Effect of stock density on ground cover on a southwest Montana foothills rangeland
by John Jesse Hansen

A Thesis submitted in partial fulfillment of Master of Science in Range Science
Montana State University

Abstract:
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Cover responses of total dense clubmoss, live dense clubmoss, and bare ground, as estimated by line intercept, did not change significantly in response to the treatments. Lack of change in these cover classes may be attributed to insufficient time for animal-site interaction.

Cover of other vegetation and litter changed significantly in response to grazing but not in response to stock density. Dung cover yielded a significant change for the mid-summer, 74 cow-calf pairs/ha treatment. This change in dung cover was attributed to random dung deposition.

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John Jesse Hansen

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Stock density was a factor in the grazing process under which many of our native grasslands evolved. As such, stock density is worthy of investigation. Stock density has been little researched until recently and information concerning this factor is limited.

In 1986 a study was initiated at MSU's Red Bluff Research Ranch in southwest Montana to investigate the effect of stock density on ground cover of a native foothills grassland. Three levels of stock density were utilized: 0, 37, and 74 cow-calf pairs/ha, at two periods in the grazing season, spring and mid-summer. Grazing time per replicate pasture was 24 hours.

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INTRODUCTION

Grasslands of the northern Great Plains and mountain foothills evolved under herbivory from large ungulates and other herbivores. Through this coevolution, plants present on these grasslands evolved adaptive traits and processes in response to the type of herbivory present (Coughenour, 1985). Historically, the large herbivores had been the American bison (Bison bison), pronghorn antelope (Antilocapra americana), wapiti (Cervus elaphus), mule deer (Odocoileus hemionus), and to a limited extent, bighorn sheep (Ovis canadensis). Due to European man's influence in North America, these native herbivores have decreased in number and have been replaced by domestic livestock including cattle (Bos taurus), sheep (Ovis orientalis), horses (Equus caballus), and goats (Capra aegagrus).

The bison was the major large herbivore present in very large numbers on the grasslands between the Appalachian and Rocky Mountains. Early descriptions of bison grazing behavior were made by explorers and travelers during the 1800's (Koch in Brown and Felton, 1955; Lewis and Clark, 1806; and Reighard in Sellers, 1982). Descriptions by these observers indicate that bison were present on the northern Great Plains in large numbers and tended to herd in small, closely associated groups of about 100 individuals. Large animal numbers per unit area (stock density) during grazing activity is a trait common among large, wild ungulates (McNaughton, 1984). The high stock density present under natural grazing was a factor present during coevolution of grasslands and herbivores and formation of many of the native grasslands.

It may be assumed that the native wildlife impacted the ecosystem with three basic mechanisms: 1. herbivory, 2. physical activity, and 3. deposition of feces and urine. Interaction and timing of these mechanisms were part of the processes responsible for formation and maintenance of the grasslands of western North America.

Following the introduction of domestic livestock, importance of native large herbivores in the grassland ecosystems declined. The grasslands necessarily changed to reflect the changes in herbivores and their different interactions with plants. Plant communities apparently changed in terms of species dominance. Plant species formerly relegated to secondary roles became dominant.

Observations of plant species composition changes lead to initiation of grazing research and consideration of grazing management as a tool in agriculture. Early studies considered grazing methodology with deferment and rest as primary treatments and the concept of stocking rate as a factor in plant community responses (Smith, 1895). Many studies have dealt with the influence of stocking rate on vegetation (Sarvis, 1941; Clarke et al., 1943; Lewis et al., 1956; and Houston and Woodward, 1966). Influence of stocking rate on animal performance has also received much attention (Woolfolk and Knapp, 1949; Cook et al., 1953; Lewis et al., 1956; Cook et al., 1962; Houston and Woodward, 1966; and Houston and Urick, 1972). Grazing methodology has also received a considerable amount of research and speculative attention (Anderson, 1797 in Johnstone-Wallace and Kennedy, 1944; Smith, 1895; Heady, 1961; Hormay and Talbot, 1961; and Shiflet and Heady, 1971).

Despite all the research on plant and animal responses to grazing and grazing management, one variable that has been little considered or investigated is stock density. Increased use of short duration grazing methods and their resultant higher stock densities has caused stock density to receive more attention as a factor in grassland response to grazing (Kothmann, 1984). But only four studies (Walker and Heitschmidt, 1986; Warren et al., 1986; Heitschmidt et al., 1987; and Pierson and Scarnecchia, 1987) were encountered in the literature to date that consider stock density as the research variable when investigating grazing response of North American grasslands.

Stock density is a unique variable in that it is not described by any other defined variable, and as such lends itself to investigation. As a factor in the evolution of some of our native grasslands, it is worthy of investigation. It may be an important factor when considering the response of native grasslands to grazing domestic livestock.

To better understand effects of stock density on native grasslands, a study was initiated in 1986 to investigate the effect of stock density on ground cover on a mountain foothills grassland. The study site was located in an area containing plant species which had coevolved with large herbivores. The study was sponsored by the Montana State University Animal and Range Sciences Department and the Montana Agricultural Experiment Station.

The purpose of this study was to investigate stock density as a factor in grazing influences of domestic livestock on a native grassland. Objectives of the study were to investigate the effect of stock density on ground cover and how specific animal impact mechanisms influence ground cover.

LITERATURE REVIEW

Historical Grazing Characteristics

In much of Montana the bison was the major large herbivore prior to settlement by European man. By better understanding the nature of the herbivory of these animals we may gain a better understanding of the response of present rangelands to herbivory by domestic livestock.

The bison is the native large herbivore that most resembles domestic cattle both in size and forage preference and so deserves much of the attention in this review. Records and observations of early bison numbers and behavior are not as plentiful as would be desired. Most of the observations are by trappers, hunters, travelers, and explorers.

An early traveler, Peter Koch (in Brown and Felton, 1955), related the following account:

> "In March 1870, I traveled from Muscleshell to Fort Browning on Milk River, and for a distance of forty miles I do not think we were out of easy rifle shot of buffalo. . . we could see many miles on either side; but . . . the eye only met herd after herd of grazing and slowly moving buffalo. . . . Three days later I passed over the same trail on my return trip, and the vast herds had disappeared as if by magic. Only two or three old bulls were still wandering over the prairie."

Lewis and Clark (1806) encountered large numbers of bison during the exploration of the Missouri and Yellowstone Rivers. Nearly every daily journal entry described large herds of bison. Upon arriving at the Great Falls of the Missouri, they encountered large numbers of bison. In reading their journals it is apparent that these animals did not remain in an area for a great length of time. Approximately three weeks after their arrival at the Great Falls the herds had moved to another area, except for a few scattered individuals.

Large herds of bison generally associated themselves into numerous small herds with a resultant high stock density. George W. Reighard, an early buffalo hunter, gave the following account of his observations of bison in the Kansas City Star for November 30, 1930 (in Sellers, 1982):

> "I have read after many writers who described a herd as 'blackening the plains.' They never herded that closely together. A grazing herd, undisturbed, would be divided into small groups, each group close together, and there would be ordinarily, about twenty-five or thirty buffaloes to the acre. They drifted along, about as closely together as cattle cluster when grazing loosely on the range. But looking at a buffalo herd from a knoll or hill, it seemed to be almost a solid mass, with the green sod showing only here and there, between groups."

