Special Report 1092
June 2009

Range Field Day 2009 Progress Report

Oregon State University | Agricultural Experiment Station

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Dedication

This Range Field Day is dedicated to Dr. Dave Ganskopp (cover photo), who has elected to retire from his current position with the Agricultural Research Service.

Dave spent most of his professional career at the Eastern Oregon Agricultural Research Center (EOARC) in Burns. During those 27 years, he made major contributions to the EOARC program and to our understanding of rangelands and livestock behavior. He has published many scientific and popular press articles over the years and has received honors and awards from both ARS and the Society for Range Management. Because of Dave's efforts, we have a better understanding of why cattle graze, where they do, and why they select one plant over another.

Dave enjoys this line of work and does not plan to give up research entirely. We expect to see him continue working on the mysteries of livestock behavior, but with more hunting and fishing thrown into the mix.

Thanks, Dave, for all your contributions.

Sincerely,
Tony Svejcar
Research Leader, USDA-ARS

Agricultural Experiment Station
Oregon State University

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EOARC
A Vision for Rangeland & Pasture Research

Eastern Oregon Agricultural Research Center
Department of Range Ecology and Management
Oregon State University
Agricultural Research Service, U.S. Department of Agriculture

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This report is a cooperative effort of the Department of Rangeland Ecology and Management, Oregon State University, and the Eastern Oregon Agricultural Research Center. Mention of any commercial product does not constitute endorsement by Oregon State University or the USDA-Agricultural Research Service. The Eastern Oregon Agricultural Research Center, which includes the Burns and Union Stations, is jointly operated and financed by the U.S. Department of Agriculture-Agricultural Research Service, Oregon State University, and the Oregon Agricultural Experiment Station.

Acknowledgments
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Forward

With our nation's ever increasing appetite for food, fiber, water, energy, and recreation, America's population is becoming more and more aware of rangeland's significant contributions to society. As a result, there is greater interest in rangeland management than ever before. Historically, focus has been given to our extensive federal holdings, but recognition that many of our issues must be addressed at landscape scales now mandates that adjacent private land be considered part of the puzzle as well.

In addition to this increased scrutiny, rangeland/livestock managers are now challenged by new issues related to invading exotic plants, altered fire regime effects on native and introduced plant communities, potential climate change, and sustaining habitats for animals that may range over as little as one acre to more than several hundred square miles. Reestablishment of large predators over portions of their historic range is also complicating life for livestock and wildlife managers.

Our research on rangeland functions and livestock and wildlife grazing continues to advance practices that properly use our forages, sustain or improve the health of our ecosystems, and foster production of economically viable outputs. This report addresses several issues including: fire and grazing interactions, resilience of communities to grazing and fire, and developing a better understanding of the factors affecting grazing patterns and seasonal movements of cattle and wildlife at pasture and landscape scales.

The formal presentations of our 2009 Range Field Day will focus on several aspects of rangeland/animal relationships and behavior. Topics include cattle and wolf interactions, cattle/deer/elk/and human interactions, use of riparian pastures by cattle, pre- and post-fire cattle distribution, and beef cattle temperament effects on livestock reproduction and performance. Other reports within this document discuss post-wildfire grass establishment, efficacy of crested wheatgrass barriers for retarding spread of medusahead, western juniper density and year effects on soil seed banks, grazing history effects on post-burn vegetation recovery, and measurement scale effects on our characterizations of sage-grouse habitat.

If one has additional questions on these topics or portions of this report, we encourage you to contact the authors directly for more detailed information. The ultimate goal of our research programs is to make a difference. Your questions and feedback will help steer us toward relevant or critical issues that are truly pertinent to your needs and concerns. Your input has and will continue to provide guidance for our efforts.

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Wolf-cattle Interactions in the Northern Rocky Mountains

Patrick E. Clark and Douglas E. Johnson

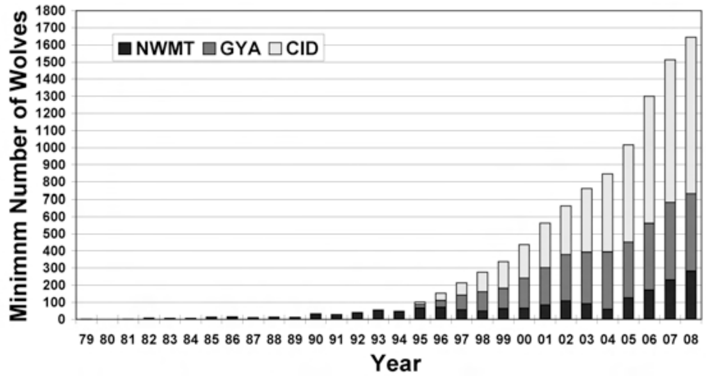
SUMMARY

Since gray wolf reintroduction in 1995, wolf populations in the northern Rocky Mountains have increased dramatically. Incidents of wolf predation on livestock have increased with wolf populations. Although rough tallies of livestock death or injury losses caused by wolf predation are made each year, we know almost nothing about the indirect effects of wolf-livestock interactions on cattle production. Research projects were initiated during 2004 in central Idaho and 2007 in western Idaho-northeastern Oregon to evaluate habitat use, activity budget, and productivity responses of range cattle to increasing wolf predation pressure. Global positioning system (GPS) tracking collars were used to locate mature beef cows every 30 minutes or every 5 minutes throughout 3- to 6-month grazing seasons. Effects of wolf presence on cattle preference for riparian/upland habitats, terrain use, bunching/dispersion, and activity budgets are being evaluated relative to forage conditions, cattle age/experience, and other production system and environmental factors. Preliminary results suggest individual cows exhibit considerable variability in their preference for near-stream habitats (less than 100 yards from perennial streams). Annual variability in near-stream preference was noted and the relationship between this variability and wolf presence levels is being evaluated. Annual variability in cattle activity budgets was detected and evaluations are underway to determine if this variability is an effect of recent technology upgrades or is a consequence of variability in wolf presence. We found GPS tracking technology accurate enough to detect predator-avoidance behavior in cattle, including bunching and sustained-flight events, even at the coarse, 30-min collection interval. The northern Rocky Mountains is a very complex ecological system involving numerous interacting factors; consequently, it will require at least several more years of data collection before we can begin to draw conclusions from these studies. When developing grazing plans, however, cattle producers and natural resource managers of the northern Rockies should consider that the presence of reintroduced gray wolves may be influence cattle distribution and behavior and these effects may continue for some time after wolves have left or have been removed from the grazing area.

INTRODUCTION

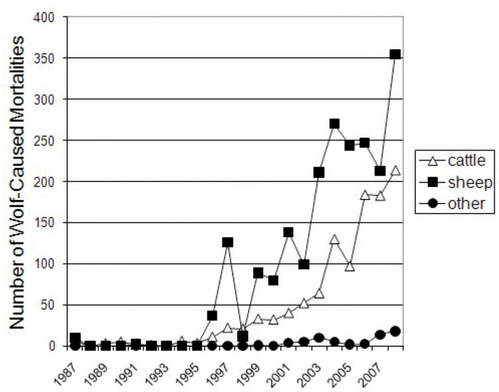
In 1995 and 1996, gray wolves (*Canis lupus*) were reintroduced to Yellowstone National Park and central Idaho by the U.S. Fish and Wildlife Service. This large carnivore had been absent since the 1930's and, as an apex predator, has induced changes in both the natural ecosystems and livestock production systems of the northern Rocky Mountains. Wolf numbers and range have increased steadily since their reintroduction (Fig. 1). By 2008 there were at least 846 wolves in Idaho, 497 in Montana, and 302 in Wyoming. A wolf pack was also confirmed in Washington in 2008 (Sime and Bangs 2009).

Figure 1. Expansion of gray wolf populations in the Northern Rocky Mountains between 1979 and 2008. CID = Central Idaho; GYA = Greater Yellowstone Area; NWMT = Northwestern Montana. (Sime and Bangs 2009).



As wolves expanded their range, reports of livestock predation also increased in the northern Rocky Mountain region (Fig. 2). The extent of wolf reintroduction effects on livestock production systems and regional ecosystems are largely unknown. Considerable controversy exists regarding the effect of wolves on livestock-rearing systems. Some have suggested wolf predation will reduce economic viability of range livestock enterprises to the point of economic failure, adversely impacting the economy of rural communities. Others have emphasized the positive aspects of wolf introduction, centering on the economic benefits resulting from increased tourism and possible increases in land values.

Figure 2. Confirmed wolf kills of livestock from 1987 to 2008 in the northern Rocky Mountain region. (Sime and Bangs 2009)



The economic and environmental effects of wolf reintroduction are by no means clear-cut. One contention is that livestock harried by wolves become stressed, forage less efficiently, gain fewer pounds and may have more difficulty rebreeding and producing off-spring. It has been suggested wolf presence may also alter distribution patterns and resources impacts of livestock and wild ungulates. Numerous studies have examined wolf/wild prey species interactions and feedback mechanisms. Recent studies in Yellowstone National Park (YNP) found reintroduction of wolves changed ungulate habitat selection patterns (Creel et al. 2005) and in some cases, elicited recovery responses in riparian vegetation such as cottonwood (*Populus spp.*) (Ripple and Betscha 2003). Pyare and Berger (2003) suggested, however, that our understanding of the ecological impacts of wolf re-introduction within the YNP, where livestock are absent, is quite incomplete. A more complicated situation exists on rangelands occupied by livestock, wild ungulates, and wolves. Some recent work has been done in the northern Rocky Mountains (e.g., Bradley and Pletscher 2005, Oakleaf et al. 2003) but most of our limited understanding of wolf-livestock interactions is based primarily on studies from Canada, Europe, and the upper Midwest. No study, however, has rigorously evaluated the environmental consequences of these interactions. If cattle and elk respond similarly to wolf presence by reducing riparian occupation, total impacts on riparian vegetation and stream-water quality may be reduced. Will this shift in ungulate distribution then result in concentrated use and impact on preferred upland sites? Will this shift also increase interspecific competition between sympatric ungulates and reduce their productivity and, in the case of cattle, profitability? The true magnitude and extent of environmental effects of wolf reintroduction on grazed rangelands is essentially unknown.

The objective of our research is to evaluate effects of wolf presence on cattle habitat selection, terrain use, activity budgets, expression of predation-avoidance behavior, and productivity. We are particularly interested in wolf-presence effects on cattle preference for near-stream or riparian habitats.

METHODS

Distribution, activity, and movement pattern responses of beef cattle to the presence of reintroduced gray wolves have been evaluated since 2004 on mountainous rangeland of central Idaho and since 2007 in the mountains of western Idaho and northeastern Oregon. Twenty mature beef cows equipped with GPS collars are being tracked on two central Idaho study areas while 10 beef cows are being tracked in each of 3 study areas in Idaho and 3 study areas in Oregon. GPS locations of collared cattle have been recorded every 30 min prior to 2008 and every 5 min in 2008 during the grazing season (April-October). Prior to 2008, most of the GPS tracking data were collected using older model (2001 vintage), commercial tracking collars. In 2008, all 60 collars deployed on the western Idaho-northeastern Oregon sites and 17 collars on the central Idaho sites were new, custom-built devices, all recording locations and fix-quality information at 5-min intervals. The purpose for applying this new technology was to allow more intensive monitoring of cattle distribution and behavior over the entire 6-month grazing season.

Presence of gray wolves within the study areas during the trial periods is monitored by a combination of techniques including bi-weekly surveys of VHF-collared wolves; field efforts involving howling surveys, track and scat counts, and direct observation; and finally GPS tracking collars. The Idaho Department of Fish and Game (IDFG), in cooperation with USDA-APHIS Wildlife Services, began GPS tracking wolves on or near the study areas in 2006. Capture and installation of wolf GPS collars was conducted by Wildlife Services personnel following their Institutional Animal Care and Use Committee animal care and handling protocols. In addition, IDFG, Nez Perce tribe, and Wildlife Services personnel have collared wolves with VHF telemetry collars for general population monitoring. VHF-collar locations occurring in the study areas are used to augment the wolf GPS-location data. Wolf kill sites are confirmed by Wildlife Services. Direct observation of wolves and track and scat surveys in the study areas are conducted by trained range riders, IDFG field staff, and project personnel.

The experiment is a randomized block design. Experimental unit is a collared cow. Blocks are paired study sites (30,000 to 100,000+ acres/site) within a study area. Main effect is the wolf-presence treatment with at least two levels: wolf-presence detected within a study site boundary and wolf-presence undetected under otherwise equal monitoring effort and conditions. A single detection incidence is weighted to represent 3 days of wolf presence based on an assumed wolf consumption rate (minimum) of a large ungulate carcass. In other words, if one or more wolves made a large ungulate kill, it was assumed they would require, at most, 72 hours to completely consume the carcass and potentially move off the study site where the detection incident occurred. Multiple detection incidences sustained over an extended period (e.g., 1 week) allow classification of additional levels of wolf presence. Other measured or estimated factors include growing-season conditions, forage quality and productivity, terrain, location and status of water and supplement sources, human presence, road and trail density, cattle breed and experience, calf age, etc. Response variables measured are cattle preference for riparian/upland habitats, terrain use, bunching/dispersion, and activity budgets of collared cattle. Cattle productivity measures include rates of gain, body condition, and conception rates.

RESULTS and DISCUSSION

The complexity of interacting factors affecting livestock behavior, productivity, and predator-prey relationships in the northern Rocky Mountains precludes any short-term, conclusive findings from these studies. Only long-term (10+ years) research carefully replicated in both time and space will yield conclusive results in this ecosystem. The reader is seriously cautioned, therefore, to interpret the following as only preliminary results that may very likely change as additional data are collected during the course of these long-term studies.

In central Idaho, collared, mature beef cows with calves exhibited considerable variability in their preference for near-stream habitats (Fig. 3). Some individuals exhibited a neutral to slightly positive preference (use/availability = 1 to 1.5) for areas within 10 yd and areas between 10 and 100 yd from perennial streams. On the other extreme, some cows exhibited a very strong preference (use/availability greater than 3) for the 0- to -10 yd and 10- to -100 yd stream buffers.

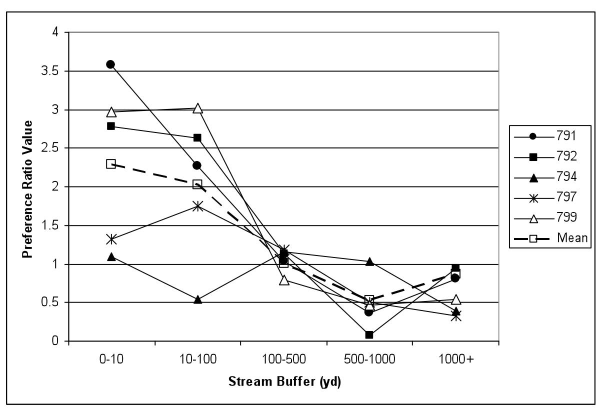
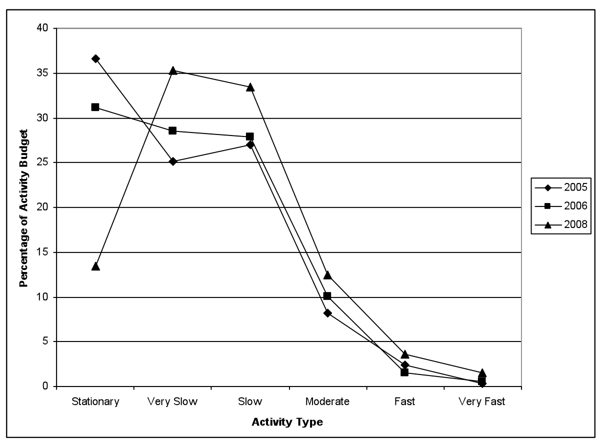


Figure 3. Preference ratio relative to distance buffers from perennial streams for five GPS-collared, mature beef cows tracked in Pasture H/Site 1 of the central Idaho study area during the 2006 grazing season.

Although study-site averages for near-stream preference generally ranged from 2 to 2.7, there was evidence of differences in variability among pastures and among years. Differing terrain and riparian vegetation structure may explain preference differences among pastures. Pastures dominated by glacial canyons with very steep canyon walls tend to limit cattle from accessing upland habitats. Pastures with more open, less confining terrain offered cattle more range-use choices. Brushy, willowdominated riparian areas present a visual obstruction for cattle occupying these areas. More open, herb and low-stature shrub-dominated riparian areas offer a greater field of view to prey animals attempting to avoid wolf predation. Annual variability in cattle preference for near-stream habitats may be explained by growing conditions and forage productivity that varied among years. Wolf presence and predation levels on cattle also varied among years. On-going evaluations are testing the strength of relationships among varying wolf-presence levels, vegetation, and environmental factors relative to variability observed in cattle preference for near-stream habitats.

Cattle activity budgets in central Idaho were defined as a composite of six possible activity types based on cattle movement rates or velocities derived from sequential GPS locations (Fig. 4). Activity budgets have been remarkably consistent among individual cows but varied among years. Prior to summer 2008, cattle activity budgets were dominated by stationary (0-0.01 mph) activity (e.g., bedding, ruminating or standing alert). In 2008, cattle activity appeared to have shifted to fewer stationary periods and more time engaged in very slow (0.01-0.06 mph) and slow (0.06-0.25 mph) movement (e.g., foraging).

Figure 4. Mean percentage of daily activity budgets for six activity types (velocity classes) exhibited by GPS-collared beef cows grazing Pasture F/Site 1 of the central Idaho study area during 2005, 2006, and 2008.



We do not currently know whether this apparent activity shift is due to changes in collar technology, GPS location collection rate, or some set of environmental or ecological factors. It is possible that more GPS location error may be accruing when the new, custom GPS technology is applied in the very rugged terrain of central Idaho compared to older, commercial technology. This would decrease the number of locations classified as stationary and inflate the apparent amount of slow and very slow movement. It is also possible that by intensifying the GPS location collection interval from 30 min to 5 min, we may be detecting brief slow and very slow movement bouts not detected by the coarser collection interval. Alternatively, these data may reflect real shifts in activity. Wolf presence prior to 2008 was highly variable but tended to be greater than during 2008, when wolves appeared to be mostly absent. Prior to 2008 cattle may have spent longer periods standing alert and watchful for predators than during 2008 when a shift toward increased foraging time may have occurred. We are evaluating field data collected concurrently by older commercial technology and newer GPS technology at similar and different collection rates to separate technology-related effects from potential wolf-presence effects on cattle activity budgets.

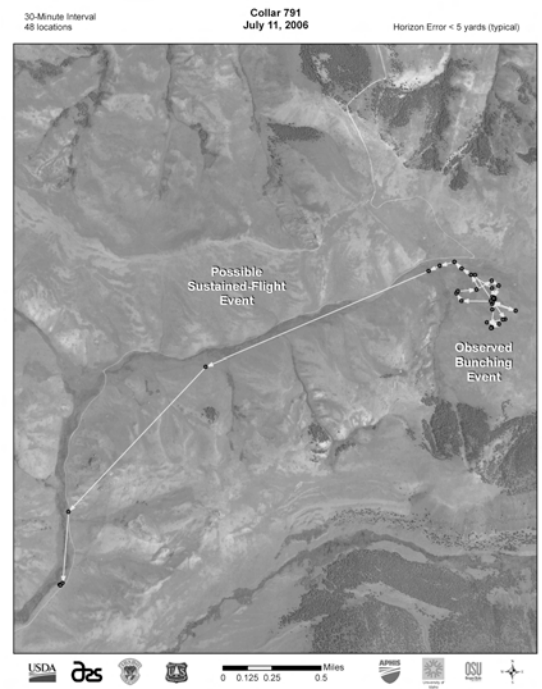


Figure 5. GPS tracking collar locations and movement path for a beef cow exhibiting predator avoidance behavior in Pasture W/Site 1 of the central Idaho study area on July 11, 2006.

Concurrent collection of direct observation field data and tracking collar data has revealed GPS technology is capable of accurately detecting cattle bunching and sustained-flight events (Fig. 5), even at a 30-min sampling interval, if the collar sample size is adequate for the herd size. Bunching events occurring during periods when wolves were present tended to occur in upland habitats where vegetation stature was low and the terrain afforded an extensive field of view. In cases where bunching events were directly observed, up to 100 head of cattle remained tightly massed and vocalizing for up to 1 hour before dispersing. Bunching events identified using GPS tracking data typically appeared, at first glance, to be 2-3 collared cows bedding (i.e., each having many consecutive stationary GPS locations) in close proximity to each other but in an unusual bedding site. Tight clustering of locations from multiple animals, during mid-day, on open, unshaded sites were situations we commonly tagged as suspected bunching events that were then evaluated with a timely field visit. Actual bedding sites on open, breezy ridge-tops, however, were difficult to separate from bunch event sites. Sustained-flight or relocation events occur when a prey animal moves a considerable distance from an area of high predation threat to an area of lower predation threat. Sustained-flight events were evident in GPS tracking data as linear paths consisting primarily of fast (0.62 – 1.2 mph) and very fast (over 1.2 mph) movement continuing more than 0.5 mi. These flight events were particularly evident if they occurred between 10:00 PM and 3:00 AM when cattle should typically be bedded following the evening foraging bout.

MANAGEMENT IMPLICATIONS

The northern Rocky Mountains is a very complex ecological system involving numerous interacting factors; consequently, it will require at least several more years of data collection before we can begin to draw conclusions from these studies. When developing grazing plans, however, cattle producers and natural resource managers of the northern Rockies should consider that the presence of reintroduced gray wolves may influence cattle distribution and behavior and these effects may continue for some time after wolves have left or have been removed from the grazing area.

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The authors wish to thank the USDA Agricultural Research Service, Oregon Beef Council, and Oregon State University for funding and support of this research. We also acknowledge Idaho Department of Fish and Game, USDA APHIS Wildlife Services, USDA Forest Service, and the Nez Perce Tribe for their support and cooperation.

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Factors Influencing Cattle, Elk, and Mule Deer Distribution in Managed Forests

Marty Vavra

SUMMARY

Intensive research involving elk, mule deer, and cattle has been conducted on the Starkey Experimental Forest and Range since 1989. The unique aspect of this research included the enclosure of 25,000 acres in 1989 to maintain a managed herd of mule deer and elk and the use of an automated telemetry system to track animal movements. Initial research focused on the influence of intensive timber management on mule deer and elk; the influence of roads and traffic on mule deer and elk; forage allocation/animal-unit-equivalencies of cattle, mule deer and elk; and the influence of age of breeding bull elk on elk production. Extensive timber harvest within Starkey had no effect on the productivity of elk but did increase their vulnerability to harvest. Roads, traffic, and cattle influence the distribution of elk, which in turn influences the distribution of mule deer. Herbivores are very adaptive in their selection of habitats and the foods they consume in those habitats. Development of management tools for allocating forage is ongoing. Human off-road recreation (e.g., All-terrain vehicle use) has an impact on elk movement rates and often initiates a flight response. Elk, in the presence of off-road recreation, alter their behavior, spending more time in hiding cover and less time foraging. They also move away from recreation routes.

INTRODUCTION

Since its creation in 1940 the Starkey Experimental Forest and Range has a long history of research involving elk, mule deer and cattle. One of the first studies on the grazing relationships of cattle, mule deer, and elk was conducted over an 11-year period (1954-1965) and stands out as one of the most important works of its kind (Skovlin et al. 1976).

