Special Report 979
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Range Field Day Annual Report, 1997

The Sagebrush Steppe: Sustainable Working Environments

Agricultural Experiment Station
Department of Rangeland Resources
Oregon State University
and the U.S. Department of Agriculture
Agricultural Research Service

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Front Cover: Marvin Klemme pictured in 1936. Looking out from the reservoir site across to the headquarters at the Northern Great Basin Experimental Range (then known as Squaw Butte). Mr. Klemme drove into Burns in 1936 and within just a few months hired a secretary and 3 field personnel. With that small crew he began to administer 13 million acres of rangeland in Oregon, through the Federal Grazing Act. The Experimental Range had been in the planning phase since 1934. After Marvin's arrival, construction of the facilities and fencing by the Civil Conservation Core was accomplished under his supervision. Though he left Oregon in 1938 to make a world tour to study range and pasture management in foreign countries, he left his mark on eastern Oregon. Grazing districts were developed and functioning, the number of livestock was reduced to match the capability of the land, and he helped develop the first guidelines for wildlife management on Grazing Service lands. Marvin died in 1992 at the age of 92. He was a soldier, laborer, logger, cowboy, government employee, world traveler, author, and cattle rancher. Most of all, he was a well liked, good man.

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Dining Out: Principles of Range Cattle Nutrition

M. L. McInnis and Martin Vavra

ANIMAL PERFORMANCE ON SAGEBRUSH-STEPPE RANGELANDS

Range cattle production in the sagebrush steppe, as elsewhere, depends upon the quality of consumed forage plants. The ultimate criterion of forage quality is measured in terms of animal performance. Figure 1 demonstrates gains of suckling calves and yearling cattle on the Northern Great Basin Experimental Range averaged over several years during the grazing season (Raleigh and Wallace 1965). Gains by yearlings are typically 2.0 pounds from late May through June; 1.5 pounds or less during July; and less than 1.0 pound thereafter (Turner and DelCurto 1991). Gains by suckling calves left with cows vary from 1.75 - 2.0 pounds during May and June; then decline to 1.5 pounds or less in July; less than 1.0 pound in August; and fall to less than 0.5 pound in September.

Typical weight changes of lactating beef cows on sagebrush-bunchgrass range are shown in Figure 2 (Turner and DelCurto 1991). Gains may exceed 4.0 pounds per day during May and June, but rapidly decline during late June and July. Spring-calving cows will gain less and lose more weight than cows that calve in the fall because of the demands of the suckling calf.

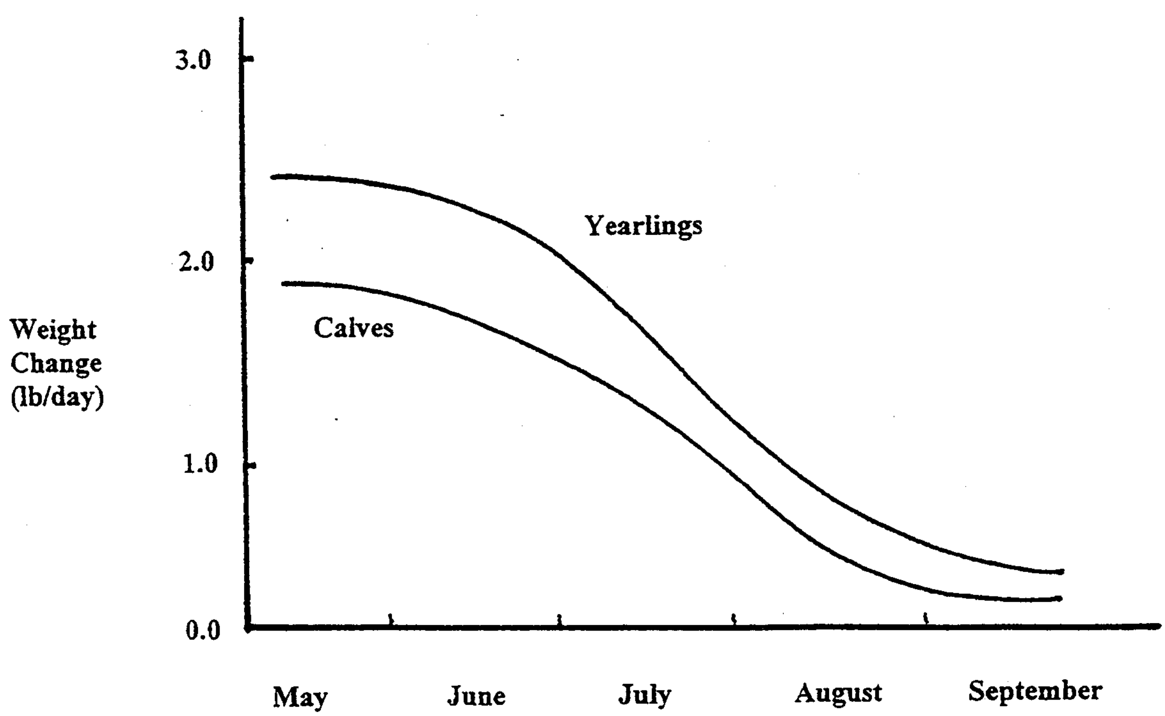

Figure 1. Weight change of suckling calves and yearling cattle during the summer grazing season on sagebrush-steppe rangeland (after Raleigh and Wallace 1965).

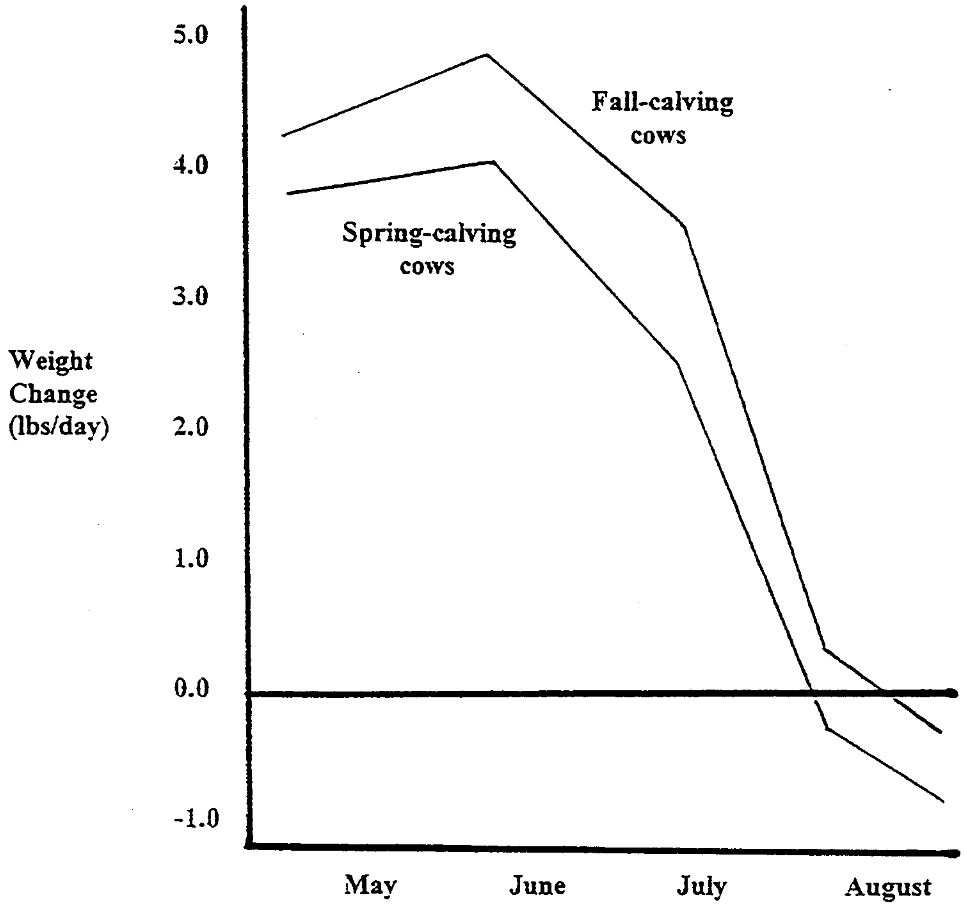

Figure 2. Weight change of lactating cows during the summer grazing season on sagebrush-steppe rangeland (after Turner and DelCurto 1991).

NUTRIENTS AVAILABLE FROM RANGE FORAGES

The gain data in Figures 1 and 2 simplify the response of animals to rangeland forage, but do reflect the dependence of animal performance on the quality of forages consumed. Most animal gains on sagebrush-steppe rangelands are made during late spring and early summer. Weight gains diminish rapidly as plants mature and forage quality fails to meet requirements for optimum growth sometime during mid-summer. The pattern of winter-spring precipitation and summer drought on sagebrush-steppe rangelands dictates a single growth cycle of forages. Thus, range forages typically provide optimum levels of nutrients and animal performance for only 2-3 month of the year.

There are many measures of forage quality including palatability, intake, digestibility, and levels of various nutrients. The principal nutrients of rangeland forages that limit animal performance are typically protein and energy. Mineral content of forages varies considerably with soil type and plant species, but phosphorous is often the most limiting. Deficiencies or toxicities of other minerals must be dealt with individually from one area to another. Vitamin A deficiency is a problem only in animals fed dry weathered feeds for 6 months or more.

Protein and energy requirements of beef cattle may be expressed in different ways. Figures 3 and 4 show seasonal declines in digestible nitrogen ("protein") and digestible energy, respectively, typical of maturing perennial bunchgrasses on sagebrush-steppe rangelands. Range grasses may fail to meet protein requirements of lactating cows by the time of seed shatter. Of course, elevation influences the yearly growth cycle of plants so that those at higher elevation mature later in the grazing season. Annual variations in climate also influence plant maturation. Browse and forbs tend to have higher levels of protein compared to grasses, especially late in the growing season. On the other hand, grasses supply more energy than browse or forbs, even after seed-shatter. Still, range forage may not meet the requirements of lactating cows after mid-summer.

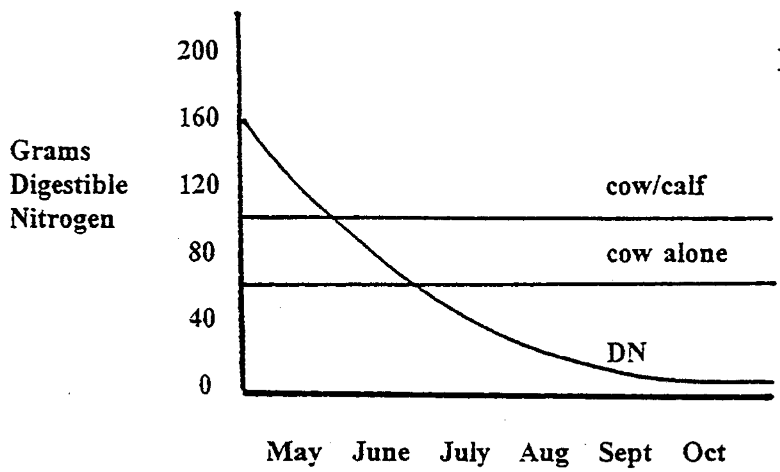

Figure 3. Digestible nitrogen (DN) typical of range forage compared to levels required by cows with calves and dry cows (after Bedell 1980).

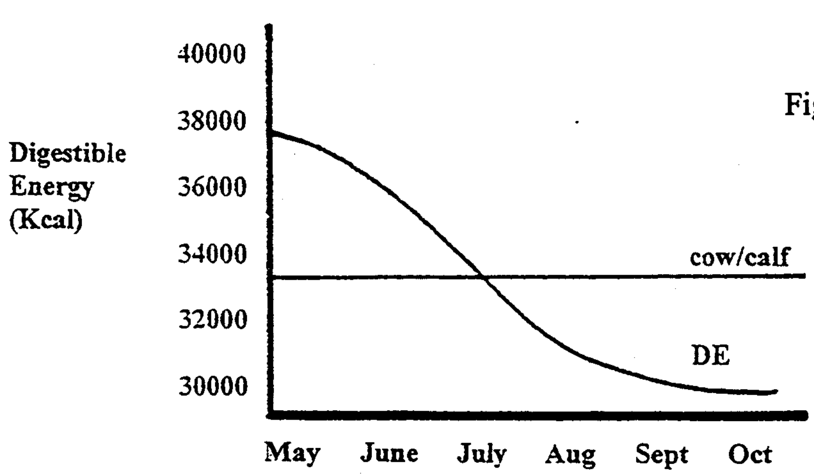

Figure 4. Digestible energy (DE) typical of range forage compared to levels required by cows with calves (after Bedell 1980).

Stage of plant maturity probably influences forage quality more than any other factor. Environmental parameters such as shading, soil type, and topography alter nutrient availability of plants by influencing phenology. Plants shaded by a shrub canopy may be slower to mature, contain higher levels of protein and minerals, and lower dry matter content than plants exposed to full sunlight. Range sites vary by topography, soils and climate. Plants on south-facing slopes are usually more advanced phenologically than plants on north-facing slopes. Leaf-stem ratios, protein, dry matter, mineral content and soluble carbohydrates are affected by the range site in which plants grow. Nutrient availability of forage on good versus poor condition rangeland depends on species composition. Forage species vary in their growth cycles with some plants maturing faster than others. Diverse plant communities that support green plants throughout the grazing season are better suited to meet nutritional needs of animals throughout the entire grazing period.

NUTRIENT REQUIREMENTS OF BEEF CATTLE

Nutrient requirements of cattle vary with class of livestock, level of production, physiological state, and environmental stress. Data published by the National Research Council (NRC) are accurate guidelines, and can be adjusted to accommodate additional requirements for range cattle to meet their needs for travel and exposure to climatic extremes. One method of planning a breeding herd nutrition program is to consider the annual cycle of a cow (Figure 5).

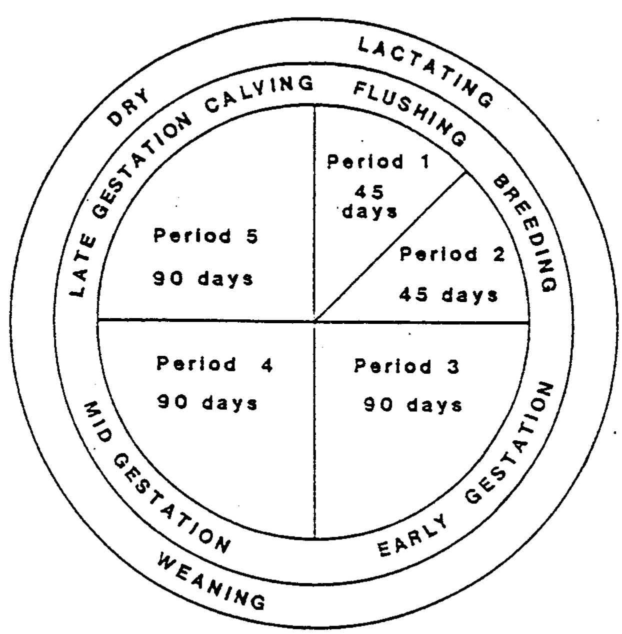

Figure 5. Annual cycle of a breeding beef cow (Dunbar and George 1986).

During period 1, cows have just calved and are lactating at their highest level. Additionally, they must begin recycling in preparation for breeding season. Nutrient requirements of a 1,000-pound breeding cow are shown in Table 1. Breeding occurs during Period 2. Cows are still lactating heavily and nutrient demands are high. During periods 1 and 2 cows require 112 percent more protein, 36 percent more energy, and 124 percent more calcium and phosphorous than during gestation (Dunbar and George 1986). These are the two most important periods during the nutritional calendar of a cow. Insufficient nutrition during periods 1 and 2 can lower milk production, calf growth, estrus, conception rates, and body condition. Period 3 is the season of early gestation. Cows are still lactating, but nutritional demands are diminishing. A cow's nutritional requirements during period 4 are the lowest in the cycle. During this period, a cow's principal function is maintenance of the developing fetus. Period 5 represents the last third of gestation. Nutrient demands of the cow are increasing because of the rapidly developing fetus. Additionally, the cow should be gaining weight in preparation for lactation.

Table 1. Approximate nutrient requirements of a 1,000-pound beef cow (NRC 1984).