The roaming and herding behavior of bison is supported by recent observations of bison grazing behavior. Norland (1984) investigated bison distribution and habitat use in Theodore Roosevelt National Park. His observations indicate that the bison in the park associated in small herds and changed grazing areas often.

From the previous descriptions of bison grazing behavior it is evident that high stock density was a variable in the natural grazing process on some grasslands. The influence and function of stock density, under conditions of free-ranging bison use, on development, maintainence, and productivity of the grasslands is unknown.

Stock Density

Stock density is defined by the Society of Range Management (1974) as "the relationship between number of animals and area of land at any instant of time". As a research variable, stock density has received little study. Literature pertaining to grazing studies is generally focused on stocking rate, seldom reporting stock density and often failing to supply sufficient information to derive stock density. Those studies not designed to investigate stock density, but with sufficient information to derive stock density, are complicated by variable stocking rate or grazing method. Recently several investigators have recognized stock density as a research variable in grazing trials. However, literature pertaining to this variable is scarce.

The following four articles are the only ones encountered that have stock density as the research variable. Three studies were done by splitting a paddock in an existing short duration grazing cell in Texas. The other study was conducted in central Washington on seeded pasture.

Walker and Heitschmidt (1986) reported an increase in cattle trail density with increased stock density on a Texas grassland. The grazing strategy utilized for this study was a short duration grazing system with stock densities of 4.2 and 12.5 AU/ha.

Warren et al. (1986) compared soil hydrologic response to three stock densities of 1.4, 2.0, and 3.0 AU/ha on a Texas grassland. They were unable to detect significant differences in sediment production and infiltration rate due to variable stock density.

Heitschmidt et al. (1987), in comparing stock densities of 4.2 and 12.5 AU/ha, noted greater total aboveground net primary productivity (ANPP) for the 12.5 AU/ha treatment as compared to the 4.2 AU/ha treatment over two years. ANPP for sideoats grama (*Bouteloua curtipendula*) was also greater for the 12.5 AU/ha treatment compared to the 4.2 AU/ha treatment over two years. During this study, the amount of litter did not show a response to stock density, nor did annual harvest efficiency. In addition, the authors suggested that grazing preference on their study site was not affected by stock density.

Pierson and Scarnecchia (1987) investigated defoliation of intermediate wheatgrass (Agropyron intermedium) with stock densities of 2.6 and 5.2 AU/ha on a seeded pasture in central Washington. Stocking rate was similar for each treatment. Their results indicate that standing crop was reduced 64% for the 2.6 AU/ha treatment compared to 58% for the 5.2 AU/ha. Mean tiller heights decreased linearly over time for both treatments with the rate of decrease greater for the 5.2 AU/ha treatment. This difference in tiller height decrease was attributed to unequal grazing pressures between treatments. There was no difference in percent of tillers defoliated between treatments.

The following studies are those in which stock density could be derived from the reported methodology. These studies generally included a stock density that was greater than that found in grazing systems other than high intensity grazing systems. It should be noted that results may be confounded by differing stocking rates associated with differing stock densities.

While investigating distance traveled by cattle, Walker et al. (1985) compared a continuous grazing method with stock density of 0.17 AU/ha to a short duration grazing system with stock densities of 4.2 and 12.5 AU/ha. They reported that cattle walked farther and travel distance was more variable under the short duration grazing strategy than the continuous grazing strategy.

Kirby et al. (1986) reported differences in forage disappearance on North Dakota rangeland that may have been partially due to stock density. They compared a repeated seasonlong grazing strategy with a stock density of 0.15 AU/ha to a short duration grazing strategy (SDG) with a stock density of 2.1 AU/ha. Graminoid disappearance was similar for both treatments, but forb disappearance was increased three-fold in the SDG treatment for 1982 and more than two-fold for 1983. Grazing distribution did not seem to differ between treatments. Interpretation of these results may be complicated by the difference in stocking rates; 0.67 AUM/ha and 1.2 AUM/ha for the season-long grazing and short duration grazing, respectively.

Koerth et al. (1983) were unable to detect differences in trampling of simulated ground nests when comparing continuous grazing with a stock density of 0.12 steers/ha and short duration grazing with a stock density of 1.2 steers/ha.

Livestock Impact Mechanisms

Domestic livestock influence range and pasture lands in three basic ways: 1. herbivory, 2. physical activity, and 3. deposition of feces and urine (Balph and Malecheck, 1985).

Domestic livestock trampling has been shown to increase soil compaction in the upper portions of the soil profile in some soils (Bryant et al., 1972) and to disrupt and break soil and cryptogamic crusts (Anderson et al., 1982 and Brotherson et al., 1983). Trampling also has been shown to increase the mortality rate in some plant species. Trampling assists the deposition of standing dead plant material onto the soil surface and thus contributes to litter cover (Heitschmidt et al., 1987; Savory in Balph and Malecheck, 1985; Bement, 1969; and Tomanek, 1969).

Herbivory by domestic livestock influences many aspects of the grassland ecosystem. Many studies have demonstrated the influence of herbivory on plant species composition (Sarvis, 1941; Clarke et al., 1943; and Houston and Woodward, 1966). Studies involving amount, frequency, and seasonal timing of herbage removal have demonstrated the effect of herbivory on plant vigor and productivity (Weaver, 1950; Albertson et al., 1953; Lewis et al., 1956; Booysen et al., 1963; and Caldwell, 1984). Additional studies have shown the effect of herbivory on sward structure (Edwards and Hollis, 1982), soil moisture content (McCarty and Mazurak, 1976), surface water run-off (Hanson et al., 1970), and amount of soil erosion (Blackburn,1984).

Deposition of waste products in the form of feces and urine influences the concentration and redistribution of nutrients on range and pasture sites (Peterson et al., 1956a and b) and can influence pasture utilization patterns and sward structure (Edwards and Hollis, 1982). Deposition of feces and urine may also influence plant mortality and species composition, killing some species by urine burn (Marsh and Campling, 1970), transporting seed of plant species (Billings, 1978) and providing a suitable environment for germination and establishment of these seeds (Stoddart et al., 1975). Water quality of streams is influenced by feces and urine deposition by increasing coliform counts and suspended solids content of the stream (Kauffman and Krueger, 1984).

STUDY SITE

The study site was located on Montana State University's Red Bluff Research Ranch at Norris, in southwest Montana, T.3S R.1W E1/2,SW1/4, section 23 (Figure 1). This site is a mountain foothills grassland (Figure 2) with the dominant forage species being bluebunch wheatgrass (<u>Agropyron spicatum</u>), needleandthread (<u>Stipa comata</u>), prairie junegrass (<u>Koleria pyramidata</u>) and standing milkvetch (<u>Astragalus adsurgens</u>) (Table 1). The soil surface is well covered with vegetation and litter (Figure 3). Bare ground estimates ranged from <1% to 22%.

