Table 22. Descriptive statistics for cattle observation routes.[1]

Statistic	Butte Pasture		Caribou Pasture		
	1980	1981	1979	1980	1981
number of observation routes (N)	29	40	12	18	21
total cattle observed (T)	539	462	705	583	1201
cattle observed per route ($\bar{x}$)	18.6	11.6	58.8	32.4	57.2
standard deviation (s)	9.6	2.9	13.7	11.9	22.5
$\bar{x}$ as percentage of animals in pasture	22	14	29	19	29
correlation between cattle observed per route and number of routes completed	.163	-.352*	$-.565^{+}$	-.629**	-.553**

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[1] $^{+}$ denotes significance at the 10% probability level;

* denotes significance at the 5% probability level;

** denotes significance at the 1% probability level.

the Caribou Pasture. An average of 14-29% of the total herd in a pasture was observed on each route and this was considered to be an adequate sample to allow inferences to be made about the behavior of the herd in general. In four of the five year x pasture subgroups, cattle continued to disperse as the season progressed, as indicated by the negative correlations between the number of cattle observed per route and the total number of routes completed.

Plant Community and Slope Aspect Utilization

The percentages of cattle observed in the various plant community groups as well as the percentage of the observation areas contributed by each plant community group are listed in Table 23. For the Butte Pasture, cattle utilization of the various communities was relatively constant between years with an increase in grassland use and a slight decrease in use of the grand fir group in 1981. The increase in grassland use may have been partly a result of cattle being on the pasture about three weeks earlier in 1981 before the vegetation on the grasslands had fully dried.

When comparing community use with availability, the most striking feature was the high cattle preference for meadow communities. This vegetation group had a habitat preference index of greater than 9.0 with almost half of the animals observed on 5% of the observation area. The grassland communities also seemed to be preferred although to a lesser extent than the meadow group. However, this preference was more a result of several important

Table 23. The percentage of total cattle observed within various plant community groups and the percentage of the observation areas contributed by each plant community group.[1]

Plant Community Group	Butte Pasture 1980	Butte Pasture 1981	Butte Pasture Available	Caribou Pasture 1979	Caribou Pasture 1980	Caribou Pasture 1981	Caribou Pasture Available
meadow	47^a	46^a	5^c	25^a	34^b	23^a	3^c
grassland	15^a	21^b	6^c	3^a	5^{ab}	6^b	9^b
ponderosa pine-Douglas fir	15^a	17^a	17^a	19^a	24^{ab}	26^b	42^c
mixed conifer	18^a	14^a	35^b	14^a	12^{ab}	9^b	24^c
white fir	5^a	2^b	37^c	-	-	-	-
logged forest	-	-	-	39^a	25^b	35^a	22^b

[1] percentages within pasture and row with the same superscripts are statistically equal at the 10% probability level for simultaneous comparisons of all plant communities between columns.

salt grounds being placed in grassland communities with the cattle usually being observed at these concentration points rather than a preference for the grasslands themselves. The ponderosa pine-Douglas fir community group was used in proportion to its availability. The mixed conifer group was used less than would be expected from its availability but was still an important cattle use area. Cattle strongly avoided the white fir community group.

In the Caribou Pasture, shifts in cattle habitat utilization occurred every year. The years 1979 and 1981 were most similar in habitat use patterns and grazing occurred in the early period in both years. The major difference in these years was a seven percentage unit increase in use of the ponderosa pine-Douglas fir community group in 1981. The year of late grazing, 1980, differed from both early grazed years in two categories. There was a large increase in the use of the meadow communities and an accompanying decrease in use in the logged forest community group in 1980. Cattle use of the remaining community groups in 1980 was intermediate between 1979 and 1981.

The meadow communities were highly preferred in the Caribou Pasture with values of the habitat preference index ranging from 7.7 to 11.3. The logged forest community group was a preferred habitat in 1979 and 1981 but was used in proportion to availability in 1980. The ponderosa pine-Douglas fir and mixed conifer communities were generally not preferred although the ponderosa pine-Douglas fir group was still an important habitat in terms of cattle occupation. The grassland communities were used in proportion to availability during two years but the actual value of this community group was biased upward by the presence of important salt grounds as in the Butte Pasture.

The percentage of cattle observed on various slope aspects and the percentage of the observation areas contributed by each aspect are listed in Table 24. Cattle use of aspect in the Butte Pasture was relatively constant between years with an increase in the use of north slopes in 1981 as compared to 1980. About half of the slope aspect categories were used to the same degree they were available. North aspects were highly preferred while east and west aspects were used only one-half to one-fifth as much as they were available. A large proportion of the meadow communities occupied north aspects while the east and west aspects supported mostly forested communities which were not preferred.

In the Caribou Pasture, use of slope aspect was variable between years. An increase in use on south slopes and a decrease on southwest slopes in 1980 seems keyed to large amounts of the meadow and logged forest community types on these respective slopes which elicited responses similar to those discussed under plant community group utilization. No obvious reason was found for the large decrease in the use of west slopes in 1980. For slopes supporting major cattle use, there was no clear preference of one aspect over another as most were used in proportion to their availability.

Table 24. The percentage of total cattle observed on various slope aspects and the percentage of the observation areas contributed by each slope aspect.[1]

	Butte Pasture			Caribou Pasture			
Aspect	1980	1981	Available	1979	1980	1981	Available
level	trace^{a}	1^{ab}	2^{b}	4^{a}	7^{a}	6^{a}	4^{a}
north	44^{a}	52^{b}	23^{c}	1^{ab}	0^{a}	0^{a}	2^{b}
south	-	-	-	26^{a}	35^{b}	27^{a}	23^{ab}
east	11^{a}	8^{a}	22^{b}	5^{a}	4^{a}	2^{b}	4^{ab}
west	3^{a}	2^{a}	11^{b}	15^{a}	6^{b}	13^{a}	17^{a}
northeast	26^{a}	26^{a}	22^{a}	0^{a}	1^{b}	trace^{a}	1^{b}
northwest	11^{a}	8^{a}	11^{a}	3^{a}	3^{a}	5^{a}	7^{a}
southeast	4^{a}	5^{a}	8^{a}	16^{a}	21^{ab}	11^{b}	17^{ab}
southwest	1^{a}	0^{a}	1^{a}	30^{a}	23^{b}	36^{c}	26^{abc}

[1] percentages within pasture and row with the same superscripts are statistically equal at the 10% probability level for simultaneous comparisons of all aspects between columns.

Association of Quantitative Physical Factors

A list of significant correlation coefficients for the associations of habitat preference indices and various quantitative habitat factors is given in Table 25. Utilization patterns were not constant from year to year as was also noted for upland utilization in the preceding section of this paper. Five of six habitat factors had significant correlations with cattle preference in the Butte Pasture in 1980 while only two were associated in 1981. While slope was strongly associated with cattle preference it was still partially modified by plant community. In both years, the highest habitat preference index was actually calculated for the 5-10% slope class rather than the 0-5% class because the most heavily used meadows were in the steeper class. Over 65% of all cattle were observed on slope gradients less than 10% which contributed 16% of the observation area. No preference was shown for slope gradients greater than 10%. Elevation was also exponentially associated with preference because all preferred communities were located at the lower pasture elevations while the upper portions were completely dominated by the white fir forest which was little used by cattle.

Water distribution was only associated with cattle preference for one year in the Butte Pasture. There was a definite aggregation of sightings in the lower distance classes for both trail and vertical distance to water but these same classes also made up fairly large areas of the observation routes. Less than 5% of all cattle were observed beyond 700 m by trail or 60 m by vertical

Table 25. Correlations between habitat preference indices (HPI) and habitat characteristics.[1,2]

Habitat Characteristic	Butte Pasture		Caribou Pasture		
	1980	1981	1979	1980	1981
% slope (exp)	-.733	-.925**	-.908*	-.892*	-.980**
elevation (exp)	-.971**	-.885*			
trail distance to water	-.675*		-.792**		
vertical distance to water (exp)	-.733*				
trail distance to salt			-.787**	-.571	-.843**
vertical distance to salt	.612			-.720*	-.746*

[1] (exp) indicates the relation was expressed as ln Y=bX+a, where Y=HPI, X=habitat characteristic, a,b=constants

[2] * denotes significance at the 5% probability level;

** denotes significance at the 1% probability level;

correlation coefficients without superscripts are significant at the 10% probability level.

distance from water. Any effect of salt distribution was totally overwhelmed by plant community factors as indicated by the single positive correlation of vertical distance to salt and cattle preference in 1980. Salt was placed almost entirely on upland areas some distance above drainage bottoms. The high preference for meadow communities in these bottoms neutralized or reversed the expected negative correlation between distance to salt and cattle use.

In the Caribou Pasture, slope was also strongly related to cattle preference in a negative exponential manner. Cattle showed a positive preference for slope gradients up to 15%. About 90% of all cattle use occurred on slope gradients less than 30%. Elevation was not associated with cattle preference in a simple manner. The greatest use occurred in the middle elevations because this was the location of the most preferred plant communities. The lower elevations were dominated by the grassland communities while the upper elevations supported the lightly used forest communities.

Cattle use was again concentrated in the lower distance classes for trail and vertical distance to water in the Butte Pasture and all correlations were negative but most were not statistically significant. About 90% of all cattle use occurred within 800 m trail distance from water but 90% of the observation area was also within this distance. Cattle preference tended to shift between adjacent distance-to-salt classes from one year to the next but in general displayed a moderate negative association with trail and vertical distance to salt.

Cattle Activities

The percentages of observed cattle engaged in various activities in the Butte and Caribou Pastures calculated over years are listed in Table 26. The allocation of time to different activities did not vary greatly between pastures. There was a slightly larger percentage of traveling time in the Butte Pasture but this difference was not of practical magnitude.

Within the Butte Pasture, there was a large difference in the proportion of time spent grazing between 1980 and 1981 with estimates of 71 and 56%, respectively. This resulted in less time spent lying and standing in 1980 while the time spent in minor activities was similar between years. No obvious explanation could be found for this discrepancy.

In contrast, grazing time within the Caribou Pasture was constant between all three years at 61, 60, and 60%, respectively. There was a rather large increase of about nine percentage units in lying time when comparing 1979 with 1980 or 1981. This resulted in the minor activities being reduced to trace levels in 1979. Again, no clear explanation is available for this phenomenon. The proportions of animals observed in all activities was virtually identical between 1980 and 1981 in the Caribou Pasture.

Table 26. Percentage of observed cattle engaged in various activities in the Butte and Caribou Pastures totaled over years.[1]

Major Activities	Butte Pasture	Caribou Pasture
grazing	64.4	60.7
lying	18.0	21.9
standing	8.3	11.2
Minor Activities		
salting	2.2	1.2
nursing	1.8	2.1
traveling	1.9^a	0.2^b
drinking	0.2	0.6
Unidentified	3.2	2.0
N	1001	2489

[1] percentages within row with different superscripts are statistically different at the 10% probability level for the simultaneous comparison of all activities between pastures.

Discussion

The extreme preference cattle exhibited for meadow communities in this study agrees with research reports from other mountainous areas (Bryant 1979, Long and Irwin 1982, Roath and Krueger 1982). While these communities are certainly preferred by cattle, it should be pointed out the habitat preference indices are calculated on the basis of plant community area, not herbage production. On average, the meadow communities produce 12-16 times as much herbage as the grassland and forest communities and about 6 times as much herbage as the logged forest communities. The meadows would be expected to support higher relative cattle use because of their higher relative herbage production. This fact does not explain all of the disproportionate use, however, since forage utilization on the meadows averaged about 75% while upland communities averaged about 9% forage utilization over the entire study.

