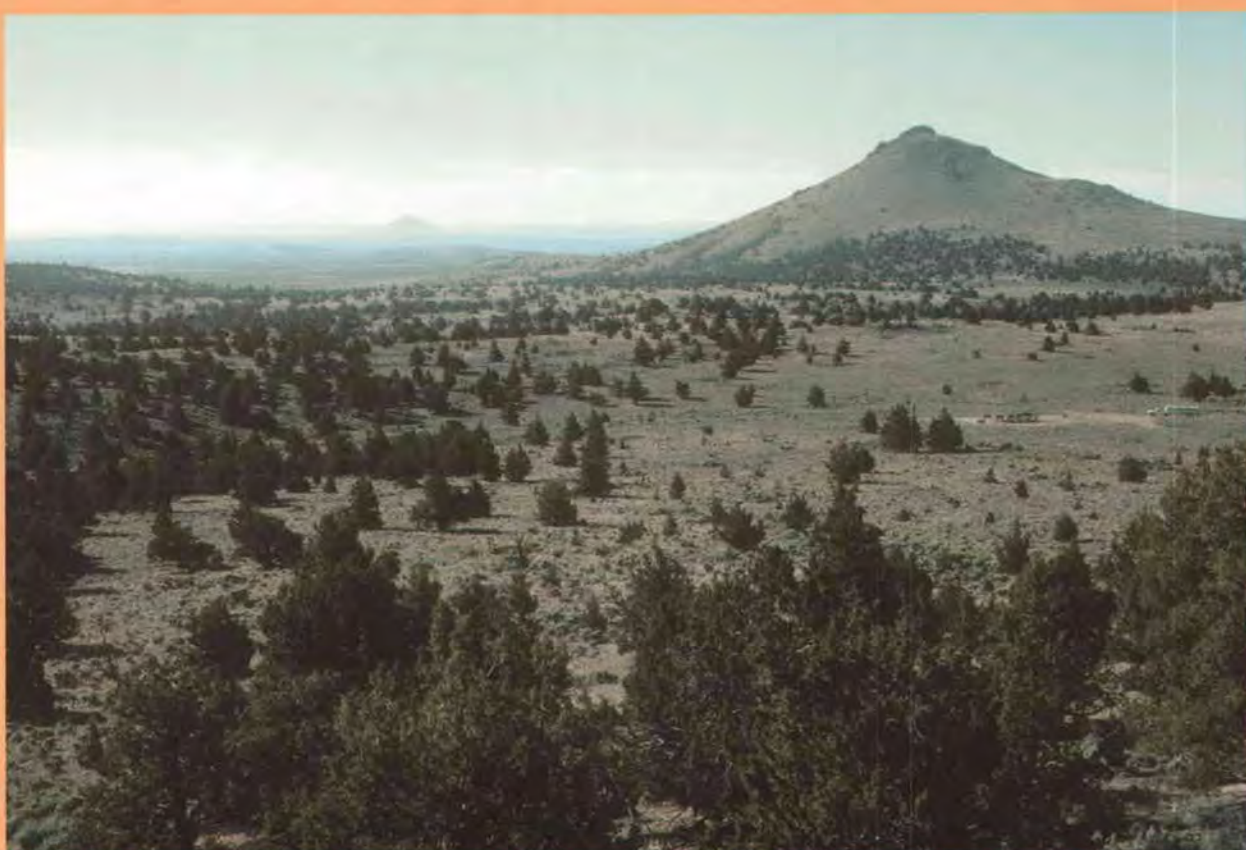
SR 1057 • January 2006

Research Progress Report 2005: Eastern Oregon Agricultural Research Center, Burns



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Cover photo

Looking south toward Placidia Butte at the Northern Great Basin Experimental Range.

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Research Progress Report 2005: Eastern Oregon Agricultural Research Center

Oregon State University Agricultural Experiment Station
in cooperation with Agricultural Research Service,
U.S. Department of Agriculture

Editors

David Bohnert, Associate Professor, Oregon State University, and
Jon D. Bates, Rangeland Scientist, USDA-ARS

Forward

The purpose of this progress report is to provide an update of recently completed and ongoing research programs at the Eastern Oregon Agricultural Research Center (EOARC), located in Burns, Oregon. Oregon State University's Agricultural Experiment Station (AES) and the U.S. Department of Agriculture's Agricultural Research Service (ARS) jointly fund the center. The mission of the EOARC is to develop agricultural and natural resource management strategies that maintain or enhance intermountain ecosystems by integrating agricultural production with sound ecological practices.

The research presented in the report covers a wide array of topics, including ecology and management of sagebrush steppe, western juniper woodlands, and riparian zones; weed ecology and management; livestock nutrition, production, and management; and wildlife-grazing interactions. Because this is a progress report, many of the results reported are not final. For this reason the information provided should not be published or used without the permission of EOARC. For additional information about any study or subject area please contact the authors in this report.

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Fire Regimes and Modern Expansion of Western Juniper in Northeastern California

Rick Miller, Emily Heyerdahl, and Karl Hopkins

Introduction

Western juniper has occupied its historical range for the past 5,000 years, based on macrofossils. During this time period, the range of western juniper has expanded and contracted in response to variation in climate and fire. However, since the late 1800s it is expanding its range and increasing in abundance at rates exceeding those of any expansion during the previous 5,000 years. Specifically, over 90 percent of modern western juniper woodlands have developed in the past 100 years. Today, western juniper occupies 3.5 million acres in northeastern California and 5 million acres in eastern Oregon. The Lava Beds National Monument in northeastern California has instituted a prescribed fire program in response to its concerns over the recent expansion of western juniper, the loss of presettlement plant communities, and an increase in fuel loads. However, the lack of information on historical fire regimes and plant succession dynamics following fire has limited the National Park Service's (NPS) ability to design and implement a prescribed fire program that simulates historical conditions and restores grassland and shrub-steppe communities.

Objectives and Methods

Our objectives were to answer the following questions for plant associations currently occupied by western juniper in the Lava Beds National Monument:

1. How frequent and severe were presettlement fires (before ca. 1870), and did fire regimes vary among the plant associations?
2. What plant communities were likely maintained under different fire-return intervals?
3. To what degree have juniper woodlands expanded since the late 1800s?

To achieve our objectives, we first identified six plant associations. To characterize the vegetation that currently exists in these plant associations (i.e., post-settlement vegetation), we measured plant characteristics at 18 sites[1], which were stratified by plant association and time-since-last-fire. We inferred presettlement vegetation in these plant associations from post-settlement vegetation, historical fire regimes, and a model of the rate of post-fire succession that we developed from chronosequences of existing vegetation (Fig. 1). We reconstructed historical fire regimes from fire scars, the establishment dates of post-fire cohorts of trees, and the death dates of trees killed by fire.

Results and Discussion

Western juniper has significantly increased in abundance and encroached on grassland and shrub-steppe communities across the Lava Beds National Monument (Fig. 1). Our data suggest that fire regimes have dramatically changed in the more productive plant associations characterized by Idaho fescue and that western juniper is a newcomer, encroaching into these communities since the late 1800s. The expansion of western juniper coincides with the reduced role of fire in the late 1800s.

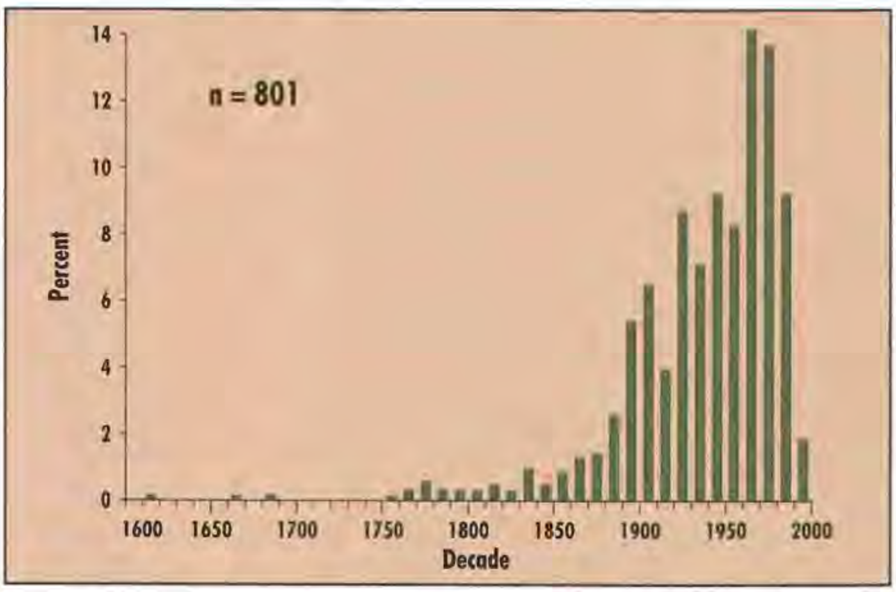


Figure 1. Establishment of western juniper by decade in the Lava Beds National Monument, California.

[1] Site is an area representing a plant association by time-since-fire combination, which is floristically and structurally similar.

Ponderosa pine/Idaho fescue plant association. Mean presettlement fire-return intervals were 8–10 years, which maintained a scattered stand of ponderosa pine with an understory of Idaho fescue. Following a fire-free period of near 100 years, plant communities have succeeded from mountain big sagebrush/bitterbrush to a dense canopy of mountain mahogany, and currently are in transition to western juniper woodland (Fig. 2).

Mountain big sagebrush-Bitterbrush/Idaho fescue and Mountain big sagebrush-Bitterbrush/Bluebunch wheatgrass-Idaho fescue plant associations. We inferred from the data that mean fire-return intervals in the remaining two mountain big sagebrush plant associations containing Idaho fescue were less than 20 years. The absence of fire has resulted in shrub canopies exceeding 40 percent and the gradual transition to western juniper woodland. Fire-return intervals of less than 20 years would have maintained a dynamic state of grass-dominated to open shrub grasslands (Fig. 3). Western juniper was not a part of the presettlement vegetation.

Mountain big sagebrush/Bluebunch wheatgrass-Thurber's needlegrass plant association. The existing vegetation suggests that the presettlement fire regime was sufficient to limit the establishment of large mature western juniper trees.

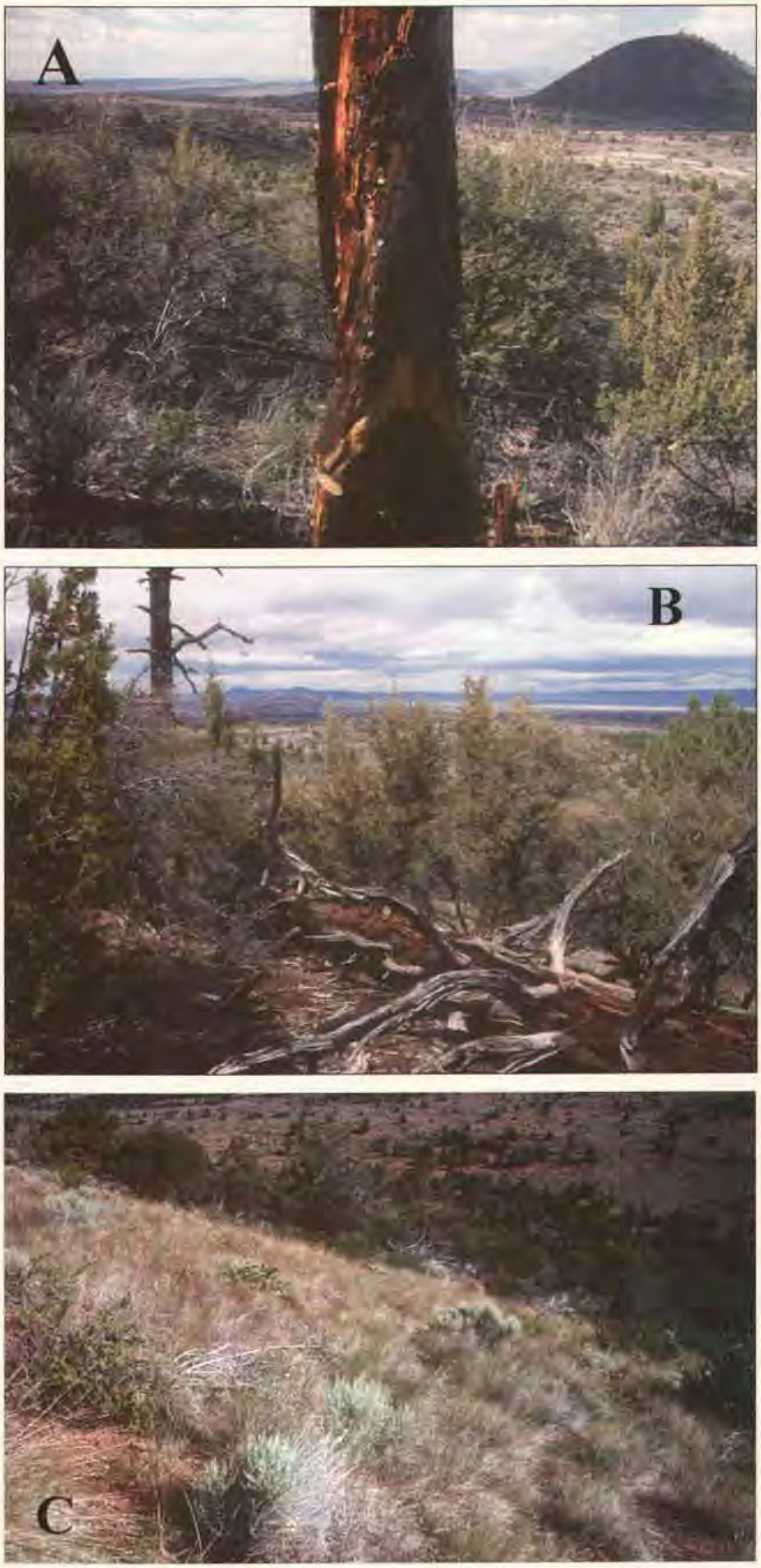


Figure 2. Presettlement fire-return interval in the ponderosa pine/Idaho fescue plant association (a and b) was 8–9 years. Last fire event was 1893 (a), 1904 (b), and early 1990s (c). Stands a and b currently are dominated by mountain mahogany and young juniper. Stand c is dominated by Idaho fescue and bluebunch wheatgrass that would have persisted under the presettlement fire regime.

The maximum fire-free interval that limits western juniper encroachment is estimated to be 50 years. Mature western juniper trees were not part of the presettlement vegetation in this plant association, based on the current lack of live or dead mature western juniper trees. However, this plant association is currently occupied by early to mid-successional western juniper woodland. The oldest trees on the site we sampled were established in the late 1800s with a second pulse following a fire in 1941. Plant community structure maintained under the past fire regime would have been a dominance to codominance of shrubs with a codominant to subdominant layer of perennial grasses.

Curl-leaf mountain mahogany-Bitterbrush-Mountain big sagebrush/Bluebunch wheatgrass-Western needlegrass plant association. In contrast, infrequent (150 years), high-intensity fires burned through this plant association, which could result in stand replacement. Plant communities were in a continual state of change between shrub-steppe and western juniper woodland, and western juniper trees were part of the presettlement vegetation. Periodic fires probably were supported by several years of wetter-than-average conditions preceding the fire event, which allowed the build-up of fine fuels and severe weather conditions during the fire event.

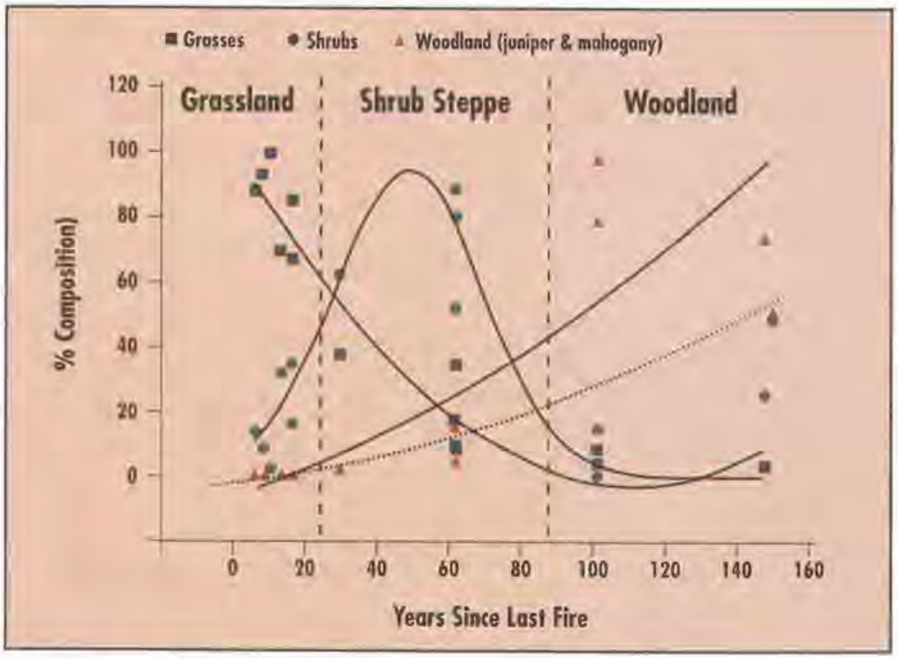


Figure 3. Model of the rate of post-fire succession from grassland to shrub-steppe to western juniper woodland. Percent composition is derived from measured cover of existing herb (i.e., grass), shrub (excluding curl-leaf mountain mahogany), and overstory layer (i.e., trees, western juniper, plus curl-leaf mountain mahogany) at Lava Beds National Monument. Moist sites are those plant associations that contain Idaho fescue; arid sites are those that contain western needlegrass.

Conclusions

Our vegetation composition, tree age distribution, and fire history data suggest that, across the southern half of the Lava Beds National Monument:

- Historically, fire regimes were heterogeneous, varying across plant associations and ranging from frequent, low-severity to infrequent, high-severity regimes.
- These fires historically prevented the development of western juniper woodlands across most, but not all, of the six plant associations that we studied.
- As a consequence of recent fire exclusion, western juniper has greatly expanded since the late 1800s.
- In the continued absence of fire, most plant associations eventually will be dominated by western juniper and hence will be outside their range of historical variation in vegetation composition and structure.

These data currently are being used by the NPS in the development of their long-term fire management plan. The fire plan takes into account in which plant communities western juniper has encroached because of the reduced role of fire and in which plant communities western juniper already was part of the plant association. This work also suggests that fire-return intervals of less than 20 years are required to maintain grasslands and less than 50 years to maintain shrub-steppe communities (Fig. 3).

Herbaceous Response to Burning of Cut Juniper

Jon Bates and Tony Svejcar

Introduction

Cutting of western juniper to increase cover and productivity of understory vegetation is a commonly applied practice in the northern Great Basin. Cut trees have typically been left on site and can cover a considerable portion of an area. In a stand that averaged 26 percent tree cover, juniper debris after cutting represented 20 percent of the area. Juniper debris impacts understory growth and successional processes in drier communities represented by big sagebrush/Thurber's needlegrass. In these communities, cheatgrass preferentially establishes under cut trees and may become a management concern if a site lacks an adequate native perennial response. Squirreltail establishes quickly in debris zones and tends to be the main perennial grass for extended periods. We also have measured declines in Thurber's needlegrass density under cut trees.

Figure 1. Debris burning in late winter, Steens Mountain, Oregon, 1998.

Experimental Protocol

Management of juniper debris after cutting has received limited attention. We investigated the effects of burning juniper debris after cutting on mortality and response of understory vegetation (Fig. 1). The study was conducted on Steens Mountain, Oregon; the following treatments were applied: 1) a control that was cut but unburned, 2) a cut treatment burned the first year after cutting, and 3) a cut treatment burned the second year after cutting. Burning was conducted during the winter when soils and surface litter were frozen and/or saturated. Burns were cooler than they would have been had they been conducted in fall with dry soil conditions.

Results and Discussion

In the first 2 years after cutting, with or without winter debris burning, there was no difference among treatments in perennial grass density. Perennial grass density in all prescriptions declined by 40–60 percent the first year after treatment (Fig. 2). However, in subsequent years perennial grass density and cover increased faster under burned debris than unburned debris, particularly Thurber's needlegrass and bluebunch wheatgrass. Increases in squirreltail density did not differ among treatments. We hypothesized that reducing the amount of litter on site by burning would reduce annual grass establishment under debris. This has not occurred. Annual grass increased similarly among burned

Figure 2. Burned debris location in spring 1998, Steens Mountain, Oregon. There has been about a 50 percent reduction in perennial grass density.

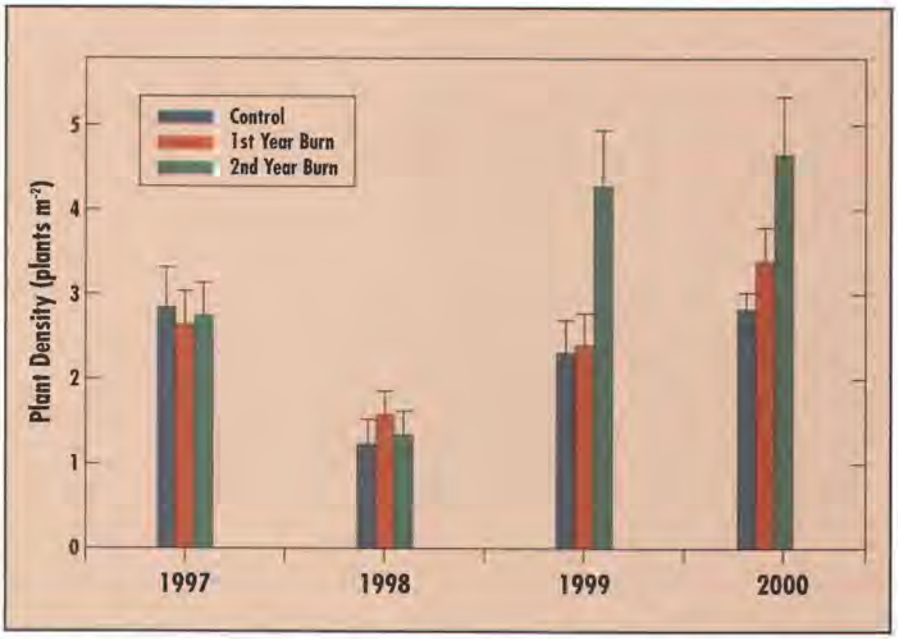


Figure 3. Density (plants/m²) changes of perennial grasses from 1997 to 2000. Pretreatment values are in 1997. Debris burning stimulated a faster perennial grass response than unburned debris.

and unburned treatments. Perennial forbs responded favorably to the burn treatments. Cover and density of perennial forbs were significantly greater in burned prescriptions than unburned. Bare ground was significantly greater in the first year burn treatment as a result of reduced amounts of juniper litter.

Winter debris burning had several positive outcomes. Burning was successful at removing 70–100 percent of fine litter. Burning opened debris zones and stimulated rapid recovery of perennial grasses and forbs. This response may be a result of increased light levels and nutrient availability. Growing season was also lengthened in burned debris areas compared to unburned debris and interspace zones. It appears that surface debris and reduced light levels inhibit germination and/or establishment of some plants. Unburned debris tended to smother perennial forbs and grasses (except squirreltail) and reduce their establishment.

Management Implications

Burning juniper debris piles in the winter when soils were wet was not detrimental to understory recovery. Mortality of perennial grasses was not increased and our results indicate that herbaceous recovery may be enhanced. The difficulties associated with winter debris burning were mainly in its application. Fuel continuity was poor and burning from tree to tree was required, which was time consuming. However, for safety and liability issues this is an advantage, as fire is unlikely to become out of control and escape. Trees also require adequate drying time to burn in the winter. In a small test, we found that trees cut after mid-September stayed green through the first winter and would not burn.

Long-term Plant Succession after Juniper Cutting

Jon Bates, Rick Miller, and Tony Svejcar

Introduction

The expansion and development of western juniper woodlands is of significant concern in the northern Great Basin. Woodland dominance can result in reduced wildlife diversity, increased erosion and runoff, and reduced understory productivity and diversity of shrub-steppe plant communities. To address these undesirable consequences, western juniper has been controlled by a variety of treatments. Current control methods are primarily prescribed fire and hand cutting using chainsaws. Control of juniper increases availability of soil water and nutrients and thus commonly results in large increases in biomass and cover of herbaceous species. There is a lack of long-term, post-treatment assessments of fire or cutting in the western juniper system.

Experimental Protocol

The purpose of this study was to evaluate long-term vegetation changes after cutting of western juniper. This study was conducted from 1991 through 2003 on private land on Steens Mountain in southeast Oregon. Cut treatments consisted of cutting all the trees on 1-acre plots. We then compared changes in herbaceous and shrub composition between cut and uncut woodlands. Juniper had dominated this site, thereby eliminating the shrubs and suppressing herbaceous species (Fig. 1). Juniper tree density was 100 trees per acre prior to cutting. In the cut treatment we also compared herbaceous response among three zones (old canopy, under-juniper debris, and intercanopy) and evaluated how quickly shrubs and juniper reestablish after cutting.

Figure 1. Woodland plot, 1991, before trees were cut, Steens Mountain, Oregon. Bareground and rock in the interspace is 95 percent. Herbaceous plant cover is about 4 percent.

Figure 2. Cut plot in 1993, 2 years after junipers were felled, Steens Mountain, Oregon. By 2003, cover of herbaceous plants was 28 percent and litter cover was 12 percent. Bareground in the interspace in 2003 was 53 percent.

Results and Discussion

Cutting resulted in increased total herbaceous biomass and cover and density of perennial grasses when compared to the woodland (Fig. 2). Density of perennial grasses increased from 2 plants/yd^2 in 1991 to 10–12 plants/yd^2 in 1997 and 2003.[2] Perennial grass density was about five times greater in the cut compared to the woodland. Herbaceous biomass has, since 1993, been about 10 times greater than biomass values in the woodlands (Fig. 3). Biomass increased about 300 percent between 1993 and 2003 in the cut treatment. Biomass and perennial grass density did not change significantly between 1997 and 2003, suggesting that it took about 6 years for understory vegetation to fully develop and occupy the site. It appears that a minimum of two plants/yd^2 are necessary to successfully recover this site with desirable species.

Within the cut treatments herbaceous composition has changed over time and has been influenced by microsite. In intercanopy zones of the cut treatment, perennial grasses were the dominant functional group, with higher cover and biomass than other functional groups in all years. However, between 1996 and 2001, cheatgrass dominated litter deposition areas (old tree canopies and under-juniper debris) (Fig. 4). The increase in cheatgrass in these areas may have been due to more favorable seedbed characteristics and increased nutrient and water availability. However, cheatgrass decreased dramatically in debris and canopy zones by 2003, with corresponding increases in perennial grass biomass and/or cover. In 2003, perennial grass biomass was two times greater than annual grass in canopy and debris zones. The cheatgrass decline may be a result of dry conditions over the past several years that reduced cheatgrass establishment and growth, less favorable seedbed properties as litter is incorporated into the soil and exposure increases, and increased competition from perennials. The main perennial grass that moved into litter deposition zones was squirreltail. Other perennial grasses have been slow to establish and develop in old canopy and debris sites.

Sagebrush and other shrubs have increased steadily since cutting, but cover remains far below potential for this site. Juniper has also reestablished in the cut treatment. One source of these trees is small individuals that are often not controlled in the initial treatment. In addition, it appears that many new trees started from seed. Juniper density in 2003 was 200 trees per acre. These trees are either seedlings or juveniles less than 18 inches tall. Unless controlled, there are presently enough young trees to redominate the site within 50–60 years.

[2] Perennial grasses included bluebunch wheatgrass, squirreltail, Thurber's needlegrass, and Indian ricegrass. Sandburg's bluegrass is a perennial grass but was not included in this total.

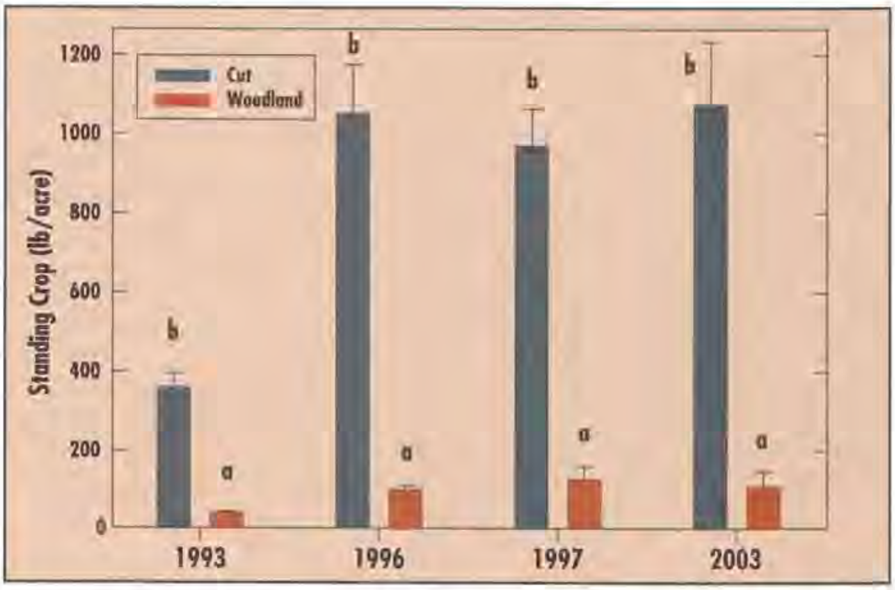


Figure 3. Herbaceous standing crop (lb/acre) in cut and woodland treatments in 1993, 1996, 1997, and 2003, Steens Mountain, Oregon. Data are in means plus one standard error. Significant differences between treatments are indicated by different lower-case letters.

Management Implications

The benefits of controlling juniper on rangelands are many. From a livestock production standpoint there is a large increase in available forage and management flexibility is improved. In this study, acres required per AUM (animal unit month) were reduced from 33 to 3 acres. Removing juniper presents managers with many options, including increasing stocking rates, improved livestock distribution, and providing proper post-treatment rest of areas where juniper has been controlled. Other ecological benefits, which are discussed elsewhere in this publication, include reducing runoff and soil erosion and increasing wildlife habitat that is lost when juniper dominates plant communities.

