EFFECTS OF GRAZING INTENSITY ON VEGETATION COMPOSITION ON RECLAIMED MINE LANDS

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Abstract

Open pit mining has created some unique challenges with respect to sustainable post reclamation grazing. Now that many mine sites in the Pacific Northwest have been successfully reclaimed, reclamation specialists are interested in returning these lands to their former uses. One such use is to provide forage for grazing animals. Because reclaimed areas have been altered, the vegetation generally is more similar to an improved pasture than native rangeland. Grazing management of these sites requires special planning and implementation. Research on post reclamation grazing and plant response has been limited. The ability to predict plant response to animal use will better allow reclamation specialists to prescribe appropriate grazing management practices to insure long-term sustainability of reclaimed plant communities. Our study was conducted on the South Henry Mine in southeastern Idaho from 1993-1998. The overall objective was to determine the effects of four different grazing intensities on the production and composition of successfully established vegetation. The study design provided for three replications at four grazing intensities. Throughout this study, we found there was no significant change in plant composition in response to grazing intensity. Also, there was no detectable recruitment of surrounding native species to the study site during this period. Another objective was to determine how selenium levels in soil affect production of alfalfa (*Medicago sativa*), smooth brome (*Bromus inermus*), intermediate wheatgrass (*Agropyron intermedium*) and orchardgrass (*Dactylus glomerata*). We found that soil selenium content reduced the production of intermediate wheatgrass.

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As the primary contributor, the Solutia Company (formerly the Monsanto Corporation) provided the study site, financial and technical support and cooperation in the research. Other contributors are the Idaho Department of Lands, Idaho Grazing Association and the University of Idaho.

Dedication

I would like to dedicate this thesis to my loving wife Billie, who encouraged me to take on this project and stood by me throughout the challenge.

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Introduction

Two hundred fifty million years ago, much of the western United States was submerged under a large sea. Sediments rich in phosphate collected in the area that is now northeast Utah, southwestern Montana, and southeastern Idaho. This area, which is called the Western Phosphate Field, contains forty percent of the nation's phosphate reserves.

Phosphate mining began in this area around the turn of the century with underground mining techniques. The process was slow and tedious with minimal yields. Gradually, as heavy mining equipment was developed, production increased. During the second half of the century, with the development of much heavier equipment, the feasibility of large-scale open pit mining was realized and the industry began to grow in earnest. In Idaho alone, production of phosphate ore went from 800 tons in 1906 to 313,000 tons in 1945 and then to 6,000,000 tons in 1990 (Day 1976, Bennett 1994).

Open pit mining creates some unique reclamation challenges for mining companies wishing to avoid erosion and weed infestation. The process of mining involves digging enormous pits, removing the phosphate ore and back-filling the pit with overburden, the leftover shale, chert, limestone and topsoil. This overburden contains material that was originally removed from the pit, which includes material from different soil horizons and deep mineral deposits. Therefore, what may have been in the bottom layer prior to mining could end up on the surface. The overburden characteristics of the mined area are no longer similar to those found in adjacent undisturbed sites. Often the substrate that makes up the overburden is altered material that supports a different plant community than the surrounding soils. Sites where plant and animal life have been removed and most of the topsoil is lost are considered drastically disturbed sites (Box 1978). Once disturbed in this manner, even hundreds of years later, soils in the mined area will remain different from surrounding soils because they likely come from different parent material or are at different stages in the soil development process (May 1967). The mined area, rocky and bare, is susceptible to erosion and weed invasion. Reclamation specialists working with mining companies concern themselves first with erosion control and secondly with restoration of desirable vegetation for forage and habitat for livestock and wildlife.

Restoration of desirable forage and habitat for livestock and wildlife is an issue because cattle and sheep grazing was the primary land use of many of the arid and semi-arid mine sites before mining (Packer and Aldon 1978). Continued grazing after mining is an important use of reclaimed land (Power et al. 1978). Livestock grazing is a use applicable and beneficial to society in many areas of the world (Packer 1974), including Solutia's South Henry Mine site as livestock grazed the area before the mining operations began.

Vegetation to control erosion is also an issue because overburden piles may contain high levels of undesirable compounds like heavy metals or salts which need to be contained. Mine spoils must be reclaimed thereby reducing the overland runoff of these undesirable components, which may pollute water and soils down stream (Nieman and Meshako 1990). One way to contain metals and salts is by using vegetation. Plants that adequately cover the soil surface protect it from rain, wind and overland water flow erosion.

Much is known about the effects of cattle grazing on rangeland but little is known about the effects of grazing on restored vegetation on reclaimed mine lands. Many studies have contributed a great deal to our knowledge of appropriate levels of utilization, or grazing intensity, on undisturbed rangeland. Studies determining appropriate levels of grazing intensity on reclaimed mine sites are limited. Southeastern Idaho was chosen as an appropriate site to examine this question. Concern focused on proper use and the negative effects of overutilization.

Improper use in the form of overutilization of reclaimed mine sites can result in an unstable environment leading to accelerated erosion, poor water quality and impacts on stream fisheries. Soil and water cleanup is difficult and expensive (Farmer and Blue 1978). The cost of overutilization of the vegetative resources also includes increased chance of weed invasion. As on other lands, there is a reduction of wilderness value, wildlife habitat, visual quality, forage production and land values due to weed invasion resulting in a high revenue loss for land users (James et al. 1975).

Another focus of this study was the effect of selenium on the grasses and alfalfa. At the South Henry Mine site concentrations of selenium in the soil were related to levels in the plants. The toxic levels of selenium to most herbivores may be exceeded in reclaimed sites where selenium concentrations in overburden are excessive. Therefore, selenium uptake by plants and its inclusion in the animal diet is of considerable importance.

Solutia, Idaho Department of Lands, Idaho Grazing Association and the University of Idaho worked cooperatively to complete the study. Managers of reclaimed mine sites are provided information helpful in better utilizing the resources available on these unique sites. Specific objectives are to:

- Determine how four grazing intensities affect compositional shifts of the four dominant plant species found on the study site: alfalfa (*Medicago sativa*), smooth brome (*Bromus inermus*), intermediate wheatgrass (*Agropyron intermedium*), and orchardgrass (*Dactylus glomerata*).

- Determine how soil selenium content affects production of alfalfa, smooth brome, intermediate wheatgrass and orchardgrass on the study site.

Literature Review

Plant Species Used in Reclamation

Introduced Perennials

The goal of reclamation is to meet or exceed previous use potential, reestablishing suitable vegetation cover and managing its use for long-term sustainability (Paone et al. 1978). Success of reclamation on surface mine overburden is largely based on the selection of plant species for particular needs. Species that provide long term cover and low maintenance are desired and are the goal of reclamationists in most instances (Ashby et al. 1989). To achieve this goal, long-lived perennials capable of germination, establishment and long-term survival are chosen. Typical species that fit this description are alfalfa *(Medicago sativa*), smooth brome (*Bromus inermus*), intermediate wheatgrass (*Agropyron intermedium*), orchardgrass (*Dactylus glomerata*), timothy (*Phleum pratense*), tall fescue (*Festuca arundinacea*), crested wheatgrass (*Agropyron cristatum*) and others (Baker et al. 1976, Young and Rennick 1983). Much is known about these species' ecological requirements and attributes. The species mix used should be similar in life form and seasonal variety characteristics to the original community if not comprised of the actual species of the original community (Larson 1980). The advantages of introduced species for reclamation projects include: relatively rapid establishment, more immediate site stabilization and high productivity (DePuit et al. 1977). On the other hand, introduced species for reclamation projects result in lower floristic diversity after stands are established, stagnate stands and species that are less likely to adapt to the local environment (e.g., drought).