Table 1. Study site species composition (%) by weight estimated from 10 one meter square clipping plots.

Species	% Composition
Stipa comata	34.8
Agropyron spicatum	18.5
Astragalus adsurgens	20.0
Festuca idahoensis	6.0
Koeleria pyramidata	5.5
Agropyron smithii	T
Lupine spp.	T
Increaser grasses	1.9
Increaser forbs	12.8
Shrubs	T

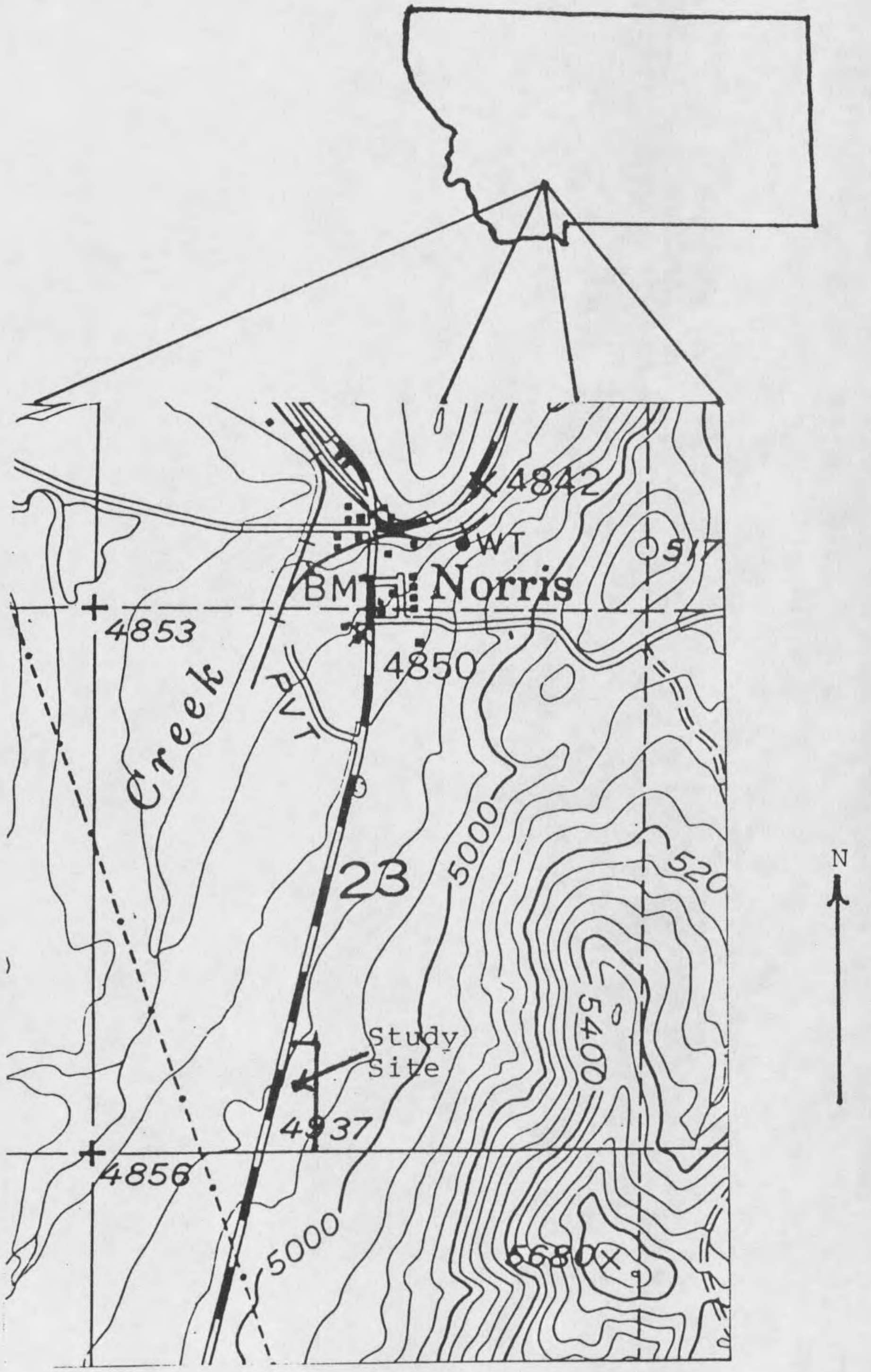


Figure 1. Map of study site location.

Figure 2. General view of study site.

Figure 3. Typical ground cover on study site after grazing treatment.

A native plant, dense clubmoss (Selaginella densa), was present as a major component of the ground cover on the study site and subsequently received a large amount of attention during the study. Dense clubmoss is prevelant on many grassland areas that historically maintained large herds of native ungulates. Amount of dense clubmoss present in plant communities prior to the influence of European man and his domestic livestock is a matter for speculation. Dense clubmoss appears to be susceptible to grazing activity of livestock (Clarke et al., 1943, Smoliak, 1965, Vogel and VanDyne, 1966, and VanDyne and Vogel, 1967).

Livestock grazing on this site has been minor and sporadic for the past 25 years. A natural water source is not present for livestock use which accounts for its current low level of use by domestic livestock.

Soils are silt loams, classified by the author as aridic, argiborols, fine-loamy mixed (Appendix B). Parent material is alluvium derived from Cherry Creek metamorphics. Topography is gently sloping with a west-southwest exposure. Study site elevation is 1500 meters.

Average annual precipitation at the nearest weather recording station (Ennis, MT.) is 26.8 cm per year with the majority of the precipitation occurring between April and September. May and June receive the greatest monthly amounts of precipitation.

Annual mean temperature is 6.4 degrees C with a mean high of 14 degrees C and a mean low of -1 degrees C. Temperature commonly ranges from 35 degrees C to -33 degrees C. Average frost free period is 96 days from June until September.

Using the Soil Conservation Service classification of range condition, range condition was estimated as high fair (46%). The range site guide utilized for this rating was the foothills and mountain 10-14 inch p.z. silty site. Current year's production, estimated by harvest in 1986, was 1180 kg/ha dry matter.