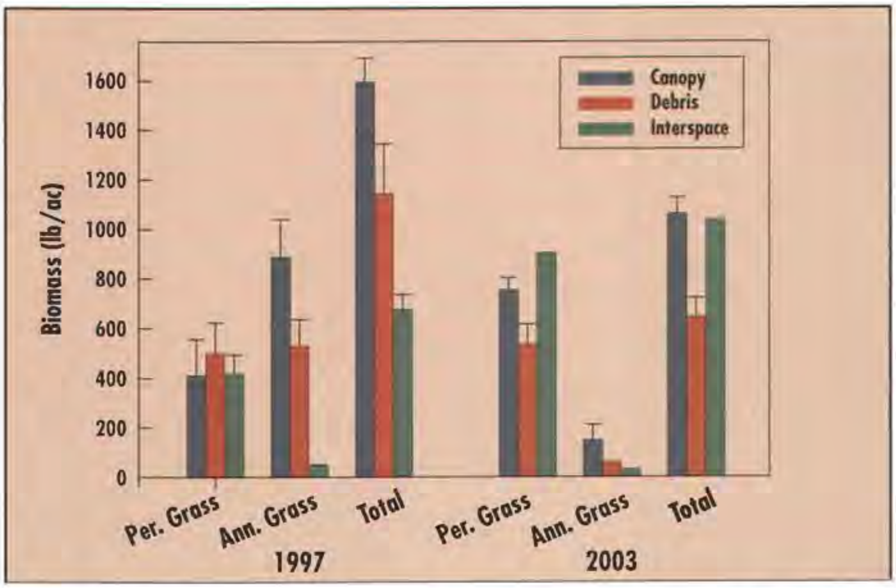


Figure 4. Functional group herbaceous biomass (lb/acre) by zone in 1997 and 2003, Steens Mountain, Oregon. Data are in means plus one standard error. Different lower-case letters indicate significant differences among zones. Functional groups are perennial grass (Per. Grass), annual grass (Ann. Grass), and total biomass (Total).

Juniper Control Using Combinations of Cutting and Prescribed Fire

Jon Bates, Rick Miller, and Roger Sheley

Introduction

During the past 20 years in eastern Oregon, western juniper has primarily been controlled by cutting and by prescribed fire. Chainsaw cutting is commonly used to remove trees in plant communities that lack sufficient fuel to carry fire through a stand. These woodlands are in mid- to late-successional stages where juniper competition has eliminated the shrub component and reduced understory production. Burning has been used in stands where sufficient ground fuels remain available to carry fire through the woodland and remove the majority of trees. Burning is most successfully applied in early to mid-woodland successional stages. Recently, Bureau of Land Management (BLM) districts in Alturas, California, and Burns, Oregon, have employed combinations of cutting and fire to remove juniper in later successional woodlands. The cutting is used to create a fuel base to carry prescribed fire through the remainder of the juniper stand.

Experimental Protocol

We developed three cooperative cutting, prescribed fire studies with Burns BLM, private landowners in Oregon and Idaho, and Idaho State Department of Lands. Projects are ongoing but our preliminary data are of value. The projects include Kiger Aspen Recovery, Upland Response to Cutting and Fire in Kiger Canyon, and South Mountain Idaho Juniper Control.

***Steens Aspen Recovery*:** Aspen stands below 7,000 ft are being replaced by western juniper in the northern Great Basin. Aspen woodlands are important for many wildlife species and aesthetically are part of the historical landscape. In a joint project with Burns BLM and Otley Brothers Ranch, we are assessing two juniper control treatments to recover aspen in Kiger Canyon, Steens Mountain, Oregon. Treatments include cutting one-third of the trees followed by early fall burning (Fig. 1) and cutting one-third of the trees followed by early spring burning. The project has evaluated the effectiveness of treatments at removing all junipers from seedling to mature trees. We are monitoring aspen recruitment, and shrub and understory cover and density response to treatment. Cutting followed by fall burning was completed in two stages. In the first stage, trees were cut in winter 2001 with fall burning applied in October 2002. In the second stage, trees were cut in spring 2003 with fall burning applied in October 2003. For the spring burning treatment, trees were cut in winter 2001 with burning applied in March 2002.

Upland Response to Cutting and Fire in Kiger Canyon: The objective of this study was to establish long-term monitoring of vegetation succession after fire in mountain big sagebrush communities. There is little long-term information available about vegetation dynamics after fire in areas previously dominated by juniper. Because the understory and shrub layers have been suppressed and depleted by competition with juniper, it may take longer for sites to recover than after historical fire disturbances. A joint project with Burns BLM and Otley Brothers Ranch was developed to assess juniper cutting and prescribed fire effects in five mountain sagebrush plant community types. All sites

Figure 1. Kiger Canyon prescribed fire, October 2001. Every third tree was cut to develop a fuel base to carry fire through the remainder of the woodland.

Figure 2. Fall burned aspen plot the first growing season after fire in Kiger Canyon.

were dominated by post-settlement juniper. Cutting was done in spring 2003, and involved dropping one-third of the trees to develop a fuel base. Pretreatment vegetation measurements were completed in July 2003. The area was prescribe-burned in October 2003.

***South Mountain Idaho Juniper Control*:** The project involved three levels of cutting followed by prescribed burning. Cutting manipulations were chainsaw cutting 25 percent, 50 percent, and 75 percent of mature post-settlement trees (trees are less than 100 years old). The objective of the prescribed fire was to kill as many remaining live trees as possible using the cut trees as a fuel base. Study sites were set up along the Juniper and Corral creek drainages on South Mountain, Idaho, in summer 2002. Sites were located on lands with private and public (Idaho Department of Lands) ownership. Two plant community types were selected. They included Western snowberry-mountain sagebrush/Idaho fescue-western needlegrass (deep soil sites) and Mountain sagebrush/western needlegrass (dry soil sites).

Pretreatment measurements of understory and overstory vegetation were completed in summer 2002. All sites were dominated by post-settlement juniper woodlands (trees are less than 100 years old) and lacked ground fuels to carry a fire without cutting. Uncut control woodlands were located adjacent to cut areas. Juniper trees were cut in October 2002. Temporary livestock exclusion fences were built around plots in May and June 2003. Prescribed fire was applied October 21–22, 2003. Burn conditions corresponded to typical BLM fire prescriptions. We established several seeding trials to test and compare natural recovery versus augmented rehabilitation. Seeding trials were developed on both plant community types, and we are evaluating establishment of three native grass species and three native forb species, alone and in combination, at rates of 15, 20, 25, and 30 lb/acre.

Results

Steens Aspen Recovery: Fall burning eliminated remaining juniper trees (seedling to mature trees) and resulted in the loss of most of the understory except for plants with growth points below ground and with fire-resistant seed (Fig. 2). Aspen response has been highly variable. The number of new aspen stems varied from 1,300 to 9,500 stems per acre. Aspen response appears to have been dependent on the condition and density of the pretreatment aspen stand.

Spring burning, which was a cooler burn, was not as successful at eliminating remaining juniper trees (10–20 percent of the mature trees remain). In addition, about 50 percent of the juniper seedlings survived the spring burn. There are enough seedlings present to redominate these stands in 70–80 years. The understory remained largely intact and growth was stimulated by removal of overstory competition.

***Upland Response to Cutting and Fire in Kiger Canyon*:** Fire removed most of the remaining live trees. Post-treatment measurements will begin in summer 2004. Results will focus on herbaceous colonization, diversity, and production; shrub dynamics; and speed of juniper reinvasion.

***South Mountain Idaho Juniper Control*:** Regardless of cutting treatment, the fire application was uniformly successful at removing remaining live junipers. We estimate that on the deep soil sites, the fire killed all remaining live trees. On the dry soil sites, we estimate that the fire killed 90–100 percent of the remaining live trees. Results indicate that cutting about 25 percent of mature trees was sufficient to remove the rest of the stand with fire. Post-fire vegetation monitoring will begin in summer 2004.

Management Implications

In areas where understory fuels are lacking, partial cutting of juniper to increase ground fuels, combined with prescribed burning in the fall, was extremely successful at removing remaining live trees. Results suggest that cutting 25–33 percent of the trees is sufficient to provide necessary fuel loads to carry fire through a stand. The amount of cutting required to develop ground fuels was 30–50 trees per acre. On our study sites, slopes were between 10 and 60 percent, which helped carry the fire upslope. More cutting may be required if working in areas that are flat. If the objective is to eliminate juniper, with minimal cutting, then we recommend communities be fall burned. If the objective is to maintain the shrub understory and keep a few mature junipers in the mix, then cooler spring burning is recommended. Spring burning may be especially useful in areas where the understory is depleted and needs to be maintained to promote more rapid recovery. However, with spring burning, follow-up management will be necessary to remove young junipers that are missed in the initial treatment.

Runoff and Erosion in Juniper Woodlands

Fred Pierson, Jon Bates, and Tony Svejcar

Introduction

The hydrologic impacts of western juniper expansion in the northwestern United States are not well quantified. Great variability in soils, geology, slopes, and precipitation patterns make it difficult to generalize the hydrologic response from one juniper-dominated stand or watershed to another. Mature juniper stands are believed to negatively impact surface hydrology and increase sediment yields. However, research documenting how western juniper expansion is affecting any of the specific components of the water budget is extremely limited. Neither the rate of hydrologic recovery nor the degree of understory needed to adequately protect a site following juniper removal have been determined.

Figure 1. There were eight replications of cut and uncut plots. In every case the uncut plots experienced runoff and erosion. This picture shows the rainfall simulator application on cut (left) and woodland (right) treatments.

Experimental Protocol

Our objectives in this study were to quantify the long-term impact of juniper cutting on infiltration, overland flow dynamics, and rill and interrill erosion rates. We compared hydrologic response of juniper-dominated plots with plots where the juniper had been cut 10 years earlier. A rainfall simulator was used to control water application (Fig. 1). Each simulation run required 9,000 gallons of water supplied by a tanker truck (Fig. 2). There were eight replications of cut and uncut plots. Each plot received two simulation events to assess

Figure 2. A 9,000-gallon tanker was required to supply water for each simulation run. It took 10 days to complete 16 simulation runs for the field portion of the project.

differences in response between treatments with dry and wet surface conditions. Water was applied at the rate of 2 inches per hour, which approximates a 100-year storm event.

Results

In every case, the uncut woodland plots experienced high runoff and erosion values. Plots dominated by juniper produce runoff from small thunderstorms that typically occur every 2 years on this site (Fig. 3). Only one cut plot produced measurable runoff. The event to produce this result was equivalent to a 50-year storm. Runoff on the woodlands was 25 times greater than on the cut treatment. For a large, 50-year return-interval thunderstorm, juniper-dominated hill slopes produced over 223 lb/acre of sheet erosion sediment compared to 0 lb/acre on the 10-year-old cut plots (Fig. 4). During large thunderstorms, rill erosion on the juniper-dominated hill slopes was over 15 times greater than on the hill slopes without juniper.

The cutting of juniper allows understory vegetation to reestablish, resulting in increased infiltration that protects the soil surface and helps retain both water and soil on site.

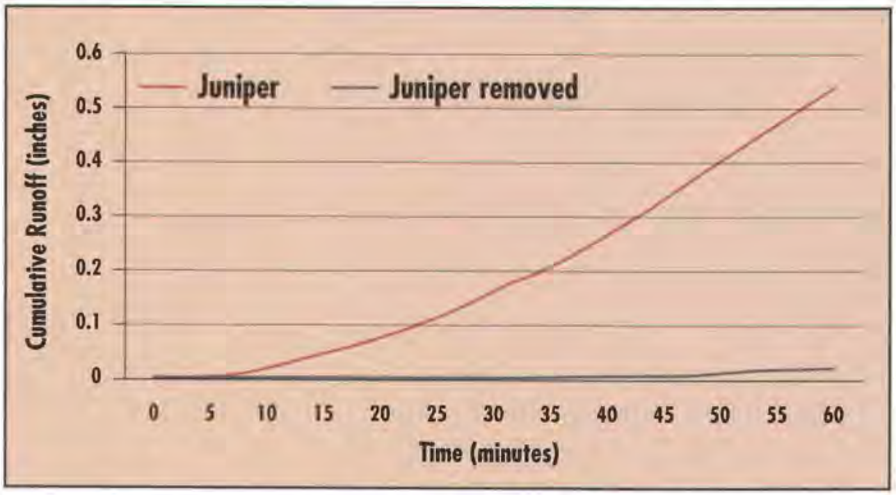


Figure 3. Cumulative runoff over a 1-hour time period. Runoff in the juniper woodland is 25 times greater than in the juniper removed (trees cut and left on site) treatment.

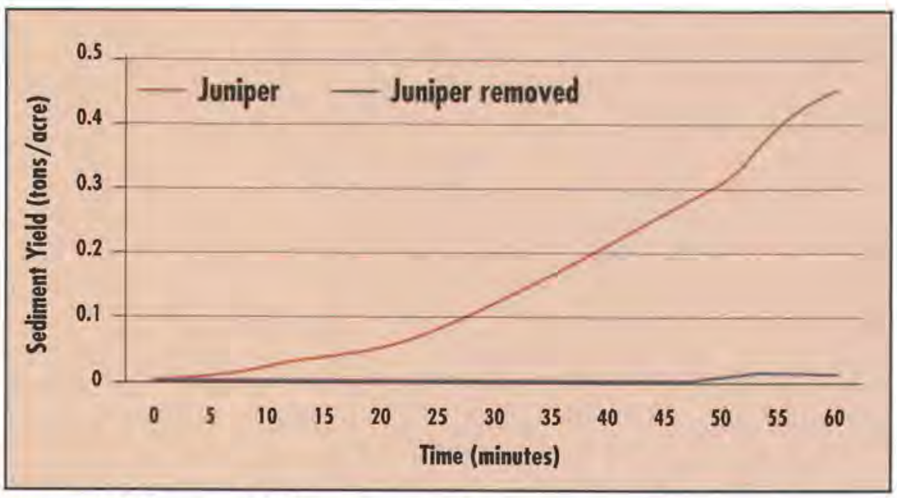


Figure 4. Sediment yield (lb/acre) over a 1-hour time interval.

Management Implications

The cutting of juniper allows understory vegetation to reestablish resulting in increased filtration which protects the soil surface and helps retain both water and soil on site.

Nitrogen Cycling in Cut Juniper Woodlands

Jon Bates, Tony Svejcar, and Rick Miller

Introduction

Western juniper expansion into sagebrush grassland alters the spatial distribution of soil organic matter and nutrients by concentrating them in litter and soils beneath tree canopies. The concentration of nutrients and organic matter in canopy soil and litter layers is thought to be physiologically advantageous for juniper by enhancing their already strong competitive abilities for water and nutrients with associated vegetation. However, very little research has evaluated how the redistribution of nutrients in juniper woodlands affects nutrient cycling and availability. Another question to address is whether the redistribution of nutrients affects understory recovery of a site after juniper is removed.

Experimental Protocol

The purpose of our study was to assess the effect of the sudden removal of overstory juniper on soil nitrogen (N) availability and N mineralization, and how this may affect understory recovery. Nitrogen availability has received the most attention in the literature because N is assumed to be the most limiting soil nutrient in wildland systems. We evaluated the influence of juniper on soil N dynamics in cut and uncut woodlands by microsite. Microsites in the cut were interspace, debris, and canopy. Microsites in the woodlands were canopy and interspace. Sampling was conducted the first 2 years after cutting. The first sample year was a moderately dry year and the second sample year was a very wet year. Measured parameters included plant extractable N (nitrate [NO_3^-] and ammonium [NO_4^-]),nitrification, N mineralization, total soil carbon and N, and herbaceous biomass and N content.

Results and Discussion

Treatment differences were limited to the first year post-cutting. The initial effect of juniper cutting was an increase in extractable N, but by the second year post-treatment, differences for the N variables among treatments and microsites were not apparent. In the dry year, extractable N and N mineralization were higher in the cut versus the woodland interspaces (Fig. 1). In the wet year, extractable N and N mineralization did not differ among the treatment microsites. Canopy and debris zones had lower N mineralization than intercanopy zones in the dry year.

The effect of year, dry versus wet, tended to overwhelm the effect of juniper removal. There were strong seasonal patterns of N mineralization that were independent of treatment or microsite (Fig. 1). In the dry growing season, N mineralization was higher than other periods and there was a large buildup of available N in soils. The buildup of available N during dry periods is not unusual in arid systems and is caused by lack of plant uptake and large die-offs of soil microorganisms.

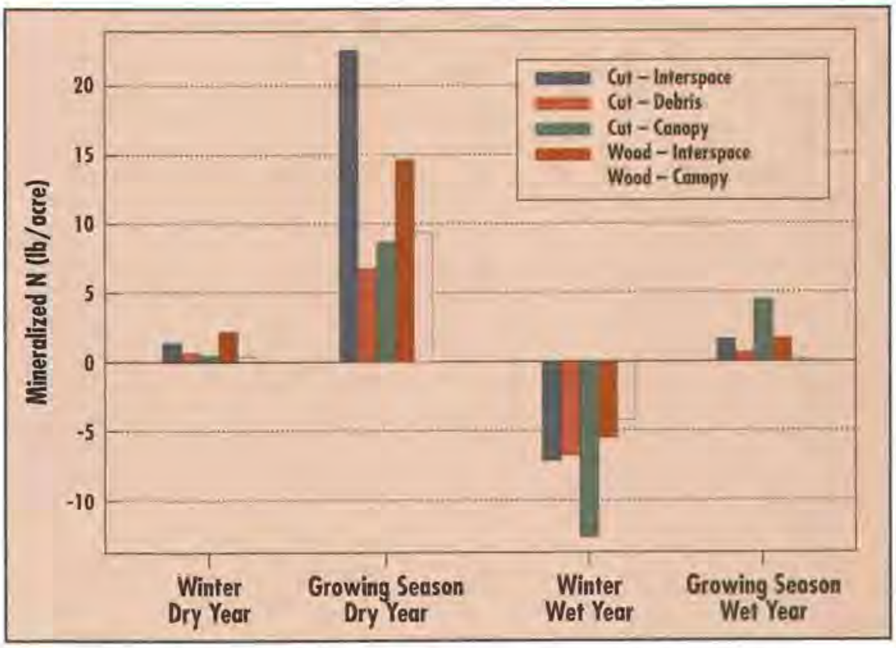


Figure 1. Seasonal soil nitrogen (N) mineralization/immobilization totals by treatment and microsite. Positive values indicate net N mineralization. Negative values (winter-wet year) indicate net N immobilization.

In the second winter (wet year), all zones had high levels of N immobilization or losses. A management concern after tree cutting in woodland and forested systems is the potential for increasing loss of soil N, primarily in the form of NO_3^-, which is highly mobile in soils. However, the methods we used to assess available N fractions and N mineralization indicate that most of the N that was "lost" during the second winter was taken up by soil microorganisms and immobilized on site and not lost by leaching or denitrification.

The effects of felling juniper trees on juniper litter decomposition and N release was examined over the same 2-year period. Litter decomposition was 37 percent greater in the cut treatment than in the woodland. Greater litter inputs and higher litter quality from juniper slash caused a priming effect, resulting in the higher decomposition rates in cut woodlands. The increase in litter decomposition in the cut treatment did not result in an earlier release of litter N. Nitrogen was limiting for decomposers under juniper debris, resulting in the importation and immobilization of litter N. Retention of N in litter in the early stages of decomposition following cutting may serve as an important sink that conserves N on site. In the woodlands, 20 percent of litter N was removed, indicating that N was not limiting during litter decomposition. The results also indicated that there was no fixed carbon/N ratio determining the timing of N release from juniper litter.

Management Implications

Despite the low availability of N in the second growing season and the retention of N in juniper litter, there was no indication that N was limiting for plant growth in the cut treatment. Herbaceous plants in the cut treatment had significantly greater N concentrations, and total biomass N uptake was nine times greater than for plants in the woodland treatment. The formation of resource islands in the woodland did not confer any benefits to the herbaceous and/or shrub understory as long as the trees remained in place. The benefits of higher resource availability were not realized until trees were cut. When trees were removed, herbaceous productivity and cover were significantly greater in canopy (resource island)-influenced soils compared to intercanopy zones.

Wyoming Big Sagebrush Cover Types in Eastern Oregon:
Ecological Potentials and Sage-grouse Guideline Habitat Requirements

Kirk Davies, Jon Bates, and Richard Miller

Introduction

Plant cover and composition are often the key attributes for describing wildlife habitat requirements. Developing vegetation guidelines for wildlife requires a detailed understanding of wildlife interactions with plant communities at many scales and over time. However, this knowledge is often lacking, thus, developing applicable habitat management guidelines for wildlife is often difficult and contentious.

Sage-grouse habitat guidelines based on plant cover have recently been developed for sagebrush communities of eastern Oregon. Many plant ecologists and land managers have questioned their appropriateness and applicability, for a number of reasons. First, sage-grouse-vegetation cover relationships tend to be based on a relatively small scale without adequate description of plant communities at the stand or landscape level. Habitat guidelines based on specific microsite cover requirements may not reflect the cover potential and variability of sagebrush communities at larger scales. Most rangeland vegetation surveys tend to focus on larger areas to describe plant communities. Preliminary evidence suggests that sagebrush cover is significantly overestimated when using smaller-scale measurements (Eastern Oregon Agricultural Research Center file data). Second, because of a lack of data for our region, guidelines have also been based on results from studies conducted outside of our area, which may not reflect cover potentials in sagebrush systems of eastern Oregon. Development of appropriate management guidelines and strategies for sagebrush obligate and facultative wildlife species requires up-to-date information on ecological site potentials within the sagebrush alliance. Surprisingly, there is a lack of information regarding the range, variability, and biological potential of vegetation characteristics within the big sagebrush alliance, particularly the Wyoming big sagebrush cover type.

Experimental Protocol

Our goal was to improve knowledge of the ecological potentials of the Wyoming big sagebrush type in the northern Great Basin. The Wyoming big sagebrush cover type was once the most extensive of the big sagebrush types but it has been severely impacted in many areas by past land use and the introduction of nonnative weeds. We chose to focus the study in the Wyoming big sagebrush cover type because it has received limited attention in large-scale vegetation cover surveys in the region and because among big sagebrush community types it has the greatest potential to be impacted by sage-grouse habitat guidelines. Our objectives were to 1) fully describe vegetation/soil characteristics at the stand level and develop an appropriate community classification system for the Wyoming big sagebrush alliance, and 2) compare stand-level cover characteristics with sage-grouse habitat requirements.

In 2001 and 2002, 107 high-ecological-condition sites were sampled, mostly in the High Desert and Owyhee ecological provinces. Several sites also were located in the northern region of the Humboldt Ecological province and Oregon portion of the Snake River province. Thirty-two of these sites were resampled in 2003 to begin assessing climatic effects on plant cover, production, and composition. Sites were divided into five associations based on differences in the abundance of dominant perennial bunchgrass species. Associations within the Wyoming big sagebrush cover type were 1) bluebunch wheatgrass, 2) Thurber's needlegrass, 3) Idaho fescue, 4) needle-and-thread, and 5) bluebunch wheatgrass/Thurber's needlegrass codominance (codominance required the species with the lower cover to contribute at least 40 percent of its combined cover). The bluebunch wheatgrass association was the most extensively sampled with 63 sites, second was the Thurber's needlegrass association with 16 sites, third was the Idaho fescue association with 14 sites, and both the needle-and-thread and the bluebunch wheatgrass/ Thurber's needlegrass associations had 7 sites.

Results and Discussion

Analysis of functional group (perennial grass, Sandberg bluegrass, perennial forbs, annual forbs, annual grass) cover illustrated vegetation differences among associations (Table 1). Analysis of species composition within associations, after excluding dominant perennial grass species used for grouping, was more homogenous than expected by chance. Inclusion of the dominant perennial grass species in the analysis increased the similarity within associations. Sites within an association tended to have similar plant species present. Thus, differences in functional group cover and species composition indicate that separating the Wyoming big sagebrush alliance by dominant grass species associations is appropriate.

Of the 107 sites, and with a strict interpretation of the plant cover guidelines, none of the high ecological condition sites would meet sage-grouse nesting and brood-rearing habitat requirements (Table 2.). The main reasons for this are 1) tall forb cover did not equal or exceed 10 percent on any sites, and 2) sagebrush cover exceeded 15 percent on less than a quarter of the sites. Rarely did tall forb cover exceed 5 percent in these communities. Sagebrush live cover exceeded the 15 percent cover requirement on 24 plots. However, if dead sagebrush cover was included, then an additional 37 sites would meet sagebrush cover requirements. Either not enough sites were sampled or the unique environmental characteristics necessary to support the required combination of cover values were not present in the Wyoming sagebrush alliance. However, the years when sampling occurred were drier than average, which may explain the low forb cover values measured. Our long-term monitoring study will continue over the next 9 years, and we may be able to develop a relationship between climate and forb cover. However, based on our stand-level surveys, the management guidelines for sage-grouse nesting and optimum brood-rearing habitats appear to be largely unachievable within the majority of the Wyoming big sagebrush alliance across the ecological provinces studied.

Management Implications

The limited potential of the Wyoming big sagebrush alliance to meet nesting and optimum sage-grouse cautions against adopting current guidelines to direct management decisions in our region. Recognizing the ecological potential of Wyoming big sagebrush across its range may result in the development of better management and more realistic management guidelines.

Table 1. Vegetation functional groups mean percent cover by association.

Functional group	*Bluebunch wheatgrass*	*Thurber's needlegrass*	*Needle-and-thread*	*Idaho fescue*	*Bluebunch/ Thurber's mix*
Poa species	6.0 A[1]	4.8 AB	1.6 C	4.5 B	6.7 A
Perennial grass	11.9 B	8.8 C	11.0 BC	19.4 A	9.4 C
Annual grass	0.8 A	0.4 AB	0.8 A	0.02 B	0.7 A
Perennial forb	4.8 A	2.5 B	0.3 C	4.4 A	5.0 A
Annual forb	0.6 AB	0.8 AB	0.2 B	0.4 AB	0.4 A
ARTRwyo[2]	12.0 B	13.5 B	9.9 B	11.1 B	16.8 A

[1] If the same letter follows the means of a functional group in different associations, there is no statistically significant difference in that functional group between those associations ($p > 0.05$). If the letter following the functional group mean in one association does not follow the functional group mean in another association, then there is a statistically significant difference between them ($p < 0.05$).
[2] ARTRwyo = Wyoming big sagebrush

Table 2. Sagebrush alliance canopy cover requirements for sage-grouse habitat.

Habitat	*Sagebrush cover*	*Perennial grass cover*	*>18-cm-tall forb cover*
Nesting	15–25%	15% or greater	10% or greater
Optimum brood-rearing	10–25%	15% or greater	10% or greater

Source: Bureau of Land Management, United States Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, and Oregon Division of State Lands. 2000. Greater sage-grouse and sagebrush-steppe ecoystem: management guidelines. August 21, 2000. p. 27.

Mountain Big Sagebrush Reestablishment Following Fire

Lori Ziegenhagen and Richard Miller

Introduction

It is a challenge for land managers to plan long-term fire management programs because there is a lack of information on natural sagebrush reestablishment and recovery rates. To better forecast natural post-fire recovery, we need to understand the variability of sagebrush reestablishment and develop predictive models for recovery timelines.

Experimental Protocol

This study examined mountain big sagebrush recovery on 16 large, uniform burns between 2 and 42 years old. These fires were located in mountain big sagebrush communities in southeast Oregon, northwest Nevada, and northeast California. Mountain big sagebrush is a subspecies of big sagebrush that, in this region, grows on higher elevation (>4,500 ft) sites with more than 12 inches of annual precipitation. We measured the percent canopy cover and shrub density on over 175 burned sites and aged 1,400 mountain big sagebrush to determine each shrub's year of establishment.

Results and Discussion

Rates of recovery for mountain big sagebrush canopy cover and density were highly variable, and reestablishment of seedlings following fire occurred in three phases. Live canopy cover of sagebrush increased approximately 3.5 times with each doubling of fire age. In other words, a 5-year-old burn with 2 percent canopy cover would have approximately 7 percent at 10 years and 24.5 percent at 20 years after the fire. Similarly, sagebrush densities increased around 900 shrubs/acre with each doubling of fire age. These rates of increase are only estimates, and fire age explained about 36–57 percent of the variation we saw across the landscape. (For a detailed list of the recovery formulas, please refer to: L.L. Ziegenhagen. 2004 M.S. Thesis. Oregon State University, Corvallis).

Although these formulas suggested that mountain big sagebrush cover and density increased in smooth lines, recovery actually occurred in pulses. Our study suggested that on large, uniform burns, post-fire mountain big sagebrush reestablishment occurred in three phases (Fig. 1). Phase one is the opportunity for immediate shrub establishment from seed that survived the fire on

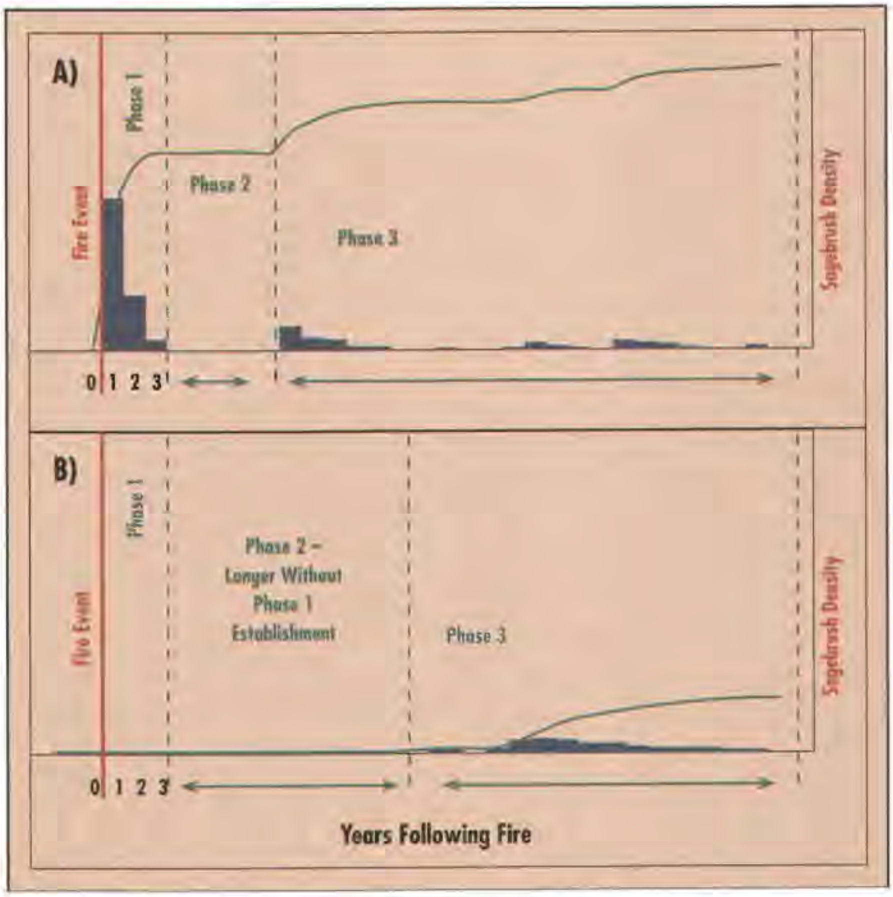


Figure 1. The three phases of shrub reestablishment following fire: A) an example fire with large initial establishment from soil seed pools, and B) an example that was missing establishment in Phase One. Fire B relied upon unburned communities for shrub reestablishment. The red vertical line represents the year of the fire. Dashed vertical green lines separate post-fire establishment phases. Gray bars represent the percent of the total sagebrush to establish each year following the fire. The solid line is a running total of sagebrush established. Years are in "crop years" (Oct.–Sept.).