In the 1980s perceived conflicts over relationships among livestock grazing, elk numbers, timber harvest, and road development led to the development of the Starkey Project. The Pacific Northwest Research Station, U.S. Forest Service, and Oregon Department of Fish and Wildlife jointly developed the research direction and provided funding. Eastern Oregon Agricultural Research Center, Union Station provided cattle and logistic support and was an active research partner. National Forest Systems provided initial funding for fence construction and the telemetry system. Through the years over 40 other partners, including Federal and state agencies, universities, tribal nations, and private organizations have participated in the project. In 1989, the project became operational with the enclosure of 25,000 acres of the Starkey Experimental Forest and Range with a high-tensile game-proof fence and establishment of an automated telemetry system. Four large studies were initially undertaken that addressed major public land and livestock/big game conflicts through the following objectives: 1) determine the influence of intensive timber harvest on mule deer, elk, and cattle; 2) determine the influence of roads and traffic on distribution of elk and mule deer; 3) evaluate the concept of animal-unit-equivalencies and develop tools for forage allocation; and 4) determine the influence of age of breeding bulls on reproductive success in elk. These studies and several "spin-off" studies encompassed the first 10 years of the Starkey Project. In 2000 planning for new projects was initiated, whose objectives include: 1) the influence of fuels reduction and prescribed fire on distribution of elk, mule deer, and cattle; 2) the influence of three levels of ungulate herbivory on secondary succession of plant communities following fuels reduction and prescribed fire; 3) the influence of off-road recreation on elk and mule deer; and 4) the influence of ATV use during hunting seasons on the movement patterns of mule deer and elk. Within the Starkey Project the Meadow Creek Study Area is maintained to evaluate the impact of various livestock grazing regimes on riparian vegetation and stream bank integrity. In this paper the results of various studies dealing with factors that influence the distribution of elk, mule deer, and cattle will be discussed.

METHODS

Research protocols were developed for each study initiated as part of the Starkey Project. Many of the studies incorporated data generated from animals tracked with the automated telemetry system and the development of Geographic Information System (GIS) data layers.

In 1989 data collection began on the movement of elk, mule deer, and cattle with the completion of all game-proof fencing and the installation of an automated telemetry system. A LORAN-C-based telemetry system was in place from 1989 through 2005. In 2006 a Global Positioning System (GPS) was fully functional and replaced the outdated LORAN system. Annually up to 40 elk, mule deer, and cattle are fitted with radio transmitters to monitor their movements.

Geographic Information Systems are widely used to develop databases for analyzing wildlife and cattle habitat relations. Construction of the Starkey habitat database began in 1989 and continues today. The database contains maps for all major resource themes, such as vegetation, topography, water, fences, soils, and roads. More than 100 variables related to distribution of mule deer, elk, and cattle have been included. Application of appropriate statistical analyses to the animal distribution data and the various physical resources in the database result in prediction of which resources and physical attributes play key roles in the distribution of animals. Further analyses provide predictive tools that managers can use to evaluate habitat effectiveness.

RESULTS AND DISCUSSION

Intensive Timber Harvest Study

Extensive logging of National Forests in the 1960s, through the 1980s elevated concerns of biologists that elk populations might be negatively impacted by the degree of timber harvest taking place. Concerns were raised over losses to thermal and security cover for elk. To address this issue on Starkey, 3,590 acres were fenced exclusively for timber harvest effects research. Fencing the study area prevented animals from leaving during the logging operation and afterward when cover was reduced. Elk were contained by the fence in an extensively logged environment. Timber harvest encompassed 1,207 acres 34 percent, of the study area, but comprised 50% of the forested lands. Most of the harvest was shelterwood and seed tree regeneration cuts that removed most of the overstory. There were 63 individual harvest units ranging in size form 3 to 55 acres. Existing management guidelines for elk cover were ignored, denying elk large blocks of security or thermal cover. Cattle grazing took place during the entire study and cattle were monitored for effects of timber harvest on their distribution. During timber harvest, elk distributed themselves more widely across the study area. When harvest was completed elk generally returned to their preharvest distribution; they were more widely distributed than before harvest, but not as much as during harvest. Cattle showed little change in distribution over the entire range of the study, before, during, or after harvest. A key part of this study was our ability to weigh both cattle and elk using the study area and compare them to cattle and elk in the Main Study Area where timber harvest did not occur. Even though elk made substantial changes in their distribution during timber harvest operations, no change in animal performance (weight change) was observed. Annual weight gains for female elk and calf elk in the timber management area were no different than those in the Main Study Area. In general beef cow and calf weight gains were higher in the timber management area than in the Main Study Area.

The elk herd in the timber management area was hunted before, during, and after timber harvest. Before timber harvest hunter success averaged 2 percent, requiring an average of approximately 19 days to achieve this level of success. During harvest, hunter success increased to 35 percent, with hunters spending an average of 9 days to achieve that success. After timber harvest hunter success remained high (32 percent and 14 days) similar to that occurring with timber harvest. Timber harvest increased vulnerability of elk to harvest because of the decrease in escape/hiding cover. In areas where landscape scale timber harvest or wild fire substantially reduces escape/hiding cover, restrictions on hunter numbers, hunting season length, decreased road access, or combinations of these changes should be considered to ameliorate elk escapement and prevent over-harvest.

Roads and Traffic

The extensive logging on National Forests mentioned above also resulted in a vast network of roads. In some cases 6 miles of roads existed per 1 mi² of forest. Generally, these roads remained open to the public. Considerable research has evaluated the impacts of roads and logging on elk distribution across affected landscapes. Starkey research indicated roads with vehicular traffic restricted the habitat used by elk in spring and summer. Open roads effectively fragment elk habitat; few patches of forest cover exist that are large enough to provide secure habitat for elk. The degree of forest density and topography can mediate some of the effects of road density. Research at Starkey indicated that traffic rates as low as 1 vehicle passing per 12 hours influenced distribution of elk. This research, as well as other studies at Starkey, also revealed that elk impacted the distribution of mule deer. Mule deer avoid habitats occupied by elk. Therefore, as elk moved away from roads mule deer selected habitats closer to roads. When managers develop habitat models to evaluate landscapes for potential elk use, roads open to traffic and traffic rate should be included as variables. Moreover, distance band approaches provide better quantification of elk-roads effects than do traditional road-density analyses.

Forage Allocation/Animal-unit-equivalencies

One of the major problems that has plagued range and wildlife managers is that of allocating forage among the various large herbivores utilizing a common landscape. Early managers used a simple animal-unit-equivalency conversion based solely on forage intake per animal per day: one cow = five deer = two elk = five sheep. The assumption was made that all animals consumed a common forage base in the same place and at the same time. The fallacy of this approach is obvious; different ungulate species do not occupy the same place at the same time, or eat the same forage plants. However, once this is recognized and the decision made to develop a realistic approach to forage allocation, the hard part begins. Factors other than the availability of nutritious food may drive where an animal forages. In a pristine landscape, the first survival priority elk may have is a highly nutritious diet. Nevertheless, as previously mentioned, elk move away from roads with traffic. In this case the need for a secure, risk-free environment may override the need for the highest quality diet. Starkey research also indicates that elk will alter their distribution on a landscape when cattle are introduced. Therefore roads and traffic and/or the presence of cattle may cause elk to seek secure but nutritionally inferior habitats. Declining forage availability is the usual driver that causes animals to seek new foraging habitats. When security becomes the first driver in habitat selection, animals may choose to exist in nutritionally inferior habitats, resulting in less than optimum body condition. Degradation of the secure habitat due to overgrazing also becomes a possibility, but is not very predictable. In late summer when forage quality decreases, elk are less likely to move away from cattle and they may share the same habitats to secure scarce nutrients. Cattle and roads can displace elk, and mule deer are displaced by the presence of elk. Therefore, when considering the allocation of forage across a landscape, these confounding influences on animal habitat choices must be addressed.

The basis for forage allocation is the identification of foods eaten by the herbivores present as well as the availability (lb/acre) of those food items. However, animals are highly adaptable in their foraging choices and show great variation in diet dependent on year, season, and forage availability. Where different species of herbivores share a common landscape, each species probably uses a foraging habitat that has been previously grazed by another species. In Starkey research, dietary overlap was lowest between cattle and mule deer in previously ungrazed paddocks. In paddocks previously grazed by cattle, dietary overlap between the two species increased. However, the nutritional quality of mule deer diets remained the same suggesting that competition did not occur. The greatest potential for dietary competition was between mule deer and elk. Diets of the two species did not change when they each grazed paddocks previously grazed by cattle or elk. Previously mentioned research revealed that mule deer use declines when elk are present, indicating interference competition may be occurring. Dietary overlap was high between cattle and elk especially in paddocks previously grazed by cattle or elk. The potential critical period for competition is late summer when the availability of high-quality forage is limited and elk and cattle tend to use the same habitats in search of that high quality forage.

The complexities of foraging behavior and animal distribution described above illustrate the challenge in developing a forage allocation model useful to managers. At this time no such model exists. Scientists working on Starkey data have developed a landscape-scale foraging simulation model. The goal is to use this model to evaluate different grazing management strategies on summer range landscapes and test various hypotheses about the effects of alternative stocking rates for ungulates. However, at this time further refinement of the model is required.

Human Disturbance

Because roads and traffic have an influence on the distribution of elk, scientists explored the potential influence of human off-road recreation on distribution of deer and elk. A 3-year study was conducted to evaluate the potential influence of mountain biking, horse riding, ATV riding, and hiking on elk and mule deer distribution. We used the telemetry system to monitor movements in response to each activity. All forms of recreation tested affected distributions of mule deer and particularly elk. Mule deer do not appear to respond strongly to any of the four activities; they may prefer to hide rather than run from disturbance, and our telemetry data would not show this response. Elk responded to all four activities by reducing feeding times, increasing movement rates, and initiating flight responses. Elk responses to ATVs and mountain bike riding were stronger than to horse riding and hiking. Foraging time was lower and flight responses higher during ATV and mountain bike riding. Elk avoided recreation routes during all recreation activities and spent more time in cover, with avoidance strongest during ATV activity.

Cattle Grazing

Telemetry data on cattle were analyzed for distribution relative to water and vegetation resources during either early (mid-June to mid-July) or late (early-September to mid-October) summer. Feeding sites for cattle were different between seasons relative to distance to water, structure of vegetation, and canopy cover. In early summer cattle avoided steep slopes, tended to disperse randomly relative to water, and preferred more southerly aspects. As forage resources were consumed in early summer and vegetation dried, however, cattle shifted distributions down from ridgetops, and moved closer to water, sites with higher forage production, and more northerly aspects. In late summer, patterns were reversed. In the first half of late-season grazing, cattle selected areas closer to water, higher forage production areas, and northerly aspects, but as resources were removed, cattle used areas far from water, more concave sites, and areas with deeper soils. Timing of grazing will have substantial effects on forage utilization and distributions relative to use of riparian areas.

In other research, scientists found that cow age and therefore experience directly influences distribution patterns and forage resource use. Cattle were monitored during peak foraging time, 1 hour before sunrise to 4 hours after sunrise and 4 hours prior to sundown to 1 hour after sundown, from July 15 to August 30. All age classes of cattle preferred areas of gentler slopes, westerly aspects, farther from water, and with greater forage production than the pasture average. Young cows (less than 5 years old) selected lower elevations and steeper slopes than the oldest cows (over 5 years old). Cattle 2–3 years old utilized areas lower in elevation and closer to cover and water, whereas cattle over 8 years old used areas of higher elevation farther from cattle fences, cover, and water. Age structure of a cow herd, then, may have an influence on how a pasture is utilized.

MANAGEMENT IMPLICATIONS

Managing forest landscapes for multiple use is a daunting challenge. Research at Starkey is informing managers through the development of predictive tools that illustrate how herbivores utilize landscapes and what biotic and abiotic factors interact to influence that utilization. The result should be forested landscapes that provide sustainable ecosystem services. Discovering the factors that influence (especially negatively) the distribution of mule deer and elk leads to the development of guidelines for critical habitat. Maintaining sufficiently sized habitat blocks for mule deer and elk through design of recreation areas and road systems should help maintain viable mule deer and elk populations and lessen the chance of habitat degradation. Knowledge of cattle grazing behavior and distribution contributes to the development of grazing systems that are not in conflict with mule deer and elk and do not degrade riparian systems and fish habitat.

ACKNOWLEDGEMENT

This summary paper presents the results of many research efforts conducted by many people. Oregon Department of Fish and Wildlife: Bruce Johnson, Priscilla Coe, James Noyes, Scott Findholdt, and Don Leckenby, retired, one of the founders of the Starkey Project. Pacific Northwest Research Station, Forest Service: Michael Wisdom, Mary Rowland, John Kie, Alan Ager, and Jack Ward Thomas and Larry Bryant, both retired, founders of the Starkey Project. Eastern Oregon Agricultural Research Center, Union Station: Timothy DelCurto.

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For publications and more information visit the Starkey web site:
http://www.fs.fed.us/pnw/Starkey

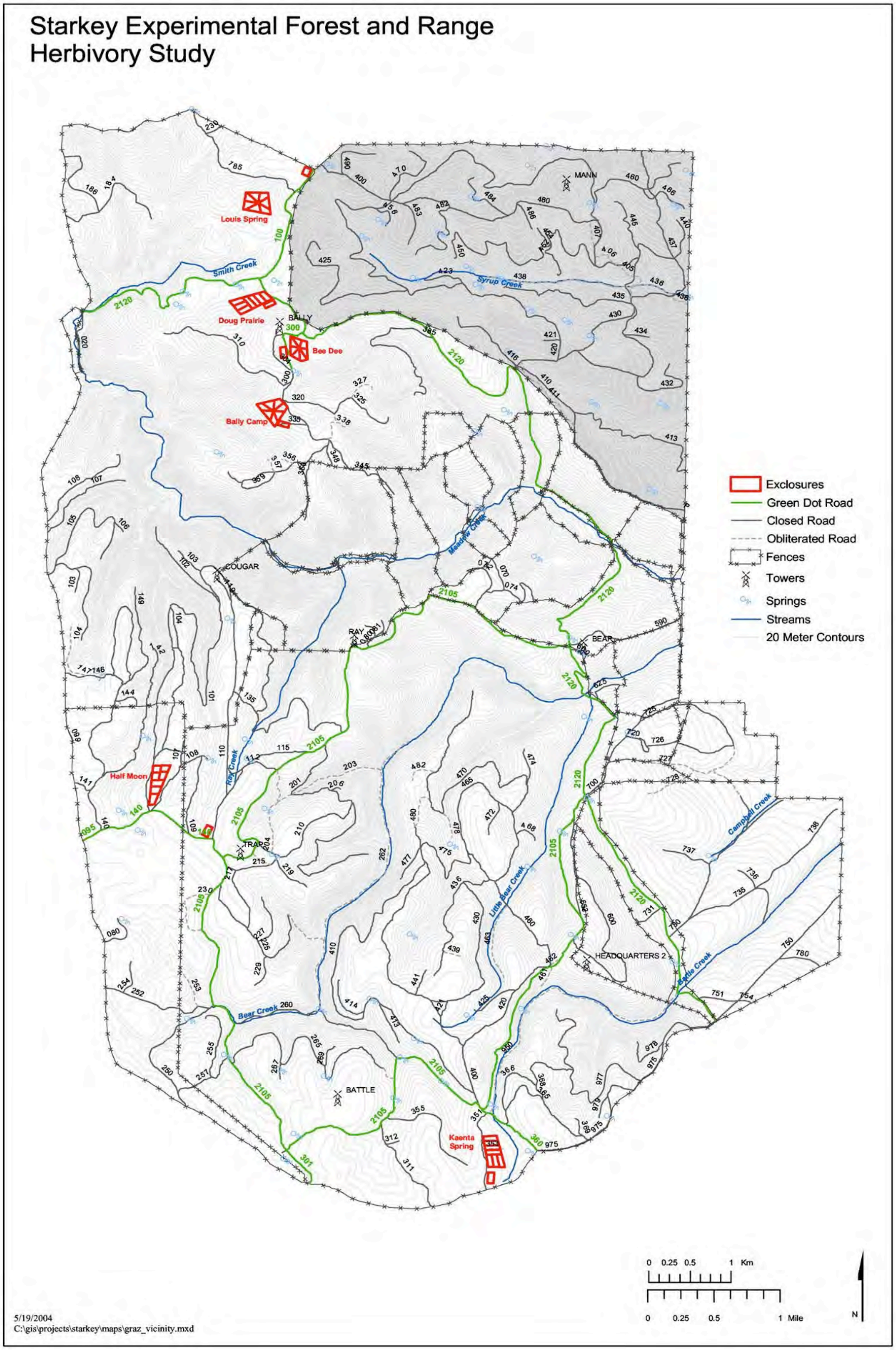

Figure 1. The Starkey Experimental Forest and Range, Blue Mountains of northeastern Oregon.

Distribution of Cattle Grazing in a Northeastern Oregon Riparian Pasture

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SUMMARY

Livestock grazing of a northeastern Oregon riparian pasture was monitored using high-frequency GPS tracking of cattle and high-resolution aerial photography. Tracking collars recorded positions, velocity, date, and time at 1-sec intervals. Areas where animals rested and moved were identified and residence times calculated for various locations and plant communities in the pasture. Tracking collars performed well and data from 74 days of continuous 24-hour observation were compiled, more than 10 days of observation on 7 cows. Activity diagrams and daily travel distances were determined for each animal, as was preference for ecological sites. Maps that showed travel routes and stream crossing areas were also produced. Managerial implications of the collected information are discussed.

INTRODUCTION

In 2002 the National Research Council (NRC 2002) conducted a study of riparian areas that found:

> "Traditional agriculture is probably the largest contributor to the decline of riparian areas… The primary effects of livestock grazing include the removal and trampling of vegetation, compaction of underlying soils, and dispersal of exotic plant species and pathogens. Grazing can also alter both hydrologic and fire disturbance regimes, accelerate erosion, and reduce plant or animal reproductive success and /or establishment of plants. Long-term cumulative effects of domestic livestock grazing involve changes in the structure, composition, and productivity of plants and animals at community, ecosystem, and landscape scales."

Modern, rational grazing management systems of riparian areas have been developed and adopted by private ranches and federal and state agencies. These systems were created by university, USDA/Agricultural Research Service, Natural Resource Conservation Service, and Federal agency personnel and are designed to reduce impacts of livestock on critical environmental attributes of riparian systems, such as vegetation along the green line, streamside shrubs, and bank overhang that can negatively impact native plants, fish, and wildlife. Managerial systems typically adjust the timing and/or intensity of grazing such that cattle impacts are controlled while economic benefits to producers are maintained. Knowledge of animal distribution within the context of site preference and site accessibility is central to the development of these grazing management plans and most were developed by experienced managers. Today Geographic Information Systems (GIS) and Global Positioning Systems (GPS) technologies provide researchers with opportunities to study livestock distribution and movement with greater precision and accuracy than was possible a few years ago. Our study was designed to test the capabilities of GPS collars logging at high frequency for monitoring cow positions in a riparian setting and to determine the relative duration of occupancy on ecological sites.

MATERIALS AND METHODS

Site Description

The study site is located in the Wallowa Mountains of northeastern Oregon approximately 21 mi (36 km) southeast of La Grande Oregon (45.13026°N, 117.70551°W) at an elevation of 3,400 ft (1,036 m). The riparian pasture (Pasture C) is approximately 139 acres (56.40 ha) and extends for approximately 1.44 mi (2.32 km) along Catherine Creek (Fig. 1). Mean annual precipitation for the study site is 23.2 inches (590 mm), most of which falls as snow during the winter months. The study pasture was photographed at high resolution, 7.8-inch (20-cm by 20-cm ground pixel size or 1:706 scale), with an aircraft-mounted Canon® 12.4 megapixel digital camera on 3 September 2008, just after livestock were moved from the unit. Images were corrected for lens curvature, then mosaiced via edge matching to create a composite image. The composited image was geographically registered (geo-rectified) using ground control points.

Geo-rectified images with 100-m (328.083 ft) UTM grid lines were used by ecologists to map vegetative communities in the riparian pasture. Communities were delineated as: 1) cobble (*Bromus tectorum* L.), 2) wet meadow (*Poa pratensis* L., *Phleum pratense* L., *Carex* spp.), 3) dry meadow (*Poa pratensis* L.), 4) Douglas hawthorn (*Crataegus douglasii* Lindl.), 5) riparian shrub (*Populus balsamifera* L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw, *Alnus incana* (L.) Moench, *Salex* spp.), 6) gravel bar, and 7) pine (*Pinus ponderosa* C. Lawson). The river was also digitized and became an eighth class as surface water (Fig. 2).

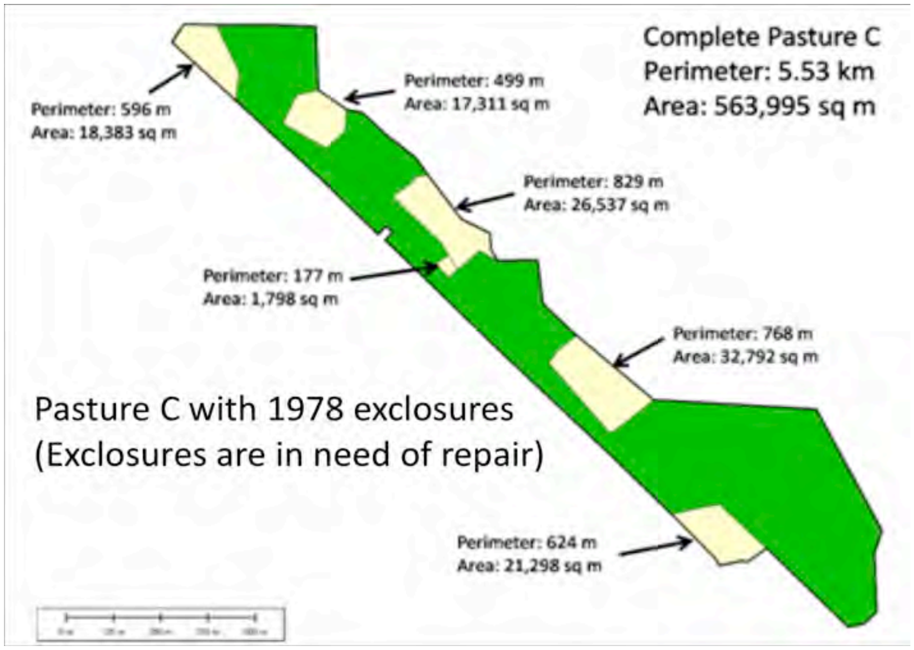

Figure 1. Catherine Creek (Pasture C) study site.

Figure 2. Vegetative communities in the northwestern portion of Pasture C on the Hall Ranch.

GPS Collars

GPS collars were constructed using a Trimble® Lassen® iQ Module, GPS data logger board, SD Card, and batteries that were enclosed in a polycarbonate waterproof case attached to sewn collar belting. Collars were color coded so individual animals could be visually identified at a distance. Collars collected the following data at 1-sec intervals; latitude; longitude [horizontal error: less than 5 m (50 percent), less than 8 m (90 percent)]; velocity (accuracy: 0.06 m/sec); elevation (altitude error less than 10 m (50 percent), less than 16 m (90 percent); date; time (accurate to better than 0.25 sec); number of satellites used in the positional fix; and an estimate of fix quality. GPS data loggers operated continuously for approximately 6.25 days and automatically restarted if power was interrupted while logging. A reference GPS unit was used as a static test during Trial 1. This unit was placed in a representative area 5 ft (1.5 m) above the ground. During Trial 1 (6.71 days of logging at 1 sec or 579,290 positional fixes) mean XY error was 5.7 ft (1.75 m) with 3.9 ft (1.19 m) standard deviation. Throughout the 6.71-day test, 2,011 points (0.35 percent) were recorded with XY errors greater than 25 ft (7.5 m) and 555 points (0.096 percent) had errors greater than 32 ft (10 m). This stationary reference GPS unit recorded only seven velocities greater than 0.00 mph (0.00 kph) during the test period.