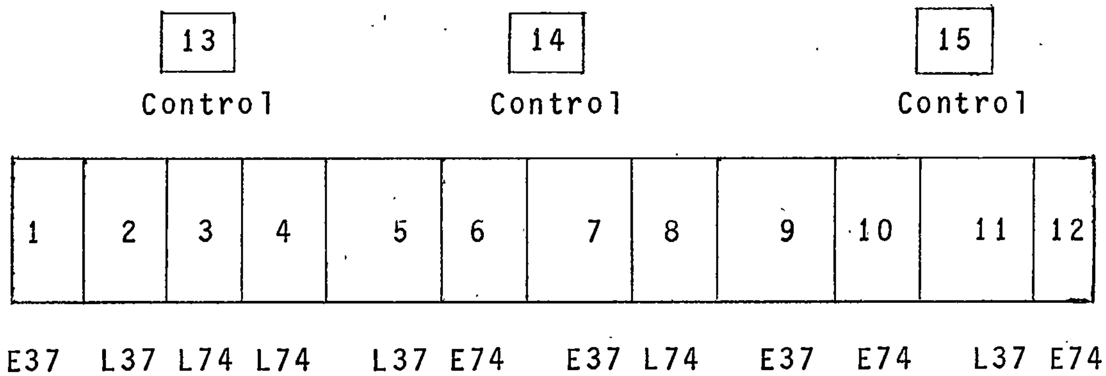
A portion of the north end of the study site, which included pastures 1-6 and 13, appeared to have received a cultural treatment, such as plowing, at some earlier time. This portion of the site is located near an old homestead. Dense clubmoss cover was less on this portion of the study site than on other portions.

METHODS

Treatments

To determine effect of stock density on ground cover, three levels of stock density were utilized, 37 and 74 cow-calf pairs/ha for the grazing trials and 0 cow-calf pairs/ha as the control (Figure 4). Treatments were replicated three times, with grazing treatments randomly assigned to replicate pastures (Figure 5).

Figure 4. Stock density treatment of 74 cow-calf pairs/ha.



E37 = Early summer 37 cow-calf pairs/ha
E74 = Early summer 74 cow-calf pairs/ha
L37 = Mid-summer 37 cow-calf pairs/ha
L74 = Mid-summer 74 cow-calf pairs/ha

Figure 5. Diagram of pasture arrangement, pasture number, and treatment assignment.

Desired stock densities were achieved by utilizing 30 cow/calf pairs on pasture sizes of .4 and .8 ha. The zero stock density treatment consisted of 3 exclosures placed approximately 90 m east of the pastures to be grazed. This placement of controls minimized their interference with cattle movements among pastures. Temporary electric fencing was utilized with a battery powered energizer. Most of the same cattle were used throughout the study.

Two grazing periods during the growing season were utilized to evaluate effects of time of grazing on changes in ground cover. A mid-spring treatment period was utilized to evaluate treatment effect during moist soil and vegetation conditions and a mid-summer treatment was used to evaluate treatment effect during dry soil and vegetation conditions.

A 24 hour grazing period was used to keep the cattle on a relatively normal level of forage intake. This length of grazing allowed maximum stock density for the forage available and allowed regular timing of the cattle moves.

Ground Cover Estimation

Five cover categories were sampled: total dense clubmoss, live dense clubmoss, bare ground, dung, and other vegetation and litter. Total dense clubmoss consisted of both dead and live dense clubmoss material that was attached to a rooted dense clubmoss plant (Figure 6). Live dense clubmoss was considered to be that portion of the plant that was green and green-brown in color. Dead dense clubmoss was considered that portion of the plant that was grey or grey-brown. Any dense clubmoss plant parts not attached to a rooted dense clubmoss plant were considered litter and not part of the dense clubmoss cover, either total or live.

Total clubmoss cover was considered important because dead clubmoss may still influence the productivity of the site. Live dense clubmoss cover was estimated to ascertain whether the treatments would influence dense clubmoss mortality.

Bare ground cover was estimated to determine the influence of treatments on this cover class. Any changes in bare ground cover would be considered an important indication of singular or aggregate changes in other cover classes.

Figure 6. Close-up view of dense clubmoss.

Dung cover was estimated to determine the amount of change in this cover class due to treatments. This cover type was considered important in view of dense clubmoss's susceptibility to manure and nitrogen applications (Heady, 1952 and Ryerson et al., 1970). This cover class also may influence post-treatment estimates of other cover classes.

Vegetation (other than dense clubmoss) and litter were estimated due to their importance for forage production and site stability. Hydrologic characteristics of a site have been linked to vegetation and litter cover (Blackburn, 1984).

Ground covers of total clubmoss, live clubmoss, bare ground, and dung were estimated by a line intercept method. This method was chosen for its reliability and consistancy in estimating mat-forming and low-growing plant cover. Cover estimates for other vegetation and litter were derived by subtraction.

Cook and Stubbendieck (1986) suggested 15 m of line intercept as a minimum for low-growing, mat-forming plant cover estimation. Two permanently located 30 m transects were located in each replicate pasture. Transects were located diagonally to the entrance point of each pasture to avoid biases by excess livestock movement associated with entrance points. Fifteen alternate subdivisons of each transect were sampled, with the starting meter (meter 1 or 2) being randomly chosen. All intercepts were recorded to the nearest centimeter.

Sampling was conducted prior to the grazing treatments (April, 1986 = S1), four weeks after the grazing treatments (June, 1986 and September, 1986 for early and late treatments, respectively = S2),and the following spring (April, 1987 = S3). The S2 sample was utilized to assess any immediate response in ground cover due to mechanical disruption by trampling and treading or covering with dung. The S3 sample was utilized to allow time for any effect of collective impact mechanisms to become apparent over time in the live and total clubmoss cover.

A portion of the cover estimates for total dense clubmoss and live dense clubmoss required adjusting to compensate for differences not attributable to treatments. Pre-treatment cover estimates (S1) for controls, L37, and L74 treatments were made when the dense clubmoss was in a desiccated and dormant stage due to dry conditions present during June, 1986. Post-treatment cover estimates (S2) for E37 and E74 treatments were also made at this time. Pre-treatment cover estimates for E37 and E74 treatments were made in May, 1986 when the dense clubmoss was in a moist and non-dormant state. The dry and desiccated condition of the dense clubmoss yielded cover estimates lower than the moist and non-desiccated condition. This was attributed to absorption of water and subsequent swelling of the dense clubmoss and to spreading and unfolding of live dense clubmoss plant material. This created artificially large differences between pre-treatment and post-treatment cover estimates that could not be accounted for by the treatment effects. Adjustment factors were derived to compensate for the differences in cover estimates due to conditions at time of sampling. The assumption was made that total and live dense clubmoss cover had not significantly changed during the growing season for the control replicates. A multiplier was calculated for each replicate control to set the pre-treatment cover estimates for total and live dense clubmoss equal to that of the September, 1986 post-treatment estimate. These multipliers were then used to adjust the cover estimates upward for the June, 1986 post-treatment cover estimates (S2) of the E37 and E74 treatments and the pre-treatment estimates (S1) of the controls, L37 and L74 treatments. The adjustment factor utilized for a replicate pasture was that of its locationally corresponding control.

Statistical Methods

Statistical analyses consisted of one-way analysis of variance to detect differences among treatments. Sums of squares were partitioned (Snedecor and Cochran, 1980) to isolate influences of stock density (D), time of grazing (T), stock density x time of grazing interactions (DxT), and grazing versus no grazing (GvsNG). Separation of means was accomplished utilizing a protected least significant difference (LSD) method (Snedecor and Cochran, 1980). This method of mean separation was chosen for its power to detect differences. A significant F-test was required prior to this test to hold the experiment-wise error rate to a minimum.