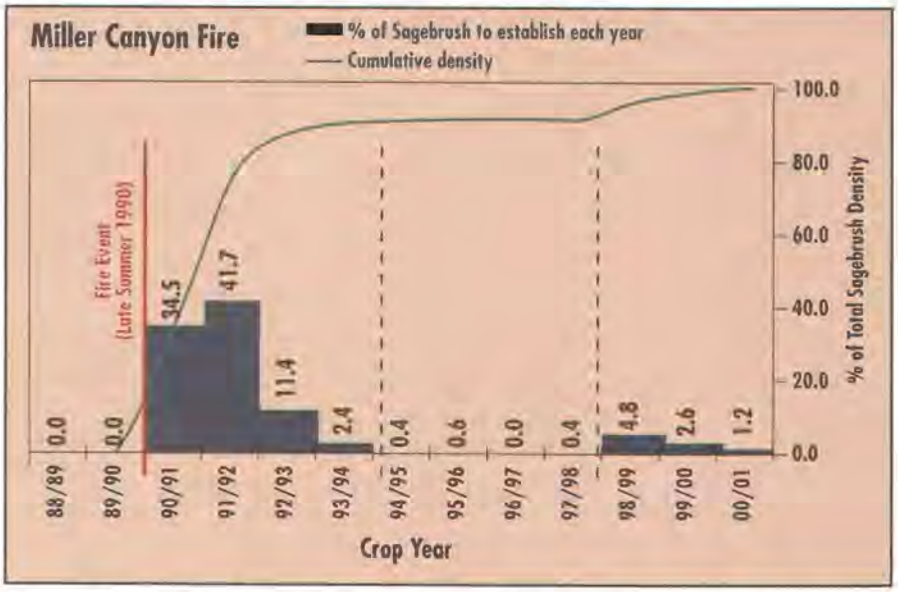


Figure 2. Example of the Three Phases of Shrub Reestablishment on Miller Canyon, a burn located near Burns, Oregon. The red vertical line represents the year of the fire. The dashed vertical green lines separate post-fire establishment phases and the grey bars represent the percent of the total sagebrush on Miller Canyon that established each year following the fire. The solid green line is a running total of sagebrush establishment as it approaches the total. In 2000/01 sagebrush density was approximately 1,700 shrubs/acre. Years are in "crop years" (Oct.–Sept.).

the soil surface (soil seed pools). Phase two is a lull in shrub establishment and phase three begins when newly established shrubs are mature enough to produce new seed. The Miller Canyon Fire near Burns, Oregon (Fig. 2), illustrates these three phases of reestablishment. The length of phase two is determined greatly by the success or failure of soil seed pools to establish seedlings during phase one. Without successful establishment during phase one, phase three begins only after sagebrush seed from adjacent unburned communities migrates into the interior of these large burns. Mountain big sagebrush seed dispersal is limited to only a few yards from the parent plant and migration across a landscape is a slow process.

Management Implications

Many fire-management programs require a target canopy cover across a given landscape and a given acreage to be burned every year. In our study region, mountain big sagebrush required, on average, 36 years after a fire to acquire a canopy cover of 25 percent. However, more importantly, the range of time needed for this recovery to occur was 25–57 years. Although recovery rates were highly variable, results did emphasize the importance of soil seed pools in establishing mountain big sagebrush during the years immediately following a fire. Higher densities at the end of phase one of post-fire establishment would lead to a faster recovery rate in following years. If shrub densities after 2–4 years were below target level, predictions of the recovery timeline should be lengthened and the timing of future burning projects across the landscape reevaluated. Furthermore, the availability and size of soil seed pools (the size of the previous fall's seed crop) should be considered when planning a proper time to burn mountain big sagebrush sites.

Carbon Dioxide Flux on Sagebrush Rangeland in Eastern Oregon

Raymond Angell, Tony Svejcar, and Jon Bates

Introduction

Atmospheric carbon dioxide (CO_2) is taken up by plants and is utilized through photosynthesis to create sugars that are later used to grow leaves, stems, and roots. Carbon dioxide concentration in the atmosphere is steadily increasing for various reasons, but burning of fossil fuels provides the major contribution to this increase. Plants buffer this increase by assimilating atmospheric CO_2. Scientists have attempted to balance the distribution of CO_2 between what are called sources and sinks. Sources release CO_2 into the air; sinks remove it from the air.

Rangelands occupy about 50 percent of the world's land surface area and could play an important role in the global carbon cycle. They are less productive than forested systems, but because of their extensive distribution they have the potential to sequester significant amounts of carbon. Sagebrush-steppe occupies more than 88 million ha in western North America, but very little is known about the magnitude and seasonal dynamics of CO_2 uptake by plants. We initiated this study to measure the flux over this important ecosystem as influenced by environment and management.

Figure 1. Bowen ratio energy balance instrumentation (Model 023/CO_2 Campbell Scientific, Inc., Logan, Utah, USA)

Experimental Protocol

Measurements began in 1995 and are continuing through 2006 in an effort to determine the effect of climatic variability on CO_2 fluxes. The study was established on sagebrush-steppe at the Northern Great Basin Experimental Range (43° 29'N 119° 43'W; 1,380 m elevation), about 64 km west of Burns, Oregon. The study site was a 160-ha ungrazed Wyoming big sagebrush (*Artemisia tridentata* Nutt. subsp. *Wyomingensis*) community (10 percent canopy cover). Understory species include Thurber's needlegrass (*Stipa thurberiana* Piper), bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), Sandberg's bluegrass (*Poa sandbergii* Vasey), bottlebrush squirreltail (*Sitanion hystrix* [Nutt.], Smith), prairie lupine (*Lupinus lepidus* Dougl.), hawksbeard (*Crepis occidentalis* Nutt.), and longleaf phlox (*Phlox longifolia* Nutt.). Livestock have not grazed the community since 1995. Above-canopy 20-minute-average CO_2 flux was measured continuously using Bowen ratio energy balance instrumentation (Model 023/CO_2, Campbell Scientific, Inc., Logan, Utah, USA) (Fig. 1). Bowen ratios were calculated from temperature and humidity data. The turbulent diffusivity, assumed equal for heat, water vapor, and CO_2, was then calculated. Average CO_2 fluxes were calculated as the product of turbulent diffusivity and the 20-minute CO_2 gradient, correcting for vapor density differences between the arms of the system. Samples were obtained at 75 and 175 cm above the ground. Negative values indicate plant uptake of CO_2 (flux toward the surface).

Results and Discussion

This region is characterized by a short period of adequate soil moisture in spring, followed by summer drought. Active CO_2 uptake generally begins in April. Peak CO_2 uptake occurs in May and June, with lower flux rates in July and August (Fig. 2). Coincident with maximum forage yield, average daily uptake usually peaks in late May at about 5 g CO_2 m^{-2} d^{-1}, and then steadily declines, approaching zero in September. Plant growth during July and August varies greatly among years, based on soil water content and results in large variations of CO_2 flux between years. Also, this region can experience freezing nighttime temperatures during the growing season, resulting in damage to plant tissues. In June 1996, freezing nighttime temperatures (-6°C) occurred during peak growth on two consecutive nights. Following the frost, CO_2 released to the atmosphere exceeded uptake by plants and the site became a source of CO_2 for the year.

Figure 2. Five-year average monthly carbon dioxide flux over ungrazed sagebrush-steppe on the Northern Great Basin Experimental Range in southeast Oregon. Negative flux is toward the surface.

Annual CO_2 flux on this site has averaged -0.2 kg CO_2 m^{-2} y^{-1}, indicating that this plant community is a CO_2 sink, although this may be an overestimate because we have not experienced a severe drought during this study. Annual CO_2 fluxes have ranged from 0.3 to -0.5 kg CO_2 m^{-2} y^{-1}. These values are about half of the 1.1 kg CO_2 m^{-2} y^{-1} reported for tallgrass prairie, reflecting the lower productivity of these semiarid rangelands.

Implications

Based on data obtained here, sagebrush-steppe ecosystems in the northern Great Basin usually are sinks for atmospheric CO_2, and are sequestering carbon in the soil. Even though the magnitude of annual CO_2 uptake is smaller than in ecosystems with longer growing seasons, this uptake is important because of the large number of acres covered by sagebrush-steppe in western North America.

Effects of Altered Precipitation Timing on Sagebrush-Steppe Communities

Jon Bates, Tony Svejcar, Rick Miller, and Ray Angell

Introduction

Alteration of precipitation patterns and inputs as predicted by general circulation models has the potential to cause major changes in productivity, composition, and diversity of terrestrial ecosystems. Current climate models have shown little agreement as to the potential impacts to our region of predicted climate warming. Models predict that with climate warming, our area may receive more summer or more winter precipitation. However, in our region the timing and amount of precipitation already are extremely variable from year to year. Climate has a huge impact not only on forage production but on assessment of rangeland condition. Thus, land managers face a big challenge in separating the effects of management from those of climate. Unfortunately, changes in rangeland condition frequently are assumed to be a result of management rather than climate.

Experimental Protocol

We evaluated vegetation response to altered timing of precipitation during a 7-year study in a Wyoming big sagebrush community. Four permanent rainout shelters and an overhead sprinkler system were used to control water application and seasonal distribution. Precipitation treatments under each shelter were WINTER, SPRING, and CURRENT. The WINTER received 80 percent of its water between October and March; 80 percent of total water added to the SPRING treatment was applied between April and July; and the CURRENT treatment received precipitation matching the site's long-term (50-year) distribution pattern. A CONTROL treatment, placed outside each shelter replicate, received natural precipitation.

Current ecological thought is that summer precipitation will favor shallower-rooted grasses over deeper-rooted sagebrush, with winter precipitation favoring shrubs over grasses. The basis for this reasoning is that in climates with summer precipitation, prairie ecosystems exist (e.g., the Great Plains), and in areas with a winter pattern of precipitation, shrubs are dominant (e.g., the Great Basin).

Results and Management Implications

In this study, plant community composition and productivity were significantly influenced by the precipitation treatments. A shift in precipitation distribution to a spring/summer pattern (SPRING treatment) had the greatest potential for altering the composition and structure of sagebrush-steppe vegetation (Fig. 1). This result contrasted with our initial hypothesis that shallower rooted grasses would gain a competitive advantage over shrubs if precipitation was shifted from winter to spring. The SPRING treatment had lower production,

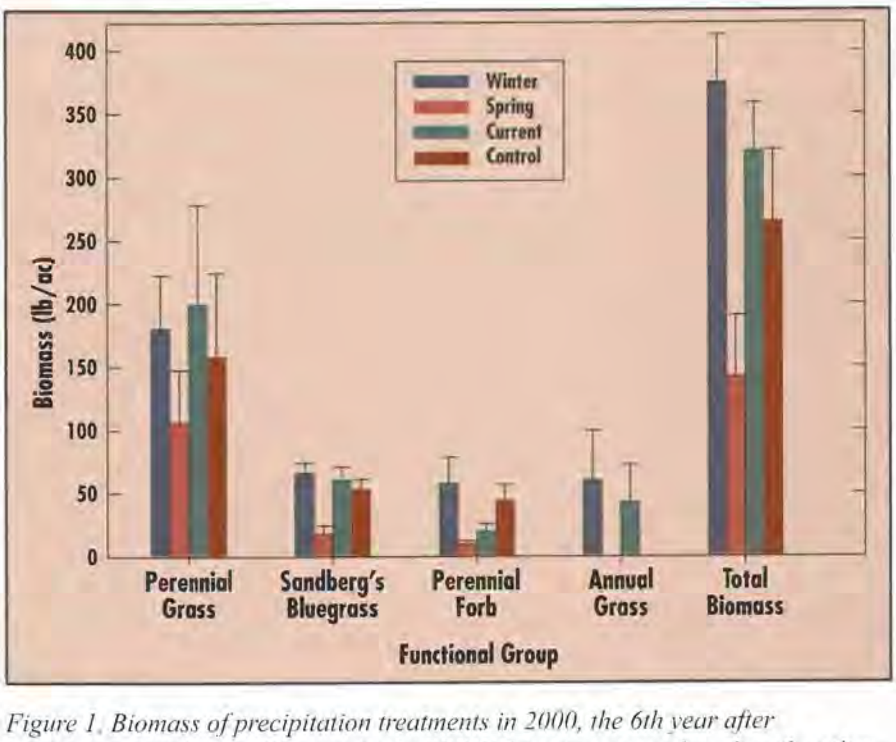


Figure 1. Biomass of precipitation treatments in 2000, the 6th year after treatments were begun. Biomass in the SPRING treatment was less than the other treatments for all functional groups.

more bare ground, and lower rangeland condition than the other treatments. Annual and perennial forbs native to the system were the most susceptible to a shift to more spring/summer moisture, declining in density, cover, and biomass. A long-term shift to a spring/summer-dominated precipitation pattern would lead to the forb component being lost or severely reduced. Without alternative summer-active species, the loss of cool-season forbs would adversely impact many wildlife species whose diet for at least part of the year is dependent on forbs. In addition, the decline in forage production under this scenario would adversely affect livestock operations. A shift to more winter precipitation did not significantly alter the competitive balance in the sagebrush-steppe, though many species responded favorably to this scenario. This is because the WINTER precipitation regime more closely conformed to long-term precipitation patterns for the site. In the WINTER treatment there was a significant increase in cheatgrass, but we attribute this to the "shelter effect" rather than to the precipitation treatment itself. Had the WINTER treatment been exposed as was the CONTROL, we are confident that cheatgrass would not have responded as favorably, because of colder temperatures and surface frost activity. However, if temperatures increase as predicted by general climate models, the potential exists for increased annual grass establishment into areas where it is still a minor component of the sagebrush system.

Russian Knapweed Control Is Improved by Mowing Prior to Fall Herbicide Application

Michael Carpinelli

Introduction

Russian knapweed (*Acroptilon repens*) is a perennial weed that forms dense colonies from adventitious shoots arising from an extensive root system. It infests some of the most productive pasture and hayland of the Great Basin. Past efforts to control this species has had limited success. Fall application of a persistent, soil-active herbicide may be an effective way to control Russian knapweed growth the following year. In past research, control of other perennial weed species by mowing prior to fall herbicide applications produced inconsistent results. In this study, we tested mowing alone and two persistent, soil-active herbicides with and without mowing.

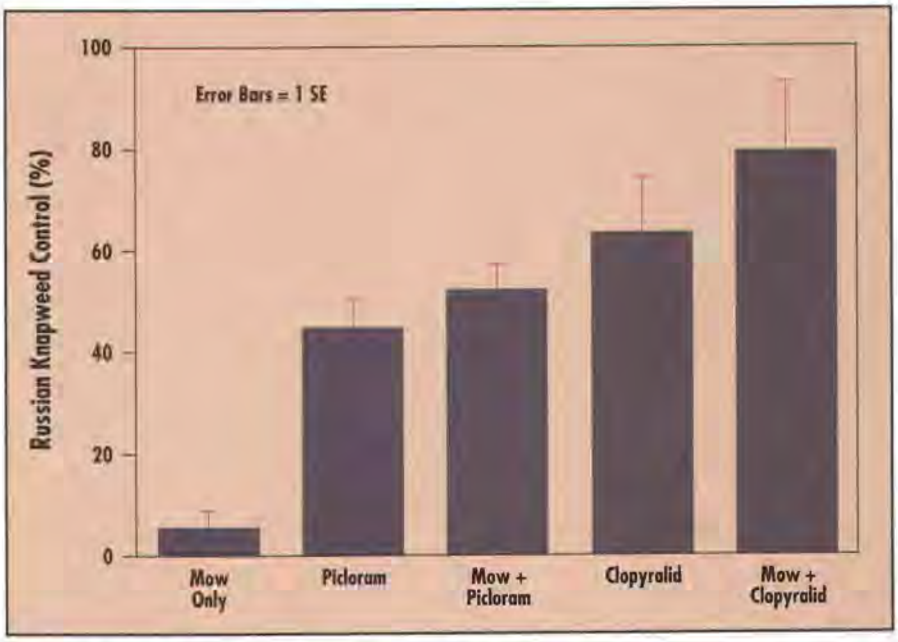


Figure 1. Mowing prior to herbicide application improved Russian knapweed control with both picloram (Tordon®) and clopyralid (Transline®).

Experimental Protocol

In Novemer 2001, picloram (1 quart/acre Tordon®) or clopyralid (1 pint/acre Transline®) was applied with and without mowing to a Russian knapweed-infested pasture near Burns, Oregon. Two other treatments, mow-only and untreated, also were included. Mow-only and mow-herbicide treatments were done with a Brown Brush Monitor,™ which mows and applies herbicide in a single pass and deposits the cuttings in a narrow row to one side of the swath path. Herbicide-only application was made with a boomless nozzle mounted on the back of an all-terrain vehicle. Visual estimates of Russian knapweed control were made in summer 2002.

Results and Discussion

Russian knapweed control using Tordon® or Transline® was improved when mowing preceded herbicide application. Mowing may have increased herbicide efficacy by removing standing dead plants and allowing more herbicide to reach the soil, where it was taken up by plant roots the following spring.

Management Implications

Mowed cuttings that evenly cover the soil surface may interfere with herbicide-soil contact. For this reason, mowing with conventional equipment may not increase efficacy of fall-applied herbicide unless the cuttings are windrowed. Using the Brown Brush Monitor® may enhance herbicide efficacy by increasing the amount of herbicide that reaches the soil. Increased herbicide in the soil in the fall makes more get into plants the following spring.

Grazing as a Management Tool for Perennial Pepperweed

Michael Carpinelli

Introduction

Perennial pepperweed (*Lepidium latifolium*) is a Eurasian weed that spreads from seed, as well as from new stems arising from its creeping root system. It invades productive habitats such as flood meadows, riparian areas, and wetlands in most western states, where it displaces desirable forage species. It is possible that grazing may be used to control perennial pepperweed. Livestock may be especially effective in areas that are inappropriate for chemical or mechanical control, such as riparian areas and wetlands.

Current research is comparing the effects of grazing perennial pepperweed-infested flood meadows by cattle, sheep, and goats at different times of the year. The goal is to determine which animal species and which season of grazing best controls perennial pepperweed while favoring desirable forage species. Preliminary observations show that all three animal species will eat perennial pepperweed before, during, and after flowering. If livestock are used in control efforts, there is a concern that the animals may ingest seeds that may then be spread to uninfested areas. The goal of this study was to determine the viability of perennial pepperweed seeds after passage through the digestive tract of ruminants.

Experimental Protocol

Prior to performing a standard germination test, perennial pepperweed seeds were incubated in the rumens of fistulated steers for 48 hours. Germination tests also were conducted on seeds that were soaked in water for 48 hours and seeds that were not soaked.

Results and Discussion

Ruminal incubation or soaking in water increased germination more than 10-fold compared to seeds that were kept dry prior to the germination test. Germination of seeds that were ruminally incubated was similar to that of seeds soaked in water. If livestock graze perennial pepperweed that has gone to seed, they should be held on weed-free forage for about 1 week prior to being moved to uninfested areas; otherwise, viable perennial pepperweed seeds may be deposited in their dung. The spread of perennial pepperweed may be reduced by controlling it in areas where its seeds may be transported by water (riparian areas, flood meadows, and irrigation ditches).

Management Implications

Ideally, it may be best to graze perennial pepperweed at or before flowering to reduce the likelihood that animals ingest their seeds.

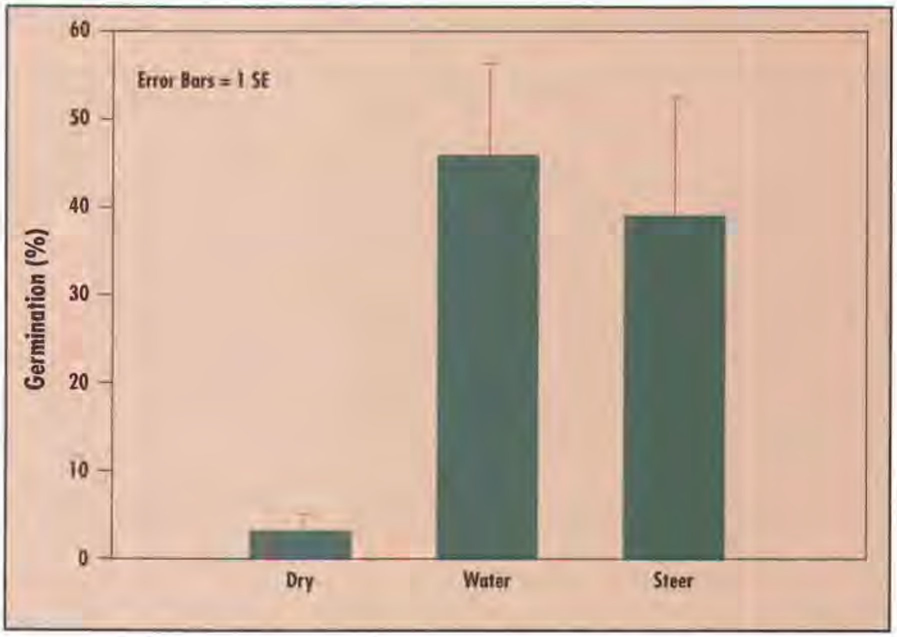


Figure 1. Germination of perennial pepperweed seeds that were soaked in water or ruminally incubated increased about 10-fold compared to seeds that were kept dry prior to being tested for germination.

Seed Development of Perennial Pepperweed Plants Growing in Flood Meadows

Mark Reynolds, Tony Svejcar, Paul Doescher, Dale Brown, and Dave Courtney

Introduction

Knowledge of seed characteristics is important for developing control strategies for weeds. A species of recent interest is perennial pepperweed (*Lepidim latifolium)*, which has the ability to dominate some of the most productive ecosystems of the West, such as wetlands and riparian zones. It also is an increasing problem in hay meadows of this region. There is concern that hay from pepperweed-infested fields may contain viable seed that could be spread to noninfested areas. The species is difficult to control because of a persistent rootstock that is resistant to many herbicides and is able to readily sprout after mechanical top removal and tillage of infested soils. Pepperweed has been reported to be slow to spread, although dissemination can be rapid and widespread in flood events.

This study was designed to evaluate the germination of perennial pepperweed seed collected on various dates to determine the likelihood that the plant will be spread in hay from infested fields.

Experimental Protocol

Pepperweed seed was collected at four sites, each within 2 miles of the Eastern Oregon Agricultural Research Center (EOARC) in Burns, Oregon, during the 1997 and 1998 growing seasons. All sites were flood meadow communities that contained perennial pepperweed and were not cut for hay. Seed was collected weekly from mid-July to mid-September of 1997 and 1998. Seed was left in the stalk until the spring of 1999 in order to simulate storage conditions of harvested hay.

Seeds collected at the four sites during the growing season were germinated under optimum conditions (alternating 8 hours light at 86°F and 16 hours dark at 68°F) determined by initial germination trials (EOARC file). The germination trial presented here was run for 17 days to allow for complete germination of all viable seed.

Results and Discussion

Assessment of the different collection dates and locations revealed lowest germination for the earliest collection dates and the highest germination at the later dates (Tables 1 and 2). There was a large increase in germination rate during late July and early August.

The initial work required to establish the germination requirements of this species resulted in some interesting observations. For example, seed that was soaked in water overnight produced a very thick gelatinous coat that allowed the seed to float. The expanded seed coat also elevated the seed off the container surface. These seed characteristics illustrate how the dissemination of perennial pepperweed seed may be accomplished during flood events. The results also demonstrated that late cutting (August and September) creates a risk of baling hay that contains viable perennial pepperweed seed.

The spring of 1998 was cooler and wetter than 1997. Therefore, seed development may have been slowed or suppressed and may account for lower germination percentages for seed collected during the 1998 growing season, especially seed collected on July 28 and August 5. There also appeared to be a higher proportion of seeds collected in 1998 that were infected with a fungus. The fungus may have contributed to lower germination levels in 1998, especially from sites 2 and 3 during the last sampling.

Management Implications

Flood meadows that are infested with perennial pepperweed and cut for hay should be cut as early as possible. If hay from infested fields is cut after late July, movement of the hay should be carefully monitored to avoid contamination of clean fields.

Table 1. Germination after 17 days of perennial pepperweed seed collected at various dates in 1997. Means followed by different letters are statistically different.

	Collection date					
	7/15	7/21	7/30	8/7	8/15	8/27–28
Site no.	Germination %					
1	5	15	16	55	81	98
2	25	12	11	42	82	96
3	6	16	30	72	94	98
4	13	14	42	74	83	98
Average	12[d]	14[d]	25[c]	61[b]	85[a]	98[a]

Table 2. Germination after 17 days of perennial pepperweed seed collected at various dates in 1998. Means followed by different letters are statistically different.

	Collection date				
	7/20	7/28	8/5	8/25	9/16
Site no.	Germination %				
1	8	1	54	95	93
2	0	20	21	77	56
3	19	2	66	88	26
4	0	5	34	93	95
Average	7[c]	7[c]	44[b]	89[a]	68[a]

Integrating 2,4-D and Sheep Grazing to Rehabilitate Spotted Knapweed-infested Rangeland

Roger L. Sheley and James S. Jacobs

Introduction

The pervasiveness and persistence of invasive plants, combined with the cost of control, supports implementation of integrated management. Integrated weed management involves the deliberate selection, integration, and implementation of effective invasive plant management strategies with due consideration of economic, ecological, and sociological consequences. Grazing animals can be a major component of integrated invasive plant management. Integrating grazing with other weed management techniques, such as herbicide application, has shown considerable promise. The objective of this study was to determine the effects of integrating 2,4-D and repeated sheep grazing on spotted knapweed-infested plant communities. We hypothesized that integrating a single spring 2,4-D herbicide application would remove adult plants, grazing would control new growth, and spotted knapweed density, cover, and biomass would decrease, allowing grasses to reoccupy the site.

Experimental Protocol

Studies were conducted from 1997 to 2001 on two sites in western Montana near Missoula (site 1) and Drummond (site 2). Spotted knapweed density was approximately 38 and 116 plants/yard^2 at the onset of the study for sites 1 and 2, respectively. Four treatments were applied in a randomized complete block design and replicated three times at each site. The treatments were: 1) a control that received no 2,4-D or repeated grazing; 2) repeated sheep grazing of 95 percent knapweed utilization or 60 percent grass utilization repeated three times in 1998, 1999, and twice in 2000 and 2001; 3) 2,4-D amine applied in spring 1997 at the rate of 11.4 lb a.i./acre; and 4) 2,4-D amine applied in spring 1997 at the rate of 11.4 lb a.i./acre, combined with repeated sheep grazing of 95 percent knapweed utilization or 60 percent grass utilization repeated thrice in 1998, 1999, and twice in 2000 and 2001. Density (plants/yard^2) and biomass (lb/acre) of spotted knapweed and biomass of grass were sampled in September 1998 through 2001. Spotted knapweed and grass cover were sampled in 1999, 2000, and 2001.

Results and Discussion

Strong evidence was found supporting the hypothesis that integrating a spring 2,4-D application to remove the adult plants combined with repeated sheep grazing to control seedling and juvenile plants would decrease spotted knapweed density, cover, and biomass, allowing residual grasses to reoccupy the sites. Combining 2,4-D and sheep grazing caused the greatest decrease in spotted knapweed density 5 years after treatment began (Table 1). Herbicide treatment changed the knapweed population to younger plants that are more palatable to sheep, which prefer seedlings and regrowth from crowns over that of associated grasses.

Management Implications

Herbicide studies in the late 1970s and 1980s demonstrated 2,4-D application resulted in at least 80 percent spotted knapweed control for a single year when applied early in the growing season. Research conducted beyond a single growing season indicated substantial site-to-site variation. Over time, spotted knapweed rosette density, cover, and biomass generally increased, suggesting that the sites will return to spotted knapweed dominance when herbicide management is used alone without repeated applications.

Spotted knapweed is highly nutritious and sheep tend to prefer broad-leaved forbs to either grasses or shrubs. Sheep provide good control of spotted knapweed, and in some cases, the level of control was better than that of 2,4-D alone. Grasses appear to respond favorably to the grazing system of 95 percent spotted knapweed or 60 percent grass utilization applied in this study. The combination of 2,4-D application and repeated sheep grazing may allow perennial grasses to better compete with spotted knapweed. The integration of the herbicide application and sheep grazing may prove more effective in controlling spotted knapweed than herbicide application alone.

Table 1. Spotted knapweed and grass biomass at Missoula and Drummond, Montana, in the control (no treatment), sheep grazing, 2,4-D, and combined sheep grazing and 2,4-D treatments. Means are combined over the years.

Treatment	*Biomass (lbs/acre)*			
	Missoula		*Drummond*	
	Spotted knapweed	*Grass*	*Spotted knapweed*	*Grass*
None	672	59	560	64
Sheep	158	55	288	95
2,4-D	223	217	529	242
Sheep + 2,4-D	46	158	242	193

Identification of the Limiting Resource within a Semi-Arid Plant Association

Jane Krueger-Mangold, Roger Sheley, and Tony Svejcar

Introduction

Competition for essential resources, such as water, nutrients, and light, is a key force structuring plant communities. The Idaho fescue/bluebunch wheatgrass plant association is widespread throughout the Pacific Northwest and is typical of rangeland in western Montana. In other plant associations typical of western grasslands, research has indicated that water is the major limiting resource, with nitrogen (N), and phosphorus (P) having lesser influence. The Idaho fescue/bluebunch wheatgrass appears to be susceptible to invasion from nonnative species; therefore, it is important to identify the major limiting resource within this plant association. The objective of this research was to determine the resource most limiting to plant growth within an Idaho fescue/bluebunch wheatgrass plant association.

Experimental Protocol

The study was conducted on two sites in western Montana. Site 1 was located at Redbluff Research Ranch about 1 mile east of Norris, Montana. Site 2 was located in the Story Hills about 3 miles northeast of Bozeman, Montana. In the spring (site 1) and fall (site 2), six essential plant resources were applied to 8.2- by 16.4-ft plots. Treatments included 1) water added at a rate of the 50-year average for May, June, and July (plus ambient precipitation); 2) light reduction of 50 percent; 3) 100 lb N/acre; 4) 54 lb P/acre; 5) 100 lb potassium (K)/acre; and 6) 100 lb sulfur (S)/acre. In addition to these main treatments, potential interactions were addressed by applying water in combination with all resources except for the untreated control. Above-ground biomass was sampled during peak standing crop in 2000 at site 1 and in 2001 at site 2. Below-ground biomass was collected at site 2, but not at site 1 because the soils were too rocky for such sampling.

Results and Discussion

The results indicate that N is the most limiting resource for the dominant functional group in the Idaho fescue/bluebunch wheatgrass plant association at the two test sites. Addition of N yielded the highest total above-ground biomass (1,647 lb/acre), which was statistically higher than any other resource treatment, except the control (1,239 lb/acre). Nitrogen produced the highest above-ground grass biomass, which was statistically different from the control (1.8 times greater than that of the control) (Fig. 1). No other treatment was statistically different than the control, including the water treatment. Addition of N increased Idaho fescue biomass over that of any other treatment (Fig. 1).