NUTRIENT	PERIOD				
	1	2	3	4	5
Dry matter (lbs/day)	20.6	21.0	19.5	18.1	19.6
Crude protein (lbs/day)	2.5	2.6	2.0	1.3	1.6
ME (Mcal/day)	22.7	23.0	19.0	14.5	17.3
P (grams/day)	25.0	27.0	20.0	15.0	18.0
Vitamin A (1,000's IU)	37	38	36	25	31

NUTRIENT DEMAND AND SUPPLY ON SAGEBRUSH-STEPPE RANGELANDS

Figure 6 shows the generalized relationship between availability of nutrients from primary forages on sagebrush-steppe rangelands and nutrient demand by a breeding beef cow. Although stage of plant development will vary as discussed above, a cow that calves March 1 (Figure 6, point A), will likely experience some period of inadequate nutrition from range forage early in the season because of increasing demands for nutrients by the lactating cow. Nutrient demand of this cow peaks about 80 days postpartum when lactation reaches its maximum level (May 19 in this example). Soon after, principal grasses will likely peak in biomass and quality, and nutrient availability may exceed demand for a time. Forage quality declines rapidly after seed shatter and plants enter senescence. There will typically be a second period of nutrient deficiency that will persist until weaning (Figure 6, point B), which normally occurs about 205 days postpartum (October 23 in this example).

The challenge faced by managers is to manipulate either the nutrient supply curve or the nutrient demand curve to reduce or eliminate periods of inadequate nutrition. Several management strategies are available including delaying calving, early weaning, supplemental feeding, and range seeding. Such management strategies are the topic of the paper by DelCurto and Vavra (this Special Report).

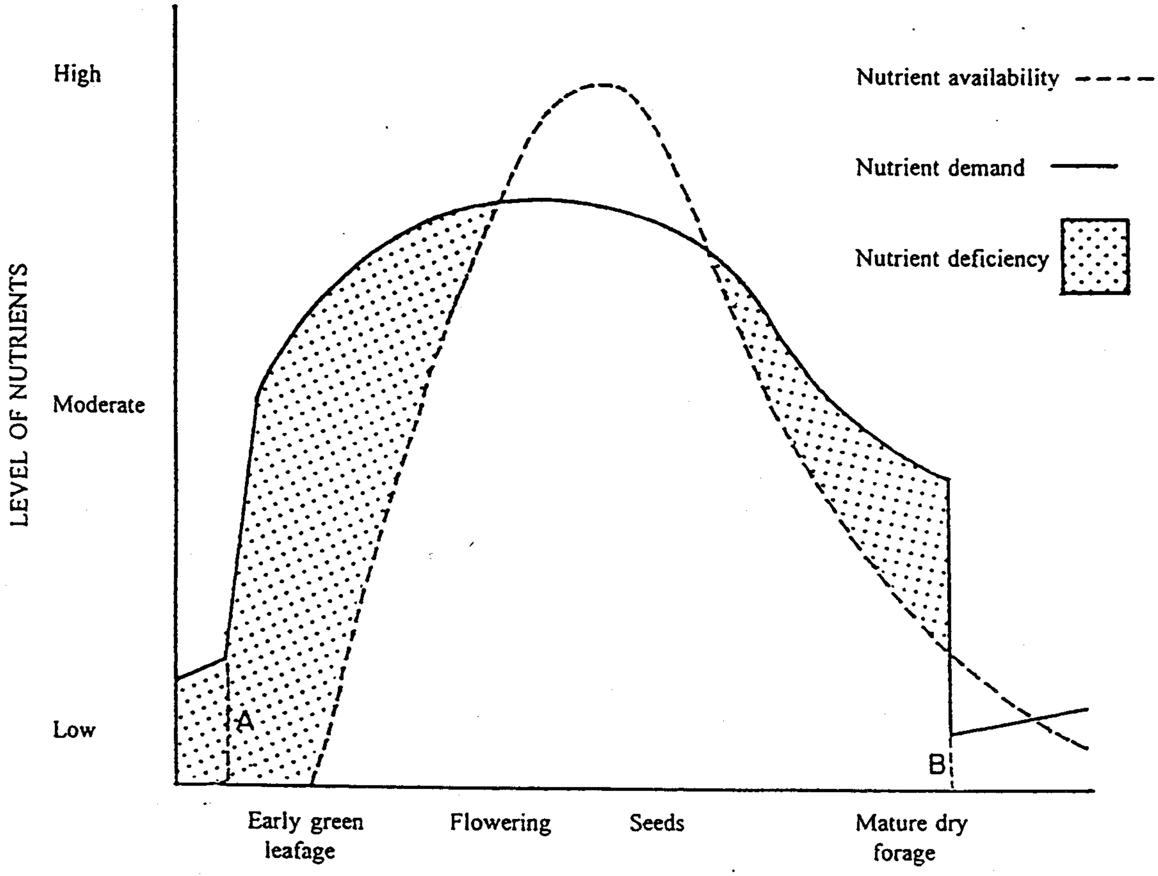

Figure 6. Generalized relationship between nutrients supplied by principal forages in the sagebrush-steppe and nutrients required by a breeding beef cow. Point A represents a hypothetical calving date of March 1, and point B represents a weaning date of October 23 (205 days postpartum).

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MIXING AND MATCHING: GRAZING WET MEADOWS AND DESERT RANGE

Raymond Angell

SUMMARY

Southeast Oregon livestock producers manage two very different forage resources. The majority of grazing lands in southeast Oregon are sagebrush rangeland. These desert ranges are capable of producing excellent forage for livestock. However, the growing period is short because soil water is quickly depleted. The second forage resource is found in lowlands where runoff from high elevation snowpack provides irrigation during spring. These meadows are crucial in the annual livestock production cycle because they are managed to produce hay for the winter feeding period. Because they receive added water, they can produce ten times or more forage than desert rangeland, and they have a longer period of forage growth.

The highly productive meadows provide several alternatives to the traditional hay-only management. Growing cattle can graze these meadows in spring and summer and can gain over 2 pounds per day through August, with no supplementation. This provides the benefit of added pounds of gain as well as freeing up desert range for other uses such as fall grazing with mature cows. A second option is to utilize native meadows in an early-weaning program wherein calves are placed on hay meadow regrowth after weaning in September. These calves can gain an additional 20 pounds per head compared to calves weaned on the desert in October. Additionally, their dams will do better on the lower quality range forage because they are not nursing a calf. A third option is to bring in cow/calf pairs in August and allow them to strip-graze rake-bunch hay through September. In a 2-year study, we found that calf gains during September were increased by 50 pounds compared to pairs grazing desert range during that time. As part of that study, calves were weaned in late September and kept on meadow forage, while their dams were returned to graze native range during winter. An economic analysis of the study found that winter grazing on desert range was more profitable than feeding baled hay, although much more influenced by severe weather than other methods.

INTRODUCTION

"In this day of high investment, high cost, and narrow economic margins in livestock operations, it is not enough to increase the forage quantity and quality. The livestock rancher must increase the efficiency of his livestock in the job of converting forage to pounds of saleable product." That's a pretty fair assessment of the situation today isn't it? Actually those words were penned by Art Sawyer in 1961, while he was the superintendent of the OSU Experiment Station in Burns Seems that some things in the livestock business never change.

As land managers, one of our goals is to obtain the greatest net income we can from the land that are consistent with sound land management practices. We want these practices to maintain or enhance the use of that land. Additionally, we would like to improve hay quality, enhance animal performance, and have the option to rest portions of native range to improve its condition, as well as stockpile forage for later use, or even prepare for a prescribed burn.

Within that context, we are constrained by two things: the 12-month production cycle of forage and livestock and the productivity of the lands which we control. Ranchers operate within the constraints of the annual forage and livestock production cycles. Any change in one of the components of the system effects all the others. Eastern Oregon livestock producers often work within a forage production system centered around the annual production cycle of native hay meadows. These meadows are under private ownership, and are the base property for most ranching operations. Native meadows can produce anywhere from 2,000 to 6,000 pounds per acre of dry forage. Compare that to forage yields on sagebrush range; they're typically one tenth, or less, of meadow production.

Traditionally, native wet meadows have been hayed in July, continuing through early August, in some instances. In this context, one crop of hay is produced, and any regrowth is stockpiled for use by livestock in fall when they return from summer ranges. Traditionally, livestock spend half of the year on meadows grazing residual forage or being fed hay. Recently, interest has increased regarding alternative uses on native meadows. I will review three alternative management ideas in this paper, which are summaries of previous research at this station. They illustrate the potential for innovative management using two very different forage resources.

Livestock producers in eastern Oregon have access to three broad categories of grazing land. First, native or improved meadows provide an abundance of forage, which has historically been harvested for hay. These are the most productive forage resources available for our use. Second, sagebrush range is utilized as spring and early summer range, although some utilize it for the entire spring and summer grazing period. These lands are limited by water availability for forage production and livestock drinking water. These lands constitute the largest acreage in southeast Oregon. Finally, forested grazing is provided at higher elevations. These lands provide green feed during the period when forage is mature and dry on the lower elevation sagebrush ranges. This paper will discuss a few ideas for integrating meadows and desert range to enhance both forage and livestock production.

On average, meadows consistently produce much more forage per acre than desert rangeland (Figure 1). Actual production will vary across sites and years. As the figure shows, growth begins at about the same time in both systems, based on soil temperature and water availability. We can use the high level of productivity on native meadows to our advantage to develop new grazing and haying combinations. Three options we have investigated are spring grazing with yearling steers or heifers, early-weaning of calves, and placement of cow/calf pairs on rake-bunches during September and October.

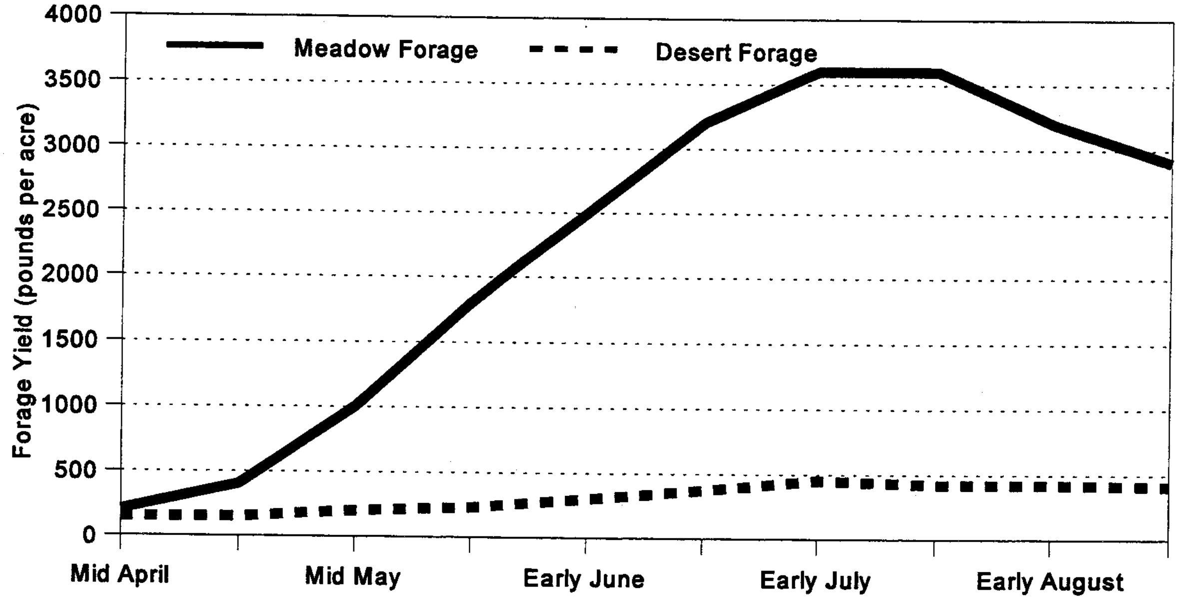

Figure 1. Generalized forage growth curves for native meadow vegetation and desert rangeland in eastern Oregon. The difference in production between the two systems allows flexibility in management. Actual yields can vary by 50 percent or more, based on site and precipitation.

METHODS

Meadow Grazing

Eastern Oregon native meadows were historically dominated by rushes and sedges, along with grasses like Nevada bluegrass, and forbs such as annual white-tip clover. However over the last 20 years meadow foxtail, an introduced grass, has increased in density and coverage on many meadows. While it is nutritious and productive, it tends to mature earlier than associated native species. Because length of flooding on these meadows is not easily controlled, hay quality can suffer from delayed cutting. We investigated spring and summer grazing as an alternative to haying. In two studies, we grazed yearling cattle on meadow forage beginning May 1 through late July or mid August. In both studies, cattle were allowed free access to all parts of the pasture, which included areas flooded to a 24 inch depth. Higher elevation loafing areas were available in several locations. Most of the pasture we used is dominated by meadow foxtail, with reed canarygrass in lower areas and saltgrass on higher ground.

Early Weaning

Forage quality on desert range decreases quickly in summer, and by late August growing animals cannot perform up to their potential. If regrowth is available on hayed meadows, calf performance can be improved by weaning in early to mid-September and placing them on these meadows to graze the higher quality regrowth and hay aftermath. The mature cows can remain on desert range, and without the suckling calf will do well, entering the winter in better body condition than if weaning is in mid-October. In a study at Eastern Oregon Agricultural Research Center (EOARC), cattle were separated into two groups. One group was early-weaned in mid-September, and the other was weaned at the traditional mid-October date. Early weaned calves were placed on meadow regrowth and received 2 pounds of barley and 1 pound of cottonseed meal daily. Late-weaned calves remained on desert range with their dams. After weaning in October, all calves were placed together and fed the barley and cottonseed meal supplement. Hay feeding began in mid-November.

Rake-bunch Grazing

Placing meadow hay in rake-bunches rather than baling has been practiced for many years. The usual practice is to rake-bunch a field in July, then place cattle on the field in early fall as they are brought in from the range. Feeding efficiency can be quite low under this system, because cattle pick the highest quality forage from each bunch and leave the rest, often lying down on it, increasing wastage. Earlier work at this station demonstrated that restricting animals to about a seven-day rake-bunch supply at a time greatly enhanced the efficiency of utilization. Cattle performance was excellent, and labor costs remained less than conventional hand feeding.

This idea was combined with the early weaning concept. During a 2-year study, cows with suckling calves were brought off the desert in August and placed on rake-bunches. After about eight weeks on rake-bunches and meadow regrowth, the calves were weaned in late September, and their dams returned to the desert to graze through the winter. Calves received 1 to 1.5 pounds of a 85:15 cottonseed meal/barley mix each day. Cows remained on range all winter during the 2-year study. Objectives were to improve calf gains in late summer, and to decrease the winter feeding requirements by placing dry, mature cattle on desert range after weaning. The hay that was not consumed by cattle was then available for sale.

RESULTS

Meadow Grazing

Cattle gains on meadow forage were at least as good as gains on desert range during spring (Figure 2). During our studies, unsupplemented cattle gained 2 pounds per day or better through the end of July. In one study, season-long (May 1 to Sept. 4) daily gain on meadow forage averaged 2.6 pounds per day (Blount et al. 1991). A second study found similar gains during the May- to July-period. Based on historical data, yearlings grazing sagebrush rangeland can be expected to gain about 1.6 pounds per day between May and August. For the cattle used here that represents an additional gain of up to a pound per day for yearlings on meadow forage. In one year (1989) strip grazing was compared to continuous grazing. Initial cattle performance was similar on both systems. However, later in the summer performance declined under strip grazing because the rotation interval was too long and forage became overly mature.