Native Perennials

An alternative to using introduced species in an area is to have a diverse plant community of native species. There are several ways of obtaining this goal. Planting a variety of native species is one way, but this has not always been possible due to seed availability and cost. Sporadic rates of establishment resulting in erosion problems were experienced in Montana when seeding native plants (DePuit et al. 1977). The success of this activity is based on the soil characteristics after mining. A clear long-term strategy toward using introduced species and/or native species must be completed in order to choose appropriate plant material.

Soils of Reclaimed Lands

The environment created by the mining process is quite different from that of pre-mining. Temperature and water/soil relations are altered in drastically disturbed sites. Temperature fluctuations in bare soil are much greater than soil insulated by vegetation. Seedling establishment is reduced with high temperature fluctuations (Orr et al. 1997). High water infiltration occurs in topsoil and less through lower horizons on non-mined areas. Consequently, topsoil provides an environment where more water can reach plant roots. However, in mined sites where mixed overburden material lies on the surface, less infiltration may occur because of the absence of topsoil making these sites less favorable environment for plant roots (Paone et. al 1978).

Plant Response to Grazing

Effect of Carbohydrate Reserves on Plant Composition

Matching stored carbohydrate fluctuations in plants with timing of grazing is an important part of grazing management. The time of year in which plants are grazed and the level of defoliation affect carbohydrate reserves and, eventually, plant fitness. Managing vegetation for adequate carbohydrate reserves is controversial because of the complex physiology involved with carbohydrate reserves and the wide variation among grass species (Matches 1992). Plants have two kinds of carbohydrates, structural and non-structural. Structural carbohydrates include cellulose, hemicellulose and lignin which make up part of the plant's cells and cell walls, thereby providing strength and structural support to the plant. Non-structural carbohydrates, the mono- and polysaccharides also called "total available carbohydrates," include sucrose, fructosans, starch and dextrins (Trlica 1977). These non-structural carbohydrates, carbohydrate reserves, are a storable source of energy for the plant and can be translocated to different parts of the plant as needed. Carbohydrate reserves are primarily stored in roots, but there are also small amounts stored in stem and leaf material. In early spring, reserves are used to generate new, above-ground growth and rapid root growth. Typical grass plants will begin storing carbohydrates early in the growing season and continue until fall. Some carbohydrate reserves are used during winter dormancy for respiration of viable plant material and above- and below-ground bud formation (White 1973).

Effect of Grazing on Carbohydrate Reserves

Buwai and Trlica (1977) and White (1973) studied the differences in response to grazing by different species. They found species that replaced their carbohydrate reserves fast were more tolerant of grazing than species that took a long time to replenish reserves.

Plants are most competitive and vigorous when their carbohydrate reserves are intact. Livestock grazing can reduce these carbohydrate reserves by removing photosynthetic material, reducing the level of photosynthesis taking place in the plant. Plant carbohydrate reserves and the rate in which reserves are replenished vary among species giving some species an advantage over others when all are grazed equally. Plant species that can replace carbohydrate reserves quickly reduce the time they are less vigorous and vulnerable to competition. Those species that are faster at replenishing their reserves are said to be grazing tolerant. Compositional changes take place when plants of differing tolerances compete for available resources. As some members of a less competitive plant species become less vigorous and die, other species take their place changing the plant community's composition (Etherington 1976).

Historically, the belief was that the most detrimental time for a plant to be grazed was in early to mid-spring when carbohydrate reserves in the roots have just been used for initial growth and the plant is depending on photosynthetic material to provide food for maintenance and growth. This belief was based partially on work by Deregibus et al. (1982). Their study showed a reduction in carbohydrate reserves following defoliation. Moreover, Richards (1984) indicated root reserves are not translocated to above-ground portions of the plant for regrowth, but are used to maintain pre-defoliation growth rates of fine roots. Richards and Caldwell (1985) concurred by showing decreases in carbohydrate reserves in grasses even with no shoot regrowth following defoliation. Therefore, residual leaf material and available axilary buds have as much to do with regrowth as carbohydrate reserves.

Competition

Composition of plant communities often shift as particular plant species populations grow and decline. Such shifts can result from differences in life history of individual plants including longeviety, reproductive potential and elongation of axillary buds or tillering. If seed production or the rate of tillering is reduced, changes in plant composition can take place. Specific environmental conditions affect species differently. Therefore, to understand shifts in community composition, both environmental conditions and specific life history traits need to be examined.

When a plant species sequesters all the natural resources it needs, the growth rate increases exponentially (Leopold 1949). Lack of rainfall, a particular nutrient or too few warm days, for example, can reduce the growth rate and survivability of a plant. Aside from these primary environmental constraints, a required resource can be limited by competition from neighboring plants.

Competition among plants has been studied extensively. Competition studies in maturing natural environments are fewer and less crucial because nitch differentiation between species limits competitive interaction. Studies on plant competition in natural or multispecies environments have included the effects of neighboring plants on growth, density and reproductive success for individual species (Etherington 1976). Smyth (1997) experimented with native grass/legume competition on a coal mine site in the Rocky Mountains of southeastern British Columbia. He found that bunchgrasses did not limit growth of native legumes, but the rhizomatous grasses did. Some legumes, like purple milk vetch (*Astragulous alpinus)* were able to compete with rhizomatous grasses because of their ability to alter their growth habit (i.e. alter their physical shape) to reduce direct competition for space and sunlight with rhizomatous grasses.

Plant composition can also be influenced by grazing. Herbivory can reduce the prevalence of plant species less tolerant to grazing. Species most preferred by herbivores tend to be more heavily grazed, magnifying the grazing affects. Grazing can lead to reduced growth rates, root mass and fitness. For example, in a greenhouse study in England, clipping Yorkshire-fog (*Holcus lanatus*) clones reduced growth rates compared to unclipped plants (Bullock et al. 1994b). Olson and Richards (1988b) found mortality rates increased with heavy grazing on crested wheatgrass. Bullock et al. (1994a) found that the number of Redtop bent grass (*Agrostis stolonifera*) and perennial ryegrass (*Lolium perenne*) tillers were not affected by spring and summer grazing, while winter grazing decreased their density. Bullock et al. (1994a) concluded winter grazing would be the most likely cause of compositional changes in grassland plant communities. Jasmer et al. (1982) found that thickspike wheatgrass (*Elymus lanceolatus*) tolerated defoliation better than crested wheatgrass, causing crested wheatgrass population numbers to decrease at a coal strip mine in New Mexico. A three-year study where sheep grazed bull thistle (*Cirsium vulgar*) indicated winter and spring grazing and increased summer grazing significantly increased the population growth rate (Bullock et al. 1994c). A study of little blue stem (*Schizachyrium scoparium*) in Texas revealed herbivory was responsible for fragmenting large plants into smaller plants. The smaller plants had more tillers per cm^2 than the original large plant. Only severe grazing treatments caused a reduction in tiller numbers (Butler and Briske 1988). However, herbivory can either increase or decrease plant diversity depending on the characteristics of the individual plants, the plant community and intensity of grazing (Whelan 1989). Whether grazing only reduces the numbers of individuals of a plant species or eradicates it, the reduction may provide safe sites for other species to enter the system or for other plants to increase their percent of total plant composition.