Year to year variations seemed to have a relatively small effect on plant community use as compared to the effect of grazing period. Under early season grazing on the Caribou Pasture, both the meadow and logged forest community groups were preferred habitats. When grazing occurred during the late period, cattle use increased on the meadow and decreased by about one-third on the logged forest communities. The grassland and forest sites were not preferred during either period. Most of the logged forest plant communities on the observation area had been at least partially seeded with introduced pasture grasses. As discussed previously, the earlier plant growth cycle on these logged areas decreased the palatability of the herbage on these sites which in turn resulted in less cattle use. Most of this shift in cattle occupation was apparently absorbed by the meadow communities, a conclusion supported by riparian meadow camera monitoring to be discussed in a later portion of this paper.

Cattle use of slope aspect was somewhat variable between years. However, cattle use of and preference for various slope aspects could usually be explained in terms of the plant communities supported on these aspects. Cattle preference did not appear to be influenced directly by slope aspect.

Of the quantitative factors analyzed, slope gradient was most strongly and consistently associated with cattle preference. The negative exponential function used to associate cattle preference and slope gradient indicates that preference decreases most rapidly on slope gradients between 0 and 10% and then decreases slowly as gradient increases beyond 20%. The negative effect of slope gradient on cattle distribution is well known on mountain rangelands (Mueggler 1965, Cook 1966, Patton 1971, Van Vuren 1982).

Elevation was strongly associated with cattle preference in the Butte Pasture. However, as with slope aspect, elevation appeared to act indirectly through plant communities rather than directly influencing cattle behavior. This same indirect effect of elevation appeared to operate in the Caribou Pasture.

Water distribution was inconsistently related to cattle preference. Although a negative association with cattle preference was apparent, this association appeared to be overruled by other factors and was not statistically significant. Water distribution was largely removed as a limiting factor since over 70% of the observation areas were less than 600 m from water. Other workers have reported similar results on relatively well watered ranges (Julander and Jeffery 1964, Cook 1966, Clary et al. 1978).

The location of preferred plant communities neutralized or reversed the expected relationship between salt distribution and cattle preference in the Butte Pasture. This phenomenon has also been reported by Bryant (1979). Salt distribution was moderately correlated with cattle preference in the Caribou Pasture. However, several salt grounds at higher elevations or relatively out-of-the-way locations were not used by cattle in the Caribou Pasture. This evidence along with results from the Butte Pasture and other research reports (Cook 1966, Wagnon 1968, Bryant 1979) suggested the association of salt distribution and cattle preference in the Caribou Pasture may only have been an association and not a cause-and-effect relationship. More controlled experimentation with salt distribution on mountain rangelands seems warranted.

The percentage of daylight hours cattle spent grazing averaged about 60% over both pastures. This compares to an average of about 50% from other research reports (Weaver and

Tomanek 1951, Dwyer 1961, Herbel and Nelson 1966, Sneva 1970, Zemo and Klemmedson 1970, Shaw and Dodd 1979), all of which were on level to rolling ranges. These studies also reported an average of about 18% lying and 27% standing compared to 20% and 9%, respectively, in this study. Cattle on mountain rangelands apparently spend a greater proportion of the daylight hours grazing and a smaller proportion standing than cattle on more level ranges. This may be due to a higher expenditure of energy by animals grazing on rougher topography. Within this study, year to year changes in the allocation of time to the various activities could not be attributed to grazing system or to period of use within grazing system.

Riparian Meadow Utilization

Riparian Meadow Production

Total herbage production on riparian meadows estimated from plots protected from all large animal grazing is listed in Table 27. Riparian meadow production in the Caribou Pasture was higher than in the other two pastures in both 1980 and 1981 with an overall average of about 4000 kg/ha. Meadow production was similar in the Butte and Deerhorn Pastures in both years and averaged near 2500 kg/ha. The higher production in the Caribou Pasture is attributable to the occurrence of mainly high producing moist meadow types in this pasture. While the Deerhorn Pasture also contained more moist meadow sampling sites than the Butte

Table 27. Total ungrazed riparian meadow herbage production, 1980-1981.[1]

Pasture	Herbage Production, kg/ha		
	1980	1981	Average
Butte	2490^{a}	2250^{a}	2370^{a}
Caribou	4360^{b}	3725^{b}	4045^{b}
Deerhorn	2360^{a}	2645^{a}	2500^{a}
Average	3070	2875	2970

[1] means with the same superscript within columns are not significantly different at the 5% probability level.

Pasture, the Deerhorn moist meadow sites were on the lower end of the productivity range for moist meadows.

Residual Meadow Herbage

The weight of residual herbage on unprotected plots measured at two week intervals throughout the grazing season is depicted in Figure 4 for 1980 and Figure 5 for 1981. Each point represents the mean of four sampling sites. Mathematical expressions describing the lines are presented in Table 28 and were obtained from regression analysis. From general principles, it was felt that the rate of decline in residual forage would be rapid initially and then decrease over time as the residual herbage levels dropped. This suggested a negative exponential function, and regression models of this form fit the data well. In the Butte and Deerhorn Pastures, where total meadow herbage production averaged about 2500 kg/ha, the residual herbage curves appeared to approach a similar basal level after which little additional forage removal occurred. This basal level was reached rapidly in the Deerhorn Pasture in 1980 (early grazing) when low starting herbage levels were combined with higher animal numbers under deferred-rotation grazing. Curves from the Caribou Pasture, with total meadow herbage production of about 4000 kg/ha, maintained a more rapid rate of forage decline, and did not approach some lower basal herbage level within the sampled time period.

It appeared cattle were allowed to exert sufficient grazing pressure to remove as much herbage as was physically possible from

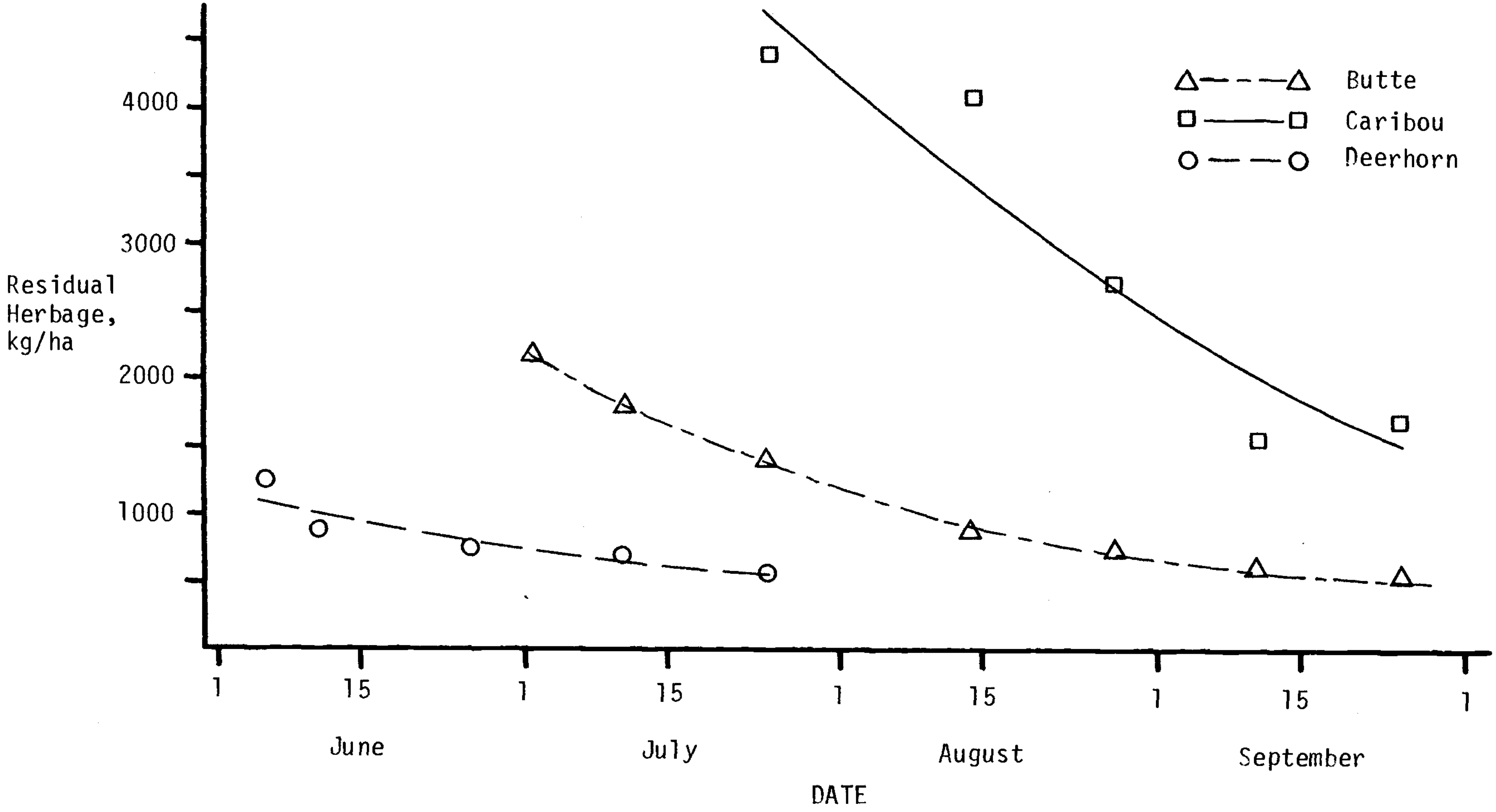

Figure 4. Residual herbage on riparian meadows, 1980.