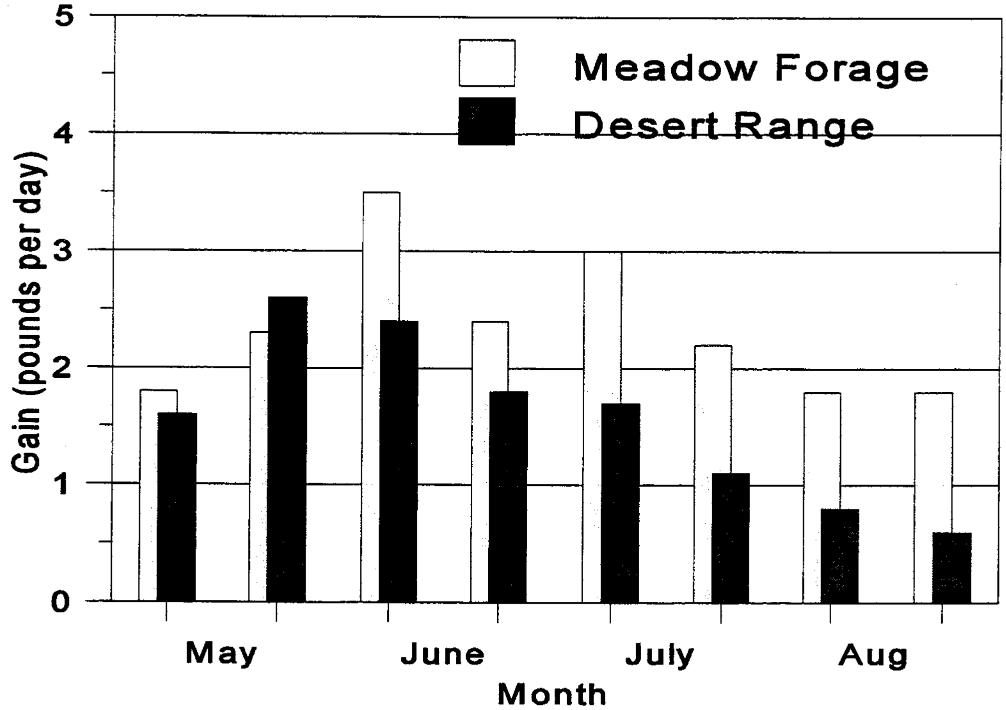

Figure 2. Typical daily weight gains for yearling cattle grazing sagebrush rangeland or meadow forage at Eastern Oregon Agricultural Research Center, Burns.

In our experiments at the Research Center, we we have utilized between 1.5 and 4.2 animal unit months (AUMs) per acre on unfertilized native meadow. Over the long haul, 1.5 to 2.0 AUMs per acre is probably most appropriate and would provide a good starting point. Compare that rate of harvest with a typical value for sagebrush rangeland of between 0.1 to 0.2 AUMs per acre. This example demonstrates how a small portion of native meadow can be used to free up a sizeable portion of desert rangeland for resting or late season use. One acre of foxtail meadow will free ten acres or more of typical sagebrush rangeland for other uses. Alternative uses for this rangeland could include fall grazing by dry cows after weaning, rest until the next growing season, or a build up fine fuel loads for a prescribed burn.

Early Weaning

In studies at EOARC, early-weaned calves were removed from their dams on September 12, and put on meadow aftermath and regrowth (Raleigh, et al. 1970). Conventionally managed calves remained on desert forage with their dams until October 12. Early-weaned calves gained 20 pounds per head more than conventionally managed calves between the September and October weaning dates (Figure 3); about 0.7 pounds per day of increased gain. The performance of early-weaned calves remained greater than late-weaned, even after the calves were brought together and managed in one group. Between September 12 and November 12, early-weaned calves had gained about 50 pounds per head more than conventionally managed calves.

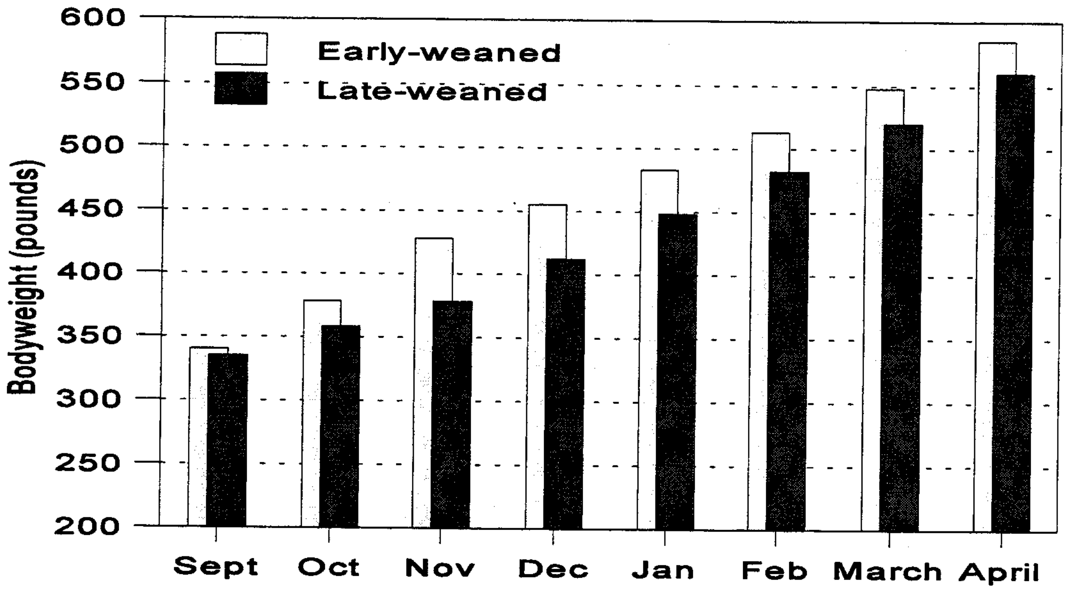

Figure 3. Typical weight of early-weaned (September) versus late-weaned (October) calves at the Eastern Oregon Agricultural Research Center, Burns, Oregon.

These results demonstrate another way that meadows can be used to enhance performance and improve management flexibility. Here, mature animals with lower requirements were left on rangeland, while growing animals were placed on higher quality meadow forage. In some cases other options, such as good quality high-elevation range or rake-bunched hay, are present. In all cases the final decision will be based on the quality of feed resources available and the costs associated with each option.

Rake-bunch Grazing

Cows managed under this system utilized rake-bunch hay for two months, and then returned to sagebrush range in late September after calves were weaned. During the 2-year study, cows were able to remain on range the entire winter. We are on the edge of the area where winter grazing is feasible, but occasionally it was necessary to feed baled hay. Cow/calf pairs grazing on rake-bunches significantly outperformed pairs that had remained on sagebrush range (Table 1). Cows maintained their weight while cattle on sagebrush range lost weight. Calf performance was significantly improved by being given rake-bunch hay, with average daily gains about 70 percent greater than calf gains on rangeland (1.1 vs. 1.9 pounds per day). In this management strategy, cows gained body condition during August and September, prior to returning to sagebrush, and calves put on an additional 50 pounds of body weight prior to winter. This study did not extend on through November, however if it had, differences between the two groups would have been even greater.

Primary expenses incurred with this type of management are fencing for rake-bunch feeding, and labor for moving the cows from sagebrush range to rake-bunch and back. Fencing cost is minimized by using polywire electric fencing with step-down style posts. An economic analysis of winter feeding alternatives showed that winter grazing was economically feasible, with expected returns about $50.00 greater than for baled hay (Bates, et al. 1990). This economic benefit would not be realized in a severe winter because cows would need to be fed baled hay.

Table 1. Weight changes (lbs.) over 2 years for cows and calves grazing rake-bunch hay during August and September versus sagebrush rangeland at the Eastern Oregon Agricultural Research Center, Burns, 1987-88.

	Cows		Calves	
	Rake-bunch	Sagebrush	Rake-bunch	Sagebrush
Weight	---------- pounds ----------			
August	1002	1014	315	310
September	1026	935	400	351
Avg. daily gain	0.5	-1.7	1.9	1.1

Returning cows to sagebrush range is not feasible for everyone. However, these data point out that even a short 6- to 8-week period can be used to put additional gain on calves and improve cow body condition. After early-weaning in September, cows could be put on meadow aftermath to graze free choice until winter conditions require feeding either baled or rakebunched hay. The key is to remain flexible and develop a specific plan tailored to your operation.

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MANAGEMENT OF BEEF CATTLE FOR ECONOMIC SUSTAINABLILITY: A REVIEW OF RESEARCH

Tim DelCurto and Marty Vavra

INTRODUCTION

Beef cattle producers are faced with the never-ending dilemma of maintaining economic viability during times of low market values and, more recently, increased public criticism of beef product quality and industry compatibility with the environment. Unlike other meat animal industries, such as swine and poultry, the beef industry in the western United States is very dynamic with a great deal of diversity mostly related to arid environments and subsequent effects on forage quality, quantity, and associated relationships to beef cattle nutritional requirements. As a result, the western beef cattle industry is very extensive with optimal production being a function of the resources each ranching unit has available and matching the type of cow and/or production expectations to the available resources. Successful beef producers are not necessarily the ones that wean the heaviest calves, display 95 percent conception, or provide the most optimal winter nutrition. Instead, the successful producers are the ones who display economic viability despite the economic and public pressures that can and will continue to plague the industry.

In a real sense, there is not a right way to manage cattle in the western United States. What works for one producer, may not be appropriate for the neighboring ranch. Economic viability often relates to three general factors: 1) value of beef, 2) input costs per cow, and 3) the production per cow (Figure 1). Unfortunately, beef cow/calf producers are usually considered "price takers" in that they have very little influence on setting market value for commercial beef cattle. In addition, the beef cow/calf industry is one that typically over produces, which often leads to price scenarios that are less than desirable. Therefore, the cow/calf producer, by default, must focus on finding an optimal balance between beef cattle production and economic inputs to attain the associated level of production. In this kind of management scenario, it is not uncommon for a beef cattle manager with modest production expectations, but low input cost per cow, to have similar or better economic prospects than a producer with high beef cattle production expectations. Obviously, the producer with high levels of beef cattle performance had input costs per cow that was greater than the production advantages.

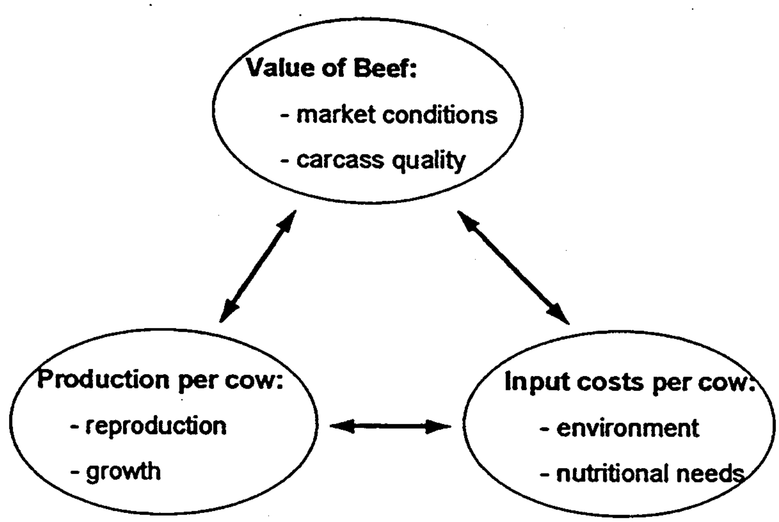

Figure 1. Economic strategies for beef cattle production focus on the following three factors: 1) value of beef, 2) production per cow, and 3) costs per cow.

What follows is a general discussion of potential management strategies that may offer economic advantages to western range livestock producers. Many scenarios or strategies may not be appropriate for your environment or production goals. Instead, most of the following information should be considered potential management alternatives that *may* offer economic advantages by decreasing input costs per cow.

When is the Best Time to Calve?

One of the most fundamental management decisions that has profound effects on beef cattle nutritional requirements is calving date. The western beef cattle industry is dominated by spring-calving beef cattle. In addition, time of calving has generally been related to the "55 days to grass" philosophy. This management strategy has gained popularity for a variety of reasons. First, the gestation length in beef cattle is approximately 284 days. Therefore, if your cow herd calves approximately 55 days before the onset of green forage, the cows will be exposed to green, highly nutritious, forage for approximately 25 days before they need to conceive and stay on a 365 day calving interval. In a sense, the 25 days of high forage quality is a natural "flushing" mechanism that usually prompts a cow to begin cycling if she had adequate body condition to begin with. Obviously, if your goal is to match the cow's nutritional requirements to the range forage quality, a producer might coincide calving with the onset of green forage (McInnis and Vavra, this publication). However, the "55 day before grass" philosophy has another advantage, the calf. A typical beef calf does not become a functioning ruminant until approximately 90 to 120 days of age. This event is usually associated with a cow that has passed its peak lactational period (day 70 to 90) and, as a result, calf performance will depend, to a greater degree, on the forage quality available to the calf. Thus, a calf born March 1, will be effectively utilizing forage available in June. In contrast, a calf born May 1, will not be effectively utilizing forage resources until August. Because of the vast difference in calf nutrition from day 90 to weaning, the earlier born calf will have weaning-weight advantages that greatly outweigh the 60 day difference in age. Obviously, if higher weaning weight is a measure of economic importance (you market calves in the fall), than the "55 day before grass" philosophy may be your best approach.

Are Weaning Weights Really Important?

The beef cattle industry in the United States has seen dramatic changes in production efficiencies over the last 30 years. In particular, weaning weights have increased from approximately 400 lbs in 1967, to greater than 600 lbs in 1997. The increase in weaning weights is related to increased use of continental breeds, greater selection on growth traits, and general improvements in management efficiency. If your goal is to market your spring calves in the fall, then this change in production efficiency has improved your economic potential.

However, the increase in weaning weights is an improvement in production efficiency that has some indirect problems. First, the target slaughter weight of market cattle has not changed dramatically during this time period. As a result, the opportunities to put on post-weaning weight have become more limited with the higher weaning-weight cattle. For example, if a spring calving beef cow/calf producer weans his cattle in late October at 600 lbs, he/she may choose to sell in the fall market or retain calves over the winter feeding period. Because of the bigger calves his options are reduced. With only marginal gains of 1 to 1.5 lbs per head per day gains, this producer will come out of the winter feeding period (120 to 150 days) with 700 to 800 lb yearlings. The opportunities to place these animals on spring grass have become very restricted because to fit market standards the yearlings need to be placed in the feedlot (avg 90 days) with an expected gain of 300 to 350 lbs, and a target end weight of 1200 to 1300 lbs. Therefore, spring calving cow/calf production with high weaning weights have, as a result, limited opportunities as stocker cattle on grass markets.

Another change in the beef cattle industry in recent years is the trend to retain ownership and/or branded markets. These changes have indirectly led producers to reevaluate weaning weight goals because of opportunities to capture weight gains on yearlings and the need to provide cattle at finished weights over a yearly time frame. For producers who wish to retain ownership of cattle after weaning, weaning weight takes on less significance.

In fact, these producers are ones that should consider calving dates strongly if he/she wishes to decrease costs per cow. Moving the calving date to coincide range/pasture forage quality with cow nutrient demands may effectively reduce costs associated with supplementing cows during nutrient deficiencies. Weaning weight advantages are reduced, but the producer has more opportunities to capture that gain later in stocker, backgrounding, and finishing phases.

Fall Calving.

While this particular strategy does not closely match the cow's nutrient demands with range/pasture forage resources, some benefits do exists. By calving during the fall (September to October), a calf is produced that is big enough to efficiently use the early high-quality forage available in the spring; with the cow still producing some milk, to make rapid gains during this period. This program allows calves to stay on the cows longer and continue to make economical gains. In contrast, spring born calves are often not able to effectively utilize spring and early summer forages.

Likewise, fall calving may provide benefits relative to the environment that calves are exposed to at birth. Typical spring calving conditions include poor calving weather, long breeding seasons, and problems, such as infectious diarrhea and respiratory diseases, which are compounded by calving on wet muddy flood meadows. Wind is also prevalent at this time of year, and wind-chill can adversely affect calf morbidity and mortality.

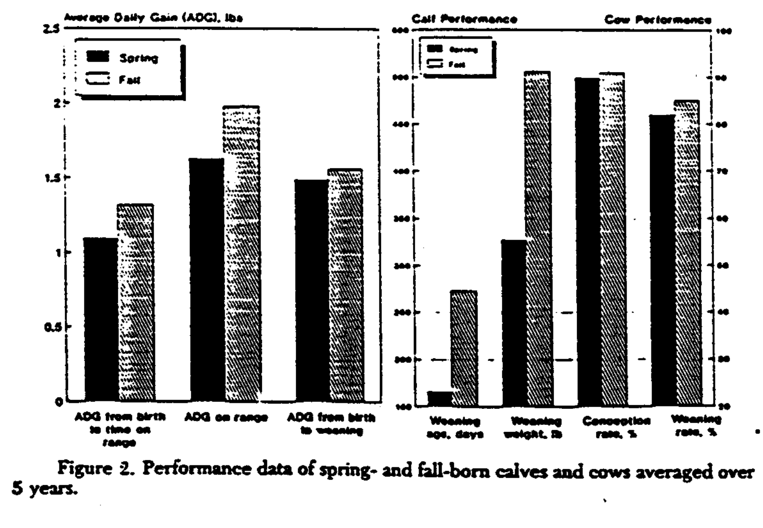

Figure 2. Performance data of spring- and fall-born calves and cows averaged over 5 years.