Cattle Grazing Characteristics

Studies have shown that cattle select plant communities with greatest nutrient harvest (Stuth 1991). Cattle generally are more selective when forage availability is high and cattle can afford to be more selective, spending more time moving among feeding stations and eating only choice forage. Over the course of the growing season, plants age causing quality, including digestibility, to decline. As forage quality decreases, cattle are less selective and, therefore, spend less time moving among feeding stations. Furthermore, cattle must compensate for lower quality by eating more. Even later in the season as forage becomes limited, animals will stay at a feeding station until almost all of the green forage is gone (Stuth et al. 1987). Consequently, it is less likely there will be species replacement while cattle are less selective.

Palatability of plant species falls along a gradient from preferred to avoided species. O'Reagain and Grau (1995) observed that cattle and sheep switch from plant species that are most palatable to ones that are less palatable when the availability of the most palatable species decreases. For example, cattle feeding on Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) switch to crested wheatgrass as Idaho fescue and bluebunch wheatgrass availability declines. O'Reagain and Grau (1995) suggested three identifiable stages in species selection transitions:

- In the first stage, animals select the most preferred species in the pasture with some utilization of less-preferred species.
- The second stage begins when approximately 60 percent of the culms of the preferred species have been grazed at least once with increased utilization of less-preferred species.
- The third and final stage commences when 80--100 percent of culms of the preferred and less-preferred species have been defoliated at least once and grazing of previously avoided species are finally initiated.

The increased consumption of preferred species is consistant with the idea that herbivores may cause species replacement.

The size of a bunchgrass is another component in the selection of food by cattle. Ganskopp and Rose (1992) observed cattle's propensity to choose a particular size of bunchgrass when presented with different sized crowns. Their study was conducted on plantings of crested wheatgrass. Mid-sized plants (35-115 cm^2) are more productive than plants with small (< 25 cm^2) or very large (>125 cm^2) crowns. To maximize efficiency, cattle choose mid-sized plants where they get more biomass per bite than with small or very large plants. Cattle prefer one large bite from a mid-sized plant to several bites from a plant that has a larger basal area. Species that tend to be mid-sized at maturity may be replaced by other-sized species under heavy grazing.

A study by Daniel et al. (1993) found that range condition can also affect diet selection. In assessing differences in cattle diets under good and fair range condition, they found availability of forbs, which are higher in protein, phosphorus and soluble carbohydrates than grasses, influenced diet selection. When range condition is good, forbs are more abundant than in poorer range conditions. A larger percentage of cattle diets consist of forbs on rangeland in good condition due to availability. On range in poor condition, shrubs are more abundant and make up a larger portion of the overall cattle diet. Range condition on reclaimed mine land is typically good with high productivity and a variety of desirable species.

Soil Selenium Content and Toxicity

Selenium is a micro-nutrient essential to animals, but toxic at relatively low levels. Conditions created by surface mining often favor the availability of selenium to plants and ultimately, foraging animals.

Parent materials with the highest selenium concentrations are black shale with, on average, 600 parts per million ppm and phosphate rocks, 1-300 ppm. Selenium is also found in limestone at about 0.05 ppm (Haygarth 1994). Black shale, phosphate rocks and limestone are all found in overburden material at phosphate mines.

The availability of selenium to plants is affected by several soil properties including pH, soil water and soil texture. Selenates and organic selenium are the forms most readily available to plants. Basic rather than acidic soils favor uptake by plants. Reduced environments caused by very moist conditions can cause low plant availability. Oxidized environments associated with arid conditions and aerated soils favor higher plant uptake of selenium. Clay soils, sulfur, phosphates and organic matter compete with plants for soil selenium and must be considered when determining selenium availability (Neal 1990). Similarly, selenium mobilization increases with rising pH and sandier soils. Therefore, plant uptake and toxicity associated with selenium tends to be low in regions with good drainage.

Selenium in natural deposits generally is found in a reduced state. After mining, the exposure to atmospheric oxygen oxidizes selenium, allowing the potential for increased uptake by plants (Neal 1990). Excessive selenium can be taken up by plants and ultimately result in plant and animal toxicity problems.

In reclaimed areas, despite some soil conditions that favor lower selenium uptake in plants, the potentially higher selenium concentrations in overburdens can still lead to higher selenium concentrations in plants, leading to toxicity in animals.

Selenium Toxicity in Plants

Selenium toxicity in plants can occur as selenium availability increases. Symptoms of selenium toxicity in grasses have been reported to include snow-white chlorosis of the leaves and pink root tissue. Plant species respond differently to selenium toxicity. For example, symptoms of crested wheatgrass and bermudagrass (*Corynephorus dactylon*) are different from those of tall fescue (Wu 1994). Selenium toxicity seems to be limited to more vegetative tissues since plant biomass and shoot growth are negatively affected, but seed germination is not affected (Wu 1994).

Several management options exist that can minimize selenium toxicity by lowering selenium concentrations in soils. Grazing can be used to remove selenium by harvesting vegetation, although prolonged grazing may lead to animal toxicosis. Selenium leaching can be controlled by maintaining adequate organic matter and forages with root systems that take up and recycle the selenium. Applying a layer of top soil or overburden material low in selenium content to the surface of the overburden area reduces soil selenium and selenium availability to plants.

Animal Toxicity

Use of forages on selenium rich overburdens by livestock and wildlife may lead to animal toxicities. Signs of toxicity include hair loss, sloughing, cupping, and irregularity of hoofs and eventual death.

With many toxic plants, symptoms like nausea allow animals to associate toxicity with the problem plant. One problem with selenium toxicity is that animals may have difficulty identifying potential toxic plants. Therefore, animals continue consuming toxic plants until they move or are removed from the selenium rich area, die, or are treated for the toxicity. Death is usually a result of respiratory failure along with starvation and thirst (Committee on Animal Nutrition 1984).

Alkali disease is the chronic suffering of selenium toxicity. Blind staggers is an acute form of selenium toxicity. The mechanism by which selenium can cause toxicity is based on its similar chemistry to sulfur. Excessive selenium causes replacement of sulfur in protein leading to hoof, hair, and mane problems (Bull 1997). Sulfur is important in strengthening protein bonds. Sulfur supplements are effective in reducing or eliminating selenium toxicity. Remedies for animals with deficiencies include injections, dietary supplements, salt licks and drenches (Cheng 1980, Hao 1982) as cited by Wu (1994).

A firm estimate of selenium concentrations that are toxic to animals has not been set, likely because of different responses to selenium toxicity among individuals and species. For example, factors that affect animal toxicity include, class of animal, season of use and duration of use. Horses are more sensitive to selenium toxicity than cattle and sheep. Early season grazing seems to be less detrimental, as is short-term grazing on selenium rich sites.

Concentrations over 10 ppm in plants may cause problems and concentrations of 20 ppm or more in vegetation are likely to cause selenium toxicity problems (Bull 1997). A more conservative estimate has suggested that symptoms of selenium toxicity may appear in animals eating plants with as little as 5 ppm of selenium (Raisbeck 1997). Raisbeck's research and experience has served to confirm that 5 ppm Se is the dietary level considered deleterious for wildlife and livestock, if consumed over a long period of time (Raisbeck 1997).

Methods

Site Description

The study site is located on the overburden material from an open pit phosphate mine that was successfully revegetated in the early 1980's. Three pastures totaling approximately 40.5 hectares are situated 29 kilometers north of Soda Springs and seven kilometers east of Blackfoot Reservoir and the town of Henry, Idaho. The mine site is situated on the northeastern side of Wooley Range along an ecotone between Douglas fir (*Pseudotsuga menziesii*) forest and sagebrush/grass plant communities. The elevation at the site, which is 2042 m, is the major reason why there is a relatively short growing season. The average daily maximum temperature ranges from 11° C in April to 27° C in August. The average daily minimum temperature ranges from -5° C in April to 6° C in August. The mean annual precipitation is 56 cm. Variation in monthly precipitation is minimal with an average maximum of 6.19 cm in April and an average minimum of 3.38 cm in June (Abramovich et al. 1998). The overburden material, alkaline and very rocky, was mechanically shaped to a 3:1 slope. At the time of the initial seeding, 784 kg/ha of fertilizer of unknown composition was applied. The site was seeded with a mix using a cultipacker seeder (Brillion Iron Works) (Webster-Lau 1998).