We should note that rapid head movement, such as a collared cow's head toss while fighting flies, can result in a recorded velocity by the GPS collar. This typically occurs as single velocity values in a series of no velocity values. Obviously, "head tosses" during grazing would not be distinguishable from normal grazing velocities.

Animals

Seven Angus and Angus-cross commercial cows from a herd of 33 cows and calves were collared with GPS units that recorded positions at 1 sec intervals. Two trials were run. Trial 1 lasted from when cows entered the pasture on 12 August 2008 to 17 August 2008. Trial 2 lasted from 27 August to 1 September 2008 and ended just before animals left the pasture. A total of 6,378,700 positions were recorded on the collared cows (74 days of continuous 24-hour observation periods). During Trial 2 several cows also carried Vibracorders® to monitor head motion. These units knocked against GPS collars and caused GPS collars to fail.

At the end of each trial data were downloaded from the GPS units and stored in electronic format. Animal positions were grouped by day with only 24-hour continuous observation periods used for analysis. Daily data were sorted by velocity into the following classes based on a 61-sec running average using the Animal Movement Classifier software (Johnson et al. 2008): 1) stationary - no recorded velocity for 61 sec, 2) very slow – mean velocity between 0.0006 mph (0.001 kph) and less than 0.06 mph (0.1 kph), 3) slow - mean velocity between 0.06 mph (0.10 kph) and less than 0.62 mph (1.0 kph), 4) moderate - mean velocity between 0.62 mph (1.00 kph) and less than 2.49 mph (4.00 kph), and 5) fast - mean velocity greater than 2.49 mph

(4.00 kph). Distance traveled for each animal and day was calculated by summing the displacement from each GPS position with a recorded velocity. This typically reduced the number of locations from 86,400 in 24 hours to less than 9,000, which reduced accrued GPS errors. Times when animals had no GPS velocity thus were not used to calculate path distance. Those locations when animals were stationary for 10 min or longer were tallied and a minimum convex polygon was created as an ArcGIS® shapefile® that was attributed with entry date and time, duration in seconds, and surface area of the polygon.

RESULTS AND DISCUSSION

Velocity of GPS-collared cows was plotted to determine daily activity patterns (Fig. 3). The velocity pattern shows that cattle were actively moving beginning between 4:00 and 5:00 local time and continued, with relatively brief inactive periods, until approximately 19:00 hours. Movement, as indicated by velocity, appeared to be more intense during the first day that animals were in the pasture (Fig. 3) but the general active periods were similar through the Trial. As can also be seen in Figure 3, cow 6220 was regular in her activity pattern throughout Trial 1, indicating a stable environment. Night is characterized by fewer, separated velocities but some sustained movement can occur. During this trial civil twilight began at 5:30, sunrise was at 6:02, sunset was at 19:46, and the end of civil twilight occurred at 20:17.

An examination of the classified activity for this animal also indicates that less time was spent in travel toward the end of the grazing period. On August 12, cow 6220 logged 48,122 positions (55.7 percent) classed as stationary, 10,554 positions (12.2 percent) as very slow, 19,916 (23.1 percent) as slow, 7,547 positions (8.7 percent) as moderate, and 248 positions (0.3 percent) as fast. Of a potential 86,400 positions, 86,387 positions (99.98 percent) were recorded for the day. On 31 August 2008 cow 6220 recorded 60,109 positions (69.6 percent) classed as stationary, 12,591 positions (14.6 percent) as very slow, 12,942 (15.0 percent) as slow, 678 positions (0.8 percent) as moderate, and 0 positions (0.0 percent) as fast. Of a potential 86,400 positions, 86,320 positions (99.91 percent) were recorded for the day. This suggests less movement at lower speeds as the grazing period progressed.

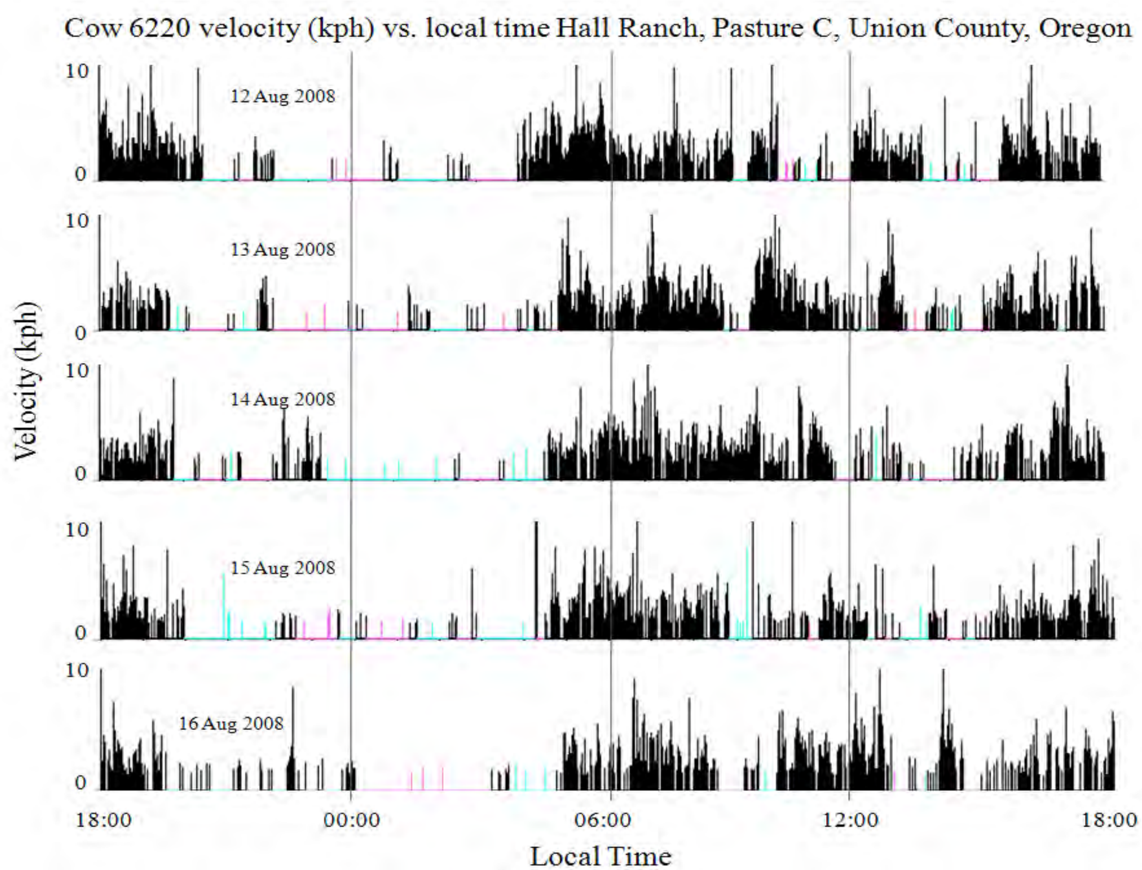

Figure 3. Activity pattern of cow 6220 between 12 and 16 of August 2008. Recording began just after cattle entered the pasture (17:00 hours) and continued for the following 5 days. Gray bands on the time axis represent classified stationary locations with duration longer than 10 minutes.

Travel distance was calculated for each collared animal in the herd (Tables 1 and 2) by calculating X,Y displacement between positions with a recorded velocity. This alleviates most of the pseudo travel that results from summing GPS errors while the animal was actually stationary. Over the duration of both trials the trend in daily distance traveled was to shorter distances ($DDT_{km} = -0.1576x + 6.3171$, $R^2 = 0.5086$), which could indicate that animals learned where the best forage was located and were more efficient foragers as time in the pasture progressed. This trend could be explained by other factors as well.

Cattle distribution in the pasture was not uniform (Fig. 4). The northwestern portions of the pasture were more attractive to cattle than were the brushier, densely wooded or steeper sloped sites in the southeast, thus the bulk of the occupancy was in the northwestern areas. Preferred areas tended to be more open with more grass, which corresponded to meadow areas. Also obvious was that some of the exclosures were in disrepair and fencing did not restrict cow movement. For example, cows freely moved through the northwestern-most exclosure, crossing broken fences at numerous locations.

Table 1. Travel distance (mi/day) for each collared cow during Trial 1, Catherine Creek Pasture, Hall Ranch, Union County, Oregon.

	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
Cow	**12 Aug 08**	**13 Aug 08**	**14 Aug 08**	**15 Aug 08**	**16 Aug 08**	**17 Aug 08**	**18 Aug 08**
6220	5.275 mi	4.362 mi	4.064 mi	2.896 mi	3.560 mi	3.250 mi	
6126	3.523	4.058	3.219	2.336	2.678	2.529	3.958
1154	3.921	4.039	4.045	3.766	3.175		
9217	4.232	2.927	3.480	2.691	1.982	2.740	
5223	3.237	3.125	3.393	2.734	2.548	2.417	
4282	5.331	4.312	5.145	3.368	3.592	3.548	
5027	4.430	4.033	3.815	3.157	2.666	3.070	
Mean	4.281	3.83	3.877	2.995	2.883	2.927	3.958

Table 2. Travel distance (mi/day) for each collared cow during Trial , Catherine Creek Pasture, Hall Ranch, Union County, Oregon 2.

	Day 16	**Day 17**	**Day 18**	**Day 19**	**Day 20**	**Day 21**
Cow	**27 Aug 08**	**28 Aug 08**	**29 Aug 08**	**30 Aug 08**	**31 Aug 08**	**1 Sep 08**
6220	2.523 mi	4.362 mi	2.113 mi	2.144 mi	1.914 mi	2.175 mi
6126	2.044	2.684	1.510	2.069	1.752	2.734
1154	2.908	3.598	1.964	1.734	2.026	3.020
9217	2.057	0.000	0.000	0.000	0.000	0.000
5223	2.243	2.889	1.423	1.634	1.647	2.678
4282	2.672	3.386	1.684	1.939	2.324	2.852
5027	2.684	0.000	0.000	0.000	0.000	0.000
Mean	2.448	3.386	1.740	1.901	1.932	2.691

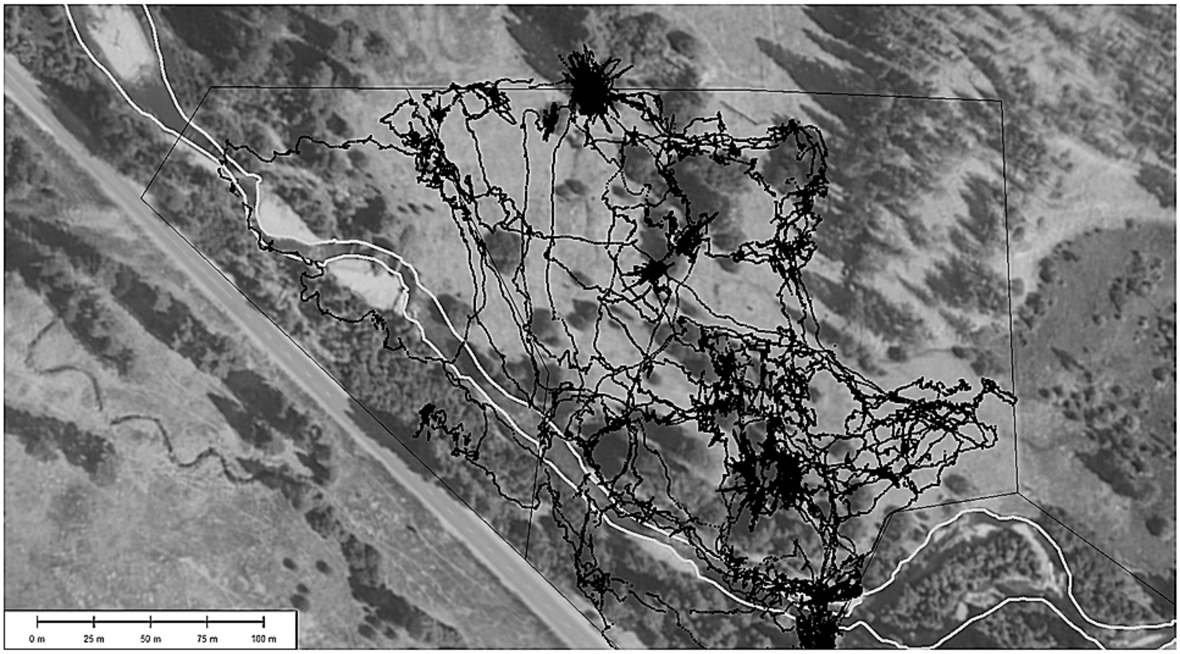

Figure 4. Distribution of collared cattle (black dots) during the August/September 2008 grazing season for the northwestern portion of the Hall Ranch Pasture C. Note the locations that cattle used to cross Catherine Creek (outlined in white) and the meandering travel routes through the brushy areas. Each point represents 1 sec of occupancy.

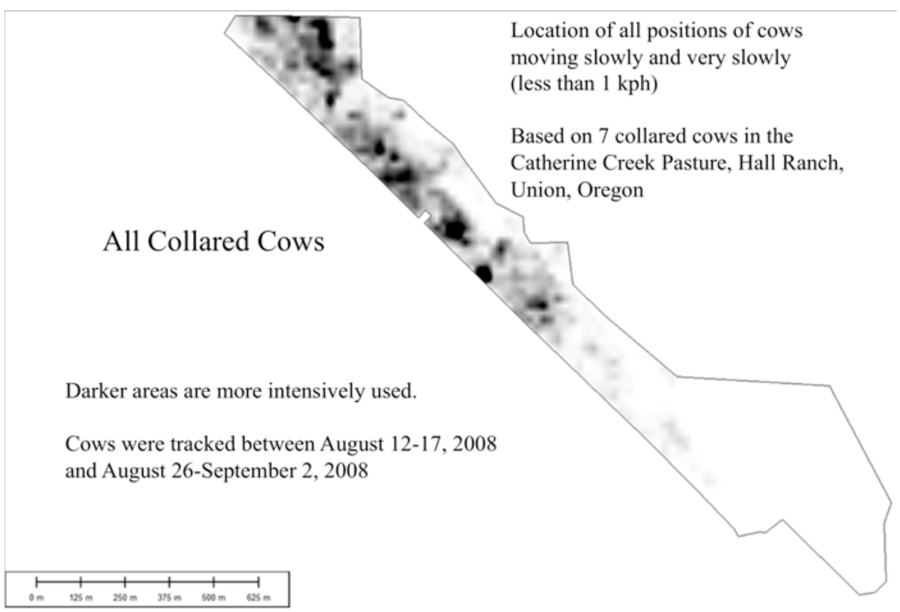

Figure 5. Distribution of collared cattle while moving slowly or very slowly during the August-September 2008 grazing season for the Hall Ranch Pasture C. The pasture was divided into 65-ft by 65- ft (20 m by 20 m) cells and the time (sec) of presence was tallied for all cows and days of observation. Darker gray shading indicates longer occupancy times. The maximum occupancy was 23,000 sec, minimum was 0.

In an attempt to identify where cattle grazed, we extracted those positions that were classified as slow or very slow movement. A 65-ft by 65-ft (20 m by 20 m) grid was created for the pasture and points were tallied to produce a map that shows the duration of occupancy in each cell (Fig. 5). This map contains values from 0 sec occupancy per cell to approximately 23,000. Sites that were preferred tended to center on areas with abundant grass forage. Locations where cows were stationary for more than 10 minutes tended to be near preferred grazing areas and associated with shade trees.

We created preference indices for our vegetation communities map by dividing the percent use (while moving very slowly or slowly) by its relative percentage in the pasture (Table 3). Wet meadows and dry meadows were both preferred as would be expected (Table 3). We did not expect that cobble/BRTE (cheatgrass) sites would also be preferred. Upon examination of the cattle locations plotted on the vegetation communities map, we found that this vegetation type was small (because it represents an old river channel) and perpendicular between two favorite grazing areas. Thus most of the occupancy was during transit between favorite foraging locations. Preference in these communities appears to rank in decreasing order with potential grass production. We hypothesize that forage quality and quantity at the feeding patch/community level is an important factor in determining relative use. Unfortunately standing crop was not measured prior to grazing.

Table 3. Preference of cows grazing the Hall Ranch Catherine Creek Pasture, Union County, Oregon for vegetative communities.

Vegetation community	Total % of area	Total % of use	Preference index
Cobble/BRTE	0.37	1.38	3.68
Wet meadow	0.16	0.60	3.68
Dry meadow	10.24	31.32	3.06
Hawthorn	13.33	29.31	2.20
Riparian shrub	7.28	14.02	1.93
River	3.90	2.78	0.71
Gravel bar	1.59	0.84	0.53
Pine	63.13	18.35	0.29
Total	100	98.60	

MANAGEMENT IMPLICATIONS

The techniques described in this paper were effective in monitoring cattle grazing in a riparian pasture. GPS collars recorded animal position with reliability except when Vibracorders® were also carried and we were able to ascertain where and when cattle utilized various vegetative communities and where favorite day and night camps were located. Cow preference for sites in the pasture was mapped and these locations could be used as key areas for managerial decision making. For example, the standing crop at two or three locations might provide a rancher with an index of how much forage remains to be grazed and when animals should be moved. Although not specifically reported in this paper, we also identified locations where cattle crossed the stream, duration of occupancy, and sites that were used for watering. These areas could be monitored for stream bank or environmental impacts. Obviously, this type of information can be used to rationally assess effects of livestock grazing on pastures with riparian systems. We should also be able to use these types of data to suggest managerial interventions such as off-stream watering, trail building, stream crossing improvement, or fencing configurations to mitigate problems.

Cattle activity in this study was centered on meadow areas and travel routes between them. Extensive portions of the pasture were unused. If the managerial goal is to increase cattle production or increase livestock dispersion, our technologies could suggest ways to do it. For example, meadow areas in this pasture are being invaded and dominated by hawthorn. Hawthorn sites are less preferred than are open meadows and as time passes grazing capacity will diminish as meadows convert to brush. Our technologies could be used to estimate benefits from brush control.

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Pre- and Post-burn Cattle Distribution Patterns in Sagebrush Steppe

Dave Ganskopp, Dave Bohnert, Dustin Johnson, and Kristen Munday

SUMMARY

Grazing management of rangelands exposed to either wild or prescribed burns is a challenging issue, and post-burn grazing patterns of stock are not well quantified in the sagebrush steppe. We tracked the grazing patterns of cattle with GPS collars in pastures during growing seasons prior to and after prescribed burns. In growing seasons after fires, burned sites that had historically been avoided by cattle became preferred foraging areas with 7 to 30 times more use than would be expected from chance alone. If grazing is deferred until August when all herbage is cured, cattle will focus less intensively on burns and use more of the adjacent unburned terrain. Nutritional advantages still accompany use of burned sites in August, however, and stock will still make greater than expected use of those areas. If managers plan to use prescribed fires, we suggest entire pastures be burned to avoid undue concentrations of foraging stock. Pastures with burns of limited scale may still be grazed in subsequent years, but managers need to be astute to avoid irreversible damage to recovering herbage.

INTRODUCTION

Both controlled burns and wildfires are prominent components in the history and management of sagebrush-steppe rangelands. Controlled burns may be used to retard competitive woody plants like sagebush (*Artemisia* spp) or western juniper (*Juniperus occidentalis* Hook.), enhance the nutritional value of herbaceous plants, or add diversity to the landscape by altering plant community structure and composition. While controlled burns are applied with specific objectives in mind, wildfires may be accidents or products of Mother Nature, and they may or may not have a desirable effect on the landscape.

With our ever increasing presence of invading weeds and annual grasses, post-burn landscape management efforts should insure that existing herbage recovers fast enough to block invasion of sites by undesirable species. We know that wildlife and livestock are attracted to recently burned locales, and that untimely and/or excessive grazing can hinder vegetation recovery. The relative appeal, however, of burned and unburned sites to foraging cattle has not been well quantified in sagebrush-steppe communities. The objectives of this research were to monitor use of burned and unburned sites by grazing cattle and to assess several forage quality attributes that may contribute to their uneven distribution across the landscape.

METHODS

Research was conducted in two 2,000 acre pastures on the Northern Great Basin Experimental Range 30 miles west of Burns, Oregon. Woody vegetation included a sparse western juniper overstory and a shrub layer dominated by Wyoming (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) or mountain (*A. tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle) big sagebrush or low sagebrush (*A. arbuscula* Nutt.). Prominent grasses included bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), Idaho fescue (*Festuca idahoensis* Elmer), Sandberg's bluegrass (*Poa secunda* J. Presl), or bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey) depending on locale and soils.

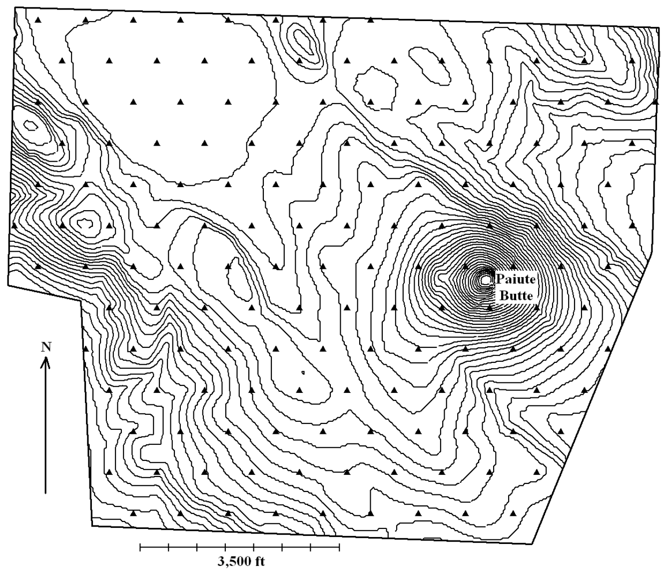

Figure 1. Twenty-ft contour lines and the locations of forage sampling sites (black triangles) in a 2,105-acre pasture in a study evaluating grazing cattle responses to prescribed burns on the Northern Great Basin Experimental Range during four grazing seasons from 2004 through 2007.

Beginning in early June 2004 herbage was sampled from 150, 10.7-ft^2 plots arranged in an offset grid pattern in each pasture (Fig. 1). At each location, a frame was dropped and all grasses and forbs rooted therein were clipped to a 1-inch stubble, the material was bagged, and bags were labeled with an identifying number. Subsequent forage quality assays for each sample included crude protein (CP), neutral detergent fiber (NDF), and digestibility as indexed by *in situ* dry matter disappearance (ISDMD). Immediately after clipping, 15 cow/calf pairs were released to each of the 2 pastures. Four cows in each pasture were equipped with GPS collars to monitor their whereabouts and establish their activities at 5-min intervals over the next 15 days. Motion sensors within the collars that were sensitive to the animal's head movements let us determine when cattle were foraging. Grazing coordinates were retained, and coordinates where cattle were resting or walking were not included in these analyses. Also, with an assumption that water was the primary attraction near stock tanks, grazing coordinates within 50 yards of the single tank servicing each pasture were excluded.

With one exception, these same June herbage sampling and cattle stocking regimes were sustained through 2005, 2006, and 2007. The exception occurred in August 2007 when herbage was re-sampled and pastures stocked a second time to assess cattle distribution after all forage was dormant and cured.

In September 2004 approximately 63 acres were burned in our first pasture and in September 2006, 120 acres burned in our second pasture. With this regime, we obtained one season of pre-burn cattle distribution data and three measures of post-burn cattle use from our first pasture. The second pasture provided three seasons of pre-burn cattle distribution data and one summer (June and August) of post-burn monitoring.