Statistical analysis was performed on mean differences between sample 1 and sample 2 (D1), and between sample 1 and sample 3 (D2) for all cover classes in each replicate pasture. Type I error rates were held at $P<.05$ for all analysis of variance and LSD tests, unless otherwise indicated.

All statistical analyses were performed using the micro-computer software statistical program MSUSTAT version 3.2 (1984). The program used for analysis of variance and LSD tests was AVMF, a multi-factor analysis of variance program.

RESULTS

Total Dense Clubmoss

Total dense clubmoss adjusted mean cover estimates and differences are shown in Table 2. Total dense clubmoss cover showed no significant differences due to treatment.

Table 2. Total dense clubmoss adjusted mean cover (%) and differences for each treatment replicate.

Treatment/ Replicate	Mean Cover 1/			Difference 2/	
	S1	S2	S3	D1	D2
Cont/1	76.8	76.8	72.0	0.0	4.8
Cont/2	75.9	75.9	71.6	0.0	4.3
Cont/3	82.1	82.1	79.8	0.0	2.3
E37/1	12.9	14.6	12.3	-1.7	0.6
E37/2	11.3	8.5	8.3	2.8	3.0
E37/3	21.3	22.0	24.7	-0.7	-3.4
E74/1	9.1	10.1	8.2	-1.0	0.9
E74/2	11.1	10.9	10.3	0.2	0.8
E74/3	40.2	39.9	38.4	0.3	1.8
L37/1	18.3	18.0	17.7	0.3	0.6
L37/2	31.2	29.4	29.4	1.8	1.8
L37/3	6.8	6.8	6.9	0.0	-0.1
L74/1	37.6	35.2	35.1	2.4	2.5
L74/2	45.5	38.3	38.1	7.2	7.4
L74/3	10.7	10.1	11.1	0.6	-0.4

1/ Represents cover estimates for sample periods 1,2,and 3.

2/ D1 and D2 represent differences between S1 and S2, and S1 and S3, respectively.

Live Dense Clubmoss

Live dense clubmoss adjusted cover estimates and differences are shown in Table 3. Live dense clubmoss cover showed no significant differences due to treatment. Partitioning of treatment sums of squares yielded no significant differences.

Table 3. Live dense clubmoss adjusted mean cover (%) and differences for each treatment replicate.

Treatment/ Replicate	Mean Cover 1/			Differences 2/	
	S1	S2	S3	D1	D2
Cont/1	21.0	21.0	19.4	0.0	1.6
Cont/2	28.0	28.0	24.6	0.0	3.4
Cont/3	34.8	34.8	30.3	0.0	4.5
E37/1	7.0	8.1	7.2	-1.1	-0.2
E37/2	4.4	2.3	3.0	2.1	1.4
E37/3	12.2	9.3	12.7	2.9	-0.5
E74/1	4.6	3.8	4.0	0.8	0.6
E74/2	6.8	5.0	5.0	1.8	1.8
E74/3	17.6	12.7	14.9	4.9	2.7
L37/1	9.5	9.8	7.9	-0.3	1.6
L37/2	10.2	11.6	11.4	-1.4	-1.2
L37/3	4.5	4.4	3.8	0.1	0.7
L74/1	16.2	13.3	12.0	2.9	4.2
L74/2	18.8	13.2	15.9	5.6	2.9
L74/3	4.2	3.9	3.9	0.3	0.3

1/ Represents cover estimates for sample periods 1, 2, and 3.

2/ D1 and D2 represent differences between S1 and S2, and S1 and S3, respectively.

Bare Ground

Bare ground adjusted cover estimates and differences are shown in Table 4. Bare ground cover showed no significant differences due to treatment. Partitioning of treatment sums of squares yielded no significant differences.

Table 4. Bare ground mean cover (%) and differences for each treatment replicate.

Treatment/ Replicate	Mean Cover 1/			Difference 2/	
	S1	S2	S3	D1	D2
Cont/1	3.3	3.8	5.6	-0.5	-2.3
Cont/2	0.9	0.0	2.5	0.9	-1.6
Cont/3	0.03	0.06	0.0	-0.03	-0.03
E37/1	5.8	7.6	11.4	-1.8	-5.6
E37/2	1.4	2.0	3.8	-0.6	-2.4
E37/3	3.0	3.0	4.5	0.0	-1.5
E74/1	10.8	13.2	21.8	-2.4	-11.0
E74/2	9.2	16.1	21.9	-6.9	-12.7
E74/3	4.2	7.9	9.0	-3.7	-4.8
L37/1	7.2	9.7	8.6	-2.5	-1.4
L37/2	8.1	9.2	6.6	-1.1	1.5
L37/3	3.7	12.1	12.3	-8.4	-8.6
L74/1	5.7	6.0	9.7	-0.3	-4.0
L74/2	7.6	6.6	10.2	1.0	-2.6
L74/3	3.8	5.8	7.5	-2.0	-3.7

1/ Represents cover estimates for sample periods 1, 2, and 3.

2/ D1 and D2 represent differences between S1 and S2, and S1 and S3, respectively.

Other Vegetation and Litter Cover

Adjusted cover estimates and differences for vegetation (other than dense clubmoss) and litter are given in Table 5. Differences in this cover class were not significant due to treatment. Partioning of treatment sums of squares yielded a significant difference for GvsNG for D2.

Table 5. Vegetation (other than dense clubmoss) and litter mean cover (%) and differences for each treatment replicate. 1/

Treatment/ Replicate	Mean Cover 2/			Differences 3/	
	S1	S2	S3	D1	D2
Cont/1	18.9	18.6	21.7	0.3	-2.8a
Cont/2	23.2	24.1	25.9	-0.9	-2.7a
Cont/3	17.2	17.2	19.7	0.0	-2.5a
E37/1	81.3	76.6	75.6	4.7	5.7b
E37/2	87.3	89.2	87.6	-1.9	-0.3b
E37/3	75.7	74.6	70.4	1.1	5.3b
E74/1	80.1	76.6	70.0	3.5	10.1b
E74/2	79.7	72.5	67.4	7.2	12.3b
E74/3	55.6	51.7	52.0	3.9	3.6b
L37/1	74.5	72.3	73.7	2.2	0.8b
L37/2	59.9	61.4	64.0	-1.5	-4.1b
L37/3	89.5	80.7	80.4	8.8	9.1b
L74/1	56.7	58.0	54.4	-1.3	2.3b
L74/2	46.9	53.9	50.4	-7.0	-3.5b
L74/3	85.5	81.6	78.2	3.9	7.3b

1/ Differences followed by a similar lower case letter do not differ at P<.05 according to the LSD procedure.
2/ Represents cover estimates for sample periods 1, 2, and 3.
3/ D1 and D2 represent differences between S1 and S2, and S1 and S3, repectively.

Dung Cover

Dung adjusted mean cover estimates and differences are shown in Table 6. Differences among treatments were significant.