Of the approximate 18 species seeded at the time of reclamation, four species now dominate. They are alfalfa (*Medicago sativa*), smooth brome (*Bromus inermus*), intermediate wheatgrass (*Agropyron intermedium*), and orchardgrass (*Dactylus glomerata*). Other species are present, but represent less than one percent of total composition. They include crested wheatgrass (*Agropyron cristatum*), timothy (*Phleum pratense*), thistle (*Cirsium spp.*) and several annual forbs.

Grazing intensities

In 1993, the 40.5 hectares were divided into three pastures, designed to provide three replications, of equal plant production and approximate size. Four 1000 m^2 treatment sites were selected in each pasture. Each pasture was grazed by between 15 and 17 head of steers, depending on the yearly plant production. The cattle were free to graze the entire pasture as well as the treatment areas except as described below. Limiting the number of days cattle had access to the treatment areas provided a gradient of grazing intensity. For each pasture, treatment one (the control) was permanently fenced from the rest of the pasture and excluded from grazing. Treatment two was grazed for the first 21 days of the grazing season and then fenced for the remainder of the season. Treatment three was grazed for approximately 42 days at the beginning of the season before being fenced off. The fourth treatment was grazed for the entire grazing period of approximately 63 days along with the remainder of the pasture. The treatment locations were chosen to minimize initial differences among treatment site productivity with respect to species composition. Each of the four treatments was randomly assigned to one of the four treatment sites. In each treatment site, four parallel transects were established to measure pasture and plant community characteristics. A buffer of at least 2 m was placed between transects and the fences. Five 50 x 50 cm quadrats were randomly placed 5 m apart along each transect to measure species frequency and production. During the last week in June plants inside each quadrat were clipped at ground level and bagged in paper grocery bags and labeled for species and quadrat location. The paper bags were hung in large mesh bags to prevent damage by mold or mildew until they could be oven dried. The grocery bags with plant contents were dried in ovens at 70° C for 48 hours. At that time, the bags were weighed and placed back in the oven at the same temperature for an additional 24 hours. They were then weighed again. If the weight was the same as the previous day, it was determined that the plant contents were completely dry. If, however, the weights were different, the bags were dried an additional 24 hours and weighed (and repeated if necessary) until the weights were identical on two consecutive days.

Upon the cessation of grazing in treatment areas, the actual level of grazing, or utilization, was estimated. Frequencies of grazed plants and average stubble height of grazed plants as a measure of forage use, were collected for the three most abundant forage species: alfalfa, smooth brome and intermediate wheatgrass. The relative proportions of plants grazed were estimated in each treatment by stepping off two paces along a transect line, finding the nearest plant of each species, and recording it as grazed or ungrazed. This procedure was repeated 100 times for each treatment. The amount of plant tissue removed by grazing was determined by stepping off two paces along a transect, finding the nearest grazed and ungrazed plants of each species and recording the measured height of 50 grazed plants and 25 ungrazed plants for each treatment. The relative proportion of grazed plants together with the amount of tissue removed, provided an estimate of total plant utilization.

Soil selenium content

During the summer of 1997, an intensive set of soil and plant tissue samples, twelve for each treatment, were collected: three in the Douglas-fir forest above, three in the aspen (*Populus tremuloides*) that was a transition between forest and non-forest and three in the sagebrush/grass below the study area. Soil nutrients, selenium, phosphorus, potassium and sulfate were measured at two depths, 3 cm and 12 cm.

Plant tissue samples were collected by clipping individual plants at the base and depositing the samples into paper grocery bags. The bags were hung in large mesh bags to air dry before being analyzed. Smooth brome, alfalfa and intermediate wheatgrass plants were collected inside the treatment areas. In the sagebrush/grass area, mountain timothy (*Phleum alpinum*) was collected; Canada wildrye (*Elymus canadensis*) was collected from the aspen grove and Douglas-fir forest. All species were collected near the soil sample pits in each area. Mountain timothy and ryegrass were chosen as sample species because of their similarity to the introduced species used for reclamation in the study area.

The analysis was completed by Analytical Sciences Laboratory in the Holm Research Center at Moscow, Idaho. Chemical analysis was done on soil for pH, available phosphorus and potassium, selenium and sulfate sulfur. Plant tissue ICP, (hydride-generated inductively coupled plasma atomic emission spectrometry) (Anderson and Isaacs 1993) analysis was done for selenium content.

Analytical Procedures

Alfalfa, smooth brome, intermediate wheatgrass and orchardgrass production was collected over six years and summarized by treatment. Production within each microplot was weighed in grams, and averaged within each treatment. There was an apparent correlation between intermediate wheatgrass production and selenium levels in the overburden soil. After a correlation between plant production and selenium levels was suspected, a more detailed look seemed prudent. Selenium levels in the soil were analyzed and compared to production of the dominant plant species using several procedures.

Analysis of variance (ANOVA) and a repeated measures analysis of variance (REANOVA) (alpha = .1) were used to evaluate the grazing treatment effect on alfalfa, smooth brome, intermediate wheatgrass and orchardgrass data. The alfalfa, smooth brome and intermediate wheatgrass data was transformed using square root. Alfalfa, smooth brome and intermediate wheatgrass were also analyzed separately to determine the relationship between soil selenium and plant production using an analysis of co-variance. The variables were soil selenium content and plant production. Additionally, a Chi Square analysis was used to evaluate the orchardgrass production relative to soil selenium content. Chi Square was used because an assumption necessary in using the analysis of co-variance, homogeneity of variance, was violated. The data were not considered normal because of many entries with a value of 0.

Results and Discussion

The following results assess the impact of livestock grazing and soil selenium content on four dominate plant species, alfalfa, smooth brome, intermediate wheatgrass and orchardgrass, on reclaimed mine land.

Livestock grazing, regardless of intensity, tended to have little impact on the prevalence of the major species at the South Henry Mine. Specifically, there were no significant differences over the six year study in the relative proportion of alfalfa (P=.3256), smooth brome (P=.2323), intermediate wheatgrass (P=.2994), or orchardgrass (P=.2743) among the different treatments.

Livestock grazing has been shown to reduce growth rates, root mass and fitness of plant species (Bullock 1994b et al.). Species differ in response to grazing as demonstrated by Jasmer et. al. (1982) when he compared thickspike wheatgrass (*Agropyron dasystachyum*) and crested wheatgrass plants after defoliation on a coal strip mine in New Mexico. The thickspike wheatgrass tolerated defoliation better than crested wheatgrass. Heavy or severe grazing often is necessary to achieve vegetation changes. The lack of difference between the control and grazing treatments in my study may be attributable to the relatively low utilization levels in the study even for the heaviest grazing treatment. The level of use in each treatment was measured as a function of two variables, stubble height remaining after grazing and the percent (or frequency) of plants grazed. For our study, light, moderate and heavy grazing were defined by the utilization experienced in the light, moderate and heavy treatments. The percent stubble height remaining with the light treatment was similar among the three dominant species: 79% for alfalfa, and 78% for both smooth brome and intermediate wheatgrass. The frequency of grazed plants averaged 33% among species with alfalfa at 40%, smooth brome at 29% and intermediate wheatgrass at 32%. The average stubble height remaining with moderate grazing was also similar among alfalfa, smooth brome and intermediate wheatgrass (66, 71 and 66%, respectively). The frequency of grazed plants with moderate grazing averaged 58% (68% for alfalfa, 54% for smooth brome and 47% for intermediate wheatgrass). The average stubble height remaining with heavy grazing was similar among the three dominant species (67, 66 and 59% for alfalfa, smooth brome and intermediate wheatgrass, respectively). The frequency of grazed plants averaged 67% among species (70% for alfalfa, 62% for smooth brome and 69% for intermediate wheatgrass). As expected, when grazing intensity increased, the remaining portion (stubble height) of plants grazed decreased (Figure 1) while frequency of plants grazed increased (Figure 2).

