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Title: Cattle Grazing Habits and Movements Related to Riparian Habitats and Forested Ranges with Inference to Acute Dietary Bovine Pulmonary Emphysema (ADBPE)

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William C. Krueger

Grazing on the mountainous forested ranges of the Camp Creek Unit, Malhuer National Forest, was typified by irregular distribution of free-ranging cattle. A combination of management and physical, topographic constraints caused cattle to concentrate on the riparian zone early in the grazing season in 1977 and 1978. A large percentage of cattle days and vegetation utilization on the riparian zone occurred in the first four weeks. Utilization on herbaceous vegetation was moderately heavy, 76 and 72 percent in 1977 and 1978, respectively. Impact of grazing on the most prevalent herbaceous species, Kentucky bluegrass, was minimal. Shrub use was greatest when herbaceous vegetation was more mature and less succulent. Utilization of major shrubs was not excessive in either year, and likely had no long term affects on either the abundance or vigor of the shrubs. There were no substantial physical impacts of the livestock on the unit, including the

stream channel.

Environmental and topographic parameters were analyzed to establish causes of cattle behavioral responses. Distinct home range groups of cattle were identified through examination of quantity and pattern of forage use, cattle distribution, herd social structure and cattle activities. The home range of one group encompassed only upland areas. Water and vegetation type were important parameters in determining area and degree of use. Vertical distance above water was the most important factor in determining vegetation utilization on moderately steep slopes. Time after sunrise and relative humidity factors were key parameters in determining kind of cattle activity and timing of the activity.

Cattle grazing the research unit had a history of ADBPE when grazed in the rotation used during the study. Typically, 2-4 cows died of ADBPE each time this rotation was followed. Only one such acute case of ADBPE developed during this study. Conditions in both years minimized the expected incidence of the disease. In 1977, a major drought caused vegetation on the unit, where emphysema was expected to occur, to be very dry. A large number of dry cows and late season precipitation in 1978 altered cattle grazing patterns reducing the chance of ADBPE. In both years, only a small proportion of the herd was comprised of highly susceptible animals. These combined factors reduced the probability of the incidence of ADBPE in the study herd.

Cattle Grazing Habits and Movements Related to Riparian Habitats and Forested Ranges with Inference to Acute Dietary Bovine Pulmonary Emphysema (ADBPE)

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Leonard Roy Roath

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Associate Professor of Rangeland Resources and
Leader of Rangeland Resources Program
in charge of major

Redacted for Privacy

Head, Department of Animal Science

Redacted for Privacy

Dean of Graduate School

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INTRODUCTION

Cattle have been grazing mountain rangelands in the western United States in excess of 125 years (United States Senate 1936). Since the inception of this grazing, obtaining proper distribution of livestock on mountainous areas has been a noted problem. Cattle have a tendency to concentrate on the meadow areas, often resulting in heavy utilization of these meadows, leaving many other areas largely unused. The ecologic management ramifications of improper distribution of grazing pressure can be extensive.

Greater emphasis is now being placed on multiple use management of mountainous areas as a response to increased demands. To make sound multiple use decisions, a great deal of information is needed on every aspect of the entire ecosystem. Unfortunately, much of this information is unavailable at this time.

Detailed information on livestock use of vegetation and pattern of use, in reference to reasons how and why these actions occur, is also unavailable. Additionally, the influence livestock behavior has on management of livestock on forested range and on the overall utilization of vegetation remains mostly unassessed. Cully (1938) accurately stated the point: "In order to work out the most effective plans for managing the range it seems only natural that one first study the cattle as they graze naturally on the range, observing what they do and, in so far as possible, why they do it."

The application of livestock movement, behavior and forage utilization information are many. Total resource management plans can be drafted with the knowledge that livestock impacts and responses can be reasonably predicted and taken into account. Each land area may be managed according to its potential and best use. Livestock nutritional diseases can be avoided by understanding livestock forage utilization, forage quality, and behavioral patterns which may alter forage use.

Acute dietary bovine pulmonary emphysema is one of these dietary diseases which is prevalent in some areas in the west. Frequently this nutritional disease is associated with herds using forested, mountainous rangelands. The areas in which this disease seems endemic have suffered considerable economic loss due to animal mortality. The John Day area in the southern Blue Mountains of Oregon is one such area. The economic loss in that area was so profound that special Forest Service and Agriculture Experiment Station funds were allocated to study the disease and isolate factors contributing to its incidence. Those funds provided the impetus for this study.

The primary objective of this study was to determine how the disease of acute dietary bovine pulmonary emphysema (ADBPE) was related to livestock using forested ranges, and to identify those factors contributing to the incidence of the disease. The isolation of these factors presented a complex problem. Previous evidence had established that ADBPE was a nutritionally related disease. Therefore, identification of contributing factors required quantification of animal forage intake, animal behavior, herd social structure, animal response to environmental parameters and detailed analysis of animal movements. Additionally, individual animals had to be identified so each animal's grazing history could be recognized in relationship to any subsequent occurrence of the disease.

LITERATURE REVIEW

Acute Dietary Bovine Pulmonary Emphysema

Acute dietary bovine pulmonary emphysema is a disease which has plagued grazing animals world-wide. The first documentation of the disease was in the early 1800's. Leslie (1949) reported that an English volume published in 1820 described the occurrence of the disease. Since that time, ADBPE has been reported in nearly every grazing area across the world. Complete literature reviews pertaining to the history, etiology, research and endemic areas of ADBPE are available in Elliot (1976) and Van Zwoll (1975).

No concrete evidence typing ADBPE to diet was available until workers at Washington State University were able to produce a disease with identical pathology and clinical signs by employing large oral doses of D, L-tryptophan (Dickinson et al. 1967). This research has been verified by many individuals (Carlson et al. 1968; Dickinson 1970; Monlux et al. 1970). The transition from laboratory to field incidence was made by Breeze (1976), Elliot (1976), and Selman et al. (1977). This information documented that animals moving from very short pasture to very lush pasture were prone to develop ADBPE. Selman et al. (1977) found 3-methyl indole, a tryptophan metabolite, in the rumen liquor of cattle which had ADBPE. Elliot (1976) suggested that some preconditioning of the animals previous to pasture change mediates the incidence of the disease. Current unpublished work (File data, Rangeland Resources Program, Oregon State University) helps substantiate this hypothesis. Additionally, this work suggested that energy levels in the diet may be an integral factor in the incidence of ADBPE. A factor contributing to the preconditioning concept is that animals which tended to graze the meadow areas in mountainous terrain were noted to have a higher incidence of ADBPE (Elliot 1976). The meadow areas in that study were heavily utilized and those cows in that area did not alter their grazing pattern. This would invariably contribute to lower intake and lower total nutrient intake.

These observations lead to related literature concerning livestock intake, forage availability, diet quality, and many other factors. These may be altered by the previous parameters such as livestock behavior patterns, physical and topographic constraints on movements, animal response to environmental conditions and others. Information on these parameters not only can be tied to nutritional diseases, but to the overall relationship between the animal and its habitat.

Livestock Use on Riparian Habitat

Riparian habitats have become the objects of intense concerns because of the identification of these areas as critical habitats for the support of livestock and wildlife. These areas also play an integral role in protecting streams and maintaining water quality so important for fish populations and for human water use. The Oregon-Washington Interagency Wildlife Council (1978) printed a precise definition of riparian zone: "Riparian zones are defined as those areas associated with streams, lakes, and wet areas where vegetative communities are predominantly influenced by their association with water." They also indicated that these habitats are often the foci of populations of big game and birds, and are primarily responsible for maintaining quality of fish habitat. Ames (1977) and Hubbard (1977) concurred that riparian habitats are key areas for wildlife species. Cook (1966) and Patton (1971) indicated that these riparian areas were also very important sources of forage and water for cattle grazing mountainous ranges. Reid and Pickford (1946) concluded that the riparian areas produced 10-15 times more forage per acre than the forested range, making these key grazing areas for cattle. It has been established that the riparian area is a critical area for preservation and maintenance of many animal populations. However, many articles suggested that these areas are also subject to alteration by many of the same animals which are so dependent on it (Ames 1977; Oregon-Washington Interagency Wildlife Council 1978; Behnke and Raleigh 1978; Bolt et al. 1978; Orr 1960; Winegar 1977).

The great bulk of the literature published on the effect of animals on the riparian area is the result of after-the-fact observations. Damage has been sustained and only guesses can be made as to what and how much impact can be attributed to each of the possible influences. Very often allusions to, or statements of, the impact of livestock overgrazing come from such observations (Ames 1977; Behnke and Raleigh 1978; Winegar 1977). Objective literature, with documentation of influences predicted on baseline information, are almost totally lacking in the literature. Therefore, one must depend on peripheral information to assess influences on riparian habitat.

Influences of animals on riparian areas can be divided into three principal categories: (1) utilization on herbaceous vegetation, (2) utilization of woody vegetation, and (3) physical damage to the site by trampling. Numerous scientists have observed or measured the use of vegetation on the riparian areas (Cook 1966; Hayes 1978; Hedrick et al. 1968; Pickford and Reid 1948). Almost no available information quantified the impact of herbage removal on the riparian habitat as a whole. Granted, measurement of this impact is a difficult task. Information is available on the physiologic response of plants to defoliation, but very little of this pertains to herbaceous plants in, or common to, riparian zones. Pond (1961) documented the yield response of Kentucky bluegrass on meadow areas to clipping. Volland (1978) found that deferment of Kentucky bluegrass meadow increased yield through the first six years following deferment. After that time, yield fell progressively until the eleventh year when the project terminated. At that time the productivity and root mass was less than those from the adjacent continuously grazed Kentucky bluegrass meadow. Etter (1951) has a detailed analysis of morphologic and physiologic response of bluegrass to herbage removal. Branson (1956) and Mueggler (1967) are among many who have produced information on the effect of defoliation of bunchgrasses; however, these results are not from plants growing on riparian areas. This information can only be used as broad guidelines in predicting the response of bunchgrasses on riparian areas.

Documentation of the impact of summer use on riparian shrubs is nearly absent from the literature. Bolt et al. (1978) discussed the effect of an unspecified amount of use on hardwood species in South Dakota. Aldous (1952) documented the effect of percentage winter leader removal on browse species.

The physical effect of trampling on soils and vegetation is reasonably well documented. Bryant et al. (1972), Orr (1960), Reynolds and Packer (1963), and Thomas (1960) all reported that soil bulk densities were appreciably increased due to trampling of grazing animals. Thomas (1960) concluded that heavy textured soils tend to be the most affected by trampling. Also, wet soils are prone to greater compaction than dry soils. Bryant et al. (1972), Orr (1960), Reynolds and Packer (1963), and Thomas (1960) found that Kentucky bluegrass yields were reduced by increases in soil bulk densities. Reynolds and Packer (1972) also reported that red alder growth ceased when bulk densities reached 1.50. The drawback of most trampling studies is that there is little quantification of the amount of trampling done to produce a given affect. Trampling information specifically dealing with riparian areas was reported by Orr (1960). He found that grazing outside an exclosure maintained higher soil bulk densities than inside the exclosure. Bryant et al. (1972) reported soil compaction on a bluegrass area, which has implications to riparian areas. Knight (1978) reported that he could detect no differences in bulky density between grazed and ungrazed areas. Federer et al. (1961) reported that soil compaction increases were ameliorated by heavy winter snows.

Laycock and Harness (1974) and Thomas (1960) documented substantial loss of available forage due to trampling down of standing herbage.

The impact of grazing on stream channels is largely unmeasured. Hayes (1978) found that grazing did not accelerate streambank erosion, and Knight (1978) could resolve no differences in streambank erosion in grazed and ungrazed areas. Behnke and Raleigh (1977) suggested that stream morphology is a function of the external influences. However, Morisawa (1968) concluded that stream morphology and movement was primarily controlled by the stream gradient and the stream bed material. Those streams with very steep gradients and unconsolidated or coarse bed material tend to have braided stream courses, while streams not possessing those characteristics develop other morphologies. Meandering in a stream develops to achieve an equilibrium between stream length and stream energy (Leopold and Langbein 1960; Leopold et al. 1964). Additionally, meandering streams tend to occupy and reoccupy every possible position in the stream valley (Leopold and Langbein 1960).

Livestock Distribution and Forage Use

Livestock distribution on mountainous forested ranges has been a topic of considerable discussion among ranchers and public land managers for many years (United States Senate 1936). During this time there have been many disagreements concerning the achievement of good livestock distribution, what factors are involved, and what affect these factors have in determining livestock use on an area.

Cattle frequently display a tendency to concentrate on sites near water and areas of gentle topography, avoiding other portions of the grazing unit. Anderson and Currier (1973), Williams (1954), and Valentine (1947) found pronounced zones of utilization with respect to such areas and suggested that stocking rates account for differential utilization. Recommendations were also made to rectify the distribution problem, such as better dispersion of waterholes, building trails in rough country, and salting in different areas.

Water has long been considered a primary factor in determining distribution of livestock (Gonzalez 1964; Green et al. 1958; Hedrick et al. 1968; Hodder and Low 1978; Martin and Ward 1973). Gonzalez (1964) and Hodder and Low (1978) found that water was the single most important factor in determining overall distribution of cattle. Water has also been demonstrated to have considerable control on the utilization of forage. Hickey and Garcia (1964), Hodder and Low (1978), Martin and Ward (1973), Phillips (1965) and Valentine (1947) showed utilization was greatest near water and proportionally less as the distance increased. The distance cattle have grazed away from water varied considerably. Hodder and Low (1978) recorded distances as far as four kilometers, while Mueggler (1965), Peterson and Woolfolk (1955), Phillips (1965), and others recorded much shorter distances. The relationship between distance from water and utilization is not a consistent one. Peterson and Woolfolk (1955) reported that heavy utilization on the vegetation altered characteristic patterns of grazing displayed by livestock using less heavily utilized units. Hodder and Low (1978), and Moorfield and Hopkins (1951) found livestock grazed farther from water when forage was dry. Clary et al. (1978) found no significant relationship between utilization and distance from water.

Cook (1966), Patton (1971), and Phillips (1965) concluded that slope can have a pronounced affect on modifying the distance which cattle will graze from water. Those studies reported that utilization decreased rapidly with increase in slope, maintaining the same distance from water. Mueggler (1965) found that 81 percent of the total variation in use could be accounted for by the percent slope and distance upslope from water. Gonzalez (1964) seemed to suggest, however, that grazing may be more related to elevation above water, stating that there was no utilization on steep slopes above water. Van Vuren (1979) substantiated this observation, reporting vertical rise above water accounted for 92 percent of the variation in livestock use of slopes. He stated that cattle were seldom seen greater than 90 meters above the water.

Salt has also been identified as an important factor in determining livestock distribution. However, there is considerable conflicting information in the literature, regarding the affect of salt on cattle distribution. Green et al. (1958), and Martin and Ward (1973) found that utilization was increased near salting areas. Cook (1966) found that cattle were attracted to salting areas, but utilization near salt was modified by site factors such as steepness of slope to where the salt was placed, and vegetation type. Phillips (1965) found that utilization of forage near salt was related to distance from water; the further from water salt was placed, the smaller the increase in utilization around salt. Miller and Krueger (1976) concluded that distance from salt and water accounted for 79 percent of the variation in vegetation use. Hedrick et al. (1968) stated that salt placement could only be used as supplemental, not a primary, factor in distributing animals since it "had little effect on livestock use patterns in the mixed coniferous forest." Hedrick et al. (1968) did conclude that forest density and understory vegetation were the primary factors determining grazing use in mixed coniferous forest. Clary et al. (1978) found a similar relationship between canopy cover, perennial grass production, and livestock forage consumption.

Gonzalez (1964), Phillips (1965) and Van Vuren (1979) noted pronounced aspect preferences on the areas grazed by cattle. North slopes were avoided while east slopes were preferred by cattle.

The preference of aspect probably has some relationship with preferred vegetation types. Cook (1964) and Gonzalez (1964) found that vegetation type was a very important factor in determining the amount of grazing done on a site. Patton (1971) and Workman and Hooper (1968) showed that trails through rough topography substantially increased cattle distribution.

An economic analysis of projects to increase livestock distribution found that pond construction and spring development were economically justifiable (Workman and Hooper 1968). Trail construction was also economically feasible. Herding and increases in dispersion of salting areas were not justifiable for public agencies, but were marginally profitable for ranchers. Fencing was not an economically justifiable project in either case.