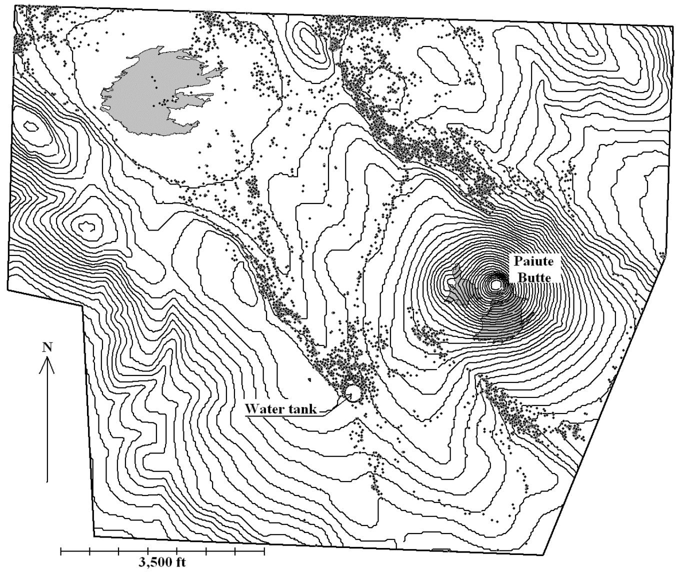

Figure 2. The locations of 5,296 grazing coordinates (small black dots) obtained from four GPS- collared cattle grazing on the Northern Great Basin Experimental Range for 15 days in June 2004 in a study evaluating pre- and post-fire cattle distribution. Coordinates within 50 yards of water (N= 946) were excluded from these analyses. The three gray areas denote locations that were subsequently burned in September 2004.

Cattle use of sites was quantified with an occupancy : availability ratio. For instance, if 20 percent of our cattle grazing records occurred in an area constituting 10 percent of the pasture, our occupancy : availability ratio of 20 : 10 would reduce to a value of 2.0. We would infer that area was preferred by cattle. An occupancy : availability ratio with 10 percent of our cattle grazing records in an area constituting 30 percent of the pasture would reduce to 0.30, and we would suggest that area was avoided by stock. In an ideal situation where cattle were uniformly dispersed across a pasture, an occupancy : availability ratio of about 1.0 would indicate cattle used the area roughly in proportion to its presence.

RESULTS

Areas that were eventually burned in our two pastures initially attracted very few grazing cattle (Fig. 2) prior to the burns. Only about 1.6 percent of the grazing coordinates occurred in the 4.1 percent of the pastures that eventually were burned. This generated an occupancy : availability ratio of 0.39, suggesting those areas were generally avoided by stock prior to our prescribed fires.

In June of the first growing season after our fall burns, cattle focused much of their foraging attention on the burned areas. About 31 percent of our grazing cattle records occurred within the burn boundaries (Fig. 3). With the burns making up 4.1 percent of the pasture area, an occupancy : availability ratio of 7.6 suggested those locales had become highly preferred grazing sites.

Cattle did not discover the burned areas for the first 2 days of use in 2005 and never used the burned areas on the steep south and west slopes of Paiute Butte during the 2005, 2006, or 2007 grazing seasons (Fig. 3). Grades in those areas approach 45 to 80 percent, and cattle typically avoid terrain where slopes exceed 20 percent. If we discount the burned areas ignored by the cattle on the steep hillsides in Figure 2, 31 percent of our grazing records were actually contained by the 2 percent of the pasture that was burned in the more level north-west corner. This elevates our occupancy : availability ratio to a more valid 15.5. That same burned area supported 39 percent of the grazing coordinates in 2006, and 62 percent of the grazing records in June 2007.

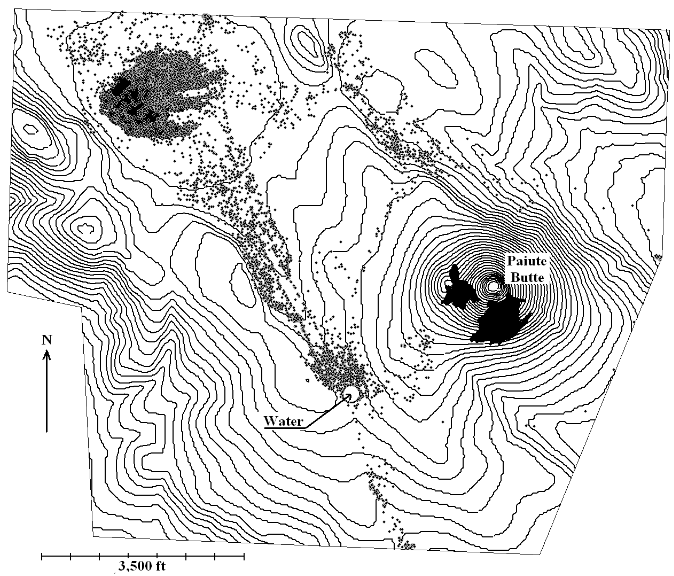

Figure 3. The locations of 6,274 grazing coordinates (small black dots) obtained from four GPS collared cattle grazing on the Northern Great Basin Experimental Range for 15 days in June 2005 in a study evaluating pre- and post-fire cattle distribution. Coordinates within 50 yards of water (N= 946) were excluded from these analyses. Blackened areas denote sites that were burned the prior September.

We stocked our pastures with GPS-collared cattle again in August 2007 to see if cattle would exhibit the same grazing patterns when forages were dormant and cured. Cattle responded by exploring considerably more of their pasture in August (Fig. 4) than in June, but they were still attracted to the burned area. About 15 percent of their total grazing efforts were contained by the 2 percent of the pasture area that was burned. See the north-west corner of the pasture in Figure 4. Again, an occupancy : availability value of 7.5 suggested the burned site was still a highly preferred foraging area.

Nutritional analyses of forage samples found no differences between standing crop or forage quality between the burned and unburned sites prior to our prescribed fire applications (Table 1). In the first growing/grazing season after the burns, CP was almost 3 percentage points and digestibility about 13 percentage points higher within the burns than in surrounding areas.

Conversely, NDF, which is negatively correlated with forage intake and digestibility in cattle, was about 9 percentage points lower within the burned locales than in unburned areas.

Due to the prior use in June, our August 2007 forage samples revealed less available herbage in our burned than unburned areas (244 vs. 347 lbs/acre, respectively). Crude protein, digestibility, and NDF assays, however, still suggested cattle could harvest a nutritionally superior diet within burned sites (Table 1) even though all herbage was cured and dormant.

DISCUSSION

Grazing cattle were attracted to small burned areas within larger unburned environments. Previously avoided locales were converted to highly preferred grazing sites with grazing intensities 7 to 30 times greater than expected with a uniform distribution. Other research on the Northern Great Basin Experimental Range has shown that well managed post-fire grazing by cattle during the growing season does not retard vegetation recovery in healthy communities,

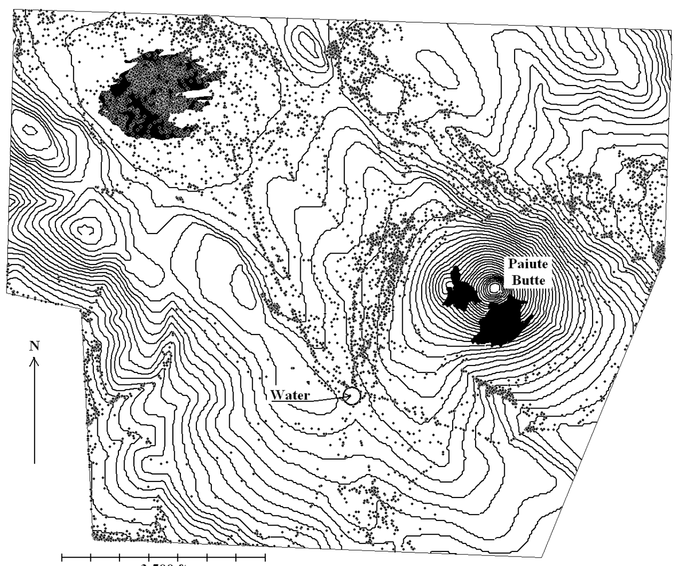

Figure 4. The locations of 7,146 grazing coordinates (small black dots) obtained from four GPS- collared cattle grazing on the Northern Great Basin Experimental Range over 15 days in August 2007 in a study evaluating pre- and post-fire cattle distribution. Blackened areas denote sites that were burned in September 2004.

and that by the second or third year after a fire, herbaceous cover, standing crop, and seed production in burned pastures can exceed that of unburned pastures (Bates et al. 2009). That study, however, was conducted in pastures that were uniformly burned, uniformly grazed by cattle, and herbage utilization closely monitored to assure use did not exceed 50 percent by weight.

Our central issue in this study was that grazing cattle could not be managed in our extensive pastures, and they had a choice of using either burned or unburned sites. Cattle elected to concentrate their grazing on burned locales with herbage utilization levels likely exceeding 70 percent of standing crop. This level of use leaves little residual herbage on the burned sites and a wealth of standing cured straw in the neighboring unburned and ungrazed areas. In subsequent years, cattle again focused their attention on the burned locales. This likely occurred because burned areas repeatedly generated a wealth of high quality herbage, and stock did not need to sort through a mix of old and new growth like that found on neighboring unburned sites.

Post-grazing site surveys of herbage use showed that cattle grazed burned sites with almost surgical precision. Grass tussocks within the confines of a burn were always grazed, while unburned tussocks only inches outside of burn boundaries were untouched. Grazing distribution patterns exhibited this same effect (see Fig. 3) with the preponderance of grazing restricted to the burn and the direct route to and from stock water.

Deferring the grazing season until August, when all herbage has cured, may provide some relief for burned areas. Cattle still used burns at greater than expected frequencies, but they also explored and used a greater proportion of their pastures than earlier in the season (Figs. 3 and 4). There were still nutritional advantages to be had by grazing the burns in August with elevated crude protein and digestibility and reduced neutral detergent fiber in the burns (Table 1).

Table 1. Forage quantity and quality attributes sampled before and after prescribed fires in two pastures on the Northern Great Basin Experimental Range during studies evaluating the grazing distribution of GPS-collared cattle for 15-day June grazing trials in 2004-2007 and a 15-day August grazing trial in 2007. Sample location values listed in bold font are statistically different ($P < 0.05$).

		Sample location	
Sampling period	Forage attribute	Outside burned area	Inside burned area
June, pre-burn	Standing crop (lbs/acre)	393	407
	Crude protein (%)	8.2	8.2
	Digestibility (%)	64	61
	Neutral detergent fiber (%)	66	65
June, 1-year post-burn	Standing crop (lbs/acre)	445	500
	Crude protein (%)	**8.0**	**10.8**
	Digestibility (%)	**58**	**71**
	Neutral detergent fiber (%)	**62**	**53**
August, post-burn	Standing crop (lbs/acre)	**347**	**244**
	Crude protein (%)	**7.3**	**11.1**
	Digestibility (%)	**64**	**76**
	Neutral detergent fiber (%)	**62**	**52**

We may have partially created these advantages with our prior June grazing that removed growing herbage and stimulated production of new and more nutritious regrowth than was found in surrounding areas. Conventional wisdom suggests that removal of cured herbage when grasses are dormant has little effect on the health or subsequent vigor of the remaining plant tissues.

Steep slopes (Fig. 3 and 4) or excessive distances from water that typically retard cattle use, *may* provide some protection from grazing for recently burned areas. In the second pasture used in this study, a burn about 0.8 mi from stock water was not discovered in the first post-burn grazing session. This happened because cattle restricted their use to the two burns closest to the tanks. In both the slope and distance instances, we emphasize the word "may", because those areas might have garnered more attention if they had simply been discovered.

MANAGEMENT IMPLICATIONS

Post-fire pasture management has and will likely continue to be a great frustration for rangeland and livestock managers under both prescribed and wildfire circumstances. If the inordinate concentration of stock that occurred in this study was allowed to continue, the vigor and species makeup of those burned sites would most assuredly deteriorate. A reduced stocking rate would not rectify the issue, because the remaining cattle would still focus their grazing efforts on the nutritionally superior burned locales. With these thoughts in mind, we offer a few suggestions.

1. If prescribed burns are employed, attempt to burn all or as much of a pasture as possible. If a complete burn is attained, the entire pasture will subsequently support high-quality herbage, and stock will have little reason to focus their attention on limited portions of the landscape. Other aspects affecting livestock distribution though, like extreme slopes or excessive distance from water will still exert their influence.

2. When limited portions of pastures do burn, astute management may still allow some grazing without deleterious effects if the sites were initially in good condition. Stocking rate and duration should be adjusted to assure conservative use (less than 50 percent removal) of herbage from burned sites. With grazing efforts concentrated in burned areas, stocking rate and duration should reflect the carrying capacity of the burn rather than the full potential of one's pasture. Another option is to fence burned sites or limit stock access to the area by providing water in some distant portion of the pasture. If water manipulations are used, herbage use in burns should still be monitored, because cattle may travel further than normal to access newly discovered high-quality forage.

3. Deferring grazing until all herbage has cured should reduce but not eliminate livestock focus on burned areas. Burned locales will still support nutritionally superior herbage because only current year's growth is available. With greater dispersal of stock, deferred grazing should yield more harvested animal unit months, have little effect on plant vigor with only dead herbage being used, and perhaps help trample in shattered seed.

4. Concentrated grazing patterns will likely persist for at least 2 to 3 years, so post-burn herbage recovery and grazing management should be closely monitored in subsequent

years. Wildlife, like deer, elk, or pronghorn may also focus on small-scale burns. Therefore, utilization monitoring should not be solely synchronized with the turn-in and turn-out of stock.

5. One positive aspect of these cattle responses to burns is that prescribed fire could be used to attract cattle to historically unused portions of pastures. If that is an objective, and the areas are well out of their habitual haunts, stock may need to be trailed to those sites for an introduction. The same management issues and concerns listed above will still apply.

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Does Disposition Affect Reproduction in Beef Cattle?

Reinaldo Cooke and David Bohnert

SUMMARY

Disposition has been shown to significantly affect feed intake and growth rates of beef cattle. However, little research has evaluated the effects of poor disposition, and methods to improve this trait, on reproductive function of beef females. Thus, two experiments were conducted to determine the effects of disposition and acclimation to human handling on reproductive function of mature cows and developing heifers. Results indicated that cows with poor disposition had impaired reproductive performance compared to cohorts with good disposition. Further, acclimation of beef heifers to human handling was an alternative to improve their disposition and consequently enhance their reproductive development. We concluded that disposition affects reproductive performance of beef females, whereas management strategies targeted to improve the disposition of the cowherd, such as selection for good disposition and/or acclimation to human interaction, will benefit reproductive rates and consequently the overall productivity of cow-calf operations.

INTRODUCTION

For nearly a century, the word “disposition” has been used to define the behavioral responses of cattle when exposed to human handling. As cattle disposition worsens, their response to human contact or any other handling procedures becomes more agitated and/or aggressive. Within the beef cattle industry, producers consider disposition a selection or culling criteria for cattle primarily for safety reasons. Still, several research studies demonstrated that feedlot cattle with excitable disposition experienced reduced growth rates compared to cohorts with good disposition. This effect was attributed to reduced feed intake, and also to altered physiology of temperamental animals to support their behavioral responses. As an example, blood concentrations of cortisol, a hormone directly associated with stress responses, are typically elevated in cattle with excitable disposition. Cortisol can directly impair synthesis of hormones associated with growth, health, and reproductive function of cattle, which can lead to decreased performance and reproduction.

However, the effects of disposition on reproductive function of beef females are still unknown. Further, frequent human interaction and handling has been shown to improve disposition and reduce cortisol concentrations in beef cattle. Based on this rationale, two experiments were conducted to determine the effects of disposition and acclimation to human handling on reproductive performance of mature cows and developing heifers.

METHODS

Both experiments were conducted, from 2006 to 2008, at the University of Florida–Range Cattle Research and Education Center, Ona. Three methods were used to characterize cattle disposition in both experiments (these methods are also being currently used at the Eastern Oregon Agricultural Research Center to determine disposition of the research cowherd):

1) Chute score: Observation of animal behavior when restrained in the chute. This score ranges from 1 to 5 (very calm to very agitated, respectively).

2) Exit score: The speed at which the animal leaves the chute is measured. Following that, velocities are ranked and animals are scored from 1 to 5 (slowest to fastest, respectively).

3) Pen score: Animal response to human presence in the pen after leaving the chute. This score also ranges from 1 to 5 (calm to aggressive behavior, respectively).

After all measurements are assessed, an overall disposition score is assigned to each animal, which is a combination of one-third of each individual measurement and is also referred to as disposition score.

Experiment 1

Over 2 years, disposition scores and blood samples were collected from 400 Braford and Brahman x Angus mature cows after weaning (August). From August to January, half of these cows were subjected to an acclimation process, whereas the other half remained within normal production conditions. For the acclimation treatment, the same technician interacted with the cows twice weekly by walking among them and offering a small amount of range cubes. The amount of range cubes offered was too little to impact the cows nutritionally (0.2 lbs/cow weekly). In January, prior to the beginning of a 90-day breeding season, disposition scores and blood samples were collected a second time to determine treatment effects. Blood samples were analyzed for cortisol concentrations.

Experiment 2

Growth rates, puberty attainment, and pregnancy rates of 80 replacement Braford and Brahman x Angus heifers were assessed during this 2-year study (40 heifers each year). Approximately 30 days after weaning (August), half of these heifers went through an acclimation process, whereas the other half remained within normal production conditions. Acclimation consisted of bringing heifers to the cowpens three times per week during a 1-month period where heifers were exposed to common handling practices, such as chute restraining. Disposition scores and blood samples of heifers from both groups were collected prior to and at the end of the acclimation period. Puberty attainment was monitored monthly until the beginning of the 60-day breeding season (January). Blood samples were analyzed for cortisol concentrations.

RESULTS AND DISCUSSION

Experiment 1

No differences were detected between treatments for disposition scores, cortisol concentrations, and pregnancy rates (Table 1). However, when analyzing data combined from both treatment groups, we found that disposition score and blood cortisol concentrations affected pregnancy rates during both years (Fig. 1). This analysis was performed within each year because mean days postpartum across breeds at the onset of breeding differed from year 1 to year 2 (88 versus 34 days, respectively), and suggests that excitable disposition and consequent elevated cortisol concentrations are detrimental to reproductive function of cows. Additionally, as observed in year 2, extremely reduced cortisol concentrations and disposition score during the early postpartum period may denote health disorders that negatively affect cattle reproduction, such as lethargy, lameness, and immunosuppresion.

In conclusion, acclimation of beef cows to human interaction did not influence disposition, concentrations of blood cortisol, and pregnancy rates. Nevertheless, measurements and physiologic responses associated with disposition influenced the probability of cows to become pregnant during the breeding season. Therefore, management strategies that improve cow disposition will likely benefit reproductive performance and consequent productivity of cow-calf operations.

Table 1. Disposition score, blood cortisol concentrations, and pregnancy rates of beef cows exposed or not (control) to human acclimation procedures.

Item	Acclimated	Control	*P-value*
Disposition score [a]			
Beginning of acclimation period	2.49	2.51	0.79
End of acclimation period	2.51	2.48	0.70
Cortisol, ng/mL			
Beginning of acclimation	35.6	35.1	0.78
End of acclimation	30.9	32.0	0.59
Pregnancy rates, %	84.1	84.9	0.78

[a] Disposition score: 1 = calm behavior; 5 = agitated/aggressive behavior.

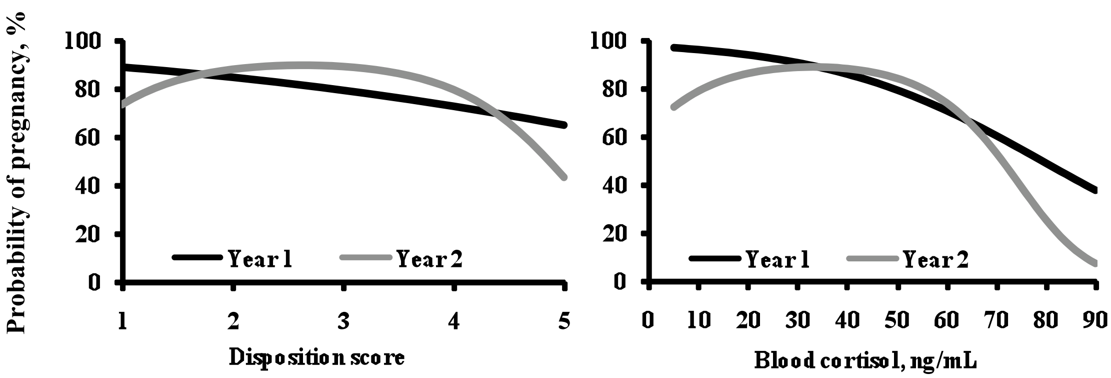

Figure 1. Effects of disposition score and blood cortisol concentrations, assessed at the beginning of the breeding season, on the probability of beef cows to become pregnant. Linear (year 1) and quadratic (year 2) effects were detected for both analyses (P < 0.05).

Experiment 2

Acclimated heifers had decreased average daily gain compared with non-acclimated heifers (1.1 vs. 1.3 lbs/day, respectively; Table 2). We attribute this response to the additional exercise that acclimated heifers were exposed to during the frequent walking to and from the working facility. During each acclimation event, heifers had to walk nearly 1.3 miles in addition to the activity inside the handling facility, whereas control heifers remained on their pasture. This is likely the reason for the average daily gain difference since both groups were provided similar pastures and supplements. Despite the slight decrease in body weight gain, puberty and pregnancy attainment were hastened in acclimated heifers compared to control cohorts (Fig. 2). Further, after the acclimation process, acclimated heifers had decreased mean chute score (1.35

versus 1.86) and blood cortisol concentrations (37.8 versus 50.5 ng/mL) compared to non-acclimated cohorts (Table 2).

Results from this experiment indicate that acclimation of heifers to handling procedures and human interaction reduced average daily gain because of the additional exercise that heifers were exposed to, but decreased blood cortisol concentrations, reduced chute score, and enhanced reproductive performance. Therefore, acclimation of replacement heifers to human handling after weaning may enhance their disposition and consequent reproductive development, and thus increase the efficiency of heifer development programs within cow-calf operations.

Table 2. Average daily gain, disposition and chute score, and blood cortisol concentrations of heifers exposed or not (control) to handling acclimation procedures.

Item	Acclimated	Control	*P-value*
Average daily gain, lbs/day	1.1	1.3	< 0.01
Disposition Score [a]			
Beginning of acclimation period	2.55	2.42	0.49
End of acclimation period	2.68	2.52	0.59
Chute score [a]			
Beginning of acclimation	1.89	2.03	0.38
End of acclimation	1.35	1.86	< 0.01
Cortisol, ng/mL			
Beginning of acclimation	39.2	42.1	0.32
End of acclimation	37.8	50.5	< 0.01

[a] Disposition and chute score: 1 = calm behavior; 5 = agitated/aggressive behavior.

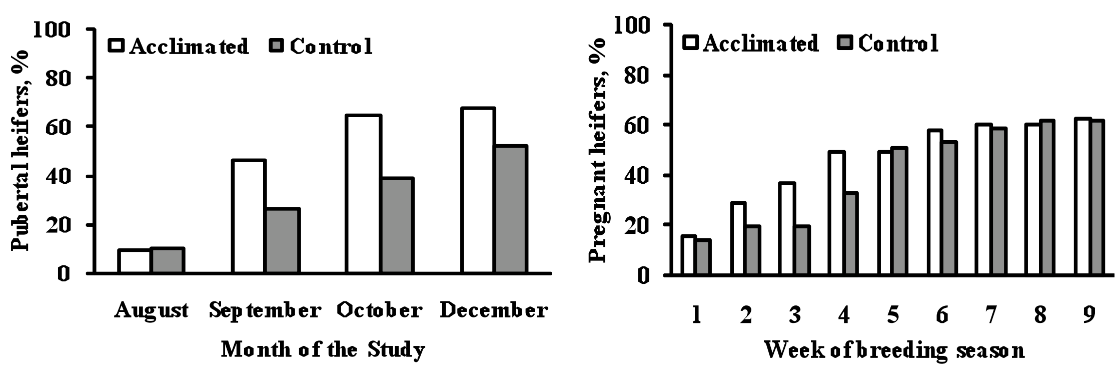

Figure 2. Puberty attainment and pregnancy rates of heifers exposed or not (control) to handling acclimation procedures. A treatment effect was detected for both analyses (P < 0.05).