Pastures often are not considered heavily grazed with these levels of utilization. Without achieving traditional levels of "heavy grazing", this study more accurately compares light and moderate grazing to no grazing. The grazing intensities are relatively light. For example, traditional heavy grazing studies have utilization levels of anywhere from 40 to 70% and frequency of close to 100%. In this study, utilization for the heavy grazing treatment was, on average, low (24%) with an average percent stubble height remaining of 64% and an average frequency of grazed plants of 67%. Effects of grazing are more severe as the number of days of grazing increases (Buwai and Trlica 1976, Bullock 1994b et al.). The limited vegetation changes among grazing treatments may be attributable to the relatively low utilization in the treatments but also may be influenced by the relatively uniform selection of species by the grazing cattle. Selective grazing can influence plant composition because palatable species are more likely to be eliminated leaving unpalatable species to thrive (Burrows 1990). The four dominant species of this study have been reported to be similar in palatability (McKee 1948, Stubbendieck et. al. 1997) and were selected relatively evenly. A second explanation for limited vegetation changes in this study is that selective grazing did not result in an unbalanced use of any species.

Fluctuations between alfalfa and smooth brome's relative production may not be directly related to grazing. These fluctuations are reflective. For example, in this study peaks in alfalfa production tend to coincide with valleys in smooth brome production (Figures 3 & 4). There was no block effect with production among the three blocks or pastures. Therefore, production among the three blocks was averaged in Figures 3 and 4. There are two explanations for why production of alfalfa and smooth brome are correlated negatively. Vegetative changes between the two species may be caused by one species replacing the other. If this is the case, then this study shows that in some years alfalfa replaces smooth brome and the reverse is true for other years. For some species like annual grasses and forbs, species composition can change dramatically from year to year in response to annual temperature and precipitation or disturbance variations (Heady 1977) but long-lived perennials like alfalfa and smooth brome, mortality rates are too low in any one year making large shifts in populations less likely.

The phenological stage when production was assessed may better explain the yearly fluctuations between alfalfa and smooth brome. Plant species initiate growth at different times in the spring and progress through their yearly phenological stages at different rates. For example, in my study alfalfa achieves full growth later in the spring than smooth brome. Forage assessments were conducted every year the third week in June and because of temperature and precipitation variations among years, it may be expected that either alfalfa or smooth brome may be favored in any one year. Figures 5 and 6 detail temperature and precipitation variations from 1993 to 1998 revealing 1995 and 1998 as particularly cold springs. In those years smooth brome production and relative proportion peaked while alfalfa production and relative proportion dropped. Assessment of production done while plants are at earlier phenological stages, as in 1995 and 1998, likely favor relatively higher smooth brome production and may explain the yearly fluctuations between smooth brome and alfalfa.

Impact of Selenium Content

A separate study involving the relationship between soil and plant tissue selenium was done on the South Henry Mine site and was incorporated into part of the production analysis. Soil selenium content among the three pastures varied greatly (Table 1).

Table 1. Production by species and soil Se content for each pasture.

Species	Pasture 1	Pasture 2	Pasture 3
Alfalfa production (g/m)	96	112	128
Smooth brome production (g/m)	96	16	176
Intermediate wheatgrass production (g/m)	88	52	24
Orchardgrass production	9	42	49
Soil Se (ppm)	1	1	1

Average selenium in the soil of pasture one was much lower than for pastures two and three. Coincidentally, intermediate wheatgrass production in pasture one was much higher than in pastures two and three. Three models were used to decipher the relationship between soil selenium and intermediate wheatgrass production. One model analyzed intermediate wheatgrass production with grazing level and pastures (block) as variables. A second model included the variables grazing level, pasture (block) and selenium concentrations as a covariate. A third model was constructed using grazing level and high vs. low selenium s the two variables. The analysis without selenium in the model (Table 2) shows a significant block affect (P=.0236) suggesting that there were significant differences in production of intermediate wheat grass among the pastures. The analysis using selenium as a covariate in the model further indicates a significant pasture affect (P= .0277) but no affect of selenium on production (P=.2938; Table 3). To increase the power of detecting a significant effect on production from selenium block 1 was converted to "low selenium and blocks 2 and 3 were converted to "high selenium." The new model separating pastures into high selenium and low selenium (Table 4) which results in a significant selenium affect (P=.0220). There was no significant treatment, block or selenium affect on alfalfa or smooth brome production as seen in Tables 5 and 6. The orchardgrass analysis (Table 7) did not show a significant treatment, block or selenium affect. Because of the small sample size, the results may be rather insensitive to small changes.

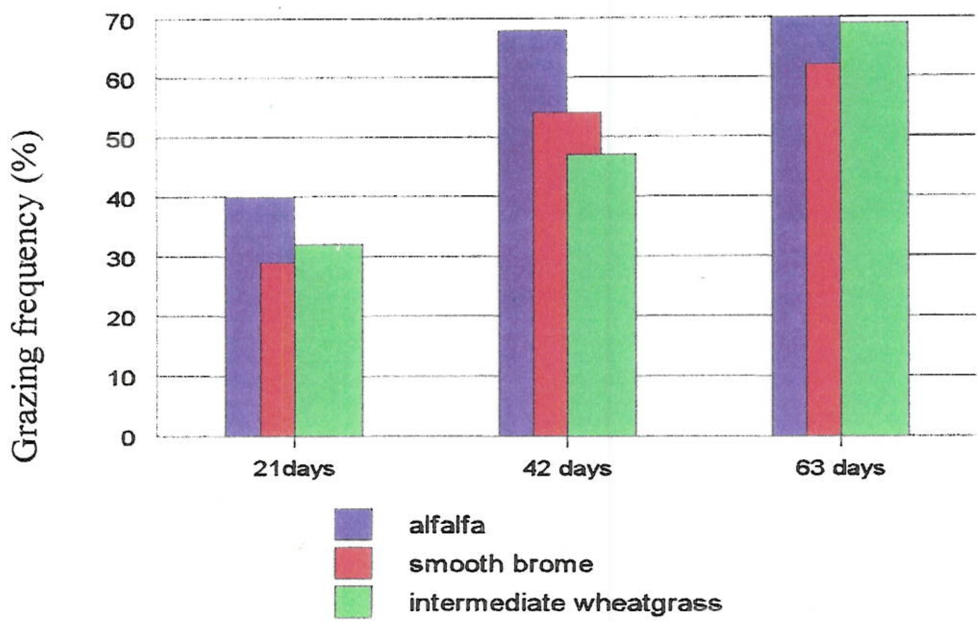

Figure 1. Percent stubble height remaining for three grazed plant species relative to nongrazed plants after 21, 42 and 63 days of grazing.