Forage Intake and Quality

Livestock nutritional plane is directly dependent on amount of forage intake and the quality of forage eaten. If the forage quantity and/or quality drop, the animal can be subject to a nutritional deficiency when forage conditions appear "normal." Forage intake of free-ranging animals can vary greatly as affected by several factors. Johnstone-Wallace and Kennedy (1944) found that livestock were very opportunistic, consuming large amounts of forage when the availability was high. Their measurements found per cow consumptions of 32 pounds of Kentucky bluegrass dry matter per day. Hodgson and Wilkinson (1968) found cattle consumed large amounts of dry matter when availability was high. Johnstone-Wallace and Kennedy (1944), and Hodgson and Wilkinson (1968) reported substantial decreases in intake when the amount of forage per unit area decreased, even though the total amount of forage available would not limit intake. Chacon and Stobbs (1977) also found great decreases in rate of intake when less forage was available. One would assume that grazing time would increase as forage becomes increasingly less available in an effort to achieve the same total fill. Arnold (1960) reported that sheep grazing time increased linearly with decrease in forage availability. However, the study concluded this increase was insufficient to maintain body weight. Peterson and Woolfolk (1955) found that livestock on heavily stocked range spent much more time grazing than cattle on more lightly stocked range. Conversely, Chacon and Stobbs (1968), and Johnstone-Wallace and Kennedy (1944) did not show increases in cattle grazing time, in response to decreasing forage availability. Chacon and Stobbs (1968) also concluded that duration of grazing did not correspond to amount of intake. Cook and Harris (1952) and Chacon and Stobbs (1968) demonstrated decreases in diet quality with increased utilization. Handl and Rittenhouse (1972) found that dry matter digestibility caused greater reductions in intake than forage availability.

Animal nutritional plane is often higher than the average nutritional value of the forage available. To a large extent this is accounted for by animal selectivity and preference in forage selection (Cable and Shumway 1966). Cook et al. (1962) reported that animals changing from one forage species to another, even with increase in grazing intensity, may increase nutrient intake. Cook (1964) found that selectivity varies according to available plants, stage of plant maturity, intensity of grazing and weather conditions. Dwyer et al. (1964) showed that herbaceous plant maturity caused marked decreases in palatability, which illicited increases in animal selectivity. Arnold (1964) reported that selectivity was greatest when feed is abundant. Culley (1938) found that during the growing season most plants were used indiscriminately by cattle with only a few being notably selected for or against. Arnold (1964) and Arnold and Maller (1977) showed that selection of forages is strongly related to previous grazing experience.

Cook et al. (1967) reported that grasses decreased in palatability as season progressed and browse palatability increased during the same interval. Livestock use on those forage components reflected this trend. Cable and Shumway (1966) reported that dietary protein found in the rumen could only be accounted for by browse consumption.

Livestock Activities and Behavior

Cattle behavior can be influenced by pasture conditions, environment and many other factors to substantially alter an expected manner of movement or response. Livestock behavior has been observed for centuries and most livestock men have an intuition for how animals respond without analyzing why the animal responds that way. A Scotsman, in 1797, designed a grazing system based on his observations of livestock behavior and knowledge of animal production (Johnstone-Wallace and Kennedy 1944). However, Cory (1927) is generally credited with initiating scientific observations of cattle grazing behavior. In general, most livestock behavior studies reported are more oriented to activities and duration of activities than to studying behavior in relationship to cattle movements, use of habitats, use of vegetation, forage intake and animal nutritional plane. Tribe (1950) pointed out that "how, when, where, and why" livestock behave in a given manner is much more important than "for how long."

Results of activity observations have revealed that range cattle have a pronounced tendency to display two primary grazing periods, one following sunrise for approximately three hours and one for three hours duration before sunset (Gonzalez 1964; Dudzinski and Arnold 1979; Hughes and Reid 1951; Sheppard et al. 1957; Smith 1973; Sneva 1970). Reports also indicated secondary grazing periods occurring at various other times during the day. The most consistent of these was a grazing period about midday. Moorefield and Hopkins (1951), and Herbel and Nelson (1966) reported active grazing during this time, while Gonzalez (1964) and Hughes and Reid (1951) reported this was a minor period of rather listless grazing. Johnstone-Wallace and Kennedy (1944) and Gonzalez (1964) also reported night grazing to occur. Sneva (1970) and Hughes and Reid (1951) found that no night grazing took place. Several scientists indicated that the primary grazing periods were in response to light periodicity, particularly to first morning light and last evening light (Dudzinski and Arnold 1979; Hughes and Reid 1951). However, Compton and Brundage (1971) reported that grazing in Alaska began between 6:00 and 7:00 a.m.

without regard to sunrise. Peterson and Woolfolk (1955) found a shift in grazing period activity related to season, with more daytime grazing in the fall and winter months.

Scientists have often reported that grazing time was influenced by a behavioral response to external factors such as temperature, cloudiness, and humidity. Gonzalez (1964) found that initiation of the morning active grazing period was delayed by cloudy weather. Temperature and humidity are frequently mentioned as important factors in determining cattle activities. Dudzinski and Arnold (1979) found that temperature and relative humidity were key influences concerning length of grazing time and timing of activities during the daylight hours. Ehrenriech and Bjugstad (1966) reported grazing time was negatively related to a temperature-humidity index which combined temperature and humidity to arrive at a "comfort index." Schein (1962) reported that warm blooded animals respond behaviorally to heat by seeking shade, lethargy and a shift in grazing periods. Gonzalez (1964) reported that while cattle grazing time did not decrease with temperature, the hottest grazing periods were spent grazing more in the shade than previously.

Observations by many people indicated that particular animals do not associate at random with other individuals of the herd, but rather associate as groups of individuals. Arnold and Dudzinski (1978) reported that there are definite social structure and grouping patterns within a herd of cattle. Herbel and Nelson (1966), Moorefield and Hopkins (1951), and Müller et al. (1976) recorded that groups of cattle were observed. However, the discreteness of the groups was variable. Herbel and Nelson (1966) found that the small grazing groups rejoined at waterholes. Moorefield and Hopkins (1951) noted groups of animals grazing together but did not comment on the integrity of the groups. Dudzinski et al. (1969), Müller et al. (1976), and Squires (1975) found grazing group size decreased when environmental or nutritional stress became evident. Squires (1975) also reported that sheep in hilly areas, where vision barriers existed, form discrete home range groups. Elliot (1976) documented the formation of home range groups for cattle using mountainous range.

CHAPTER I

Cattle Grazing Influences on a Mountain Riparian Zone

CATTLE GRAZING INFLUENCES ON A MOUNTAIN RIPARIAN ZONE

Abstract

A combination of management and physical topographic constraints caused cattle to concentrate on the riparian zone early in the grazing season in 1977 and 1978. A large percentage of cattle days and vegetation utilization on the riparian zone occurred in the first four weeks. Utilization on herbaceous vegetation was moderately heavy, 82 and 75 percent in 1977 and 1978, respectively. Impact of grazing on the most prevalent species, Kentucky bluegrass, was minimal.

Shrub use was greatest when herbaceous vegetation was more mature and less succulent. Utilization of major shrubs was not excessive in either year, and very likely had no long term effects on either the abundance or vigor of the shrubs. There were no substantial physical impacts of the livestock on the unit including the stream channel.

Introduction

"Riparian zones are defined as those areas associated with streams, lakes, and wet areas where vegetative communities are predominantly influenced by their association with water" (Oregon-Washington Interagency Wildlife Council 1978). They are key areas for a wide variety of uses. Fisheries and wildlife biologists have suggested mountain riparian zones are critical habitats in maintaining viable populations of fish, birds, small and big game animals (Ames 1977; Hubbard 1977). These areas are extremely important in providing forage and water for domestic animals (Cook 1966; Phillips 1965). Watershed specialists have indicated that the riparian zone plays an integral role in water quantity and quality (Horton and Campbell 1974). The U. S. government land management agencies, committed by law to manage for multiple use, have identified riparian zones as critical management areas.

These areas, critical to so many uses, are very often subject to great impacts from those users. Wildlife often concentrate in these areas, creating a substantial impact on browse and herbaceous vegetation. Domestic livestock also tend to use the riparian zone extensively. Recreationalists camp, picnic, fish and hunt along the streams, occasionally inflicting considerable damage on the area. Roads and logging activities can also greatly affect the riparian zone.

It becomes apparent that this zone is subject to combined impacts of the many activities centered on it. Often the users which are so dependent on a riparian zone are also principal instruments of damage.

Thus, the riparian zone has become a center of attention for range, wildlife and watershed scientists, conservationists, government agencies and livestock producers. The result of this is conflict of interests and opinion as to the relative impact of any given activity. Many public statements have been made, policies formed and judgments imparted, often based on little scientific information.

The purpose of this study was to address that gap in available information, providing information on the influence of cattle grazing on a mountain riparian zone.

The influence of grazing on riparian zones can be divided into three principal actions: (1) utilization on herbaceous vegetation, (2) utilization of woody vegetation, and (3) physical effects on the site from trampling. Conservationists and scientists have suggested that perennial over-grazing, combined with other events, have caused substantial degradation of the riparian habitat (Ames 1977; Behnke and Raleigh 1978; Winegar 1977). The cited situations are opinions or case studies of long term habitat abuse. Scientific information is mostly unavailable where baseline vegetation, habitat classification, soils, water quality and subsequent influences of grazing have been measured.

Study Area

The research was conducted on one unit of a Forest Service allotment in the southern Blue Mountains, approximately 35 miles south of John Day, Oregon. The riparian zone is characterized by seasonally sub-irrigated Kentucky bluegrass (Poa pratensis) meadows ranging from 20 to 150 meters wide, bordered by steep north and south slopes. This riparian zone extended the full 8.9 kilometers of the unit and ranged in elevation from 1440 to 1545 meters. The north slopes are forested with Douglas fir (Pseudotsuga menziesii) and slopes range from 30 to 70 percent. South slopes are dominated by mountain big sagebrush (Artemisia tridentata ssp. vaseyana) and bluebunch wheatgrass (Agropyron spicatum). The slope on these areas is 20 to 60 percent.

The meadow was subdivided into two types. The dry bluegrass meadow type was characterized by Kentucky bluegrass, June grass (Koeleria cristata), mountain brome (Bromus marginatus), Columbia needlegrass (Stipa columbiana) and western snowberry (Symphoricarpos occidentalis). The wet meadow type was characterized by Kentucky bluegrass, Baltic rush (Juncus balticus), sedges (Carex spp.), slender wheatgrass (Agropyron trachycaulum), Columbia needlegrass and numerous forbs including cinquefoil (Potentilla spp.), western yarrow (Achillea millefolium) and pussy toes (Antennaria *rosea*) in the herbaceous portion. In each of the meadow types, bluegrass was by far the most abundant comprising 46 percent of the vegetation by weight and about 65 percent of the perennial grasses. Forbs constituted about 24 percent of the vegetation composition, while sedges and other grasses comprised 20 and 9 percent, respectively. Columbia needlegrass and slender wheatgrass combined to form about one percent of the vegetation, by weight.

A shrub component including mountain alder (*Alnus incana*), willow (*Salix* spp.) and red-osier dogwood (*Cornus stolonifera*) was present near the stream channel. Shrubby cinquefoil (*Potentilla fruticosa*), twinberry (*Lonicera involucrata*) and bog birch (*Betula glandulosa*) occurred occasionally in wet meadows. Currant (*Ribes* spp.), rose (*Rosa woodsii*) and mountain silver sagebrush (*Artemisia cana* ssp. *viscidula*) were interspersed through both meadow types.

Methods

The procedures for assessing the impact of grazing influence entailed: (1) intensive sampling of vegetation for sequential vegetation disappearance employing the double-sampling technique described by Wilm et al. (1944). This sampling regime employed a one quarter meter square frame. Three transects of ten plots per transect were examined each week. The transects were paced using random numbers of paces to determine plot location. Two clipped sample plots per transect were used for estimate correction. Ten movable cages in 1977 and 15 in 1978 were used to account for regrowth of vegetation. (2) Shrub utilization data was obtained by double-sample procedures from shrubs in five one-tenth hectare plots per year. Every shrub within the plot was estimated for leader weight remaining and percentage leader removal. Five clipped samples per species were used to correct the weight estimates. Weight removal was calculated from weight remaining and utilization data. (3) Observation data were collected for cattle numbers and movements on the riparian area. There were nine sampling days in 1977 and 19 sampling days in 1978. (4) Observations were also made on pattern of forage utilization over the grazing season including order of plant utilization, and apparent relative plant palatability. The grazing season began on June 29 and June 23, producing a grazing season of 48 and 53 days for 1977 and 1978, respectively.

Standard analysis of variance and Duncan's new multiple range test were used to test vegetation data. Chi-square statistics were used to detect differences in proportion of animal days and vegetation versus proportion of time by period. Additionally, this test was used to compare proportion of animals and proportion of vegetation removal per period. The term significant means $P \leq .05$ unless otherwise specified in the text.

Results

Vegetation Utilization

The riparian zone on this unit occupied 44.6 hectares, which constituted 1.9 percent of the total land area, and produced approximately 21 percent of available forage on this pasture. Because of livestock concentration, limitations on livestock movements imposed by steep slopes, and erratic distribution of watering areas away from the creek, the riparian zone accounted for 81 percent of the total herbaceous vegetation on the unit removed by livestock in both 1977 and 1978. The utilization on herbaceous vegetation on the riparian zone in 1977 was 76 percent, which equaled 1845 kg/ha vegetation removal (Table 1). Utilization in 1978 was 2089 kg/ha or 72 percent of the available forage. Utilization on perennial grasses was 83 and 75 percent for 1977 and 1978, respectively. The average yield of herbaceous vegetation for 1977 was 2268 kg/ha compared to 2795 kg/ha in 1978. The yield difference reflected a lower growing season precipitation received in 1977 which was only 49 percent of the amount received in 1978.

The herbaceous vegetation use, by period, was comparatively large during the first portion of the grazing season (Table 1). There was also a trend of progressively smaller amounts of vegetation removal later in the grazing season. Significantly more utilization

TABLE 1. Vegetation Removal and Animal Days on the Riparian Zone for 1977 and 1978.

	Time		Herbaceous Vegetation Removal			Animal Days		
	wks	% elapsed time	kg/ha	%	%/wk	numbers	%	%/wk
1977	3.7	55	1539 a*	83	22	3696	69	19
	1.0	15	64 b	4	4	651	12	12
	1.0	15	117 b	6	6	466	9	9
	1.0	15	125 b	7	7	538	10	10
	6.7		1845			5351		
1978	4.7	61	1757 a	84	18	4448	69	15
	1.0	13	247 b	12	12	609	12	12
	1.0	13	85 c	4	4	623	10	10
	1.0	13	0 c	--	--	825	12	12
	7.7		2089			6485		

* Values within years for kg/ha designated with different letters are significantly different, $P \leq .05$.

occurred during the first grazing period than any other period. In 1978, the utilization in the fifth week was also greater than in succeeding periods. In the last two weeks of both years, there was no significant amount of vegetation use on the riparian zone. The use on the adjacent vegetation types became more prevalent during the last two weeks for both years. The steep south slope type bordering the riparian zone was most used during this time.

Shrub use on the riparian zone was different in 1977 compared to 1978 (Table 2). Average utilization of leaders was significantly greater in 1977 than in 1978 for willow, currant, rose and snowberry. Utilization on alder was not significantly different between years. High degrees of utilization on leaders were also prevalent on twinberry and bog birch in 1977, however, insufficient samples were taken to test the differences between years.

The total utilization of available shrubs on a weight basis was 48 percent in 1977 and 31 percent in 1978 for all species combined. Willows provided 37 percent of the shrub weight used on the area in 1977, but accounted for only 27 percent of the total shrubs available. Twinberry appeared to be used greatly in excess of its availability. Because twinberry was relatively rare, the weight estimate was not reflective of amount of utilization which might have occurred had the availability been greater. Rose, snowberry and currant, combined, were used comparable to their presence. They had 15 percent of the

TABLE 2. Percentage Shrub Utilization and Weight Removal for 1977 and 1978.