Weaning weights of fall-born calves at the Northern Great Basin Experimental Range have exceeded that of spring-born calves by 150 to 200 lbs, with over 1100 calves over 5 years (Figure 2; Turner and DelCurto, 1991). Most of the fall-born calves were creep fed 20 to 100 pounds of feed. Due to confinement on winter feed grounds, creep feeding the fall-born calf is more practical than on ranges with spring-born calves. Most of the weight advantage is due to higher gains early in the spring on range, creep feeding, and the additional length of time on the cow. Conception and weaning rates were also slightly higher in fall-calving cows.

Obviously, winter nutritional management needs to be increased dramatically with fall-calving cows with the highest nutritional demands associated with lactation and, unfortunately, the winter feeding period. However, this is a time period when cows are on base property and the manager has easy access to animals and facilities. In addition, reproductive management becomes more conducive to intensive breeding systems accommodating artificial insemination programs and/or fewer bulls needed for natural mating. Confinement breeding may, in turn, result in shortened breeding seasons.

In addition to higher nutritional input costs per cow, fall calving has another major deterrent. Public land managers currently view an animal over 6 months of age as an animal unit. This halves the cow herd in respect to public land grazing making this strategy nearly impossible to implement where public lands are the source of summer forage resources. These policies exist despite data showing that the fall-calving cow/calf pair consumes only 25 percent more forage than the spring-calving cow/calf pair (Kartchner et al., 1979). A potential strategy may be to wean fall calves before turnout on public land permits. Regardless, dry cows and cows with older calves spread out over the range better, improving distribution, and reducing overgrazing associated with poor distribution.

Early Weaning as A Management Tool

Traditionally, beef producers in the Great Basin have weaned calves at approximately 7 months, which usually coincides to late October or November for spring calving herds. However, gains of calves and cows are often poor by late August, particularly during years of poor forage quality/quantity. By removing these calves early, they can be put on better feed with the cows remaining on range. Dry cows do well on range forage during the fall, and without suckling calves will come into winter in better condition. Improved body condition translates into a cow that will be easier to feed during the winter period and have a higher chance of breeding back in a 365 day calving interval.

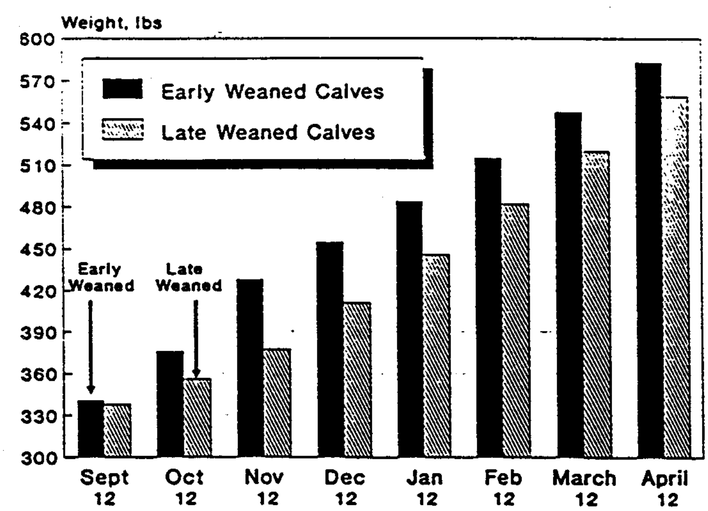

Figure 3. Influence of weaning date on calf weight.

Figure 3 presents some early weaning data from the Eastern Oregon Agricultural Research Center herd (Turner and DelCurto, 1991). Early-weaned calves were removed from their dams on September 12, and put on meadow aftermath and regrowth, plus supplemented with 2 pounds of barley and 1 pound of cottonseed meal. Late-weaned calves remained on range with their dams until October 12, and then were managed with the early-weaned calves. On November 12, all calves were fed meadow hay and received 2 pounds of barley and 1 pound of cottonseed meal throughout the winter.

Early-weaned calves outgained late-weaned calves by 20 pounds from September 12 to October 12, despite going through the stress of weaning and adjusting to new feed. During the next period of time, from October 12 to November 12, the early-weaned calves out-gained late-weaned calves by an additional 31 pounds and were now 51 pounds heavier. Late-weaned calves compensated somewhat over the remainder of the winter, but were still 24 pounds lighter on April 12.

A number of factors need to be considered when deciding if early weaning is appropriate. First, forage quality must be limiting to the point that calves will not do well and cows will likely lose body condition from late-August to the October or November weaning date. If forage quality and quantity is not limiting, then there is really no advantage to early weaning. The real advantage of early weaning is to improve the weight and body condition of the cows from late-summer to the beginning of the winter feeding period. In addition, the producer must provide adequate forage/nutrition to the early-weaned calf. For producers that frequently have limited nutritional options during the late-summer and fall period, early weaning may provide an alternative that allows for more efficient management of the mature cow body condition relative to a dynamic arid rangeland environment.

Alternative Winter Nutritional Management Strategies

Beef cattle producers in the Western U.S. and, more specifically, intermountain and Pacific Northwest, compete at an economic disadvantage relative to other regions in North America due to high winter feed costs. Many producers currently feed 1.5 to 2.5 tons of hay to their mature cows during the winter feeding period. This represents a costs of $75 to $150 per cow per year, and may be greater than 50 percent of the input costs per cow per year. Obviously, our ability to compete with other regions of North America may relate to how effective we can reduce winter feed costs, yet still maintain acceptable levels of beef cattle production.

Rake Bunch Hay. The Eastern Oregon Agricultural Research Center conducted approximately 10 years of research evaluating rake bunch hay as an alternative to traditional winter management. With this system, hay is cut, then raked into small piles, 80 to 120 lbs with a bunch rake, and left in the field. Cows are then strip-grazed, by using New Zealand type electric fences, throughout the winter. As a general summary of 10 years of data, cows wintered on rake-bunch hay, came out the winter period in better condition than traditionally fed cows, and did not require supplements or additional hay. Likewise, conception rates, calving interval, weaning weights, and attrition rates have been equal between control and treatment groups. In addition, the costs of winter feeding rake-bunch hay has been $30 to $40 less per head than the traditional feeding of harvested hay. For additional information relative to rake-bunch hay feeding, please refer to Turner (1987), and Turner and DelCurto, 1991.

Winter Grazing. Another alternative to traditional winter feeding may by winter grazing "stockpiled" forage. To effectively use this alternative, the producer must defer grazing of irrigated pasture or native range to the fall or winter months. The range forage-base will be dormant and, as a result, will likely need some supplementation, depending on quality of selected diets, body condition status of mature cows, and stage of gestation. More thorough discussions of winter grazing (Brandyberry et al., 1994) and supplementation of low-quality roughages (DelCurto et al., 1991) are provided.

Like rake-bunch hay, winter grazing may decrease winter feed cost by $20 to $30 per cow during mild to average years. To effectively utilize winter grazing in a management program, the producer must have access to the animals to accomodate supplementation programs. Water must be available throughout the fall or winter grazing period, although snow can be effectively utilized by the cow. In addition, the grazing area must be relatively free of snow accumulation during most years.

Indirect benefits of winter grazing relates to the increased management opportunities of traditional hay meadows for spring and early summer grazing. In addition, fall and winter grazing is an alternative use of native rangelands that may provide some significant advantages. First, grazing dormant forage will have minimal impact on the plant as compared to traditional spring and summer grazing. Second, grazing dry-gestating cows will be marked by better distribution over the grazing area with greater distance traveled from water, better use of slopes, and more uniform use of the grazed area.

Grass Seed Residues. Yet another alternative to traditional winter management would be the use of grass seed residues produced as a bi-product of Oregon's Grass Seed Industry. Currently, Oregon's Grass Seed Industry produces over 1 million tons of crop residues. While only 50 percent of these residues appear to be viable as a livestock feed resource, there are a number of reasons producers should consider these feeds as a winter alternative. First, many of these grass species are perennial forages (Kentucky bluegrass, tall fescue, perennial ryegrass, bentgrass, etc.) and, as a result, are substantially better than annual cereal grain straws. Second, the use of burning as a tool to sanitize fields and remove residues has been eliminated as a primary tool for grass seed producers. As a result, there is a critical need to find an effective use for these residues. Third, the Japanese export market has became "soft" in recent years, making delivery of grass seed residues to the eastern portions of Oregon more economically viable.

In most cases, grass seed residues should not be considered a complete feed for wintering mature beef cows. Instead, grass-seed straws should be tested and supplements formulated to meet the cow's nutritional requirements yet maximize the use of the low-quality roughage. For more thorough reviews of grass seed residues and associated supplementation, refer to DelCurto (1991), Chamberlain and DelCurto (1991), and Turner et al., 1995.

Currently, grass-seed straw is being delivered to eastern Oregon for approximately $40 to $50 per ton. The economic viability of this feed resource should not only be compared to costs associated with meadow-hay production, but also other potential benefits. First, feeding grass straw frees up meadows for grazing and/or other uses. Second, grass-seed residues represent a clean feed with limited weeds, with the exception of the seeds from the residue itself. In many cases, seeds from bluegrass, tall fescue, and perennial ryegrass germinating on disturbed winter feed grounds should not be considered a problem. Third, feeding residues on winter feed grounds or traditional hay meadows represents an increase in nutrients added to the site.

Decreased fertilizer costs and improved organic matter of the soil may result from long-term feeding of grass seed residues.

Other Considerations. Research at the Eastern Oregon Agricultural Research Center has shown that ionophores, specifically rumensin, can improve winter beef cow performance or reduce winter feed needs (Turner et al., 1977; Turner et al., 1980). Cows fed a full feed of meadow hay plus 200 mg of monensin had daily gains of .2 pounds higher than cows fed meadow hay alone. In studies where cow weights were kept equal between control cows receiving meadow hay and cows receiving meadow hay plus monensin, hay savings of up to 13 percent were realized. Monensin represents another management tool for improving cow condition or reducing feed needs, while maintaining cow condition through the winter feeding period.

There are several other potential tools or management strategies that may help reduce winter feed costs. Obviously, if you are using low-quality roughages such as stockpiled forage and crop residues, your supplementation strategy must emphasize minimizing supplemental costs while maintaining acceptable beef cattle performance.

SUMMARY

The ability of western beef cattle producers to effectively compete with other regions of North America may depend on management strategies that emphasize profit margins rather than weaning weights. The above information only "scratches the surface" of potential alternative management strategies that may offer economic advantages. Keep in mind that western beef cattle producers and resources are dynamic and incorporation of some of these strategies has to fit your production philosophy, production goals, and holistic ranch management plan.

Readers are encouraged to request information described in the selected references. In addition, feel free to contact the Eastern Oregon Agricultural Research Center if you need additional information relative to any of the alternatives discussed in this paper.

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LIVESTOCK SYSTEMS COMPLEMENTARY OR COMPATIBLE WITH WILDLIFE

Mitchell J. Willis

SUMMARY

Literature relevant to livestock grazing systems complementary or compatible with wildlife is reviewed. Four ways that grazing systems can impact wildlife habitat are discussed with examples. Case histories used to benefit broad categories of wildlife are presented. An array of systems, seasons of use, stocking rates, and classes of livestock are advocated. The most consistent theme is the need for flexibility and tailoring of a system to fit site specific needs.

INTRODUCTION

The concept of grazing cattle to benefit wildlife, or at least not diminish the suitability of habitat for wildlife is volatile, controversial, and challenging to anyone trying to implement such a system or even write about it! To deny that conflicts between livestock grazing and wildlife occur would be akin to burying our heads in the sand. These conflicts have grown from an obscure regional issue to one of national prominence (Severson and Medina 1983). We need research that identifies specific areas of conflict and also develops techniques for compatible or complementary relationships between livestock and wildlife. It is important to recognize that grazing is an action that changes habitat. By changing habitat on an area, wildlife species that thrived under previous conditions will be negatively impacted, while others may benefit from the change.

Grazing systems in this paper means grazing by livestock as part of a specific plan, or under some set of controls to achieve a specific set of objectives. Bryant (1982) in a review of 214 studies of grazing systems and wildlife concluded that generally a system, any system, as opposed to season- or year-long grazing, is better for wildlife than none. Grazing systems on a piece of ground directly and indirectly influence plant life on an area for both the short- and long-term. Changes in plant life also affect wildlife using the area. Wildlife use of the area (particularly large herbivores) ultimately cause an effect back on the grazing system as well. In this paper I will address four ways livestock grazing systems can influence wildlife habitat to benefit a variety of wildlife species, and provide some specific examples.

Just as the physics law says for every action there is an equal and opposite reaction, there are reactions by wildlife species other than those targeted. In many cases, a program or grazing system designed to help one wildlife species will have a negative impact on another. Consideration for non-target species should be inherent in any plan design. For example, Bock et al. (1984) found in adjacent grazed and ungrazed blocks, that the grazed area had significantly higher numbers of birds in the summer, while rodents were significantly higher in the ungrazed area.

Mechanisms of Habitat Alteration

Livestock grazing systems affect wildlife directly and indirectly; only the direct affects will be covered here. The most obvious direct influence of grazing systems is upon vegetation, a primary component of wildlife habitat. Grazing systems can alter wildlife habitat in four ways by affecting the structure, composition, nutritive quality, and productivity of vegetation (Severson and Urness 1994). Putting the needs of wildlife species together with knowledge of the desired grazing system can result in a compatible or complementary product.

Altering Plant Composition: Specific locations on rangelands often provide critical habitat to individual species. Livestock can be used to alter plant composition to provide an essential component, such as browse for wintering mule deer (*Odocoileus hemionus*). Smith (1949) was one of the first authors to document how summer grazing by cattle affected the composition of vegetation by increasing the abundance and vigor of shrubs over 11 years improving the site for wintering mule deer. Spring grazing of forage around bitterbrush (*Purshia tridentata*) plants by cattle provided favorable conditions for establishing bitterbrush and increasing big and low sagebrush (*Artemisia tridentata* and *A. arbuscula*). Neal (1981) noted that periodic heavy spring grazing with removal of 75-100 percent of the annual bunchgrass production, produced changes in vegetation favorable to wintering mule deer. In particular, he found increased establishment of bitterbrush and big sagebrush. He recommended removing cattle before bitterbrush seeds reached the red-juice stage (mid-July) annually and heavy grazing only periodically (15-20 yr. intervals) to maintain the bitterbrush productivity. The use of cattle to lightly graze moist meadows in northern Nevada delayed phenological progression and supported desirable forage species for sage grouse (*Centrocercus urophasianus*), most notably common dandelions (*Taraxicum officinale*) (Evans 1985).

Altering Productivity. In some cases, a primary land management objective might be to increase the productivity of a desirable species, such as bitterbrush. Spring and summer horse grazing improved production of bitterbrush in a northern Utah study (Reiner and Urness 1982). Horses were observed to graze around bitterbrush plants, but left the shrubs unbrowsed. Austin and Urness (1995) found that horse grazing in the spring reduced plant competition and shifted the growth advantage to shrubs, benefitted shrub survival, seedling recruitment, and reduced winter injury to some shrub species.

Anderson and Scherzinger (1975) described a controlled grazing system that increased the quality and quantity of winter forage for elk and resulted in a 2.6-fold increase in AUMs and an increase in wintering elk from an average of 120 head (1948-60) to 1191 head in 1974. Rhodes and Sharrow (1983) found that spring and summer sheep grazing in Douglas fir (*Pseudotsuga menziesii*) plantations resulted in lower October standing crop, yet by March there was generally a higher standing crop of herbaceous plants in the grazed areas than in the ungrazed, which greened-up earlier, and was favored by black-tailed deer (*Odocoileus hemionus columbianus*). Spring grazing by sheep reduced competition to bitterbrush and increased the available browse for mule deer (Jensen et al. 1972, Smith et al. 1979).

Altering Plant Nutritive Quality. Several studies have addressed the concept of increasing the quality of forage through livestock grazing systems. Vavra and Sheehy (1996) described how the nutritive quality of winter forage for elk may be improved through spring livestock grazing by conditioning forage. They contended that grazing at the boot stage, followed by livestock removal, causes grasses to regrow and then cure with plant nutrients in the above-ground portion of the plant. Pitt (1986) found clipping bluebunch wheatgrass (*Agropyron spicatum*) late in the spring increased fall growth of higher nutritive quality. Bell (1971) and McNaughton (1984) described grazing (in this case, by wild ungulates) as a positive force in improving forage quantity and quality in the Serengeti of Tanzania and Kenya. Anderson and Scherzinger (1975) applied these principles to cattle grazing on elk winter range in Oregon. Livestock grazing systems to improve forage quality should recognize, and be designed to benefit, the desired ecological status of the area. This process should include adherence to moderate utilization (Anderson et al. 1990). In this case, grazing should be heavy enough to "top-off" the vegetation, yet leave enough for quick, sufficient re-growth.