Table 6. Dung mean cover (%) and differences for each treatment replicate. 1/

Treatment/ Replicate	Mean Cover 2/			Differences 3/	
	S1	S2	S3	D1	D2
Cont/1	1.0	0.8	0.7	0.2a	0.3a
Cont/2	0.0	0.0	0.0	0.0a	0.0a
Cont/3	0.7	0.6	0.5	0.1a	0.2a
E37/1	0.0	1.2	0.7	-1.2ab	-0.7a
E37/2	0.0	0.3	0.3	-0.3ab	-0.3a
E37/3	0.0	0.4	0.4	-0.4ab	-0.4a
E74/1	0.0	0.1	0.0	-0.1a	0.0a
E74/2	0.0	0.5	0.4	-0.5a	-0.4a
E74/3	0.0	0.5	0.6	-0.5a	-0.6a
L37/1	0.0	0.0	0.0	0.0a	0.0a
L37/2	0.8	0.0	0.0	0.8a	0.0a
L37/3	0.0	0.4	0.4	-0.4a	-0.4a
L74/1	0.0	0.8	0.8	-0.8b	-0.8b
L74/2	0.0	1.2	1.3	-1.2b	-1.3b
L74/3	0.0	2.5	3.2	-2.5b	-3.2b

1/ Differences followed by a similar lower case letter do not differ significantly at P<.05 according to the LSD procedure.
2/ Represents cover estimates for sample periods 1, 2, and 3.
3/ D1 and D2 represent differences between S1 and S2, and S1 and S3, respectively.

LSD separation of means indicates that cover change increase due to the L74 treatment was significantly different. Neither stock density nor time of grazing could explain this difference, as partitioning of treatment sums of squares yielded a significant test for the DxT interaction but not for either the D or T partitionings. This analysis indicates that the change in dung cover for the E37, E74, and L37 treatments was not great enough to separate it from the controls.

DISCUSSION

Ground Cover Response

Lack of significant change in total and live dense clubmoss cover with one application of high stock density may be partially attributed to the tough and resilient nature of dense clubmoss plant material. With this quality, trampling would have to be very intense to make a significant change in dense clubmoss cover with just one application of intense trampling.

Lack of contact time between dense clubmoss and the animals is another, and possibly major, reason for lack of significant response to treatments. Observations leading to this investigation were made on a time control grazing study (Sindelar, 1987), which was conducted approximately 2 km northeast of this study site. The time control study was conducted over a period of four years. This allowed for several years of trampling at a stock density of approximately 2 AU/ha before dense clubmoss was noticeably damaged. Earlier literature references to dense clubmoss' suseptibility to trampling damage were gained through study of plant community responses to grazing strategies. These studies took place over a period of years and thus allowed collective animal impacts over the course of time to act upon dense clubmoss.

Literature referring to dense clubmoss's susceptibility to grazing activity indicates that there may be a relatively narrow set of grazing conditions under which dense clubmoss cover will decrease. Grazing characteristics that may influence dense clubmoss cover include stocking rate, grazing system or method, and amount and length of rest periods. Manipulation of grazing activities to provide an environment that increases shading, increases the amount of area with high nitrogen concentration, and provides for the maximum amount of physical disruption to dense clubmoss should cause the greatest decrease in dense clubmoss cover.

Lack of significant change in bare ground cover was unexpected, considering that grazing commonly has been associated with increased bare ground (Klemmedson, 1956 and Meeuwig, 1965). With the lack of significant differences in the GvsNG analysis, it was not surprising to have a non-significant test for stock density. Possible reasons for lack of significant differences due to stock density are (1) error in cover estimation and (2) insufficient treatment time. Insufficient treatment time is the most likely reason.

Significant differences in other vegetation and litter cover in the GvsNG analysis were expected. A decrease in cover is most likely in the litter portion of this cover type. Lack of significant differences in D1 and presence of significant differences in D2 indicate a cover type capable of rapid change. Heitschmidt et al. (1987) reported litter cover increased, or remained unchanged, immediately after a grazing treatment but litter cover declined over time after the grazing event. A decrease in litter cover in grazed versus ungrazed areas is in accordance with Smoliak (1965) and Tomanek (1969).

Differences in dung cover due to treatment could not be attributed to density, time, or grazing. The most plausible explanation is random chance in dung placement.

Livestock Impact Mechanisms

Although treatments produced no statistically significant changes in total and live dense clubmoss cover, damage to and minor cover changes in dense clubmoss cover were observed. Observed damage to dense clubmoss was due to trampling and treading activity and to dunging.

Trampling is defined, for this discussion, as an animal's hoof activity that causes relatively severe disruption of the soil surface and plant material, usually produced by agitated behavior with little concern by the animal for hoof placement and greater than normal applied force. Treading is defined as an animal's hoof activity that causes relatively little severe disruption of the soil surface and plant material, usually produced by un-agitated behavior with concern by the animal for hoof placement and normal applied forces associated with normal movement.

Trampling damage took the form of uprooted and displaced portions of dense clubmoss plants. E37 and E74 treatments showed the majority of this type of damage. A spring rain and snow storm occurred part way through the period when these treatments were applied. Soil moisture was markedly increased. This allowed the animals' hooves to sink further into the ground and to produce a shearing action to dislodge and damage the dense clubmoss plants (Figure 7). The cattle tended to group together and mill during the storm, producing a concentrated application of hoof action to portions of some replicate pastures and subsequently increased damage to the dense clubmoss cover (Figure 8).

Damage due to treading occurred primarily in pastures receiving L37 and L74 treatments. These treatments were applied when dense clubmoss was in a dry and dormant condition and subsequently a more brittle condition. Damage to dense clubmoss under these conditions was of a compression and abrasion nature, with portions of dense clubmoss plants crushed and removed by more of a scuffing action (Figure 9). This type of damage removed portions of the above ground dense clubmoss plant material without removing or apparently disrupting below ground material.

Figure 7. Damage to dense clubmoss due to shearing action of trampling.

Figure 8. Site in pasture 12 that received extreme trampling.

Figure 9. Illustration of treading damage to dense clubmoss.

Covering of dense clubmoss by dung resulted in death of dense clubmoss immediately under the dung pile (Figure 10). There was no evidence of dense clubmoss mortality immediately adjacent to the dung pile at S3, suggesting lack of sunlight or smothering is initially most detrimental to dense clubmoss. More time may be required to observe effects of increased nutrient concentration adjacent to the dung pile. Susceptability of dense clubmoss to dung cover could be significant over a period of years. One cow can cover approximately 0.04 ha/year with fecal material (Tainton, 1981), which may result in a large area of dense clubmoss treated with dung over time (Figure 11).

Figure 10. Dense clubmoss killed by dung cover.

Figure 11. Typical dung cover and distribution after a 74 cow-calf pairs/ha treatment.