Shrub	area occupied				
1977	Ha	% area	% avail. wt.	% leader util.	% wt. removed
Alder	9.8	72	57	39	47
Willow	1.6	12	27	64	37
Rose				34	
Currant	1.2	9	14	57	15
Snowberry				53	
Dogwood	0.2	2	T	61	T
Bog Birch	0.6	4	T	48	1
Twinberry	0.05	0	T	75	T
Shrubby Cinquefoil	0.15	1	T	21	T
	13.60				
1978					
Alder	9.8	72	61	28	51
Willow	1.6	12	20	54	33
Rose				8	
Currant	1.2	9	12	32	11
Snowberry				20	
Dogwood	0.2	2		T	
Bog Birch	0.6	4	6	28	5
Twinberry	0.05	0	T	44	T
Shrubby Cinquefoil	0.15	1		0	
	13.60				

weight use and made up 14 percent of the shrubs available. Alder, on the other hand, was not preferred, providing 57 percent of the available shrub production but only 47 percent of the total use on shrubs. The 1978 weight utilization had the same trend found in 1977, but at lower levels.

The pattern of shrub utilization was very different between years. In 1977, utilization was initiated at the time when cattle came into the unit and was progressive throughout the season. Willow was utilized in excess of its percentage availability. Rose, snowberry and currant use was approximately the same as availability. The only shrubs which showed obvious avoidance by livestock were shrubby cinquefoil and mountain silver sagebrush.

In 1978, shrub utilization during the early portions of the grazing season was low. Even preferred species were used very little during the first four weeks of the grazing season. When shrub utilization began, more selectivity relative to species was demonstrated than in 1977. Willow and currant received the most use at that time. Alder was not used until later in the season. Species such as dogwood and rose, which had received considerable use in 1977, received little or no use in 1978.

Cattle Days on the Riparian Zone

Number of cattle and the duration of time spent on the riparian zone are important factors in assessing the net impact of cattle on that zone. A characteristic pattern of livestock time spent on the riparian zone was evident. The proportion of cattle days compared to the proportion of grazing time by period revealed that, in 1977, the percentage of cattle days spent on the riparian zone in early periods was significantly larger than the percentage of time by period (Table 1). In 1978, the percentage of cattle days was not different from the percentage of time by period. The pattern of cattle days spent on the riparian zone reflected a managerial influence on cattle movements. Cattle were turned on at a single gate where the road funneled the cattle onto the riparian zone. Therefore, nearly the whole herd was on the riparian zone at the initiation of the grazing season.

They remained on the riparian zone seven to ten days with some animals progressively dispersing onto other areas. Cattle numbers on the riparian area stabilized after about 21 days at 35 to 40 percent of the herd with other cattle moving back and forth between upland types and the riparian zone. This movement was more prevalent in 1977 primarily because of limited water availability away from the riparian area, due to limited precipitation. An important factor to note is that the livestock dispersed before the forage became limiting.

In both years the trend in percentage of animals per week was the same, showing progressively fewer animal days per week through the sixth week. However, the last week reflected an increase in animal days on the riparian area. Number of cattle days on the riparian zone were based on actual sightings. The portion of the cattle which moved between the uplands and the riparian zone may not have been included in the observation data. The number of animal days on the meadows accounted for 71 percent of the vegetation disappearance in 1977 and 81 percent in 1978. Based on percentage of total animal days per week, a large number of the animals were on the meadows during the first period in both 1977 and 1978.

Observation of Physical Disturbance

Camp Creek, the primary stream on the unit, is a small mountain stream although the total watershed area is reasonably large. The creek flow is characteristic of most mountain streams, showing peak flows during the spring runoff and low flows during the hot days of late summer. About 90 percent of the stream bank could be characterized as stable. There were areas which showed active erosion. These areas all occurred in a meandering portion of the stream where the flood plain was widest. There was considerable evidence, presented by stands of alder and willow along old channels, that the stream has completely changed course several times. Active erosion was occurring where the hydraulic force was greatest, on the downstream concave portion of each meander. On the unit there was only one instance where there was in indication that livestock trampling was contributing to or causing bank erosion. This occurred where a trail was altered to circumvent a fallen log. All regular livestock crossings on the creek were on gentle slopes and no perceptable bank erosion was evident. In two locations beaver dams had flooded cattle trails and trampling had occurred in the trail area.

Ground squirrels (Spermophilis spp.) and beaver (Castor canadensis) had excavations in and along the stream bank, causing the bank to be unstable in those areas. Additionally, beaver created runways out into the riparian zone. Ground squirrel numbers were large and colonies of these animals were prevalent on the riparian zone, primarily on the dry meadow area, but evidence of ground squirrel utilization on the surrounding wet meadow area was apparent. Some deer (Odocoileus hemionus hemionus) were present on the area, but their impact was not measured and was assumed to be low compared to other influences.

Discussion

Physical limitations on cattle movements imposed by slope, and management practice of turning the cattle in at one point contributed to concentrating the cattle on the riparian zone early in the grazing season. The use resulting from this action represented a large proportion of the total season use on the riparian vegetation (Table 1). However, the percentage of total forage removed was significantly greater than the percentage of animal numbers for that period. Johnstone-Wallace and Kennedy (1944) reported intake values of 32 lb/day (14.6 kg/day) dry matter for cattle using bluegrass when forage was highly available. They, as well as Hodgson and Wilkinson (1968), reported marked declines in forage intake when forage availability per unit area decreased, even though total forage available was not limiting. Similar patterns of herbage intake displayed by the cattle on the riparian zone could explain a substantial portion of the disparity between percentage forage consumed and percentage of cattle days spent grazing.

Cattle using the riparian zone showed little inclination to use the south slopes bordering that area through much of the grazing season even though utilization on vegetation was progressively reducing available forage.

During the last two weeks of the grazing season observation of cattle indicated that there was increased use on the associated south slopes. This probably occurred because of a combination of factors. During this period of both years a substantial amount of rainfall occurred, which is known to increase the palatability of cured vegetation (Springfield and Reynolds 1951). Nighttime low temperatures were dropping to -2 to 8°C on the riparian zone and a noticeable cold air accumulation could be felt in the early evenings. Nearly all of the grazing on the south slopes occurred during the evenings and early mornings. Behavorial scientists have indicated that animals tend to avoid cold pockets in bedding and grazing (Arnold and Dudzinski 1978). Therefore, it seems most plausible to think that the use on the slopes was due to differential palatability and a microclimate induced animal behavior response.

Kentucky bluegrass was the dominant grass on the riparian zone and probably exerted major control over the relative stability of the vegetation communities. Therefore, the impacts of grazing on Kentucky bluegrass will be addressed as a primary indicator of the influence of grazing on stability of the riparian zone. Grazing on Kentucky bluegrass was at a level which has been demonstrated to have small impacts on vigor and cover. Etter (1951) found bluegrass clipped to one inch, season long for four years, did not reduce numbers of shoots or rhizomes. However, some reduction in yield was shown. Volland (1978) reported that production of a previously continuously grazed riparian zone increased significantly for six years after deferment was initiated. After that time, production decreased progressively. At the end of 11 years of deferment the ungrazed area had lower production and root mass than the adjacent continuously grazed area. Grazing on the riparian zone reduced the height of Kentucky bluegrass to about one inch after four weeks and that level was maintained for the duration of the grazing season. It seems highly unlikely, based on the growth habit and physiology of bluegrass, that cattle grazing bluegrass meadows over a six week time-span from early to mid-summer would cause sufficient impact to reduce the cover of Kentucky bluegrass. The impact of grazing on the other herbaceous components can not be evaluated because no data exist to allow evaluation of responses.

Observations on livestock utilization of herbaceous vegetation on the riparian zone, when deferred until mid-August, indicated that use was much lower on the herbaceous component. This phenomena was produced by a combination of low relative palatability and cold air accumulation on the meadows. Apparently, the utilization of herbaceous components in the riparian zones could be manipulated by changing season of use.

The impact of grazing on shrubs was more difficult to assess because of the variability of shrub utilization caused by year effect, and lack of information on the response of riparian shrubs to summer utilization. Aldous (1952) published information reporting the response of shrubs to degree of winter utilization. Those results indicated that willow responded to 50 percent annual utilization of leader material with increases in production of 248, 118, and 164 percent in successive years. Willow was within the limit of proper use in 1977 and 1978 that should allow for increases in production (Table 2). Red-osier dogwood was used relatively heavily in 1977. However, the height growth, leader length and numbers were exceptionally large the following year. Utilization on dogwood was light in 1978. Aldous (1952) indicated that red-osier dogwood could not withstand 90 percent annual utilization for a prolonged period over several years, but 25 percent annual utilization had no negative impacts over years. Therefore, dogwood on this area should tolerate use one year at moderate levels followed by a year of light utilization. Insufficient evidence is available from the literature to predict the influence of grazing on other shrubs.

Observations indicated the dry year induced livestock to use browse more than they did in a more mesic year. Cattle grazing a unit deferred until fall utilized browse heavily on the riparian area, even though utilization of herbaceous vegetation was low. Apparently, season of use and degree of shrub utilization were related to palatability of the available herbaceous vegetation and perhaps to change in the palatability of the browse itself.

The potential physical impact of cattle can be divided into four categories: (1) trampling loss of vegetation, (2) physical damage to shrubs and trees, (3) trampling and compaction damage to soil, and (4) soil disturbance. It seems likely that the share of the vegetation utilization which could not be accounted for by consumption during the total number of animal days is attributable to trampling loss. This was accentuated in this study because the area was approaching maximum yield at the same time that the cattle were turned onto the allotment. Laycock and Harness (1974) concluded that trampling loss alone could account for up to 23 percent of the total vegetation yield. Laycock et al. (1972) reported even larger losses of 50 percent due to trampling. The amount of physical damage to shrubs and trees on the area due to trampling and rubbing was minimal, primarily because the cattle tended to bed off the riparian zone in the edge of the timber and used the large conifers for rubbing. Pathways were maintained through shrub areas, but this represented a relatively small area. Perhaps the greatest potential physical impact of cattle on the riparian zone is the trampling and soil compaction effect. When meadows are very wet, cattle can severely trample the riparian zone and cause substantial impacts on the vegetation; destroying crowns, roots and plant community integrity, creating an open niche for weedy species. On this area there were only two isolated occurrences of excessive trampling of boggy areas. Both occurred where a regularly used cattle trail was flooded by water backed up by beaver dams. Other equally wet areas which cattle grazed did not have concentrated groups of animals on them, and the total impact was minimal.

Reynolds and Packer (1963), Bryant et al. (1972), and Thomas (1960) indicated livestock trampling can cause reductions in forage yield. Yields during this study were 2268 kg/ha and 2795 kg/ha, which when compared with data from Volland (1978), would suggest that forage production was not seriously depressed. Cattle were introduced on the riparian zone after the soil was firm, tending to reduce compaction. Additionally, Federer et al. (1961) found that summer compaction affects were ameliorated over winter by frost and heavy snow cover. Therefore, on this area soil compaction increases which may have occurred should have been eliminated by the severe winters prevalent in the area.

Soil disturbance by the cattle was present but was of generally small consequence. The major disturbance of soil occurred in dusting areas, which was combined with ground squirrel influence. Cattle opportunistically used ground squirrel infested areas on the dry meadow as dusting spots in 1977. However, this activity was much less pronounced in 1978. That summer the cattle dusted on the slopes adjacent to the bottoms under the conifers, minimizing this effect on the riparian zone.

The effect of cattle on the stream bank deterioration was negligible, since the principal crossings were on gentle banks adjacent to riffles. The primary cause of stream bank erosion was probably geologic stream course movement. The statement by Leopold and Langbein (1966) "the stream will occupy and re-occupy every possible position of the flood plain," supports this observation. Vegetation on the stream banks was stable and livestock trails down the stream bank were absent, with one isolated exception. There was no evidence, on this unit, indicating that cattle caused acceleration of stream bank erosion. These observations are similar to the findings of Hayes (1978) and Knight (1978).

Conclusions

Combinations of factors caused cattle to concentrate within the riparian zone early in the grazing season, and to use a relatively high proportion of the vegetation during the first four weeks of the grazing period. After this period cattle numbers on the riparian areas stabilized and remained consistent until shortly before a pasture change.

Pattern of shrub utilization was related to relative vegetation palatability on the riparian zone and adjacent areas, and showed a great deal of variation according to years and season of use. Shrub use tended to increase as the season progressed. Shrub utilization was lowest when herbaceous vegetation was lush and very palatable, and greatest when herbaceous vegetation was coarse and mature.

The influence of grazing on Kentucky bluegrass was minimal as far as maintenance of cover and plant vigor was concerned. Additionally, grazing pressure apparently was not depressing yield. The greatest quandary is the problem of maximizing shrub growth and optimizing herbaceous yield. Seemingly, the management requirement which would benefit shrubs most, grazing when the herbaceous component is lush, would shift utilization away from shrubs. However, this action could have the greatest potential for damaging the herbaceous component. Conversely, late season grazing minimizes impact on herbaceous components, but increases shrub utilization.

There is a potential for physical damage on the riparian zone. Initiation of grazing after riparian zone soils have become firm should mitigate the potential physical damage. In this study localized physical damage did occur in flooded areas and rodent burrow areas, both created by an interaction with other animals using the riparian zone.

There was no evidence that cattle affected herbaceous or woody vegetation sufficiently to cause accelerated erosion, or that they caused stream bank deterioration by trampling. Nearly all the erosion present was attributed to geologic erosion caused by stream action in meandering.

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CHAPTER II

Cattle Grazing and Behavior on a Forested Range

CATTLE GRAZING AND BEHAVIOR ON A FORESTED RANGE

Abstract

Environmental and topographic parameters on a mountainous forested range were analyzed to establish causes of cattle behavioral responses. Distinct home range groups of cattle were identified through examination of quantity and patterns of forage use, cattle distribution, herd social structure and cattle activities. The home range of one group encompassed only upland areas. Water and vegetation type were important parameters in determining area and degree of use. Vertical distance above water was the most important factor in determining vegetation utilization on moderately steep slopes. Time after sunrise and relative humidity factors were key parameters in determining kind of cattle activity and timing of the activity.

Introduction

Cattle have been grazing forested ranges in the Western United States for more than 125 years (United States Senate 1936). When grazing was initiated land and forage seemed unlimited, although neither assumption was true. Grazing units on the forest have been fenced, restricting livestock to a given area. This placed definite limits on forage and often increased animal concentration on key vegetation types. Some vegetation types were over-utilized while others were left totally ungrazed.

As the demand for more and varied uses of mountain land areas increases, it becomes important to enhance livestock distribution, alleviating concentration problems and minimizing real or potential conflicts with other resource demands. Detailed information assessing the pattern of livestock use, the types and amounts of forage consumed, and detailed information on livestock distribution is required. This is only baseline information, in order to apply it one must know the cause and the mechanism of each parameter. Cully (1938) accurately stated the point: "In order to work out the most effective plans for managing the range it seems only natural that one first study the cattle as they graze naturally on the range, observing what they do, and so far as possible, why they do it."

Determining causes for observed actions of cattle overlaps range management and applied behavioral sciences. External physical and biotic influences interact with the animal's innate behavioral complex to produce a given response. Measurement of influencing parameters must be matched with the animal response and examined to establish some idea of the cause and effect relationship. Distance from water, topography, temperature, humidity and forage availability have been rated as important parameters in modifying animal behavior. Herd structure is a behavioral factor which could have considerable influence on grazing patterns and forage use. Many studies have observed a given event and assessed the impact on vegetation, but those observations were often not analyzed in terms of what caused the event.

The objectives of this research were to: (1) identify forage use and patterns of forage use, (2) document patterns of livestock distribution on the unit, and (3) analyze this information in relationship to topography, environment, biotic influences and cattle behavior to establish causal correlations.

Literature Review

Livestock distribution is regarded as one of the most important range management problems. Williams (1954) concluded that the more range sites in a unit, the greater the problem in obtaining uniform distribution of grazing use on all sites.

Many authors consider water availability to be a primary factor in controlling livestock use (Gonzalez 1964; Hodder and Low 1978; Martin and Ward 1973). Gonzalez (1964) found that water was the single most important factor in determining the overall livestock distribution. Phillips (1965), Hodder and Low (1978), Valentine (1947) and Martin and Ward (1973) found that water not only controlled distribution of cattle, but controlled the amount and pattern of vegetation utilization. The relationship between distance from water and forage utilization is not a consistent one. Forage succulence, grazing intensity, site and topographic features all modify the relationship or replace distance from water as a controlling factor in livestock forage utilization (Cook 1966; Gonzalez 1964; Hodder and Low 1978; Mueggler 1965; Peterson and Woolfolk 1955; Phillips 1965).