Although the sites were characterized as Idaho fescue/bluebunch wheatgrass plant associations, the majority of the biomass in our study was that of Idaho fescue. The effects of N addition on biomass were most pronounced in native grasses, especially Idaho fescue. This suggests that competition models based on limiting resources may be most accurate and predictive when constructed specifically on the dominant species' response.

Management Implications

It is often assumed that water, not N, is the limiting resource in semi-arid systems. Our results suggest that competition for N, especially among grasses, may be a critical factor even in semi-arid grasslands. The information obtained from this research is a crucial initial step in developing competition models that may be useful for understanding plant community dynamics, including invasions by nonnative species.

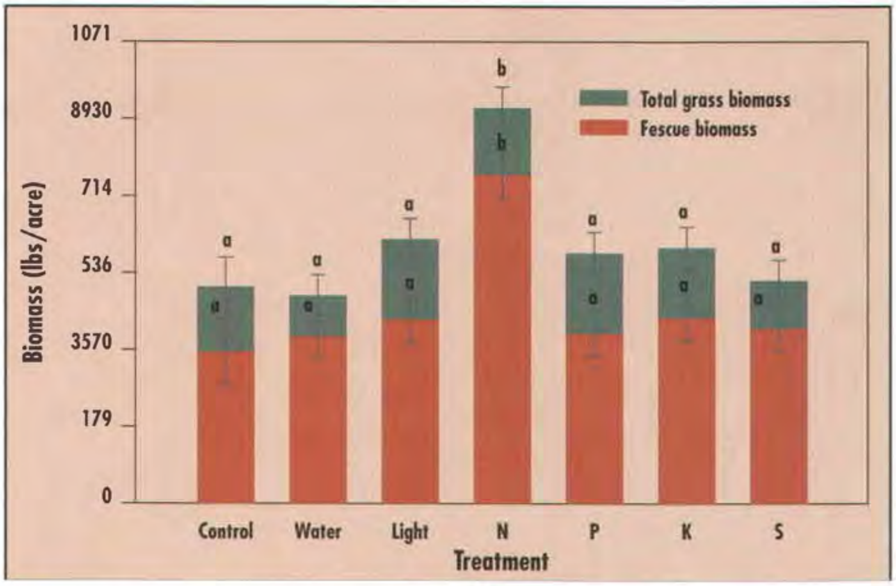


Figure 1. The mean total above-ground grass biomass and Idaho fescue biomass as affected by resource treatment for the two sites. Significant differences within plant groups, across treatments, are shown with lower-case letters. Error bars show mean +/- 1 SE.

Using Sampling and Inverse Distance Weighted Modeling for Mapping Invasive Plants

Elizabeth A. Roberts and Roger L. Sheley

Introduction

Invasive plant distribution maps are a critical component of invasive plant management and periodic repeated mapping is essential for evaluation and adaptive management. Time and cost constraints currently limit the extent, accuracy, and repeatability of invasive plant mapping. Efficient methods of accurately mapping invasive plants are needed. Inverse Distance Weighted (IDW) interpolation modeling is a potential timesaving alternative to current survey methods for generating rangeland invasive plant distribution maps. Interpolation modeling uses sample data sets and spatial relationships among samples to predict values at unknown locations. Of the various interpolation methods, IDW is a very user-friendly technique. The objective of the study is to produce the best map for the lowest cost while choosing a sampling method that results in the best representation of the invasive plants' distribution across the landscape. Specifically, the research evaluated the success of three sampling methods and six sampling densities using IDW to predict Russian knapweed and spotted knapweed distribution patterns.

Experimental Protocol

Prediction success was evaluated for invasive plant distributions at two locations. The Russian knapweed site was a 2.1-mile^2 riparian zone along the Missouri River within the Charles M. Russell National Wildlife Refuge in north-central Montana. The spotted knapweed site encompassed 5.2 miles^2 of upland, mixed forest-rangeland on the Northern Cheyenne Indian Reservation in southeastern Montana. Environmental System Research Institute's ArcViewGIS 3.2 and the Spatial Analyst extension were used to create presence/absence invasive plant distribution maps using IDW interpolation modeling techniques. Eighteen sampling strategies (three sampling methods by six sampling density combinations) were tested to predict Russian knapweed and spotted knapweed distribution patterns for the two Montana rangeland environments. The three sampling techniques were systematic, random, and systematic-random. The optimum sampling density for each sample method was also evaluated. Invasive plant distribution maps were created using full-coverage field survey mapping methods and Global Positioning Systems (GPS). An accuracy assessment of the field survey maps was conducted prior to testing the sampling and IDW interpolation techniques. Invasive plant distribution maps were created from computer-generated samples extracted from the field survey infestation maps. Accuracy of predicted maps were determined by re-referencing the field survey maps.

Results and Discussion

Sampling density had the greatest and most consistent effect on prediction accuracies. However, optimum sample density was not determined because even at the highest sample densities accuracies continued to increase. At the 0.25-percent sample density (the highest tested density), overall accuracies ranged from 78 to 87 percent for the Russian knapweed site and from 92 to 96 percent at the spotted knapweed site (Fig. 1). The accuracy levels for vegetation mapping are suitable for invasive plant management.

Sample method did not have as strong an influence on accuracy values as sample density (Fig. 1). At both study sites, however, systematic sampling performed significantly better than the other sampling methods for some of the accuracy estimates. In contrast, at no time did either the random or systematic-random sample methods perform better than the systematic sampling for any of the accuracy estimates at either site.

Management Implications

This study suggests that sampling and IDW can produce high accuracy presence/absence distribution maps for two invasive species at two study sites. The accuracies meet the United States Geological Survey 85-percent classification accuracy standard for vegetative mapping and are suitable accuracy levels for invasive plant management. Based on experience from invasive plant managers, traditional survey maps rarely exceed these accuracy levels. Since sampling (even at the 0.25-percent density) would take less time than traditional surveys, IDW can be considered a potential alternative to traditional survey mapping.

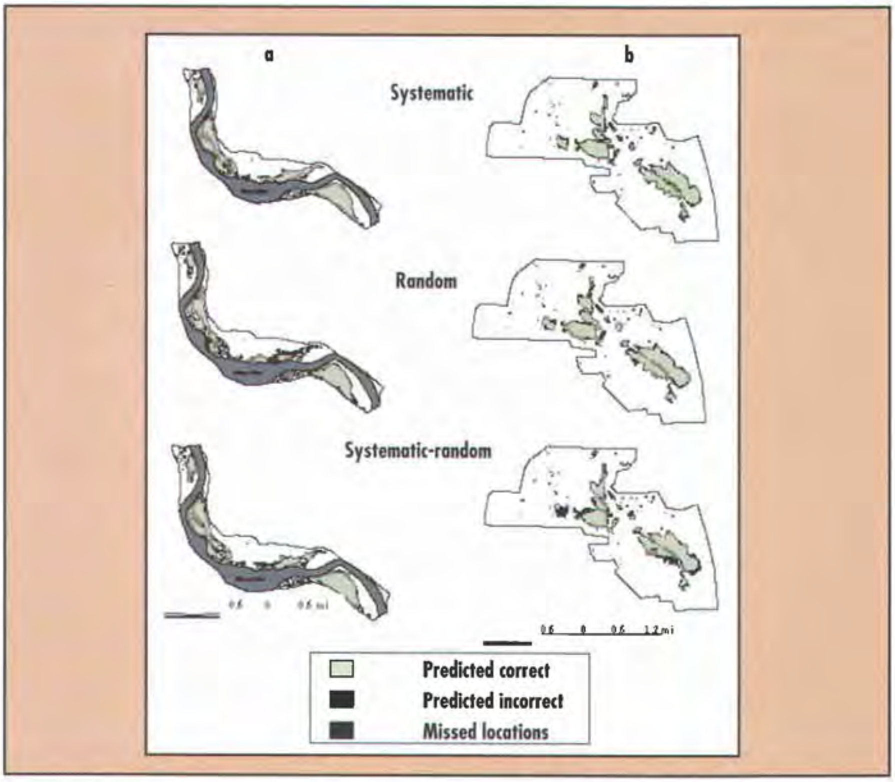


Figure 1. Comparison of predicted infestation maps at 0.25-percent sampling density: predicted correct vs. predicted incorrect vs. missed locations at (a) a Russian knapweed site, and (b) a spotted knapweed site.

Plant Species Diversity in a Grassland Plant Community:
Evidence for Forbs as a Critical Management Consideration

Monica L. Pokorny, Roger L. Sheley, and Tony J. Svejcar

Introduction

Grasslands are the earth's largest biome, comprising 24 percent of the world's vegetation and about 309 million acres in the United States. Grassland habitat types in the northwestern United States are based on grassland vegetation types, serial stages of each type, and response to grazing management practices. While forb species are listed as diverse components of grassland communities, grasses have been the primary focus in classification and land management practices. Vegetative classifications historically have assessed species composition once during the growing season, which does not account for the diversity of spring or fall forbs. Although ecologists and land managers have recognized the importance of diverse plant communities for the maintenance of healthy ecosystems, only limited attention has been given to the role of forbs in grasslands. The purpose of this research was to quantify species and functional group diversity in a grassland plant community in southwestern Montana. Specific objectives included identifying plant species richness, density, and biomass within an Idaho fescue/bluebunch wheatgrass grassland habitat type, using a multiple-season sampling method, identifying various functional groups based on their morphology, and comparing the richness to previously described diversities of this habitat type.

Experimental Protocol

The study was conducted on two sites within the Idaho fescue/bluebunch wheatgrass habitat type, which lies at the cool-wet end of grassland habitats. Sites were located approximately 43.5 miles west of Bozeman, Montana, on an east-northeast aspect of a 20-degree slope at 5,327 ft elevation. Species richness and density were measured during the spring, summer, and fall of 2000 and biomass data were collected during the spring, summer, and fall of 2001. Species richness was measured by counting all species present on 4.8-yard^2 plots. Forb density was measured per 4.8-yard^2 plot, while grass density was determined by counting tillers per species within a 0.7- by 1.6-ft frame. Diversity indices were calculated for each functional group. Biomass by functional group was clipped from three 0.7- by 1.6-ft frames per 4.8-yard^2 plot.

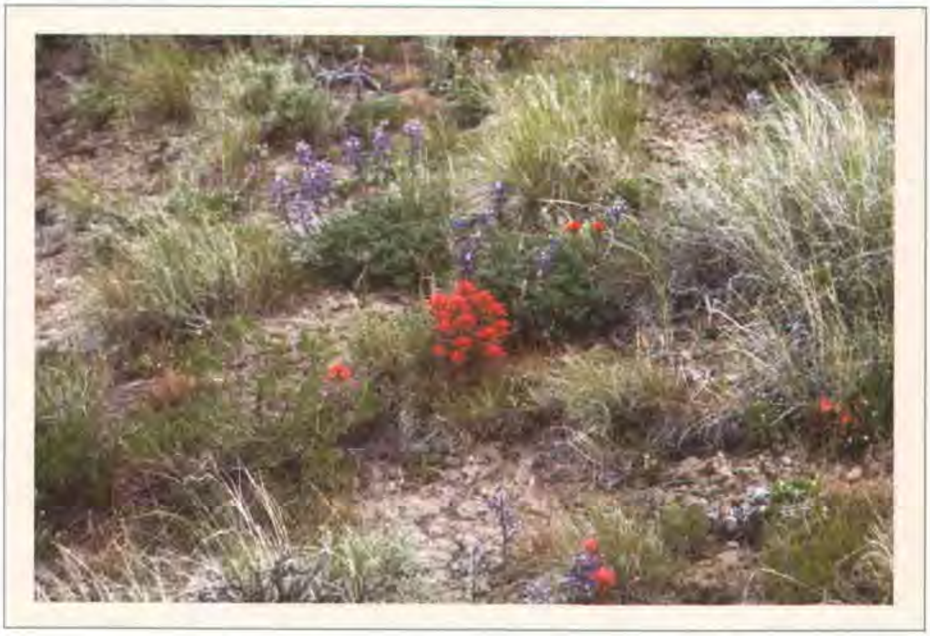
Results and Discussion

Species diversity was high in both sites. Sampling over time allowed documentation of greater species richness than previously was suggested for this habitat type. Forb functional groups represented the majority of the richness and biomass of the grassland community studied. Forbs accounted for 83 percent of the vascular species richness in our research. In addition, forbs represented a greater proportion of plant biomass than grasses on the study sites. Although three to four grass species may comprise a large portion of the biomass in grasslands, forbs contribute more to community diversity. The data indicate that greater species richness coincided with greater overall biomass or productivity. This finding is consistent with other research suggesting increased diversity is positively correlated with increased community productivity and stabilization due to more complete use of resources. Because maintenance of functional group diversity is suggested for maintaining optimum plant community function, more emphasis should be placed on managing grasslands for forb functional group diversity.

Management Implications

Land managers should recognize forb species and forb functional group diversity in grassland classifications and should quantify species at least twice during the growing season for these community types. By sampling once in the spring and once in the summer, land managers should be able to measure approximately 95 percent of the diversity in Idaho fescue/bluebunch wheatgrass habitat types. In comparison, a maximum of 76 percent of community diversity was recorded with only one summer field sampling.

Land managers should establish and maintain forb species and forb functional group diversity in land



Native community of forbs and grasses representing many functional groups.

management decisions. Intermediate levels of disturbance through regulated grazing timing and intensity, planned herbicide application, and periodic prescribed burning have been proposed to maintain the highest level of diversity.

Maintaining functional group diversity should be a primary objective of land managers because increased functional group diversity correlates with increased stability and productivity of the land. Increasing functional diversity also decreases the risk of invasion by undesired species. Indigenous forb functional groups should be recognized as an essential component for proper land management because they may increase community resistance to noxious weed invasion.

Restoring Species Richness and Diversity in a Russian Knapweed-infested Riparian Plant Community using Herbicides

Roger L. Sheley and Stephen M. Laufenberg

Introduction

Russian knapweed (*Acroptilon repens*) was introduced to North America in the 1900s and is now found throughout the United States. It is most commonly found in the semiarid portions of the West but also occupies river bottoms and riparian woodlands. Russian knapweed spreads aggressively and has a competitive advantage over many native species, often forming monocultures after becoming established. Nonnative plant species such as Russian knapweed can displace native vegetation and decrease plant diversity, thereby altering the structure and function of ecological systems. Reduction in plant diversity is detrimental to the productivity and stability of ecological systems. Previous research indicates that a variety of herbicide formulations can provide short-term suppression of Russian knapweed. However, further research on controlling Russian knapweed with herbicides appropriate for use in wet areas and river bottoms is needed. Our specific objectives were to determine the influence of three herbicides, clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®), at different application rates and timings, on richness and diversity of total species, total native species, and total nonnative species within a Russian knapweed-infested plant community.

Experimental Protocol

Two study sites were selected in north-central Montana on the Charles M. Russell National Wildlife Refuge along the Missouri River riparian corridor. In a randomized complete block design at both sites, 28 treatments (3 herbicides, 3 rates of application, 3 application timings, untreated control) were applied June through August 2000. The three herbicides (clopyralid plus 2,4-D, glyphosate, and fosamine) were applied in June (spring rosette stage of Russian knapweed), July (bud to bloom stage), and August (flowering stage). Low, medium, and high rates of each herbicide were applied at each application date. Density of each species was recorded during June and August of 2001 and 2002. In addition, species richness (the total number of species per experimental plot) and species diversity (the number of individuals of each species) also were calculated.

Results and Discussion

In June 2001, there were no significant differences in species richness between the control and herbicide treatments (Fig. 1). By August 2002, only the glyphosate treatment (5.5 species/yard^2) yielded greater total richness over that of the control (4.2 species/yard^2, Fig. 1). Although glyphosate increased total species richness compared with untreated controls, the majority of the species were nonnative annual forbs. Sampling in June 2001 indicated no differences in diversity between any herbicides and the control (Fig. 2). In August of 2002, diversity after application of clopyralid plus 2,4-D remained similar to that of the control (1.7 species/yard^2), but glyphosate (2.8 species/yard^2) and fosamine (2.4 species/yard^2) increased total species diversity (Fig. 2). Between June 2001 and August 2002, total species diversity for glyphosate treatments increased from 2.3 species/yard^2 to 2.8 species/yard^2.

Management Implications

In this study, glyphosate increased total species richness compared with untreated areas. Although the majority of these species were nonnative annual forbs, they play an important role in recovering the function of the system. Management strategies aimed at enhancing ecosystem function, and possibly niche occupation to prevent reinvasion by Russian knapweed, may possibly be met with glyphosate application; however, restoring plant communities with native species using this herbicide seems less likely.

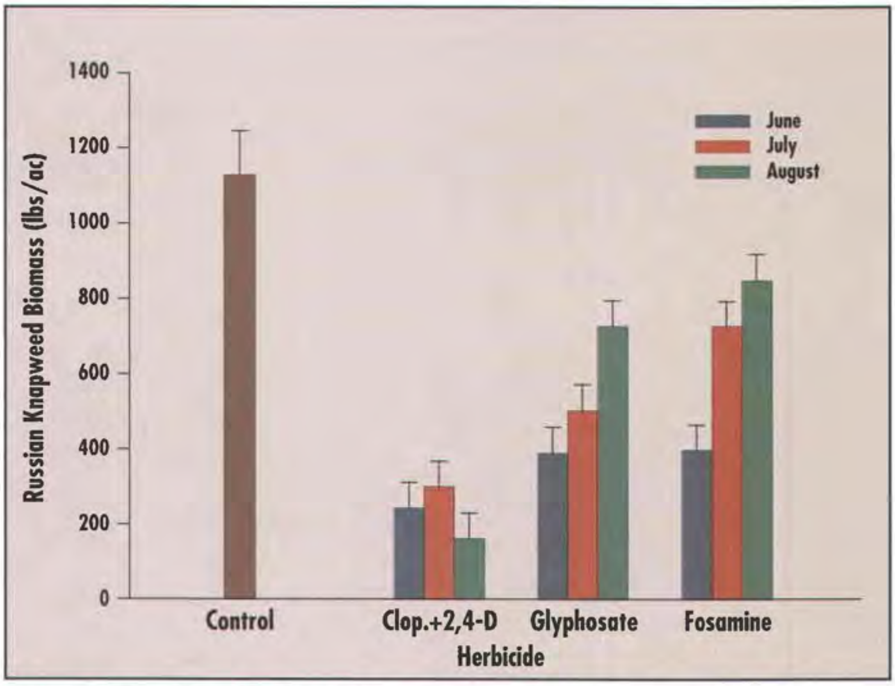


Figure 1. The effect of herbicide by year on total species richness. Control is no herbicide treatment, Clop. + 2,4-D is clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®).

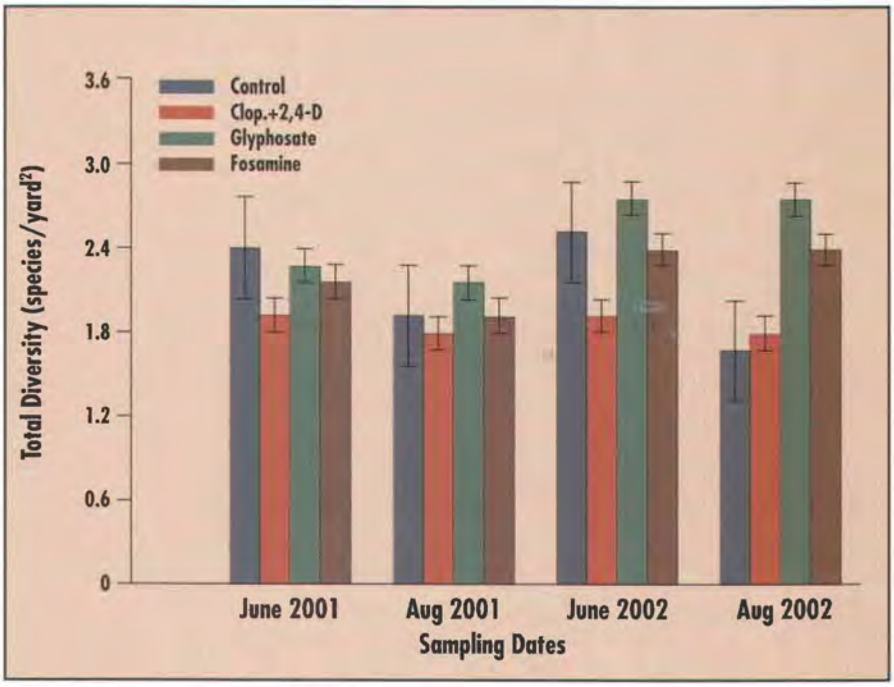


Figure 2. The effect of herbicide by year on total species diversity. Control is no herbicide treatment, Clop. + 2,4-D is clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®).

Herbicide Effects on Density and Biomass of Russian Knapweed and Associated Plant Species

Stephen M. Laufenberg and Roger L. Sheley

Introduction

Non-native invasive plants can reduce wildlife habitat, increase soil erosion and stream sedimentation, and decrease plant species diversity. One such invasive species of concern is Russian knapweed (*Acroptilon repens*), a rhizomatous perennial forb that is difficult to control and considered to be the most persistent of the knapweeds. Infestations of Russian knapweed can displace vegetation through a combination of competition and allelopathy, which reduces the health and productivity of the land. It has become clear that controlling Russian knapweed is paramount to recovering and maintaining the plant communities that it infests. Previous research involving herbicide suppression of Russian knapweed has focused primarily on controlling the weed, with limited regard to the effects on the existing plant community. The objective of this study was to determine the influence of clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®), at different application rates and timings, on Russian knapweed and associated existing plant groups, based on species density and biomass.

Experimental Protocol

Two study sites were selected in north-central Montana about 170 miles north of Lewiston, Montana on the Charles M. Russell National Wildlife Refuge along the Missouri River riparian corridor. In a randomized complete block design at both sites, 28 treatments (3 herbicides, 3 rates of application, 3 application timings, untreated control) were applied June through August 2000. The herbicides (clopyralid plus 2,4-D, glyphosate, and fosamine) were applied in June (spring rosette stage of Russian knapweed), July (bud to bloom stage), and August (flowering stage). Low, medium, and high rates of each herbicide were applied at each application date. Density was recorded for all existing plant species and Russian knapweed during June and August of 2001 and 2002. Biomass of all species and Russian knapweed was collected in August 2001 and 2002 using a 4.74-ft^2 hoop randomly placed once within each plot.

Results and Discussion

Of the herbicides tested in this study, clopyralid plus 2,4-D provided the best control of Russian knapweed. Russian knapweed biomass was reduced from 1,116 lb/acre to about 223 lb/acre using clopyralid plus 2,4-D, irrespective of rate or timing of application (Fig. 1). Also, density of Russian knapweed was reduced by about 70 percent for clopyralid plus 2,4-D compared with the untreated control (Fig. 2). Grass density and biomass was either maintained (nonnative grass understory) or increased (native grass understory) using clopyralid at medium or high rates. Neither glyphosate nor fosamine provided

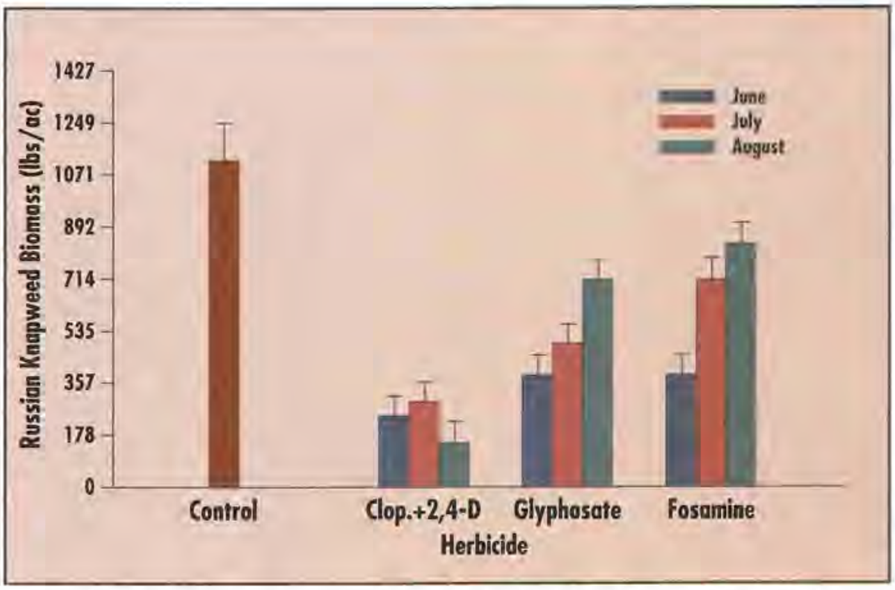


Figure 1. The effect of application timing by herbicide on Russian knapweed biomass. Control is no herbicide treatment, Clop. + 2,4-D is clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®).

Mapping Leafy Spurge and Spotted Knapweed Using Remote Sensing

Shana D. Wood, Rick L. Lawrence, and Roger L. Sheley

Introduction

Invasive nonnative plants are threatening the biological integrity of North American rangelands and the economies supported by those ecosystems. Spatial information is critical to fulfilling invasive plant management strategies. Traditional invasive plant mapping has utilized ground-based hand or GPS (Global Positioning System) mapping. The shortfalls of ground-based methods include the limited spatial extent covered and the associated time and cost. Mapping vegetation with remote sensing covers large areas and maps can be updated at an interval determined by management needs. The objective of the study was to map leafy spurge and spotted knapweed using finely delineated color (hyperspectral) imagery (16.4-ft and 9.8-ft resolution) and assess the accuracy of the resulting maps.

Experimental Protocol

The imagery covered two sites in Madison County, Montana; each site was approximately 2,528 acres. The leafy spurge site was located about 10 miles southwest of Twin Bridges at the southern end of the Highland Mountains. Leafy spurge primarily occupied drainage bottoms and surrounding hillsides and was distributed with native vegetation in low- to high-density infestations and occasionally grew in dense monocultures. The spotted knapweed site was located in the northern foothills of the Gravelly Range and included the town of Virginia City and areas due west and south. Spotted knapweed infestations tended to be mixed with other vegetation and had a higher percentage of bare soil exposed than the leafy spurge site. The hyperspectral imagery was obtained in August 1999 using the Probe-1 sensor. The images were recorded from an average altitude of 8,200 ft with the Probe-1 site ground resolution of 16.4 ft. In August 1999, crews collected ground reference data of the target invasive species and associated vegetation using GPS receivers that had an accuracy of 6.7–16.4 ft after differential correction. Infestations ranged from 7 to 606 $yards^2$ and samples were split randomly into two equal sets: a) those used to differentiate between species and b) those used to compare GPS map points of infestations with image map points. Images were georeferenced to a digital orthophotoquad. Two different methods of GIS (Geographic Information System) analysis, classification tree analysis (CTA), and fuzzy set theory were used to classify the hyperspectral imagery and to adapt for over-classification of target species, respectively.

Results and Discussion

Although healthy vegetation exhibits similar reflectance properties, differentiation between species is possible due to plant structural characteristics, leaf area and geometry, surface construction, water content, and in the visual spectral range, pigmentation. Target species map accuracies were 61 percent for leafy spurge and 74 percent for spotted knapweed with the application of CTA alone (Fig. 1). The application of fuzzy set theory resulted in substantial increases in overall accuracies (especially with leafy spurge), without impairing accuracy of associated vegetation. The accuracies increased to 82 and 86 percent for leafy spurge and spotted knapweed, respectively. This is comparable to the highest ground-based mapping accuracy levels. Application of the fuzzy set theory overcomes several problems that have been noted in the past with mapping invasive species using airborne digital imagery.

Management Implications

This study provided valuable information about applying airborne hyperspectral imagery for mapping invasive species. Operational and practical methods were applied to classify the imagery. Given the time and cost required to perform intensive ground surveys, the tradeoff of lower accuracy might be worthwhile in situations where an estimation of infestation distribution over large areas will assist timely implementation of invasive plant management objectives. However, the use of fuzzy set analysis enables accuracies comparable to ground surveys.

substantial Russian knapweed control or increases in grasses. No herbicides increased native forbs, which are particularly important to the sustainability of the plant community.

Management Implications

Only increases in grasses were detected in this study, which demonstrates that the rehabilitation of the plant community's structure was not successful. Without sufficient community structure and competition from other critical plant groups, Russian knapweed will most likely recover from suppression treatments. Therefore, herbicides alone are inadequate for the restoration or rehabilitation of desirable plant communities infested with Russian knapweed. Although revegetation is expensive and has a high risk of failure, this study indicates that herbicides must be combined with revegetation in areas lacking a diverse mixture of species capable of occupying the newly opened niches.

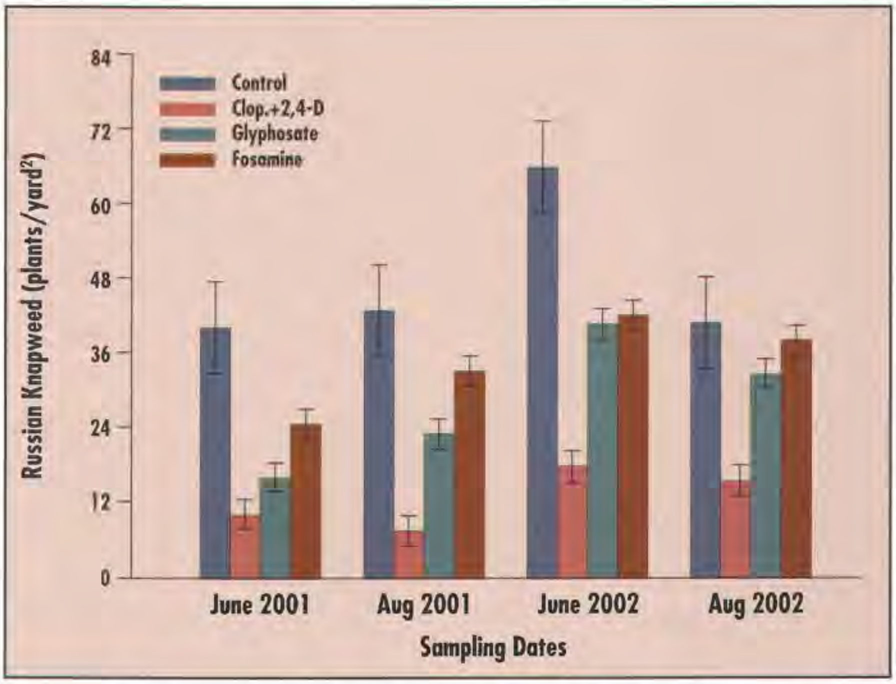


Figure 2. The effect of herbicide on Russian knapweed density at four sampling dates. Control is no herbicide treatment, Clop. + 2,4-D is clopyralid plus 2,4-D (Curtail®), glyphosate (Roundup®), and fosamine (Krenite®).