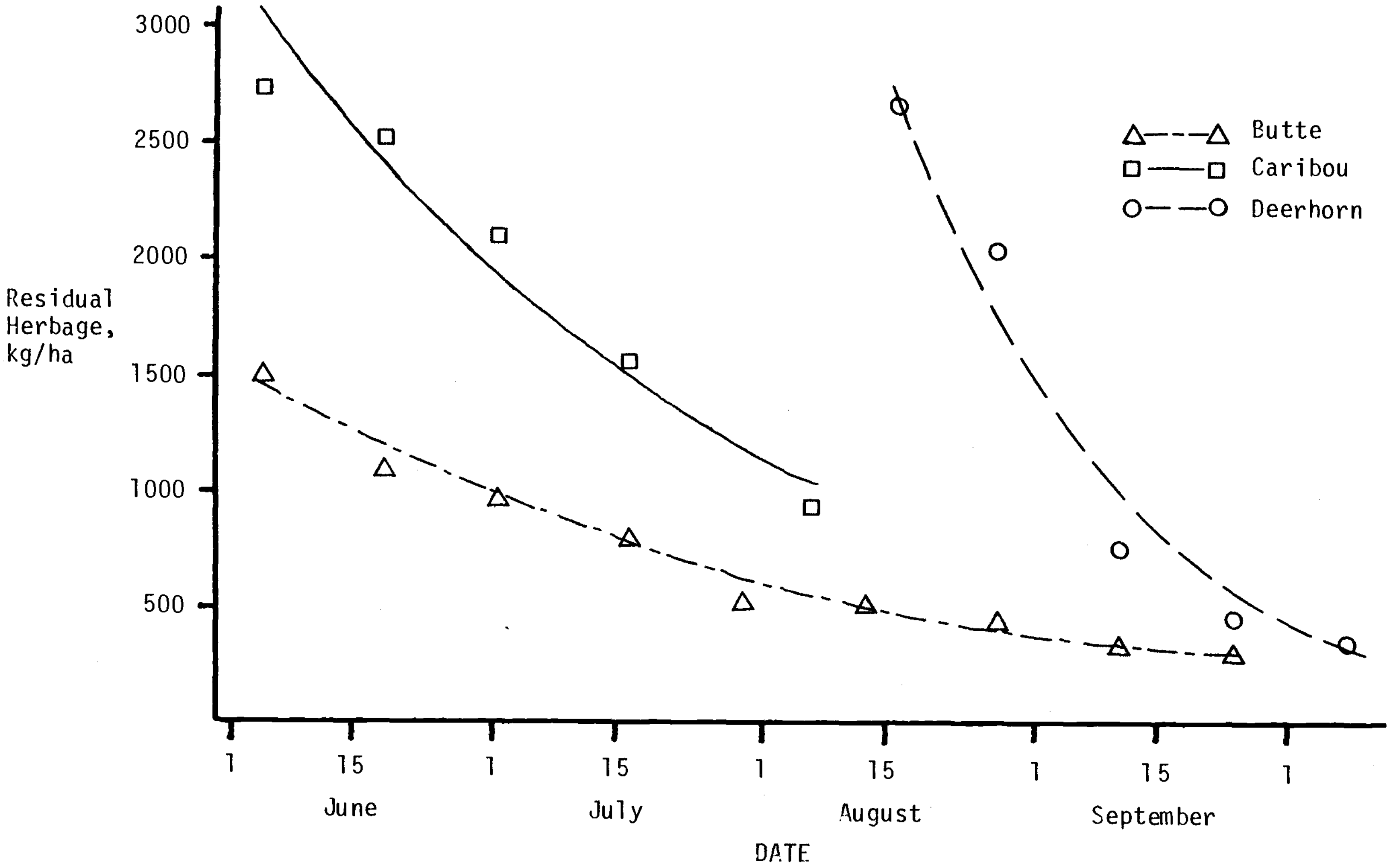

Figure 5. Residual herbage on riparian meadows, 1981.

Table 28. Equations relating residual herbage on riparian meadows and days of grazing in the pasture.[1,2]

Pasture	Year	Grazing Period	Equation	R^2
Butte	1980	Continuous	$\hat{Y}=2026.0e^{-0.02X}$	.98**
	1981	Continuous	$\hat{Y}=1375.5e^{-0.01X}$	.97**
Caribou	1980	Late	$\hat{Y}=4667.9e^{-0.02X}$	.89*
	1981	Early	$\hat{Y}=3045.4e^{-0.02X}$	.95**
Deerhorn	1980	Early	$\hat{Y}=1043.9e^{-0.01X}$	.84*
	1981	Late	$\hat{Y}=2674.0e^{-0.04X}$	.96**

[1] $\hat{Y}$ = residual herbage, kg/ha

X = days of grazing in pasture

[2] * denotes significance at the 5% probability level;

** denotes significance at the 1% probability level.

the lower producing meadows. Possibly some minimum stubble height was reached at which the cattle could no longer remove appreciable amounts of forage. Because of higher production in the Caribou Pasture, the cattle were on a different portion of the exponential curve and were unable to reduce the residual herbage to a basal level. Given a longer period of grazing or higher animal numbers, the same type of relation displayed in the other pastures would probably have developed in this pasture. It is speculated that the final basal herbage level would be somewhat higher on the higher producing meadows because of a greater plant density. In other words, because of a higher density of individual plants, the higher producing meadows should have more herbage below a given stubble height than the lower producing meadows.

Two other points can be made from these residual herbage graphs. First, there was never an increase in residual herbage even though regrowth was occurring through June and July. Forage consumption levels were high enough to remove all regrowth as well as a portion of the residual herbage stock. Second, it appeared that residual herbage levels declined more steeply under deferred-rotation grazing than under continuous grazing in three of the four comparisons. This may have occurred because stocking density was roughly twice as high on the deferred-rotation system.

Table 29 lists the mean residual herbage levels on the riparian meadows at the end of the respective grazing periods. As noted earlier, the early grazing period in 1981 was about 18 days longer than planned. For the purposes of this analysis, the final

Table 29. Mean residual herbage on riparian meadows at the close of grazing, 1980-1981.[1]

Grazing Period	Residual Herbage, kg/ha		
	1980	1981	Average
Continuous	570^a	329^a	449^a
Early	560^a	1180^b	870^b
Late	1685^b	354^a	1019^b
Average	938	621	779

[1] means with the same superscript within columns are not significantly different at the 5% probability level.

residual herbage for that period was considered to be the residual herbage level predicted from the regression equation in Table 29 for the planned grazing season ending on August 1.

In 1980, the late grazed pasture had higher levels of residual herbage than either of the early or continuously grazed pastures. The early grazed pasture had higher final herbage levels than the late or continuous pastures in 1981. Overall, the deferred-rotation pastures had similar final herbage levels and these levels were higher than those observed on the continuous pasture. It would seem that deferred-rotation grazing lessens the final intensity of use of riparian meadows when compared to continuous grazing. However, the herbage production differences discussed earlier suggest a different interpretation of these results.

In both years, the pasture with the highest residual herbage level was also the pasture with the highest herbage production, the Caribou Pasture. The two pastures with similar herbage production, the Butte and Deerhorn Pastures, had similar final herbage levels in both years. This occurred even though the Butte Pasture was grazed continuously both years while the Deerhorn Pasture was grazed once early and once late. This would indicate that when riparian meadow production averages about 2500 kg/ha, deferred-rotation and continuous grazing result in equal intensities of riparian meadow use at the stocking levels used in this study.

In the pasture containing meadows producing 4000 kg/ha of herbage, it appeared that late grazing lessened the intensity of use over early grazing. This conclusion ignored the apparent year differences. Mean final herbage levels averaged over years do not differ among early and late season grazing, indicating no effect of season of grazing within the deferred-rotation system.

Cattle Occupation of Riparian Meadows

Estimates of actual cattle occupation on riparian meadows as observed by time-lapse photography are presented in Table 30. Although the 1981 early grazing period extended longer than planned, camera monitoring on the early grazed pasture was concluded on August 6. Total cattle occupation was about equal under continuous and late grazing with early grazing receiving about half as much animal use. Total occupation in the continuous system was relatively constant over years. In the deferred rotation system, all meadows showed positive increases in occupation of 20-100% when going from early to late season grazing. However, probably because of the small sample size of two cameras per pasture, these means were not statistically different ($p > .10$). On a daily basis, late season grazing resulted in twice as much cattle occupation as continuous grazing ($p < .10$). Daily occupation under early season grazing was not different from late or continuous grazing.

The frequency of cattle occupation of riparian meadows on the basis of total frames and total days is shown in Table 31. The

Table 30. Mean magnitude of actual cattle occupation of riparian meadows.[1]

Grazing Period	Total Occupation (AUD/ha)	Daily Occupation (AUD/ha/day)
Continuous	61.8^{a}	0.53^{a}
Early	35.7^{a}	0.58^{ab}
Late	71.4^{a}	1.05^{b}

[1] means having the same superscript within columns are not significantly different at the 10% probability level.

Table 31. Frequency of cattle occupation of riparian meadows.[1]

Grazing Period	% Frames Occupied	% Days Occupied
Continuous	5.6^{a}	58.8^{a}
Early	3.8^{b}	61.5^{a}
Late	7.3^{c}	57.8^{a}

[1] percentages having the same superscript within columns are not significantly different at the 10% probability level.

area viewed by each camera ranged from .12 ha to .26 ha. It seemed likely frequency of occurrence might be dependent on plot size since frequency is not an absolute measure. A similar relation is well known from vegetation sampling (Mueller-Dombois and Ellenberg 1974). Correlation coefficients between view area and frequency were 0.04 on a total frame basis and 0.0002 on a daily basis (n = 12). Since these correlations were nonsignificant, there appeared to be no relation between frequency of cattle occupation and camera view area for the range of situations encountered in this study.

The proportion of camera frames in which at least one cow was present was higher under late grazing than early grazing ($p < .05$). Occupation on a total frame basis for continuous grazing was not different from either early or late grazing ($p < .10$). The proportion of days during which at least one animal was present on the study sites was very similar across grazing periods. These results indicated that cattle occupied any single riparian site fairly often (high daily frequency) but did not stay on that site for long periods of time (low total frequency). Martin (1979) also observed a low total frequency of cattle occupation on a riparian zone in central Arizona. Though present for a small proportion of the total time, cattle still had enough time to remove substantial amounts of forage.

When the data for the magnitude of occupation and the frequency of occupation were considered together, there was a suggestion that late grazing concentrated cattle use in the riparian zone over continuous or early use. This would seem reasonable for at least two reasons. First, by mid to late August most upland forage species have dried considerably, declined in nutrient content, and become less palatable (Skovlin 1967). This is especially true for pinegrass, a major upland forage species (McLean et al. 1969). At this time the riparian meadows still support large amounts of green palatable herbage. Second, temporary water supplies in the uplands would begin to dry up by this time forcing the cattle to depend more heavily on the riparian zone for a source of water.

Table 32 lists some correlations between total cattle occupation and three expressions of forage utilization on riparian meadows. The change in residual herbage was calculated as the amount of residual herbage at the onset of grazing minus the amount of residual herbage at the close of the grazing season. Forage removed was calculated as total ungrazed herbage production minus final residual herbage. This would overestimate actual forage removal because total herbage production was probably reduced by grazing. Each monitored meadow site was considered an observation within year. The Little Boulder Creek site was not used because the camera view area did not cover the entire area used for utilization sampling. Most of the correlations are low and not stable between years. It appears the rate of forage removal by cattle on these sites was not constant across meadow sites or time.

Table 32. Correlations between total cattle occupation of riparian meadows and three expressions of forage utilization.[1]

	Total Occupation, AUD/ha	
Utilization Expression	1980	1981
change in residual herbage	.895*	-.149
forage removed	$.836^{+}$	.055
final residual herbage	.382	.090

[1] + denotes significance at the 10% probability level;
* denotes significance at the 5% probability level;
N = 5.

Seasonal Profiles of Cattle Occupation

Examples of the pattern of daily cattle occupation through the grazing season are illustrated in Figures 6 and 7. The variability of occupation from day to day is apparent. Cattle were present in large numbers or for long periods of time for one or a few days and then were totally absent for a similar time period. Figure 6 for the Butte Pasture in 1981 shows the influence of the cattle turn-on point on the timing of meadow use. About 25% of all cattle occupation on this site for 1981 occurred on the first day of grazing because the cattle were turned onto the pasture 0.8 km downstream from the site. On the Deerhorn Pasture, one monitored meadow was on the east side of the pasture while the second was on the west. Cattle were turned onto the pasture one year on the east and the next year on the west depending on whether the pasture was grazed early or late. Meadows near the turn-on point were grazed immediately while the meadows on the opposite end of the pasture received no utilization for 7 to 14 days.

The seasonal profiles of cattle occupation did not appear to respond greatly to forage utilization or to seasonal weather. There was no large increase in cattle occupation during July and August, the hottest months of the year. Such an increase would have been expected if cattle were using the riparian zone to escape heat stress as has sometimes been suggested. There was also no close visual correlation between the profiles of occupation and residual herbage discussed earlier.