Altering Plant Structure. Manipulating the structure of vegetation to benefit wildlife is a relatively simple concept. Schulz and Guthery (1988) found bobwhite quail use increased in pastures with rapid-rotation type grazing systems. They attributed this to the increased bare ground and decreased amount of perennial grass. Sedivec et al. (1990) compared four grazing systems and a control in North Dakota, and found that although upland duck and sharp-tailed grouse (*Tympanuchus phasianellus*) nest density was higher in ungrazed sites in North Dakota, nest success was higher in plots with twice-over rotation grazing systems in place. They cautioned, however, that grazing should not commence until the third or fourth week of May, to allow ducks to initiate nesting. One of the two primary goals of Anderson and Scherzinger's (1975) work was to reduce the amount of old vegetative material, and prevent the formation of wolf plants on the Bridge Creek Management Area in Oregon. Spring grazing accomplished this objective and also conditioned the forage for winter grazing by elk (see Altering Plant Nutritive Quality).

Response of Wildlife Groups to Grazing Systems

Small Mammals. Small mammals, such as smaller rodents and lagomorphs, can constitute the largest number of vertebrates on an area. Small mammal abundance and species richness was found to be higher in long-term (30+ years) ungrazed sites in Utah, over comparable actively grazed sites by Rosenstock (1996). He cautioned that small mammal community composition varied almost as much within treatments as among them, and thus, his results should be considered cautiously. Bock et al. (1984) also found small mammals more abundant inside a large, long-term exclosure than immediately outside in a southeast Arizona study. Johnson (1981), studying small mammal abundance and composition in southeastern Idaho, noted few significant differences by individual species between grazed and ungrazed sites, but believed that overall differences were more likely attributable to plant cover differences than other factors.

Upland Birds. Guthery (1986) recommended creating small overgrazed areas within pastures to create bobwhite quail (*Colinus virginianus*) feeding habitats. Salt or supplementary feed areas were suggested to create these sites. Sage grouse males are known to strut on areas of bare ground or low statured vegetation (Batterson and Morse 1948, Willis et al. 1993). Some of these areas have been maintained by heavy livestock use around water developments and salt grounds. Rest-rotation grazing improved sage grouse habitat by increasing forb abundance in the summer (Neel 1980), moderately grazed meadows were more attractive than protected meadows, and overgrazed meadows were unused by sage grouse.

Guthery (1996) proposed a theoretical approach to grazing as a tool for upland birds, which considered the usable space to a bird (i.e., structural habitat) and usable time (the portion of the year space is available). Grazing decisions should consider: 1) the vegetation status of the management area; 2) whether grazing could improve the status; 3) if grazing is useful, developing stocking rate and season in order to maximize space and time, or provide acceptable residual cover at a critical time; and 4) how to accomplish proper grazing distribution or pressure.

Nongame Birds. Nongame birds, those not generally hunted, comprise a large proportion of the wildlife species occupying rangeland. Response of nongame birds to grazing is likely the most variable of any wildlife group. Knopf (1996) noted that aquatic bird species are relatively unaffected by grazing, birds of prey are mainly affected by grazing impacts on their prey, wetland-associated species are influenced by grazing affects on nesting cover, and terrestrial species are affected by how grazing alters food and cover.

Waterfowl. An abundance of papers have been written on waterfowl and grazing. Kantrud (1990) summarized many papers addressing livestock grazing and fire impacts on waterfowl. Generally, moderate grazing commencing after most ducks have initiated nesting has been considered beneficial to the waterfowl by opening up closed stands and reducing height and density of tall, emergent plants. Braun (1978) warned, and Kantrud (1990) reaffirmed, that livestock grazing has been detrimental when not well planned and controlled.

Big Game. Skovlin et al. (1968) and Sheehy (1987) pointed out that deferred or rotational systems provided elk and cattle the opportunity to graze without social interactions. Vavra and Sheehy (1996) pointed out temporal separation was the most important factor separating elk and cattle use of common range, and also that natural factors such as distance to hiding cover contribute to spatial separation of elk and cattle. Among 12 generalizations from the studies of elk and cattle interactions presented by Wisdom and Thomas (1996), perhaps the most important was their last: "Perception is rarely reality when judging competitive interactions between elk and cattle." They proposed monitoring, research, and professional expertise to provide objectivity in addressing potential conflicts. Peek and Krausman (1996) reported sufficient information is available to make livestock grazing and mule deer compatible, and described deferred grazing; high-intensity, short duration grazing; and rest-rotation systems. They pointed out however, that many of these systems required extra fencing and water development to work.

CONCLUSIONS

A recent symposium was held to assess using livestock as a tool to enhance wildlife habitat (Severson 1990). All six of the papers, which covered theoretical and species accounts, discussed the proper timing of grazing as a critical element in successfully using livestock as a tool. In some cases, deferral was beneficial, and in others early grazing was prescribed.

Variety of habitat, either by patchy distribution of plant community types, or by a variety of conditions within a plant community tends to support a broader array of wildlife than monocultures. Grazing animal behavior tends to promote among-site heterogeneity of vegetation, especially when coupled with periodic fire (Glenn et al. 1992). Of all the research studies reported in this paper, only two supported "heavy" grazing. Even in those situations, the prescription was for localized areas of disturbance, to promote habitat diversity.

The role of livestock grazing on rangelands, particularly the public rangelands of the West, is changing rapidly and is subject to increased scrutiny. Constraints on wildlife are increasing as well, through urban sprawl and other rural developments, which are at a time an all time high for for consumptive and non-consumptive uses. Current public interest and involvement regarding livestock and wildlife is a motivational factor to develop better, closer relationships, and better overall management of public lands. Obviously, closer working relationships are necessary to make livestock and wildlife habitat use more compatible or complementary. It is not enough in this day and age to revel in the glories of the past. As Connolly and Wallmo (1981) noted, even if mule deer habitats have gained from past livestock grazing, those benefits were purely by coincidence, not by planning.

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SELECTIVE LIVESTOCK GRAZING: A TOOL FOR VEGETATION MANAGEMENT

Dave Ganskopp, Ruben Cruz, Tony Svejcar, Jerry Farstvedt, and Fred Taylor

SUMMARY

We report on four different projects exploring opportunities to enhance or alter forage characteristics or quality with manipulative grazing practices. These trials were designed to: 1) evaluate the potential for woody plant control by Spanish goats, 2) assess the seasonal effects of cattle grazing among newly established bitterbrush, 3) define the seasonal preferences of cattle grazing among crested wheatgrass and our native grasses, and 4) see if defoliation of Thurber's needlegrass at different times of the growing season can stimulate the production of highly nutritious regrowth. Spanish goats demonstrated little potential to affect established Wyoming big sagebrush. When herbaceous forages were dormant approximately 8 percent of their diet was derived from western juniper, suggesting they may hold some promise for controlling newly established or young trees with moderate cattle grazing, where 30 to 40 percent of available herbage was utilized. Recently established bitterbrush plants were seldom grazed when associated grasses were green and leafy. After 3 years, shrubs in early grazed pastures were twice as large as those in pastures with no livestock grazing. Cattle did graze young bitterbrush when grasses were dormant and brown, and greatly reduced shrub stature when compared with plants in non-grazed pastures. Among the eight different grasses common to the region cattle favored crested wheatgrass over native grasses early in the growing season and when grasses were flowering. After forages ceased growth and turned brown, the steers' preferences shifted to giant wildrye, but they did make more equitable use of all available grasses. Early to mid-season defoliation of Thurber's needlegrass can be used to stimulate production of high quality regrowth that may be reserved for late-season use by growing livestock or wildlife. Regrowth potential is severely limited in dry years, and managers should make grazing schedule adjustments to defer a pasture the next growing if it is heavily grazed in the early to mid-growing season.

INTRODUCTION

Throughout history humans have attempted to manipulate vegetation to their own ends. Aborigines employed fire to alter the landscape composition, and tillage methods have been with us since the first intensive row-crop efforts. In this century selective and non-selective herbicides entered the picture and have been used for both intensive and extensive agricultural endeavors. In addition to controlling undesirable weeds or pests, we have chemicals that may be used to arrest or alter plant growth. While much of our intensive agricultural output is indeed chemical dependent, chemical usage has become prohibitively expensive and politically sensitive in the extensive rangeland settings of the western United States. Land managers are now exploring more "natural" means of manipulating vegetation. These include biological control of problem pests or weeds, controlled burns, and prescription grazing programs. The objective of this discussion is to briefly present results from some of our recent research trials that explore opportunities to manipulate the character or quality of our rangeland forages.

MATERIALS AND METHODS

Four projects in the area will be reported on. These include: 1) a trial to evaluate the potential for woody plant control by Spanish goats, 2) a trial to assess the seasonal effects of cattle grazing among newly established bitterbrush, 3) trials to define the seasonal preferences of cattle grazing among crested wheatgrass and our native grasses, and 4) clipping trials on Thurber's needlegrass to see if defoliation at different times of the growing season can stimulate the production of highly nutritious regrowth.

Potential for woody plant control by Spanish goats

Trials occurred on the Northern Great Basin Experimental Range on native rangeland pasture during two stages of plant growth. The objective was to assess potential impacts of goats on encroaching Wyoming big sagebrush and western juniper. The first 4-day trial occurred when all grasses and forbs were green and growing. The second was conducted after soil moisture reserves were depleted, and all grasses and forbs had stopped growing and turned brown. We measured the amount of forage available to the goats by clipping 25, 10.77 ^{ft2} plots before each trial. Over 4 successive days eight goats were released in a 4.2 acre pasture each day and a technician equipped with a lap-top computer counted the number of bites each animal harvested from the first 50 plants it grazed. This generated a listing of 1,600 plants and the bites harvested from each plant for a 4-day trial.

Seasonal effects of cattle grazing among newly established bitterbrush

Trials were conducted for 3 years on Bureau of Land Management property on foothill rangeland where the sagebrush and forest vegetation types come together. A wild-fire severely burned the area in 1990, and a portion of the revegetation effort was directed at reestablishing bitterbrush, a palatable shrub important to both livestock and wildlife. The vegetation was allowed 2 years to reestablish without grazing. In 1993, trials were initiated to see if grazing at different times of the year affected the cow's preference for bitterbrush or the well being of the shrubs. Levels of forage utilization were monitored by clipping 10.22 ft^2 plots before and after the cattle grazed. Utilization of the bitterbrush was documented by measuring heights and crown diameters of 25 shrubs before and after grazing, and by checking each shrub for evidence of grazing every 2 days while cattle were present. Each trial was terminated when the level of herbaceous forage utilization approached 50 percent, or 90 to 95 percent of the shrubs had been grazed.

Seasonal preferences of cattle grazing among eight grasses

Nine experimental paddocks 0.07 acres in size were established on the Northern Great Basin Experimental Range. Each paddock supported 800 plants equally divided among eight different species (100 plants of each species) planted on 2-foot spacings. Forages included: 1) Nordan crested wheatgrass, a long used and well established introduction to the region, 2) bluebunch wheatgrass, 3) Idaho fescue, 4) bottlebrush squirreltail, 5) Sandberg's bluegrass, 6) needle-and-thread grass, 7) Thurber's needlegrass, and 8) giant wildrye. Nine 2.47 acre pastures were also established with electric fences on native rangeland to evaluate cattle preferences in settings where the availability of each forage was quite variable. Three pastures and three paddocks were grazed by steers during three different phases of the growing season. The first trials occurred when grasses were vegetative (leafy with no seed stalks visible), the second when reproductive stems were fully extended and the heads were flowering, and the last when all plants had ceased growth and turned brown (dormant). Cattle diets were quantified by following each of three steers and recording every bite harvested from each grass, on a lap-top computer. We measured available forage in each setting by clipping plants or plots before each trial.

Regrowth quality and quantity in Thurber's needlegrass

One hundred fifty Thurber's needlegrass plants were transplanted to a common garden in the nursery area of the Northern Great Basin Experimental Range and allowed two growing seasons to reestablish themselves. Trials began in late April of the third- and fourth-growing seasons. At 2-week intervals, for 14 weeks, a group of eight plants was clipped to a 1-inch stubble yielding a total of seven different defoliation dates or treatments. Soil moisture was measured each time a group of plants was defoliated to see if moisture availability could be used to predict how much regrowth would occur. In both years all plants stopped growing by late July, and the regrowth was harvested from all treatments on 31 July. Regrowth samples were weighed and crude protein analyses were conducted to assess forage quality

RESULTS AND DISCUSSION

Woody plant control by Spanish goats

Among the various breeds of goats, Spanish goats are often regarded as browsers. At both stages of growth the goats exhibited a very diverse diet, utilizing 25 different species. Browse, however, was a minor component of their diet. When forages were actively growing forbs were the most prominent component of the diet (Table 1). Thread-stalk milk-vetch was most important at 28 percent. Yarrow ranked second at 17 percent, and clasping pepperweed was third at 9 percent. Roughly 28 percent of their diet came from grasses. Bluebunch wheatgrass ranked first at 9 percent, crested wheatgrass second at 8 percent, and Idaho fescue third at 5 percent. Less than 1 percent of their diet was taken from sagebrush, and slightly less than 1 percent was harvested from western juniper. Available herbage in these trials averaged 477 pounds per acre, and our pastures were stocked at a rate of approximately 1.6 goats/acre/month. After herbaceous forages were dormant, herbage production averaged 574 pounds per acre. The goats still relied heavily on forbs and grasses. Use of western juniper increased, however, to greater than 8 percent of total bites. Approximately half of these were juniper foliage and the remainder involved stripping bark from limbs or trunks of trees. Less than 1 percent of total bites were harvested from sagebrush.

Table 1. Percent of grasses, forbs, shrubs, and trees in diets of Spanish goats foraging in sagebrush/steppe rangeland pasture on the Northern Great Basin Experimental Range in 1993, near Burns, Oregon, at two stages of plant growth.

Growth stage of vegetation	Grasses	Forbs	Shrubs	Trees
Active growth	28.2	70.6	0.3	0.9
Dormant	34.7	56.4	0.1	8.8

Despite the fact that severe defoliation is capable of killing sagebrush, we see little evidence that goats will exert sufficient use on established shrubs to affect any significant mortality. Some suggested that we should have used heavier stocking rates and thus force goats into utilizing shrubs and trees. While we realize that animals can be forced onto nearly any diet in the absence of choice, the goal of these trials was to affect the woody component without severely impacting the desirable herbaceous forages. Their use of juniper when the forages were dormant implies that goats may have some potential to affect young trees, most likely by stripping their trunks of bark. In our holding pens the goats completely stripped the bark from the trunks of several large trees. There was sufficient cambium, however, in the inaccessible fissures of the trunks that the trees survived. In conclusion we see little opportunity to affect sagebrush and juniper in extensive rangeland pastures with light levels of stocking. Additional trials are required to determine if goats might be capable of controlling newly established juniper or sagebrush seedlings.