On mountainous ranges slope is frequently a factor which plays an integral role in controlling distribution of cattle and the overall degree of forage use (Cook 1966; Patton 1971; Phillips 1965). Mueggler (1965) found that 81 percent of livestock use on slopes was accounted for by percent slope and distance upslope from water. Van Vuren (1979) reported that distance upslope was much less important than vertical rise above water. That study found 92 percent of the variation in livestock use on slopes could be accounted for by vertical rise above water. Cattle were seldom seen greater than 90 meters above water.

The effect of salt on forage utilization is subject to discussion. Green et al. (1958) and Martin and Ward (1973) found utilization increased near salt, while Hedrick et al. (1968) found that salt had little effect on forage use.

Vegetation type and the aspect that type occupies has been shown to be instrumental in determining the amount of forage use. Clary et al. (1978) and Hedrick et al. (1968) concluded that canopy cover, combined with amount of understory vegetation, were the principal factors controlling forage use on forested ranges. Gonzalez (1964), Phillips (1965) and Van Vuren (1979) found that interaction between preferred forage and preferred aspect seemed to dictate vegetation utilization in many areas.

The total use of forage on an area may be substantially influenced by animal behavioral factors. Johnstone-Wallace and Kennedy (1944) found that amount of intake by cattle was related to relative availability of forage. When forage was highly available, livestock consumption was much higher than the normally expected amount of dry matter intake. As forage availability per unit of area decreased intake declined, even though total amounts of forage would not limit intake. Behavior patterns also affect animal selectivity and preference of forage species, dictating pattern and amount of plant species use (Arnold 1960; Arnold and Dudzinski 1978; Cable and Shumway 1966; Peterson and Woolfolk 1955).

Behaviorally mediated home range groups of animals have been reported by Elliot (1976). The formation of home range groups of animals oriented to certain areas could substantially affect forage consumption patterns and amounts for a unit as a whole.

Information on daily activity patterns has been documented in many cases. Arnold and Dudzinski (1978), Gonzalez (1964), Hughes and Reid (1951) and Sneva (1970) reported that cattle displayed a characteristic pattern of two primary grazing periods, one following daylight and one preceding sunset. Many reports indicated various secondary grazing periods. A midday grazing period was the most consistently noted secondary period (Gonzalez 1964; Herbel and Nelson 1966; Moorefield and Hopkins 1951). Johnstone-Wallace and Kennedy (1944) and Gonzalez (1964) recorded night grazing, while Hughes and Reid (1951) and Sneva (1970) found no night grazing.

Grazing periods were generally reported to be related to first daylight in the morning and last light in the evening (Arnold and Dudzinski 1978; Hughes and Reid 1951). Compton and Brundage (1971) reported, in Alaska, that grazing was initiated between 6:00 and 7:00 a.m. without regard to sunrise.

Various environmental parameters including cloudiness, temperature and relative humidity modify duration of grazing and timing of other events (Arnold and Dudzinski 1979; Ehrenriech and Bjugstad 1966; Gonzalez 1964).

Study Area Description

Research was conducted on a unit of a Forest Service allotment on forested mountainous range in the southern Blue Mountains of Oregon. The unit consisted of 2656.5 hectares of primarily forested land, and was bisected by a permanent stream. Topography was steep adjacent to the riparian zone and gentle to moderately rough in upland areas. Elevation on the unit ranged from 1440 m to 1800 m. Precipitation has a characteristic pattern of deep winter snows, especially on the higher elevations, with some rain during spring and dry summers. Precipitation ranges from approximately 36 cm per year on the lower elevations to over 60 cm per year at higher elevations (Carlson 1974). Upland areas have moderate soil depths. The A horizon consists of 11-30 cm of volcanic ash with 7-25 cm clay subsoils beneath. Rock outcrops are frequent. The lowlands are riparian zones with characteristic silt loams on the flood plain.

Ten vegetation types were identified on the area, but only eight supported reasonable amounts of grazing. These vegetation types were: (1) riparian, (2) sagebrush (*Artemisia tridentata* ssp. *vaseyana*)-Sandberg bluegrass (*Poa sandbergii*), (3) steep south slope, (4) open hills, (5) pine (*Pinus ponderosa*) uplands, (6) Douglas fir (*Pseudotsuga menziesii*) slopes, (7) pine-bitterbrush (*Purshia tridentata*), and (8) pine-bluebunch wheatgrass (*Agropyron spicatum*) (Figure 1).

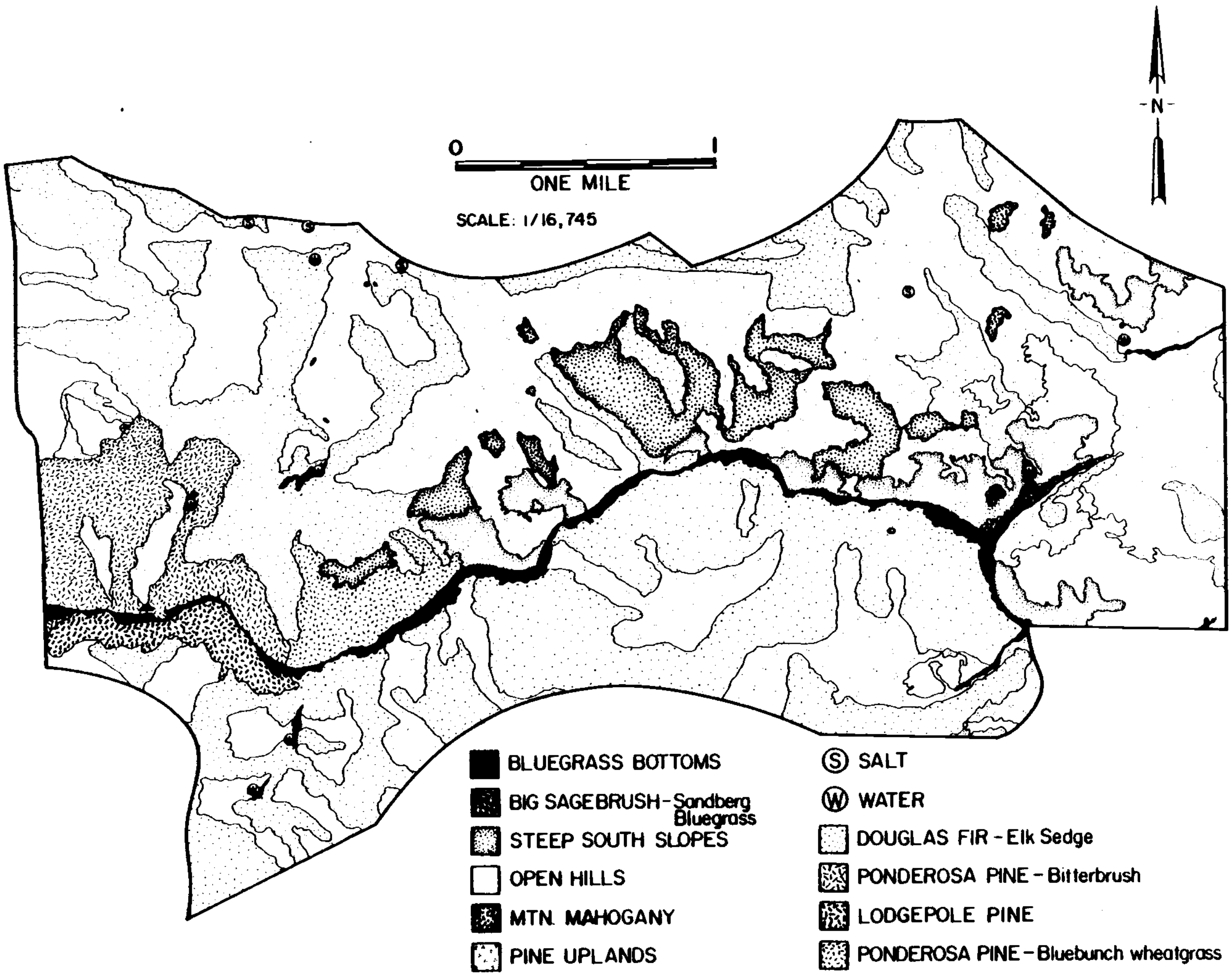

Figure 1. Study area map of vegetation types.

The riparian type was characterized by Kentucky bluegrass (Poa pratensis), sedges (Carex spp.), and a great many forbs including cinquefoil (Potentilla spp.), camas (Camasia spp.), western yarrow (Achillea millefolium) and many others. Columbia needlegrass (Stipa columbiana), slender wheatgrass (Agropyron trachycaulum) and mountain brome (Bromus marginatus) were also present on the riparian type, but did not constitute a substantial component of the total yield.

The sagebrush-Sandberg bluegrass type had mountain big sagebrush and Sandberg bluegrass as the most prominent plant species in the type. Mountain big sagebrush served as an overstory dominant with bluebunch wheatgrass as the herbaceous dominant on the steep south slopes. This type had characteristic slopes of 30-70 percent.

Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass were the dominant grasses under mountain big sagebrush on the open hills. The open hills type occupied rolling upland areas where conifers were precluded because of the south-southwest exposure.

Pine upland and Douglas fir types were interspersed. The pine type occupied the level or gently rolling upland areas having slopes of 0-15 percent, with Douglas fir dominating on the steeper aspects. Slopes of 10-40 percent were common in this type. Ponderosa pine was the dominant overstory in the pine upland, with elk sedge (Carex geyeri) and pine grass (Calamogrostis rubescens) in the understory. Heartleaf arnica (Arnica cordifolia) was the primary forb in this type.

The Douglas fir type showed the same basic understory dominants, but Douglas fir was the overstory tree. Coniferous canopy cover averaged 57 percent.

The pine-bitterbrush type had shallower rocky soils with slopes ranging from 0 to 15 percent. That community, in addition to the conifer canopy cover of 36 percent, had an intermediate shrub layer of bitterbrush. Elk sedge was more sparse and was accompanied by western needlegrass (*Stipa occidentalis*) as well as heartleaf arnica in the herbaceous layer. The pine-wheatgrass type was found on south exposure slopes ranging from 20 to 60 percent and at mid-elevations. Soils were thin and rocky. Pine was dispersed through this type with bitterbrush and bluebunch wheatgrass providing the understory components.

Grazing seasons on the study unit were initiated on June 29 and June 23 in 1977 and 1978, respectively. Two hundred fifty cattle grazed the unit both years. Precipitation was quite low for 1977, resulting in early plant maturity and dessication. Many catchment type watering areas and seeps which cattle normally used were dry, severely restricting available water on the unit. Precipitation was normal or slightly above for 1978, resulting in a longer duration of lush forage and greater water availability.

Methods and Procedures

Vegetation use by livestock was accounted for by utilization estimates combined with forage production measurements for two successive seasons, 1977 and 1978. The forage production by species was measured on the uplands employing the double-sampling technique described by Wilm et al. (1944). Ten estimates of one-half square meter rectangular plots for three transects were made in each vegetation type. Two correction plots per transect were clipped to ground level. Percentage utilization estimates by weight were made at the end of the grazing season. Average utilization was estimated, as well as utilization zonation in relationship to measured distance from water, distance from salt and elevation.

Forage removal on the riparian area was measured using sequential double-sampling throughout the grazing season. One-quarter square meter plots were used on the riparian area and fifteen movable cages were employed to correct for regrowth.

Detailed observations of cattle numbers and cattle movements were collected throughout the grazing season. A minimum of two observations per week were taken in 1977 and a minimum of three per week in 1978. Time of cattle movements, location, and activities were recorded.

Environmental observations of temperature and relative humidity were accumulated from six hygrothermograph locations, three on uplands and three on the riparian zone. Grazing season precipitation events were measured at two rain gauge stations. Barometric pressure was recorded with an altimeter barometer once per day at the same location to obtain consistent readings.

Analysis of variance was employed to analyze vegetation data. Regression techniques and discriminant analysis were used to interpret livestock movement and behavior data. Significance was based on $P \leq .05$ level unless otherwise specified.

Results and Discussion

Vegetation Types and Forage Use

Cattle use on mountainous habitats is controlled by an interaction of factors including topography, vegetation type, climate, availability of water and livestock behavior. The total area of the unit was 2656.5 hectares. Only 922.1 hectares were grazed, representing 35 percent of the land area available (Table 1). Obviously, livestock dispersion on the unit was not uniform on vegetation types or land area (Figure 2). The riparian zone comprised 1.9 percent of the total area but constituted 5.4 percent of the grazed land area, reflecting a 250 percent difference. Most vegetation types used were grazed in greater proportion than their availability. The Douglas fir-elk sedge

TABLE 1. Areas and Percentages for the Vegetation Types on the Camp Creek Unit.

Vegetation Types	Area (Ha)	% of Area	% Type Grazed	Area Grazed	% of Grazed Area
Riparian Zone	49.4	1.9	100	49.4	5.4
Sagebrush-Sandberg bluegrass	7.7	0.3	100	7.7	0.8
Steep South Slopes	122.8	4.6	47	57.7	6.3
Open Hills	95.8	3.6	46	44.1	4.8
Pine-Bluebunch wheatgrass	49.9	1.9	55	27.4	3.0
Pine-Bitterbrush	125.2	4.7	75	93.9	10.2
Pine Uplands	1042.6	39.2	42	437.9	47.5
Douglas fir-Elk sedge	1005.9	37.9	20	201.2	21.8
Lodgepole pine	38.7	1.5	1	0.4	t
Mountain mahogany	118.5	4.5	2	2.4	t
Total	2656.5			922.1	34.7

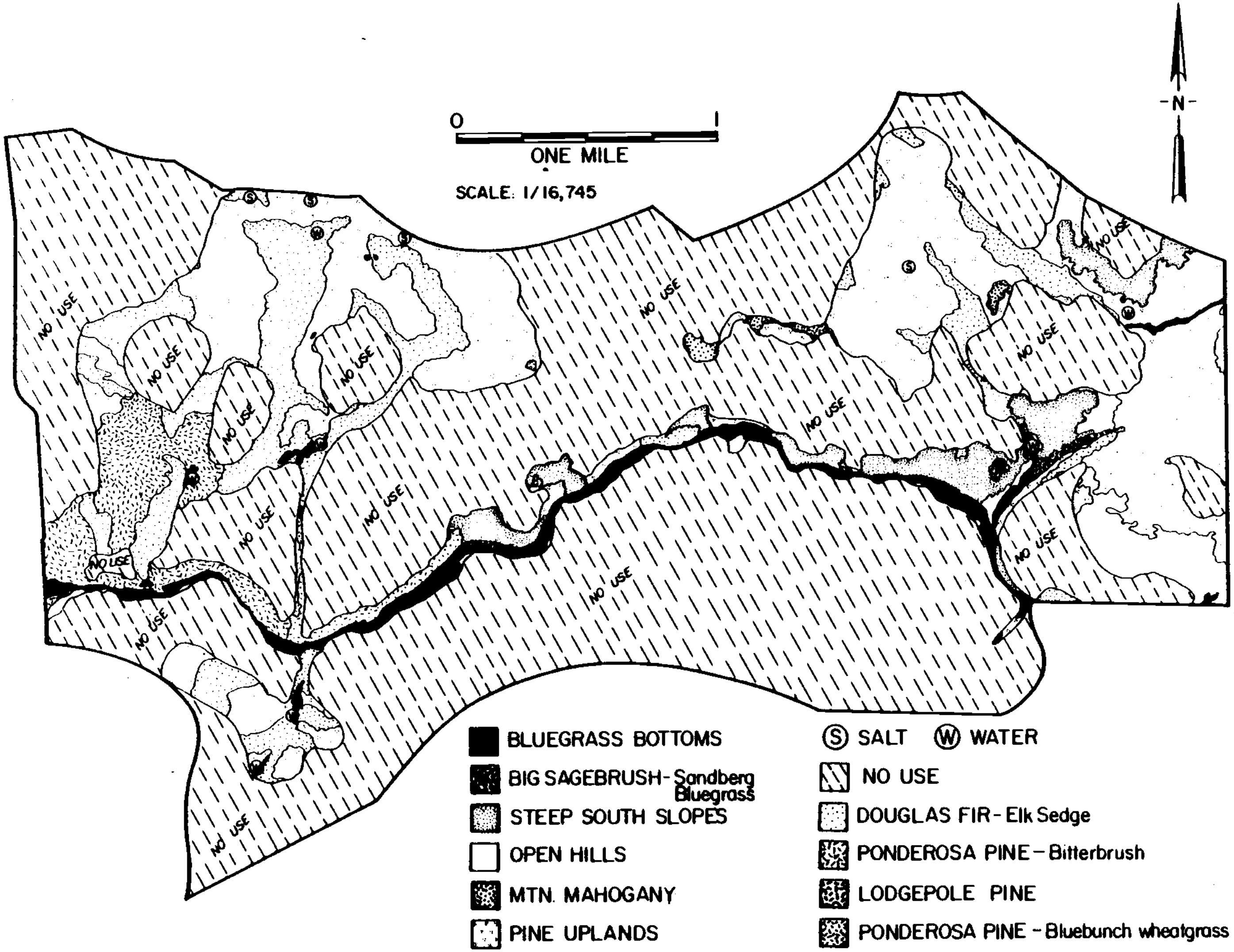

Figure 2. Vegetation types grazed on the Camp Creek unit.

type was grazed less than availability. Negligible amounts of use occurred on the lodgepole pine (Pinus contortus) and mountain mahogany (Cercocarpus ledifolius) types. A high percentage of the pine-bitterbrush type was grazed. Only on the riparian zone and the sagebrush-Sandberg bluegrass types was 100 percent of the land area grazed.