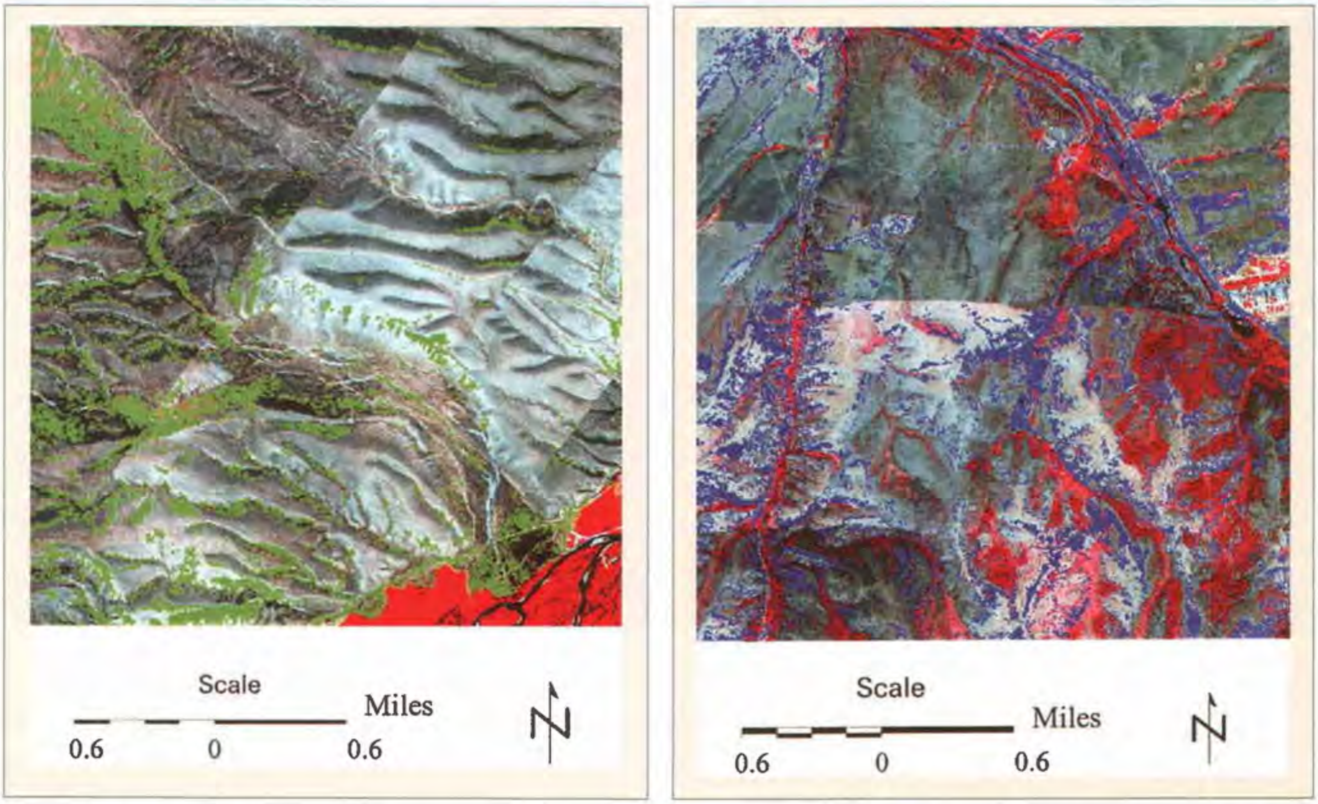


Figure 1. (Left) Classification of leafy spurge overlaid on hyperspectral imagery. Bands 24 (784 nm), 16 (662 nm), and 9 (555 nm) are displayed as red, green, and blue. (Right) Classification of spotted knapweed overlaid on hyperspectral imagery.

Beet Pulp Supplementation of Heifers Grazing Native Flood Meadow

David W. Bohnert and Christopher. S. Schauer

Introduction

It has been suggested that low levels of energy supplementation using starch-based supplements (corn, barley, wheat, etc.) can enhance the average daily weight gain of cattle grazing forage in an early vegetative state. However, past research has indicated supplementation of cracked corn to beef heifers grazing early-season native flood meadow doesn't increase average daily gain (ADG) over unsupplemented heifers. Another form of energy supplementation is fermentable fiber. Sources of readily fermentable fiber, such as beet pulp, soybean hulls, and wheat midds, offer an alternative to starch-based supplements. It has been proposed that high-fiber energy supplements do not elicit the negative ruminal effects often associated with starch supplements. Therefore, the objective of this research was to determine the influence of increasing amounts of beet pulp on the performance and diet digestibility of beef heifers grazing early-season native flood meadow pasture.

Experimental Protocol

Sixty-four Angus × Hereford heifers were provided 0.00, 0.55, 1.11, or 1.65 lb/day of dried beet pulp for 84 days beginning May 5, 2000. Heifers weighed approximately 630 lb at the beginning of the experiment. We measured heifer average daily weight gain and quality of standing forage for the duration of the experiment.

Results and Discussion

Heifer ADG (2.45, 2.38, 2.29, and 2.38 lb/day for 0.00, 0.55, 1.10, and 1.65 lb/day of dried beet pulp, respectively) was not affected by beet pulp supplementation. This agrees with previous work in which heifers grazing early-season native flood meadow and supplemented with increasing levels of cracked corn did not improve ADG compared with unsupplemented heifers.

Standing forage increased as grazing season progressed while diet quality decreased. However, diet quality throughout the experiment was greater than or similar to beet pulp and was sufficient to support excellent gains as demonstrated by the unsupplemented heifers (Table 1). It is probable that nutrient intake by heifers was not increased due to beet pulp supplementation; therefore, supplementation provided little to no benefit while increasing feed costs.

Management Implications

Beet pulp supplementation of growing beef heifers grazing early-season native flood meadow does not influence animal performance. Therefore, beet pulp supplementation is not an economical option to include in grazing management plans for growing ruminants consuming high-quality native flood meadow pasture.

Table 1. Quantity and quality of standing forage in flood meadow pastures during beet pulp supplementation.

	Day of study (2000)			
Item	***May 5***	***June 2***	***June 30***	***July 28***
Standing forage, lb/acre	905	1,268	2,106	1,862
Forage quality, %				
Crude protein (CP)	23	18	15	12
Neutral detergent fiber (NDF)	44	49	53	58
Acid detergent fiber (ADF)	23	25	29	30

Mineral Concentration Patterns among Our Major Rangeland Grasses

David C. Ganskopp and David W. Bohnert

Introduction

Ranchers and forage managers need knowledge of the mineral content of their forages to assure efficient growth, reproduction, and strong immune responses from their animals. Despite a long history of livestock grazing in the northern Great Basin, annual and seasonal mineral concentrations of many of the region's prominent forages have not been measured. Because cattle in the sagebrush-steppe typically derive 85–90 percent of their annual rangeland diet from grass, an assay of our most prominent grasses provides a relatively accurate depiction of their mineral status. We addressed this problem with monthly sampling of grasses (April through November) during 1992, a drier than average year (86 percent of average precipitation), and 1993 when precipitation was 167 percent of average, about 10 inches per year.

Experimental Protocol

Six study locations near Burns, Oregon, were selected, with each supporting a broad array of grasses. All sites were characterized by Wyoming big sagebrush, which dominates most of the landscape in the region. On a north-south line the sites spanned 47 miles and on an east-west axis encompassed 73 miles. Once a month, for 8 months each year (April-November), each site was visited and samples of seven grasses were collected. Forages included in the study were Sandberg's bluegrass, cheatgrass, bottlebrush squirreltail, bluebunch wheatgrass, Idaho fescue, Thurber's needlegrass, and giant wildrye. Samples were assayed for phosphorus, potassium, calcium, magnesium, manganese, iron, copper, zinc, and sodium.

Results and Discussion

Generally, mineral concentrations averaged about 41 percent higher among the grasses for the drier (1992) of the 2 years (Fig. 1). Growth restriction during drought is accompanied by mineral concentration in a reduced standing crop. Conversely, dilution of mineral concentrations with more favorable growing conditions is frequently seen and attributed to accumulation of more stem material under optimal conditions.

Of major interest are those minerals that occurred at deficient levels among grasses on a year-round basis. These included copper, zinc, and sodium, and their deficiencies should most definitely be given some consideration by stockmen (Fig. 1).

Lactating beef cattle need about 9.6 parts per million (ppm) of copper in their diet, and our grasses furnish less than half the needed level at their peak. A wide array of symptoms accompany copper deficiencies, and their diversity may be linked to complex interactions involving other minerals. Some of the clinical signs include bleaching of hair, nervous symptoms (ataxia) in calves whose dams experienced deficiency during pregnancy, lameness, and swelling of joints. Serum assays of beef cattle at the Eastern Oregon Agricultural Research Center (EOARC) revealed marginal copper levels; nevertheless, through 1988 clinical symptoms had not been noted. Recently, however, some herds in southeast Oregon have developed health and reproductive disorders attributed to copper deficiency. Consequently, many producers have begun monitoring the copper status of their animals and have become more attentive to their mineral programs.

Zinc requirements for beef cattle forage are about 29 ppm. Over the months sampled, our grasses supplied from two-thirds to less than one-third of the needed levels. Zinc deficiencies can cause parakeratosis (inflamed skin around nose and mouth), stiffness of joints, alopecia, breaks in skin around the hoof, and retarded growth. Deficiencies have been induced experimentally in calves, but no applied reports of zinc deficiencies have occurred in sheep or cattle. However, researchers in Idaho have seen improved gains among zinc-supplemented calves.

Sodium concentrations varied considerably among the grasses, with substantial monthly differences between years (Fig. 1). To meet requirements for beef cattle, forages should contain about 672 ppm of sodium. All of our forages were deficient throughout both years. The highest sodium content attained by any of the grasses was Sandberg's bluegrass in late October of 1992, and it averaged only 177 ppm.

Among animals, sodium is found primarily in extracellular fluids. In conjunction with potassium and chlorine, it assists with maintaining osmotic pressure, acid-base equilibrium, nutrient passage into cells,

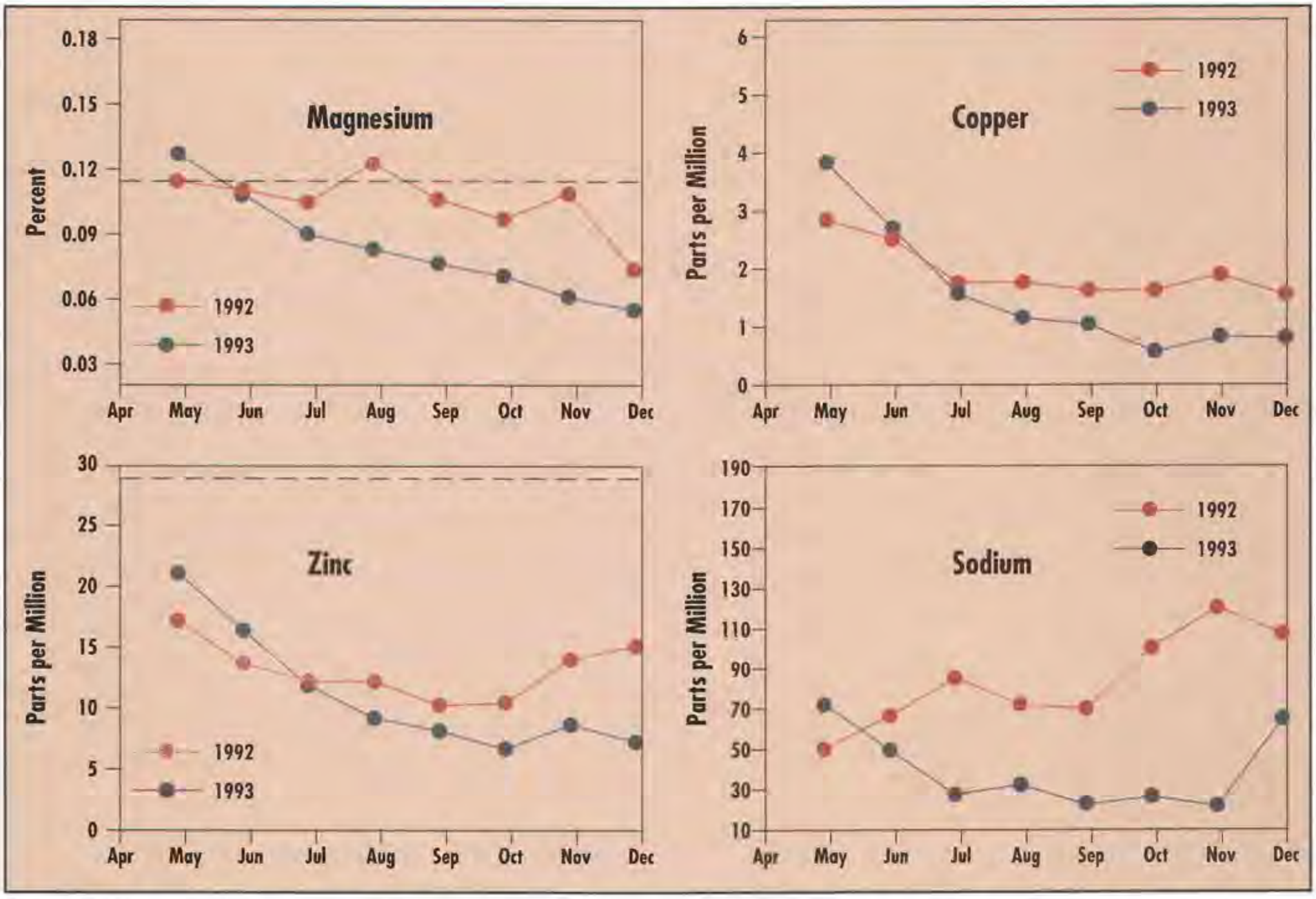


Figure 1. Mean monthly magnesium, zinc, copper, and sodium concentration of common rangeland grasses sampled from late April through late November in 1992 and 1993 near Burns, Oregon. Dashed lines, if present, denote required dietary concentrations. Required concentrations for copper and sodium are 9.6 and 672 parts per million, respectively.

and water metabolism. Animals have considerable ability to conserve sodium, but that luxury is not available to lactating cattle suffering from a lack of salt in the diet. Prolonged deficiencies cause loss of appetite, decreased growth or weight loss, unthrifty appearance, and reduced milk production, but supplemental salt can also stimulate weight gains among animals that are not showing signs of deficiencies.

The dietary magnesium requirement for lactating cows is about 0.115 percent. Forages were at or above this level for 2 of 8 months in 1992 and only 1 of 8 months in 1993 (Fig. 1). Magnesium is especially important for cellular and nervous system functioning among all animals. Lactating animals also transfer large amounts of magnesium to their calves, and they extract the needed quantities from their body reserves to sustain their calf when forages are deficient. Grass tetany generally occurs during early spring, when grasses are exhibiting rapid vegetative growth and lactation demands of cattle are peaking. That being the case, cattle should have supplemental sources of magnesium whenever their diet is deficient.

Other minerals that were seasonally deficient in our forages were calcium, phosphorus, potassium, and manganese. Calcium and manganese were largely deficient for cattle early in the growing season with levels increasing as the grasses matured into summer. Phosphorus and potassium levels were typically adequate early in the growing season and declined to deficient levels by July and August.

Iron is not an issue in our area because levels were more than adequate among all grasses for all periods sampled. However, high levels of iron can potentially lower copper availability and exacerbate management problems associated with copper deficiencies.

Conclusions and Management Implications

Given the logistical demands of determining forage nutritive value and supplement delivery in extensive pastures, ranchers for the most part cannot respond to seasonal mineral dynamics. Most likely, the best approach is to use a supplement formulation to correct all known year-round and potential seasonal deficiencies of their forages. Based on our findings, mineral supplementation is probably more of an issue during what we perceive as good forage years than when plant growth and development are arrested by drought.

When formulating mineral supplements, one should remember that mineral excesses are capable of inducing other deficiencies. For cattle pasturing in the northern sagebrush-steppe, we recommend that eight of the nine minerals evaluated in this study be added to the mix, and these include calcium, magnesium, copper, phosphorus, potassium, zinc, manganese, and sodium. Adequate concentrations of iron were available on a year-round basis. Those interested in a more detailed account on the mineral concentration dynamics of a particular grass should contact the EOARC in Burns and request a reprint of:

Ganskopp and Bohnert. 2003. "Mineral concentration dynamics of 7 northern Great Basin grasses," *Journal of Range Management* 54:640–647.

The Nutritional Dynamics of Our Major Rangeland Grasses

David C. Ganskopp and David W. Bohnert

Introduction

Stockmen and wildlife managers need to be aware of the seasonal nutritional dynamics of forages in their pastures to sustain adequate growth and reproduction of their animals. Similarly, those marketing or purchasing pasture should be aware of forage nutrient value to assure exchange of equitable payment. In the northern Great Basin, rangeland grasses typically begin growing in the early spring and stop growing by mid-summer when soil moisture is depleted. Cattle on our rangelands can gain as much as 4 lb per day early in the season and lose almost a pound a day by mid- to late August. Within the same interval, calf gains may range from 1.5 lb to as little as 0.2 lb per day. Our objective was to describe the seasonal and annual nutritional dynamics of seven of the region's most prominent grasses. Forages were sampled in 1992, a drier than average year, and 1993, when above-average precipitation occurred.

Experimental Protocol

Six study locations within the vicinity of Burns, Oregon, were selected, with each supporting a broad array of forage species. All sites were dominated by Wyoming big sagebrush, which characterizes most of our landscape in the region. On an east-west line, the sites spanned 73 miles; north-south extremes encompassed 47 miles. Once a month, for 8 months each year, each site was visited and samples of the seven grasses collected. Grasses included in the study were Sandberg's bluegrass, cheatgrass, bottlebrush squirreltail, bluebunch wheatgrass, Idaho fescue, Thurber's needlegrass, and giant wildrye. Samples then were analyzed for crude protein and forage digestibility, as indexed by in vitro organic matter disappearance.

Results and Discussion

Crop year (September–June) precipitation accumulations for 1992 and 1993 were 86 and 167 percent of average, respectively. A model for predicting annual herbage yield in the region suggested that we had about 484 lb/acre of forage in 1992 and 1,121 lb/acre of herbage in 1993.

Intuitively, and from a production standpoint, we tend to view the wetter years as being the good times. From a forage quality standpoint, however, just the opposite is true. Figure 1 illustrates the average crude protein content of the grasses from late May through late November of each year. The solid line near the middle of the graph depicts the 7.5-percent crude protein level. This is about the concentration needed for livestock and big game to efficiently digest the foods they eat and gain weight. In 1992, we had 5 months in which the crude protein content of the grasses was above, or just touching, the 7.5-percent line. The up and down inflections of the 1992 line also show that even though it was a dry year, the grasses greened up in response to some July and October rains. This suggests that in drier years our grasses become somewhat dormant when soil moisture is depleted, but they can wake up and start growing again if we have significant rainfall.

In 1993, however, there were only 3 months (May, June, and July) where the crude protein concentration of the grasses was above or

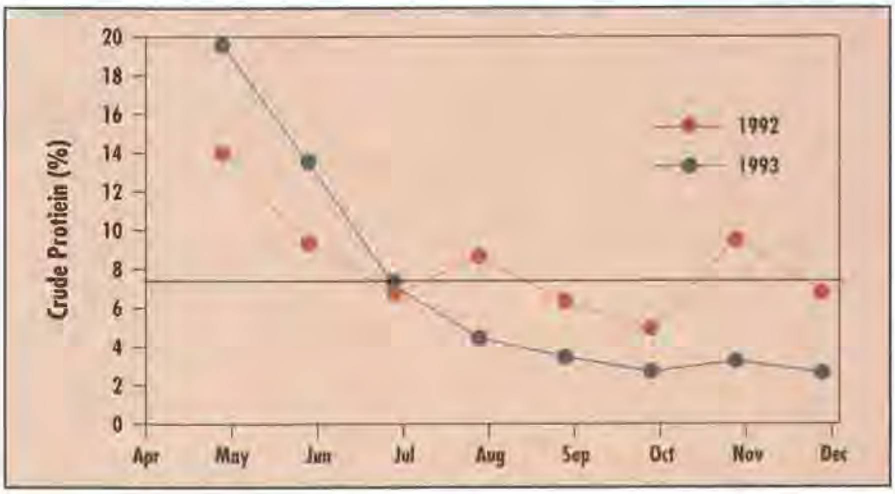


Figure 1. Mean monthly crude protein content of common rangeland grasses sampled from late April through late November in 1992 and 1993 near Burns, Oregon. The horizontal line near the center of the graph marks the 7.5 percent crude protein level.

near the 7.5-percent line. In wetter years, our grasses can easily grow and progress through their annual life cycle. In those instances, they produce leaves, generate a flower or seed stalk, fill their seeds, and then each individual stem dies. These stems produce a wealth of biomass that is made up of an almost woody-like material with little nutritional value. Once a stem has produced seed, it typically dies, with next year's herbage coming from buds in the base of the plant. It appears that those buds are difficult to wake up, as 2.5 inches of precipitation in July 1993 failed to generate a perceptible response from the grasses.

Forage digestibility values tell a similar story, with the grasses being more digestible for 5 of 8 months in 1992 than they were in 1993 (Fig. 2). When forages are highly digestible, cattle can consume and assimilate more nutrients because their digestive tracts function more efficiently than when they are ingesting poor-quality herbage.

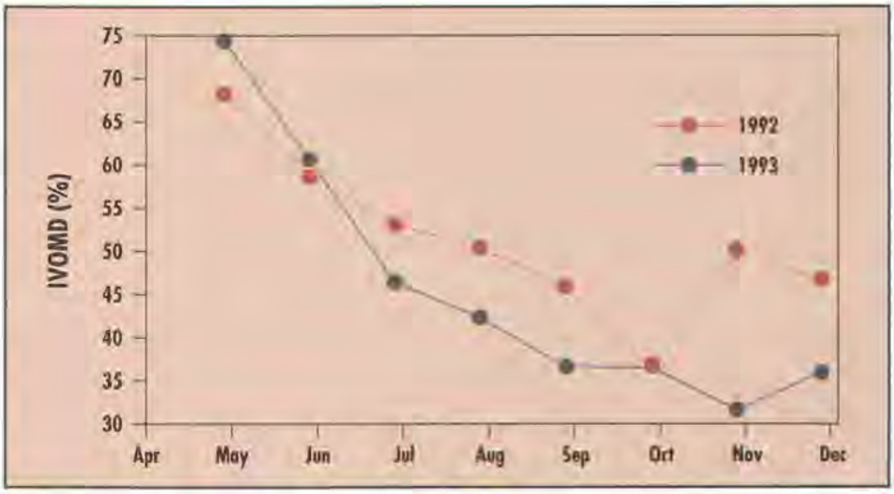


Figure 2. Mean monthly digestibility as indexed by in vitro organic matter digestibility (IVOMD) of common rangeland grasses sampled from late April through late November in 1992 and 1993 near Burns, Oregon.

Conclusions and Management Implications

A growing season with less-than-average moisture can generate grass that sustains a higher plane of nutrition for up to twice as long as a growing season with abundant moisture and greater forage production. We suspect that when cool-season grasses begin growth with less-than-optimum moisture, tillers become inactive as moisture is exhausted, but they can resume mid-summer growth if effective precipitation occurs. Conversely, when abundant moisture is available, grasses quickly advance through maturity and generate an abundance of low-quality reproductive stems. Subsequently, those tillers die, and the grasses enter a dormant stage where they do not respond to even elevated levels of summer precipitation. While annual yield of herbage is closely correlated with yearly and sometimes seasonal precipitation accumulation, forage quality dynamics are more complex and are certainly affected by seasonal events. These findings suggest that stockmen should be more concerned with mid- and late-summer supplementation programs for their animals in years that exhibit the best growing conditions for our grasses. Those interested in more detail on nutritional characteristics of particular grasses should contact the Eastern Oregon Agricultural Research Center in Burns and request a reprint of:

Ganskopp and Bohnert. 2001. "Nutritional dynamics of 7 northern Great Basin grasses," *Journal of Range Management*. 54:640–647.

Effect of Crude Protein Supplementation Frequency on Performance and Behavior of Cows Grazing Low-quality Forage

David W. Bohnert, David C. Ganskopp, Christopher S. Schauer, and Stephanie J. Falck

Introduction

Decreasing the frequency of crude protein (CP) supplementation is a management practice that decreases labor and fuel costs. Research has shown that CP supplements can be fed at infrequent intervals to ruminants consuming low-quality forage, and acceptable levels of performance and nutrient utilization are maintained. Also, grazing time has been reported to decrease by 1.5 hours per day for supplemented compared with unsupplemented cows. Research from Montana has demonstrated that supplement placement can be used to modify livestock distribution. However, there is limited research evaluating the effect of CP supplementation frequency on grazing behavior of beef cows. The objectives of this study included determining whether infrequent supplementation of CP to cows grazing low-quality forage affects cow performance, grazing time, distance traveled, percentage of supplementation events frequented, and variability of supplement intake.

Experimental Protocol

One hundred twenty pregnant (approximately 60 days), nonlactating cows were used in an 84-day period (from about August 9 to November 1) in each of 3 years to evaluate the influence of CP supplementation frequency on cow performance, grazing time, distance traveled, cow distribution within pasture, percentage of supplementation events frequented, and variability in supplement intake. Three 2,000-acre pastures (40 cows per pasture) at the Northern Great Basin Experimental Range, located approximately 40 miles west of Burns, Oregon, were used to evaluate treatment effects on cow behavior. Treatments were allotted to pastures and included an unsupplemented control, daily supplementation of 2 lb of cottonseed meal, and supplementation once every 6 days with 12 lb of cottonseed meal. Cottonseed meal (43 percent CP) was provided 10 minutes after an audio cue at approximately 8:00 A.M. for each supplementation event. Four cows from each treatment (each year) were fitted with global positioning system (GPS) collars (Fig. 1) to obtain data related to distribution within pasture and grazing behavior.

Results and Discussion

Cow weight and body condition score were improved with CP supplementation and not affected by supplementation interval (Table 1). However, time spent grazing by supplemented cows was approximately 2 hours less per day than what was observed for cows not receiving supplement. Nevertheless, distance traveled per day and distribution within pasture was not affected by CP supplementation or its frequency. Also, the number of supplementation events frequented was similar for cows receiving cottonseed meal daily or once every 6 days. Variability of supplement intake by cows was similar for those receiving cottonseed meal once every 6 days compared with those receiving it daily.

Management Implications

Infrequent supplementation of CP to cows grazing low-quality forage results in animal performance similar to that resulting from daily supplementation while decreasing time spent grazing. In addition, data suggest that CP supplementation interval has no affect on average distance traveled per day, cow distribution within pasture, or the percentage of supplementation events frequented. Infrequent supplementation is a management alternative that can help lower costs associated with CP supplementation of cows grazing native range in the northern Great Basin.

Figure 1. Cow fitted with a GPS collar used to determine grazing behavior.

Table 1. Effect of crude protein supplementation frequency on grazing behavior and performance of cows grazing native range in the northern Great Basin.

	Supplementation interval		
Item	*No supplementation*	*Daily*	*6 Days*
Initial weight, lb	1,036	1,025	1,032
Initial body condition score	4.7	4.6	4.7
Weight change, lb	37	112	95
Body condition score change	0.0	0.4	0.3
Grazing time, hours/day	9.6	7.1	7.9
Distance traveled, miles/day	3.7	3.6	3.7
Pasture distribution, %[a]	70	69	67
Supplementation events frequented, %[b]	---	66	70
Variability of supplement intake, %	---	28	28

[a] Pasture distribution = percentage of acres occupied per pasture by cows with global positioning system collars.

[b] Supplementation events frequented = percentage of supplementation events frequented by cows with global positioning system collars.

Effect of Ruminal Protein Degradability and Supplementation Interval on Nutrient Utilization and Performance of Ruminants Consuming Low-quality Forage

David W. Bohnert

Introduction

Many cattle in the western United States consume low-quality forage (<6 percent crude protein [CP]) from late summer through winter. Supplementation with protein increases cow weight gain and body condition score, forage intake and digestibility, and can improve reproductive performance. However, winter supplementation can be very expensive, with winter-feed costs in the Intermountain West often totaling $100–200 per cow per year. In addition to that, winter supplementation includes other expenses such as the labor and fuel associated with supplement delivery.

Decreasing the frequency of protein supplementation is one management practice that decreases labor and fuel costs. In addition, research has shown that protein can be supplemented at infrequent intervals and cows still maintain acceptable levels of performance; however, data are limited comparing the effects of rumen degradable protein (DIP; broken down within the rumen by ruminal microorganisms) and rumen undegradable protein (UIP; "escapes" ruminal degradation and enters the small intestine for digestion) supplemented at infrequent intervals. Consequently, three experiments were conducted to evaluate the affect of rumen CP degradability and supplementation frequency on ruminant performance and nutrient utilization.

Experimental Protocol

Seven steers in Experiment 1, 7 wethers in Experiment 2, and 84 pregnant (approximately 200 days) Angus × Hereford cows in Experiment 3 were provided 5 percent CP meadow hay and allotted to one of seven treatments: no supplementation or provision of a DIP or UIP supplement daily, once every 3 days, or once every 6 days. All supplemented treatments provided the same quantity of supplemental protein over a 6-day period. In other words, the once every 3 and 6 days treatments received 3 and 6 times the quantity of supplement on the day of supplementation, respectively, compared with the daily supplemented treatments. The DIP supplement was soybean meal and the UIP supplement was a mixture of soybean meal and blood meal.

Results and Discussion

Experiment 1 was conducted to determine the effects of rumen CP degradability and supplementation frequency on nutrient intake and digestibility by steers consuming low-quality forage. Results indicated that protein supplementation increased nutrient intake and digestibility. There was no difference between DIP and UIP treatments or supplementation intervals. These data suggest that livestock producers can provide a protein supplement as infrequently as once every 6 days to cattle consuming low-quality forage without negatively affecting nutrient intake and digestibility compared with daily supplementation.

Experiment 2 was conducted to determine the effect of rumen CP degradability and supplementation frequency on efficiency of protein use and nitrogen excretion by wethers consuming meadow hay. Protein intake and the quantity of protein digested that was incorporated into body tissues was increased with CP supplementation. As in Experiment 1, no differences were noted between DIP and UIP treatments or supplementation interval. Also, no difference was noted between DIP and UIP treatments, or between supplementation intervals, in the quantity of nitrogen excreted in urine or feces. These data indicate that infrequent supplementation of CP to ruminants consuming low-quality forage can result in efficiency of protein use (maintenance of body protein status), even when provided as infrequently as once every 6 days.

Experiment 3 was conducted to evaluate cow performance during the last third of gestation, as affected by rumen CP degradability and supplementation interval. Similar to the previous results, CP supplementation improved cow weight and body condition score at calving compared with no supplemental protein (Fig.1). Additionally, no differences were noted regarding CP source or supplementation frequency. This experiment illustrated that nutrient intake and nutrient utilization can be maintained in a production setting with infrequent supplementation of CP to ruminants consuming low-quality forage.