MANAGEMENT IMPLICATIONS

These results indicate that excitable disposition negatively affects reproductive performance of beef females; therefore management strategies targeted to improve disposition of the cowherd will enhance the productivity of cow-calf operations. Acclimation to human handling may be an alternative; however, according to our data, only replacement heifers responded positively to the acclimation process. Perhaps disposition cannot be altered in mature cows, and selection or culling for this trait may the most appropriate method to improve disposition of older animals. These experiments, however, were conducted with Brahman-crossbred cattle in a subtropical environment. Similar studies are being currently conducted at the Eastern Oregon Agricultural Research Center to determine the effects of disposition and acclimation procedures on reproductive function of Angus-influenced heifers and cows.

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Crested Wheatgrass Impedes the Spread of Medusahead

Kirk W. Davies, Aleta M. Nafus, and Roger L. Sheley

SUMMARY

Establishing crested wheatgrass around the edge of medusahead infestations slowed the spread of the infestations into surrounding noninfested native plant communities. Crested wheatgrass decreased the availability of soil resources to medusahead and probably physically intercepted some of the dispersing medusahead seeds. Both the areas where crested wheatgrass was established and the areas protected by the crested wheatgrass had less medusahead than the control treatments.

INTRODUCTION

Invasive plants are decreasing biodiversity, reducing productivity, degrading wildlife habitat, and altering ecological functions of rangelands (DiTomaso 2000, Davies and Svejcar 2008). Efforts to restore plant communities invaded by exotic plant species are expensive, rarely successful, and may exacerbate the negative impacts of the invaders. Thus, efforts should be directed at preventing exotic plant invasions. To investigate the potential for competitive vegetation to reduce the spread of invasive plants, we evaluated the ability of crested wheatgrass (*Agropyron desertorum*) to reduce the establishment and spread of medusahead (*Taeniatherum caput-medusae*) into noninvaded plant communities.

METHODS

This study was conducted in the northwestern foothills of Steens Mountain in southeastern Oregon. Soils are a complex of different series with 20-35 percent clay content and moderate to high shrink-swell potential. Twelve sites were selected along medusahead invasion fronts. Each site was divided into two treatments 1) crested wheatgrass barrier (established crested wheatgrass) or 2) undisturbed control. Crested wheatgrass was established by drill seeding at 11 lbs/acre in a 45- by 18-ft band in front of the medusahead invasions three growing seasons prior to medusahead spread measurements. Herbaceous plant cover and density were measured in 2008. Nutrient supply rates of potassium, phosphorus, and inorganic nitrogen were also measured for each treatment plot.

RESULTS

In the Crested Wheatgrass Barrier

Medusahead and total annual grass cover were more than 7.1- and 2.7-fold greater, respectively, in the control treatment than in the crested wheatgrass treatment ($P < 0.01$ and $P = 0.04$, respectively; Fig. 1A). Medusahead and annual grass density were approximately 7.8- and 2.8-fold greater, respectively, in the control compared to crested wheatgrass treatment ($P = 0.01$ and 0.04, respectively; Fig. 1B). Potassium and ammonium concentrations were approximately 2- and 15-fold greater, respectively, in the control than crested wheatgrass seeded treatments ($P < 0.01$).

Beyond the Crested Wheatgrass Barrier

Medusahead cover and density were less in plant communities protected by a barrier of established crested wheatgrass than unprotected plant communities (42- and 47-fold difference, respectively; $P < 0.01$; Fig. 2).

DISCUSSION

Establishing competitive plants around infestations can reduce the spread of invasive plants by increasing the biotic resistance of the plant community to invasion and limiting the dispersal of invasive plant seeds into adjacent noninvaded plant communities. In this study, lower soil nutrient concentrations and less medusahead cover and density in the crested wheatgrass areas suggest that the establishment of crested wheatgrass increased the biotic resistance of these plant communities to invasion. The 40-fold greater presence of medusahead in plant communities without a crested wheatgrass barrier between them and the medusahead invasion demonstrates the effectiveness of a competitive vegetation barrier at reducing the spread of invasive plants into surrounding noninvaded plant communities. However, some medusahead seeds were able to establish beyond the barrier. This suggests the effectiveness would be improved by increasing the width of barriers and/or locating them further from the infestation edge to allow better establishment of competitive vegetation prior to experiencing pressure from the invader. The incorporation of an early detection and eradication program for satellite populations that establish beyond competitive vegetation barriers would also be fundamental to effectively reduce invasive plant spread.

MANAGEMENT IMPLICATIONS

Establishing crested wheatgrass adjacent to medusahead infestations can reduce the spread of medusahead. The establishment of crested wheatgrass appears to increase the biotic resistance of plant communities to invasion and reduce invasive plant propagule pressure in adjacent noninvaded areas. However, some medusahead may establish beyond the crested wheatgrass barrier; integrating crested wheatgrass barriers with other management actions will therefore probably be the most effective strategy to limit the negative impacts of medusahead. Considering the general failure of herbicides to impede the spread of invasive plant species, we suggest more efforts should focus on increasing the biotic resistance of plant communities to invasion and decreasing invasive plant propagule pressure.

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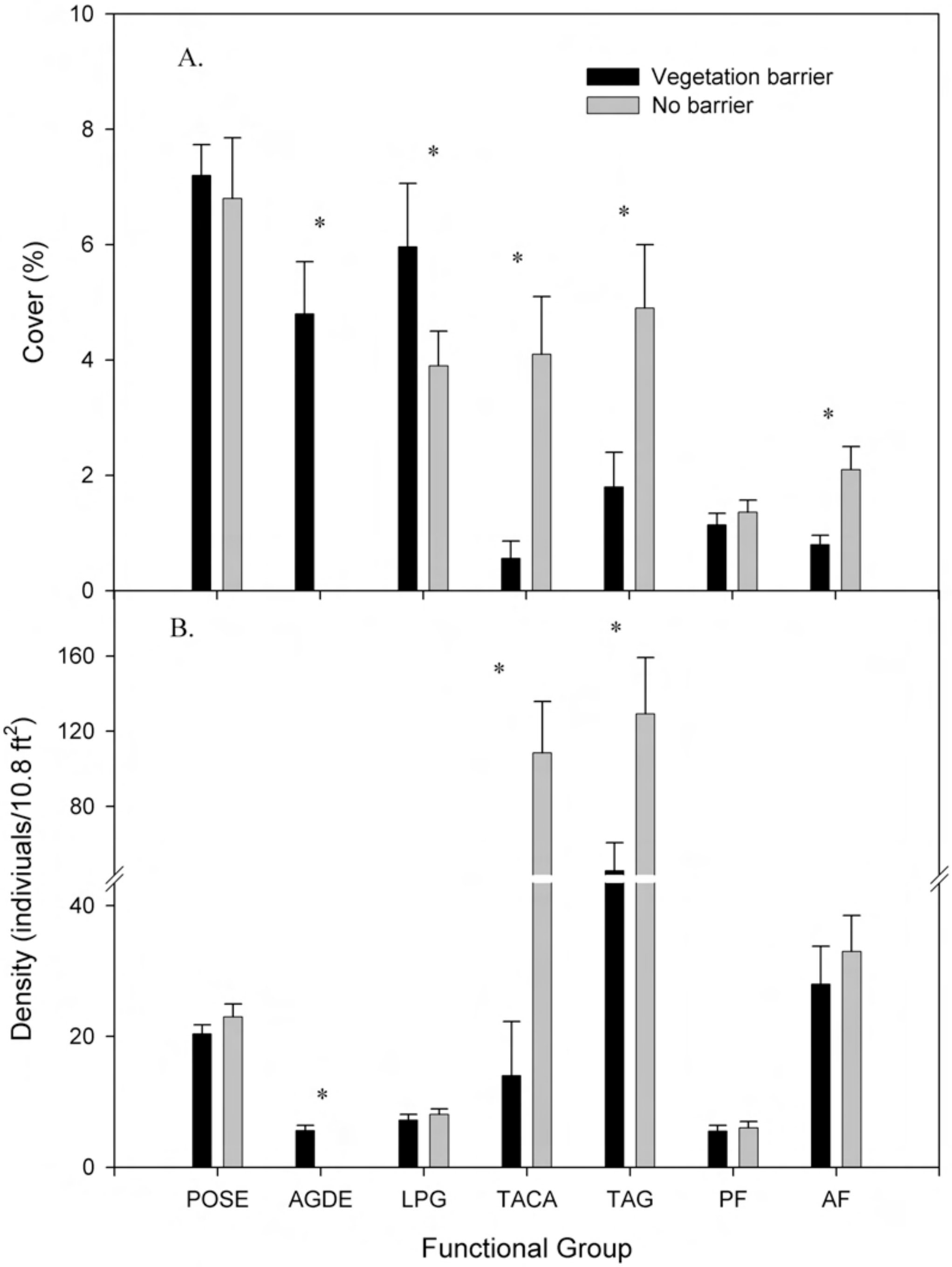

Figure 1. Cover (A) and density (B) of plant functional groups in the crested wheatgrass barrier and no barrier treatments (mean + S.E.). POSE = Sandberg bluegrass, AGDE = crested wheatgrass, LPG = large perennial bunchgrass, TACA = medusahead, TAG = total annual grass, PF = perennial forb, and AF = annual for. Asterisk (*) indicates significant difference between treatments (P < 0.05).

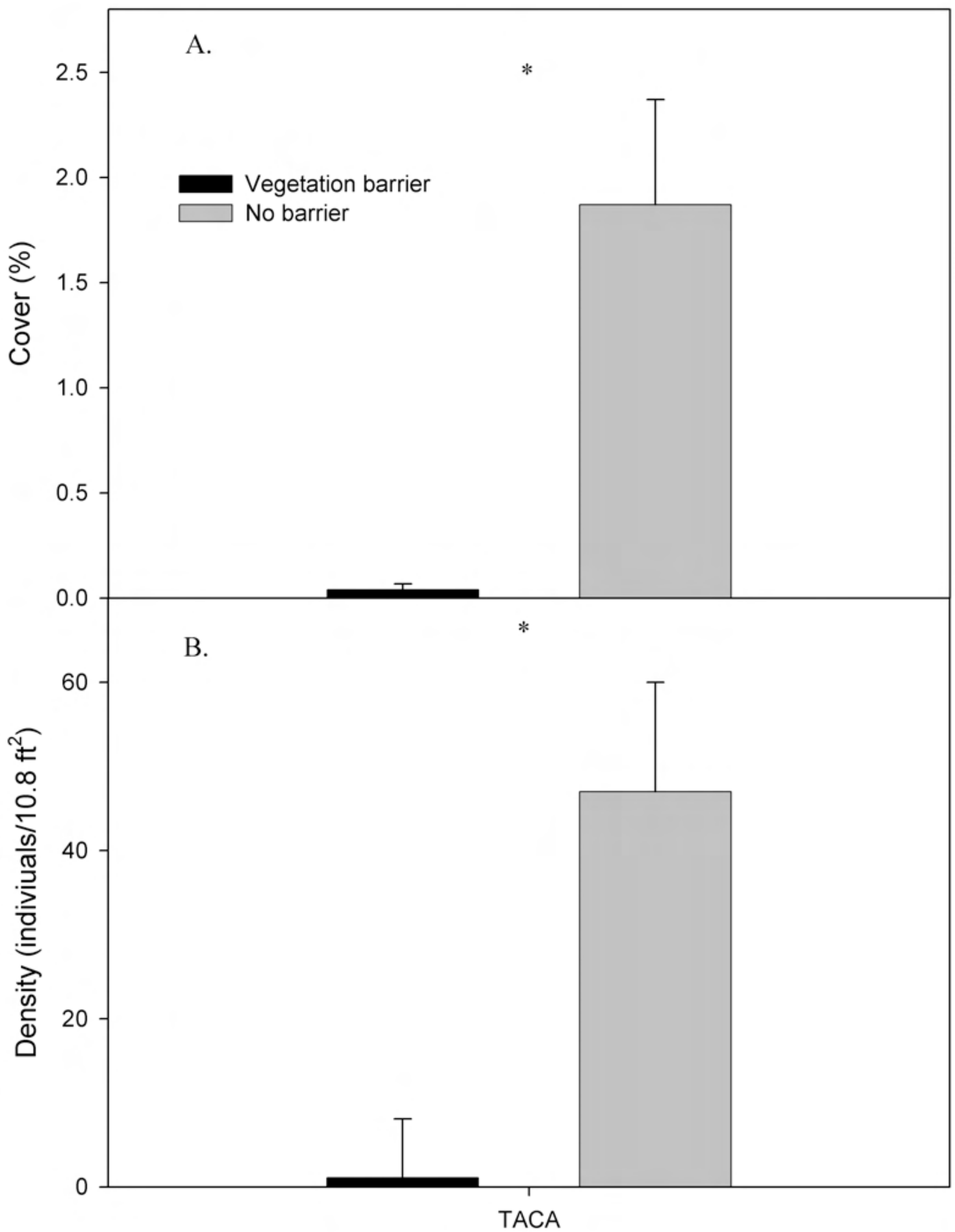

Figure 2. Medusahead (TACA) cover (A) and density (B) in the plant communities protected by a crested wheatgrass barrier and plant communities without a barrier between them and a medusahead infestation (mean + S.E.). Asterisk (*) indicates significant difference between treatments ($P < 0.05$).

Grazing History Influences the Response of Sagebrush Plant Communities to Fire

Kirk W. Davies, Tony J. Svejcar, and Jon D. Bates

For more information see: Davies, K.W., T.J. Svejcar, and J.D. Bates. *IN PRESS.* Interaction of historical and non-historical disturbances maintains native plant communities. Ecological Applications

SUMMARY

Response to fire differed in moderately grazed areas compared to areas protected from livestock grazing since 1936. Long-term protection from livestock grazing resulted in cheatgrass (*Bromus tectorum*) invasions following fire, while moderately grazed areas were not invaded. After burning, cheatgrass biomass production and density were more than 49- and 15-fold greater, respectively, in the areas protected from grazing than moderately grazed areas. These differences were still evident 14 years post-fire and demonstrate that grazing history can have significant influence on the ability of plant communities to tolerate fire. These results suggest that moderate levels of livestock grazing may be needed in sagebrush-steppe communities to protect the habitat of sage-grouse and other sagebrush-obligate wildlife species.

INTRODUCTION

The impacts of livestock grazing prior to fire on native plant communities are relatively unknown. Because domestic livestock grazing is not part of the historical disturbance regime for Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) communities in the Intermountain West (Mack and Thompson 1982), some have suggested that its impacts would be negative (Fleischner 1994, Noss 1994). Historical disturbances are often considered a requirement to maintain native plant communities and this has resulted in the reconstruction of historical disturbance regimes to direct ecosystem management. However, some ecosystems have experienced irrevocable changes in environmental conditions and biotic potentials that could potentially alter the response of plant communities to disturbances. For example, climate change or invasive plants may result in different responses from plant communities to disturbances than would be expected under historical conditions.

We evaluated the impacts of grazing and no grazing prior to fire in Wyoming big sagebrush plant communities. Understanding the impacts of grazing prior to fire in Wyoming big sagebrush plant communities is important because most of these plant communities are grazed by domestic livestock, are at risk of burning, and provide valuable habitat for wildlife. With the introduction of exotic annual grasses such as cheatgrass (*Bromus tectorum*), the impact of grazing or no grazing prior to fire in Wyoming big sagebrush plant communities is unknown.

METHODS

The study was conducted on the Northern Great Basin Experimental Range (NGBER) in southeastern Oregon about 56 km west of Burns, Oregon. Treatments were: 1) ungrazed unburned, 2) ungrazed burned, 3) grazed unburned, and 4) grazed burned. Ungrazed treatments were implemented with the erection of 4.9-acre domestic livestock grazing exclosures in 1936. The grazed treatments were areas adjacent to the exclosures and had moderate livestock grazing (30-40 percent of available forage used) until 1990. In the fall of 1993, prescribed burns were applied to both the grazed and ungrazed treatments. Average fine fuel loads were about 100 lbs/acre greater in the ungrazed than grazed treatments prior to burning. Vegetation characteristics were sampled in 2005, 2006, and 2007 (12, 13, and 14 years post-burning).

RESULTS

Density

Large perennial bunchgrass and cheatgrass densities were influenced by the interaction of burning and grazing ($P < 0.01$; Fig. 1). Large perennial bunchgrass density was lowest in the ungrazed burned treatment and highest in the grazed burned treatment with an approximately 1.9-fold difference between the two treatments. Burning decreased perennial bunchgrass density in the ungrazed treatment but did not influence bunchgrass density in the grazed treatment. Cheatgrass density was 15-fold greater in the ungrazed burned treatment than the other treatments. Perennial forb density was decreased by burning ($P < 0.01$), but was not influenced by grazing ($P = 0.36$).

Biomass

Large perennial bunchgrass production generally increased with burning ($P < 0.01$; Fig. 2). Bunchgrass production increased more with burning in the grazed compared to the ungrazed treatment. Burning the grazed treatment increased perennial bunchgrass production 1.6-fold. Cheatgrass biomass production was 49-fold more in the ungrazed burned treatment than in the other three treatments ($P < 0.01$; Fig. 2). Perennial forb biomass production decreased 3-fold when the ungrazed treatment was burned ($P < 0.01$). Biomass production of annual forbs, consisting mostly of exotics, increased with burning ($P < 0.01$). However, annual forb production was lowest in the ungrazed unburned treatment and highest in the ungrazed burned treatment. In the ungrazed burned treatment, cheatgrass produced more biomass than all the perennial herbaceous vegetation combined.

DISCUSSION

Grazing history influenced the response of Wyoming big sagebrush plant communities to fire. Moderately grazing sagebrush plant communities with livestock increased the ability of the native herbaceous plant community to tolerate fire and thus, prevented cheatgrass invasion. The invasion of the ungrazed treatment post-fire has probably changed the future disturbance regime of those communities. The invasion of cheatgrass often increases fire frequency due to an increase in the amount and continuity of fine fuels. The invasion of cheatgrass and, subsequently, the altered future disturbance regime will negatively impact sage-grouse, pygmy rabbits, and other sagebrush-obligate wildlife species.

Moderate grazing probably mediated the effects of fire because it reduced the amount of fine fuel. Less fuel, especially around perennial bunchgrasses, probably increased the survival of native herbaceous perennial vegetation. The accumulation of fuels on perennial grasses has been demonstrated to increase mortality from burning (Odion and Davies 2000). Mortality of perennial bunchgrasses would potentially open the plant community to cheatgrass invasion. Davies (2008) demonstrated that perennial bunchgrasses were the most critical plant functional group for preventing exotic annual grass invasions.

Although domestic livestock grazing was not part of the historical disturbance regime of these plant communities, it may now be needed because of new pressures from invasive plants and climate change. However, individual circumstances will dictate the value of emulating historical disturbance regimes for maintaining native plant communities. In our specific example, the historical disturbance regime of Wyoming big sagebrush plant communities is estimated to have consisted of 50- to greater than 100-year fire-return intervals (Wright and Bailey 1982, Mensing et al. 2006) and lacked large herbivore grazing pressure (Mack and Thompson 1982). Emulating this disturbance regime for Wyoming big sagebrush plant communities did not produce the expected effect of shifting the dominance from shrubs to native forbs and perennial grasses. Long-term protection from livestock grazing followed by fire resulted in substantial cheatgrass invasion and a large increase in non-native forbs.

MANAGEMENT IMPLICATIONS

Preventing grazing in Wyoming big sagebrush plant communities weakened the ability of the perennial herbaceous vegetation to tolerate fire. Moderate livestock grazing appears to be beneficial to the long-term sustainability of Wyoming big sagebrush plant communities. Preventing grazing to protect sagebrush plant communities may actually facilitate their demise and accelerate the plight of sagebrush obligate-wildlife species.

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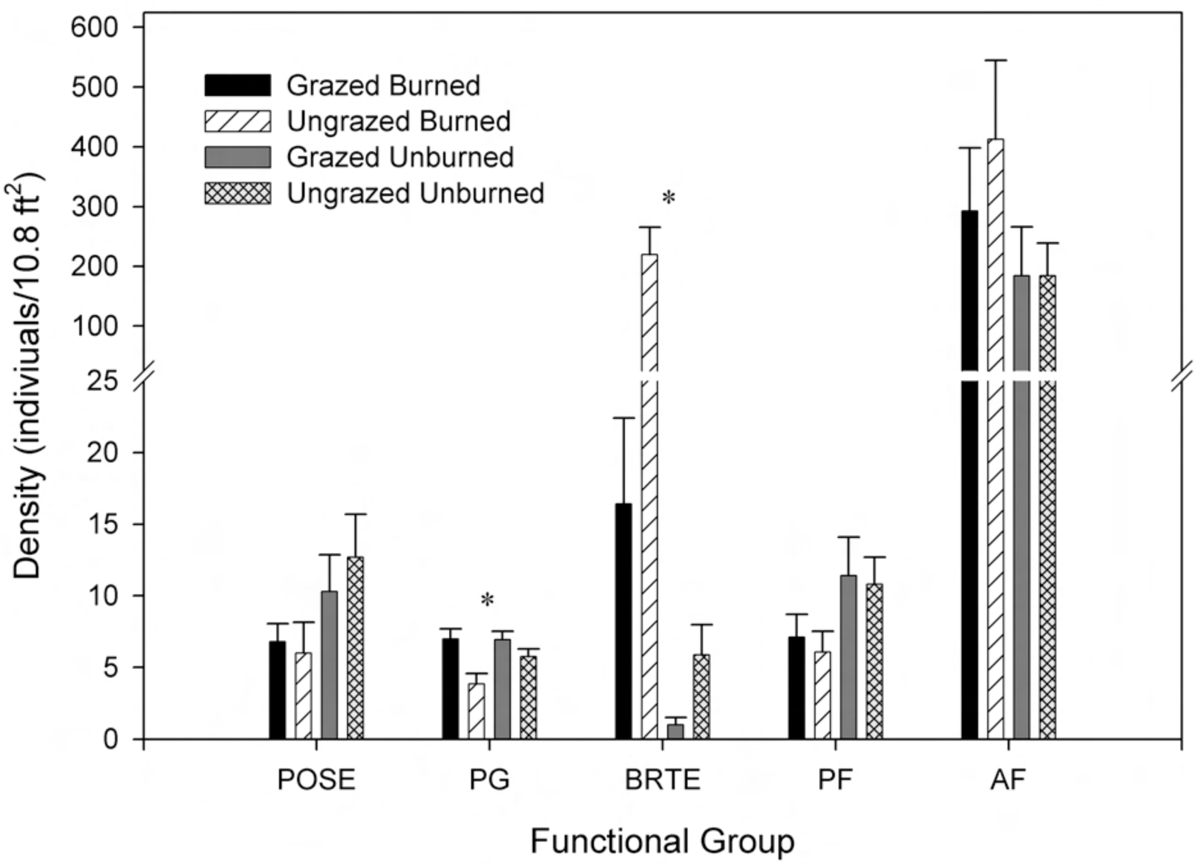

Figure 1. Plant functional group density (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. POSE = Sandberg bluegrass PG = tall perennial bunchgrass, BRTE = cheatgrass, PF = perennial forb, and AF = annual forb. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that functional group ($P < 0.05$).