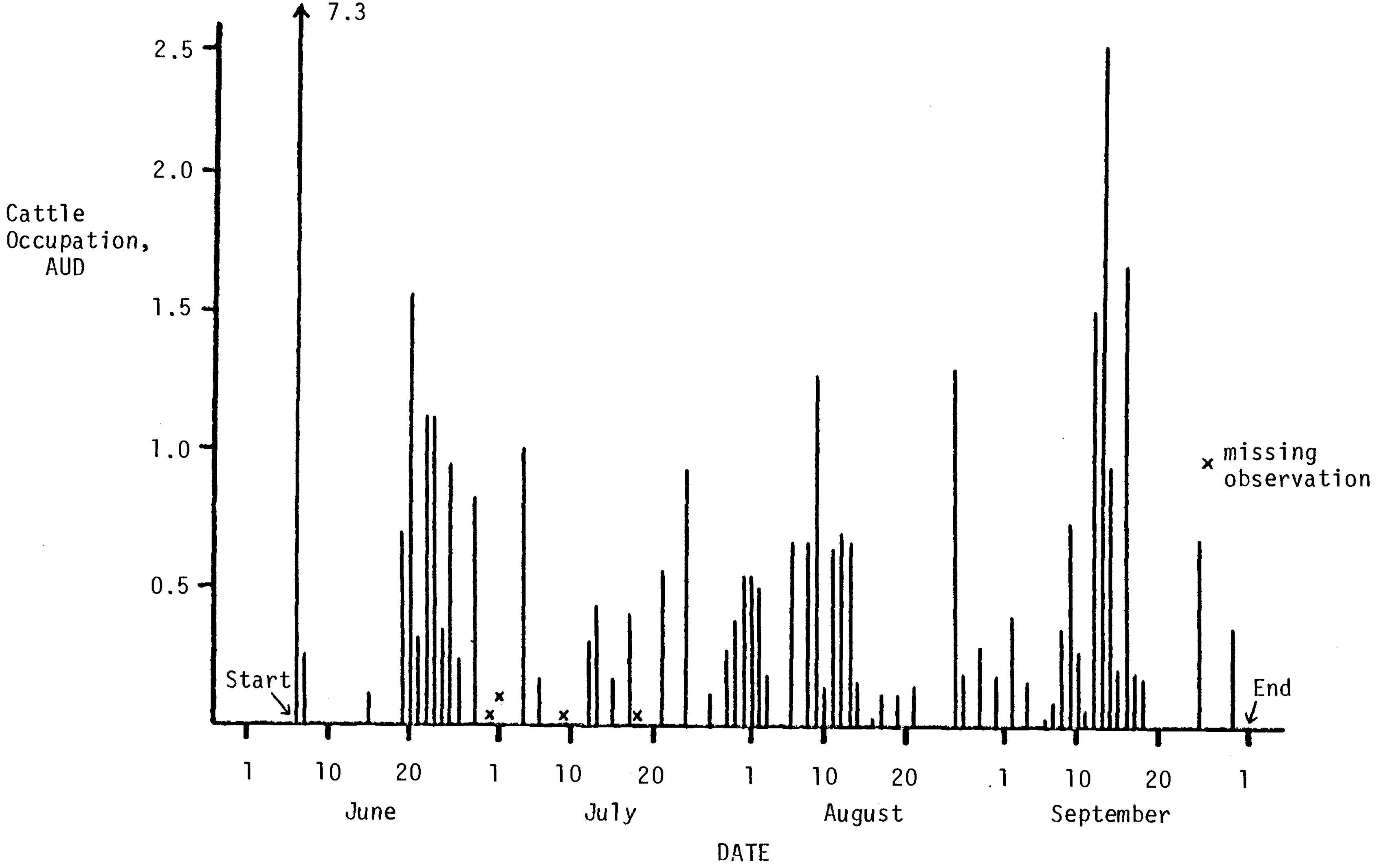

Figure 6. Daily cattle occupation of Butte Creek riparian meadow site, continuous grazing, 1981.

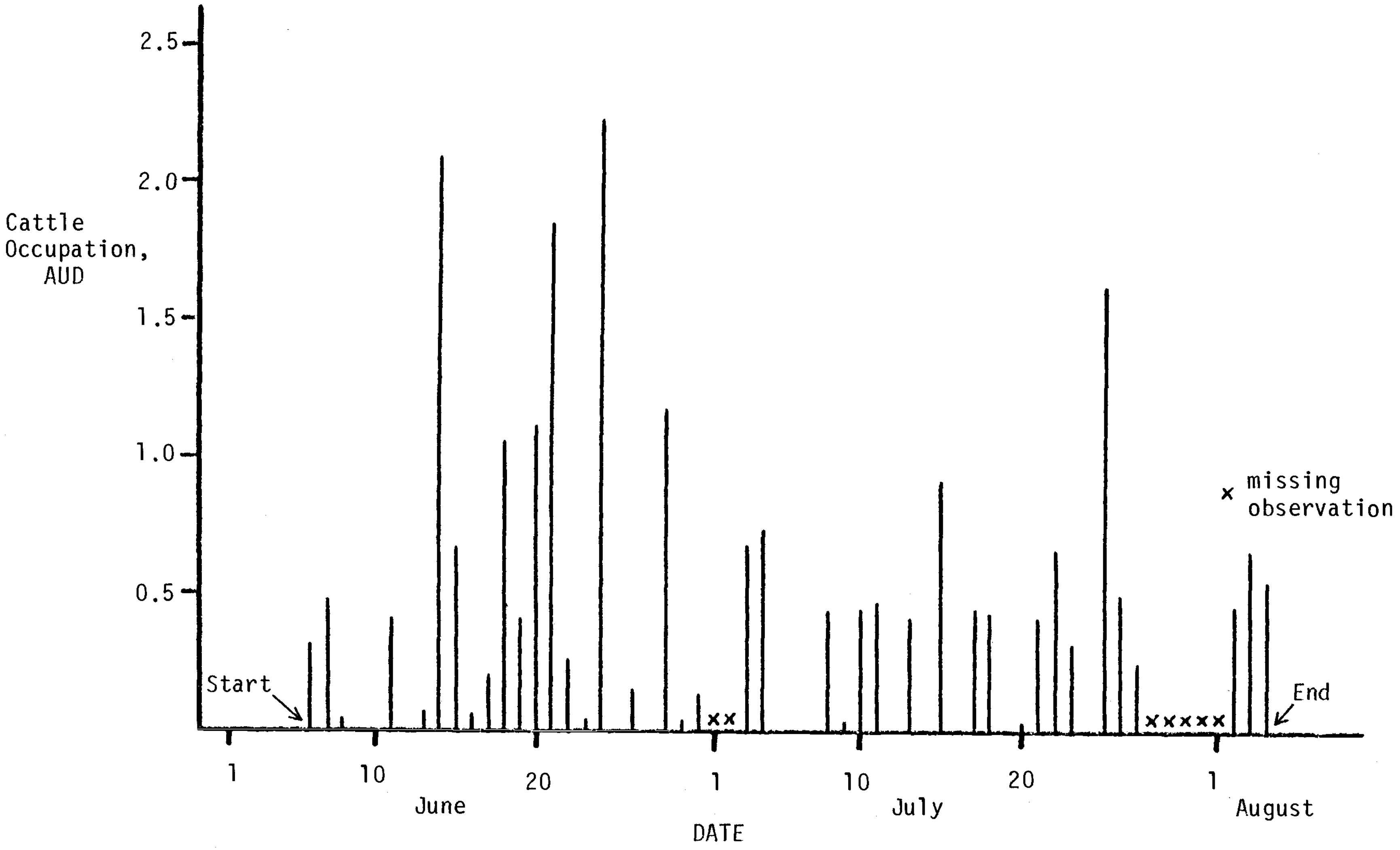

Figure 7. Daily cattle occupation of Caribou Creek riparian meadow site, early grazing, 1981.

These relationships were further examined for all meadow sites by calculating correlation coefficients between cattle occupation on a particular day and the maximum temperature on a riparian meadow weather station for that day. Correlations were also determined between occupation on a given day and number of days cattle had been grazing the pastures. In calculating correlations for occupation and days of grazing, the first four days of grazing were not included to avoid bias resulting from large numbers of animals occurring on meadows near turn-on points. Sample sizes varied because of unequal length of grazing periods and missing data.

The results of these correlation analyses are shown in Tables 33 and 34. The association between occupation and maximum temperature was poor or non-existent. Some coefficients were negative while others were positive and there was great variation between years. Pastures did not seem to influence these relationships. The correlations between occupation and days of grazing followed the same pattern with the coefficients being variable and mostly non-significant. In the Deerhorn Pasture in 1981, cattle were turned onto the pasture on the west boundary in August and drifted across the pasture to the east. Deerhorn Creek was near the turn-on point and this site received heavy early use with no use at all for the last week of the grazing period as cattle moved out of the area. This resulted in a significant negative but still rather low correlation between occupation and time. The opposite situation occurred on Placer Gulch which was located on

Table 33. Correlations between daily meadow occupation and daily maximum temperature.[1]

Pasture	Site	1980	1981
Butte	Butte Creek	.150	.238*
	Ruby Creek	.024	-.093
Caribou	Caribou Creek	.268*	.010
	Little Boulder Creek	.195	.077
Deerhorn	Deerhorn Creek	-.075	.238
	Placer Gulch	-.048	-.026

[1] * denotes significance at the 5% probability level; N = 42 to 85.

Table 34. Correlations between daily meadow occupation and days of cattle grazing on the pasture.[1]

Pasture	Site	1980	1981
Butte	Butte Creek	-.073	.238
	Ruby Creek	.040	-.047
Caribou	Caribou Creek	-.166	-.149
	Little Boulder Creek	-.063	.117
Deerhorn	Deerhorn Creek	-.198	-.555**
	Placer Gulch	.012	.315*

[1] * denotes significance at the 5% probability level; ** denotes significance at the 1% probability level; N = 43 to 107.

the east end of the pasture. Cattle did not arrive on the site until 16 days after they had been turned onto the pasture, resulting in a low positive correlation between occupation and days of grazing.

Daily Profiles of Cattle Occupation

The proportion of total cattle use observed during each hour of daylight averaged over grazing period and year is illustrated in Figure 8. Occupation was low during the morning hours. Cattle use increased sharply around 11:00 a.m., rose to a peak in late afternoon and dropped sharply again near dusk. All grazing periods exhibited this same general pattern, with the peak of occupation varying between 2:00 and 6:00 p.m. These profiles agree with the widespread casual observation that cattle congregate in the riparian zone during the warmer afternoon hours. Correlations between hourly cattle occupation and temperature and relative humidity for 1980 were 0.848 and -0.816 respectively, both of which were significant ($p < .05$). However, this afternoon congregation by cattle may be a result of other factors. The microclimate may not differ greatly between riparian meadows and some upland forest communities as will be discussed later in this paper.