Management Implications

Infrequent supplementation of sources of natural protein (soybean meal, cottonseed meal, blood meal, etc.) to ruminants consuming low-quality forage is an acceptable management alternative to daily supplementation. In addition to similar nutrient utilization and performance by ruminants, infrequent supplementation can reduce labor and fuel costs by as much as 83 percent compared with daily supplementation (Table 1). However, producers should consider the use of an Extension agent, specialist, or nutritional consultant when designing an infrequent supplementation regime, because certain sources of supplemental CP (urea-containing supplements, for example) can cause toxicity concerns and may potentially result in death of livestock if not managed properly.

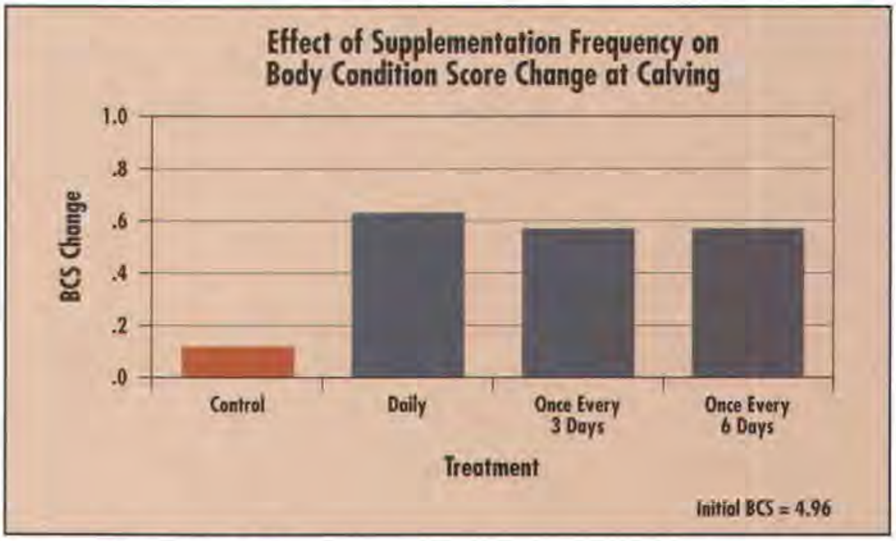


Figure 1. The effect of CP supplementation frequency on cow performance.

Table 1. Economics of infrequent supplementation over a 30-day period.

	Supplementation interval			
Item	***Daily***	***2 days***	***3 days***	***6 days***
Fuel cost ($)[a]	225.00	112.50	75.00	37.50
Labor cost ($)[b]	543.75	271.88	181.25	90.62
Total costs	768.75	384.38	256.25	128.12
Cost reduction	0	50%	67%	83%
Benefit ($)	0	384.38	517.50	640.63

[a] Fuel cost calculated as 3 gallons/supplementation day at $2.50/gallon.
[b] Labor cost calculated as 2.5 hours/supplementation day at $7.25/hour.

A Nutritional Calendar for Forage Kochia

David W. Bohnert, Christopher S. Schauer, Michael F. Carpinelli, and Stephanie J. Falck

Introduction

In the northern Great Basin, annual feed costs represent a major obstacle to beef producers and threaten the future of beef production. Feed costs can range from $100 to $200 per cow each year. In addition, much of the range in the northern Great Basin is becoming infested with cheatgrass due to past overgrazing and/or recurring wildfires. Forage kochia (*Kochia prostrata*) (Fig. 1) may be a complementary forage that can decrease winter supplementation costs while aiding in fire prevention. However, very little research has explored the nutritional quality of forage kochia for grazing ruminants.

Forage kochia is a half-shrub native to the arid and semiarid regions of central Eurasia. Because of its natural ability to survive in arid climates and on saline soils, many scientists and rangeland managers consider forage kochia a prime candidate for use in western range rehabilitation and fire prevention efforts. It tends to slow the spread of wildfires when used as a greenstrip; however, it will burn if surrounded by sufficient fuel. Following burning, it will sprout and regrow and is used extensively for seeding after fires on cheatgrass-dominated rangelands to help prevent future wildfires. No research has yet determined whether forage kochia seeds consumed by ruminants have the ability to germinate after passage through the digestive tract, thereby spreading to other range sites.

This experiment was conducted to develop a nutritional calendar for forage kochia and to determine whether forage kochia seeds are viable and germinate following passage through the gastrointestinal tract of ruminants.

Experimental Protocol

In 1986 and 1987, forage kochia was established on plots 1.25 miles north of Mud Lake in the Harney Basin of southeastern Oregon. These plots were fenced and excluded from cattle grazing but were accessible to wildlife. Plants were clipped on the 15th of July 2001, October 2001, January 2002, and April 2002. Samples were analyzed for nutritional content. Also, five ruminally cannulated steers were used to determine the viability of forage kochia seeds following ruminal incubation.

Results and Discussion

Forage kochia crude protein (CP) concentrations were higher in July through January than normally found in native grasses within the northern Great Basin (Fig. 2). During periods when native cool-season grasses were actively growing, forage kochia CP concentration was lower than native grasses. Also, ruminal digestibility of dry matter and CP from forage kochia decreased linearly from July 2001 through April 2002. However, these levels would increase the ruminally digestible dry matter and CP normally available to ruminants

Figure 1. Forage kochia (Kochia prostrata) growing in the Catlow Valley of southeast Oregon.

grazing dormant native range. These results suggest that forage kochia may function as a complementary forage source to grazing animals during periods when native grasses are dormant by supplying needed protein for both wildlife and domestic livestock.

Following ruminal incubation, no germination of forage kochia seeds occurred, compared with 95 percent for nonincubated seeds. These results are encouraging because they demonstrate the inability of forage kochia to become an invasive, noxious weed via ruminant dispersal.

Management Implications

Forage kochia can function as a complementary forage for domesticated livestock and wildlife grazing dormant cool-season forage in the northern Great Basin, without increasing potential stand spread through dispersal of viable seeds following grazing. During periods of native grass dormancy, forage kochia may improve the dietary CP of wildlife and domesticated livestock grazing rangelands inter-seeded with forage kochia. Furthermore, forage kochia has the potential to be a sustainable management alternative by which livestock producers in the northern Great Basin can decrease winter supplementation costs, help stabilize erodable soils, and aid in suppressing wildfires.

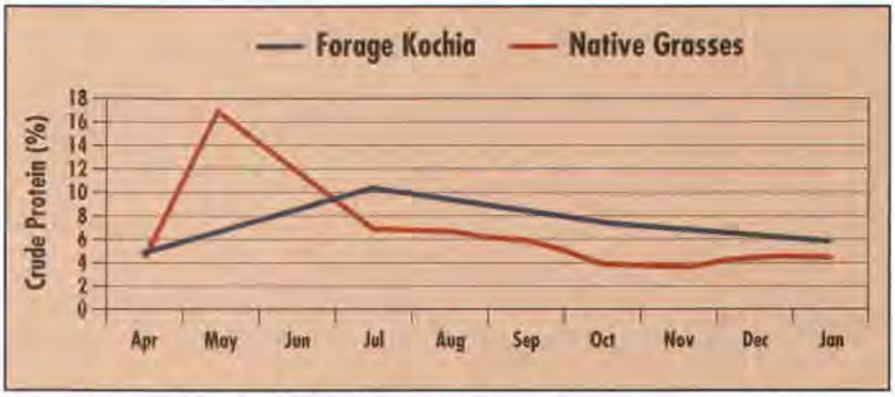


Figure 2. The effect of calendar date on crude protein concentration of forage kochia and native grasses.

Management Considerations for Use of Perennial Ryegrass Straw as a Forage Source for Beef Cattle

David W. Bohnert, Michael J. Fisher, and Christopher S. Schauer

Introduction

In the Pacific Northwest, grass seed is a major agricultural product. One of the most common grasses grown is perennial ryegrass. The traditional manner of straw disposal following seed harvest has been burning; however, the large amount of smoke produced causes adverse impacts upon the environment and can create situations that prove dangerous or fatal to humans. An alternative way to dispose of grass seed straw is use by ruminant livestock. Straw can be a low-cost winter forage resource for cow/calf operations in the Pacific Northwest.

In recent years, much of the grass seed industry's focus has been on producing "turf-type" grasses. Many of the "turf-type" perennial ryegrass varieties contain a fungal endophyte. This can be a problem because the endophyte produces the ergot alkaloid lolitrem B, which can have toxic effects (ryegrass staggers) when consumed by livestock. Symptoms of ryegrass staggers include uncoordination, staggering, tremors, head shaking, and collapse. Therefore, the objective of our study was to evaluate the effect of increasing lolitrem B concentration in perennial ryegrass straw on beef cattle.

Experimental Protocol

Sixteen steers in Experiment 1 and 72 pregnant (approximately 200 days) Angus × Hereford cows in Experiment 2 were used to evaluate the effect of increasing lolitrem B in perennial ryegrass straw on nutrient intake and digestibility, physiological variables (heart rate, respiration rate, and temperature), and cow performance. The perennial ryegrass straw was low quality (5 percent crude protein [CP]); therefore, approximately 2 lb/day of soybean meal was provided as a CP supplement in both experiments. In Experiment 1, steers were provided perennial ryegrass straw containing 0, 511, 1,038, or 1,550 parts per billion (ppb) lolitrem B for 25 days. In Experiment 2, cows were provided straw containing 467, 1,242, or 2,017 ppb lolitrem B during the last third of gestation (approximately 90 days). Following calving, all cows were provided meadow hay (6 percent CP) and soybean meal until spring turnout.

Results and Discussion

Experiment 1. No symptoms of ryegrass staggers were observed in steers consuming perennial ryegrass straw containing up to 1,550 ppb lolitrem B. Also, lolitrem B concentration had no effect on straw intake or digestibility by steers. Similarly, increasing lolitrem B concentration did not alter ruminal fermentation. Heart rate, respiration rate, and body temperature were normal for all steers, with little effect due to lolitrem B level.

Experiment 2. Thirteen of 24 (54 percent) cows consuming perennial ryegrass straw with 2,017 ppb lolitrem B developed ryegrass staggers. They were removed from the study and provided meadow hay and a CP supplement up to calving. These cows all calved normally, weaned a healthy calf, and were pregnant at weaning. Total dry matter intake by cows was not affected by lolitrem B concentration. Additionally, cow weight and body condition score change during the study were not affected by the lolitrem B content of the perennial ryegrass straw. Also, milk production of cows, measured approximately 8 weeks after calving, was not negatively affected by the lolitrem B level in straw consumed during the last third of gestation.

Management Implications

Feeding perennial ryegrass straw with greater than 2,000 ppb lolitrem B to beef cattle can cause neurological disorders that increase management concerns. While death can occur from the disorder, it usually is associated with misadventure (e.g., stumbling off of a cliff, entering a pond to cool off and drowning, etc.). Animals suffering from perennial ryegrass staggers should be removed from the causative feed source. Clinical signs normally subside in 2–14 days. Blending of straws containing low and high concentrations of lolitrem B to obtain a concentration equal to or less than 1,550 ppb can be a safe and economical management alternative for Intermountain cow/calf producers.

Daily and Alternate-day Supplementation of Natural Protein and Non-protein Nitrogen to Ruminants Consuming Low-quality Forage

David W. Bohnert, Thomas A. Currier, Christopher S. Schauer, and Stephanie J. Falck

Introduction

Supplementation of natural protein (alfalfa, soybean meal, cottonseed meal, etc.) to ruminants consuming low-quality forage (<6 percent crude protein [CP]) has improved forage intake, nutrient digestibility, animal performance, and reproductive efficiency compared with nonsupplemented controls. Similarly, providing non-protein nitrogen (NPN), such as urea or biuret, to ruminants consuming low-quality forage also has increased forage intake, nutrient digestibility, and animal performance, compared with no supplemental CP. Urea is very soluble in water and is degraded rapidly within the rumen to ammonia. This can result in ammonia toxicity if a large amount of urea is consumed in a short period of time. In contrast, biuret is insoluble and is broken down to ammonia slowly within rumen. As a result, biuret is safer and can be fed at higher levels than urea.

Non-protein nitrogen, primarily urea, is a popular source of supplemental CP because it is normally less expensive per unit of CP, compared with most natural protein sources. In addition to actual supplement costs, supplementation includes other expenses such as the labor and equipment associated with supplement delivery; therefore, infrequent supplementation of CP to ruminants consuming low-quality forage can decrease supplementation costs. Nevertheless, infrequent supplementation of NPN to ruminants is not a common management practice because of the potential for ammonia toxicity and decreased supplement intake, and it is often considered inferior to sources of natural protein. Therefore, we conducted a series of experiments to compare daily and every-other-day supplementation of natural protein or sources of NPN on forage intake, nutrient digestibility, and efficiency of CP use in ruminants consuming low-quality forage.

Experimental Protocol

The first set of experiments evaluated daily and every-other-day supplementation of two NPN sources, urea or biuret, to lambs, steers, and cows consuming grass seed straw. The second set of experiments compared daily and every-other-day supplementation of urea or soybean meal to lambs and steers consuming the same low-quality hard fescue straw.

Urea versus biuret. Five steers, 5 wethers, and 80 pregnant (approximately 200 days gestation) Angus × Hereford cows were provided 4 percent CP grass seed straw and allotted to one of five treatments. Experimental treatments included no supplementation or provision of a urea or biuret supplement daily or every other day. All supplemented treatments provided the same quantity of supplemental protein over a 2-day period, so that the every-other-day treatments received double the quantity of supplement on the day of supplementation, respectively, compared with the daily supplemented treatments. The urea and biuret supplements (5.3 percent urea and 6.1 percent biuret, respectively) were soy hull-based and contained approximately 30 percent CP.

Soybean meal versus urea. Five steers and 5 wethers were provided 4 percent CP grass seed straw and allotted to one of five treatments. Experimental treatments included no supplementation or provision of a soybean meal (SBM) or urea supplement daily or every other day. All supplemented treatments provided the same quantity of supplemental protein over a 2-day period, same as above. The SBM and urea supplements (31.0 percent SBM and 5.3 percent urea, respectively) were soy hull-based and contained approximately 30 percent CP.

Results and Discussion

Urea versus biuret. These experiments were conducted to determine the effects of type of supplemental NPN and supplementation frequency on nutrient intake and digestibility and performance by ruminants consuming low-quality forage. Supplementation with NPN increased nutrient intake and digestibility, the quantity of protein digested and incorporated into body tissues, and cow weight and body condition score at calving compared with no supplemental NPN. No differences were noted between daily and every-other-day supplementation. Therefore, with proper nutritional management, the nutrient intake, nutrient utilization, and cow performance can be maintained with daily or every-other-day supplementation of NPN to ruminants consuming low-quality forage.

Soybean meal versus urea. These experiments were conducted to compare daily and every-other-day supplementation of SBM or urea to ruminants consuming low-quality forage. Supplemental CP from both SBM and urea increased intake and digestibility of nutrients and the quantity of CP digested and incorporated into body tissues. Also, no difference was noted between daily and every-other-day supplementation. Therefore, nutrient intake and nutrient utilization by ruminants consuming low-quality forage was not affected by source of CP, even when provided every other day.

Management Implications

The cost of a CP supplement can be reduced by incorporating NPN (specifically urea) into the supplement rather than using all natural protein, with little effect on nutrient intake, nutrient digestibility, or cow performance. However, to minimize the potential of ammonia toxicity, producers should consult a nutritionist or Extension specialist for assistance in developing a supplementation plan that uses urea as a source of supplemental protein. This is especially true when the supplement will be provided every other day. Considerations include adequate bunk space, accessibility of supplement by animals, water supply, forage availability, and supplement carrier (ground corn, ground barley, ground soy hulls, etc.). In addition, the labor and fuel costs associated with supplement delivery can be reduced by approximately one-half with every-other-day compared with daily supplementation.

Improving Late-summer and Winter Forage Quality with Livestock Grazing

David Ganskopp, Tony Svejcar, and Marty Vavra

Introduction

Some years ago (1963), Dwayne Hyder and Forrest Sneva noted that spring grazing of boot-stage or later crested wheatgrass stimulated a growth of new stems that did not progress through their typical reproductive phases of development before curing. They speculated the resulting cured but leafy herbage would be of higher nutritional value than ungrazed forage reserved for late-summer or fall use. In 1975, E. William Anderson and Richard J. Scherzinger reported that use of a similar grazing program in the Bridge Creek, Oregon, area subsequently resulted in a four-fold increase in the number of wintering elk frequenting the area. Several researchers have subsequently explored the forage-conditioning hypothesis with clipping and grazing studies with mixed results. The objective of this study was to test the forage-conditioning hypothesis with cattle grazing. Our specific goals were to 1) evaluate the subsequent fall and winter nutritional characteristics of bluebunch wheatgrass, Idaho fescue, and bottlebrush squirreltail in stands that were ungrazed, lightly grazed, or heavily grazed by cattle during the boot-stage of grass development; and 2) determine the effects of implementing these same treatments on fall forage supplies.

Experimental Protocol

The study area occupied Bureau of Land Management-administered, pine-forest, sagebrush-steppe transition range and big-game winter range near Burns, Oregon. Nine small pastures supporting a shrub layer dominated by Wyoming big sagebrush and a herbaceous layer supporting the three grasses were used in 1998 and 1999. Three lightly grazed pastures supported two cows for about 11 days when grasses were in the boot-stage, three supported four cows, and three were ungrazed by livestock. Herbage was sampled at four times in the pastures: 1) just prior to grazing, 2) just after cows exited, 3) early September, and 4) late December. Forages were analyzed for crude protein (CP) content and digestibility.

Results and Discussion

Crop-year precipitation for both years of study was above average, with 1998 being 196 percent of average and 1999 being 106 percent of average. There were no differences in forage quality between grazing treatments when cattle entered the pastures in either year. Average forage utilization by cattle in lightly grazed pastures was 33 percent by weight and 69 percent in heavily stocked pastures. The September standing crop was 675 lb/acre in ungrazed pastures, 462 lb/acre in lightly grazed units, and 219 lb/acre in heavily grazed paddocks. Using the ungrazed standing crop as the standard, light grazing reduced fall standing crop by 32 percent and heavy grazing reduced fall standing crop by about 67 percent.

The fall and winter CP content of the grasses was affected by the species of forage, differences between years, grazing treatments, and the months they were sampled (September and December). However, several consistent patterns were evident in the data (Fig. 1). First, ungrazed controls always ranked lowest for CP content, with lightly grazed grasses being slightly higher, and heavily grazed grasses consistently the highest. Within the three species of grasses, the CP content of heavily grazed forage exceeded that of ungrazed controls for 11 of 12 comparisons. Crude protein content of lightly grazed grasses exceeded that of ungrazed controls for 6 of 12 comparisons. These included the last three sampling dates for Idaho fescue, December 1998 and September 1999 for bottlebrush squirreltail, and December 1998 for bluebunch wheatgrass. Between the two grazed treatments, the CP percentages were consistently higher for bottlebrush squirreltail in heavily grazed units than in lightly grazed pastures. Crude protein content of heavily grazed Idaho fescue and bluebunch wheatgrass significantly exceeded that of lightly grazed pastures on only one date (September 1999).

Among the grasses and within sampling dates, the CP content of grazed bottlebrush squirreltail always exceeded that of grazed bluebunch wheatgrass. Grazed bottlebrush squirreltail CP was greater than Idaho fescue for four of eight comparisons. These were the heavy-grazing treatment of December 1998, light- and heavy-grazing treatments of 1999, and the heavy-grazing treatment of December 1999. Crude protein percentages of grazed Idaho fescue were higher than those of grazed bluebunch wheatgrass in 1998 but similar in 1999. With one exception, the CP concentration of ungrazed controls was similar among species. The exception occurred in December 1998, when Idaho fescue had a higher CP content (4.7 percent) than bluebunch wheatgrass (3.1 percent). Digestibility data exhibited patterns similar to the CP data and are not presented.

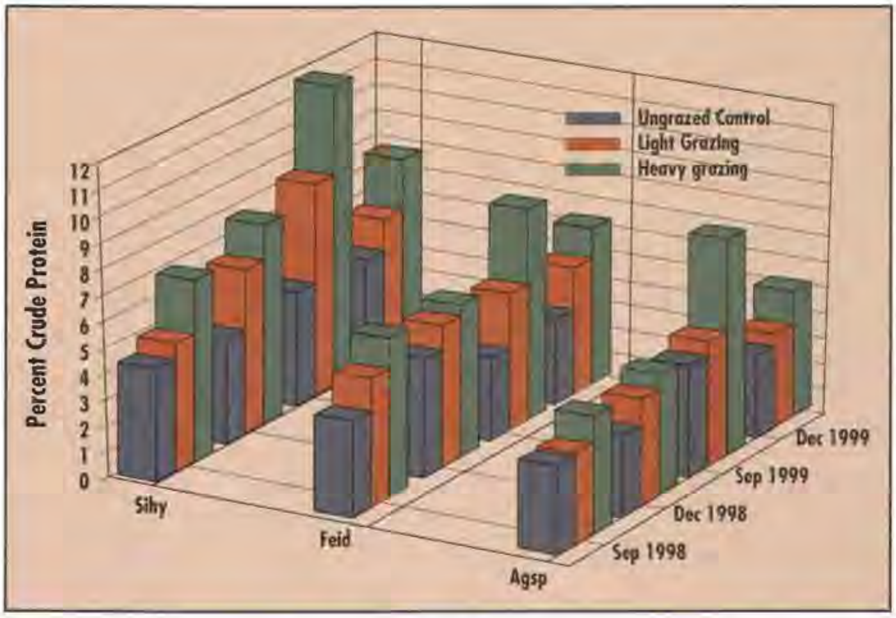


Figure 1. September and December crude protein content of bluebunch wheatgrass (Agsp), Idaho fescue (Feid), and bottlebrush squirreltail (Sihy) in ungrazed, lightly grazed, and heavily grazed pastures on big game winter range near Burns, Oregon, in 1998 and 1999.

Management Implications

Typically all but the earliest of growing season grazing among cool-season grasses causes some depression of growth or peak standing crop. The earliest grazing, however, removes only leafy material, does not suppress development of reproductive stems, and has negligible effects on late-season forage quality. That being the case, one should expect some depression of herbage yield (32–65 percent) if grazing applications are late enough to effect a positive change in nutrient content. With the assumption that 7.5 percent CP is an "adequate" forage quality threshold, there were six instances where fall and winter CP concentration equaled or exceeded 7.5 percent. Four occurred with bottlebrush squirreltail, one with Idaho fescue, and one with bluebunch wheatgrass. Five instances were a product of heavy grazing and one occurred in lightly grazed units.

If one's goal is to generate herbage with elevated fall/winter CP concentrations, then forage conditioning efforts probably will yield progressively greater returns from bluebunch wheatgrass, Idaho fescue, and bottlebrush squirreltail herbage, respectively. Our results suggest that bluebunch wheatgrass is probably the most difficult of the three species to condition with livestock grazing.

Judicious use of spring grazing to enhance late-season forage quality is an option for managers, and it probably should be applied within a rotation program that allows rest or deferred use of a pasture every second or third year. Opportunity costs of spring grazing also occur in that both annual and fall/winter standing crops will be reduced. The remaining herbage, however, will be nutritionally superior to ungrazed stands of grasses reserved for fall and winter use by livestock or big game.

Regrowth of Herbaceous Riparian Vegetation following Defoliation

Chad S. Boyd and Tony J. Svejcar

Introduction

End-of-growing-season herbaceous stubble height is an important consideration for managers of riparian areas grazed by livestock. Residual vegetation can influence riparian ecosystem structure and function by filtering and stabilizing water-borne sediments. This helps encourage streambank development and improves soil water storage capacity and site conditions for riparian-associated plant species. End-of-growing-season stubble height requirements are often used to ensure adequate residual vegetation in systems grazed by livestock. In such cases, managers need to know how much regrowth can be expected by the end of the growing season. Previous research indicates that both timing and intensity of defoliation can impact regrowth of herbaceous riparian vegetation. However, only a limited number of studies have addressed the simultaneous effects of timing and intensity of defoliation. Our objective was to determine the impact of timing and intensity of defoliation on regrowth of herbaceous riparian species.

Experimental Protocol

We used three small (generally less than 8 ft wide) streams in Harney County, Oregon. On each creek, four research sites were selected and fenced with electric fencing in April of 2000 (Fig. 1). Data were collected during the growing seasons of 2000–2002. Plant community types varied across and within streams and included sedge, rush, and grass-dominated stands. Treatments were applied within 3-ft-wide treatment bands that were located adjacent to the stream (CLOSE) and 12 ft distant (FAR). In all cases, the FAR plots were still within the stream's zone of influence (i.e., influenced by its water status). Within a treatment band, we located 15- by 20-inch treated (clipped) plots. Plots were clipped to 2, 4, or 6 inches, or left unclipped, in either June or July. End-of-growing-season stubble height was then measured in October of each year. Within a clipping treatment, values for end-of-season stubble height were averaged across years.

Results and Management Implications

Regrowth varied with clipping height, time, and distance from stream channel (Fig. 2). End-of-season height increased with increasing clipping height and generally was higher for plots close to the stream channel and those clipped in June. Values for end-of-growing-season height ranged from a low of 3.5 inches for the 2-inch, FAR, July clipping treatment, to a height of 7.5 inches for the 6-inch, FAR, June clipping treatment (Fig. 2). We selected study sites to be representative of the variability of stream systems in our area. Despite the resultant variability in plant community types between and within creeks, clipped stubble height and time of clipping were strongly associated with end-of-season regrowth performance. The regrowth response of plants to timing of clipping supported the management concept that later clipping (July) produces less regrowth than early clipping (June). This trend probably would have been accentuated with clipping even later in the growing season.

From a management perspective, height regrowth response at the clipping heights and times used

Figure 1. In this study we used a total of 12 research sites located along three different streams in Harney County, Oregon.

in this study generally provided sufficient regrowth to meet end-of-growing-season stubble height requirements on federal lands (approximately 4–6 inches). A 4-inch stubble height requirement was met by all but the 2-inch, FAR, July clipping. Conversely about one-half of the clipping treatments (mainly those clipped in June) met a 6-inch requirement. Managers should also consider that stubble height is only one of many tools available to gauge management impacts on resource integrity. Use of stubble height guidelines as a grazing management tool should be within the context of a more comprehensive management plan that includes consideration of upland forage conditions, habitat use patterns of livestock, and variability associated with site and climate factors. Further research is needed to improve our understanding of stubble height impacts on below-ground (root) production dynamics, and the role of residual vegetation in influencing bank building processes and site development.

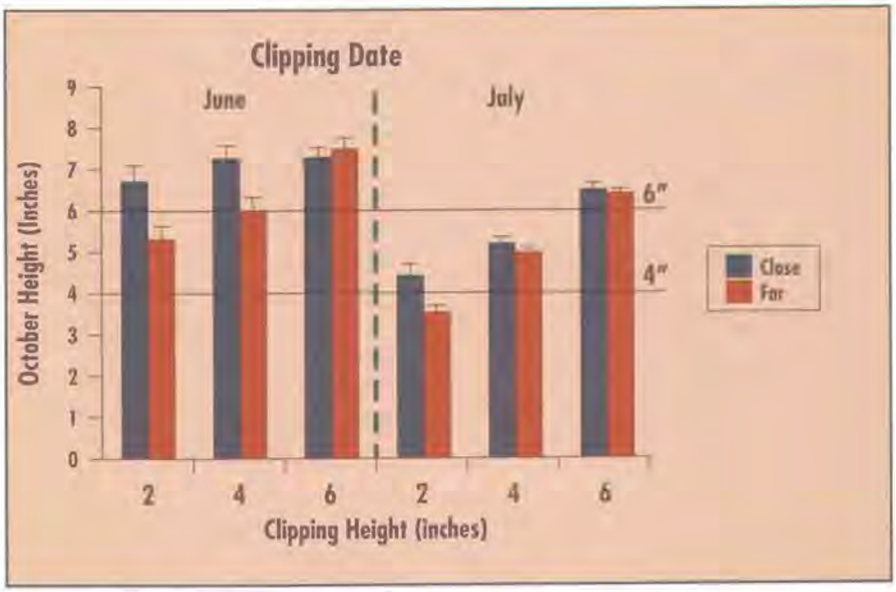


Figure 2. The influence of clipping height and time, and distance from active stream channel on end-of-growing-season (October) height for herbaceous riparian plants in plots located along small streams in Harney County, Oregon. Lines have been superimposed to indicate a 4- and 6-inch stubble height requirement.

Altering Beef Cattle Distribution within Rangeland Pastures with Salt and Water

David C. Ganskopp

Introduction

Most of the problems associated with grazing animals in extensive rangeland pastures are related to their uneven patterns of landscape use. Several landscape factors affect distribution, including distance to water, composition of plant communities, degree of slope, dense woody vegetation, mineral sources, and even tides and prevailing winds. Animal factors affecting distribution include species, breed, sex and age, requirements for escape or hiding cover, and knowledge of the area. Fencing, water, and salt are three of the most frequently used tools for altering cattle distribution in large pastures. Cattle are attracted to water in arid regions, but mixed results have been obtained with salt and mineral supplements. The goal of this study was to evaluate the effectiveness of moving salt and water within large (2,000+ acre) pastures to modify livestock distribution.

Figure 1. Beef cow no. 126 wearing a GPS (global positioning system) collar used to determine her precise location and activity at programmed intervals on the Northern Great Basin Experimental Range near Burns, Oregon.

Experimental Protocol

The research was conducted in the three largest (2,000+ acres each) pastures on the Northern Great Basin Experimental Range near Burns, Oregon. Forty Hereford X Angus cow/calf pairs simultaneously grazed each pasture in June and July, with two animals in each pasture wearing a global positioning system (GPS) collar configured to acquire the animal's position at 20-minute intervals (Fig.1). This schedule collected 72 positions for each animal each day. The collars also contained motion sensors that let us ascertain whether cattle were resting or grazing at each position. One of three treatments was applied to each pasture at weekly intervals. These included 1) salt and water together at a central point, 2) water moved to a distant locale with salt remaining in its original location, and 3) salt moved to a distant point with water remaining at its original location. Cattle were herded to each new site whenever salt or water was moved. Data that were analyzed included average distance of cattle to salt, average distance to water, total distance traveled per day, daily resting and grazing times, and the location of cattle centers of activity.

Results and Discussion

All indications were that cattle moved their centers of activity more (1,541 yards) when water was moved in a pasture than when salt (1,094 yards) was moved (Fig. 2). On average, cattle stayed within about 1,274 yards of water regardless of the resource moved (Table 1). This suggested that they followed the water tank to its new locale and remained nearby. Whenever salt or water was moved, the average distance of cattle from salt always increased, again suggesting there was little inclination to remain near salt.