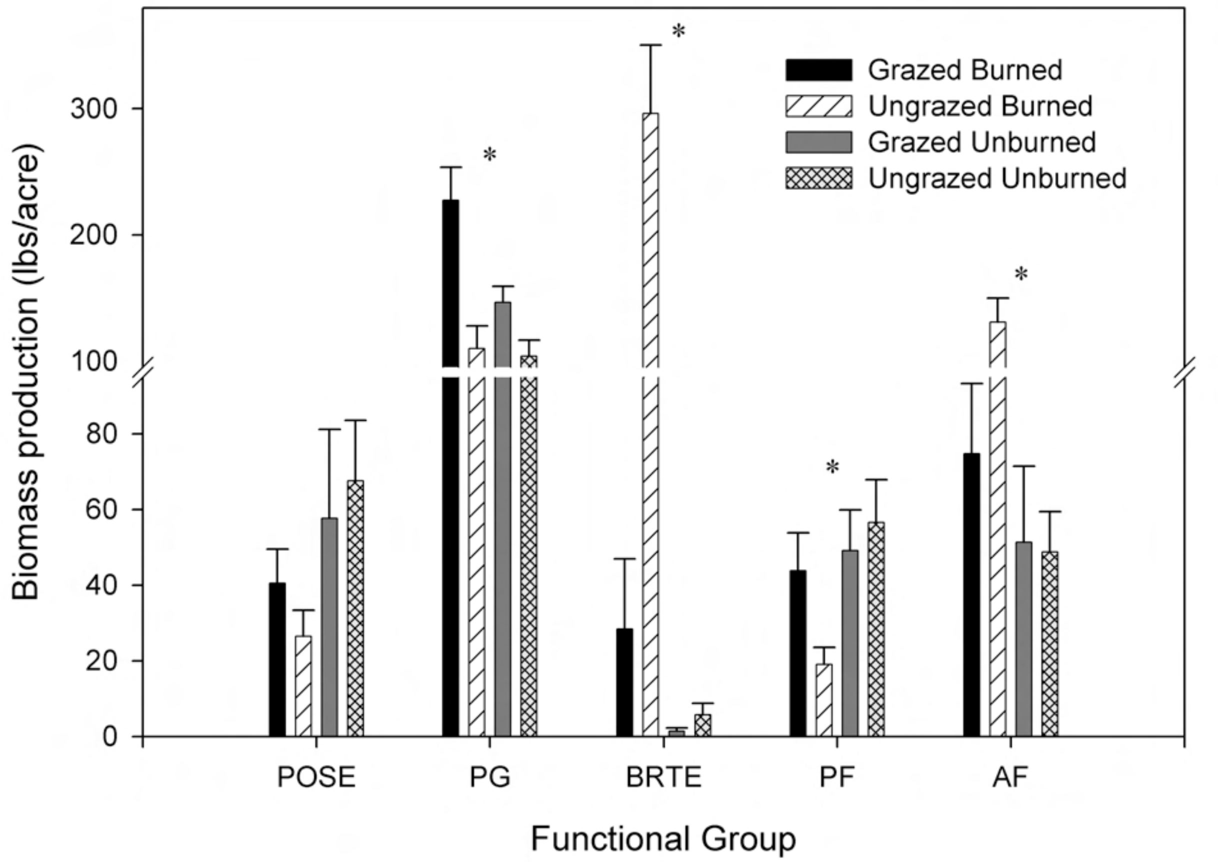

Figure 2. Plant functional group biomass production (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. POSE = Sandberg bluegrass, PG = tall perennial bunchgrass, BRTE = cheatgrass, PF = perennial forb, and AF = annual forb. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that functional group (P < 0.05).

Promoting Native Vegetation in Medusahead Infestations

Kirk W. Davies, Roger L. Sheley, and Aleta Nafus

For more information see: Davies, K.W. and R.L. Sheley. (*IN PRESS*). Promoting native vegetation and diversity in exotic annual grass infestation. Restoration Ecology.

SUMMARY

Restoring medusahead-infested native communities may be most successful if there is enough remnant native vegetation to eliminate the need for revegetation efforts. Prescribed burning followed by imazapic (Plateau®[1]) application provided the best control of medusahead and resulted in the greatest increases in native vegetation density, cover, and diversity. Native vegetation can be at least partially restored in medusahead infestations by selectively controlling medusahead without implementing seeding treatments.

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Oregon State University, or the authors and does not imply its approval to the exclusion of other products.

INTRODUCTION

Medusahead (*Taeniatherum caput-medusae*) is one of the most problematic of the exotic annual grasses invading rangelands. The invasion of medusahead in native plant communities decreases biodiversity, reduces livestock forage production, degrades wildlife habitat, and alters ecological functions (Davies and Svejcar 2008). As with other annual exotic grasses invasions, revegetation of medusahead-invaded plant communities is often unsuccessful because seeded vegetation rarely establishes (Young 1992, Monaco et al. 2005). Most research has focused on the most effective treatments to control annual grasses in near-monocultures of exotic annual grasses. Davies and Johnson (2008) suggested that restoration would be more successful in annual grass-invaded communities that still have enough native vegetation to eliminate the need for revegetation efforts.

We expected that fall or spring prescribed burning followed with imazapic application would be the most effective medusahead control treatments and that controlling medusahead would produce a positive response in native vegetation because of a release from medusahead competition and/or suppression that would outweigh any negative impacts of the treatments on the native vegetation.

METHODS

The study was conducted in southeastern Oregon. The study sites were formerly sagebrush (*Artemisia* sp.)-bunchgrass steppe. Treatments were: 1) imazapic (*Imazapic*); 2) spring prescribed burn and imazapic (*Spring Burn-Imazapic*); 3) fall prescribed burn and imazapic (*Fall Burn-Imazapic*); 4) spring prescribed burn (*Spring Burn*); 5) fall prescribed burn (*Fall Burn*); or 6) control (*Control*). The spring prescribed burn was applied in mid-May 2006 and the fall prescribed burn was applied in mid-October 2006. Imazapic was applied as Plateau® at 6 oz/acre in mid-October 2006 after the fall prescribed burn.

RESULTS

Density and Cover

Burning followed by imazapic application resulted in greater perennial bunchgrass density and cover ($P < 0.05$; Fig. 1). *Spring Burn-Imazapic*, *Fall Burn-Imazapic,* and *Imazapic* treatments reduced medusahead density more than the *Control*, *Spring Burn,* and *Fall Burn* treatments ($P < 0.05$). *Spring Burn-Imazapic* and *Fall Burn-Imazapic* decreased medusahead cover more than the other treatments ($P < 0.05$; Fig. 2). Annual forb density and cover decreased with *Spring Burn-Imazapic*, *Fall Burn-Imazapic*, and *Imazapic* treatments ($P < 0.05$); however, annual forb cover became relatively similar to the *Control* treatment by the second year post-treatment.

Plant Species Diversity

The *Spring Burn-Imazapic* treatment (0.80 ± 0.07 Shannon diversity index) had greater diversity than the other treatments ($P < 0.05$), except it did not differ from the *Fall Burn-Imazapic* treatment (0.68 ± 0.10) ($P = 0.14$). Plant species diversity did not differ among the *Spring Burn* (0.60 ± 0.07), *Fall Burn* (0.56 ± 0.11), *Imazapic* (0.54 ± 0.08), and *Control* (0.46 ± 0.08) treatments ($P > 0.05$).

DISCUSSION

Restoration without seeding may be successful in areas with some native plants growing in association with medusahead infestations; however, additional treatments may be necessary to expedite vegetation recovery. Our results demonstrate that native vegetation can be promoted in medusahead infestations by selectively negatively impacting medusahead. However, not all treatments were successful at promoting native vegetation and controlling medusahead. Prescribed-burn treatments without imazapic application were ineffective as medusahead control treatments and generally did not promote native vegetation. Prescribed-burn treatments combined with imazapic application generally produced the best control of medusahead and the greatest positive response from native functional groups. However, imazapic, either as the sole treatment or in combination with prescribed burning, reduced annual forb cover in the first post-treatment year and density in both years post-treatment. The similarity in lifecycles between annual forbs and medusahead resulted in nontarget impacts with the use of a pre-emergence herbicide. Similarities between native plant functional groups and exotic invaders must be carefully evaluated prior to treatment to minimize negative nontarget impacts.

The increase in large perennial bunchgrasses, which are the most important native plant functional group to impede exotic annual grass invasions (Davies 2008), and plant diversity with prescribed burning and imazapic treatment suggests that these plant communities can be restored, at least partially, when sufficient native vegetation remains in exotic annual grass infestations. The results of this study suggest that by controlling invasive annual grasses and potentially other invasive plant species in plant communities with some native vegetation remaining, the likelihood of failure can be minimized and the high cost of seeding native species can be avoided. However, the gradual increase in medusahead in the second year post-treatment in even the most effective control treatments suggests that further treatments may be needed to ensure continued increases in native vegetation. Although seeding native species may not be required, it may improve and hasten recovery.

MANAGEMENT IMPLICATIONS

Plant communities invaded by exotic annual grass that have some residual native perennial vegetation can be at least partially restored with appropriate annual grass control. Prescribed burning prior to imazapic application provided the best control of medusahead and facilitated a generally positive response from the native plant functional groups, with the exception of annual forbs. Considering the numerous failed attempts to reestablish native plants following exotic annual grass control, resources may be more effectively allocated to controlling exotic annual grass infestations in areas with enough native vegetation remaining to eliminate the need for exhaustive restoration, including seeding.

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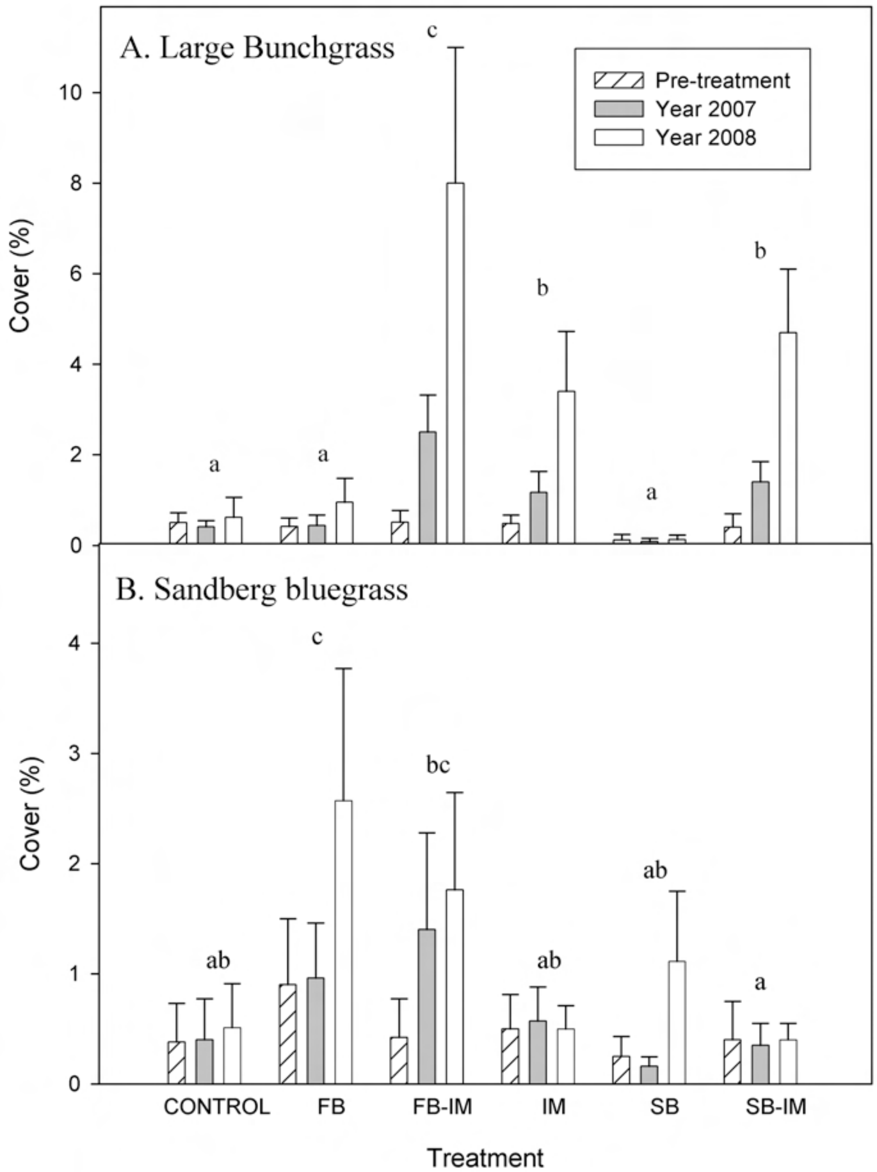

Figure 1. Large perennial bunchgrass (A) and Sandberg bluegrass (B) cover values (mean + S.E.) in the various medusahead control treatments prior to treatment and in 2007 and 2008. Comparisons of treatment effects were made only on post-treatment data. Pretreatment data are reported to demonstrate that prior to treatment applications, plots were similar. Treatments are: CONTROL = control, FB = prescribed fall burn, FB-IM = prescribed fall burn followed with fall imazapic application (6 oz Plateau® per acre), IM = fall imazapic application, SB = prescribed spring burn, and SB-IM = prescribed spring burn followed with fall imazapic application. Different lower case letters indicate differences between treatments after treatment application ($P < 0.05$).

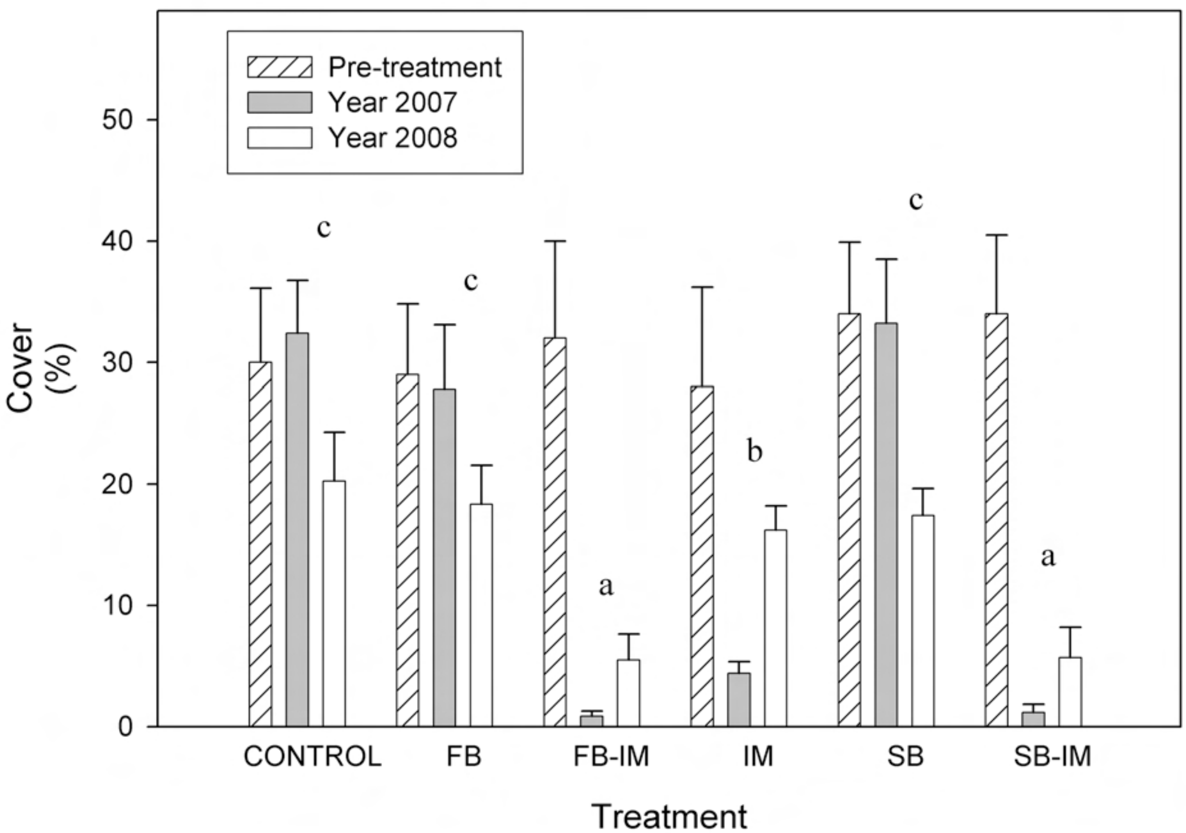

Figure 2. Medusahead cover values (mean + S.E.) in the various medusahead control treatments prior to treatment and in 2007 and 2008. Comparisons of treatment effects were only made on post-treatment data. Pretreatment data are reported to demonstrate that prior to treatment applications, plots were similar. Treatments are: CONTROL = control, FB = prescribed fall burn, FB-IM = prescribed fall burn followed with fall imazapic application (6 oz Plateau® per acre), IM = fall imazapic application, SB = prescribed spring burn, and SB-IM = prescribed spring burn followed with fall imazapic application. Different lower case letters indicate differences between treatments after treatment application ($P < 0.05$).

Cattle Grazing Strategies That Limit Stream Bank Degradation

Mike McInnis and Jim McIver

SUMMARY

This report summarizes our two published studies that test whether altering timing of grazing (McInnis and McIver 2009) or providing cattle with off-stream drinking water and mineral supplements (McInnis and McIver 2001) can lessen grazing-induced damage of stream banks. In each 2-year study, grazing treatments were replicated along a mountain stream in northeastern Oregon. Estimates of stream bank cover and stability were taken before and after each grazing period. The first study compared early summer to late summer grazing, and found that cattle spent more time in uplands earlier in the year when green forage was available, resulting in development of just 3 percent uncovered stream banks compared to 8 percent late season. Similarly, early summer grazing resulted in 13 percent unstable stream banks compared to 31 percent later in summer. Our second study compared stream banks in pastures provided with off-stream water and mineral supplements to pastures lacking those amenities. Off-stream water and supplements attracted cattle into the uplands enough to reduce development of ncovered/ unstable stream banks from 9 percent in non-supplemented pastures to just 3 percent in supplemented pastures.

INTRODUCTION

Riparian areas are critical components of western rangelands and function to store water, recharge aquifers, moderate flood intensity, maintain water quality by filtering chemical and organic wastes, trap sediments, and provide habitat for wildlife. Cattle are naturally attracted to riparian areas because of shade, drinking water, and forage. Roath and Krueger (1982) estimated 81 percent of forage used by cattle came from a streamside meadow representing only 2 percent of the grazing area. Such disproportionate use, especially under conditions of *heavy* cattle grazing, can lead to a cascading loss of riparian vegetation, breakdown of stream banks, stream widening, impairment of water quality, and loss of wildlife habitat. Our studies were part of larger projects that compared cattle distribution in riparian pastures during early versus late summer (Parsons et al. 2003) and with versus without off-stream water and mineral supplements (Porath et al. 2002). Those studies successfully altered distribution of cattle and resulted in increased use of uplands. The objective of our research was to determine whether such grazing strategies would limit cattle-induced degradation of stream banks.

METHODS

Research was conducted on the Hall Ranch Unit of Oregon State University's Eastern Oregon Agricultural Research Center near Union, Oregon. Nine pastures (averaging about 28 acres; range 22-37 acres) were delineated along a 1.5-mile reach of Milk Creek (Fig. 1). Grazing treatments were randomly assigned to pastures within each of three blocks. Cow-calf pairs were introduced into the grazed pastures to achieve moderate stocking rates averaging about 1.7 acres/Animal Unit Months (range 1.2-2.2 acres/AUM). Stocking rates and length of grazing bouts were chosen to achieve a moderate grazing intensity of about 50 percent utilization of key forage species. Actual utilization was measured and averaged less than 50 percent in every case.

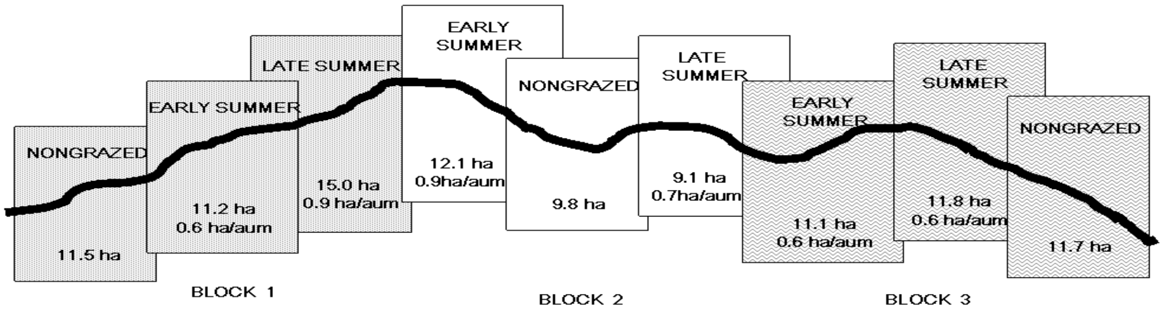

Figure 1. Schematic diagram (not to scale) showing experimental pastures on Milk Creek in northeastern Oregon. Each of three blocks contained three grazing treatments (study no. 1 described in text): (1) nongrazed; (2) early summer grazing (mid-June to mid-July); (3) late summer grazing (mid-August to mid-September). Black line represents Milk Creek, which flows from Block 1 in the south through Block 3 in the north. Pasture arrangement was identical in study no. 2, but grazing treatments differed (see text).

Study No. 1: Altering Timing of Grazing

During 1998 and 1999 three grazing treatments were examined: (1) nongrazed; (2) early summer grazing (28 days; mid-June to mid-July); and (3) late summer grazing (28 days; mid-August to mid-September). Estimates of stream bank cover and stability were taken before and after each grazing period by pacing both sides of the creek and examining plots (about 20 x 12 inches) along the "greenline" (the first vegetation at the water's edge). Additionally, frequency of cattle hoof prints (plots with hoof prints/total number of plots) was measured as an indicator of cattle presence. Plots were classified as "covered" if they contained any of the following features: (1) living perennial vegetation ground cover greater than 50 percent, or (2) roots of deeply-rooted vegetation such as shrubs or sedges covering more than 50 percent of the plot, or (3) at least 50 percent of the stream bank surface covered by rocks of cobble size or larger, or (4) at least 50 percent of the bank surface covered by logs 4 inch diameter or larger. Otherwise plots were rated "uncovered". Cover estimates were based on visual assessment of the vertical projection of a polygon drawn around extremities of above-ground parts onto the ground.

Plots were classified "stable" unless they exhibited any of the following features: (1) blocks of banks broken away and lying in the stream channel adjacent to the bank

("bank breakage"), (2) bank sloughed into the stream channel ("slump"), (3) bank cracked and about to move into stream ("fracture"), (4) bank uncovered as defined above with an angle visually estimated steeper than 80 degrees from horizontal ("vertical bank"). Plots exhibiting any of those features were rated "unstable".

Each plot was rated according to stream bank cover and stability and grouped into one of four classes: (1) covered/stable, (2) covered/unstable, (3) uncovered/stable, (4) uncovered/unstable. One person collected all data.

Study No. 2: Providing Off-stream Water and Mineral Supplements

During 1996 and 1997 three replications of each of the following grazing treatments were studied using the same pasture design described above: (1) nongrazed; (2) "supplemented" pastures in which free-choice off-stream water and trace mineralized salt was provided; and (3) "nonsupplemented" pastures in which no off-stream water or salt was provided. Free-choice off-stream water and salt was provided in supplemented pastures about 400 yards upslope from Milk Creek. Feeders containing salt were placed about 15 ft from water troughs. Cow-calf pairs grazed 42 consecutive days beginning mid-July. Frequency of hoof prints and estimates of stream bank cover and stability were made before and after grazing the second year of the study using the methods described above.