Cattle Activities on Riparian Meadows

Table 35 lists the percentage of cattle observed in three major activities on the riparian meadows as determined by time-lapse camera monitoring. Also included is the same information

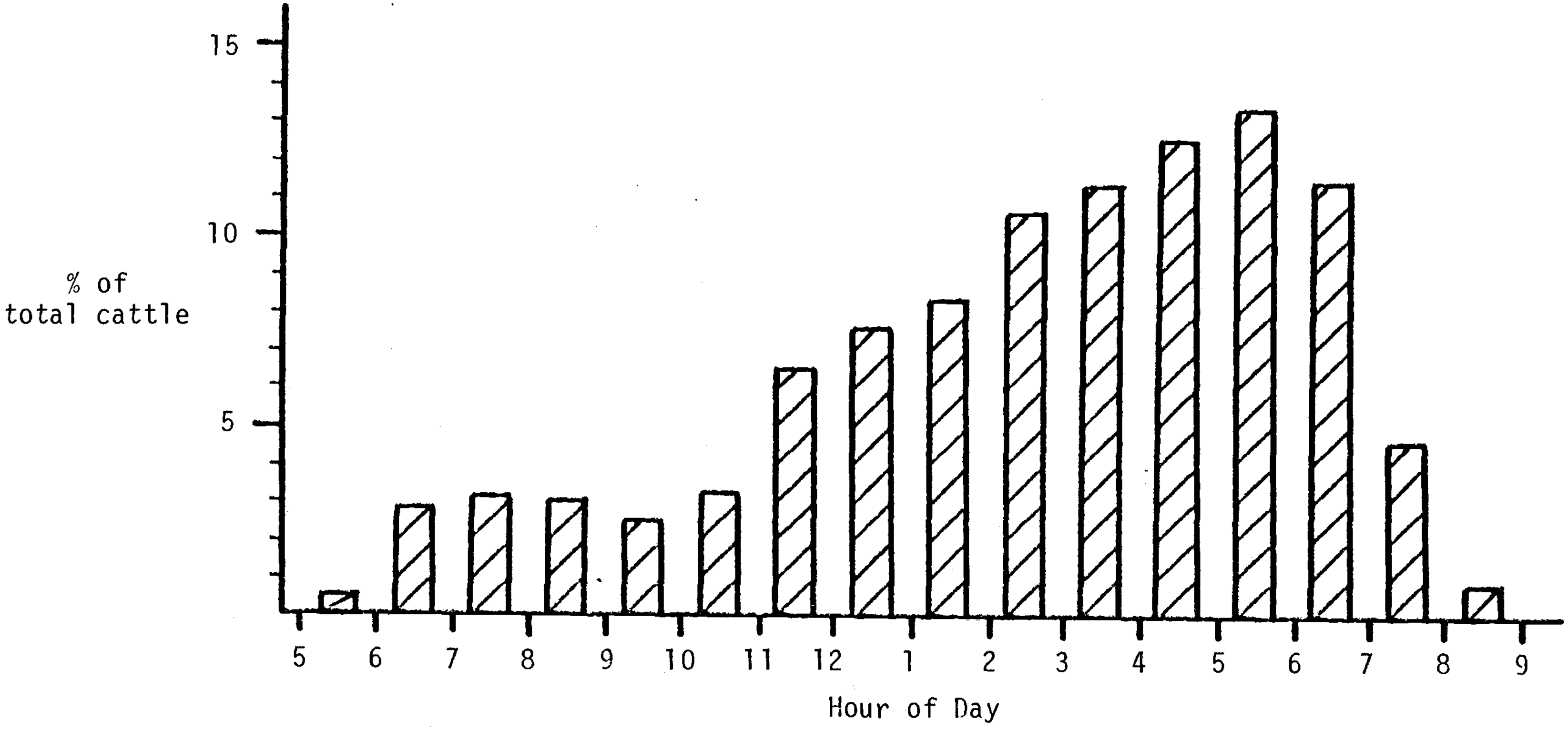

Figure 8. Percentage of total cattle observed on riparian meadows throughout the daylight hours, totaled over all sites and years.

Table 35. Percentages of total cattle observed in major activities over the entire study and on riparian meadow communities during three grazing periods.[1]

Activity	Pasture Average	Meadow		
		Continuous	Early Grazing	Late Grazing
grazing	63.1^{a}	73.4^{b}	85.4^{c}	65.6^{a}
lying	21.8^{a}	11.8^{b}	5.6^{c}	20.5^{a}
standing	10.3^{a}	9.9^{a}	5.3^{b}	11.2^{a}
N	3587	4388	2187	2978

[1] percentages within rows with the same superscript are statistically equal at the 10% probability level for simultaneous comparisons of all activities between columns.

for cattle over the entire study area as determined from cattle observation routes. The latter percentages include cattle on both upland and meadow areas. These percentages are interpreted to be the average fraction of time an individual animal allocated to the various activities.

The distribution of time spent in the various activities was quite different for all three meadow grazing periods. The early and late periods were the most different with the continuous period being intermediate. Grazing time decreased sharply from the early to the late period. This resulted in an increase in the other activities, especially lying. From the perspective of potential forage removal, an increase in grazing time in the early period would partially offset the lower frequency of cattle occupation at that time.

In comparing activity distributions on the meadows with the activity distribution on the study area as a whole, a similar situation occurred. The allocation of time in the late period on meadows was the same as the allocation on the entire pasture. The comparison between the early meadow period and the whole pasture was similar to the comparison between early and late meadow periods as already discussed.

These results indicated cattle were using the riparian meadows primarily as a source of forage in the early grazing period. Cattle did not favor the meadows over the uplands in allocating time to any activity in the late grazing period. For the entire season, the proportion of time spent grazing while on riparian meadows was ten percentage units higher than the proportion of grazing time averaged over all plant communities. This would tend to increase the disproportion between the levels of herbage utilization on the meadow and upland plant communities.

Discussion

On pastures producing 2500 kg/ha of riparian meadow herbage, deferred-rotation grazing did not change the final intensity of utilization when compared to continuous grazing. The cattle had sufficient time to remove as much forage as was physically possible under both systems. It appeared that proper stocking levels would be more important than grazing system in this situation. With meadows producing 4000 kg/ha of herbage, the early and late grazing periods in the deferred system did not differ from each other in final utilization levels. Deferred-rotation grazing cannot be compared to continuous grazing in this situation because no higher producing meadows experienced continuous grazing.

While the final level of use was similar between the three grazing periods for a given level of production, the pattern of forage utilization differed among periods. Early grazing resulted in rapid defoliation of the herbaceous plants which extended from the mid-vegetative stage to a time when similar ungrazed plants were in the seed fill stage of growth. Once grazing began there was no chance for unrestricted regrowth. Herbage measurements taken in late September indicated no measureable regrowth occurred on early grazed meadows, either dry or moist, after cattle were removed in August. The situation was much the same on the continuously grazed meadows except the rate of defoliation was not as rapid. The residual herbage curve still decreased steadily indicating that all regrowth was being quickly consumed. Constant defoliation with no suitable period allowed for regrowth is generally considered to be detrimental to production, carbohydrate storage, and vigor of grass plants (Trlica 1977).

When a meadow was grazed during the later period, the major forage plants had completed most of their life cycle and were usually in the seed fill stage of growth. Defoliation occurred fairly rapidly (50% utilization within 35 and 17 days in 1980 and 1981, respectively) and continued past the time when cold temperatures limited plant growth. Defoliation began at a time when carbohydrate reserves were probably increasing and it is likely that some carbohydrate storage continued for a time after defoliation.

Final stubble heights on the current study plots were seldom greater than 5 cm and were sometimes less than 2.5 cm. Based on available information, it appeared the early and continuous grazing treatments would be most detrimental to the meadow plants (Pond 1961, McLean et al. 1963). Although it was not the subject of the study, deterioration of the herbaceous plant community did not seem to be occurring. Many of the sites were dominated by Kentucky bluegrass which is known to withstand heavy defoliation (Etter 1951). The sod on all sites was generally thick and vigorous with no indication of thinning. Grazing use at the observed intensities has probably occurred for at least 20 years (U.S. Forest Service 1967); and while species composition may have changed (Reid and Pickford 1946), these sites do not appear to be actively degrading. Apparently more research is necessary to determine the effects of various schedules of defoliation on the herbaceous plants of riparian meadows.

Two other cattle impacts which might depend on grazing period include shrub utilization and physical impacts. There is some evidence to indicate late season grazing may increase shrub utilization on the riparian zone (Martin 1979, Roath and Krueger 1982). Even if late grazing did increase shrub use by cattle, it would be difficult to assess the real impact of such an increase because virtually no information is available on the tolerance of riparian shrubs to growing season defoliation.

Physical impacts of cattle on riparian meadows may include soil compaction and streambank erosion. The occurrence of soil compaction on meadow soils subjected to cattle grazing has been demonstrated (Orr 1960). This compaction could reduce herbage yields on the meadows (Bryant et al. 1972). Orr (1960) felt meadow soils would be most susceptible to compaction in early to mid summer. This would suggest early and continuous treatments would result in greater soil compaction than the late grazing period. However, neither the relation between meadow soil compaction and season of grazing nor the extent to which summer compaction effects are reversed by winter freezing and thawing cycles is well known.

Two short term studies have shown no clear relation between grazing period and streambank erosion (Hayes 1978, Buckhouse et al. 1981). The overwinter run-off period resulted in more bank loss than the grazing treatments in both studies. Sufficient long term research data are not presently available to predict the susceptibility of streambanks to erosion in relation to different periods of grazing.

Major reasons often given for the attractiveness of riparian meadows to cattle, as discussed earlier, are large amounts of nutritious palatable herbage, moderate slope gradient, reliable water supply and more favorable microclimate. At the onset of grazing, there was definitely more herbage available on the meadows than on the adjacent uplands. It has been seen the amount of riparian herbage soon decreases to low levels while adjacent upland forage was utilized an average of only 8-12%. Cattle continued to use the riparian meadows even as the herbage levels decreased to the physical limits of grazing. These cattle were almost certainly reducing the rate of forage intake per unit of time spent grazing. Johnstone-Wallace and Kennedy (1944) reported cattle often overconsumed forage on Kentucky bluegrass pastures when it was highly available and then depressed intake severely when the amount of herbage dropped to lower levels. This could account for the general lack of agreement between the residual herbage curves and the seasonal occupation curves as well as the poor correlations between total occupation and forage utilization. Cattle that continued to use riparian meadows with low levels of available herbage were probably depressing animal production and may have been conditioning themselves for later physiological disorders (Roath 1980).

The moderate slope gradients of riparian meadows would be an attractant to cattle on this mountain allotment to serve as resting areas and travel routes. However, there were also many active and closed roads, railroad grades, topographic benches, and ridgetops which could serve the same purpose and which probably covered much larger areas than the riparian meadows.

The riparian meadows with their attendant streams offered a more reliable water source than upland water developments. Many of these developments on the allotment were small, shallow ponds which became dry by late summer. However, ponds and troughs built near the better flowing springs did hold water for the entire summer. Streams still had an advantage over these developments in the quality of their free-flowing water as compared to water held in an impoundment.

The riparian meadows undoubtedly had a less stressful microclimate than some upland communities. However, the overall superiority of the riparian microclimate over the upland microclimate in relation to cattle heat stress was questionable and will be discussed more fully later in this paper.

The riparian meadows did not necessarily possess favorable characteristics which could not be found in upland situations, especially after appreciable herbage removal had occurred on the meadows. More likely, it was the unique placement of all of these characteristics in a single community which made the meadows so attractive. At various times through the season, each of these factors probably acted alone and in combination with the others to maintain the uniform high preference of these sites by cattle.

Finally, it might be useful to point out the added flexibility available by changing the cattle turn-on point for a pasture. The start of grazing on a particular meadow may be changed by as much as two weeks in these relatively large range pastures depending on where the cattle enter the pasture. While the final intensity of use would not differ, the timing of use could be modified. This suggests the possibility of an internal pasture rotation which could be alternated among years. Also, the length of the actual grazing period for an area of critical concern or special interest could be shortened by turning cattle onto the pasture at a point far removed from the area of interest.