If salt and water shared a common locale, cattle were found within 250 yards of salt and water 191 and 192 times within a week, respectively. When water was moved away from salt, cattle were near water 284 times and within 250 yards of salt

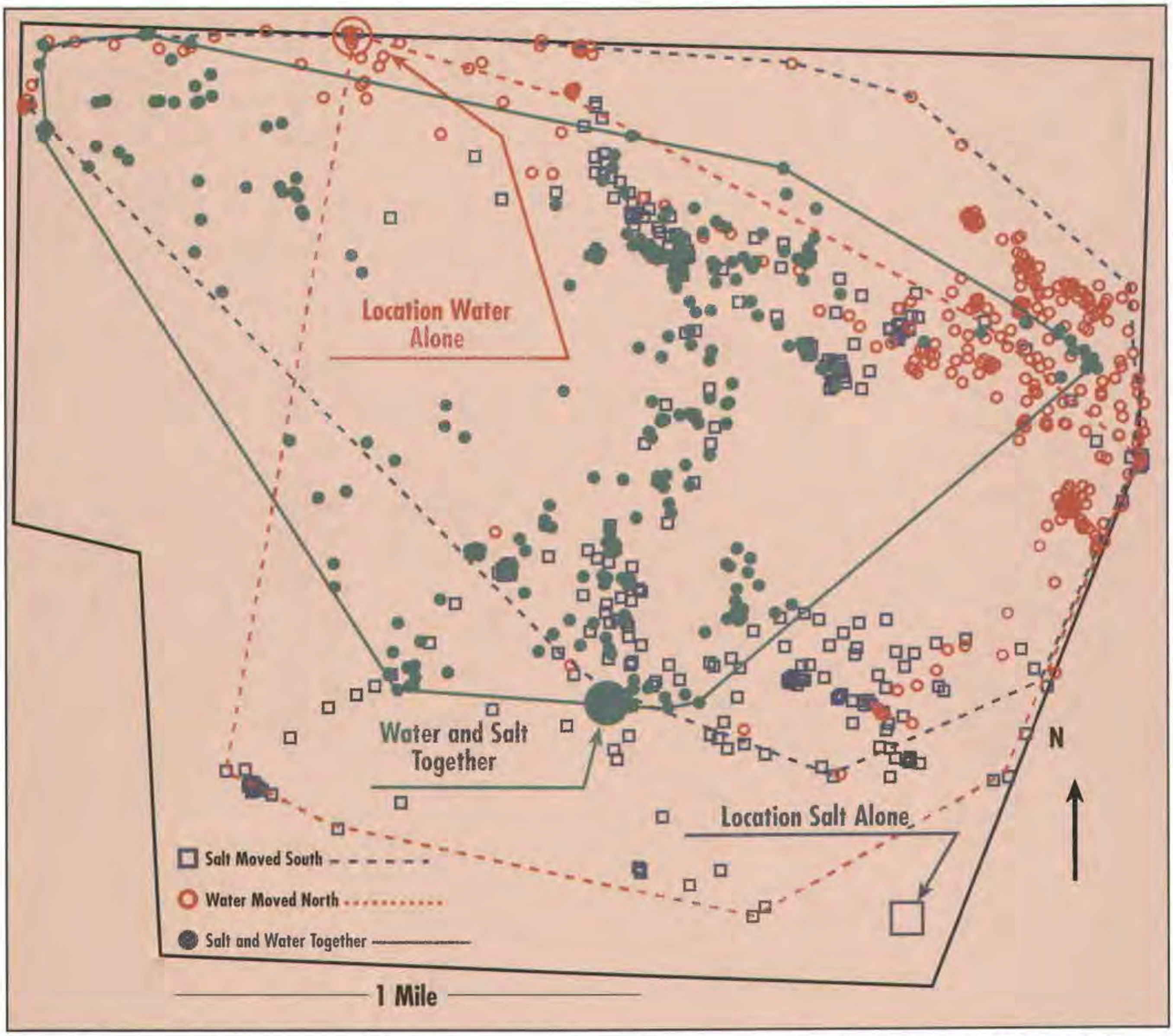


Figure 2. Locations of one cow in a 2,000-acre pasture sampled at 20-minute intervals with a collar-borne GPS (global positioning system) unit in June and July 1999 near Burns, Oregon when water and salt were moved to different locations within the pasture at weekly intervals.

only twice. Distance traveled per day (average = 3.59 miles), grazing time (11 hours per day), and resting time (10.1 hours per day) were unaffected by movements of salt or water. This implied that cattle did not increase their travels, or alter their time spent grazing, when water and salt were separated.

Management Implications

The movement of portable stock tanks or closing access to specific watering points is very effective at altering the distribution patterns of beef cattle on our arid rangelands. Cattle do not simply travel to distant water and return to their habitual foraging locations, but will alter their spatial distribution to remain in the vicinity of water. This practice may be used to 1) ensure more uniform use of forages across large pastures over time, 2) attract cattle to areas not habitually used, 3) temporarily lure cattle away from seasonally sensitive portions of a pasture (overgrazed areas or nesting or strutting grounds) without the expense of fencing, or 4) facilitate the gathering of herds in large pastures. Separations of salt and water sources will not cause cattle to alter their grazing times or expend more energy traveling each day. Finally, salt appears to be ineffective at markedly altering cattle distribution and most likely will not rectify a large-scale livestock distribution problem. Due to several mineral deficiencies in our forages, however, trace mineral salt should still be provided to cattle on a year-round basis, and its dispersal in a pasture will certainly not cause harm. Mineral intake, however, probably will be highest if it is provided near water sources.

Table 1. Average distance of cattle from water and salt, distance traveled per day, time spent grazing and resting per day, and area covered per day when water and salt occurred at a common locale and when water or salt were moved to a distant area in pastures in June and July 1999 near Burns, Oregon.

	Treatment			
Variable	***water and salt shared location***	***water moved to distant area***	***salt moved to distant area***	***water and salt separated***
distance to water (yd)	$1{,}142^{1}_{a}$	$1{,}078_{a}$	$1{,}601_{a}$	$1{,}340_{a}$
distance to salt (yd)	$1{,}126_{a}$	$2{,}209_{b}$	$1{,}648_{c}$	$1{,}928_{bc}$
distance traveled per day (miles)	3.61_{a}	3.43_{a}	3.72_{a}	3.58_{a}
grazing time (hr/day)	10.7_{a}	10.8_{a}	11.3_{a}	11.0_{a}
resting time (hr/day)	10.2_{a}	10.6_{a}	9.5_{a}	10.0_{a}
area occupied (acres)	785_{a}	573_{a}	$1{,}055_{a}$	812_{a}
shift of center of activity (yd)	- -	$1{,}541_{a}$	$1{,}094_{b}$	- -

[1] Values within rows sharing a common letter are not significantly different ($P \leq 0.05$).

Will Spring Cattle Grazing among Young Bitterbrush Enhance Shrub Growth?

David Ganskopp, Tony Svejcar, Fred Taylor, and Jerry Farstvedt

Introduction

Because of its palatability and sustained levels of forage quality, antelope bitterbrush is a desirable shrub for cattle and wintering big game on western United States rangelands. Earlier research in Utah and Oregon established that conservative early spring livestock grazing could stimulate bitterbrush growth compared to shrubs in ungrazed communities. Spring grazing of stands by cattle removed competing grasses and forbs and left more moisture and minerals for the shrubs later in the growing season. Because little information is available regarding the grazing management of newly established stands of bitterbrush, this study was undertaken to 1) determine the effects of light and heavy spring cattle grazing on the subsequent growth of young shrubs, and 2) explore stocking pressure thresholds for management of young bitterbrush.

Experimental Protocol

Nine small pastures (about 1.9 acres each) north of Burns, Oregon, were used for the study. They occupied areas reclaimed by Bureau of Land Management and Oregon Department of Fish and Wildlife personnel and seeded with bitterbrush after the 1990 Pine Springs Basin wildfire. Treatments included 1) control pastures ungrazed by livestock, 2) lightly grazed pastures, and 3) heavily grazed pastures. Stands were grazed by cattle in 1997, 1998, and 1999 when grasses were in the vegetative to boot-stages of growth beginning in about mid-May each year. Lightly grazed pastures supported two cows, and heavily grazed pastures supported four cows for about 14 days each. Before the study began, we measured forage standing crop and the height and diameter of shrubs. We returned every other day while cattle were present and checked 25 shrubs in each pasture for signs of browsing by cattle or trampling damage. When cattle exited the study, we again measured the height and diameter of the bitterbrush and sampled standing crop to assess degree of utilization on the grasses. Finally, we returned a third time in early September and remeasured the shrubs to see how they had grown over the summer.

Results and Discussion

Average forage utilization was 32 percent in lightly grazed pastures and 59 percent in heavily grazed units. On average, 14 percent of the bitterbrush was partially browsed by cattle in lightly stocked pastures and 62 percent was browsed in heavily stocked units. Cattle did not initially begin foraging on bitterbrush, but began browsing plants

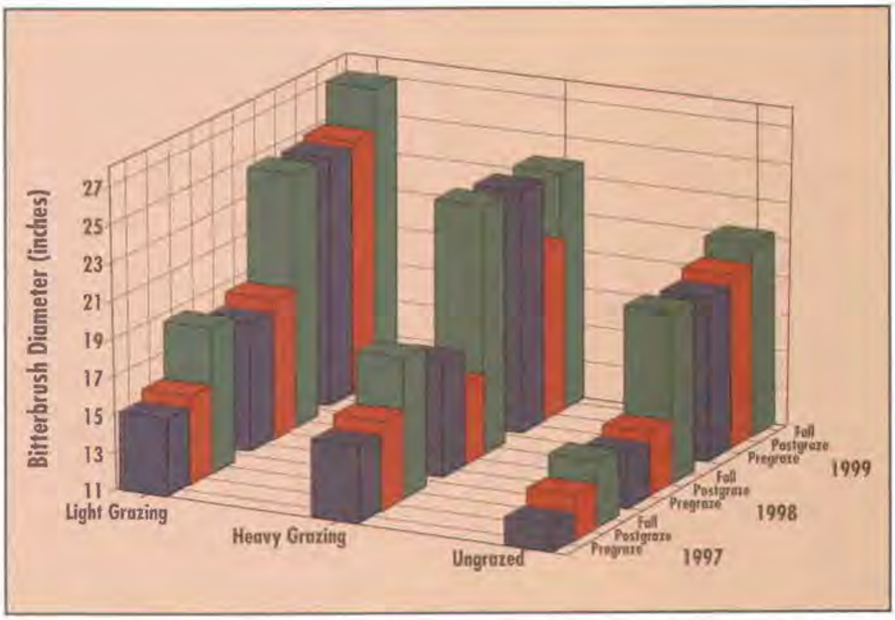


Figure 1. The changes in bitterbrush diameter monitored in lightly grazed, heavily grazed, and ungrazed pastures before and after grazing by cattle and at the end of the growing season during 1997–1999 on big game winter range near Burns in southeast Oregon.

by about days 5–6 in the heavily grazed treatment and about day 8 in the lightly grazed paddocks. Bitterbrush diameter was reduced by about 1.7–3.7 inches in heavily grazed pastures for 2 of 3 years of study (Fig. 1). Height was not reduced by cattle browsing in any of the treatments, and no growing season browsing by big game occurred among bitterbrush in ungrazed controls. Analyses of standing crop data suggested cattle began foraging on bitterbrush in spring months when forage levels declined to about 90–135 lb/acre. Trampling damage included evidence of broken twigs or skinned bark on the main trunk of shrubs. About 29 percent of the shrubs received some trampling damage under light grazing, and 55 percent suffered trampling damage with heavy grazing. Trampling impacts appeared to be a simple function of time and the number of animals stocked per acre. Only one shrub, located where the cattle habitually bedded in a heavily grazed pasture, was lost to trampling.

At the end of the growing season (early September), bitterbrush in lightly grazed stands exhibited a 50-percent greater increase in diameter (Fig. 1), 30 percent greater increase in height (Fig. 2), and 8 percent longer twigs than shrubs in ungrazed pastures. For 2 of 3 years, bitterbrush shrubs in heavily grazed pastures were about 4.2 inches wider in the fall than shrubs in ungrazed controls. In the third and driest of the 3 years, bitterbrush in the heavily grazed units did not exhibit the same degree of compensatory growth as in the previous years and was about 1.7 inches shorter than lightly grazed or ungrazed controls at the end of the growing season. Bitterbrush in heavily grazed pastures was either wider or the same diameter as ungrazed controls at the end of the growing season in all 3 years.

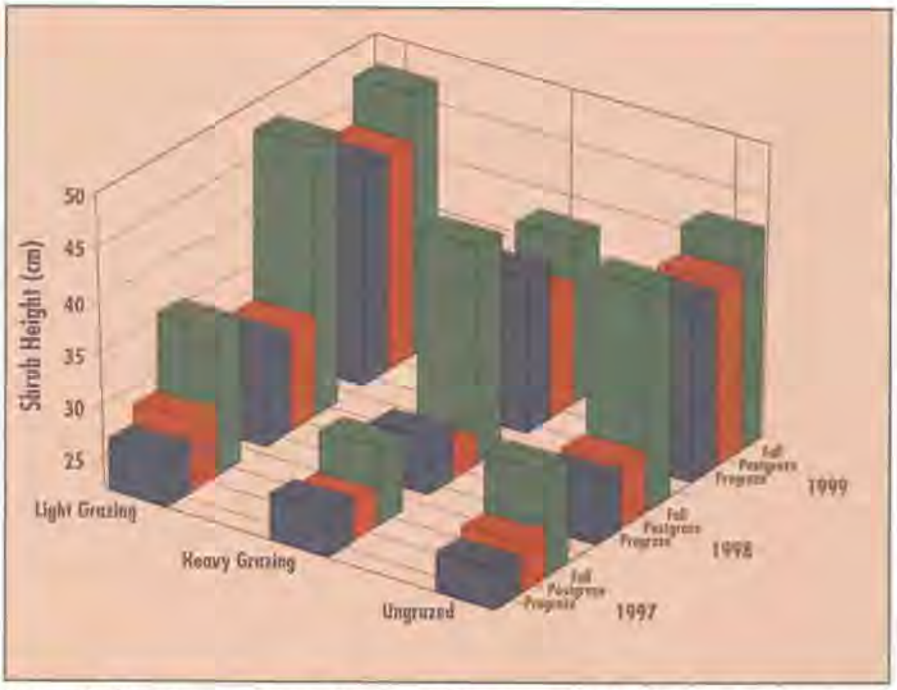


Figure 2. The changes in bitterbrush height measured in lightly grazed, heavily grazed, and ungrazed pastures before and after grazing by cattle and at the end of the growing season during 1997–1999 on big game winter range near Burns in southeast Oregon.

Management Implications

These findings suggest that if a manager's goal is to stimulate bitterbrush growth in northern Great Basin grass/shrub communities, the stand should be lightly grazed (about 30–40 percent utilization of the herbaceous forages) by cattle when bitterbrush is flowering and accompanying grasses are in the vegetative to late-boot stages of phenology. This level of grazing will stimulate bitterbrush growth, and shrubs will be wider and taller than companions in ungrazed pastures. Heavier grazing applications, where utilization approaches 60 percent on herbaceous forages, can have some immediate effect on bitterbrush diameter. Browsed shrubs in heavily grazed pastures, however, can respond with as much growth as cohorts in ungrazed pastures if cattle leave while there is still sufficient soil moisture for twig growth to continue. In drier growing seasons, bitterbrush may not be able to compensate for heavy, early-season browsing if soil moisture is depleted and shrubs cannot initiate mid-summer growth. While some trampling of young bitterbrush may occur, young shrubs are quite resilient and can tolerate moderate damage without long-term effects.

Does Wolfy Forage Affect Cattle Distribution in Rangeland Pastures?

David C. Ganskopp and David W. Bohnert

Introduction

Two grasses, common to the sagebrush-steppe, are well known for their propensity to become "wolfy." Both bluebunch wheatgrass (*Agropyron spicatum*), a native species, and crested wheatgrass (*A. desertorum*), an introduced grass, produce durable seed stalks that can persist within bunches for 1 or more years (Fig. 1). Earlier research at the experiment station has demonstrated that cattle are aware of even one cured stem in clumps of green grass, and they are about 40 percent more likely to reject a wolfy plant than one that is not contaminated with cured stems. There has been little research, however, on how cattle respond to stands of wolfy forage at landscape levels. Therefore, the objective of this study was to determine how cattle move about and use portions of pastures supplying either wolfy herbage or forage consisting of only current year's growth. This was accomplished by first conditioning portions of our pastures, and then equipping cattle with GPS (global positioning system) collars to monitor their grazing habits the subsequent growing season.

Experimental Protocol

Four pastures, each about 33 acres in size, were split with electric fence near the end of the growing season in mid-July 2000, on the Northern Great Basin Experiment Range near Burns, Oregon. One half of each pasture was designated as a "wolfy" treatment, while the other was designated as a "conditioned" treatment. Over 7 days, about 75 cow/calf pairs were rotated through the conditioned portions of each pasture and left to forage until herbage was reduced to about a 1-inch stubble. No cattle were allowed in the wolfy sectors. Electric fences were removed, and in late May 2001 we sampled standing crop and forage and diet quality in both the wolfy and conditioned sectors (Fig. 2). Also, GPS-collared cattle were placed in each pasture. The GPS units were configured to ascertain a cow's position and activity level every 10 minutes for a total of 144 positions per day. At this time, half of each pasture supported wolfy herbage, made up of current and last year's growth, and the other half contained only green herbage with little to no standing dead stems.

Figure 1. A wolfy crested wheatgrass pasture near Burns, Oregon. Herbage has been grazed from the topmost portions of some bunches. Substantial forage is wasted, however, because current year's growth is intermixed with older, cured materials that are nutritionally deficient and present a physical barrier to cattle grazing.

Results and Discussion

When cattle were turned in, standing crop was about 484 lb/acre in wolfy sectors and less than half as much (180 lb/acre) in conditioned areas. About one-half of the wolfy herbage was cured material. Chemical analyses of standing crop found higher levels of crude protein (CP) and digestibility in the conditioned sectors (11 percent CP and 58 percent digestibility) than in the wolfy portions (6.5 percent CP and 47 percent digestibility). Diet quality of rumen-cannulated steers confined to each treatment, however, was identical, averaging about 13 percent CP and 59 percent digestibility. This suggested that cattle are very good at sorting old and new herbage and that they can, at least initially, extract a high-quality diet from among wolfy herbage.

From a total of 12,096 coordinates obtained by our GPS units, 41 percent occurred in the wolfy sectors and 59 percent were in the conditioned areas. For the 45 percent of the time cattle were grazing each day, about 18 coordinates were in wolfy sectors and 42 coordinates occurred in conditioned portions of the pastures. Therefore, cattle preferred conditioned areas 2.3 times more than wolfy areas when grazing. On the last day of the trial, however, 72 percent of their grazing activities occurred in the wolfy areas, suggesting that the cattle may have depleted the feed supply in the conditioned portions of their pastures. Over the 7-day trial, standing crop decreased by about 13 percent in the conditioned portions of pastures and actually increased by about 10 percent in the wolfy sectors.

On average, cattle traveled about 2.71 miles per day. They also traveled slightly more each day as the trials progressed (2.25 miles on day 1 increasing to 2.87 miles on day 7), suggesting that travel may have increased as the forage supply dwindled. With the exception of their trips to water, it appeared that cattle did little traveling when they were not grazing. On average, 92 percent of their total travel in a day was associated with grazing activities.

Figure 2. Wolfy and conditioned sectors of a crested wheat grass pasture grazed by GPS-collared cattle on the Northern Great Basin Experimental Range near Burns, Oregon, in May, 2001. Herbage in the wolfy sector (left of center) consists of last year's old material and current season's growth and exhibits a lighter colored complexion. Grass on the conditioned side (right of center) is primarily current season's growth and contains little if any cured material.

Management Implications

Given a choice, cattle exhibit a significant preference for conditioned portions of rangeland pastures as opposed to those areas supporting wolfy forage (about 2.3 to 1). Indeed, wolfy areas in pastures actually grew additional herbage while cattle were present in our study. This behavior may partially explain why livestock appear to habitually use the same areas in a pasture over successive years. They are quite likely avoiding those areas that support a mixture of old and current season's herbage and are selecting those areas and grasses where they do not have to sort among old and new growth. Previous work at the station has shown that cattle are much less aware of stemmy forage after all grasses have cured. That being the case, the use of high numbers of stock to clean out wolf plants will probably be more successful if heavy grazing is applied late in the growing season. Other options for removing wolfy vegetation include mowing or prescription burning. Regardless of the treatment chosen, removing wolfy forage will encourage more uniform use of a pasture and more complete use of the available herbage by livestock or wildlife.

Grazing following Juniper Cutting

Jon Bates

Introduction

Removal of western juniper by cutting can increase understory biomass, forage quality, ground cover, and plant diversity. These results are based on resting sites 2 or more years after treatment. There is limited research on how grazing influences herbaceous recovery after juniper cutting. Reintroducing livestock too quickly after treatment may inhibit herbaceous recovery, particularly on sites with a diminished perennial component, and promote dominance of the site by undesirable exotic grasses and forbs. However, cut juniper sites often account for only a small proportion of a field. Resting fields for longer than 2 years may not be feasible for livestock operators or land managers, especially if longer-term rest or deferment interfere with other land management goals and objectives. Because the amount of woodlands treated has increased significantly during the past decade, evaluating grazing impacts following juniper control is important for developing strategies that successfully rehabilitate shrub-grassland plant communities in the northern Great Basin.

Experimental Protocol

Understory succession in western juniper woodlands on Steens Mountain, Oregon, was assessed under grazed and ungrazed conditions immediately following tree cutting over a 4-year period. Cattle grazed plots only the first 2 years after treatment. Plots were not grazed the 3rd and 4th year post-treatment to evaluate short-term impacts on herbaceous biomass and seed production. The prescription was to graze the field for a short duration in the spring when perennial grasses were in vegetative to early-boot growth stages. Stocking rates were 0.3 cow-calf pairs per acre for 5 days in early May 1999 and 0.38 cow-calf pairs per acre for 4 days in early May 2000. Utilization in cut-grazed plots averaged 73 percent in 1999 and 71 percent in 2000. Utilization above 70 percent is considered heavy in sagebrush plant communities. Utilization in uncut grazed plots averaged 64 percent in 1999 and 15 percent in 2000.

Results and Management Implications

Juniper cutting resulted in increased herbaceous cover, biomass, and seed production when compared to woodland controls. By the third year post-cutting, perennial bunchgrass and annual grass canopy cover in both cut-grazed and cut-ungrazed treatments were significantly greater than in the uncut treatments.

However, grazing had no measurable short-term impacts on understory recovery as measured by plant cover and biomass. Increases in herbaceous cover and biomass were similar in grazed and ungrazed-cut treatments (Fig. 1). In the cut treatment, biomass of the large perennial grass group was greater in the ungrazed prescription. This difference was attributed to the accumulation of dead leaf and reproductive material within grass bunches between 1999 and 2002 in the ungrazed treatment.

These trials were conducted across relatively dry years, with little spring precipitation. Soils on this site are shallow and dry relatively quickly. Regrowth on the cut-grazed plots was adequate following May grazing in 1999 and

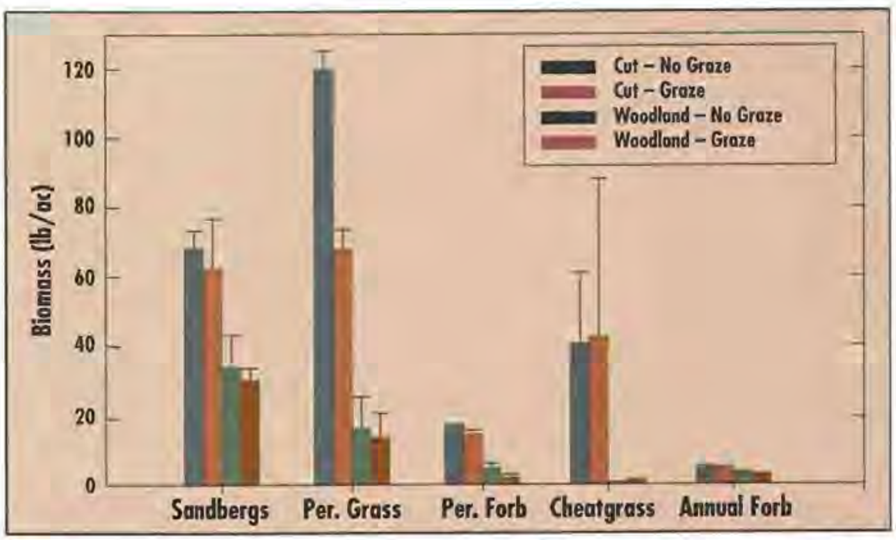


Figure 1. Biomass (lb/acre) comparisons for species functional groups collected in June 2002 on Steens Mountain, Oregon, as affected by juniper cutting and grazing treatment. Values are in means ± one standard error.

Table 1. Comparison of total seed production (lb/acre) for perennial grasses collected on Steens Mountain, Oregon, as affected by juniper cutting and grazing treatment. Weights are for raw seed produced with awns remaining on seeds.Table 1. Comparison of seed production (lb/acre) values for perennial grasses collected on Steens Mountain, Oregon, as affected by juniper cutting and grazing treatment.

Treatment	*Sandberg's bluegrass*	*Bluebunch wheatgrass*	*Basin wildrye*	*Junegrass*	*Indian ricegrass*	*Squirreltail*	*Thurber's needlegrass*
				lb/acre			
2000							
Cut	0.6 ± 0.3 a[1]	2.0 ± 1.4 a	0.4 ± 0.3 ab	0.6 ± 0.6	4.0 ± 2.3 bc	2.4 ± 1.0 c	5.9 ± 1.9 c
Cut-graze	0.1 ± 0.0 a	0.04 ± 0.0 a	0.3 ± 0.0 ab	0.0 ± 0.0	1.5 ± 0.4 b	0.5 ± 0.1 a	0.6 ± 0.2 b
Woodland	0.2 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 a
Woodland Graze	0.2 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 a
2001							
Cut	5.0 ± 1.5 b	8.3 ± 4.2 b	1.1 ± 0.6 b	2.2 ± 2.2	8.1 ± 5.3 c	5.8 ± 4.2 cd	12.8 ± 10.1 c
Cut-graze	4.8 ± 1.0 b	6.1 ± 3.0 b	0.3 ± 0.2 ab	0.0 ± 0.0	8.5 ± 5.7 c	6.8 ± 1.4 d	5.3 ± 2.5 c
Woodland	4.6 ± 1.6 b	0.0 ± 0.0 a	0.0 ± 0.0 b	0.0 ± 0.0	0.0 ± 0.0 a	0.0 ± 0.0 a	0.2 ± 0.0 a
Woodland Graze	5.0 ± 1.3 b	0.0 ± 0.0 a	0.0 ± 0.0 b	0.0 ± 0.0	0.1 ± 0.1 a	0.0 ± 0.0 a	0.1 ± 0.0 a

[1] Weights are for raw seed produced with awns remaining on propagules. Different lower case letters indicate significant differences among treatment means within a column ($p < 0.05$).

2000, but this growth was primarily vegetative with little seed produced. The dry conditions were a major factor in the lack of perennial grass recruitment for the grazed and ungrazed-cut treatments.

The relatively short and heavy grazing prescriptions imposed were detrimental to perennial grass seed production (Table 1). Thurber's needlegrass seed production was the most negatively impacted by the grazing prescription. Seed production of other perennial grass species was less affected by the grazing treatment and made a relatively quick recovery the fourth season after cutting. To provide plants the opportunity to maximize seed crops and enhance opportunities for seedling establishment when environmental conditions are favorable, this site requires rest or deferment the first few growing seasons.

A Visual Obstruction-based Technique for Photo Monitoring of Willow Clumps

Chad S. Boyd and Tony J. Svejcar

Introduction

Willow and associated riparian shrubs fill a variety of important ecological roles in many riparian ecosystems. With this importance comes the management need to document changes in willow abundance over time. This is particularly true in areas where willows are being restored or where herbivory may negatively impact willow resources. However, measuring changes in abundance of woody plants has proven difficult in field application. One potential solution to this monitoring challenge is the use of ground-based photographs to estimate willow abundance. Photo monitoring can reduce observer bias, provide a permanent record of vegetation status, and samples (photographs) can be reanalyzed at a later date if new technologies become available. Our objective was to evaluate the use of a visual obstruction/photo-based approach for monitoring point-in-time abundance of willow clumps and changes in abundance associated with defoliation by herbivores. We focused on young willows (≤6.5 ft in height) because this size class represents a critical life stage in the development of willow clumps and can be impacted easily by herbivory.

Experimental Protocol

The study site was located in the Big Creek drainage in Grant County, Oregon. Sampling took place during peak biomass (August) of 2000 and 2001. The technique focused on the relationship between visual obstruction of a photoboard and the abundance of obstructing willows, in this case Booth's willow. Rather than moving the photoboard to a willow clump, clumps—or portions of clumps—were cut, transported to the photoboard location, and clamped in a holding device located immediately in front of the photoboard (Fig. 1). The photoboard (59 by 79 inches) was constructed from plywood painted fluorescent orange to increase color variation between the board and willow clumps when determining visual obstruction. Twenty-five willow clumps were sampled in each year of the study. Willow clumps were defoliated by hand in four to seven increments and harvested material was dried and weighed. Defoliation removed leaves plus the tips of new stem growth. For simplicity, we refer to this material as current annual growth or CAG. Photographs were taken before and after each removal (Fig. 1); these defoliations were meant to simulate the effects of herbivory. The visible photoboard area was determined using color recognition software. We determined visual obstruction by comparing the photoboard area in each photograph to that visible for the same board without obstructing willow.

Results and Management Implications

Results suggest that the technique presented here can be used to predict both qualitative (i.e., increasing or decreasing amount) and quantitative (i.e., amount of increase or decrease) changes in

Figure 1. These images show a willow clump during (left) and after defoliation (right). Clumps were defoliated in four to seven increments, and photographs were taken before and after each defoliation.

willow abundance within the size class of clumps used in our work. The technique accurately predicted the weight of total clump CAG (Fig. 2a), and the strong relationship between disappearance of CAG and change in visual obstruction (Fig. 2b) suggests this technique may be useful for monitoring changes in willow abundance associated with herbivory.

For field monitoring purposes, we constructed a portable lightweight version of the photoboard on an aluminum frame fitted with a board of 2-mm-thick fluorescent orange (59 by 79 inches) that was elevated 16 inches from the ground surface (Fig. 3). Stabilizing legs allowed the board to be freestanding. The board was painted fluorescent orange, and the frame was constructed in two pieces so that the more portable half frame could be used for very small willow clumps. Visual obstruction values for the half board may be expressed as a percentage of either the half or whole board. For clumps wider than our photoboard, it was not possible to estimate total clump CAG. However, with accurate repeat board placement it was possible to estimate changes in the amount of willow CAG influencing the photoboard over time. These data can be used as both a quantitative (i.e., index to weight of total clump CAG) and qualitative (i.e., is visual obstruction, and thus CAG weight, increasing, decreasing, or staying the same over time?) monitoring tool.