RESULTS AND DISCUSSION

Study No. 1: Altering Timing of Grazing

Frequency of plots with cattle hoof prints in nongrazed, early-grazed and late-grazed pastures, respectively, averaged 0 percent, 53 percent (SE$\pm$ 11 percent), and 90 percent (SE $\pm$ 1 percent). Change in stream bank cover resulting from early grazing (-3 percent) was not statistically different from nongrazed controls, but was significantly less than the 8 percent reduction in cover observed following late summer grazing (Table 1). Stream bank stability decline resulting from early grazing (-13 percent) was less than half that observed after late-season grazing (-31 percent). The greatest change was in the covered/stable category, which declined 10 percent during early summer and 28 percent during late summer. Grazing resulted in increased percentages of covered/unstable and uncovered/unstable stream banks, and in each category the increase was greatest for the late summer grazing treatment. There were proportionally larger changes in stability compared to cover that resulted from grazing (Table 1). Therefore decline in bank stability likely contributed more to change in the uncovered/unstable category than did decreases in cover.

Study #2: Providing Off-Stream Water and Mineral Supplements. Following grazing, the percentage of plots having cattle hoof prints averaged 0%, 26% (SE $\pm$ 4) and 31% (SE $\pm$ 5) in control, supplemented, and non-supplemented pastures, respectively. While there was a trend for supplemented pastures to have a lower frequency of hoof prints in the greenline compared to non-supplemented units, the two treatments did not differ statistically. Neither stream bank cover alone nor stability alone differed between grazed treatments, and both decreased compared to nongrazed controls (Table 2). When combined, stream bank cover and stability declined 9% in non-supplemented pastures compared to only 3% in supplemented pastures. Declines in stream bank stability contributed more to this change than declines in stream bank cover.

Table 1. Mean proportions of stream bank (m/100 m of stream bank) before grazing, after grazing and change for nongrazed pastures (control), early summer grazing (mid-June to mid-July), and late summer grazing (mid-August to mid-September), 1998 and 1999. See McInnis and McIver (2009) for full data set.

Streambank parameter	Non-grazed pastures			Early summer grazing (m/100 m of stream bank)			Late summer grazing		
	Before	After	Change	Before	After	Change	Before	After	Change
Covered	90	91	$+1^{a}$ *	90	87	-3^{a}	95	87	-8^{b}
Stable	92	92	0^{a}	91	78	-13^{b}	99	68	-31^{c}
Covered/ stable	83	84	$+1^{a}$	81	71	-10^{b}	94	66	-28^{c}
Uncovered/ stable	9	8	-1^{a}	10	7	-3^{a}	5	2	-3^{a}
Covered/ unstable	7	7	0^{a}	9	16	$+7^{b}$	1	21	$+20^{c}$
Uncovered/ unstable	1	1	0^{a}	0	6	$+6^{b}$	0	11	$+11^{c}$

[*] Change within stream bank parameters among treatments (rows) with different superscripts are significantly different (lsd; $P < 0.05$; $n = 6$).

Table 2. Mean proportions of stream bank (m/100 m of stream bank) before grazing (June), after grazing (September), and change for nongrazed pastures (control), supplemented pastures (water and mineralized salt), and nonsupplemented pastures, 1997. See McInnis and McIver (2001) for full data set.

Streambank parameter	Non-grazed pastures			Supplemented pastures (m/100 m of stream bank)			Nonsupplemented pastures		
	Before	After	Change	Before	After	Change	Before	After	Change
Covered	92	92	0^{a}*	94	90	-4^{ab}	89	83	-6^{b}
Stable	91	91	0^{a}	95	85	-10^{b}	93	76	-17^{b}
Covered/ stable	90	90	0^{a}	89	79	-10^{b}	82	68	-14^{b}
Uncovered/ stable	3	3	0^{a}	5	6	$+1^{a}$	10	8	-2^{a}
Covered/ unstable	5	5	0^{a}	5	11	$+6^{ab}$	8	15	$+7^{b}$
Uncovered/ unstable	2	2	0^{a}	1	4	$+3^{b}$	0	9	$+9^{c}$

[*] Change within stream bank parameters among treatments (rows) with different superscripts are significantly different (lsd; $P < 0.05$; $n = 6$).

MANAGEMENT IMPLICATIONS

Proper management of stream banks is key to maintaining properly functioning riparian areas. Cattle impact stream banks through two processes: grazing and trampling. Several studies have shown that loss of cover by grazing can reduce resistance of stream banks to high flows and increase erosion. Trampling can loosen fragments of soil, making them more erodible, and hoof action can shear off segments of stream banks, making them less stable. Our studies show how the following two grazing strategies can help encourage cattle into uplands and thereby limit stream bank degradation.

Strategy No. 1: Alter Timing of Grazing

Parsons et al. (2003) found that during the cool season of early summer, when forage quality and quantity were not limiting and ambient air temperatures were moderate, cattle were evenly distributed across riparian areas. As ambient air temperature and forage dry matter increased during the hot season of late summer, cattle spent more time near the stream compared to uplands. We found that grazing during either season impacted stream banks compared to nongrazed controls. However, grazing during mid-June to mid-July, when cattle were attracted to adjacent uplands, limited damage to stream bank cover and stability compared to grazing later in the year when cattle congregated in riparian areas. Grazing should not occur so early in the season as to trample wet soils, but early grazing may have an additional benefit of allowing time for subsequent regrowth of grazed riparian plants before high flows the following year. Cattle may behave differently in other geographic areas, and be attracted to uplands at other times of the year compared to our study in northeastern Oregon. Land managers must consider timing, as well as frequency and intensity of grazing impacts on individual streams and even portions of streams to formulate best management practices for meeting grazing and land management objectives in specific watersheds.

Strategy No. 2: Provide Off-Stream Water and Salt Supplements

These amenities resulted in slightly (though not statistically) less use of stream banks by cattle compared to nonsupplemented pastures. The difference was enough to reduce development of uncovered/unstable stream banks threefold.

ACKNOWLEDGEMENTS

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Describing Greater sage-grouse (*Centrocercus urophasianus*) Nesting Habitat at Multiple Spatial Scales in Southeastern Oregon

Steven Petersen, Richard Miller, Andrew Yost, and Michael Gregg

SUMMARY

Plant community structure associated with greater sage-grouse (*Centrocercus urophasianus*) nesting habitat has been well described at the plot scale immediately around the nest, frequently less than 200 ft^2. However, less is known about nesting habitat attributes at the landscape scale. The purpose of this research was to characterize sagebrush habitat structure surrounding nest sites at multiple spatial scales and to compare these with random locations. Nest site coordinates were obtained from1995 to 2003 as part of a long-term sage-grouse reproductive study at Hart Mountain National Wildlife Refuge in southeastern Oregon. In the same region, plant communities were mapped within a 76,000-acre area (6.25-mile radius) from a centralized lek using aerial photography and computer mapping tools (ArcGIS 9). At each nest site, patch (a distinct plant community type) size, shape, distribution, composition, and density were described for six different spatial scales ranging from 82 to 3280 ft radiuses surrounding the nest. Similar measurements were collected at random sites. Although differences were small at fine scales (80 ft), patch density and richness were greater around the nest than at random points as scale increased. Habitat heterogeneity became an important component of broad-scale habitat selection. These data suggest that plant community structure associated with greater sage-grouse nest sites at the small scale is a mosaic of plant communities that vary in structure and composition. This implies that habitat assessment at fine scales may not be adequate to accurately predict sage-grouse nesting habitat potential.

INTRODUCTION

Greater sage-grouse depend throughout the year on sagebrush (*Artemisia* spp.) communities for foraging, nesting, and hiding cover. Most studies report a positive relationship between sage-grouse nesting success and adequate sagebrush structure (Gregg et al. 1994, Connelly et al. 2000). A significant amount of work has been done to determine what characteristics in a sagebrush community are most important for successful sage-grouse nesting. This includes studies used in developing the guidelines for assessing sage-grouse nesting requirements across the species' range. Most of the results were determined from small-plot field measurements placed directly around the nest (7.5-ft radius or a 200-ft^2 area surrounding nest site locations). However, concerns and controversy have developed in applying small-scale habitat preferences and requirements across large heterogeneous landscapes. Requirements for structure and composition are frequently not entirely met, particularly in the more arid sagebrush communities characterized by Wyoming big sagebrush (*A. tridentata* spp. *wyomingensis*) (Davies et al. 2006).

At the landscape scale, sagebrush stands can exhibit significant heterogeneity in both community structure (spatial arrangement of plant cover and height) and composition of different plant life forms (shrubs, grasses, and forbs). According to Kie et al. (2005), the arrangement of these plant life forms in communities can influence the distribution of animal species. Past research suggests sage-grouse select small areas of vegetation structure for nesting that often do not represent the average structure of vegetation in the area surrounding the nest. For example, sagebrush cover may be higher immediately adjacent to the nest than the average cover representing the surrounding plant community or landscape. Therefore, applying these requirements (e.g., nest patch) to large heterogeneous landscapes becomes a major challenge.

Connelly et al. (2003) recognize the value of remote sensing and Geographic Information System (GIS) for digitizing plant communities and measuring the size and juxtaposition of habitat patches (vegetation units that are composed of uniform and relatively homogeneous assemblage of species growing at a particular point in time and space with a distinct boundary). They also suggest that patch size, habitat quality, connectivity, patch edge, and distance between patches be measured to determine relationships between plant community structure and habitat selection preferences. The purpose of this study is to quantify patch density and richness surrounding nest locations at multiple spatial scales and to relate these patterns to habitat assessment at fine-scales.

METHODS

Between 1994 and 2003, 260 collared Greater sage-grouse hens were tracked to their nest site using radio telemetry. At the nest site, a coordinate position was obtained for that location using Global Positioning System (GPS). During 2005, high resolution aerial photographs (digital orthophoto quadrangles, DOQ) were used to delineate distinct plant community types across the study site. In 2006, the accuracy of mapping was increased by including 3.3-ft resolution NAIP color images for patch delineation. We defined patch as a plant community type with a distinct boundary separating it from adjacent community types of different composition and structure. Plant community types in this study were characterized by the dominant overstory shrub species). They included low sagebrush (*Artemisia arbuscula*), Wyoming big sagebrush, mountain big sagebrush (*A. tridentata* ssp. *vaseyana*), bitterbrush (*Purshia tridentata*), and low sagebrush-mountain big sagebrush and low sagebrush-bitterbrush where patches were too small to map (Fig. 1). In addition to dominant or co-dominant shrub community types, tree cover was mapped for western juniper (*Juniperus occidentalis*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), and quaking aspen (*Populus tremuloides*).

Figure 1. Highly preferred greater sage-grouse nesting habitat on the Hart Mountain Wildlife Refuge. The majority of vegetation shown is a complex of two plant community types, mountain big sagebrush and low sagebrush, with small inclusions of mountain mahogany and aspen.

Nest site locations were overlaid onto the vegetation map. In addition to the actual 260 nest sites, an equivalent number of points were randomly located across the vegetation map to characterize vegetation for the study area. At each point (both nest and random or non-nest locations) the spatial pattern and composition of plant community types surrounding the nest and random points were described for 6 different scales, ranging from 82 to 3280-ft radius from the point (Fig. 2). The 82-ft radius scale (0.5 acres) was designed to assess habitat structure at fine-scales, 820-ft plots (48 acres) at moderate scales, and 3281-ft radius (775 acres) at broad scales. Measurements included 1) the size and shape (or amount of edge) of each community type, 2) patch density, and 3) composition of community types. Plant community patch density is defined as the total number of plant community type patches that occurred in the radial area from a particular point. Patch richness represents the number of different community types within a particular radial distance from a nest site or random point. T-tests were conducted to test whether the mosaic of patches were more complex surrounding nests sites than random sites.

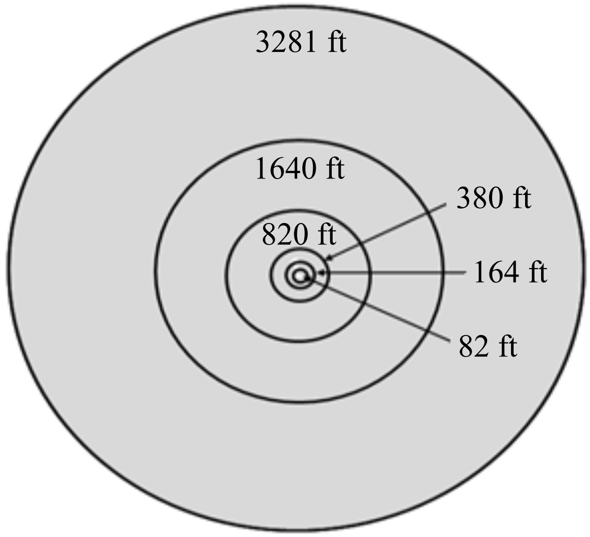

Figure 2. Plot dimensions representing different scales at each sage-grouse nest site and random point.

RESULTS

Sage-grouse nest sites were located in areas that were more diverse than the overall landscape. This included the number of distinct vegetation patches and the number of different patch types at each scale that we analyzed. The magnitude of the difference between nest and random points increased with scale (Fig. 3). Greater complexity of community type patch shape and varying sizes surrounding nesting points compared to non-nesting points was more consistent as scale increased. Results of the t-test analysis showed that patch differences between actual and random nest sites was significant at all spatial scales we examined. The level of significance increased as scale increased. Additional analyses are currently being conducted and will be available soon.

DISCUSSION

Greater sage-grouse selected nest sites with greater plant community heterogeneity, in particular at moderate (over 48 acres) to broad (over 375 acres) spatial scales. In summary, greater sage-grouse hens selected areas with greater levels of plant community diversity (e.g., mosaic of patches containing low sagebrush, mountain big sagebrush, bitterbrush community types) compared to areas with larger patch sizes that results in less diverse habitat. A diverse habitat can provide additional resources (i.e., greater forage availability such as forbs and insects) that may not be available in a more homogenous environment. Studies indicate that nesting habitat occurs most frequently in big sagebrush-dominated communities; however, the juxtaposition of these communities to other plant community types (i.e., low sagebrush) and the complexity and composition of the surrounding ecosystem should also be considered when managing greater sage-grouse populations. In addition to exploring the usefulness of using one or more landscape attributes (i.e., patch density, size, composition, etc. or topographic features) in predicting nest site habitat, the primary question that we pose is what scale of analysis provides the highest predictive power. We are currently addressing this question.

MANAGEMENT IMPLICATIONS

To effectively conserve greater sage-grouse populations, methods are needed to accurately and efficiently assess habitat requirements. We suggest that land management be applied at the landscape scale, where plant community heterogeneity can be more accurately identified.

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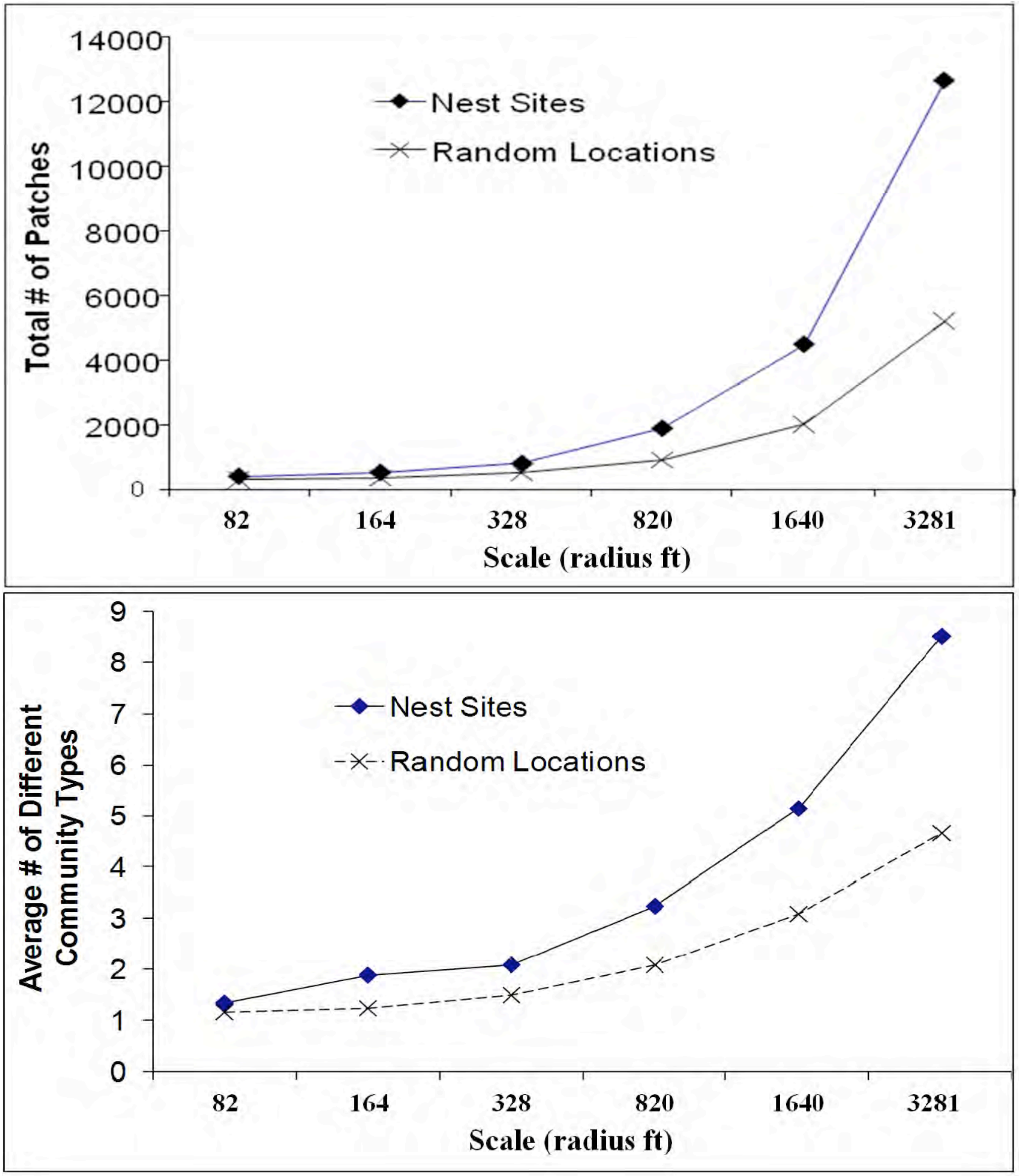

Figure 3. The number of total distinct community patches and average number of different community types surrounding both nest and non-nest (random) points at six different scales radiating from the point.

An Investigation into the Relationship between Seed Bank Density and Juniper Abundance in Oregon's Sagebrush Steppe

Corinne M. Duncan, Richard F. Miller, and David A. Pyke

SUMMARY

Expansion of western juniper (*Juniperus occidentalis*) into the sagebrush steppe has resulted in significant changes in understory vegetation. A consequence of increased western juniper dominance may be a depletion of the seed bank. The seed bank represents seeds left in the soil from current and previous years' seed crops. Seed bank depletion can be a problem because a reduction in available seed weakens a site's ability to restore itself after disturbance. Our research evaluated the effect of increasing western juniper abundance on the number of seeds in the seed bank over 2 years (2006-2007). Specifically, we asked the question "does total number of seeds (or seed density) decrease in the seed bank as western juniper cover increases?" Two eastern Oregon juniper woodland-sagebrush steppe sites were selected. Each site contained western juniper that ranged from sparse to dense stands. Seed bank samples were collected in the fall of each year. To approximate the number of seeds in the seed bank we watered the samples in a greenhouse, and counted and identified the resulting seedlings. Total seed bank density, at both sites in the first year, decreased as western juniper cover increased; this relationship, however, was not consistent in the second year. Both sites received above-average precipitation in 2006 and received below or near average precipitation in 2007. We propose, and our data support, the hypothesis that in years receiving above average precipitation, areas with lower amounts of western juniper contain a higher abundance of seeds than areas with high amounts of western juniper. This hypothesis suggests that the ability of a site to recover after disturbance may be strongest in areas of low western juniper cover. Other studies support this hypothesis and we encourage the undertaking of a long-term study testing this idea and potentially providing confirmation of its value as a predictor for prioritizing restoration in sagebrush steppe, where encroachment of western juniper is a problem.

INTRODUCTION AND OBJECTIVES

Woody plant expansion is occurring throughout the world (Mariotti and Peterschmitt 1994, Hopkins et al. 1996, Roques et al. 2001, Silva et al. 2001). Of concern in the Great Basin is the expansion of pinyon and juniper woodlands (Miller and Wigand 1994, Miller et al. 2008). The northwestern representative of the pinyon-juniper zone is western juniper (*Juniperus occidentalis*) (Billings 1951). Research suggests that seed banks may become increasingly depleted as trees expand into shrub-dominated communities (Koniak and Everett 1982, Bakker et al. 1996, Price and Morgan 2008). The seed bank represents the seeds left in the soil from current and previous years' seed crops. This depletion is concerning because a reduction in the number of seeds weakens a site's ability to regrow vegetation after disturbance. This could translate to a decline in vegetative cover that protects the soil surface and thereby increase erosion (Pearson et al. 2007). Further, depleted seed banks could result in a compromised resistance to colonization by invasive species. Disturbance that removes a portion of the vegetation provides available open spaces for the establishment of new plants. If the seed bank is depleted of native seed, weedy species with high dispersal capabilities and high growth rates are more likely to become disproportionately established (Tausch 1999).

Identification of relationships between the abundance of expanding tree species and the composition of the seed bank may be useful for evaluating restoration potential. Such a relationship could indicate whether a community has the ability to recover on its own. To begin to investigate the possible effects of increasing tree dominance on seed banks in the sagebrush steppe, we evaluated total seed bank density (seed abundance) along a gradient of increasing western juniper canopy cover. Specifically, we asked the question "does total seed bank density decrease as western juniper cover increases?"

METHODS

Devine Ridge and Bridge Creek:
Two study sites, Devine Ridge and Bridge Creek, were selected to represent the juniper woodland-sagebrush steppe zone. These sites were located in eastern Oregon and were recently invaded by western juniper. Each location captured a range of western juniper cover varying from sparse to dense stands. Evidence of rapid tree growth and lack of large, spreading branches (Miller et al. 2005) suggested that most of trees on both sites established after the late 1800's.

The 62-acre Devine Ridge site was 9.9 mi north of Burns, Oregon at an elevation of approximately 4,900 ft, and was comprised of a mountain big sagebrush/Idaho fescue (*Artemisia tridentata* ssp. *vaseyana*/*Festuca idahoensis*) plant association. Soils were relatively shallow (8-20 inches), course, sandy loams. Temperature extremes over the last 30 years ranged from 99.0°F to -27.9°F. Long-term mean annual precipitation was 10.6 inches. Total precipitation for the 2005-2006 and 2006-2007 water years (September through August) were 16.5 inches and 8.9 inches, respectively (Oregon Climate Service 2008).

The Bridge Creek site was located about 1.8 mi northwest of Mitchell, Oregon at about 2,600 ft in elevation. The site was approximately 37 acres and was occupied by a basin big sagebrush/bluebunch wheatgrass (*A. tridentata* ssp. *tridentata*/*Pseudoroegneria spicata*) plant association. Soils were course, loam to sandy loams. Temperature extremes over the last 30 years ranged from 107.1°F to -27.0°F. Long-term mean annual precipitation was 11.3 inches. Total precipitation for the 2005-2006 and 2006-2007 water years were 14.6 inches and 12.5 inches, respectively (Oregon Climate Service 2008).