Forage consumption per hectare on the riparian zone was far greater than on any other type. This reflected difference in forage availability, time spent on the area and lack of physical constraints to grazing. The proportion of forage consumption provided may be an indication of the contribution of each type to livestock grazing. The riparian zone, which contributed 21 percent of the total vegetation on the unit, produced 81 percent of the forage consumed in both 1977 and 1978. The precipitation in 1977 was 49 percent of that in 1978. This caused significantly different forage production on the riparian area, 2268 kg/ha versus 2795 kg/ha for 1977 and 1978, respectively. Difference in precipitation did not produce a significant difference in forage production on the uplands. The sagebrush-Sandberg bluegrass type directly adjacent to the riparian zone received larger amounts of forage use than the upland vegetation types. The yield on the sagebrush-Sandberg bluegrass type was about 500 kg/ha. Presumably, greater forage availability on this type would have greatly changed its contribution to the total forage resource. Vegetation types directly adjacent to the riparian zone tended to have a larger percentage of areas used than upland types. Cook's (1966) findings suggested similar relationships. However, there was no evidence that amount of utilization on the riparian zone affected the amount of utilization on these adjacent vegetation types. This agrees with the findings of Patton (1971) and Phillips (1965).

Consumption of vegetation on upland types tended to be low per hectare. The pine-bitterbrush type, which had 75 percent of its area grazed, received very low use per hectare (Table 2). Cattle dispersed widely over the area but spent little time grazing in this type. This was also true for the open hills and pine-bluebunch wheatgrass types. These types had a small percentage of the total use and were considered to be unimportant in relationship to other types. The pine upland type produced 11 and 13 percent of the forage consumed in 1977 and 1978, respectively, and produced about 240 kg/ha in both years. The proportion of forage consumed indicated that this was the most important upland type for grazing. The Douglas fir-elk sedge type comprised the greatest percentage of the land area, about 38 percent, but produced only three percent of the forage consumed in 1977 and 1978.

The pine upland, which was used more than other upland types, had an open canopy cover and gentle terrain. This type and the pine-bitterbrush type had similar terrain and canopy cover, however,

TABLE 2. Forage Consumption and Percentage Forage Consumption on Each Vegetation Type on the Camp Creek Unit.

Vegetation Types	1977 kg/ha Consumed	1977 Ha Grazed	1977 % Total Forage Consumed	1978 kg/ha Consumed	1978 Ha Grazed	1978 % Total Forage Consumed
Riparian Zone	1937	49.4	81	2198	49.4	81
Pine Uplands	30	2137.9	11	40	437.9	13
Douglas fir-Elk sedge	20	201.2	3	20	201.2	3
Steep South Slopes	50	57.5	2	30	57.7	1
Open Hills	10*	44.1	T	10*	44.1	T
Pine-Bitterbrush	10*	93.9	1	15	93.9	1
Pine-Bluebunch wheatgrass	10*	27.4	T	10*	27.4	T
Sagebrush-Sandberg bluegrass	80	7.7	1	83	7.7	1

* Estimated values based on reconnaissance

cattle used the pine uplands type much more than the pine-bitterbrush. This difference in use was reflected both by amount of vegetation consumed per hectare (Table 2) and by number of animals observed in the type. Similar results were found by Clary et al. (1978). The Douglas fir-elk sedge type received more use near water, but use rapidly decreased with distance away from water. This would seem to be the result of a combination of factors; primarily slope common to the site, degree of overstory canopy, aspect of the area and sparse understory vegetation. Hedrick et al. (1968) and Miller and Krueger (1976) found that a combination of overstory canopy cover and the amount of herbaceous vegetation in the understory were prominent factors in determining use on mixed coniferous forests. Miller and Krueger (1976) found that tree canopy cover accounted for 98 percent of the variation in herbaceous plant yield in the understory. The lodgepole pine type had a north aspect and negligible amounts of use occurred on that type. Gonzalez (1964) and Van Vuren (1979) reported in research done in Utah, that northerly aspects were avoided by cattle. The mountain mahogany and lodgepole pine had extreme slopes, also, that apparently precluded cattle use.

The square root of the distance from salt accounted for 64 percent of the variation in utilization, while 38 percent of the variation in utilization was accounted for by the square root of the distance from water (Table 3). Combining the two parameters in a multiple

TABLE 3. Utilization on Perennial Grasses in Relationship to Distance from Salt and Water.

Rep. 1			Rep. 2			Rep. 3		
% Util	distance from water (m)	distance from salt (m)	% Util	distance from water (m)	distance from salt (m)	% Util	distance from water (m)	distance from salt (m)
35	1490	5	27	665	5	30	725	70
15	1530	50	15	710	50	20	826	125
15	1680	200	15	860	200	20	1180	600
12	1780	400	12	1160	500	15	1360	835
1	2000	935	1	1540	880	1	1540	1070

Multiple Regression Model

$\hat{y} = -0.202\sqrt{x_1} - 0.695\sqrt{x_2} + 34.525$ $\quad R^2 = 0.624 \quad t = 4.64^{**}$

x_1 = distance from water $\quad rx_1 = -0.534$

x_2 = distance from salt $\quad rx_2 = -0.804$

$rx_1x_2 = 0.556$

Linear Regression Models

Distance from Salt

$\hat{y} = 30.26 - 0.84\sqrt{x}$ $\quad R^2 = 0.644 \quad t = 4.88^{**} \quad P < .0001$

Distance from Water

$\hat{y} = 40.44 - 0.75\sqrt{x}$ $\quad R^2 = P < .01 \quad t = 3.23^{**} \quad P < .01$

regression resulted in a relationship accounting for 62 percent of the variation in utilization. The partial correlation coefficients were -0.54 and -0.78 for water and salt, respectively.

The linear model using distance from salt accounted for a reasonable amount of variation in utilization; however, the effect of distance from salt was confounded by the effect of preferred vegetation types. In each of the replications, salt was placed near a road in the pine uplands types. The measure of utilization of vegetation away from the salt block probably reflected the effect of distance from a primary travel route in a preferred vegetation type.

Observations of cattle movements in 1977 and 1978 provided evidence about the effect of vegetation type on utilization. A pine uplands area was grazed with approximately equal intensity in 1977 and 1978, even though salt was in the area only in 1978. Therefore, it would seem that utilization of that type would be more controlled by vegetation type preference than desire for salt. The confounding effect of preferred vegetation type also influenced the relationship between utilization and distance from water (Table 3, Rep. 1). Apparently the cattle were willing to travel a greater initial distance to graze in that vegetation type. The moderate amount of variation accounted for by the multiple regression model indicated that unmeasured factors influence the amount of utilization an area receives. Miller and Krueger (1976) reported distance from salt and water accounted for 72 percent of the variability in vegetation use on a pasture with gentle terrain. Cook (1966) found he could only account for about 52 percent of the variability in livestock use with 21 measured parameters. He concluded patterns of previous use on the area were the best way to predict future use on that unit.

Observations of the cattle indicated that they were using slopes adjacent to the riparian zone on the contour. When the slopes were steep, the cattle grazed relatively close to the stream, but as the slope decreased the cattle grazed farther away.

Measurements of utilization versus vertical rise (Table 4) demonstrated that utilization approached zero at 80 meters or more in vertical rise above the stream level. Regression analysis of utilization in 1977 and 1978 on the primary bunchgrass species revealed that 94 and 82 percent of the variation in bluebunch wheatgrass and basin wildrye use, respectively, were accounted for by vertical distance above the stream. Van Vuren (1979) indicated the same relationship for cattle in Utah mountain range. Calculations of vertical rise from Mueggler (1965) also suggested this relationship. The relationship between vertical rise above water and utilization on gentle slopes is poor. There may be a slope threshold value at which vertical rise above water replaces distance from water as the limiting factor on cattle distribution away from the water source. More extensive measurements would be required to make any predictions of that

TABLE 4. Utilization on Species as Affected by Vertical Distance above Water.

	Species	35[1]	50	75	> 80
1977	bluebunch wheatgrass	55	45	20	<1
	Basin wildrye	25	20	10	<1
1978	bluebunch wheatgrass	55	45	10	<1
	Basin wildrye	50	35	10	<1

Linear Regression Models

bluebunch wheatgrass	$\hat{y} = 94.73 - 1.107x$	$R^2 = .940$	$t = 9.695^{**}$	$P < .05$
Basin wildrye	$\hat{y} = 63.75 - 0.754x$	$R^2 = .818$	$t = 5.19^{**}$	$P < .01$

[1] Meters above water.

threshold value. Slopes in excess of 60 percent were not used by cattle regardless of vegetation type or aspect.

Livestock Distribution

Water was a factor which appeared to have had some control on the distribution of cattle on the Camp Creek unit. Observations of cattle distribution on the unit indicated that water was a primary factor in determining whether cattle used an area. During a dry year, 1977, when some sources of water were dry, livestock use in many areas was lower than in 1978 when water was more available. Those areas that were not utilized frequently in 1977 tended to be farther away from water than those areas receiving more frequent use. Water appeared to be the central point of distribution with all the animals returning to a watering area at least once per day.

Salt was used regularly by livestock in both years. However, there was a pronounced difference in the pattern of livestock movements to and from salt. In 1977, the dry year, cattle trailed to salt from areas near water, then trailed back to water. Cattle were not observed to bed near the salting areas. In 1978, the vegetation was succulent later in the season, and water was more widely distributed on the unit. Cattle in that year often bedded in the vicinity of the salt block, remaining in the area several hours.

Distance from water did have a strong relationship with utilization; however, it is important to note that the distances from water at which vegetation utilization approached zero, about 1900 meters, were similar within the pine upland type. Apparently, where other influencing factors do not limit cattle distribution, distance from water ultimately controls the limit of vegetation utilization. Hodder and Low (1978) indicated that in Australia, water controlled the distance cattle would travel to utilize forage. In other vegetation types, and in steeper terrain, distances from water to where the utilization approached zero were much shorter.

The study unit had been previously logged, leaving a network of logging roads and skid trails. Cattle used logging roads extensively as primary routes of travel. Roads apparently played a key role in distribution of livestock, enabling them to travel easily through steep and broken country. Some use was made of vegetation near the roads in this terrain, but the distance at which utilization occurred decreased dramatically with increases in slope above or below the road. Cattle using these steep areas returned to the road to bed or rest. The roads had been seeded to orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*) and intermediate wheatgrass (*Agropyron intermedium*) after logging and therefore also provided a substantial amount of forage.

Roads in gentle terrain did not seem to be an important factor in distribution. Cattle trails in this terrain frequently did not follow a road, even when one was near by. Preferred vegetation types, such as pine uplands, were not grazed when isolated by rough terrain with no road access. Williams (1954) and Workman and Hooper (1968) found that cattle distribution was greatly enhanced by roads or trail construction.

A characteristic pattern of cattle movement was demonstrated each year. Livestock were turned on the unit at one single gate. A road directed the cattle onto the riparian zone, where most of the cattle began grazing. After 7-10 days, livestock dispersed over the allotment to other preferred grazing areas. Approximately 35-40 percent of the cattle remained on the riparian zone for the duration of the season. Cattle seemed to congregate again on the riparian zone the last week of the grazing season.

Cattle Behavior

General patterns of herd movements on the unit were a reflection of a behavioral response. Turning the cattle in at a single point, especially where a primary route directed the animals on to a riparian zone, seemed to temporarily inhibit the formation of the grazing groups and prevented early dispersion of cattle onto other vegetation types. Arnold and Dudzinski (1978) described a typical exploring response of animals just moved to a new pasture. This did not occur with cattle in the study herd on this unit. Perhaps familiarity with the unit combined with the management influence precluded that response. Cattle which strayed in from a neighboring unit did display typical exploring activity, moving at random through the unit and from group to group.

Three discrete groups of cattle formed on the unit. These groups were oriented to particular areas of the unit, similar to the "home range" groups described by wildlife biologists (Dasmann 1964). Analysis of individual movements indicated that approximately 44 percent of the herd formed a home range group which primarily used a pine uplands area away from the stream (Figure 1). Distribution of this group was focused on three watering spots. Another home range group, comprising about 22 percent of the herd, localized in an area on the lower eastern portions of the unit. The remaining group primarily used the riparian zone and overlapped its home range boundary with both of the other two groups.

Substrata in each group were apparent. These substrata seemed to be tightly knit groups of individuals moving together within the framework of the entire home range group. The upland and the transition groups had three distinct subgroups, the east home range group had two. There was no real evidence to determine what factors controlled the animal associations in the substrata or in the home range group. These appear to be socially structured hierarchical groups. Elliot (1976) also found discrete groups of cattle on mountainous terrain. Hunter (1964) found home range behavior of sheep in hilly country in Scotland. He indicated that visual and topographic barriers caused a stronger social link between animals, creating home range groups. Behavioral scientists studying flat or gentle terrain did not observe home range group formation (Dudzinski et al. 1961; Hodder and Low 1978; Lynch 1967). Range scientists have not recognized home range groups in work reported, but most observations were of cattle grazing gentle topography (Culley 1938; Herbel and Nelson 1966; Martin and Ward 1973; Moorefield and Hopkins 1951). Substrata of the home range groups seemed to move as a unit within the home range area. Social linking between these individuals was not verified.

Size of the total areas used as a home range seemed to be consistent year to year; however, in 1977 the dry weather seemed to limit the amount of use in the peripheral areas distant from water. Cattle use was more uniform over the total area in 1978. Increased bedding time at the salt block apparently reflected less dependence on water. Moorfield and Hopkins (1951) reported similar observations, finding that when vegetation was succulent cattle spent less time near water.

Characteristic patterns of activities and movements were displayed by the animals. Individuals within subgroups showed considerable uniformity in the timing of activity and movements, although time when an activity occurred often was different between home range groups. This difference seemed to be in relationship to the area the group grazed, upland or meadow. The general pattern showed cattle would move from the bedding area shortly after sunrise and begin an active feeding period. This period varied in length but averaged about three hours. Cattle would generally bed in a shaded area until about midday, trail to water, drink, then bed in the shade near water. Shading up in the daylight hours rarely occurred on the riparian zone, cattle seemed to prefer adjacent slopes for bedding. If water and shade were near the grazing area, cattle would bed there after the morning active grazing period and remain in that area until mid or late afternoon. Lethargic grazing by some individuals, but rarely all the members of the group, frequently occurred in mid-afternoon. During the late afternoon until sunset there was another active grazing period. Cattle stayed bedded from dark until sunrise. Areas chosen for night bedding by groups using the riparian zone were on adjacent slopes. Later in the season cattle grazed the steep south slopes in the evenings and bedded on those areas. Culley (1938), Gonzalez (1964), Hughes and Reid (1951), Sheppard et al. (1957), Sneva (1970) and Tribe (1950) reported similar patterns of activity.