Aerial Microclimate

Characteristics of the sites used to monitor microclimatic conditions are listed in Table 36. Site codes beginning with WC indicate the Windlass Creek drainage and site codes beginning with LB denote the Little Boulder Creek drainage. The final letter of the site code indicates the vegetation type with M for riparian meadow, F for forest, and C for clearcut.

Site WCM did not contain trees directly in the riparian zone. This riparian meadow was approximately 10 m wide and bordered by ponderosa pine-Douglas fir forest. The estimated canopy cover was

Table 36. Characteristics of microclimatic monitoring sites.

Site	Vegetation Type	Forest Canopy Cover (%)	Slope Aspect	Slope Gradient (%)	Elevation (m)
WCM	riparian meadow	27	SW	5	1170
WCF	conifer forest	32	W	8	1270
WCC	clearcut forest	2	S	8	1345
LBM	riparian meadow	46	S	5	1220
LBF	conifer forest	49	SW	20	1350
LBC	clearcut forest	1	S	23	1385

the result of partial shading by this border forest. Actual shading would show large variations as sun azimuth changed throughout the day. Site LBM was directly shaded by ponderosa pine growing on coarse subsoils directly within the riparian zone.

Little or no attempt was made to standardize aspect, slope, and elevation among sites. All of the vegetative types did not occur on all topographic situations. The vegetation itself integrated the various environmental factors into a unified expression for each site. The placement of stations roughly followed the natural arrangement of the vegetation types and so was considered to be a valid comparison between them.

Means of the various microclimatic parameters for 1980 and 1981 are listed in Table 37. Few statistically significant differences were found among the vegetation types. The riparian meadow type had a significantly lower average air temperature than the forest and clearcut in 1981 ($p < .05$). Minimum air temperature was lower in the meadow than in both upland types in 1980 ($p < .01$) but was only lower in the meadows versus the clearcuts in 1981 ($p < .10$). Maximum air temperature and afternoon average air temperature differed little among the vegetation types. These results can be attributed to cold air drainage onto the meadows at night.

Average relative humidity was higher on the meadows as compared to the uplands in 1980 ($p < .01$). The meadow sites exhibited slightly higher afternoon average relative humidities in 1981 ($p < .10$). Meadow sites appeared to experience higher levels

Table 37. Means of microclimatic variables for three vegetation types, 1980-1981.[1]

Microclimatic Parameter		1980		
		Riparian Meadow	Forest	Clearcut
Temperature, °C	average	13.9	14.5	14.5
	maximum	22.4	22.2	22.4
	minimum	6.1^{a}	7.8^{b}	7.8^{b}
	afternoon average	20.2	20.1	19.9
Relative Humidity, %	average	64.4^{a}	54.5^{b}	55.6^{b}
	maximum	88.5	78.9	78.0
	minimum	29.8	27.3	29.6
	afternoon average	39.1	35.7	37.6
Temperature-Humidity Index	average	57.8	57.7	57.8
	maximum	64.7	64.1	64.6
	minimum	49.2^{a}	50.7^{b}	50.7^{b}
	afternoon average	63.1	62.7	62.6

[1] means within row and year with different superscripts are statistically different at the 10% probability level.

Table 37. (cont.) Means of microclimatic variables for three vegetation types, 1980-1981.[1]

Microclimatic Parameter		1981		
		Riparian Meadow	Forest	Clearcut
Temperature, °C	average	15.4^a	16.6^b	17.1^b
	maximum	26.9	27.1	27.0
	minimum	4.6^a	5.7^{ab}	7.4^b
	afternoon average	24.6	25.8	25.0
Relative Humidity, %	average	55.4	47.6	44.9
	maximum	92.0	84.0	79.6
	minimum	18.4	18.5	17.4
	afternoon average	23.8^a	22.6^b	22.3^b
Temperature-Humidity Index	average	59.0	59.9	60.2
	maximum	68.1	68.5	68.0
	minimum	47.3^a	48.3^a	50.2^b
	afternoon average	66.5	67.0	66.6

[1] means within row and year with different superscripts are statistically different at the 10% probability level.

of maximum relative humidity in both years. These differences were not statistically significant because of a block by vegetation type interaction. While the meadow sites had the highest maximum relative humidity in both blocks, the difference between the meadows and the upland communities was much smaller in the Windlass Creek drainage than in the Little Boulder Creek drainage. Minimum and afternoon average relative humidity levels were very similar for all vegetation types.

The only statistical differences observed for the temperature-humidity index (THI) were in the daily minimums. The meadow sites had slightly lower minimum THI values than the uplands in 1980 ($p < .01$). In 1981, the clearcuts showed slightly higher minimum THI values than either the meadows or the forest ($p < .10$).

The THI was originally devised to combine temperature and relative humidity into a single measure to be related to human comfort. About 10% of test subjects feel discomfort when the THI reaches 70. When the THI reaches 79, 100% of test subjects feel discomfort (Cargill and Stewart 1966). The THI has also been related to cattle behavior and production. Johnson et al. (1962) reported a negative curvilinear relation between THI and milk production beginning at a THI value of 70. A similar relation was calculated for the THI and grazing time with reductions starting at values of 63-65 and increasing rapidly above 70 (Ehrenreich and Bjugstad 1966). Cargill and Stewart (1966) reported a reduction in milk production of one standard deviation when the THI reached 76. It appears that THI values below 70 should have little or no effect on animal behavior.

Additional information regarding the THI is listed in Table 38. The percentage of sample days with THI values above 70 showed little variation or trend among vegetative types. Similarly, the maximum observed value for the THI exhibited little or no trend among vegetation types.

The year effect was not of particular interest and was not tested statistically. Casual comparison indicated 1980 was somewhat cooler and more humid than 1981 with lower THI values in 1980 as a result.

The only differences in the temperature and moisture regimes of the three vegetation types were in minimum temperature, maximum relative humidity, and minimum THI. These conditions occurred together just before dawn and were certainly not causing heat stress in cattle.

The measurements most important in determining heat stress are the afternoon averages for all quantities, the maximum temperature and THI value, and the minimum relative humidity. When these values were compared, there was seen to be virtually no difference among vegetation types. A large proportion of days never reached temperature and humidity levels which would result in heat stress, irrespective of community.

Temperature and humidity are only two parameters determining an animal's microclimatic environment. Wind and radiation exchange must be added to make a complete evaluation of the

Table 38. Percentage of sample days with temperature-humidity index values greater than 70 and maximum observed temperature-humidity index values for microclimatic monitoring sites.

	% of Days with THI > 70		Maximum THI	
Site	1980	1981	1980	1981
WCM	15	35	73	76
LBM	15	35	74	76
WCF	10	50	74	79
LBF	5	25	72	76
WCC	15	35	74	78
LBC	15	35	74	76

thermal environment (Moen 1968, Porter and Gates 1969). Since these measurements were not taken, absolute statements about the attractiveness of the three communities to cattle in relation to possible heat stress cannot be made. Some estimates, however, may be possible.

Direct beam solar radiation is closely associated with the net radiation load of the animal (Monteith 1973). Potential direct beam solar radiation increases as aspect approaches south and slope gradient increases on southerly facing slopes (Buffo et al. 1972). Potential direct beam solar radiation decreases with slope gradient on northerly facing slopes. On southerly facing pastures, upland slopes would be expected to have a higher direct radiation load than relatively level riparian meadows. The opposite would be true on northerly exposures. The actual effect on the animal would be ameliorated by tree canopy cover, and the relationships just discussed could even be reversed in some situations. Increased radiation loads would indicate the potential for increased animal heat stress.

Because of complex topography, mountain wind behavior is difficult to predict. However, as vegetation canopy decreases in height or density, surface windspeed should generally increase (Monteith 1973). Increased windspeed would improve the efficiency of heat loss by the animal as long as skin temperature was above air temperature. This would result in a decreased potential for heat stress.

With all of the above results in mind, some speculation as to the relative attractiveness of the three vegetation types is possible. In this southerly facing pasture, the riparian meadows would appear to have an advantage in having lower potential radiation loadings since they were almost always located on gentle slopes while the other types generally occurred on steeper slopes. Clearcuts had the added disadvantage of low amounts of tree canopy cover. Canopy relations were often favorable on the riparian meadow sites. Many of these sites had at least some tall shrub or tree cover directly within the riparian zone. Even on those sites without such cover, the adjacent forest supplied shade for these narrow corridors for several hours a day. The effectiveness of this type of shading depended on the orientation of the riparian corridor. Canopy cover within the forest took on values of 0% up to nearly 100%. It could be expected that there were large areas of forest with canopy cover equal to or exceeding that of the riparian meadows.

Clearcuts probably experienced the largest amount of wind of the three types because of tree canopy removal. The amount of wind increase on logged versus unlogged communities would depend on the size, shape, and orientation of the clearcuts. Riparian meadows may have also had somewhat higher wind levels than the forest types due to the funneling nature of the narrow drainages and the generally more open canopy structure.

Because of the high levels of solar radiation, which were only partially ameliorated by increased wind velocities, the clearcut areas probably produced the highest levels of animal heat stress of the three communities. It is difficult to rank the forest and meadow types in terms of relative heat stress. The meadows were somewhat variable in canopy cover but less variable in slope gradient. The forest communities were variable in both canopy cover and slope gradient. Given the rough equivalence of the temperature and humidity regimes, it seems certain there were large areas of upland forest which were equally or less stressful than the riparian meadows in terms of animal heat relations. On mountain rangeland, it possible that the idea that a more favorable microclimate in the riparian zone serves as a major cattle attractant is not as important as is currently thought. A more complete test of this hypothesis would require the measurement and comparison of all four of the determinants of microclimate (temperature, humidity, wind, radiation) as well as the animal's physiological ability to react to them.

Cattle Home Range Behavior

Fifteen of the approximately 200 cows grazing the Caribou Unit were marked with colored collars in 1980 and 1981. The number of times an individual cow was relocated ranged from 1 to 10 in 1980 and 0 to 16 in 1981. Two cattle were never relocated in 1981 but one of these had actually been released into a different pasture after being marked. Loss of marking collars also reduced the number of sightings for some animals since only eleven and fourteen collars were recovered in 1980 and 1981, respectively.

When the number of relocations is small, the size of the estimated home range is often positively correlated with the number of sightings (Hayne 1949). The area added by each additional sighting eventually declines as the estimated size of the home range approaches the true size. Correlations for numbers of sightings and size of estimated home range were calculated for 1980 and 1981. When the number of sightings for an individual was greater than or equal to seven in 1980 and greater than or equal to eight in 1981, the correlations between number of sightings and home range size were small (less than 0.4) and nonsignificant. These minimum sample sizes were then set as limits for the inclusion of individual cows in further statistical analyses. It was felt this would result in a minimum bias resulting from unequal numbers of sightings among individuals. Nine individuals met these requirements for 1980 with eight satisfying the limits for 1981, for a total of 17 cattle to be included in the statistical analyses.

Mean estimates of home range parameters classified by breed group and year are listed in Table 39. Purebred cattle included Hereford, Angus, and Red Angus breeds. Crossbred cattle included Hereford x Angus and Hereford x Red Angus. In 1980, the grazing period in the Caribou Pasture extended from August 1 to October 15. Grazing occurred between June 6 and August 17 in 1981.

Table 39. Mean estimates and ranges of home range statistics for purebred and crossbred cattle, 1980-1981.[1]

	Home Range (ha)			Activity Radius (m)			Maximum Distance Between Sightings (m)		
Breed Group	1980	1981	Average	1980	1981	Average	1980	1981	Average
purebred	285	291	288	1213	1128	1170	3618	3118	3368
crossbred	370	420	392	1377	1228	1311	4055	4043	4049
average	332	356	343	1304	1178	1245	3861	3580	3729
range of values	138 - 649			785 - 1721			2060 - 6010		

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[1] all means within home range expressions are statistically equivalent at the 10% probability level.