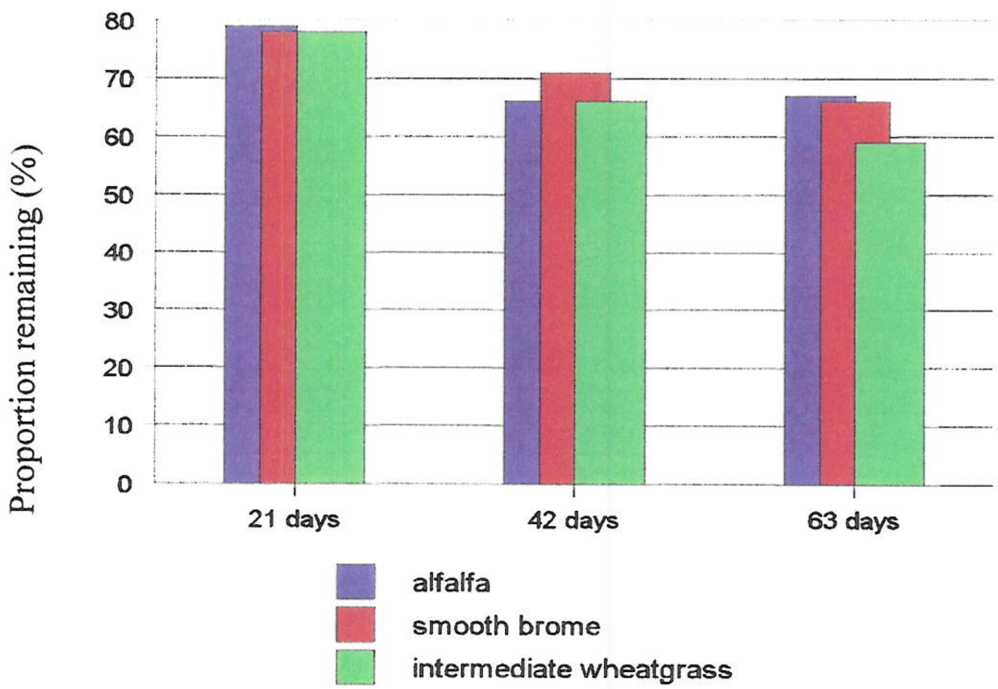

Figure 2. Frequency of three grazed plant species relative to nongrazed plants after 21, 42 and 63 days of grazing.

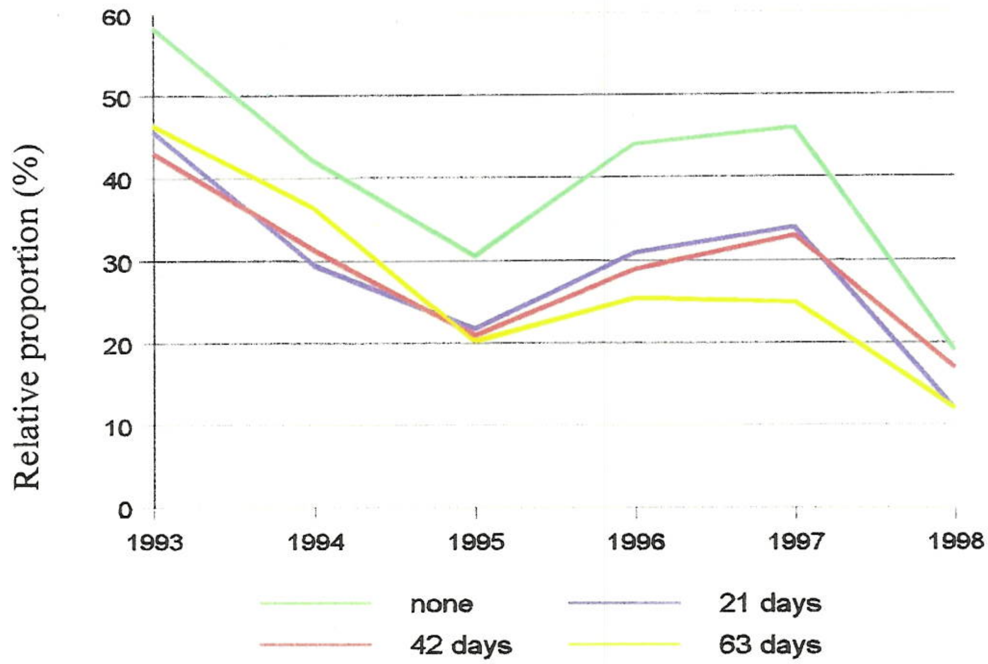

Figure 3. The relative proportion of alfalfa biomass under four grazing treatments over a six year period from 1993 through 1998.

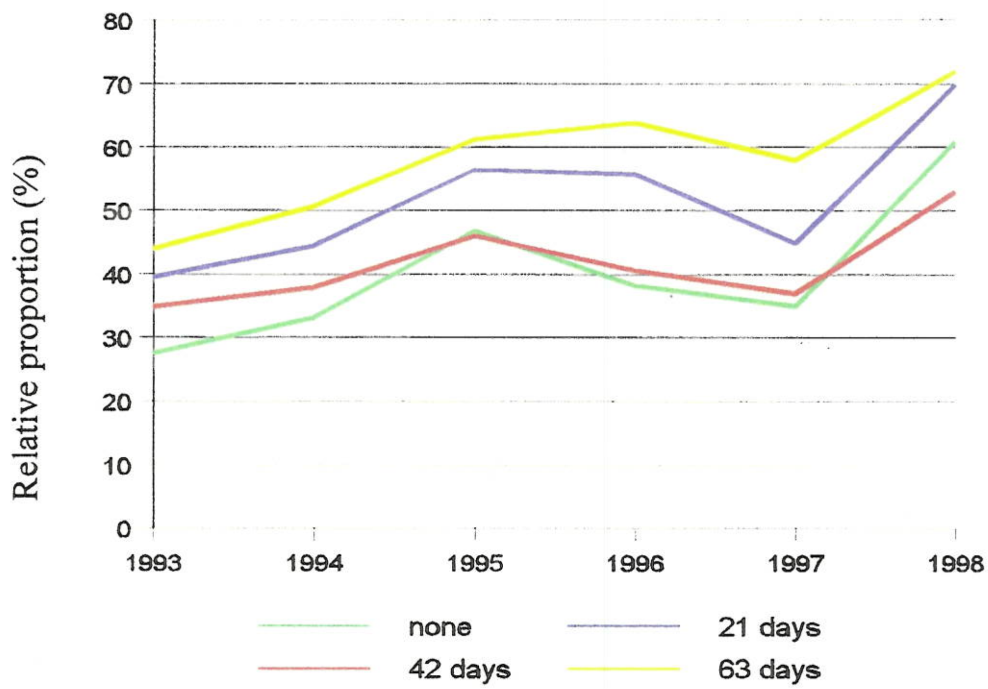

Figure 4. The relative proportion of smooth brome biomass under four grazing treatments over a six year period from 1993 through 1998.