Cattle grazing of newly established bitterbrush

Cattle exhibited significant seasonal differences in their rates of use on bitterbrush. When grasses were green and growing, the cattle foraged on approximately 3 percent of the shrubs each day. Our trials at this time of year were 12 to 14 days in length, and roughly 43 percent of the bitterbrush received some degree of utilization by the time trials ended (Figure 1). In this phase of our trials we achieved a 30 to 45 percent utilization level on the grasses before cattle were removed. When the grasses were dry and dormant, the rate of shrub use by cattle was about four times higher than earlier trials. Cattle grazed on approximately 12 percent of the bitterbrush plants each day, and the trials were terminated after 6 to 8 days because nearly all of the shrubs had been utilized. In the 3 years of study, the control (ungrazed by livestock), green forage (May-June), and dormant grazed (August-September) pastures received the same treatment each year. We did not rotate our grazing treatments among the pastures. After the shrubs had been under these treatments for 3 years, there was a substantial difference in sizes of bitterbrush. The largest shrubs occurred in pastures that were grazed by cattle when the grasses were leafy and green (Figure 2). These plants averaged about 1.4 cubic feet in volume. Shrubs in control pastures, that received no cattle grazing, were about 0.7 cubic feet in volume. And bitterbrush in pastures grazed when the grasses were dormant were only about 0.1 cubic feet in volume. Wintering wildlife did have access to all of these pastures; and in some years, depending on

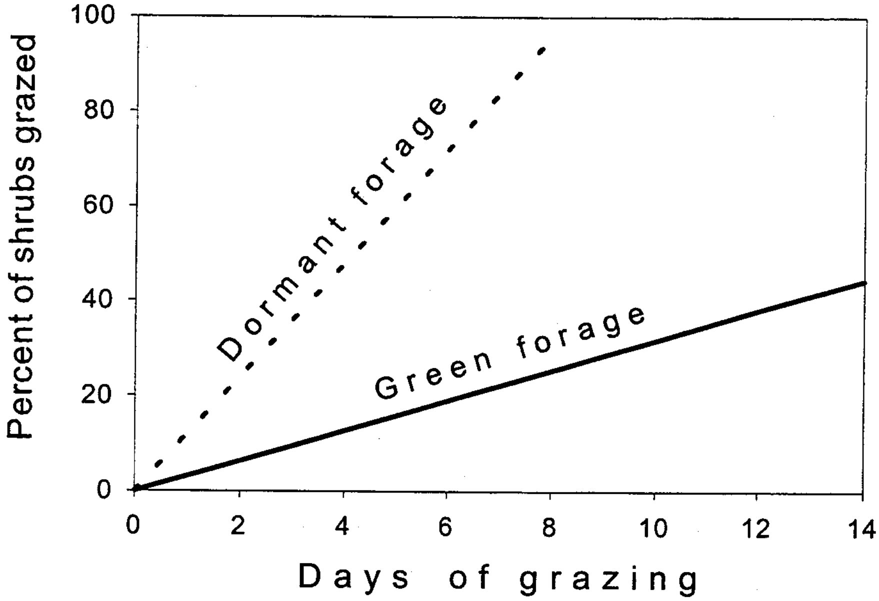

Figure 1. Percent of bitterbrush plants grazed by cattle when forages are green and growing and after herbaceous forages have gone dormant on sagebrush/forest transition range near Burns, Oregon. during 1993-1995 grazing seasons

snow pack, they did make significant use of the shrubs. On a relative scale, shrubs in pastures grazed when the grasses were green were the largest. Control and dormant grazed bitterbrush were one half and 1/12 as large, respectively.

Past research has shown that established bitterbrush is one of the few shrubs that is more productive if it is moderately browsed each year (Kituku et al. 1994). Browsed bitterbrush produces more and longer twigs than shrubs protected from grazing. This compensatory response may not occur on less productive or droughty sites, and in some years low temperatures or drought may reduce overall twig growth (Jensen and Urness 1979, Garrison 1953). Grazing trials in Utah during the early growing season have been especially successful where horses foraged among bitterbrush. Horses focus almost entirely on grasses, even with heavy stocking rates. Heavy use of the competing grasses briefly stalls grass growth and transpiration, and leaves a greater portion of the soil moisture and nutrients available for the shrubs while the grasses are initiating new growth (Urness 1981). In our trials we suspect that both the moderate use of the shrubs and the removal of leaf area from competing grasses stimulated the growth of bitterbrush. We are planning a project to investigate how moderate and heavy stocking rates affect bitterbrush in the near future.

In summary, if a manager's goal is to maximize growth and twig production of bitterbrush for winter wildlife use, we suggest that early spring cattle grazing, when grasses are green and leafy, will significantly increase plant growth over that of even protected shrubs. In addition, the leafy regrowth of the grasses may be of higher quality and also more attractive for late-season use by wildlife. Repeated spring use of a pasture can have detrimental effects on grasses, however, so a long-term management program should also include occasional growing season deferment. Cattle show more interest in bitterbrush after the grasses extend their seedheads, and appear to focus heavily on bitterbrush after the grasses have turned brown. Late-season cattle grazing can have a detrimental effect on young bitterbrush. Unmanaged cattle grazing is not recommended after grasses enter the reproductive phase of growth if newly established bitterbrush plants are present or browse is to be deferred for subsequent wildlife use.

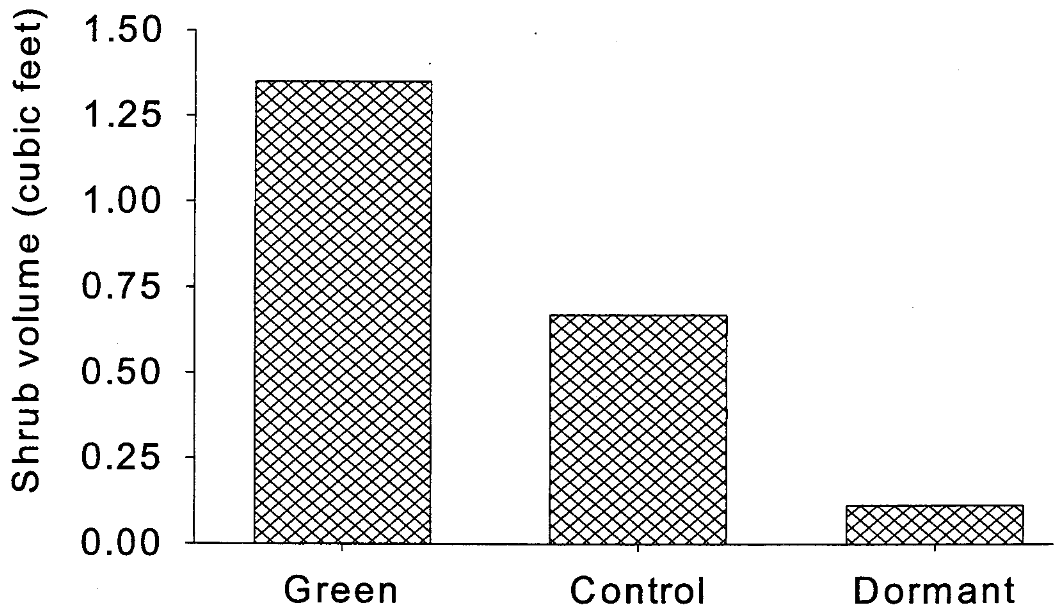

Figure 2. Volume (cubic feet) of bitterbrush on foothill rangeland near Burns, Oregon, after 3 years (1993-1995) of trials in ungrazed control pastures and pastures grazed by cattle when forages were green and leafy or dormant and brown.

Seasonal preferences of cattle for grasses

Cattle proved to be very selective in their use of grasses, especially when all were green and actively growing. In our experimental plots, crested wheatgrass was the clear favorite (72 to 90 percent of the diet) when the grasses were in the vegetative or anthesis (flowering) stages of growth (Table 2). In those same trials, giant wildrye ranked a distant second (4 to 14 percent), with no significant differences among the remaining grasses.

During our anthesis trials in the plots, we wanted to learn more about the steers' preferences for the lower ranking grasses, so we clipped all the crested wheatgrass to ground level, removed that material, and sent the steers back in. They responded by taking 51 percent of their total bites from giant wildrye, 17 percent from bluebunch wheatgrass, 16 percent from Thurber's needlegrass, and the remaining 16 percent was about equally distributed among the remaining 4 grasses. This clearly illustrated that cattle simply shift their focus to the number two choice when a preferred forage is depleted. Although the data are not shown, the steers also began to regraze crested wheatgrass plants in all of these trials well before any of the grasses were entirely consumed.

Table 2. The percent of steers' diets derived from several grasses and the percent of total forage contributed by each grass in experimental plots and native-rangeland pastures at three stages of phenology during grazing trials on the Northern Great Basin Experimental Range near Burns, Oregon, in 1993.

Stage of Phenology	bluebunch wheatgrass	Idaho fescue	squirreltail	needle-and thread	Sandberg's bluegrass	Thurber's needlegrass	crested wheatgrass	giant wildrye	prairie Junegrass
	Experimental plots steer diets (%)								
Vegetative	4.6	0.7	3.6	0.9	0.4	3.7	72.0	13.8	--
Anthesis	1.4	0.6	1.2	0.7	0.9	0.8	90.4	3.8	--
Dormant	9.4	5.9	4.8	3.1	4.1	9.7	25.8	37.1	--
	Experimental plots herbage available (%)								
Vegetative	2.7	6.1	5.1	3.0	1.6	11.1	35.5	34.8	--
Anthesis	2.1	5.9	3.0	3.4	2.3	8.3	42.8	32.2	--
Dormant	0.7	1.5	2.1	5.6	0.8	5.3	62.6	21.4	--
	Rangeland pastures steer diets (%)								
Vegetative	4.3	2.1	0.0	0.0	7.9	0.4	81.0	2.4	1.4
Anthesis	20.5	15.7	0.9	1.3	1.9	0.5	27.1	9.2	22.7
Dormant	36.8	11.0	0.3	0.0	0.4	0.5	8.5	31.3	10.1
	Rangeland pastures herbage available (%)								
Vegetative	17.8	11.7	0.7	0.0	45.5	1.4	6.4	4.8	11.1
Anthesis	28.4	11.6	1.2	0.0	32.5	2.0	0.0	3.9	20.3
Dormant	42.7	9.3	0.7	0.0	22.1	3.7	0.0	2.6	17.7

When the grasses were dormant, the cattle shifted their focus to giant wildrye in the plots, and crested wheatgrass dropped to a second place ranking. More of the other forages were used than in any of the previous trials. Looking at the proportions of herbage available in the plots one could easily argue that the steers simply focused on the most available grasses in these trials (Table 2). Crested wheatgrass and giant wildrye were clearly the most productive, collectively accounting for 70 to 80 percent of the total biomass. This argument clearly fell apart, however, when we moved the steers into the rangeland pastures. When the grasses were vegetative in the pastures, crested wheatgrass was 80 percent of the steer's diet and made up only about 6 percent of the available forage. From a steer's point of view, this was roughly the equivalent of sorting through over 1,265 plants to find 81 plants that they liked. When the grasses were in anthesis, 27 percent of their diet still came from crested wheatgrass, which we didn't even detect when we sampled available forage. Clearly the steers were seeking out crested wheatgrass. They would walk 50 to 100 yards, bypassing hundreds of other plants, to find what they wanted. Similar to the plot trials, the steers grazed from a broader array of plants when the grasses were dormant.

The primary purpose of presenting this information was to illustrate that cattle can be extremely picky grazers when they have high quality forage and the opportunity for selection. In other environments it has been observed that a few forage species often bear the brunt of the grazing load (Hurd and Pond 1958), and in many of our large but lightly stocked rangeland pastures this is often the case. Our experience suggests that if one can briefly observe animals in a representative area, he can quickly identify what the key forages might be at that time.

In closing, we suggest a number of potential management options. One is interseeding or interspersing crested wheatgrass in native rangeland pastures. The preference for crested wheatgrass might be used to lessen the grazing demands previously born by native perennials early in the grazing season. Experience has shown that such pastures must be intensively managed to prevent a build up of standing litter in the crested wheatgrass (Hilken 1984). Cattle will reject the crested wheatgrass if the plants contain a preponderance of dead stems, and out of necessity, they will again focus on the native grasses. Crested wheatgrass might also be used to encourage livestock use of less frequented regions of larger pastures. Again though, the stand should not be allowed to accumulate standing litter. Along the same lines, one might establish less palatable forages in environmentally sensitive areas to discourage persistent livestock presence. Second, if one can identify key forage species at specific times of year, especially during the early to mid growing season, livestock grazing might be used to alter the composition of a pasture by persistently affecting or avoiding a given forage. Third, our steers grazed more equitably among all of the grasses after foliage had cured. Pasture clean up of rank standing litter by cattle can probably be more easily accomplished if grazing is postponed until all the forages have cured and the animals are less selective. High stocking rates have little effect on the vigor of grasses at this time, and the animals will utilize a broader array of forages. Finally, we do not want to infer that cattle will not graze any particular forage. Given a limited selective opportunity, they will consume and do very well on many forages they do not particularly care for as long as their nutritional demands are fulfilled.

Regrowth quality and quantity in Thurber's needlegrass

Initial herbage production and regrowth quantity and quality varied substantially between years (Figure 3). In both years the earliest three or four defoliations resulted in reduced total forage yields for the growing season. Precipitation was about 77 percent of average in year one, and none of the plants defoliated after 19 June produced regrowth because soil moisture was almost entirely depleted by the plants' initial growth efforts. The greatest amount of herbage production was attained by plants defoliated on 3 and 17 July (about 220 units), and consisted

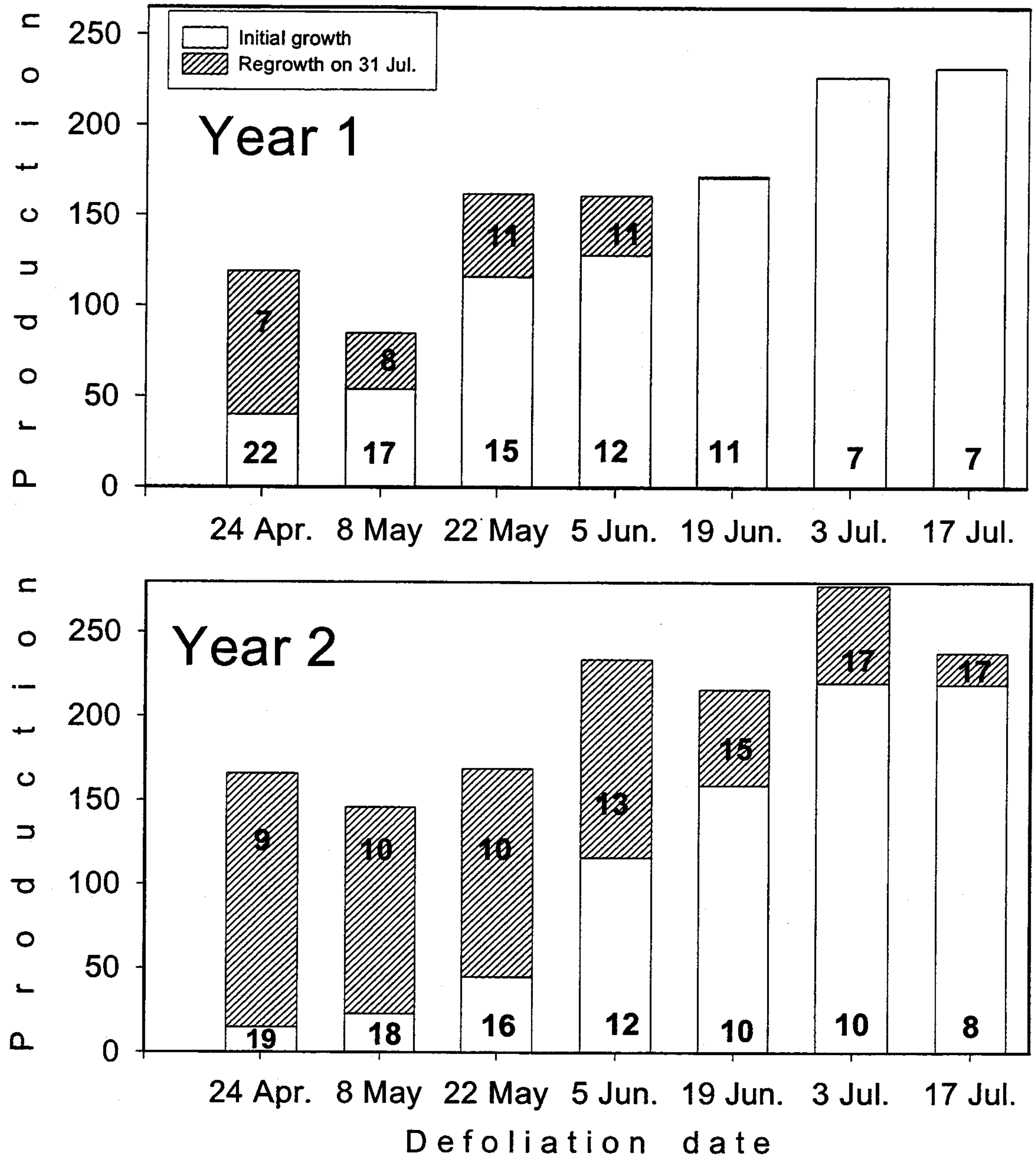

Figure 3. Biomass and crude protein content of initial growth of Thurber needlegrass harvested on seven dates during the growing season and biomass and crude protein content of subsequently produced regrowth harvested on 31 July in 1985 (year 1) and 1986 (year 2) on the Northern Great Basin Experimental Range near Burns, Oregon. Numbers within bars depict percent crude protein content of forage.

entirely of initial growth. Crude protein of needlegrass began the season at about 22 percent crude protein and declined to a marginally acceptable 7 percent level by 17 July. Regrowth was harvested from all treatments at the end of July, and the earliest defoliation dates always produced the highest amounts of regrowth. Crude protein of regrowth from plants defoliated early in the growing season ranged between 7 to 8 percent, while mid-season defoliations (22 May and 5 June) produced high quality regrowth (11 percent crude protein), but very low yields. In year 2, when precipitation was 111 percent of average, the initial growing effort of needlegrass appeared to cease around 3 July. Regrowth, however, enhanced total herbage yield for all treatments. Crude protein of the needlegrass began the season at 19 percent and declined to 8 percent by mid July. Crude protein of regrowth ranged between 9 and 17 percent, which would provide more than adequate forage for animals returning to a pasture in late July if one was using a 2-crop grazing regime.