The indices of home range size tended to be larger for crossbreds than purebreds in every case but none of the observed differences were statistically significant. Year (season of grazing) had little effect on home range estimates. Considering all observations, the magnitude of the difference between minimum and maximum values ranged from 220% to 470% for the three indices.

The home ranges were three- to many-sided polygons with large differences in width, length, and orientation between individuals. Three examples of cattle home ranges are displayed in Figure 9. Most home ranges included portions of at least two drainages and tended to cut across the general topography. Correlation coefficients among home range indices are listed in Table 40. While all indices were positively associated, many of the correlations were not particularly large and were not stable between years. This indicated that the shape of the home range varied considerably between individuals and years.

Cattle were turned onto the pasture from the southeast and dispersal across the pasture was complete in about two weeks. Two-thirds of the cattle centered their activities in the western half of the pasture. Forage was generally more abundant in this section because of a higher proportion of disturbed timber stands seeded to introduced pasture grasses.

Three types of home range behavior were observed. The first would be considered the classic type in which the animal moved back and forth from one portion of its home range to another. In the second type of behavior, the animal did not actually establish

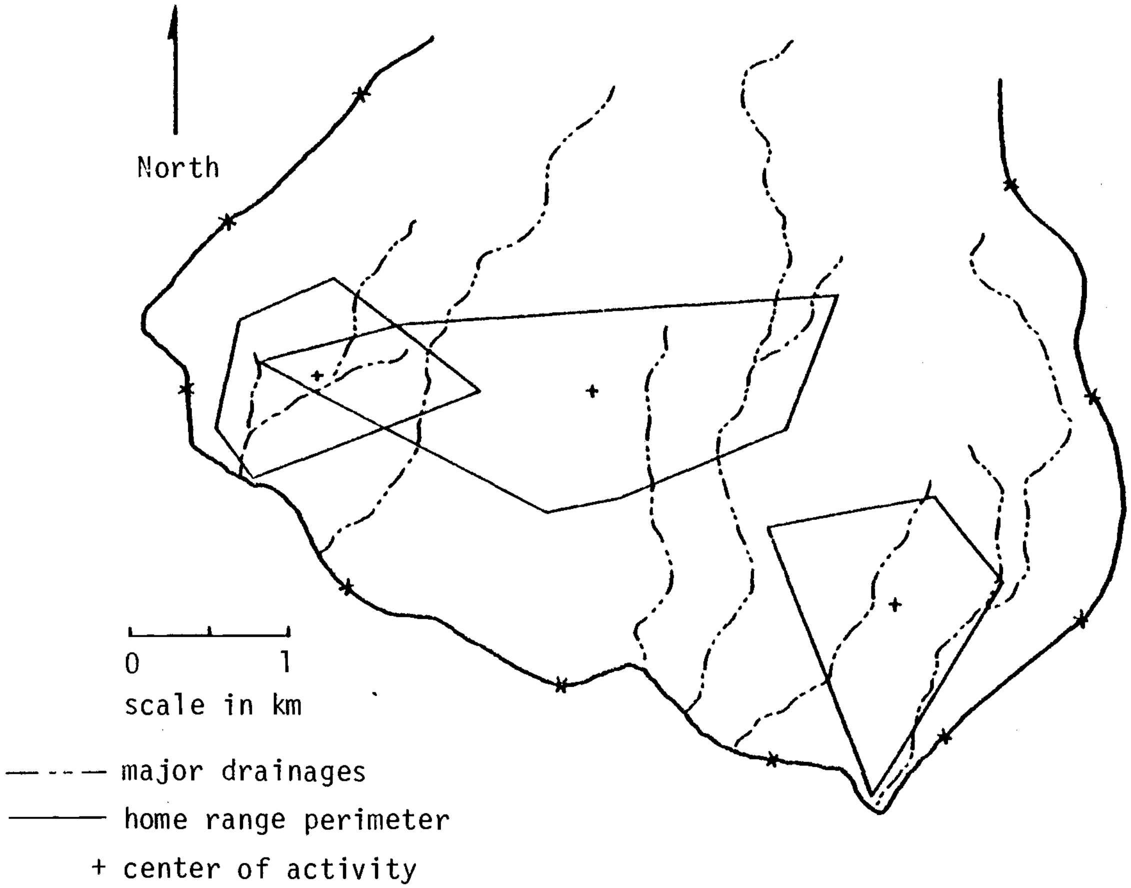

Figure 9. Examples of cattle home ranges, Caribou Pasture, 1981.

Table 40. Correlation coefficients among home range parameters of cattle, 1980-1981.[1]

Association	1980	1981
home range vs. activity radius	.708*	.482
home range vs. max. dist. between sightings	.623^{+}	.875**
activity radius vs. max. dist. between sightings	.947**	.645
N	9	8

[1] + denotes significance at the 10% probability level;
* denotes significance at the 5% probability level;
** denotes significance at the 1% probability level.

a home range but tended to slowly drift across large areas of the pasture without ever reversing its general path. The third type of behavior was shown by animals who also tended to drift across large areas but at some point reversed directions and returned to areas inhabited at an earlier time, often by a different route.

The size of the cattle home ranges reported here should be considered conservative because it cannot be assumed animals were seen on the outermost perimeter of their home range. The observed home range sizes were slightly smaller than the range of sizes (336-896 ha) reported by Martin (1979) for a similar sized pasture in central Arizona. Since not all animals were marked, the membership of various cattle groups and the degree of interchange among groups could not be determined. Most of the home ranges overlapped to some degree except those located in the far eastern and western portions of the pasture.

With an average estimated home range of 343 ha in a pasture enclosing 3610 ha, it seemed clear that individual cattle restricted their activities to specific portions of a pasture. Similar results have been reported by other workers (Elliott 1976, Martin 1979, Roath 1980). There also appeared to be enough variation among individuals to allow for selection for greater ranging ability although there was no detectable difference among breed groups in home range behavior. More research will be necessary to determine the full influence home range behavior may have on cattle distribution patterns and associated management practices. For instance, it would be of interest to know if animal production is similar within different home range groups, if the more dominant animals occupy the better areas of the range, if range improvements actually benefit the entire herd, and if removing certain animals affects the social and home range structure of the entire herd. Further research should address the relationships between home range behavior and age, sex, breed, rearing history, social organization, and stocking rate of cattle.

Summary Discussion

The riparian meadows were the major influence on overall distribution patterns on this mountain rangeland allotment. The combination of large amounts of palatable nutritious herbage, a relatively long plant growth cycle, a consistent high quality water supply, and low slope gradients made these meadows the most highly preferred areas for cattle use. Forage utilization averaged 75% by weight on the meadows over the study period while no upland plant community averaged more than 16% utilization over the same three years. On the lower producing meadows, cattle appeared to remove as much herbage as was physically possible. Late season grazing increased the frequency of cattle use on the meadows and caused a greater proportion of the total herd to be seen there. However, the period of grazing did not influence final utilization levels on the meadow sites.

When available, logged forest sites were the second most important plant community on the allotment. These sites were preferred by cattle in the early grazing period. Cattle used the logged communities in proportion to their availability in the late grazing period because the palatability of much of the herbage had decreased by that time.

Direct observation indicated the grassland community group was next in importance but utilization measurements rated this group somewhat lower. Direct observations were inflated because cattle were often seen at important salt grounds within the grasslands rather than actually grazing there. Grassland sites were reduced in importance because of their accelerated forage growth cycle which resulted in much of the herbage becoming cured and unpalatable early in the grazing season. This effect was compounded on southerly facing pastures.

The most important forested community was clearly the ponderosa pine-Douglas fir community group. It was used as available in the Butte Pasture and carried a substantial portion of the grazing load in the Caribou Pasture even though it was not a preferred community. The relative preference of this community may have been reduced by the presence of logged forest sites in the Caribou Pasture.

The grassland community group and the mixed conifer community group were utilized at similar intensities in the Butte Pasture while the mixed conifer forest received slightly more use in the Caribou Pasture. The white fir forest was seldom used by cattle. This dense forest will not be important as a range type unless it is converted to the logged forest community group.

The most important physical factor affecting distribution appeared to be slope gradient as it was consistently associated with cattle use in both pastures. Vertical distance to salt appeared to be important in the Butte Pasture when only upland utilization was considered. In the direct observation analysis, the influence of salt distribution was neutralized by cattle preference for the riparian meadows. Salt distribution was also associated with cattle use in the Caribou Pasture. These results suggested that salt distribution may have had more influence on cattle grazing behavior than is sometimes accepted. Continued experimentation on a controlled basis will be necessary to determine the true influence of salt placement on cattle grazing distribution on mountain rangelands.

Another factor which had a moderate association with utilization was herbage or grass production. This association was mainly a reflection of productivity differences between the three forest community groups. Elevation and slope aspect both appeared to have some influence on cattle behavior. This influence was indirectly applied through the effect of these two factors on plant community location. Water distribution had a weak and inconsistent association with cattle distribution. The presence of several perennial streams and upland water developments had practically eliminated the influence of water distribution on cattle grazing behavior.

The reaction of cattle to various habitat factors as discussed above illuminates only a portion of their behavior.

Home range behavior, dominance structure within the herd, mother-daughter relations, and learning all probably have some influence on the way cattle utilize a particular range. The nature of these influences and the effects they have on managerial efforts to alter grazing distribution are virtually unknown and deserve further research attention.

Most of the factors associated with upland grazing distribution in this study could be modified through management although upland grazing distribution was not a problem during the study. Some degree of forest canopy removal should create preferred grazing areas especially if palatable introduced grasses are established. Salt distribution can certainly be modified by management activities. It appeared the vertical distribution of salt may be as important on these mountainous ranges as the horizontal distribution. Slope gradient cannot be directly modified but the influence of this factor may be partially overcome through trail construction (Patton 1971) and vegetative manipulation (Cook and Jeffries 1963).

Altering the distribution patterns between uplands and riparian meadows appears to be a difficult task because of the presence of several positive factors on the riparian meadows. Deferred-rotation grazing did not reduce the intensity of herbage use on the meadows but did appear to reduce actual cattle presence in the early grazing period. The effects of other managerial options for reducing cattle use of meadows were not specifically tested in this study. Any practice which makes upland plant communities more attractive could be expected to improve the situation. Seeding palatable grasses on areas disturbed by timber harvest, maintaining good salting practice, and keeping major trails and roads open for cattle use are three options suggested from this study.

Finally, it is clear that distribution patterns change from year to year with fluctuations in annual and seasonal climatic conditions and changes in grazing management. Management practices such as salting and range riding should not be predetermined and static. They should be flexible activities adjusted throughout the grazing season as environmental conditions and utilization patterns change (Chapline and Talbot 1926, Skovlin 1965). It seems doubtful that distribution patterns on most mountain rangelands will be predicted with useful precision in the near future because they are influenced by such a complex of natural and managerial factors. As stated by Cook (1966), probably the most practical way of determining the potential grazing capacity and distribution on these mountain rangelands is to apply good management and observe the results.

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APPENDICES

Appendix 1. Common and scientific names of plant species discussed in the thesis.