In summary, our technique provides managers with a method for reliably and accurately estimating willow abundance, changes in abundance over time, and degree of utilization by herbivores. However, users should keep in mind that the relationships we report may differ by species of willow, leaf structure, and the ratio of woody to leaf plant material. For these reasons, we recommend that predictive equations be developed on a site-specific basis. Additional work is needed to test the relationships described herein with other willow species and larger clump sizes.

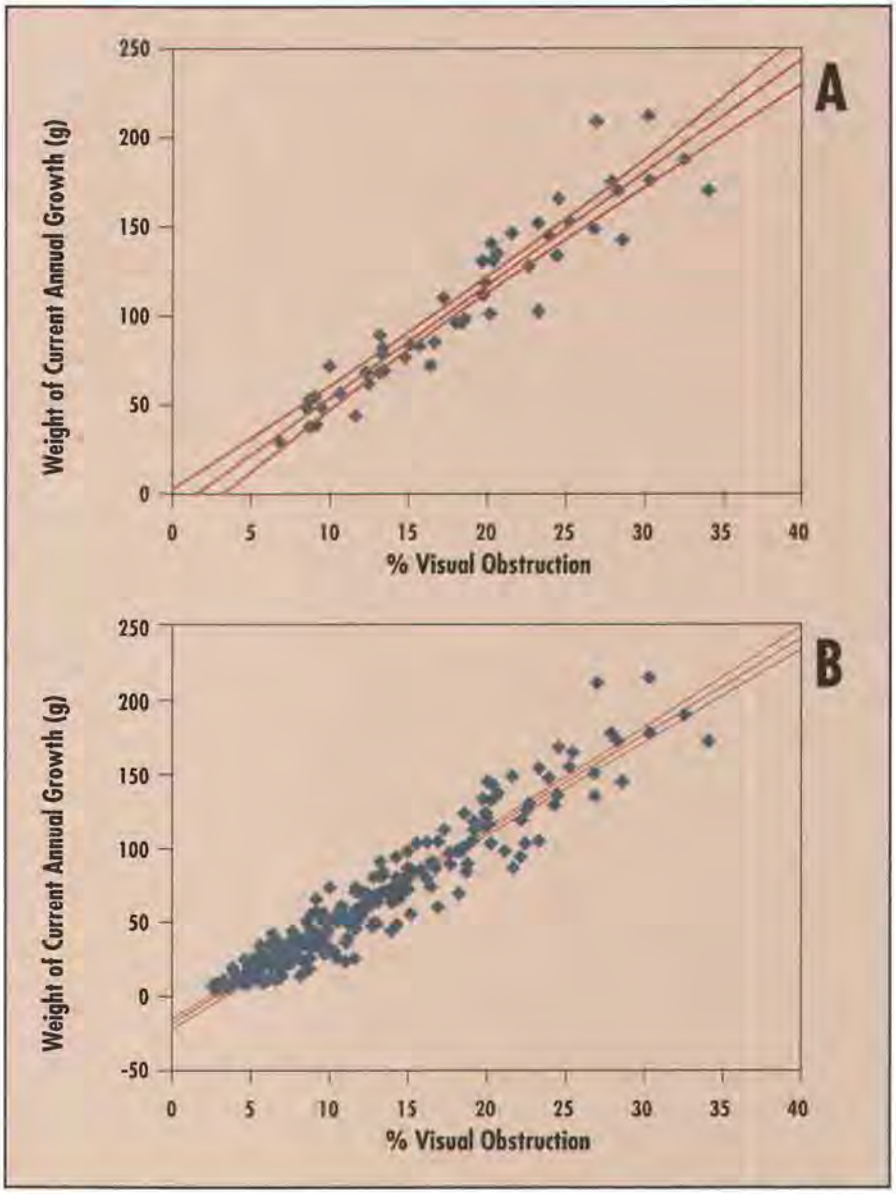


Figure 2. The relationship between percent visual obstruction of a 59- by 79-inch photoboard and (A) total weight (g) of current annual growth (leaves and tips of current annual stem growth, CAG) for harvested willow clumps and (B) remaining weight of CAG for harvested willow clumps following sequential defoliation in four to seven increments.

Figure 3. For field monitoring, we designed a lightweight photoboard constructed of an aluminum frame with a painted plastic board. For smaller willow clumps, the apparatus may be disassembled (left); the full board is used for larger clumps (right).

Using Felled Western Juniper to Exclude Willows from Herbivory

Casey A. Matney, Chad S. Boyd, and Tamzen K. Stringham

Introduction

Willow communities are critical components of riparian ecosystems and serve to provide habitat for numerous wildlife species, aid in maintenance of stream channel structure and stability, and provide shade for the aquatic environment. Restoring willow communities in areas where populations have declined or are absent is often difficult because of willow consumption by both livestock and wildlife species. Herbivory is especially problematic for young plants that have not yet produced leaves out of reach of browsing animals. A common solution to herbivory-related problems is to use fencing to exclude riparian areas from herbivores; however, this can be an expensive option and may not complement desirable grazing strategies. An alternative to fencing may be the use of structures that limit access to streamside willows but don't necessarily exclude use of the overall riparian area. Our objective was to evaluate the use of felled western juniper as a herbivory barrier for young willow plants.

Experimental Protocol

The study site was located on Steens Mountain in Harney County, Oregon, within a mountain meadow at approximately 6,800 ft elevation. The meadow was bisected by a small (less than 6 ft wide), second-order stream that had intermittent populations of small-stature willows, generally less than 2 ft high.

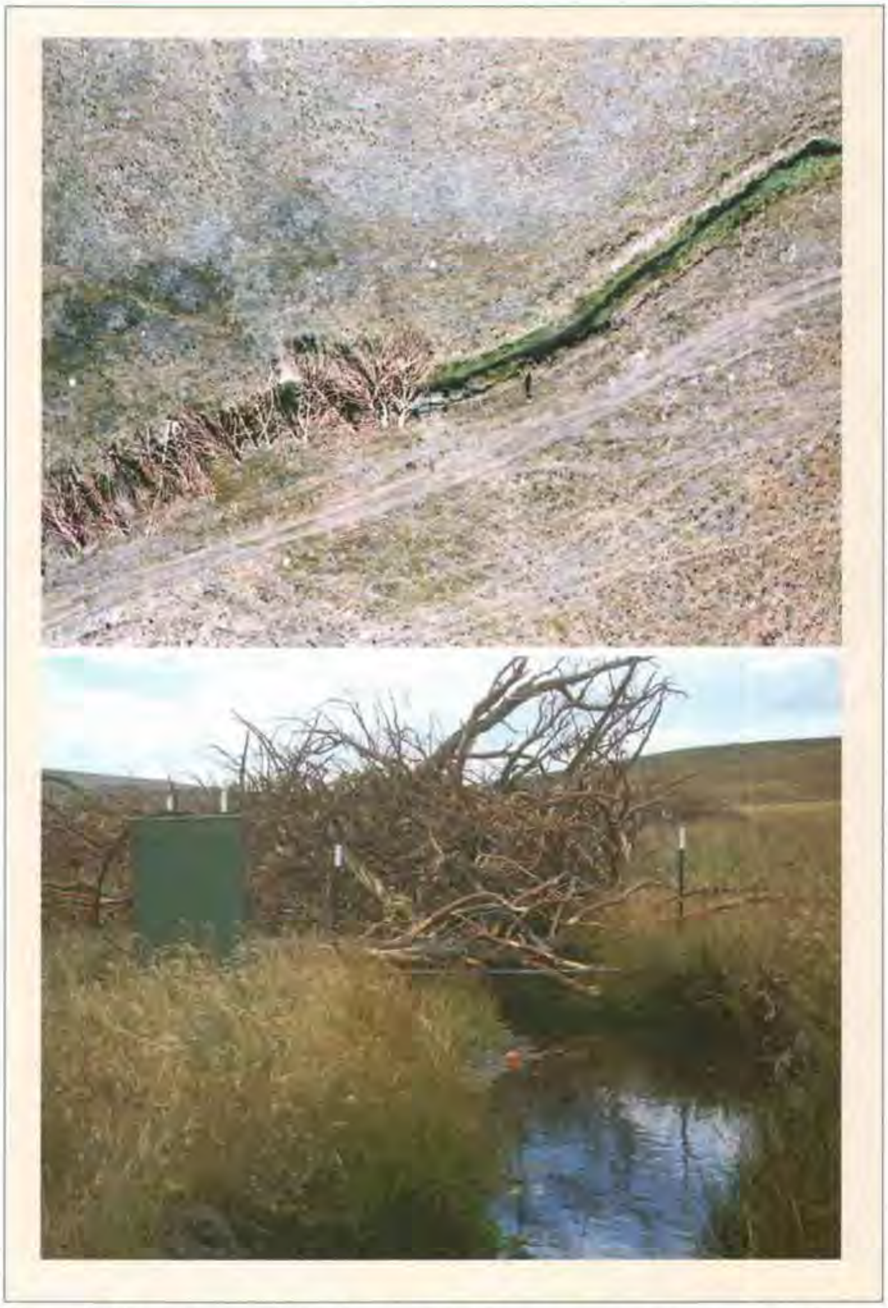


Figure 1. These images depict the transition between an open treatment and one covered with felled western juniper, Steens Mountain, Oregon.

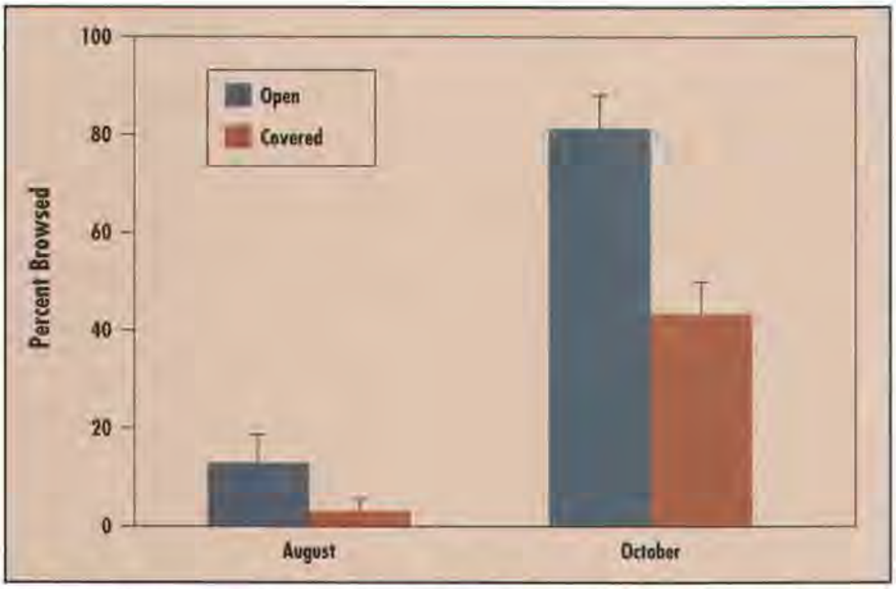


Figure 2. Percentage of willow plants browsed in open treatments versus those covered with felled western juniper for August and October 2003 sampling periods, Steens Mountain, Oregon.

Historically, the meadow had been grazed during the growing season by cattle and sheep and was populated by a variety of wild herbivores including mule deer, pronghorn antelope, and elk. For purposes of the experiment, we did not partition relative use of willows within the study area by livestock and wildlife species. The study design incorporated four 1,000-ft-long blocks of stream. We counted and marked all streamside willows within the study reach in August of 2002 using aluminum tags and survey tassels. An individual willow was defined as having a unique above-ground base that was separated from other plants by no less than 4 inches. In September of 2002, felled juniper were placed over the stream channel in an alternating covered/open arrangement, resulting in one covered and one open (500 ft) treatment per block (Fig. 1). Marked willows were located again in August and October of 2003 and scored as browsed or unbrowsed. Data presented here represent initial results of a long-term research effort.

Results and Discussion

Our study population included 100 willow plants, with 62 in covered treatments and 38 in open treatments. Most of the herbivory in the study area appeared to take place very late in the growing season. In August, only seven plants had been browsed, with all but two located in open treatments (Fig. 2). However, by October, 58 willows had been browsed and plants within open treatments were about twice as likely to be browsed compared to those in covered treatments (Fig. 2). This suggests that covering willows with felled juniper provided an effective deterrent to herbivory in the year following treatment application. The timing of willow use may relate to forage conditions in the surrounding meadow and uplands. Green grasses, sedges, and forbs were present within the meadow during the August data collection. By October, remaining herbaceous vegetation began to senesce, perhaps leading to increased browsing of willows.

Management Implications

We will continue collection of data in order to evaluate long-term implications of the covered treatments. If covered treatments increase the likelihood of willows attaining sufficient height (approximately 6 ft or greater) to escape the serious detrimental effects of herbivory, such treatments ultimately may result in a sustainable streamside willow community.

The Thermal Characteristics of Hydrologically Intact Type C and E Streams in Eastern Oregon

Karl T. Hopkins, Tony J. Svejcar, and David R. Thomas

Introduction

Many streams in eastern Oregon are listed as water-quality impaired on the basis of water temperature. Stream heating and cooling is commonly driven by exchanges of heat energy between the stream and its environment. We measured air and water temperature and stream characteristics on three Rosgen type C and E channel streams to determine whether stream type can help predict stream thermal characteristics. Type C and E streams typically are located in broad, alluvial meadows that are commonly used in agriculture. The main difference between the stream types is that type C streams have greater width-to-depth ratios than type E streams. Larger width-to-depth ratios indicate that type C streams are wider than type E streams for the same channel depth. Type C streams tend to have triangular-shaped cross-sectional profiles, as one side of the channel cuts into its bank and forms deeper water. The opposite side of the channel becomes shallow as it collects sediment. Type E streams usually have a square cross-sectional profile, as the channel is well confined by dense sedge establishment. All six streams were hydrologically intact, assessed as Proper Functioning Condition (PFC), and were located in eastern and south-central Oregon (Table 1).

Experimental Protocol

Water and air temperatures and stream geomorphic data were gathered during the summer months of 1998 and 1999. Average daily maximum and minimum water temperature and average daily maximum and minimum rates of change in water temperature were calculated following normalization of data with estimated water residence time. Water temperatures were taken at cross-sections one (beginning of measured stream) and three (end of measured stream).

Results and Discussion

More variation was detected within stream type rather than between stream types, which precluded separation of stream types C and E groups based on thermal characteristics (Table 2). Most streams, regardless of type and year, exhibited similar daily mean nighttime recoveries of approximately 0.95°F/hour cooling in the downstream direction, following normalization by water residence time. Water residence time was the calculated amount of time in hours that water would flow from the beginning to the end of the study reach. All of the streams heated at least 2.0°F/hour during the day, with some streams gaining 4.0°F/hour in the downstream direction, following normalization by water residence time. Thermal variation among the streams was likely a result of the daily initial water temperature, the gradient between stream and thermal environment, and the varied physical character of each stream within type. Atmospheric temperature is the single most critical factor for characterizing stream temperature behavior during the periods of heating and cooling.

Management Implications

Predicting the thermal character of a stream based on its Rosgen type may be difficult, considering the varied physical and thermal characteristics that streams of the same type express. Eastern Oregon streams should be managed under an adaptable and flexible plan that accounts for the individual thermal character of streams. Monitoring stream and atmospheric temperature is crucial for successful management practices. Management practices that encourage conservation of streamside vegetation and watershed function should provide desirable stream channel characteristics and flow regimes essential for high water quality.

Table 1. Rosgen stream description for each stream used in study[1] in eastern and south-central Oregon.

		Minimum			*Maximum*		
Year	***Stream***	***Water T (°F)[1]***	***Water T-residence (°F/hour)[2]***	***Air temp (°F)[3]***	***Water T (°F)[1]***	***Water T-residence (°F/Hour)[2]***	***Air temp (°F)[3]***
1998	C1	57	-1.5	39	72	2.5	93
	C2	52	-0.8	40	64	4.1	87
	C3	65	-0.9	45	76	2.2	94
	E1	58	-0.7	52	70	2.1	92
	E2	52	-0.9	40	65	3.8	86
	E3	48	-1.1	44	69	3.8	90
1999	C1	56	-1.0	36	71	3.0	90
	C2	50	-0.8	38	62	3.9	88
	C3	64	-1.0	45	76	2.0	86
	E1	56	-0.8	48	68	2.3	91
	E2	50	-0.9	38	64	4.2	85
	E3	56	-1.1	42	68	4.5	85

[1] All measurements taken at bankfull following procedures listed in Rosgen, D. (1996). Applied river morphology. Wildland Hydrology, Pagosa Springs, Colo.

Table 2. Average daily maximum and minimum water temperature at cross-section three, change in water temperature normalized by residence time, and air temperature for 39 days in 1998 (July, August, and September) and 22 days in 1999 (July and August).

		Minimum			*Maximum*		
Year	***Stream***	***Water T (°F)[1]***	***Water T-residence (°F/hour)[2]***	***Air temp (°F)[3]***	***Water T (°F)[1]***	***Water T-residence (°F/Hour)[2]***	***Air temp (°F)[3]***
1998	C1	57	-1.5	39	72	2.5	93
	C2	52	-0.8	40	64	4.1	87
	C3	65	-0.9	45	76	2.2	94
	E1	58	-0.7	52	70	2.1	92
	E2	52	-0.9	40	65	3.8	86
	E3	48	-1.1	44	69	3.8	90
1999	C1	56	-1.0	36	71	3.0	90
	C2	50	-0.8	38	62	3.9	88
	C3	64	-1.0	45	76	2.0	86
	E1	56	-0.8	48	68	2.3	91
	E2	50	-0.9	38	64	4.2	85
	E3	56	-1.1	42	68	4.5	85

[1] The average maximum and minimum water temperature at cross-section three.
[2] The average change in water temperature cross-section one to three normalized by residence time (°F/hour).
[3] Average stream air temperature.

Interspace/Under-canopy Foraging Patterns of Beef Cattle in Sagebrush Communities

Kevin France, Chad Boyd, and David Ganskopp

Introduction

Livestock grazing has been related indirectly to sage-grouse declines in the western United States and southern Canada. However, there is a lack of scientific research that directly relates the two. Sage-grouse typically nest beneath sagebrush plants where residual bunchgrass provides protection from predators. Past studies have concluded that nesting success is highest in areas with the most residual cover. Livestock grazing potentially can reduce cover and decrease concealment of sage-grouse nests. However, there is only limited research documenting livestock foraging patterns in sagebrush habitat. Research is needed to determine the effects of grazing intensity and duration on cover availability at sage-grouse nesting locations. Here we present preliminary (1st-year) data from a 2-year study designed to relate livestock grazing behavior in sagebrush plant communities with grazing occurrence on under-canopy and interspace vegetation.

Objectives

1. Use small pastures to determine the level of whole-pasture utilization at which cattle begin to use grasses under the canopy of a sagebrush plant.
2. Investigate the influence of individual sagebrush plant structure on livestock use of under-canopy grasses.

Experimental Protocol

An 18-day (July 5–23) trial was conducted in 2003 with four pastures fenced in a Wyoming big sagebrush community. Four 15-acre pastures were each stocked with four yearling heifers (average 850 lb). Within each pasture, 30 sagebrush plants were selected randomly and a perennial grass was marked permanently under the canopy of each sagebrush and a second grass plant marked in the nearby interspace. Area and volume of the sagebrush were measured, and the angle of accessibility was measured for the under-canopy grass to assess the effects of sagebrush plant structure on grazing occurrence. Grass plants were checked every 2nd day and given a grazed or ungrazed score. Changes in pasture standing crop and utilization (by weight) were assessed weekly by clipping 20 randomly located approximately 11-ft^2 plots in each pasture.

Results and Management Implications

Structure of sagebrush plants was not related to occurrence of grazing on under-canopy grasses; however, the effect of plant location (under canopy or in interspace) was significant. Grazing of under-canopy plants was negligible at light to moderate levels of pasture utilization but increased at heavier

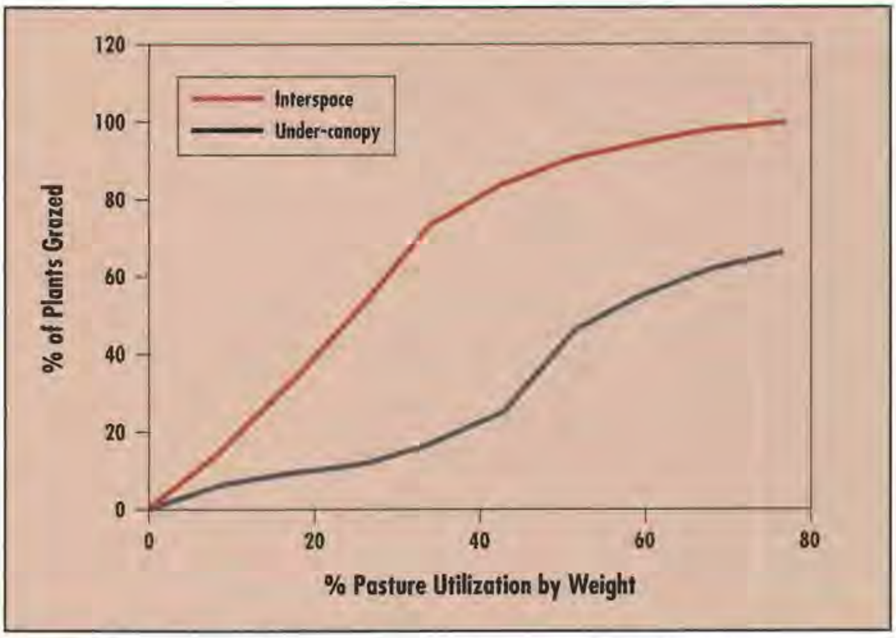


Figure 1. Percentage of interspace and under-canopy grass plants that were grazed compared to pasture utilization (by weight).

levels (e.g., at 30 percent pasture utilization, less than 10 percent of under-canopy plants had been grazed, compared to more than 60 percent of interspace plants; Fig. 1). This indicates that livestock prefer more easily accessible interspace plants and suggests that, at moderate levels of pasture utilization, grazing has a negligible impact on the reduction of under-canopy nesting cover for sage-grouse and other ground-nesting bird species.

From a management perspective, measurement of livestock utilization may or may not include sampling of under-canopy grasses. Our initial data suggest that measurement of utilization based on interspace plants alone is not representative of that for under-canopy plants, and that under-canopy plants will be used with increasing frequency beginning at around 35–45 percent pasture utilization. Readers should keep in mind that the data presented here represent the 1st year of a 2-year study and that 2003 was a dry year. In years and/or on sites with increased forage production, the nature of the relationships we describe may be altered.

Sage-grouse Winter Habitat Use and Survival

Mitchell J. Willis, Robert G. Anthony, and Richard A. Schmitz

Introduction

Research on sage-grouse has focused largely on habitat relationships, productivity, and survival from the prebreeding period through fall. A recent grant from the Species at Risk program of the U.S. Fish and Wildlife Service has allowed us to begin investigation of sage-grouse winter habitat use and survival in southeast Oregon.

Experimental Protocol

Fieldwork was conducted from mid-September through onset of breeding behavior in late February, 1989–1990, through 1991–1992. Grouse populations in Lake County (Hart Mountain National Antelope Refuge [HMNAR]), Harney County (Jack Creek), and Malheur County (Jordan Valley) were examined. The three study sites were selected to represent a range of variability in core sage-grouse habitats in Oregon. The HMNAR study site was at the highest elevation (5,000–8,000 ft) and had the most productive and diverse plant communities. The Jack Creek study site was intermediate in elevation, and was typical of Wyoming big-sagebrush plant communities in southeast Oregon. The Jordan Valley study site was lowest in elevation (3,000–5,500 ft) and included crested wheatgrass seedings over approximately 25 percent of the area. Sage-grouse hens were captured using spotlighting, net guns, and rocket nets. Radio transmitters weighing approximately 1 ounce were mounted on a reinforced vinyl poncho and placed over the neck of each hen at capture. The number of birds monitored each year varied, but attempts were made to maintain a minimum of 20 birds for each study area by periodically capturing additional hens. Hens were visually located at least every other week.

Results and Discussion

This research will attempt to quantify habitat-specific survival and identify habitat structure that is associated with survival. We will also investigate how habitat, animal movement, and winter weather interact to influence survival of sage-grouse. Specific objectives are to 1) estimate survival rates of wintering sage-grouse, 2) determine the association of habitat structure and weather to winter survival, 3) determine whether there were differences in habitat selection and use among three study areas at both the microhabitat and landscape scale between the two types of rangeland, and 4) determine whether habitat use varied according to changes in temperature, windspeed, and snow depth.

We will characterize resource selection from the location data by calculating selection indices. We will estimate variances in selection ratios for different habitat types and test for differences among habitat types and among study areas. We will model changes in selection related to month during winter, proportions of sage habitats, and proportions of converted rangelands.

Survival rates will be estimated for the fall and winter seasons (October–March), using radiotelemetry data and known-fate models. A recently developed survival/analytical package (program MARK) will be used to estimate bi-weekly survival rates. The focus of these

Strutting sage-grouse.

analyses will be to test for differences in survival among study areas and years. We will select models that most accurately reflect differences in survival due to area, time, and age of grouse. We also will make use of weather and habitat variables as covariates in the analyses, in an attempt to identify factors that influence winter survival in sage-grouse. Initial analysis indicates that survival varied among the 2-week periods but did not diminish through the winter.

Management Implications

From this research, we hope to describe important wintering habitats for sage-grouse. Land managers should be better able then to assess what habitats, if any, are in short supply for wintering sage-grouse and what factors make these habitats important. We also hope to provide statistically valid survival estimates of sage-grouse through the winter and perhaps identify factors consistently contributing to mortality. This information currently is unavailable for the species. Understanding winter survival will contribute toward understanding the status of sage-grouse, which is especially important given the current petitions to list sage-grouse as a threatened species.

Cumulative Impacts of Spring Elk Use on Steppe Vegetation

Charles G. Johnson, Mitchell J. Willis, and Martin Vavra

Introduction

In an effort to better understand herbivory by wild and domestic ungulates, range and wildlife scientists are interested in the impact of Rocky Mountain elk on vegetation structure, composition, and abundance. Elk and other ungulates, such as mule deer, may impact their environment by suppressing selected food plants. Although foraging is an active, immediate action, the effects of that action may be long term and chronic in nature, and thus are resistant to short-term investigations. In addition, elk may impact their environment by their physical presence and associated activities such as trampling. The cumulative nature of elk impacts may arise in part from their seasonal site fidelity, influenced by forces such as hunting, human encroachment, roads, timber harvest, fire, weather, or food.

The history of use by domestic ungulates in Hells Canyon, Oregon, began with the introduction of sheep in the 19th century. Cattle use in the canyon increased in the 20th century on a major portion of the Hells Canyon rangelands. In 1979, a group of cattle allotments became vacant. Concurrently, elk began a sustained population growth throughout this area, peaking in 1987 at about 5,200 elk.

Rocky Mountain bull elk.

Experimental Protocol

The objectives of this study were to 1) determine whether there were differences in vegetative and soil characteristics between sites deemed nonimpacted and impacted from springtime use by elk, and 2) determine whether there were differences in vegetative and soil factors over time at these sites.

The portion of Hells Canyon selected for the study included the 126,000-mile^2 Canyon Allotment, encompassing an elevational range from 1,000 ft along the river to 5,000 ft at the brow of the canyon rim. The allotment is contained within the Oregon Department of Fish and Wildlife Snake River Wildlife Management Unit.

The use of pre-existing, permanent monitoring points provided a credible comparison between earlier sample results and current sampled data. The areas were covered by Parker 3-Step Condition and Trend (C&T) transect clusters established in the mid- to late 1970s (early visit) and subsequently by ecological community classification plots (ecoplots) in the early 1990s (recent visit).

We investigated differences in canopy cover of perennial and annual grasses; introduced, native, and all bunchgrasses; key species (Kentucky bluegrass, Sandberg's bluegrass, bluebunch wheatgrass, Idaho fescue, ventenata [*Ventenata dubia*], prairie junegrass, cheatgrass, small bedstraw); increasers and decreasers; and other plant/soil-associated variables (moss, lichens, bare ground, bedrock, rock, gravel, pavement, and litter).

Results and Discussion

Of the 43 monitoring plots, 22 plots (51 percent) were subjectively categorized as being negatively impacted by elk by physical evidence (tracks, droppings, etc.). We included cover values for perennial grass, annual grass, cheatgrass, ventenata, moss, lichens, and bare ground as independent variables.

Perennial grass cover was slightly higher on elk-impacted sites (34 percent) than on non-impacted sites (30 percent) during the recent visit. Analysis of covariance showed a slight trend attributable to elk impact. Kentucky bluegrass was the only perennial grass to show any notable change in cover, increasing from 2.2 percent in the 1970s to 3.8 percent in the 1990s visit. The magnitude of increase was greater at impacted sites than nonimpacted sites over time.

Annual grass cover was higher on the impacted sites consistently over time. The relative influence of the two most important annual grass species, cheatgrass and ventenata, however, shifted dramatically over time. Cheatgrass was effectively replaced by ventenata over the course of the study. Cheatgrass cover decreased on elk-impacted sites between visits (averaging 5.7 percent and 1.2 percent early and recently, respectively), but was similar between time periods on nonimpacted sites, averaging 2.6 percent and 1.9 percent early and recently, respectively. Ventenata cover increased from 0 percent (a trace occurring at one location) on elk-impacted sites in the early visit to 7.3 percent in the recent visit.

Moss cover declined over time in both elk-impacted and nonimpacted categories, but more at impacted sites. Lichen cover increased over time, but when adjusted for initial differences did not show an impact effect. Litter cover increased from 44 to 66 percent over time overall. Bare ground cover was steady (11.5–11.0 percent) over time, but was higher on elk-impacted sites (13.6 percent) than on nonimpacted sites (9.0 percent).

It is unknown whether the differences we detected were the result of elk impacts over the time span of our study, the result of longer-term responses to grazing pressure by livestock and wild herbivores, an unknown factor, or a combination of factors. Our data on elk population size on the area indicate stable populations from the 1960s through 1977. We do not know what elk abundance was prior to that time.

Overall, perennial grass cover was not impaired by elk impacts, but instead was around 6 percent higher at the impacted sites than at nonimpacted sites. It is quite possible that the higher cover values were attributable to something beyond the time range of the study or the impacts of elk. If elk impacts on perennial grasses were significant in a practical sense during the time frame of our study, it would make sense that the comparisons of old versus recent visits would have reflected differences in perennial grass cover. Amount of bare ground cover, higher at the impacted sites, was indicative of trampling effects by elk. It is noteworthy that bare ground cover was substantially higher at elk-impacted sites than at nonimpacted sites when the study commenced (13.9 vs. 9.2 percent).

Management Implications

Elk may have played a role in the composition shift from cheatgrass to ventenata and the resultant increase in annual grass cover over time. If so, this is likely the most negative elk impact. Based on our findings, it appears that the years of high elk abundance in Hells Canyon resulted in impacts in spring attributable to concentrations of animals through increased bare ground and a sharp decline in mosses, but it has not altered the perennial grasses.