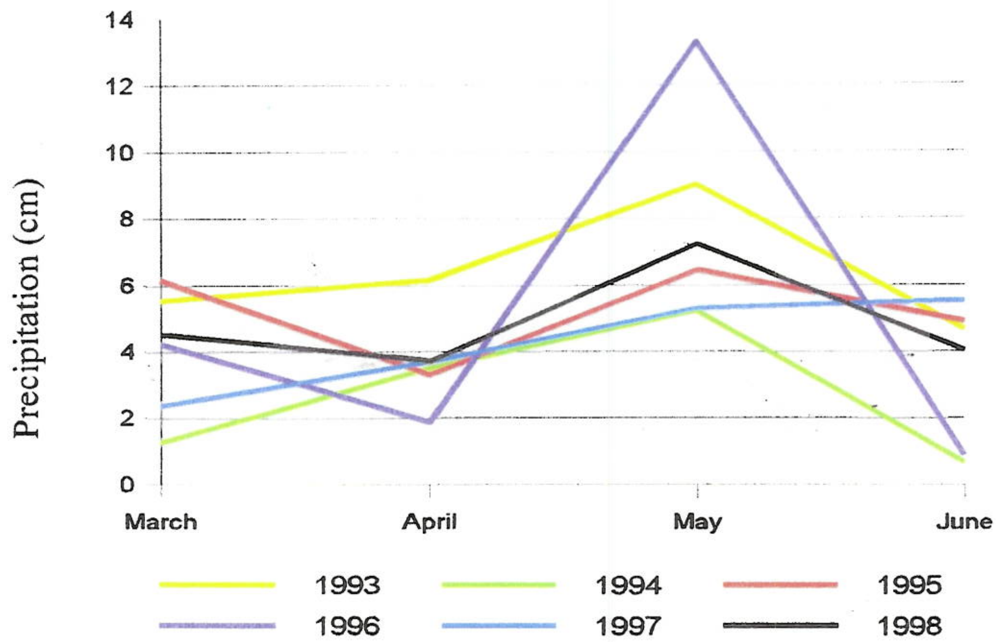

Figure 5. Mean average monthly precipitation of spring months of the six-year study.

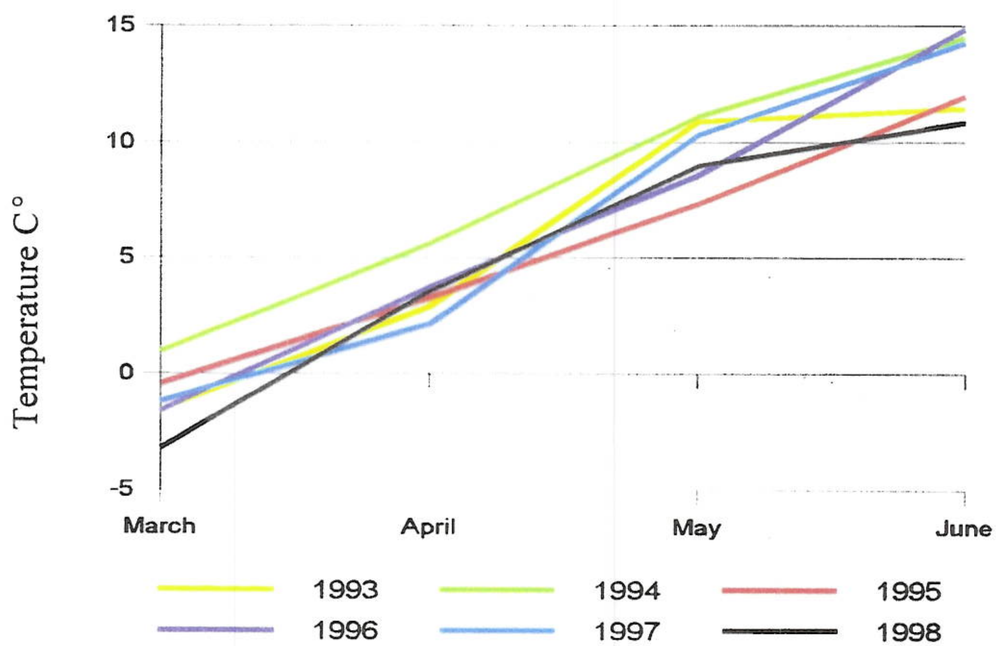

Figure 6. Mean average monthly temperature for spring months of the six-year study.

Conclusion

Reclaimed land in southeastern Idaho may be grazed at levels equal to those of this study without causing significant changes in plant composition. The results of this study indicate light and moderate grazing intensities do not change plant composition of four dominant forage species: alfalfa, smooth brome, intermediate wheatgrass and orchardgrass. Annual fluctuations in relative proportion between smooth brome and alfalfa seem to be attributable to variable weather conditions and time of sample clipping. Clipping samples at a similar phenological stage each year provides more accurate results than clipping at a particular calendar date. Regardless of time of clipping, changes in composition were very gradual but observable. Consequently, observing changes of any significance may require many more years of study with increased grazing intensity.

Selenium concentration in the soil and subsequent plant availability are both enhanced by surface mining activity. The study suggested that elevated soil selenium concentration and availability reduce production of intermediate wheatgrass. A similar response was not found when analyzing alfalfa, smooth brome and orchardgrass.

Further study

Trends in species composition were most apparent under the heavy grazing regime and, therefore, utilization levels likely were too low to induce significant changes in species composition.

One possible reason there were no significant treatment affects was the relatively low utilization levels. Relatively light utilization in the heavy grazing treatment could be remedied by fencing the heavy treatment areas and increasing the stocking rate inside them until desired utilization is reached. In doing so, heavy utilization levels may be obtained for data collection without overgrazing the remainder of the pastures.

Also, it would be interesting to compare compositional changes, especially concerning intermediate wheatgrass, in pasture one, which had a relatively low level of selenium to pastures two and three, which had relatively high levels of selenium to determine rates of compositional change based both on grazing intensity and selenium concentration.

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Appendix A

Time Period and Dates of Grazing

		Actual Grazing Dates				
Treatment #	Target Time Period Grazed	1993	1994	1995	1996	1997
1	0 days					
2	approx. 21 days	7/5 - 7/26	6/20 - 7/11	6/24 - 7/17	6/29 – 7/22	6/28 - 7/19
3	approx. 42 days	7/5 - 8/18	6/20 - 8/2	6/24 - 8/7	6/29 – 8/12	6/28 - 8/9
4	approx. 70 days	7/5 - 9/15	6/20 - 8/8	6/24 - 8/25	6/29 –8/30	6/28 - 8/30

Appendix B

Plant Composition and Production

1993 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-1 PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	55	16	17	12	trace	3262	2904	1.9
2	44	34	17	5	trace	2991	2662	1.8
3	48	19	32	trace	0	3738	3327	2.2
4	41	39	19	trace	0	4151	3695	2.5
average	47	27	22	4	trace	3536	3147	2.1

Table B-2 PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	63	32	4	0	0	3888	3460	2.3
2	40	41	19	trace	0	3819	3399	2.3
3	34	41	25	0	0	3659	3257	2.2
4	45	51	4	0	0	3842	3419	2.3
average	46	41	13	trace	0	3802	3384	2.3

Table B-3 PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	56	36	8	0	0	3942	3508	2.3
2	54	43	2	0	0	3987	3549	2.4
3	48	45	7	0	0	4500	4005	3.6
4	54	41	4	trace	0	4017	3575	2.4
average	53	41	5	trace	0	4111	3659	2.4

Table B-4 1993 AVERAGED BY PASTURE

	Species Composition (%)					Production		
Pasture	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	47	27	22	4	trace	3536	3147	2.1
2	46	41	13	trace	o	3802	3384	2.3
3	53	41	5	trace	o	4111	3659	2.4
average	49	36	13	2	trace	3816	3397	2.3

1994 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-5 PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	30	20	25	24	trace	5253	4676	3.1
2	37	29	26	8	trace	3412	3036	2.0
3	37	14	38	6	3	5354	4765	3.2
4	26	41	23	2	6	5436	4838	3.2
average	32	26	28	10	2	4864	4329	2.9