Cattle behavior interacting with other ambient factors produced a pattern of responses that determine activities, distribution, forage use and herd structure. Discriminant analysis was used to determine the importance of elapsed time after sunrise and environmental parameters in predicting the probability of a specific activity occurring. Time after sunrise was the most important parameter and change in relative humidity the second most important in predicting the probability of a given activity occurring. Although those two parameters were significant, only 59 percent of the observations could be properly classified as to site and activity. Time after sunrise dictated the probability of the type of major activity occurring in that time frame. However, change in relative humidity altered the probability of predicting a particular activity during the beginning or end of the time frame. Dudzinski and Arnold (1979) and Hughes and Reid (1951) also found that time after sunrise was an important factor in determining the time frame of activities. It seems logical that activities of cattle on a diurnal schedule would show a high relationship to time after sunrise. Other environmental parameters tend to change the timing or duration of the activities within a given time frame (Dudzinski and Arnold 1979).

Regression analysis indicated relative humidity parameters were principally responsible for the time when morning activities were initiated (Table 5). In only one case was thermal-humidity index (derived from Ehrenriech and Bjugstad 1966) an important parameter. One would assume the physiological response to humidity parameters to be a response to humidity-temperature interaction, but in most cases temperature was not a significant factor accounting for variation

TABLE 5. Results of Regression Analyses Determining Climatic Parameter Influence on Cattle Activities.

Activity	Dependent Variable	Independent Variables In Order of Importance	Variability Accounted for	Level of Sig.
<u>Bottoms</u>				
morning grazing	time after sunrise	relative humidity	0.78	0.037
		relative humidity maximum	0.98	0.002
	Regression model	$\hat{y} = -0.26x_1 + 0.15x_2 - 4.23$		
morning bedding	time after sunrise	temperature change	0.78	0.039
		relative humidity change	0.86	0.064
		relative humidity	0.92	0.101
	Regression model	$\hat{y} = -0.26x_1 + 0.58x_2 - 0.60x_3 + 11.70$		
afternoon grazing	time after sunrise	barometric pressure	0.97	0.016
	Regression model	$\hat{y} = -1.68x + 1085.6$		
<u>Uplands</u>				
morning grazing	time after sunrise	relative humidity maximum	0.89	0.041
		thermal humidity index	0.95	0.089
	Regression model	$\hat{y} = 0.18x_1 - 0.18x_2 - 0.52$		

TABLE 5. Continued

Activity	Dependent Variable	Independent Variables In Order of Importance	Variability Accounted for	Level of Sig.
Uplands (continued)				
morning bedding	time after sunrise	relative humidity maximum	0.53	0.026
		relative humidity change	0.67	0.038
		relative humidity	0.81	0.030
		temperature change	0.98	0.007
	Regression model	$\hat{y} = 0.69x_1 - 0.92x_2 - 0.56x_3 + 0.15x_4 + 4.88$		

Independent Parameters Considered

Barometric pressure, Temperature °C, Relative humidity, Thermal humidity index — at the time the activity was observed

Temperature minimum
Temperature maximum
Temperature change
Relative humidity maximum
Relative humidity minimum
Relative humidity change
Thermal humidity index maximum

in time when an activity occurred. Levels of significance were consistently higher using time after sunrise as a measure of the time an activity occurred than those using time after morning twilight as the dependent variable. Afternoon grazing was most related to barometric pressure; the total ramifications of this are not understood.

Management Implications

Management plans for grazing on mountainous ranges could best be formulated with detailed information about how cattle use those ranges and why cattle respond in a given manner. Cattle on the Camp Creek unit formed definitive home range groups of animals. These groups occupied the same home range area year to year. This suggested that the groups were semi-independent of each other. If this is so, cattle numbers could be manipulated in one group without substantially altering other groups. This could be especially valuable for the riparian zone which received a large percentage of the cattle use. Cattle which are known to be within the home range group on the riparian zone could be culled from the herd, decreasing the number of cattle on the riparian zone. Knowing which animals to cull in such a situation is contingent on knowing the herd structure and the individuals in each group.

Wildlife scientists have long known that many species will invariably return to their home ranges following disruption of their normal patterns, sometimes even after having been moved great distances. It seems unreasonable to herd cattle, which have developed a home range on the riparian zone, to an area away from there and expect them not to return to their home range. Skovlin (1957) reported that "cattle can be trained to use certain areas and will repeat that use year after year." It appears that livestock operators could take animals which have not grazed a unit before and behaviorally bond those cattle to a new area which had been previously under-utilized, given that water, forage, shade, and salt are available in that area. For this to be an effective management tool, the livestock must be handled so they disperse when turned on the pasture, avoiding initial concentration on the riparian zone.

These manipulations, however, must be consistent with other factors which control or limit grazing distribution. Water is an integral factor in determining where cattle will graze. Given that water is available, then other factors determine the amount of utilization and actual types which will be grazed. Trail building and other practices may be feasible. Some areas, because of extreme slopes or aspect, will continue to be avoided by cattle unless innovative vegetation or other management manipulations can be implemented.

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CHAPTER III

Discussion of the Occurrence of Acute Dietary Bovine Pulmonary Emphysema (ADBPE)

DISCUSSION OF THE OCCURRENCE OF ACUTE DIETARY BOVINE PULMONARY EMPHYSEMA (ADBPE)

Basic Premise

Acute dietary bovine pulmonary emphysema is a livestock disease directly linked to diet. The development of the disease shows a characteristic pattern of cattle moving from an area where forage availability is inadequate to an area where forage is very lush. Prior to the inception of this project, several hypotheses were offered as to the cause of ADBPE. The current hypothesis is that some cattle in the herd are under a nutritional stress before the pasture change due to inadequate forage availability. This nutritional stress caused rumen micro-flora and fauna, and animal physiological changes inciting the occurrence of ADBPE when cattle are moved onto lush forage. Naturally occurring indole compounds are probably also necessary components in the lush forage on the new unit. The exact mechanisms have not been identified. Some cattle may exhibit clinical signs of emphysema 7-14 days after the pasture change. Cases of ADBPE are generally confined to a few animals, but on occasion 1/5 - 1/3 of a herd may be stricken.

Factors Studied

Identification of factors contributing to ADBPE on rangeland required quantification of animal forage intake, animal behavior, herd social structure, animal response to environmental parameters and detailed analysis of animal movements. Additionally, individual animals were identified so the grazing history of each animal could be recognized in relationship to any subsequent occurrence of the disease.

Study Area Selection

The study unit selected was a Forest Service allotment on which ADBPE had occurred. The disease had been noted in cattle using this allotment when the order of cattle movement within the deferred rotation system was from Camp Creek unit to Shirttail unit. Each time this pattern occurred ADBPE caused the death of 2 - 4 animals.

The Camp Creek unit contained a small riparian zone bordered by steep slopes which reduced animal movement. These restrictions, together with extensive subirrigated meadows on the Shirttail unit, provide a combination of factors which may increase the incidence of ADBPE.

Incidence of ADBPE

Grazing utilization on the Camp Creek bottoms was moderately heavy in both 1977 and 1978. Forage availability and forage use on the riparian zone decreased substantially late in the grazing season. In 1978, no forage use could be detected during the last two weeks of the grazing season. The reduction of forage availability would inevitably lead to lower nutrient availability and probably lower nutrient intake. This may precondition some of the cows using that area, making them more susceptible to ADBPE.

Cattle movements are substantially affected by individual and combinations of climatic parameters. Both cattle movements and climatic factors might alter diets sufficiently to change the incidence of ADBPE.

Discrete home range groups of cattle which formed on the unit gave strong evidence that groups of cattle are behaviorally bonded to an area. Those bonded to the riparian zone seemed especially hesitant to leave that area, even when forage and nutrient availability fell below adequate levels.

The Shirttail unit pasture into which the cattle were moved in 1977 was probably not sufficiently lush to produce emphysema even in cows which had been preconditioned. However, the pasture was much greener in 1978. One sub-acute case of emphysema was observed.

There may have been several reasons why the expected number of cases of emphysema did not develop during this study. (1) Different breeds of cattle may have varying susceptibility to ADBPE. Hereford cows appear more susceptible than others. The herd being studied in 1978 included approximately 5 - 8 Hereford cows, one of which contracted ADBPE. (2) Many cows in the herd were dry throughout the summer of 1978, allowing them greater mobility and no stress of lactation. (3) In 1977, the vegetation on the Shirttail meadows was relatively dry and mature. The conditions necessary for the development of ADBPE were absent or marginal in both years.

Management Implications

Mountainous topography, limited water availability, herd social structure and behavior, climatic parameters and management influences, alone or in combination, do limit cattle distribution. This can create cattle concentrations until the forage resource is inadequate to maintain that number of livestock. The nutritional stress developed predisposes the cattle to ADBPE, which is more prevalent when cattle under this stress are subsequently moved to lush pastures. This study was not designed to test management alternatives for prevention of ADBPE. However, the observations made and occurrence of emphysema in one instance support the basic premise. Therefore, management techniques which insure optimum forage availability and limit livestock concentrations should reduce the incidence of ADBPE.

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APPENDICES

APPENDIX A

Vegetation Type Yield Values

Table A1. 1977 Creek Bottoms kg/ha

Week	Area	Total perennial grasses	Forbs	Total forbs and grasses
wk 1	Lower Camp Creek	521.0	82.4	603.4
	Camp Creek Meadows	566.2	45.4	611.6
	Upper Camp Creek	546.4	36.6	583.0
	Cage Grazed	1040.2	48.4	1088.6
	$\bar{x}$	668.4	53.2	721.6
	Cage Ungrazed	2110.2	150.6	2111.7
wk 2	Lower Camp Creek	532.6	68.0	600.6
	Camp Creek Meadows	740.4	245.8	986.2
	Upper Camp Creek	733.2	51.8	785.0
	Cage Grazed	411.0	32.6	443.6
	$\bar{x}$	604.3	99.6	703.9
	Cage Ungrazed	547.2	57.0	604.2
wk 3	Lower Camp Creek	426.6	155.8	582.4
	Camp Creek Meadows	533.8	145.6	679.4
	Upper Camp Creek	522.6	69.8	592.4
	Cage Ungrazed	468.2	30.8	499.0
	$\bar{x}$	487.8	100.5	588.3
wk 4	Lower Camp Creek	390.8	219.8	610.6
	Camp Creek Meadows	459.2	114.4	573.6
	Upper Camp Creek	265.6	172.2	437.8
	Cage Grazed	335.8	38.4	374.2
	$\bar{x}$	362.8	136.2	499.0

APPENDIX A. Continued

Table A2. 1977 - South Exposure Hills
Mountain Big Sagebrush - Bluebunch wheatgrass . -5 m^2 plots

	Bluebunch wheatgrass	Squirreltail	Other Grass	Cheatgrass Brome	Forbs	Shrubs	Total
Wk 1							
R1	7.65	1.04	2.16	0.73	1.32	3.98	16.88
R2	5.61	2.34	5.37	0.27	0.43	2.18	16.20
R3	13.39	1.15	2.23	0.10	0.29	14.42	31.58
$\bar{x}$	8.85	1.15	3.25	0.37	0.68	6.86	21.52
kg/ha	177.0	30.2	65.0	7.4	13.6	137.2	430.4
Wk 3							
R1	9.58	1.41	0.60	2.01	1.28	0.06	14.94
R2	6.84	0.37	13.04	4.46	2.30	5.62	32.63
R3	3.99	0.55	3.63	4.33	4.06	8.97	25.52
$\bar{x}$	6.80	0.78	5.76	3.60	2.55	4.88	24.36
kg/ha	136.1	15.5	115.1	72.0	50.9	97.7	487.3

APPENDIX A. Continued

Table A3. 1977 .5 m^2 plots
Ponderosa Pine - Elk Sedge - Pingrass

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total
Wk 1						
R1	3.58	3.55	0.26	2.20	0.80	10.39
R2	1.04	2.27	0.04	5.98	2.24	11.57
R3	8.10	1.94	0.70	1.93	0.31	12.98
$\bar{x}$	4.24	2.59	0.33	3.37	1.12	11.65
kg/ha	84.8	51.8	6.6	67.4	22.4	233.0
Wk 3 (Final)						
R1	2.15	2.42	0.76	4.06	0.48	9.88
R2	5.83	2.08	0.90	4.32	0.77	13.90
R3	4.56	3.13	0.32	1.57	0.67	10.25
$\bar{x}$	4.18	2.54	0.66	3.32	0.64	11.34
kg/ha	83.6	50.8	13.2	66.4	12.8	226.8

APPENDIX A. Continued

Table A4. 1977 .5 m^2 plots
Ponderosa Pine - Douglas-fir - Elk Sedge

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total	# Plots
Wk 1							
R1	6.50	1.33	2.29	0.17	1.42	11.71	10
R2	10.54	1.10	0.29	0.94	4.07	16.94	10
R3	8.55	1.43	1.21	2.03	0.68	13.90	10
$\bar{x}$	8.53	1.29	1.26	1.05	2.06	14.18	
kg/ha	170.6	25.8	25.2	21.0	41.2	283.6	
Wk 4 Final							
R1	3.72	2.14	1.16	0.92	0.20	8.14	12
R2	5.27	0.00	4.06	1.97	0.46	11.76	10
R3	8.04	0.37	0.44	0.19	0.24	9.28	10
$\bar{x}$	5.68	0.84	1.89	1.03	0.30	9.73	1
kg/ha	113.6	16.8	27.8	20.6	6.0	194.6	

APPENDIX A. Continued

Table A5. 1977 - .5 m^2 plots
Mountain Big Sagebrush - Basin Wildrye - Sandberg's bluegrass

	Basin Wildrye	Kentucky Bluegrass	Sedges	Other Grasses	Forbs	Shrubs	Total	# Plots
Wk 1								
R1	0.33	10.04	2.21	1.75	2.26	3.48	20.06	11
R2	0.20	10.68	3.77	5.29	2.75	5.75	28.37	7
$\bar{x}$	0.27	10.36	2.99	3.52	2.51	4.62	24.22	
kg/ha	5.30	207.20	59.80	70.40	50.10	92.30	484.40	
Wk 2								
R1	2.21	4.15	7.64	4.60	3.33	1.95	23.87	12
kg/ha	44.17	82.95	152.80	91.95	66.67	38.90	477.42	
Wk 4 Final								
R1	10.60	2.45	6.60	2.74	0.79	12.34	35.04	11
kg/ha	212.04	49.00	131.96	54.87	15.87	246.84	700.80	

APPENDIX A. Continued

Table A6. 1978 Creek Bottoms kg/ha

Week	Area	Total perennial grasses	Forbs	Total forbs and grasses
wk 1	Lower Camp Creek	874.8	350.4	1225.2
	Lower Camp Creek Cage	960.4	270.0	1230.4
	Camp Creek Meadows	896.4	203.6	1100.0
	Camp Creek Meadows Cage	672.8	146.0	818.8
	Upper Camp Creek	719.2	250.8	970.0
	Upper Camp Creek Cage	621.6	253.6	875.2
	$\bar{x}$	790.9	245.7	1036.6
wk 2	Lower Camp Creek	648.8	182.0	830.8
	Lower Camp Creek Cage	602.4	161.6	764.0
	Camp Creek Meadows	632.4	390.0	1022.4
	Camp Creek Meadows Cage	485.2	276.0	761.2
	Upper Camp Creek	493.2	266.8	760.0
	Upper Camp Creek Cage	482.0	114.8	596.8
	$\bar{x}$	557.3	231.9	789.2
	Cage Ungrazed 1	759.2	411.6	1170.8
	2	618.0	328.0	946.0
	3	550.8	237.6	788.4
	$\bar{x}$	642.7	325.7	968.4
wk 3	Lower Camp Creek	595.2	210.4	805.6
	Lower Camp Creek Cage	509.2	125.6	634.8
	Camp Creek Meadows	505.6	200.0	705.6
	Camp Creek Meadows Cage	422.4	172.0	594.4
	Upper Camp Creek	477.6	351.6	829.2
	Upper Camp Creek Cage	458.0	196.0	654.0

APPENDIX A. Continued

Table A6. Continued

Week	Area	Total perennial grasses	Forbs Forbs	Total forbs and grasses
	$\bar{x}$	494.7	209.3	703.9
	Cage Ungrazed 1	590.0	175.6	765.6
	2	476.8	223.6	700.4
	3	534.0	183.6	717.6
	$\bar{x}$	533.6	194.3	727.9
wk 4	Lower Camp Creek	558.4	207.6	766.0
	Lower Camp Creek Cage	662.8	191.6	854.4
	Camp Creek Meadows	543.6	315.2	858.8
	Camp Creek Meadows Cage	521.6	190.0	711.6
	Upper Camp Creek	481.6	185.6	667.2
	Upper Camp Creek Cage	447.6	210.4	658.0
	$\bar{x}$	535.9	216.7	752.7
	Cage Ungrazed 1	719.2	234.4	953.6
	2	507.6	278.4	786.0
	3	407.2	201.2	608.4
	$\bar{x}$	544.7	238.0	782.7