These data suggest that early growing season grazing can be used to stimulate production of high quality regrowth. This material can cure with more than adequate levels of crude protein in late July. In dry years there may be no regrowth if grazing does not occur before early June. Also in a dry year total herbage yield from a pasture will be significantly reduced. With above average precipitation we appear to have a more flexible opportunity to stimulate production of high quality regrowth, and one may not affect total herbage yield if defoliations occur after mid-growing season. Regrowth could be used by stockmen in a two-crop grazing system to boost performance of early-weaned calves or young growing animals. Dry cows or animals needing only maintenance-level rations might continue to forage in unconditioned pastures and perform adequately on the poorer quality forage.

Given the year-to-year variability in climate, growth patterns, and regrowth potentials of Thurber's needlegrass, one should base grazing management decisions on plant phenology and knowledge of available soil moisture rather than specific calendar dates. While manipulative grazing of Thurber's needlegrass has the potential to stimulate highly nutritious regrowth for livestock or wildlife, the long-term effects of intensive 2-crop grazing regimes on needlegrass have not been studied. From a conservative standpoint, any needlegrass community exposed to a 2-crop grazing program probably should be deferred for at least one growing season afterwards. If grazed during the early-boot stage of phenology, on especially dry sites, or under droughty conditions, a longer deferment may be required. A rotation-grazing program, in conjunction with several other pastures, would probably provide the greatest potential for management flexibility. Additional studies are needed to further identify Thurber's needlegrass responses to manipulative grazing practices. Presently, we are planning a a similar project on six different forages that will begin this growing season.

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SUSTAINABLE RESTORATION

Lee E. Eddleman

Sustainable restoration as it applies to rangeland ecosystems is a difficult subject to deal with. This difficulty has less to do with achievement through the application of basic concepts and sound ecological principles, as it has to do with communication problems through indiscriminate word usage, failure to recognize the underlying assumptions (or lack of them), and expectations formed out of perceptions and desires.

One basic assumption is that rangeland ecosystems are in need of improvement and require some decision making as to the processes needed to restore them to some desired state. It is also assumed that there is a need for human intervention, at some point and to some degree of intensity, in the physical-chemical-biological make-up of the system in order to move it toward the desired state of "restored". Both additions and deletions (removal) of physical structures, chemicals, and organisms are considered part of such intervention.

If the restored community or ecosystem is sustainable it generally implies that it can maintain itself at that level without outside intervention to prop it back up. Ewel (1987) defined sustainability as the capability of the restored community to perpetuate itself without outside subsidy. Although certain types of agriculture would have difficulty meeting Ewel's definition, this kind of sustainability has been the goal in range management for many years. "Restored" is used in the definition since many plant communities that we consider degraded have the capability of sustaining themselves for long periods of time. In general, a restored rangeland ecosystem that is capable of sustaining itself will be characterized by an increasing resistance to invasion by weedy plants, productivity in balance with available resources, retention of nutrients, water and energy, and complex biological interactions above- and below-ground as well as through the seasons.

Managers of natural resource lands find the word "sustainable" fraught with problems. Firstly, what are the time and space dimensions or characteristics of sustainability for restored rangeland ecosystems? And secondly what constitutes movement away from or lack of sustainability?

With regard to the first problem we have the question of: sustainable for how long? We need to remember that all communities and ecosystems are dynamic and that change is inevitable. Nevertheless, a manager needs to resolve the time frame issue. Probably one- to a few decades is a reasonable time frame for arid and semi-arid rangelands as it would cover much (but certainly not all) of the expected environmental variation.

The space dimension is equally difficult since each plant-animal community in an ecosystem is inter-linked. For example sustainable restoration of a moist swale area in an arid ecosystem would be linked to various parts (or functional units) of the upland through inputs of water, minerals, organics and sediment. Generally tablelands at the top are source areas for water and some nutrients. Steeper slopes are flow-through areas. South slopes supply inorganic nutrients and sediment while north slopes supply organic matter, nutrients, and sustained subsurface water flow. Toe slopes, if present, are accumulation areas that act as buffers to these materials being flushed out of the system. Instead they release water, minerals, organic matter and sediment at a sustained-moderated rate into moist areas and to downstream riparian areas.

The point of this is that restoration practices focused on the moist bottom alone will not be sustainable.

Each landscape unit in a watershed has a vital role to play in the sustainable restoration of other landscape units. A landscape unit may or may not be equivalent to an ecological site, rather it is a functional concept that helps us to understand, and through management promote, proper ecosystem operation. Others consider these to be functional landscape cells (see Tongway 1994). The functional approach of landscape units is closely paralleled by the current worldwide effort in ecology to classify plants into functional groups (i.e., annual-perennial, woody-herbaceous, evergreen-deciduous, fibrous root- tap root, etc.). The *Journal of Vegetation Science* (Vol. 7, 1996) is devoted to the advances and utility of functional plant types in understanding ecosystem operation.

In addition to unit specific physical and chemical processes, biota likewise selectively use specific landscape units and deposit nutrients and seed in other units. A point here is that poorly located fence lines create problems with sustainability of restoration.

As to the second problem, monitoring changing system conditions is a necessity. An understanding of plant, soil and environment interactions, as well as succession, competition, and population dynamics of plants is very helpful. Currently developing concepts of thresholds in rangeland health are particularly useful (National Research Council 1994, Laycock 1991) "Restoration", as it applies to rangeland ecosystems would seem to be a simple concept. However, this word is used in many ways and against a backdrop of expectations. The National Academy of Sciences (1974) adopted definitions for restoration, reclamation, and rehabilitation as they applied to drastically disturbed lands (e. g., surface coal mines).

> "**Restoration**" – means the return to <u>exact</u> pre-disturbance physical-chemical-biological conditions.
> "**Reclamation**" – means the site is returned to a condition habitable by organisms in <u>approximately</u> the same composition and density as existed previous to disturbance.
> "**Rehabilitation**" – means returning the site to a structural configuration and productivity level conforming to a previously developed use plan.

Restoration relies on two underlying assumptions. The first is that we already know or can determine pre-disturbance conditions and the second is that we can return the ecosystem to those conditions. From an ecological perspective, return to exact pre-disturbance conditions is not a possibility. We always lack the necessary pre-disturbance documentation. Our pre-disturbance data are usually point-data (taken at point in time such as mid-summer etc. in one or perhaps a few years) and are usually inclusive of a limited number of ecosystem values. Range and variation in all ecosystem values, such as structural configuration, operational or functional attributes and processes of materials movement around the system, in response to daily, seasonal, or yearly environmental changes are needed but seldom if ever available. Even where ranges and variations in ecosystem values are known for a particular part of or site within an ecosystem, only a limited understanding of the interaction with or connectivity to other parts of that ecosystem will be available for our use. Finally, even if we are satisfied with our understanding of pre-disturbance conditions, how do we duplicate the pre-disturbance ranges and variations in environmental factors, such as precipitation and temperature in time and space, under which those communities developed?

Reclamation relies on the first assumption of restoration as well as an assumption that we are capable of returning the ecosystem to a functional state approximating pre-disturbance conditions. To satisfy the latter we focus our efforts on establishment of above- and below-ground structures, usually plants, similar to pre-disturbance or desired conditions and then assume that the these structures will result in similar processes. Actually the literature indicates a close linkage exists between the structural patterns produced by plants and the kinds, amounts and rates of processes.

Rehabilitation relies on the underlying assumption that a pre-planned structure and productivity for the site is achievable following disturbance. Perhaps the Berkley Pit in Butte, Montana and the smelter influenced area with its slag and heavy metals concentration near Anaconda, Montana appropriately fit the concept of rehabilitation.

The usage of the word restoration today more nearly approximates the 1974 National Academy of Sciences definition of reclamation than that of restoration. Philosophically, it may be that many people are more comfortable with the word restoration due to its god-like connotations. On the other hand, when restoration is used relative to specified ecosystem values for which we have some type of database (e. g., restoration of native bunchgrasses or restoration of soil water infiltration capacity) we approach usage in a proper way.

An appropriate example is the present effort in restoring rangelands to a sustainable level of health. The approach taken relies more on the general ecosystem attributes of structure, function and process in time and space, rather than the exactness of each and every physical-chemical-biological component and therefore is a logical step in the right direction. Not only because the approach gives present land managers reasonable latitude in the decision-making process, but because it also provides for the best on-site resource retention. Future generations of land managers have the opportunity to take restoration to the next level.

Successful approaches to sustainable restoration of rangeland health are dependent on an understanding and an incorporation of the functional links of the ecosystem into the restoration process. Individual units of the landscape within the watershed are linked or connected to each other through physical, chemical, or biological processes. This linkage may be strong or it may be weak but it will be present and the sustainability of restoration will be dependent on understanding the direct and indirect strengths of these linkages. Therefore achieving sustainable restoration necessitates that certain steps be followed. Those listed below may not be entirely new (Vallentine 1989, Briggs 1996) but need to be reiterated.

1- A whole watershed (landscape) level evaluation of conditions is needed to understand the condition of each and every landscape unit. Decline in conditions is more properly understood and restoration is best treated in a whole watershed context.

2- An assessment is needed as to the degree and nature of the decline in condition of each landscape unit. At present our best reference for this assessment are the standards developed for each ecological site by the Natural Resources Conservation Service. This assessment provides practical direction for intervention. Assessment must include vegetation and soil surface conditions at a minimum.

3- An assessment is needed as to the cause of the decline in conditions. Where land management practices have led to the decline, strategies need to be developed that will alleviate or remove the causal factors of that decline. Where livestock grazing is concerned, analysis of animal numbers distribution in time and space is a must if their role in ecosystem decline is to be correctly determined. It must also be kept in mind that environmental factors beyond human control may have led to the decline in condition. Consideration should be given to climate change and particularly to sequences of precipitation and temperature extremes that send plant communities off on new trajectories.

4- Always include watershed-level management strategies as a priority in restoration practices for a landscape unit or site.

5- In general sustainable restoration is more easily achieved by starting with the upper elevation first order watersheds and moving successively to lower elevation portions of the system. In this regard, fences, with their separation of ownership and management approach, may dictate strategies which are less than desirable.

6- Where conditions warrant the addition of plant materials (seeding, plugs, tublings, cuttings etc.) the first consideration is that species chosen fall within the proper functional groups for each landscape unit. At first glance this is simply matching the plant to the environment, but where sustainable restoration is desired those species selected must re-establish into the future those processes expected on each and every landscape unit, including the dynamic process of plant community change (succession).

   In the restoration of rangeland health, consideration should be given to native species but that consideration should be secondary to proper ecosystem function. The point here is to select proper functional groups of plant species to achieve restoration of the desired ecosystem values. There is bound to be disagreement on this issue but the multitude of species involved and the lack of seed resources create roadblocks to their use. In the extreme, Linhart (1995) suggests that "native" means that the seed source be from the same slope, aspect, soils, and not more than 300 feet from the planting site. The underlying assumption is that the genetics of a remnant population, if indeed there is one, more nearly approximates that of the pre-disturbance population than that of a less disturbed population some distance away. Such an assumption should be seriously questioned.

7- Establish a monitoring program that measures the ecosystem values being restored. If the desired value is litter, estimate the percent of the surface covered by litter. If the desired value is some minimal bare ground, estimate the amount of it relative to other components of the system. If the desired value is erect deep rooted, perennial bunchgrasses, count the adults and seedlings on a specified area, say 10 sq. ft., and estimate the square feet of surface they cover. If the desired value is precipitation infiltration, measure depth of water penetration into the soil after a storm which has been preceded by a dry period and do so on a variety of landscape units. The point is to make measurements simple, direct, and repeatable and accompany the measurements with photographs.

In summary, sustainable restoration is dependent on a whole-watershed approach where considerable thought is put into the interaction of various landscape units in the watershed. Most importantly, there is no substitute for looking and thinking followed by asking questions. Finally sustainable restoration must include monitoring, followed by adjustment, adaptation, and change in management strategies if it is to be successful over the long-term.

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Fire History and Juniper Expansion in Southeastern Oregon

Rick Miller and Jeff Rose

INTRODUCTION

A statement we frequently take for granted is: " postsettlement expansion of juniper woodlands in the West is primarily attributed to the introduction and overstocking of livestock, the reduced role of fire, and optimal climatic conditions during the late 1800s." However, only a handful of studies have documented the mean fire intervals in the sagebrush steppe biome, and few if any have evaluated the chronosequence of the introduction of livestock, the reduced role of fire, and climatic conditions with the initiation of postsettlement woodland expansion.

Expansion of western juniper *(Juniperus occidentalis)* sagebrush steppe communities in the interior Northwest U.S. coincides with Euro-American settlement (Burkhardt and Tisdale 1976, Young and Evans 1981, Miller and Rose 1995). Pinyon-juniper woodlands have also expanded during this period in Utah and Nevada (Tausch and West 1988). The current expansion of woodlands is unparalleled in previous expansions, over the past 6,000 years (Miller and Wigand 1994). Presettlement expansions occurred during cool wet periods while the current expansion is occurring during a warmer drier period. Tree densities are currently higher than they were during past Holocene expansion, based on juniper pollen expansion.

The recent expansion in western juniper began during the late 1800s (Young and Evans 1981, Eddleman 1987, Miller and Rose 1995). The majority of present day woodlands are less than 100 years old (USDI-BLM 1990). Relict *Juniperus* woodlands, historical documents and photographs, pollen and macro fossil data, and the absence of stumps or logs in mountain sagebrush communities indicate presettlement woodlands were considerably less abundant in the West. Old trees are primarily confined to rocky surfaces or ridges with sparse vegetation (West 1984, Miller and Wigand 1994, Miller and Rose 1995). Trees in these locations have the ability to survive up to 1,000 years (Miller, R.F. unpublished data).

Fire is thought to have played an important role in shaping sagebrush steppe communities and limiting the expansion of juniper in the Intermountain West prior to Euro-American settlement. In the semiarid region of the Intermountain Northwest, presettlement mean fire intervals between 15 to 25 years have been reported for the mountain big sagebrush community type (Houston 1973, Burkhardt and Tisdale 1976, Martin and Johnson 1979). However, during the last 100 years the role of fire has greatly declined in these ecosystems. The decline in fire has been attributed to the reduction in fine fuels through heavy livestock grazing in the late 1800s and the fewer fires set by Native Americans during the nineteenth century (Burkhardt and Tisdale 1976, Miller et al. 1994).

Optimal climatic conditions during the late 1800s and early 1900s may have also interacted with the reduced role of fire and overgrazing by domestic herbivores to accelerate the rate of western juniper expansion into shrub steppe communities. During this period, winters became more mild and precipitation increased above the current long-term average conditions (Antevs 1938, Graumlich 1987), which promotes vigorous growth in western juniper.

sagebrush community type; and 3) determine the proportion of large to small fires and evaluate their relationship to growing conditions in years preceding fires. We hypothesized that postsettlement western juniper woodland expansion was synchronous with the introduction and overstocking of domestic livestock, changes in mean fire intervals, and optimal climate conditions for plant growth.

METHODS AND STUDY AREA

Study Area

The study area is located within the Fremont National Forest in the upper Chewaucan River Basin, 8 km south of Paisley, Oregon (Figure 1). The study unit encompasses 12,000 acres. Vegetation on moderate to moderately deep soils is characterized by mountain big sagebrush with Idaho fescue dominating the north aspects and Thurber needlegrass dominating the south aspects. The low sagebrush / Sandberg bluegrass community type occupies the shallow heavy clay soils. Associated with these plant communities are juniper trees in varying levels of density. The long-term average precipitation is approximately 15 inches.