Common Name	Scientific Name
aspen	*Populus tremuloides* Michx.
Baltic rush	*Juncus balticus* Willd.
big huckleberry	*Vaccinium membranaceum* Dougl. ex Hook.
big-leaved lupine	*Lupinus polyphyllous* var. *burkei* (Wats.) Hitchc.
bluebunch wheatgrass	*Agropyron spicatum* (Pursh) Scribn. and Smith
cheatgrass	*Bromus tectorum* L.
dandelion	*Taraxacum officinale* Weber
Douglas fir	*Psuedostuga menziesii* ssp. *glauca* (Beissn.) Franco
elk sedge	*Carex geyeri* Boott
Engelmann spruce	*Picea engelmanii* Parry ex Engelm.
grand fir	*Abies grandis* (Dougl.) Lindl.
grouse huckleberry	*Vaccinium scoparium* Leib.
hawkweed	*Hieracium albertinum* Farr.
heartleaf arnica	*Arnica cordifolia* Hook.
Idaho fescue	*Festuca idahoensis* Elmer
intermediate wheatgrass	*Agropyron intermedium* (Host.) Beauv.
Kentucky bluegrass	*Poa pratensis* L.
lodgepole pine	*Pinus contorta* Dougl. ex Loud.
mitrewort	*Mitella stauropetala* Piper
mountain big sagebrush	*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle
mountain brome	*Bromus marginatus* Nees
Nebraska sedge	*Carex nebraskensis* Dewey
northwest cinquefoil	*Potentilla gracilis* Dougl. ex Hook.
northwest sedge	*Carex concinnoides* Mack.
one-spike danthonia	*Danthonia unispicata* (Thurb.) Munro ex Maccun

Appendix 1. (continued)

Common Name	Scientific Name
orchardgrass	*Dactylis glomerata* L.
peavine	*Lathyrus nevadensis* Wats.
pinegrass	*Calamagrostis rubescens* Buckl.
ponderosa pine	*Pinus ponderosa* Dougl. ex Loud.
redtop	*Agrostis alba* L.
Sandberg's bluegrass	*Poa sandbergii* Vasey
sedges	*Carex* spp. L.
sheep sedge	*Carex illota* L. H. Bailey
springbank clover	*Trifolium wormskjoldii* Lehm.
stiff sagebrush	*Artemisia rigida* (Nutt.) Gray
subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
tailcup lupine	*Lupinus caudatus* Kell.
timothy	*Phleum pratense* L.
tufted hairgrass	*Deschampsia caespitosa* (L.) Beauv.
twinflower	*Linnaea borealis* L.
western juniper	*Juniperus occidentalis* Hook.
western larch	*Larix occidentalis* Nutt.
western yarrow	*Achillea millefolium* var. *lanulosa* Piper
whitebark pine	*Pinus albicaulis* Engelm.
white clover	*Trifolium repens* L.
wormleaf stonecrop	*Sedum stenopetalum* Pursh
yellow fleabane	*Erigeron chrysopsidis* Gray

Appendix 2. Correlations between two expressions of forage utilization and fifteen site characteristics.[1]

Butte Pasture, elk sedge-pinegrass forage type						
Site Characteristic[2]	% Utilization			Weight Utilization		
	1979	1980	1981	1979	1980	1981
PROD	.413*	.175	.289^{+}	.545**	.331*	.431*
GPROD	.353^{+}	.195	.286^{+}	.515**	.346*	.433*
CC	.264	-.183	.084	.271	-.232	-.005
LNCC	.310	-.119	.131	.304	-.161	.060
% CARU	-.104	-.216	-.324*	-.062	-.220	-.402**
% CAGE	.095	.320*	.380**	.305	.315*	.474**
ELEV	-.227	-.181	-.468**	-.213	-.184	-.478**
% SLO	-.357^{+}	-.139	-.321*	-.298	-.164	-.342*
SLLEN	-.017	-.111	-.077	-.013	-.115	-.045
DWH	.271	-.007	.145	.196	-.018	.149
DWT	.088	-.009	-.066	.033	-.026	-.050
DWV	.116	-.154	-.044	.078	-.109	-.010
DSH	-.048	-.054	.022	.052	-.100	.052
DST	-.218	-.181	-.111	-.117	-.214	-.091
DSV	-.271	-.402**	-.390**	-.246	-.393**	-.395**
N	25	45	45	25	45	45

Appendix 2. (continued)

Caribou Pasture, elk sedge-pinegrass forage type

Site Characteristic	% Utilization			Weight Utilization		
	1979	1980	1981	1979	1980	1981
PROD	.062	.012	.283	.265	.161	.424*
GPROD	.033	.053	.321^{+}	.247	.181	.467*
CC	-.310	-.158	-.282	-.236	-.221	-.365*
LNCC	-.276	-.118	-.251	-.194	-.173	-.333^{+}
% CARU	.176	-.026	.109	.295	-.011	.009
% CAGE	-.047	.148	.067	-.220	.174	.023
ELEV	-.056	.013	-.131	.014	-.002	-.169
% SLO	-.305	-.523**	-.626**	-.306	-.523**	-.590**
SLLEN	.047	.078	.043	-.046	.005	-.059
DWH	.369*	.257	.129	.406*	.277	.051
DWT	.284	.148	.080	.314^{+}	.171	.005
DWV	-.119	-.219	-.356^{+}	-.226	-.163	-.340^{+}
DSH	-.211	-.119	-.102	-.224	-.111	-.133
DST	-.246	-.178	-.161	-.254	-.168	-.181
DSV	-.012	-.144	-.074	-.043	-.112	-.129
N	29	36	36	29	36	36

Appendix 2. (continued)

Caribou Pasture, logged forest forage type

Site Characteristic	% Utilization			Weight Utilization		
	1979	1980	1981	1979	1980	1981
PROD	.436	-.449	.286	.588	-.137	.513
GPROD	.346	-.467	.452	.517	-.163	.649
CC	-.836^{+}	-.041	-.491	-.904*	-.142	-.487
% CARU	-.168	-.136	-.406	-.043	-.238	-.353
% CAGE	-.742	.450	-.648	-.772	.185	-.748^{+}
ELEV	.519	.514	.080	.494	.471	.020
% SLO	-.700	.152	-.436	-.720	-.109	-.477
SLLEN	-.942*	-.484	-.808*	-.896*	-.593	-.686^{+}
DWH	-.121	-.492	-.317	-.031	-.432	-.180
DWT	-.237	-.361	-.240	-.152	-.380	-.115
DWV	-.284	.122	-.408	-.371	.113	-.495
DSH	-.965**	-.117	-.730^{+}	-.920*	-.377	-.713^{+}
DST	-.984**	-.251	-.906**	-.941*	-.475	-.852*
DSV	-.569	-.021	-.325	-.539	-.194	-.350
N	5	7	7	5	7	7

Appendix 2. (continued)

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[1] + denotes significance at the 10% probability level;
* denotes significance at the 5% probability level;
** denotes significance at the 1% probability level.

[2] site characteristic abbreviations
PROD - total herbage production (kg/ha)
GPROD - grass production (kg/ha)
CC - forest canopy cover (%)
LNCC - natural logarithm of forest canopy cover
% CARU - % of PROD contributed by pinegrass
% CAGE - % of PROD contributed by elk sedge
ELEV - elevation above mean sea level (m)
% SLO - slope gradient
SLLEN - slope length (m)
DWH - horizontal distance to water (m)
DWT - trail distance to water (m)
DWV - vertical distance to water (m)
DSH - horizontal distance to salt (m)
DST - trail distance to salt (m)
DSV - vertical distance to salt (m)

Appendix 3. Percentage of observed cattle engaged in various activities by year in the Butte and Caribou Pastures.[1,2]

	Butte Pasture			Caribou Pasture		
Major Activities	1979	1980	1981	1979	1980	1981
grazing	59^a	71^b	56^a	61	60	60
lying	32^a	15^b	22^c	29^a	21^b	18^b
standing	3^a	5^a	12^b	9^a	10^{ab}	13^b
Minor Activities						
salting	1	2	2	T^a	2^b	1^b
nursing	-	2	2	T^a	2^b	3^b
traveling	4^a	3^{ab}	1^b	$-^a$	1^b	T^a
drinking	-	T	T	T^a	1^b	1^b
Unidentified	$-^a$	2^b	5^b	$-^a$	4^b	2^b
N	180	539	462	705	583	1201

[1] activities within row and pasture with different superscripts are statistically different at the 10% probability level for simultaneous comparisons of all activities between years.

[2] T (trace) denotes less than 0.5% of all cattle were observed in that activity.

Appendix 4. Correlations between habitat preference indices (HPI) and habitat characteristics.[1]

Habitat Characteristic	Butte Pasture 1979	Butte Pasture 1980	Butte Pasture 1981	Caribou Pasture 1979	Caribou Pasture 1980	Caribou Pasture 1981
% slope[2]	-.877*	-.733^{+}	-.925**	-.908*	-.892*	-.980**
(N)	(6)	(6)	(6)	(6)	(6)	(6)
elevation[3]	-.897*	-.971**	-.885*	-.394	-.499	-.628
(N)	(5)	(7)	(5)	(7)	(7)	(7)
trail distance to water	-.798*	-.675*	-.445	-.792**	-.497	-.303
(N)	(8)	(10)	(10)	(9)	(9)	(9)
vertical distance to water[3]	-.711	-.733*	-.612	-.477	-.452	-.556
(N)	(6)	(8)	(7)	(9)	(9)	(8)
trail distance to salt	-.368	.146	-.148	-.787**	-.571^{+}	-.843**
(N)	(10)	(10)	(10)	(10)	(10)	(10)
vertical distance to salt	.410	.612^{+}	.325	-.591	-.720*	-.746*
(N)	(10)	(10)	(10)	(8)	(8)	(8)

[1] $^{+}$ denotes significance at the 10% probability level;
* denotes significance at the 5% probability level;
** denotes significance at the 1% probability level.

[2] relation expressed as $Y=ae^{bX}$, where Y=HPI, X=habitat characteristic, e=2.718, a & b=constants.

[3] exponential relation (as for % slope) in Butte Pasture, linear relation in Caribou Pasture.

Appendix 5. Sampling plan, vegetative composition, and classification of riparian meadow sampling sites.

			% Composition				
Pasture	Site	Sampling Plan	Grass	Grasslike	Forb	Meadow Type	Comments
Butte	Butte Creek-Lower	cage	76	-	24	dry	Kentucky bluegrass, western yarrow
	Butte Creek-Upper	cage, photo	68	1	31	dry	Kentucky bluegrass, western yarrow
	Ruby Creek-Lower	cage	64	-	36	dry	redtop, Kentucky bluegrass white clover, western yarrow
	Ruby Creek-Upper	cage, photo	73	6	21	dry	Kentucky bluegrass, western yarrow
Caribou	Caribou Creek-Lower	cage	62	13	25	moist	redtop, sheep sedge, white and springbank clover
	Caribou Creek-Upper	cage, photo	42	34	24	moist	redtop, Kentucky bluegrass, Baltic rush, white clover
	Flat Creek	cage	23	60	17	moist	Nebraska sedge, Baltic rush, redtop, springbank clover
	Little Boulder Creek	cage, photo	73	14	13	moist	redtop, Nebraska sedge, white and springbank clover
Deerhorn	Davis Creek-Lower	cage	51	17	32	moist	redtop, Kentucky bluegrass Nebraska sedge, white clover
	Davis Creek-Upper	cage	89	-	11	dry	Kentucky bluegrass, western yarrow
	Deerhorn Creek	cage, photo	32	12	57	moist	springbank and white clover, redtop
	Placer Gulch	cage, photo	26	47	27	moist	Baltic rush, redtop, springbank clover