Data Collection:
Seed bank and tree cover data were collected during 2006 and 2007 within randomly selected 98- by 108-ft (0.25 acre) plots. Seventeen and 15 plots were established at Devine Ridge and Bridge Creek, respectively. At Devine Ridge, two additional non-randomly chosen plots were selected to ensure adequate sampling in the low end of the range of western juniper cover.

Canopy cover of western juniper was estimated by calculating the area covered by each tree from measurements of the longest width and the width perpendicular to the longest width of each tree. The areas for all trees rooted within a plot were summed, resulting in a single cover value for each plot.

Seed banks were sampled in late October and early November of 2006 and 2007 after most of plants had disseminated their seed and before field germination began to occur. During the fall of 2006, early snows prevented full sampling at Bridge Creek when only 9 of the 15 plots were sampled; however, a full sampling was obtained in 2007. At each plot, 10 soil cores were collected at 10-ft intervals along 4, evenly spaced 98-ft transects for a total of 40 cores. Both mineral soil and litter were included in each sample.

Germination was used as a proxy for estimation of the viable seed bank. To increase the probability of breaking dormancy, the samples were subjected to periods of cold-wet and warm-dry conditions. After collection, samples were moistened to field capacity and transferred within 3 days to a refrigerator held at 34°F for 60-days. Samples were then spread over sterile sand in 10- by 20-inch flats, and were randomly placed on greenhouse benches. Two control flats were added to test for possible contamination from windborne seed or the possibility of remaining viable seed in the sterile sand. Samples were then manually watered to initiate germination, and were subsequently checked once per day and watered as needed. As soon as seedlings could be identified, they were removed. Once germination ceased, after approximately 4 months, samples were placed under warm-dry conditions for a period of 14 days by withholding water and keeping the flats in the greenhouse. Samples were then mixed and watering was reinitiated. This second germination phase lasted for another 4 months resulting in a total germination period of 8 months, occurring January through August.

Statistical Analysis:
Due to site differences in soils and big sagebrush (*Artemisia tridentata*) subspecies, Devine Ridge and Bridge Creek were analyzed separately. Simple linear regression was employed to test for a relationship between total seed bank density and western juniper cover. Both sites and years warranted log-log transformation.

RESULTS AND DISCUSSION

Results:
No seedlings germinated in the control trays and so we assumed that contamination was insignificant. Mean seed bank density per plot at Devine Ridge was 132 seeds/ft^2 in 2006 and 72 seeds/ft^2 in 2007. At Bridge Creek, mean seed bank density per plot was 424 and 157 seeds/ft^2 in 2006 and 2007, respectively.

In 2006, western juniper cover was significantly related to seed density at Devine Ridge ($P < 0.001$). We estimated that for each doubling in western juniper percent cover, seed density decreased by 21 percent (Fig. 1). At Bridge Creek in 2006, an increase in western juniper cover was also related to a decrease in seed density ($P = 0.08$). It was estimated that every doubling of western juniper percent cover was associated with a 40 percent decrease in seed density (Fig. 1). No relationships were detected at either site in the second year (Devine Ridge: $P = 0.32$; Bridge Creek: $p = 0.15$).

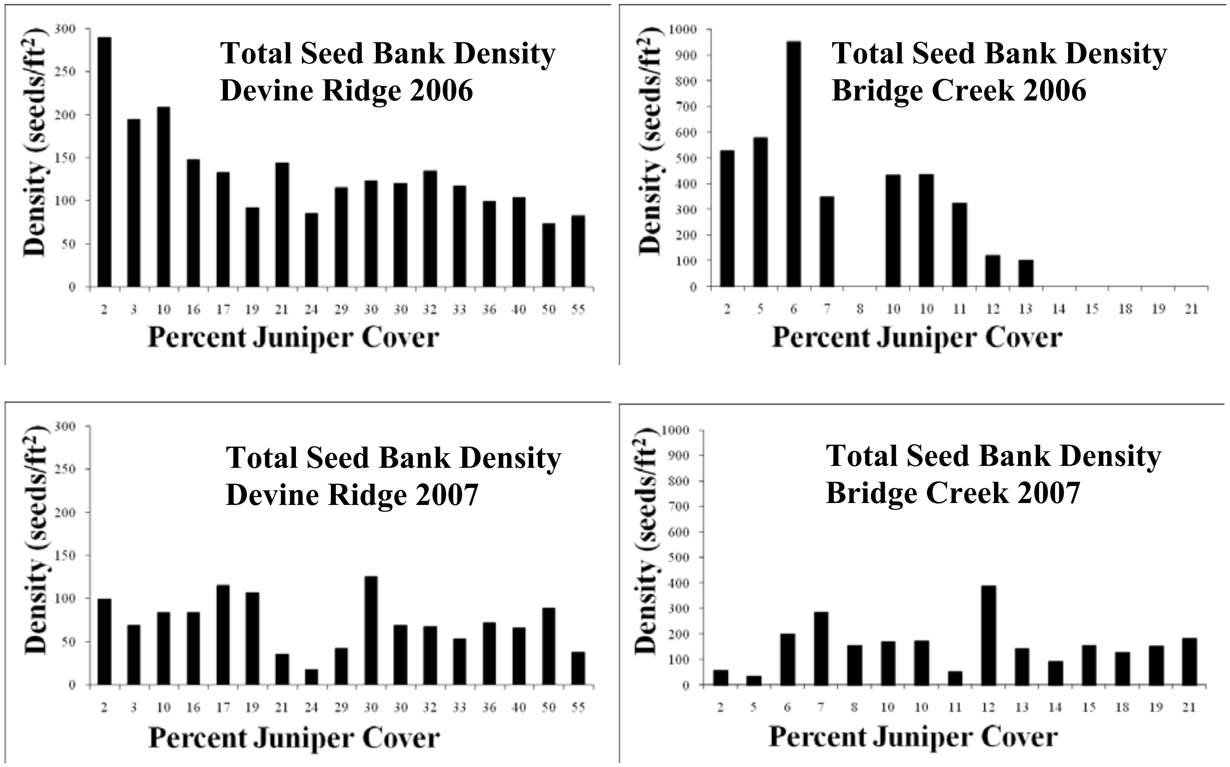

Figure 1. Total seed bank density per plot in relation to percent western juniper cover at Devine Ridge and Bridge Creek.

Discussion:
Seed bank density is related to a site's ability to recover after disturbance and thus its capacity for successful restoration (Lavorel et al. 1994, Lavorel 1999). Total seed density decreased as a function of increasing western juniper at both sites during the first year, but similar results were not observed in the second year. Other studies from the pinyon-juniper zone have also reported incongruous results. Our first year findings agree with Koniak and Everett (1982) who found that seed bank density decreased as singleleaf pinyon (*Pinus monophylla*) cover increased. Bakker et al. (1996) reported that the number of species in the seed bank decreased with increasing common juniper (*Juniperus communis*) cover. In contrast, Allen and Nowak (2008) found that both seed bank density and the number of seed bank species did not change as singleleaf pinyon/Utah juniper (*J. osteosperma*) cover increased. It is possible that this apparent inconsistency of findings may be due to variability in precipitation.

The first year of our study included a period of above-average precipitation. Precipitation for the 2005-2006 water-year (September through August) at Devine Ridge was nearly 156 percent of the average. At Bridge Creek (where the response was not as strong) precipitation for this period was 129 percent of the average. The highest total seed densities were found in the low western juniper canopy cover range (cover values below approximately one-third of maximum potential tree cover). The following year, precipitation at Devine Ridge was 84 percent of the average, while Bridge Creek received 110 percent of average. It is possible that increases in seed bank density are only expressed during considerably wetter than average years, at least in areas of low western juniper cover. We propose the hypothesis that open stands of western juniper express higher total seed bank densities than closed stands in years receiving above-average precipitation, thus suggesting that a site's ability to recover may be higher in areas of low western juniper cover. Koniak and Everett (1982), Bakker et al. (1996), and Allen and Nowak (2008) support this hypothesis. Both Koniak and Everett (1982) and Bakker et al. (1996) showed a negative response in the seed bank related to increases in tree cover. The water year prior to sampling by Koniak and Everett (1982) was 44 percent (3.9 inches) above average (California Weather Database 2008). During the Bakker et al. (1996) study period, precipitation was reported to be 46 percent (7.9 inches) above average. Finally, Allen and Nowak (2008) did not find a seed bank density response, reporting that the water years prior to their study were 34 percent and 30 percent (4.7 and 4.3 inches) below average.

MANAGEMENT IMPLICATIONS

Our results suggest that areas in the early stages of woodland expansion have a greater potential to contain higher seed bank densities in wetter than average years. Prioritization of these areas for tree removal would be wise as their resilience is likely to be greater. Validation of this relationship would allow for better prediction of recovery rates subsequent to control of woody expansion species, and we encourage further investigation into this topic.

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Shrub Microsite Influences Post-fire Perennial Grass Establishment

Chad S. Boyd and Kirk W. Davies

SUMMARY

Woody plants can cause localized increases in resources (i.e., resource islands) that can persist after fire. We tested the hypothesis that burned sagebrush subcanopies would have increased seedling establishment and performance of post-fire seeded perennial bunchgrasses compared to burned interspaces. We utilized five study sites in southeastern Oregon. The area was burned in a wildfire (2007) and re-seeded in the same year with a seed mix that included non-native and native perennial bunchgrasses. Seedling density, height, and reproductive status were measured in October of 2008 in burned subcanopy and interspace microsites. Seeded non-native perennial grasses had greater densities than seeded native species and were six times more abundant in burned subcanopies compared to burned interspaces. Density of natives in burned subcanopies was 24times higher than burned interspaces. Seedlings were taller in burned subcanopies compared to burned interspaces and subcanopy microsites had more reproductive seedlings than interspace microsites. Our results suggest pre-burn shrub cover may be important to post-fire restoration of perennial grasses. Others have found that subcanopies have increased soil organic matter, nitrogen, and carbon (i.e., resource islands) and elevated post-fire soil temperature. Determining the mechanisms responsible for increased seeding success in subcanopy microsites may suggest tactics that could be used to improve existing restoration technologies.

INTRODUCTION

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plant communities periodically burn and are at risk of conversion to exotic annual grasses after fire. Post-fire establishment of perennial grasses is critical to preventing exotic annual grass invasion of these plant communities. Revegetating Wyoming big sagebrush communities is a high priority because large areas have already been converted to exotic annual grass communities.

Establishment of desired vegetation is often needed after wildfires to restore ecosystem function and prevent invasion by exotic species. However, efforts to establish desirable vegetation are often unsuccessful in Wyoming big sagebrush plant communities (Eiswerth et al. 2009). Wyoming big sagebrush plants can create resource islands (i.e., areas of higher nutrient concentration) under their canopies (Doescher et al. 1984, Davies et al. 2007) and burning does not completely eliminate the resource island effect (Davies et al. 2009). Davies et al. (2009) speculated that, after fire, the burned subcanopies would be a more conducive environment for seedling establishment than burned interspaces. However, they did not test this theory, and the influence of resource islands on post-fire establishment of vegetation remains largely unexplored.

OBJECTIVES

The objective of this study was to determine if the success of post-fire seeded perennial grasses differed between interspace and subcanopy microsites. We hypothesized that at 1-year post-fire 1) seedling density would be greater in subcanopy microsites and 2) subcanopy sites would contain taller seedlings and a higher percentage of seedlings in a reproductive state (i.e., with developed seed heads).

METHODS

This study was conducted in the Wyoming big sagebrush alliance near Drewsey, Oregon, on land administered by the Bureau of Land Management. Elevation at study sites was approximately 3,600 ft and slopes were 2 – 5 percent. Soils were a complex series and surface textures ranged from clayey, to silty or gravelly loam underlain by clay pan or bedrock at depths from 5 to 20 inches. Annual precipitation is highly variable but averages approximately 13 inches with the majority falling as rain or snow during October to March; precipitation impacting germination, emergence, growth and survival of seedlings in this study (1 October, 2007 to 30 June, 2008) was 90 percent of the long-term average.

A 32,000-acre area, which included our study sites, was burned by wildfire in July of 2007. Prior to burning, this area was sagebrush/bunchgrass vegetation characterized by Wyoming big sagebrush, bluebunch wheatgrass (*Pseudoroegneria spicata*), Great Basin wildrye (*Leymus cinereus*), Sandberg bluegrass (*Poa secunda*), and medusahead (*Taeniatherum caput-medusae*). Our study sites were within a 9,800-acre area of the burn that was seeded with a rangeland drill in October of 2007. The seed mix included 4 lbs/acre (pure live seed) of crested wheatgrass (*Agropyron cristatum*), 2 lbs/acre of Siberian wheatgrass (*Agropyron sibiricum*), 2 lbs/acre of bluebunch wheatgrass, 1 lbs/acre of Secar Snake River wheatgrass (*Elymus wawawaiensis*), 0.5 lbs/acre of Great Basin wildrye and 0.5 lbs/acre of Sandberg bluegrass. Prior to burning, the study area was grazed by cattle during the growing season, but grazing was curtailed following fire in 2007 with continued non-use in 2008.

In October of 2008, we identified five burned sites that had supported sagebrush at the time of burning. Sagebrush subcanopy microsites were associated with persistent dead woody material and were characterized by a blackened soil surface ranging from 20 to 40 inches in diameter (Fig. 1). At each study site we randomly selected 20 subcanopy and 20 interspace microsites. For purposes of data collection and analysis we grouped seeded species and labeled *Agropyron* as "non-native" and the remaining genera as "native". At each microsite, we counted the number of perennial grass seedlings, by species group (native or non-native), within a 16 by 20-inch quadrat and measured the average seedling height by species group during October of 2008. Only those seedlings occurring within a drill row were counted. Presence or absence of reproductive seedlings (visible seed head) was noted by species group for each quadrat. Data were statistically analyzed to compare differences in seedling density, height, and reproductive status between subcanopy and interspace microsites.

RESULTS AND DISCUSSION

Non-natives dominated the perennial grass seedling population based on density with 8.0 seedlings/yd^2 (± 2.0) compared to 1.0 seedlings/yd^2 (± 0.6) for natives. Native seedlings were absent at one site in subcanopy microsites and three sites in interspace microsites; non-natives were present in all site/microsite combinations. Microsite effect on density varied by species group. Density of non-native seedlings in subcanopy microsites was about six times higher than in interspace microsites (Fig. 2). For native seedlings, density at subcanopy microsites was 24 times higher than interspace microsites (Fig. 2). In contrast to density, native and non-native seedlings had similar performance with respect to height, but seedling height varied by microsite. Seedling height for subcanopy microsites (across species) averaged 10.0 inches (± 0.8) compared to 4.5 inches (± 0.4) for interspace microsites (Fig. 2). Microsite effects on presence of reproductive seedlings varied by species group. In subcanopy microsites, a higher percentage of plots contained non-native reproductive seedlings (28 percent ± 4.9) compared to natives (3.0 percent ± 2.0, Fig. 2). The percentage of subcanopy microsite plots containing native reproductive seedlings did not differ from the percentage of interspace microsite plots containing native or non-native reproductive seedlings (Fig. 2). No reproductive seedlings were found within interspace microsites.

Overall, our results suggest that subcanopies were more conducive microsites for establishment[1] and performance of perennial grasses seeded after wildfire. The 6 - and 24-fold difference in density of introduced and native perennial bunchgrasses, respectively, between burned subcanopies and burned interspaces, along with increases in height and reproductive effort of subcanopy seedlings, indicates that shrubs had a significant positive influence on the success of revegetation efforts. Recent research suggests that shrub-associated alterations in soil properties may have at least short-term persistence after burning of the shrub (Davies et al. 2009). There is also a large increase in soil inorganic nitrogen the first year post-fire for subcanopy microsites (Stubbs and Pyke 2005, Davies et al. 2009). Eckert et al. (1986) reported reduced soil physical crusts in subcanopy microsites; soil physical crusts can reduce the establishment success of vegetation (Maestre et al. 2003). Another factor that could impact seedling success in subcanopy microsites is the darkening of the soil surface with fire (Fig. 1). Soil temperatures have been reported to increase on blackened soil surfaces following burning, leading to earlier growth initiation in spring and effectively lengthening the growing season (Wrobleski and Kauffman 2003, Davies et al. 2009). An earlier, extended growing season may be especially critical in regions where most of the precipitation occurs during winter.

MANAGEMENT IMPLICATIONS

Shrub microsites exert a post-fire influence on revegetation success as demonstrated by greater establishment and performance of post-fire seeded perennial grasses in subcanopy microsites. Seeded non-native perennial grasses were more successful (based on density and reproduction) than seeded native perennial grasses. Additional research to determine the mechanism(s) facilitating greater establishment in burned subcanopy microsites may provide

[1] Seedlings alive in October 2008 were considered to be "established" (1 year post-seeding).

information that could be incorporated into existing restoration technologies to improve efforts to revegetate Wyoming big sagebrush communities after fire.

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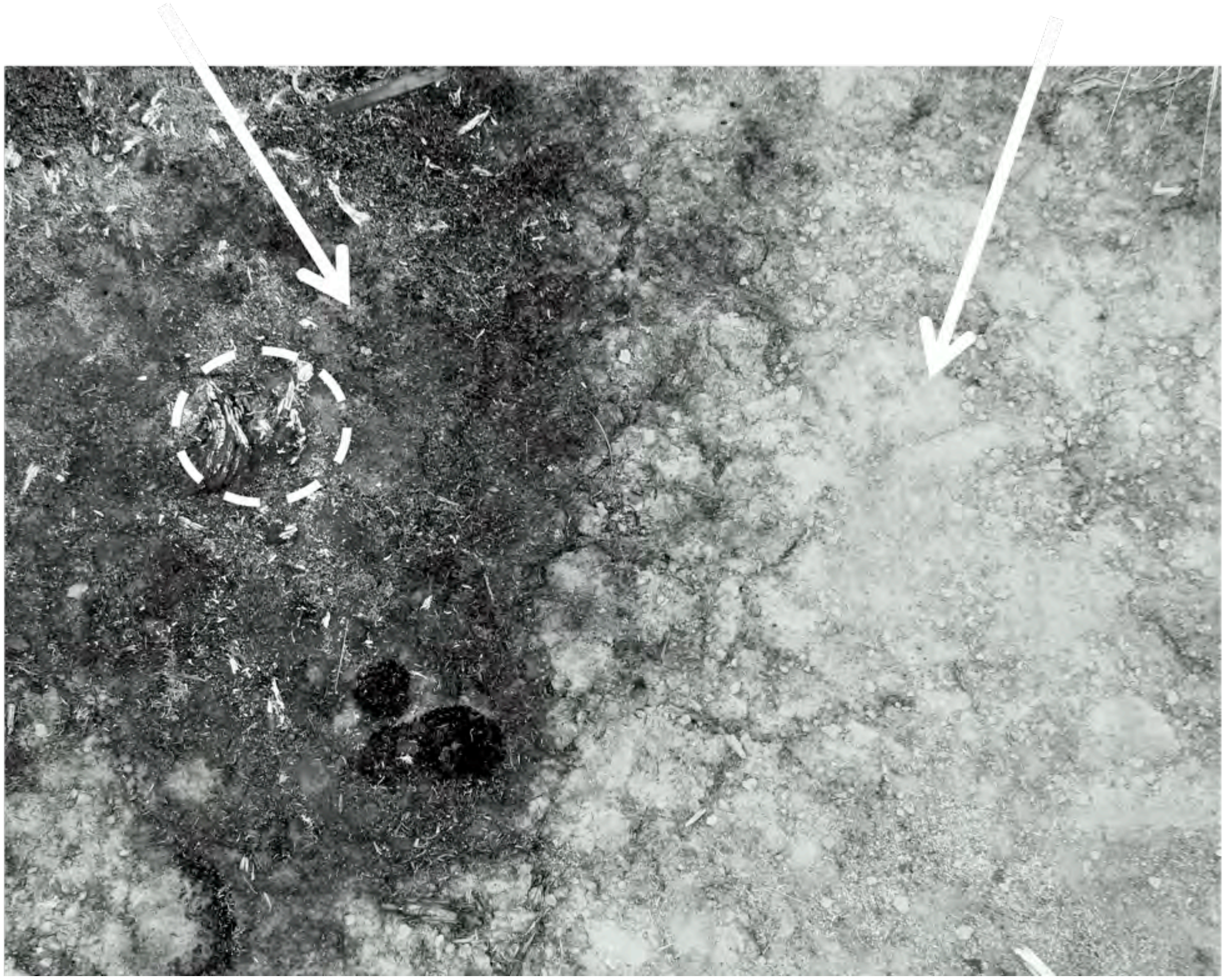

Figure 1. *Following fire, areas within the sagebrush subcanopy appeared as blackened (left arrow) compared to interspace areas (right arrow). Contiguous black areas were used to define subcanopy microsites and contiguous non-blackened areas were defined as interspace. Residual stump of original sagebrush is within dotted circle at left.*

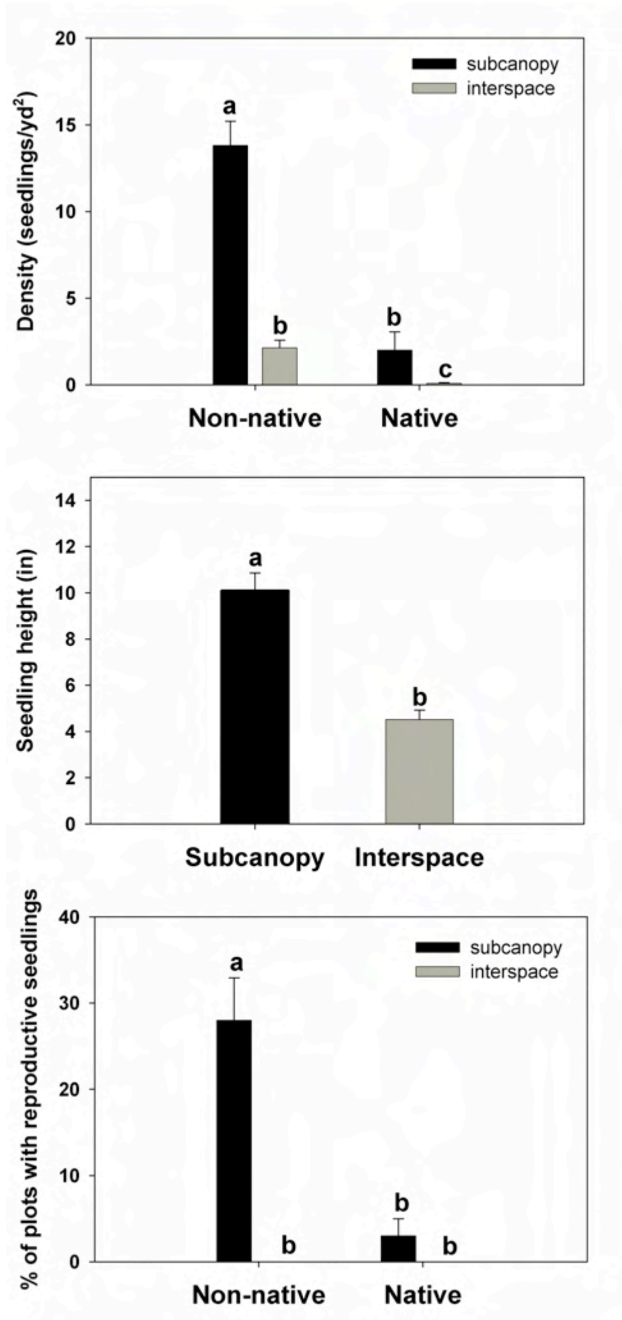

Figure 2. *Seedling density, height and percentage of plots with reproductive seedlings in burned Wyoming big sagebrush plant communities. Means are presented with their associated standard errors. Data were collected in October 2008, approximately 1 year post-seeding, and 15 months after the wildfire. Within a graph, bars without a common letter are different (α = 0.05).*