Table B-6 PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	53	34	12	trace	0	5750	5117	3.4
2	21	43	31	0	5	4635	4125	2.8
3	24	43	29	0	3	5073	4515	3.0
4	33	59	6	trace	trace	5599	4983	3.3
average	33	45	20	trace	2	5264	4685	3.1

Table B-7 PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	43	41	13	0	1	6226	5541	3.7
2	36	56	8	0	0	5580	4967	3.3
3	37	54	9	0	0	5518	4911	4.4
4	41	51	8	0	0	5063	4506	3.0
average	39	51	9	0	trace	5597	4981	3.3

Table B-8 1994 AVERAGED BY PASTURE

	Species Composition (%)					Production		
Pasture	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	32	26	28	10	2	4864	4329	2.9
2	33	45	20	trace	2	5264	4685	3.1
3	39	51	9	0	trace	5597	4981	3.3
average	35	40	19	3	1	5942	4665	3.1

1995 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-9 PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	28	30	36	6	trace	1730	1540	1.0
2	23	44	30	2	2	2123	1890	1.3
3	22	20	56	2	trace	2500	2225	1.5
4	12	46	40	trace	1	2634	2344	1.6
average	21	35	41	3	trace	2247	2000	1.4

Table B-10 PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	37	55	8	0	trace	2599	2313	1.5
2	16	58	24	0	2	2672	2378	1.6
3	16	48	33	0	2	2786	2480	1.7
4	22	75	3	0	0	2764	2460	1.6
average	23	59	17	0	1	2705	2408	1.6

Table B-11 PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	28	60	12	0	0	1794	1597	1.1
2	24	72	4	0	0	1967	1751	1.2
3	25	70	5	0	0	2325	2070	1.4
4	28	61	12	0	0	2023	1800	1.2
average	26	66	8	0	0	2027	1805	1.2

Table B-12 1995 averaged by pasture

	Species Composition (%)					Production		
Pasture	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	21	35	41	3	trace	2247	2000	1.4
2	23	59	17	0	1	2705	2408	1.6
3	26	66	8	0	0	2027	1805	1.2
average	23	53	22	1	trace	2326	2071	1.4

1996 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-13 PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	44	22	28	6	0	2324	2068	1.4
2	45	35	18	2	0	1261	1123	0.8
3	42	14	43	0	0	1132	1008	0.7
4	15	58	27	0	0	966	859	0.6
average	36.5	32.3	29	4	0	1421	1264	0.9

Table B-14 PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	50	43	7	0	0	2836	2524	1.7
2	30	56	13	1	0	2628	2339	1.6
3	23	46	31	0	0	2842	2529	1.7
4	25	73	1	0	0	2303	2050	1.4
average	32	55	13	0	0	2652	2361	1.6

Table B-15 PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	47	44	9	0	0	2357	2097	1.4
2	37	62	1	0	0	2463	2192	1.5
3	39	58	3	0	0	2712	2414	1.6
4	42	54	4	0	0	2745	2443	1.7
average	41	54	4	0	0	2569	2287	1.6

Table B-16 1996 averaged by pasture

	Species Composition (%)					Production		
Pasture	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	37	32	29	4	0	1421	1264	1
2	32	55	13	1	0	2652	2361	2
3	41	55	4	0	0	2569	2287	2
average	37	47	15	2	0	2214	1971	1

1997 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-17 PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	37	25	37	1	0	2662	2369	1.6
2	32	34	34	0	0	2944	2620	1.8
3	42	12	46	0	0	3774	3359	2.3
4	8	57	35	0	0	3030	2697	1.8
average	30	32	38	0	0	3103	2761	1.9

Table B-18 PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	56	36	8	0	0	2824	2513	1.7
2	23	57	20	0	0	2846	2533	1.7
3	17	43	40	0	0	3794	3377	2.3
4	31	65	4	0	0	3284	2923	2.0
average	32	50	18	0	0	3187	2836	1.9

Table B-19 PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	46	45	9	0	0	3310	2946	2.0
2	50	47	3	0	0	2928	2606	1.8
3	40	57	3	0	0	3456	3076	2.1
4	35	53	11	0	0	2684	2389	1.6
average	43	51	7	0	0	3095	2754	1.9

Table B-20 1997 averaged by pasture

	Species Composition (%)					Production		
Pasture	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	30	32	38	1	0	3103	2761	1.9
2	32	50	18	0	0	3187	2836	1.9
3	43	50	6	0	0	3095	2754	1.9
average	35	44	21	0	0	1085	8351	1.9

1998 SPECIES COMPOSITION AND PRODUCTION DATA

Table B-21

PASTURE ONE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. Wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	24	33	39	4	0	3230	2692	1.9
2	12	58	28	2	0	1984	1653	1.1
3	24	28	48	0	0	2148	1790	1.2
4	5	64	31	0	0	1764	1470	1.0
average	15	46	37	2	0	2282	1901	1.3

Table B-22

PASTURE TWO

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	Orchard grass	Other	kg/ha	lbs/ac	AUM/ac
1	18	77	5	0	0	2004	1670	1.2
2	6	76	18	0	0	1920	1600	1.1
3	11	48	41	0	0	2148	1790	1.2
4	15	84	1	0	0	2156	1797	1.2
average	13	71	16	0	0	2057	1714	1.2

Table B-23

PASTURE THREE

	Species Composition (%)					Production		
Treatment	alfalfa	smooth brome	intermed. wheatgr.	orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	15	73	12	0	0	2344	1953	1.3
2	19	76	5	0	0	1878	1565	1.1
3	16	82	2	0	0	2440	2033	1.4
4	16	69	15	0	0	2648	2205	1.5
average	17	75	8	0	0	2327	1939	1.3

Table B-24

1998 AVERAGED BY PASTURE

	Species Composition (%)					Production		
Pasture	Alfalfa	smooth brome	intermed. wheatgr.	Orchard grass	other	kg/ha	lbs/ac	AUM/ac
1	15	46	37	2	0	2282	1901	1.3
2	13	71	16	0	0	2057	1714	1.2
3	17	75	8	0	0	2327	1939	1.3
average	15	64	20	1	0	2222	1851	1.3

Appendix C

Results in Table Form

Table 2. Analysis of variance for intermediate wheatgrass production reveals a significant block affect.

Source	DF	F	P
Total	11		
TRT	3	1.39	.3336
BLK	2	7.46	.0236
ERROR	5		

Table 3. Analysis of co-variance, where variables are intermediate wheatgrass production and soil selenium concentration, reveals a significant block affect but not a significant selenium affect.

Source	DF	F	P
Total	11		
TRT	3	1.73	.2757
BLK	2	7.99	.0277
SELENIUM	1	1.37	.2938
ERROR	5		

Table 4. Analysis of co-variance where variables are intermediate wheatgrass production and soil selenium concentration. Selenium is divided into high selenium and low selenium. This model reveals a significant selenium affect.

Source	DF	F	P
Total	9		
TRT	3	1.20	.3776
SELENIUM	1	11.05	.0127
ERROR	5		

Table 5. Analysis of variance for alfalfa suggests no significant change in production due to treatment, block or selenium.

Source	DF	F	P
Total	11		
TRT	3	1.21	.3960
BLK	2	1.53	.3039
SELENIUM	1	1.08	.3466
ERROR	5		

Table 6. Analysis of variance for smooth brome suggests no significant change in production due to treatment, block or selenium.

Source	DF	F	P
Total	11		
TRT	3	1.35	.3586
BLK	2	1853	.3803
SELENIUM	1	.02	.8878
ERROR	5		