In many of the pastures, patches of dark green colored vegetation of rank growth form were noticeable (Figure 12). All dense clubmoss and some other species of plants were dead in the center of these patches (Figure 13). Most of these patches were approximately 45 cm in diameter with dead centers of approximately 30 cm. These patches of vegetation match the description of urine burn (Doak, 1954). Dead dense clubmoss in the center of these patches appears to decompose at a faster rate than dead dense clubmoss adjacent to the patches. Sindelar (1987) observed similar patches on a nearby study.

Figure 12. Dark green vegetation denoting a urine burn spot.

Figure 13. Close-up view of the urine burn spot in Figure 12.

Observations

Various observations were made during the study concerning subjects and processes other than the interaction of ground cover and domestic livestock. Due to the relative lack of literature pertaining to grazing studies involving high stock density on native range, the following observations are reported for purposes of speculation and hypothesis formation.

Although big sagebrush (Artemisia tridentata) represents a small proportion of the vegetation on the site, it was severely influenced by livestock. The most obvious evidence of damage to big sagebrush was in the form of rubbing, trampling and treading, and herbivory.

Rubbing by cattle on big sagebrush was observed during the spring grazing treatments which coincided with the shedding of winter hair by the cattle. Cattle were not observed rubbing on big sagebrush during the late summer grazing treatments. Damage attributed to rubbing activity consisted of breaking of branches, scarring of bark on the main stem, and breaking of the main stem, generally at or near the soil surface (Figure 14).

Figure 14. Damage to big sagebrush due to rubbing and trampling.

Trampling and treading damage was observed to varying degrees in all the replicate pastures containing other than single scattered big sagebrush plants. Damage due to trampling and treading primarily consisted of broken fine stems and scarred bark. This damage was not nearly as obvious as that from rubbing.

Herbivory of big sagebrush was only obvious during the spring grazing period. Replicate pasture 12 received particularly heavy utilization of big sagebrush, which was attributed to low forage availability and severe weather conditions.

Most of the bluebunch wheatgrass plants on the study site were "wolf plants". Utilization of wolf plants appeared to differ due to treatments. Replicate pastures receiving treatments with 74 cow-calf pairs/ha had more wolf plant utilization than replicate pastures receiving the 37 cow-calf pairs/ha treatment (Figures 15-18). Initial use of wolf plants by cattle was low, with most being utilized after preferred forage was gone. Use of bluebunch wheatgrass plants appeared to increase as the grazing trial progressed, suggesting either that cattle were learning to make more use of these plants or that limited forage availability was overriding preference. Observed initial forage preferences indicated standing milkvetch, prairie junegrass, and needleandthread were the first forage species selected.

Figure 15. Wolf plants and other forage present prior to E74 treatment.

Figure 16. View illustrating utilization of wolf plants and other forage due to E74 treatment.

Figure 17. Wolf plants and other forage present prior to E37 treatment.

Figure 18. View illustrating utilization of wolf plants and other forage due to E37 treatment.

Toward the end of the grazing trials, when entering a new replicate pasture, cattle were selecting wolf plants of bluebunch wheatgrass as readily as other forage species. Whether this apparent modification of preference was due to stocking density, stocking rate, or forage availability is unknown.

In observing regrowth of forage species after the grazing period, it appeared that bluebunch wheatgrass and green needlegrass attained grazable height faster than needleandthread and prairie junegrass. Standing milkvetch appeared to attain grazable height faster than other forbs. Over all regrowth of all forage species was excellent due to favorable moisture conditions.

Soil surface micro-topography changed markedly in all grazing treatment replicate pastures. Areas of bare ground became more uneven, with many small depressions filling with dislodged dense clubmoss material and other litter. Small pebbles left on the surface from sheet erosion appeared to have been incorporated into the upper soil horizon. Soil moisture conditions at time of treatment influenced the degree of modification. Replicate pastures grazed during wet soil conditions had more extreme soil surface micro-topographic modification than pastures grazed during dry or moist soil conditions (Figure 19). Pastures grazed during moist or dry conditions had more subtle modification.

Figure 19. Micro-topographical alteration by trampling.

Role of Stock Density

The role of stock density in the grazing process is not well understood or investigated. Recently, investigators have started researching and reporting studies concerning stock density. This discussion of stock density reflects the observations of this study and what information was gained from the limited literature available.

Stock densities utilized in this study were very high (but not unlike those reported for bison by Reighard (in Sellers, 1982) in the 1800's) when compared to those found under yearlong or seasonlong continuous grazing methods.

Many continuous grazing methods use stock densities of 0.05 AU/ha or less. Use of deferred-rotation and rest-rotation grazing systems increases stock densities, generally to about 0.2 AU/ha. However, at these low stock densities influence of stock density may be masked by influence of stocking rate. Many of the short duration grazing methods achieve stock densities ranging from 1 to 6 AU/ha. By choosing very high stock densities in this study, an attempt was made to stress the study site and hasten any responses that might be due to stock density. High stock densities also served to concentrate animal impacts associated with cattle into a short period of time and small land area, making any impacts easier to observe. Finally, resilience of dense clubmoss sod suggested the use of higher than normal stock density.

If a comparison were made between two grazing treatments consisting of 1AU/ha/month and 30/ha/24hr with stock densities of 1AU/ha and 30AU/ha, respectively, it would seem that the nature of the treatments would differ, even though the stocking rate is the same. The most obvious difference would be the concentration of animal impacts associated with that stocking rate into a period of 24 hours for the 30AU/ha treatment as compared to the 1AU/ha treatment. This concentration of impacts into a shorter period of time would allow for more time for the grazing site to recover. Recovery time would be important for plants to regrow and replenish carbohydrate reserves. Ability of plants to regrow after grazing, given adequate growing conditions, was observed during the study (Figures 20-24). Harvesting the allotted plant material in one short period would reduce grazing of regrowth before the plant has a chance to recover from the first grazing event. Recovery time would also be important for soils to recover from compaction (Warren et al., 1986).

Figure 20. Pasture 10 prior to treatment.

Figure 21. Pasture 10 four days after treatment.

Figure 22. Pasture 10, 39 days after treatment.

Figure 23. Pasture 10, 70 days after treatment.

Figure 24. Pasture 10, one year and 31 days after treatment.

Apparent differences between these contrasting treatments will be speculative until further research on this subject is initiated and completed. With the grazing studies that have been conducted and studies in areas such as animal behavior, we can begin to formulate hypotheses concerning behavior (Donaldson et al., 1971; Walker et al., 1985; and Heitschmidt et al., 1987), forage utilization (Heitschmidt et al., 1987 and Pierson and Scarnecchia, 1987) and plant-site response (Warren et al., 1986 and Heitschmidt et al., 1987).

Future grazing research should be designed with a mechanistic approach to investigation. Comparing one grazing system to another will not enable us to derive enough information concerning plant-site-herbivore interactions (Kothmann, 1984). A basic research approach will lead to further advances in applied research and methodology. Further research on stock density needs to consider more density treatments ranging from low to very high stock densities. Quantification of animal behavior, plant community, soil, and hydrologic responses due to stock density are vital to our understanding of grassland ecosystems responses to grazing.