APPENDIX A. Continued

Table A7. 1978 - .5 m^2 plots
Mountain Big Sagebrush - Basin Wildrye - Sandberg's Bluegrass

	Basin Wildrye	Kentucky Bluegrass	Sedges	Other Grasses	Forbs	Shrubs	Total	# Plots
Wk 1								
R1	0	4.40	3.14	4.64	3.80	5.11	20.11	12
R2	4.60	6.45	2.72	5.22	5.10	9.53	33.62	10
$\bar{x}$	2.30	5.43	2.93	4.94	3.95	7.32	26.87	
kg/ha	46.00	108.50	58.60	98.70	79.00	146.40	537.30	
Wk 2								
R1	.07	2.89	3.29	1.68	0.84	4.76	13.49	11
R2	.20	5.40	3.03	2.83	1.85	4.41	17.59	10
R3	1.46	3.96	2.28	1.48	2.24	3.46	14.89	10
$\bar{x}$	0.58	4.08	2.87	2.00	1.64	4.21	15.32	
kg/ha	11.53	81.67	57.33	39.93	32.87	84.20	306.47	

APPENDIX A. Continued

Table A7. Continued

	Basin Wildrye	Kentucky Bluegrass	Sedges	Other Grasses	Forbs	Shrubs	Total	# Plots
Wk 3								
R1	0	4.88	2.94	0.98	1.50	3.01	14.41	10
R2	0.18	2.98	4.82	3.05	2.80	5.98	19.97	11
R3	0	3.97	3.00	2.38	3.00	0.52	13.06	10
$\bar{x}$	0.06	3.94	3.59	2.14	2.43	3.17	15.81	
kg/ha	1.20	78.87	71.73	42.73	48.67	63.40	316.27	
Wk 4 Final								
R1	0	2.81	3.90	2.00	3.24	8.30	20.56	11
R2	0.35	4.09	8.12	2.76	3.25	2.17	20.39	10
R3	1.52	2.61	4.49	1.67	4.37	3.71	16.38	10
$\bar{x}$	0.62	3.17	5.50	2.14	3.62	4.73	19.11	
kg/ha	12.47	63.40	110.07	42.87	72.40	94.53	382.20	

APPENDIX A. Continued

Table A8. 1978 - Steep South Slopes
Mountain Big Sagebrush - Bluebunch Wheatgrass

	Bluebunch Wheatgrass	Squirreltail	Grass	Cheatgrass Brome	Forbs	Shrubs	Total	# Plots
Wk 1								
R1	12.84	1.16	3.91	1.77	4.61	17.99	41.48	12
R2	3.74	1.11	2.95	4.03	7.37	11.74	30.98	10
R3	0.53	1.53	1.92	4.45	4.12	62.31	74.86	10
$\bar{x}$	5.70	1.27	2.93	3.42	5.37	30.68	49.11	
kg/ha	114.07	25.33	58.53	68.33	107.33	613.60	982.13	
Wk 2								
R1	5.77	0.62	17.77	4.08	6.07	0.79	35.43	11
R2	13.79	0	17.70	0.35	4.09	1.52	37.46	10
R3	0.95	0.70	1.90	20.33	8.81	1.85	34.56	11
$\bar{x}$	6.84	0.44	12.46	8.25	6.32	1.39	35.82	
kg/ha	136.73	8.80	249.13	165.07	126.47	27.73	716.33	

APPENDIX A. Continued

Table A8. Continued

	Bluebunch Wheatgrass	Squirreltail	Grass	Cheatgrass Brome	Forbs	Shrubs	Total	# Plots
Wk 3								
R1	8.74	1.77	0.97	2.29	1.74	1.08	16.66	11
R2	5.98	0.64	0.69	18.34	1.51	15.64	42.88	10
R3	0.58	1.42	0.51	7.55	1.31	4.51	15.87	10
$\bar{x}$	5.10	1.28	0.72	9.39	1.52	7.08	25.14	
kg/ha	102.00	25.53	14.47	187.87	30.40	141.53	502.73	
Wk 4 Final								
R1	16.88	0.53	5.38	0.37	8.25	3.08	34.45	10
R2	0.41	1.63	5.43	9.65	4.14	7.13	26.50	10
R3	3.78	1.61	2.36	5.29	3.21	3.01	19.12	10
$\bar{x}$	7.02	1.26	4.39	5.10	5.21	4.41	26.69	
kg/ha	140.47	25.13	87.80	102.07	104.13	88.13	533.80	

APPENDIX A. Continued

Table A9. 1978 - 0.5 m^2 plot
Ponderosa Pine - Douglas Fir - Elk Sedge

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total	# Plots	# Plots Disturbed by Logging
Wk 1								
R1	2.89	0.67	4.35	2.75	0.13	10.78	15	8
R2	5.37	0.40	0.59	2.39	2.07	10.57	16	4
$\bar{x}$	4.13	0.54	2.47	2.57	2.20	10.68		
kg/ha	82.60	10.70	49.40	51.40	44.00	213.50		12/13 = 39%
Wk 4 Final								
R1	3.30	0.83	0.05	1.74	0.89	6.80	16	8
R2	3.62	0.66	0.55	1.02	0.21	6.15	15	7
$\bar{x}$	3.46	0.75	0.30	1.38	0.55	6.48		
kg/ha	69.20	14.90	6.00	27.60	11.00	129.50		15/31 = 48%

APPENDIX A. Continued

Table A10. 1978 - 0.5m^2 plot
Ponderosa Pine - Bitterbrush Type

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total	# Plots	# Plots Disturbed by Logging
Wk 1								
R1	2.67	0.49	1.13	1.44	0.22	5.65	10	4
R2	5.76	1.00	0.47	1.06	1.01	9.29	10	4
R3	2.26	1.13	0.31	1.07	0.40	5.00	10	5
$\bar{x}$	3.56	0.87	0.64	1.19	0.54	6.65		
kg/ha	71.27	17.47	12.73	23.80	10.87	132.93		13/30 = 43%
Wk 4								
R1	2.68	0.12	0.81	1.99	0.66	5.99	15	7
R2	4.17	0.46	0.38	0.95	1.39	7.22		
$\bar{x}$	3.43	0.29	0.60	1.47	1.03	6.61		
kg/ha	68.50	5.80	11.90	29.40	20.50	132.10		13/30 = 43%

APPENDIX A. Continued

Table A11. 1978 - Pine Uplands 0.5 m^2 plot
Ponderosa Pine - Elk Sedge - Pinegrass

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total	# Plots	# Plots Disturbed by Logging
Wk 1								
R1	6.68	1.41	0.03	5.55	0.52	14.19	12	4
R2	5.51	2.53	0.11	7.94	2.42	18.51	10	2
R3	3.81	1.15	1.88	5.86	0.09	12.79	10	5
$\bar{x}$	5.33	1.70	0.67	6.45	1.01	15.16		11/32 = 34%
kg/ha	106.67	33.93	13.47	129.00	20.20	303.27		
Wk 2								
R1	2.68	1.82	0.31	4.50	1.16	10.64	10	6
R2	3.98	2.50	0.09	6.02	0.98	13.58	10	2
R3	2.27	0.27	0.58	4.75	0.04	8.00	10	9
$\bar{x}$	2.98	1.53	0.33	5.09	0.73	10.74		17/30 = 57%
kg/ha	59.53	30.60	6.53	101.80	14.53	214.80		

APPENDIX A. Continued

Table A11. Continued

	Elk Sedge	Pinegrass	Other Grass	Forbs	Shrubs	Total	# Plots	# Plots Disturbed by Logging
Wk 4 Final								
R1	2.80	1.59	0.06	3.95	1.33	9.71	10	7
R2	5.62	1.36	0.07	3.05	1.01	11.10	10	3
R3	3.51	0.56	1.57	2.18	0.14	7.96	10	7
$\bar{x}$	3.98	1.17	0.57	3.06	0.83	9.59		17/30 = 57%
kg/ha	79.53	23.40	11.33	61.20	16.53	191.80		

APPENDIX B

Analysis of Variance Tables for Vegetation Production

Table B1. ANOVA

Source	SS	DF	MS	F cal.
1977 Total Perennial Grasses			wk 1 grazed vs. wk 4	
Total	508,269.3	15		
Trt (wk)	217,623.8	3	72,541.3	2.995*
Error	290,645.4	12	24,220.5	
1977 Grasses and Forbs			wk 1 grazed vs. wk 4	
Total	529,243.5	15		
Trt (wk)	130,910.2	3	43,636.7	1.31 NS
Error	388,333.2	12	33,194.4	
1978 Total Perennial Grasses			wk 1 grazed vs. wk 4	
Total	490,616.0	23		
Trt (wk)	320,026.9	3	106,675.6	12.51**
Error	170,589.1	20	8,529.5	
1978 Forbs			wk 1 grazed vs. wk 4	
Total	118,375.3	23		
Trt (wk)	4,728.5	3	1,576.2	0.28 NS
Error	113,646.8	20	5,682.34	
1978 Total Yield - Creek Bottom			wk 1 grazed vs. wk 4	
Total	730,726.2	23		
Trt (wk)	395,208.0	3	131,736.0	4.96**
Error	335,518.1	20	26,561.9	
1977 Forbs and Grasses			ungrazed vs. wk 4	
Total	16,933,118.5	24		
Trt (wk)	15,626,968.7	4	3,906,742.2	59.8**
Error	1,306,149.8	20	65,307.5	

APPENDIX B. Continued

Table B1. Continued

Source	SS	DF	MS	F cal.
1977 Perennial Grass			ungrazed vs. wk 4	
Total	18,765,881.4	24		
Trt (wk)	14,708,233.5	4	3,677,058.4	18.12**
Error	4,057,647.9	20	202,882.4	
1978 Perennial Grasses			ungrazed vs. wk 4	
Total	11,316,509.7	29		
Trt (wk)	9,852,569.3	4	2,463,142.3	42.06**
Error	1,463,940.4	25	58,557.6	
1978 Total Vegetation			ungrazed vs. wk 4	
Total	17,254,796.3	29		
Trt (wk)	16,021,772.0	4	4,005,443.0	81.2**
Error	1,233,024.3	25	49,321.0	
Total Ungrazed Vegetation Production			1977 vs. 1978	
Total	2,611,437.6	12		
Trt (yr)	766,115.0	1	766,115.0	5.47*
Error	1,845,322.6	11	167,756.6	
Total Ungrazed Perennial Grasses			1977 vs. 1978	
Total	2,063,268.6	12		
Trt (wk)	2,915.0	1	2,915.0	0.02 NS
Error	2,060,353.6	11	187,304.9	
Total Forage Remaining in wk. 4			1977 vs. 1978	
Total	2,432,905.4	9		
Trt (yr)	2,355,820.7	1	2,355,820.7	244.5**
Error	2,060,353.6	11	187,304.9	

APPENDIX B. Continued

Table B1. Continued

Source	SS	DF	MS	F cal.
Total Perennial Grasses Remaining in wk. 4				1977 vs. 1978
Total	119,771.6	9		
Trt (yr)	71,898.8	1	71,898.8	12.01**
Error	47,872.8	8	5,984.1	

* designates sig. $P \leq .05$

** designates sig. $P \leq .01$

NS indicates non-significant

APPENDIX B. Continued

Table B2. Means and Duncan's New Multiple Range Test

	1977 Total Vegetation	Perennial Grass	1978 Total Vegetation	Perennial Grass
ungrazed	2286.4 a [1/]	2117.0 a	2794.4 a	2149.4 a
wk 1	721.6 b	668.4 b	1036.6 b	790.9 b
wk 2	704.3 b	604.3 b	789.2 c	557.3 c
wk 3	588.3 b	487.8 b	703.9 c	494.7 c
wk 4	491.6 b	362.8 c	752.7 c	535.9 c

[1/] Values followed by different letters are significantly different within columns at $P \leq .05$ level.

APPENDIX B. Continued

Table B3. ANOVA
Production 1977 vs. 1978

Source	SS	DF	MS	F cal.
Sagebrush - Sandberg bluegrass				
Total	132.8	3		
Trt (yr)	7.02	1	7.02	0.11 NS
Error	25.8	2	62.9	
Pine Uplands				
Total	39.70	5		
Trt (yr)	18.55	1	18.55	3.51 NS
Error	21.15	4	5.29	
Douglas fir - Elk sedge				
Total	32.37	5		
Trt (yr)	18.45	1	18.45	5.34 NS
Error	13.82	4	3.46	
Steep south slopes				
Total	91.51	5		
Trt (yr)	20.91	1	20.91	1.18 NS
Error	70.6	4	17.66	

NS indicates non-significant

APPENDIX B. Continued

Table B4. ANOVA
Shrub Weight based on adjusted means 1977 vs. 1978

Source	SS	DF	MS	F cal.
Salix - Willow				
Total	1,094,186.4	7		
Trt (yr)	419,421.0	1	419,421.0	3.73 NS
Error	674,765.0	6	112,461.0	
Rosa - Rose				
Total	706.5	4		
Trt (yr)	360.3	1	360.3	3.12 NS
Error	346.2	3	115.4	
Alnus - Alder				
Total	92,251.6	8		
Trt (yr)	837.6	1	837.6	0.07 NS
Error	91,419.7	7	11,426.7	
Ribes - Currant				
Total	1,358,243.0	8		
Trt (yr)	73,256.3	1	73,256.3	0.4 NS
Error	1,284,986.7	7	183,569.5	

NS indicates non-significant

APPENDIX C

Plant Species List

Scientific Name	Common Name
FORBS	
Achillea millefolium	western yarrow
Acontitum columbianum columbianum	columbia monkshood
Allium tolmiei	Tomie onion
Antennaria rosea	rose pussytoes
Aquilegia formosa	sitka columbine
Arabis sparifolia	sicklepod rockcress
Arnica cordifolia	heartleaf arnica
Arnica latifolia gracilis	broadleaf arnica
Arnica sororia	twin arnica
Artemisia ludoviciana ludoviciana	cudweed sagewort
Aster campestris	meadow aster
Astragalus lentigenosus	specklepod milkvetch
Balsamorrhiza deltoidea	Puget balsamroot
Balsamorrhiza sagittata	arrowleaf balsamroot
Barbarea orthoceras	wintercress
Brodiaea douglasii	Douglas' brodiaea
Calochortus macrocarpus	sagebrush mariposa lily
Camasia quamash brevifolia	common camas
Castilleja applegatei applegatei	wavyleaf paintbrush
Castilleja cusickii	Cusick paintbrush
Castilleja linariaefolia	narrow leafed paintbrush
Chaenactis douglasii	false yarrow
Cirsium arvense	Canada thistle
Cirsium scariosum	elk thistle

APPENDIX C. Continued

Scientific Name	Common Name
Cirsium vulgare	bull thistle
Claytonia lancelata	lanceleaf spring beauty
Clematis hirsutissima	sugarbowl clematis
Collinsia parviflora	small flowered blue-eyed Mary
Collomia linearis	narrowleaf collomia
Corydalis aurea	golden smoke
Crepis accuminata	tapertip hawksbeard
Crepis atrabarba	slender hawksbeard
Cryptantha ambiqua	obscure cryptantha
Delphinium depauperatum	dwarf larkspur
Delphinium nuttallianum	upland larkspur
Delphinium trollifolium	columbia larkspur
Erigeron divergens	spreading fleabane
Erigeron pumilus	shaggy fleabane
Erigeron speciosus	showy fleabane
Erigeron ursinus	Bear River fleabane
Eriogonum elatum	tall buckwheat
Eriogonum strictum	strict buckwheat
Eriogonum umbellatum	sulphur buckwheat
Eriophyllum lanatum achilliodes	woolly sunflower
Eriophyllum lanatum integrifolium	woolly sunflower
Fragaria virginiana platypetala	broad petaled strawberry
Frasera albicaulis cusickii	white stemmed frasera
Fritillaria atropurpurea	checker lily
Fritillaria pudica	yellow bell
Galium boreale	northern bedstraw
Galium trifidum	small bedstraw