SUMMARY

Stock density was part of the grazing process under which many of our native grasslands evolved. The role this factor played in development, maintenance, and productivity of most grasslands is unknown. Stock density has been little researched until recently and information concerning this factor is limited. To better understand the response of native grasslands to various grazing strategies, it is important to study stock density as a research variable.

The purpose of this study was to investigate stock density as a factor in grazing influences of domestic livestock on a native grassland. Objectives of the study were to investigate the effect of stock density on ground cover of a native grassland and to investigate how animal impact mechanisms influence ground cover.

In 1986 a study was initiated at Red Bluff Research Ranch in southwest Montana to investigate the effect of stock density on ground cover of a native foothills grassland. Three levels of stock density were utilized: 0, 37, and 74 cow-calf pairs/ha, at two periods in the grazing season, spring and mid-summer. Grazing time per replicate pasture was 24 hours.

Ground cover of total dense clubmoss, live dense clubmoss, and bare ground, as estimated by line intercept, did not change significantly in response to treatments. Lack of change in these cover classes could be attributed to a time factor, with the treatments not providing sufficient time for animal-site interaction.

Cover of vegetation (other than dense clubmoss) and litter changed significantly in response to grazing but not in response to stock density. Dung cover yielded a significant change for the L74 treatment. The L74 treatment increase in dung cover was attributed to random placement of dung piles in accordance with the manner of dung deposition by cattle.

Observations made during the study provided points for speculation concerning forage preference, forage utilization, plant recovery after grazing, and influence of animal impact on the soil surface.

Results and observations obtained in this study and from studies conducted by investigators elsewhere indicate that stock density is a variable worthy of additional study. A better understanding of all the factors involved in grazing will enable us to better understand plant-site-herbivore interactions. An enhanced understanding of these interactions will allow better management of our range resource.

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APPENDICES

Appendix A

Table 7. Partial species list for study site.

Latin Name	Common Name
Grass and grass-like:	
Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Aristida longeseta	red threeawn
Bouteloua gracilis	blue grama
Bromus marginatus	mountain brome
Bromus tectorum	cheatgrass
Carex filifolia	threadleaf sedge
Festuca idahoensis	Idaho fescue
Koeleria pyramidata	prairie junegrass
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg bluegrass
Stipa comata	needle-and-thread
Stipa viridula	green needlegrass
Vulpia octoflora	six-weeks fescue
Forbs:	
Achillea millefolium	western yarrow
Alyssum alyssoides	pale alyssum
Alyssum desertorum	desert alyssum
Allium textile	praire onion
Antennaria spp.	pussytoes
Artemisia dracunculus	green sagewort
Artemisia ludoviciana	cudweed sagewort
Astragalus adsurgens	standing milkvetch
Astragalus crassicarpus	groundplum milkvetch
Aster falcatus	aster
Besseya wyomingensis	Wyoming kittentail
Centaurea maculosa	spotted knapweed
Cirsium undulatum	wavyleaf thistle
Delphinium bicolor	low larkspur
Gaura coccinea	scarlet gaura
Geum triflorum	prairiesmoke
Glycyrrhiza lepidota	American licorice
Grindelia squarrosa	curlycup gumweed

Table 7. Partial species list for study site. Continued

Latin Name	Common Name
Forbs cont.	
Helianthus annus	annual sunflower
Heterotheca villosa	hairy goldaster
Heuchera spp.	alumroot
Lappula redowskii	western stickseed
Liatris punctata	dotted gayfeather
Lomatium spp.	biscuitroot
Lupinus spp.	lupine
Mammillaria vivipara	cushion cactus
Melilotus officinalis	yellow sweetclover
Microsteris gracilis	pink microsteris
Oenothera nuttallii	Nuttall evening primrose
Opuntia polyacantha	pricklypear cactus
Oxytropis spp.	locoweed
Penstemon spp.	penstemon
Phlox hoodii	Hood phlox
Plantago patagonica	woolly plantain
Potentilla pensylvanica	prairie cinquefoil
Selaginella densa	dense clubmoss
Sisymbrium altissimum	tumblemustard
Solidago missouriensis	Missouri goldenrod
Sphaeralcea coccinea	scarlet globe-mallow
Taraxacum officinale	common dandelion
Tragopogon dubius	salsify
Viola nuttallii	Nuttall violet
Zigadenus venenosus	meadow death camas
Shrubs and half-shrubs:	
Artemisia cana	silver sagebrush
Artemisia frigida	fringed sagewort
Artemisia tridentata	big sagebrush
Chrysothamnus nauseosus	rubber rabbitbrush
Rosa spp.	rose
Xanthocephalum sarothrae	broom snakeweed

Appendix B

Figure 25. Study site soil pedon discription.

Classification: Aridic Argiboroll, fine-loamy mixed

Remarks: Profile moist with coarse fragments generally <10%. Temperature at 50cm. 11 degrees C. Average precipitation for this area is 26.8cm. Stones on the soil surface present. Aggregates present in the C horizons that are hard, granular shaped, 3-8 mm, of unknown origin, and apparently cemented.

Description: Colors are dry unless otherwise indicated.

A 0-12 cm. Dark gray brown (10 YR 4/2) silt loam, very dark gray brown (10 YR 3/2) when moist; single-grain to moderate very fine to fine granular structure; slightly hard (dry), very friable (moist), slightly sticky and non-plastic (wet); many very fine and fine, common medium roots; common very fine vertically continuous pores; non effervescent, pH = 7.0; 10% coarse fragments; clear smooth boundary; krotovinas present.

Bt 12-22 cm. Yellowigh brown (10 YR 5/6) silt loam, yellowish brown (10 YR 5/4) when moist; moderate fine sub angular blocky stucture; slightly hard (dry), very friable (moist), sticky and plastic (wet); many very fine and fine, common medium roots; common very fine vertically continuous pores; non effervescent, pH = 7.0; 5% coarse fragments; clear smooth boundary.

C1 22-42 cm. White (2.5 Y 8/2) silt, light gray (2.5 Y 7/2) when moist; moderate fine subangular block structure; soft (dry), friable (moist), slightly sticky and slightly plastic (wet); few fine and medium roots; common very fine vertically continuous pores; strong effervescence, pH = 8.0; <1% coarse fragments; abrupt smooth boundary.

Figure 25. Study site soil pedon description. Continued

C2 42-70 cm. Very pale brown (10 YR 8/4) silt, very pale brown (10 YR 7.4) when moist; moderate very fine to fine subangular blocky; soft (dry), friable (moist), non sticky and non plastic (wet); few fine roots; common very fine vertially continuous pores; moderate effervescence, pH = 8.0; <1% coarse fragments; abrupt smooth boundary.

C3 70-114 cm. Very pale brown (10 YR 7/4) silt, light yellowish brown (10 YR 6/4) when moist; weak very fine to fine subangular blocky breaking to single grain structure; slightly hard (dry), loose (moist), non sticky and non plastic (wet); weak effervescence, pH = 8.0; <1% coarse fragments.