APPENDIX C. Continued

Scientific Name	Common Name
Geum triflorum	prairie smoke
Geranium richardsonii	Richardson geranium
Gilia aggregata	scarlet gilia
Habenaria dilata albiflora	bog orchid
Hackelia deflexa	nodding stickseed
Happlopappas carthamoides	large flowered goldenweed
Hedysarum sulphurescens	yellow sweetvetch
Helianthella uniflora douglasii	little sunflower
Hesperochiron pumilis	dwarf hesperochiron
Horkelia fusca capitata	
Hydrophyllum capitatum	ballhead waterleaf
Ligusticum canbyi	Canby licoriceroot
Linaria dalmatica	dalmation toadflax
Lithophragma bulbifera	woodland star
Lithospermum ruderale	western gromwell
Lomatium macrocarpum	big seed bisquitroot
Lomatium triternatum	nineleaf bisquitroot
Lupinus caudatus	tailcup lupine
Lupinus lepidus	prairie lupine
Lupinus leucophyllus leucophyllus	velvet lupine
Melilotus officinalis	yellow sweetclover
Mentzelia albicaulis	white stemmed blazingstar
Mertensia campanulata	Idaho bluebells
Mertensia longifolia	small bluebells
Mimulus nanus	dwarf purple monkeyflower
Mitella stauropetala	side flowered miterwort
Montia perfoliata	miners lettuce

APPENDIX C. Continued

Scientific Name	Common Name
Oenanthe sarmentosa	water parsley
Oenothera subcaulis	longleaf evening primrose
Orthocarpus luteus	yellow owlclover
Penstemon deustus deustus	hotrock penstemon/white penstemon
Penstemon globosus	globe penstemon
Penstemon humilis	low penstemon
Penstemon speciosus	royal penstemon
Phacelia hastata hastata	whiteleaf phacelia
Phlox aculeata	prickly leafed phlox
Phlox hoodii	Hood's phlox
Phlox longifolia	longleaf phlox
Phoenicaulis cheiranthoides	daggerpod
Polemonium occidentale	western penstemon
Potentilla arguta	glandular cinquefoil
Potentilla biennis	biennial cinquefoil
Potentilla diversifolia diversifolia	varied leaf cinquefoil
Potentilla gracilis flabelliformis	northwest cinquefoil
Ranunculus cymbalaria	shore buttercup
Ranunculus glaberrimus	sagebrush buttercup
Ranunculus occidentalis occidentalis	western buttercup
Rhinanthus crista-galli	rattlebox
Scutellaria antirrhinoides	skullcap
Senecio macounii	Puget butterweed
Sidalcea oregana maxima	Oregon checkermallow
Sidalcea oregana oregana	Oregon checkermallow
Silene menzesii	Menzie silene

APPENDIX C. Continued

Scientific Name	Common Name
Silene oregana	Oregon silene
Sisyrhinchium angustifolium	blue-eyed grass
Sium suave	waterparsnip
Smilacina stellata	false solomon's seal
Thalictrum fendleri	Fendler meadowrue
Thalictrum sparsiflorum	few flowered meadowrue
Tragopogon dubius	salsify
Trifolium spp.	clover
Urtica dioicea gracilis	stinging nettle
Verbascum thapsus	flannel leaf mullein
Viola palustris	marsh violet
Viola purpurea	goosefoot violet
Xanthocephalum sarothrae	broom snakeweed
Zigadenus venosus venosus	meadow death camas
GRASSES AND GRASSLIKE PLANTS	
Agropyron cristatum	crested wheatgrass
Agropyron intermedium	intermediate wheatgrass
Agropyron pringli	Pringle wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Agropyron subsecundum	bearded wheatgrass
Agropyron trachycaulum	slender wheatgrass
Agrostis alba	red top
Alopecuris aequalis	shortawn foxtail
Bromus carinatus	California brome
Bromus marginatus	mountain brome
Bromus tectorum	cheatgrass brome

APPENDIX C. Continued

Scientific Name	Common Name
Calamogrostis rubescens	pinegrass
Carex filifolia	threadleaf sedge
Carex geyeri	elk sedge
Carex nebraskaensis	Nebraska sedge
Catabrosia aquatica	brookgrass
Dactylis glomerata	orchardgrass
Danthonia californica	California oatgrass
Danthonia intermedia	timber oatgrass
Danthonia spicata	poverty oatgrass
Deschampsia elongatum	slender hairgrass
Elymus cinerieus	basin wildrye
Elymus glaucus	blue wildrye
Festuca idahoensis	Idaho fescue
Festuca occidentalis	western fescue
Hordeum brachyantherum	northern meadow barley
Koeleria cristata	prairie junegrass
Muhlenbergia richardsonis	Richardson muhly
Phleum pratense	timothy
Poa cusickii	Cusick bluegrass
Poa glaucifolia	
Poa juncifolia	tall bluegrass
Poa nevadensis	Nevada bluegrass
Poa nervosa	Wheeler bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg bluegrass
Sitanion hystrix	bottlebrush squirreltail
Stipa columbiana	Columbia needlegrass

APPENDIX C. Continued

Scientific Name	Common Name
Stipa lettermani	Letterman needlegrass
Stipa occidentalis	western needlegrass
Trisetum canescens	tall trisetum

SHRUBS AND TREES

Abies concolor	white fir
Abies grandis	grand fir
Alnus incana	alder
Amelanchier alnifolia	western serviceberry
Artemisia cana ssp. viscidula	mountain silver sagebrush
Artemisia tridentata ssp. vaseyana	mountain big sagebrush
Berberis repens	creeping hollygrape/low Oregon grape
Betula glandulosa	bog birch
Cercocarpus ledifolius	curlleaf mountain mahogany
Chrysothamnus nauseosus	rubber rabbitbrush
Cornus stolonifera	red-osier dogwood
Eriogonum heracleoides	Wyeth buckwheat
Juniperus communis	common juniper
Juniperus occidentalis	western juniper
Lonicera involucrata involucrata	bearberry honeysuckle/black twinberry
Pinus contorta	lodgepole pine
Pinus ponderosa	ponderosa pine
Potentilla fruticosa	shrubby cinquefoil
Prunus virginiana melanocarpa	black chokecherry
Pseudotsuga menziesii	Douglas fir

APPENDIX C. Continued

Scientific Name	Common Name
Purshia tridentata	bitterbrush
Ribes aureum	golden currant
Ribes cereum	wax currant
Ribes hudsonianum petiolare	stink currant
Rosa woodsii ultramonta	woods rose
Salix spp.	willow
Sambucus cerulea	elderberry
Symphoricarpos occidentalis	western snowberry
Symphoricarpos oreophilis	
Tetradymia canescens	gray horsebrush

APPENDIX D

Readily Available Carbohydrate Data

Table D1. Summary of Readily Available Carbohydrates Data 1977 (% Cell Contents)

Creek Bottoms $\bar{x}$

	Bluegrass	Sedges	Other Grass	Forbs
Wk 1	22.34	20.92	23.18	42.60
Wk 2	22.05	21.39	22.37	38.21
Wk 3	21.61	17.46	18.13	35.02
Wk 4	20.46	20.07	18.21	36.93
$\bar{x}$	21.62	19.96	20.47	38.22

No sig across wks
Highly P < .01 grass vs. Forbs

South Slopes

	Bluebunch Wheatgrass	Squirreltail	Other Grass	Forbs	Cheatgrass
Wk 1	25.41	23.72	19.82	33.81	
Wk 4	23.53		15.88	36.82	18.71
$\bar{x}$	24.47	23.72	17.85	35.32	18.71

Sagebrush Bluegrass Bottoms

	Bluegrass	Sedges	Other Grass	Forbs
Wk 1	23.77	22.26	16.09	39.70
Wk 2	16.63	24.36	15.37	30.67
Wk 4	20.37	17.84	18.95	31.33
$\bar{x}$	20.26	21.49	16.80	33.90

APPENDIX D. Continued

Table D1. Continued

Pine Uplands

	Bluegrass	Sedges	Other Grass	Forbs
Wk 1	23.77	22.26	16.09	39.70
Wk 2	16.63	24.36	15.37	30.67
Wk 4	20.37	17.84	18.95	31.33
$\bar{x}$	20.26	21.49	16.80	33.90

Pine Uplands

	Elk Sedge	Pinegrass	Other Grass	Forbs
Wk 1	22.80	24.39	23.28	41.90
Wk 3	20.37	21.51		43.00
$\bar{x}$	21.58	22.95	23.28	42.45

Douglas fir - Elk sedge

	Elk Sedge	Pinegrass	Other Grass	Forbs
Wk 1	23.34	19.50	17.80	32.87
Wk 4	24.92		22.34	
$\bar{x}$	24.13	19.50	20.07	32.87

APPENDIX D. Continued

Table D2. Summary of Readily Available Carbohydrates Data 1977 (% Cell Contents)

Creek Bottom

	Bluegrass	Sedges	Other Grass	Forbs
Wk 1	25.25	20.43	20.73	42.04
Wk 2	23.91	19.60	22.79	46.18
Wk 3	22.20	21.06	20.84	42.00
Wk 4	20.42	17.48	19.02	38.75
$\bar{x}$	22.95	19.64	20.85	42.24

Steep South Slopes

	Bluebunch Wheatgrass	Squirreltail	Other Grass	Forbs	Cheatgrass
Wk 1	25.87	25.39	22.20	38.04	16.99
Wk 2	25.27	22.29	23.81	37.12	17.41
Wk 3	24.24	20.13	25.87	43.83	18.77
Wk 4	19.71	18.58	19.02	30.42	12.73
$\bar{x}$	23.77	21.60	22.72	37.35	16.48

Sagebrush - Sandberg Bluegrass Bottoms

	Bluegrass	Sedges	Other Grass	Forbs
Wk 1	19.84	22.85	18.49	37.61
Wk 2	17.51	24.58	20.96	44.91
Wk 3	20.31	22.52	17.15	39.90
Wk 4	23.91	22.01	17.27	37.97
$\bar{x}$	20.39	22.99	18.47	40.10

APPENDIX D. Continued

Table D2. Continued

Pine Upland

	Elk Sedge	Pinegrass	Other Grass	Forbs
Wk 1	24.73	25.75	28.91	49.55
Wk 2	22.61	22.81	21.18	50.70
Wk 4	18.57	18.46	18.15	34.97
$\bar{x}$	21.97	22.34	22.75	45.07

Douglas fir - Elk sedge

	Elk Sedge	Pinegrass	Other Grass	Forbs
Wk 1	22.00		24.03	43.99
Wk 4	20.78	23.85		33.80
$\bar{x}$	21.39	23.85	24.03	38.90

Pine - Bitterbrush

	Elk Sedge	Pinegrass	Other Grass	Forbs
Wk 2	24.80	20.06	24.28	41.69
Wk 4	21.06	20.21	22.49	33.88
$\bar{x}$	22.93	20.14	23.38	37.78

APPENDIX E

Analysis of Variance of Readily Available Carbohydrates Data (% Cell Contents)

Table E1. 1978

Source	SS	DF	MS	F	
Creek Bottom Poa ANOVA					F.01
Total	58.09	14			
Trt	45.85	3	15.28	13.77**	6.22
Error	12.24	11	1.11		
Forb ANOVA					F.05
Total	161.80	14			
Trt	98.20	3	52.73	5.66*	3.98
Error	63.60	11	5.78		
Carex ANOVA					
Total	977.43	14			
Trt	954.91	3	318.30	155.27**	
Error	22.52	11	2.05		

* designates significance $P \leq .05$

** designates significance $P \leq .01$

APPENDIX F

Cattle Movement Data 1978

Cow #	July 7	Uplands July 8	July 10	July 11	July 13 Day	July 13 Evening	July 14 Day	July 14 Evening	July 18	July 20 Day	July 20 Evening	July 21	Aug 2	Aug 3	Aug 4	Aug 7	Aug 8	Aug 10	Aug 11
1			1/ PU MWS	PU NFS								PU NFS							
2			PU RCB	PU RCB								CC						FS	
3				PU RCB								SC						CC	
4			PU RCB	PU RCB										SC				CC	
5			PU MWS	PU RCB										SC	SC			FS	
6			PU NSC	PU RCB										SC	SC			LCC	LCC
7			PU RCB	PU RCB								PU NFS			SC				
8				PU RCB										SC				SC	
9				PU RCB					CC						SC				
10			PU MWS	PU RCB					CC					FS				FS	
11	CC		PU NSC	PU RCB					CC			CC						LCC	
12	CC								CC					FS	FS			LCC	
13			PU RCB											FS	FS			CC	
14	CC		PU NSC	PU RCB				UCC	CC			SC/CC		FS				LCC	
15							UCC		CC			PU NFS		FS					
16									CC					FS	FS			FS	
17									CC			CC		FA	FS			LCC	
18									CC					SC				CC	
19						CCM			CC			CC		SC	SC				
20									CC					CC				SC	
21				PU RCB			UCC							FS	SC			SC	
22							SoC		SoC					FS				CC	
23						UCC			SoC						FS				
24			PU RCB	PU RCB			UCC	UCC	UCC					CC				CC	
25			PU RCB MWS				UCC								SC				
26	CC						SoC					PU NFS		SC					
27	CC					UCC	UCC							SC				FS	
28						UCC	UCC		UCC									SC	
29							UCC	UCC				CC						CC	LCC
30							UCC	UCC	UCC					CCM				CC	
31									UCC			PU NFS						CC	
32			PU MWS		CCM	CCM								CCM				LCC	
33			PU MWS			CCM	CCM	CCM			LCC		NQ					FS	
34			PU MWS			CCM		LCC					UFG						LCC
35			PU MWS					LCC			LCC								LCC
36		CC	PU NSC	PU RCB					CCM	LCC	LCC								LCC
37			PU RCB	PU RCB						LCC	LCC		FG						
38			PU RCB	PU NFS	CCM												CCM	LCC	LCC

APPENDIX F. Continued Upper Camp Creek

Cow #	July 7	July 8	July 10	July 11	July 13 Day	July 13 Evening	July 14 Day	July 14 Evening	July 18	July 20 Day	July 20 Evening	July 21	Aug 2	Aug 3	Aug 4	Aug 7	Aug 8	Aug 10	Aug 11
39				PU RCB					CCM									LCC	LCC
40						CCM		UCC	CCM									LCC	LCC
41							UCC	UCC										LCC	LCC
42						UCC		CCM						CCM					LCC
43								UCC									CCM	LCC	LCC
44					CCM		UCC	UCC						CCM				UCC	
45		EM			LCC		UCC	UCC	CCM		CCM			CCM/SC	SF			UCC	
46							UCC		CCM		CCM								LCC
47						UCC	UCC		CCM					LCC					
48							UCC	UCC	CCM				NQ						
49							UCC		CCM				FG						UFG
50						UCC	UCC	UCC		LCC			FG	CCM			CCM		LCC
51						UCC	UCC						FG						
52						UCC			SoC										LCC
53					LCC				UCC								CCM	LCC	LCC
54								LCC	UCC									LCC	LCC
				Lower Camp Creek 1978															
55							LCC				LCC								UFG
56		EM					LCC	LCC			LCC								
57					LCC	LCC	LCC											LCC	
58							LCC	LCC					FG					LCC	
59					LCC		LCC			LCC	LCC			LCC					LCC
60		FM			LCC			LCC		LCC			NQ						LCC
61											LCC							LCC	LCC
62							LCC	LCC		LCC									
63					LCC									CCM				LCC	LCC
64						CCM			CCM				FG						
65		EM															CCM	LCC	
66																	CCM	LCC	LCC
67						CCM												LCC	
68		EM			CCM	CCM					LCC			CCM				LCC	
69							CCM	CCM		LCC									
70											CCM		FG					LCC	
71					CCM			CCM	CCM		CCM							LCC	LCC

APPENDIX F. Continued

1/ LCC - Lower Camp Creek
CCM - Camp Creek Meadows
UCC - Upper Camp Creek
FG - Fisk Gulch
EM - East Meadow
FS - Fir Spring
CC - Cellar Creek
SC - Swamp Creek
PU - RCB - Pine Uplands - Rail Creek Butte
PU - MWS - Pine Uplands - Middle Weather Station
PU - NFS - Pine Uplands - North Fir Springs
PU - NSC - Pine Uplands - North Swamp Creek
NQ - North Quarry
SoC - South Creek