Introduction of livestock occurred in the late 1860s in the Chewaucan River Basin (Oliphant 1968). By November of 1873, approximately 4,000 cattle were reported in the lower river basin with several thousand sheep moving in the following year. During the next five years livestock numbers increased rapidly and peaked at the end of the nineteenth-century. Since 1915 sheep have declined on the forest from nearly 400,000 AUMs (animal unit months) to less than 1,000, while cattle numbers have declined about 30 percent. The U.S. Forest Service office in Paisely was established in 1908, which marks the beginning of fire suppression in the study area.

Plant community measurements

Two hundred and fifty points were randomly selected and surveyed in the study area. The major community type (dominant shrub and perennial grass), percent slope, aspect, elevation, stage of transition (Table 1), and presence or absence of presettlement juniper, old stumps, and logs were recorded. Twenty-five plots were chosen for intensive measurement through a selected random sample to represent the two major community types, low sagebrush and mountain big sagebrush, in various stages of woodland transition.

In 25-circular plots juniper density, height, and canopy cover were measured with a radius of 66 ft in mountain big sagebrush and 99 ft in low sagebrush communities. All juniper trees were counted and recorded in 1m height classes. Presettlement trees were also recorded. Tree canopy cover was estimated and all trees were cored or cross-sectioned within each plot for aging. The number of standing dead, stumps, and logs were also recorded for each plot.

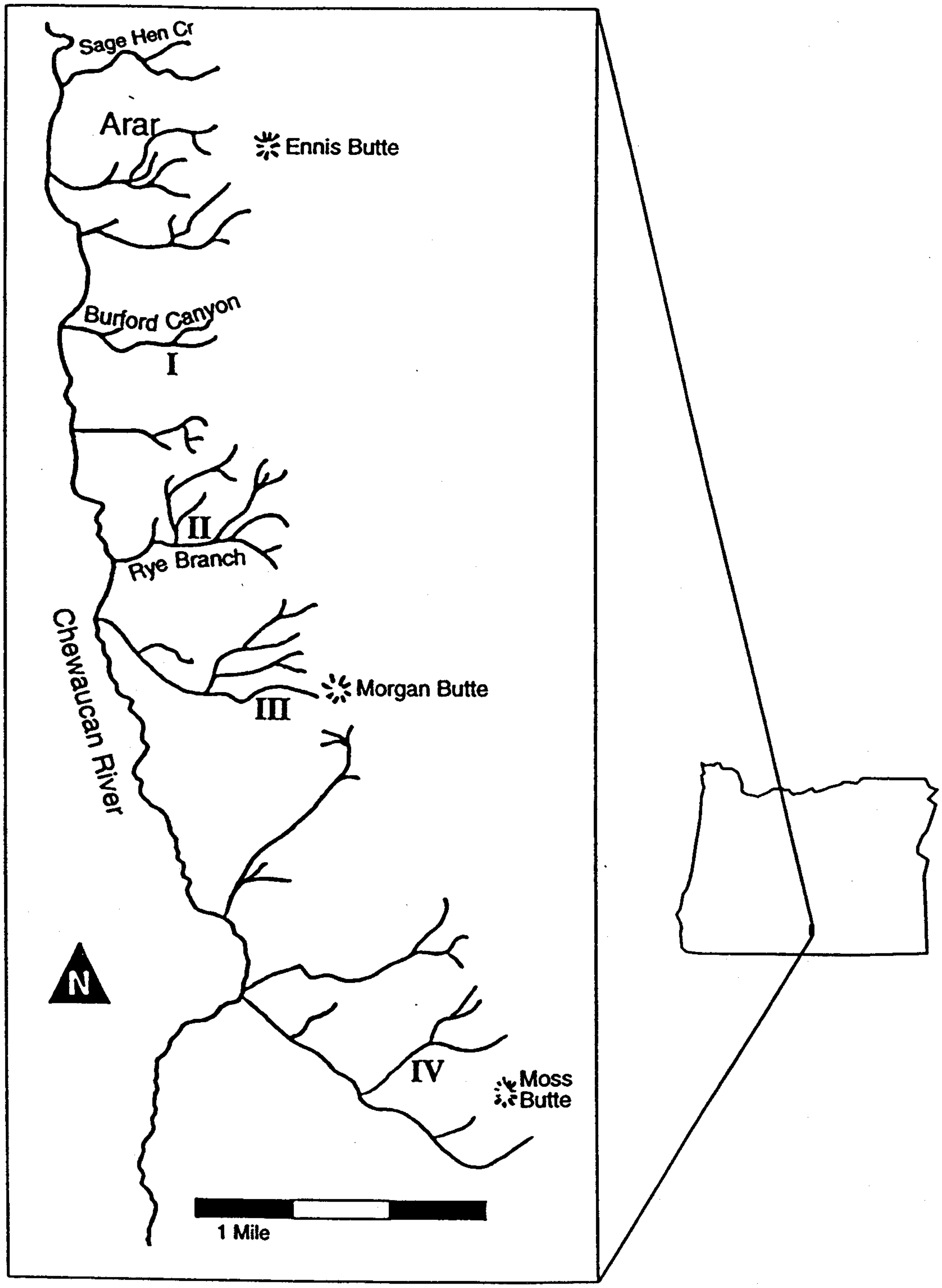

Figure 1. Map of the study area and locations of the four fire scar collection sites, I - IV, and the low sagebrush site, Arar.

Table 1. Characteristics of transitional stages during succession from mountain big sagebrush steppe communities to fully developed juniper woodlands. Chewaucan Basin, Oregon.

Characteristics (Post Settlement Stands)	Early	Mid	Late	Closed
Tree Canopy	Open, actively expanding cover ≤ 5%	Actively expanding, cover 6 to 20%	Canopy expansion greatly reduced, cover 21-35%	Canopy expansion stablized, cover > 35%
Leader Growth (Dominant Trees)	Good terminal & lateral growth	Good terminal & lateral growth	Good terminal growth, reduced lateral growth	Good to reduced terminal growth, lateral growth absent
Crown Lift (Dominant Trees)	Absent	Absent	Lower limbs beginning to die (for productive sites)	Present (for productive sites)
Potential Berry production	Low	Moderate to High	Low to Moderate	Scarce to Low
Tree Recruitment	Active	Active	Reduced, limited primarily to beneath trees	Absent
Growth (Understory Trees)	Good terminal & lateral growth	Good terminal & lateral growth	Greatly reduced terminal & lateral growth; reduced ring growth	Absent, some mortality restricted ring growth
Shrub Layer	Intact	Nearly intact to showing mortality around dominant trees	≥ 40% dead	≥ 85% dead

Fire History

A limited number of small clusters of presettlement ponderosa pine trees are scattered across the study area. Four of these sites contained fire-scarred ponderosa pine trees. Fire history was documented by collecting partial cross sections from three scarred trees within three sites: I, III, and IV, and one cross section from site II (Figure 1). Fire-scarred ponderosa pine trees ranged in age from 275 to 590 years. Cross sections were cross-dated to assign accurate dates to each fire occurrence. Seasonality of fires was estimated from the relative position of the fire scar within the annual ring. Fire events in the low sagebrush Sandberg bluegrass type were documented by collecting charred juniper stumps and logs on several sites in the Ennis Butte Basin (Figure 1). Tree ring indices 2 years prior to, and the year of fire occurrence, were compared to evaluate growing conditions preceding and during the year of fire.

Definitions (derived from W. Romme 1980)
Mean fire interval - average time between fires for a designated area during a designated time period; the size of the area and the time period must be specified.
Fire occurrence - one fire event within a designated area during a designated time.
Fire frequency - the number of fires per unit of time in a designated area; the size of the area must be specified.
Fire chronology - a chronological listing of the total fires documented for a designated area, the dates being corrected by cross-dating.
Cross-dating - correcting the chronology determined from an individual tree ring sample by comparison with a master tree-ring chronology developed for the area.

RESULTS

Juniper Expansion

Western juniper initiated expansion between 1875 and 1885 in the Chewaucan River Basin (Figure 2). Tree establishment increased rapidly during the following decades. In the mountain big sagebrush community type, rate of expansion peaked in 1915 with generally constant establishment in the open stands through 1995, with the exception of 1935-1945 (Figure 3). The decline in tree establishment during this period may be the result of the severe drought conditions during the 1930s. Mean age of trees across the study area is 68 years. Presettlement trees (>130 years) across the study area accounted for less than 1 percent of the total population. The absence of old stumps, logs, and charcoal suggest that presettlement trees have not occupied this community type in the recent past. Woody material may persist in this environment for over 130 years. In the low sagebrush community type, approximately 1.5 percent of the juniper trees measured were greater than 130 years old with several trees sampled exceeding 500 years.

Tree density and canopy cover in closed stands were 4-times and 8-times greater, respectively, than the open juniper shrub steppe stands (Table 2). Saplings were fairly common in open stands, but absent in closed stands. Expansion of juniper in open and closed stands across community types began during the same period. However, age-class distributions were different between the closed stands in the mountain big sagebrush types and the open mountain big sagebrush and low sagebrush community types (Fig. 3). Juniper establishment in the closed stands peaked during 1905 to 1915, with 78 percent of the trees establishing between 1885 and 1925 (Figure 3).

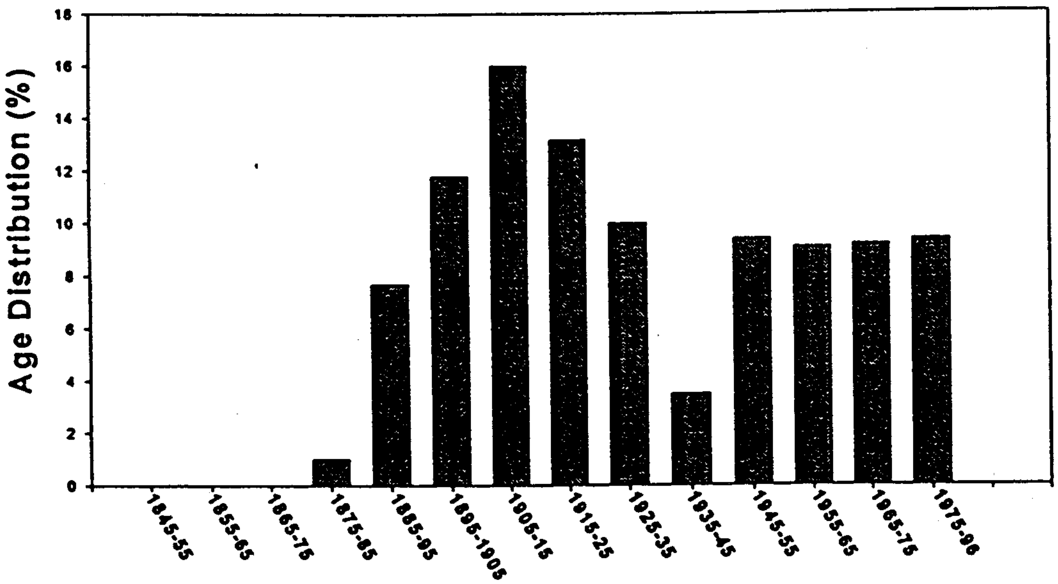

Figure 2. Age structure of juniper trees in the Chewaucan study area.

Fire History

The fire record spans 1520 to 1996, and includes 26 fire occurrences in the study area. Prior to 1903, the mean fire interval for the study area was 11.4 years. All scars occurred late in the termination of tree ring width development, indicating late summer and fall fires. Between 1632 and 1903, years between fire occurrences within the study area ranged from 4 to 23 years (where number of trees sampled was ≥ 2). Mean fire intervals within individual sample sites with two or more trees sampled ranged from 16.3 to 22.4 years prior to 1903 (Table 3). The range of years between fire occurrences within sample sites (where $n \geq 2$) was 10 to 37 years.

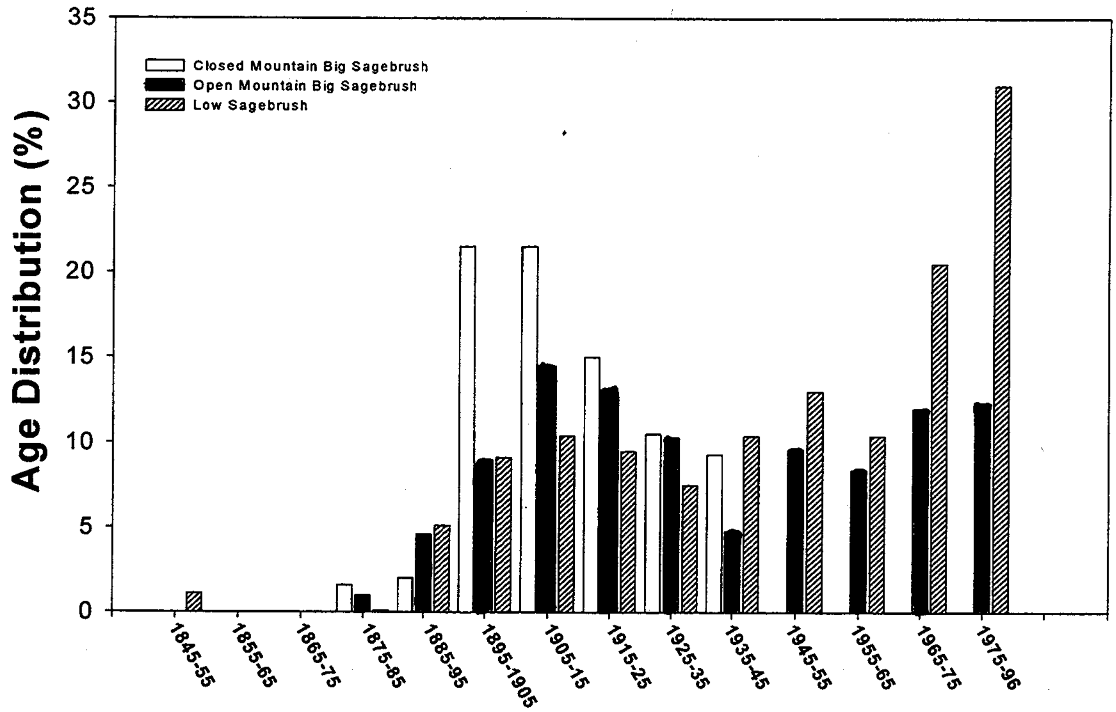

Figure 3. Age structure of juniper trees by decade for open low sagebrush and mountain big sagebrush, and closed mountain big sagebrush, Chewaucan Basin, OR.

Table 2. Stand characteristics of open and closed western juniper stands in mountain big sagebrush and low sagebrush communities types, Chewaucan Basin, OR. Mean age followed by a different letter are significantly different at P≤0.05; other characteristics were not compared statistically.

	Mountain Big Sagebrush open	Mountain Big Sagebrush closed	Low Sagebrush open
Mean age	62.6±14.1[a]	86±7.8[b]	63±19.8[b]
Median	65	85	65
Age Range	2-106	8-146	2-176
Sapling Acre^{-1}	6.5	0	5
Trees Acre^{-1}	45	185	51
Ave Tree Cover %	5	40	5

Table 3. Mean fire intervals and ranges between the first and last recorded fire, and sample sized for the individual sample sites, Chewaucan Basin, OR. Time periods in each site when sample size is ≥2 are: I - 1783 to 1996, III - 1687 to 1996, and IV - 1632 to 1996.

Site & Time Period	Fire Interval Mean	Fire Interval Range	#Samples
I 1783-1870	17	14-26	3
II 1654-1870	27	12-54	1
III 1654-1903	22	10-37	3
IV 1520-1889	16	10-33	3

Nearly half of the fires between 1654 and 1903 were large burns (Figure 4). Charcoal samples indicated the large fire in 1855 extended across the low sagebrush-Sandberg bluegrass community type in the Ennis Butte Basin. This was the most recent fire where evidence was found in all four sites. The last large fire occurred in 1870 and was followed by only two small fires, the last in 1903. During the following 93 years none of the 10 fire-scarred trees sampled were further marked by fire.

In the Chewaucan River basin, 70 percent of the large fires after 1700 were preceded by 2 years of above-average tree ring growth. All but one of the large fires were preceded by at least one above-average tree ring growth year, and none were preceded by a year with below average tree ring growth. Seventy-one percent of the large fires occurred in a year with moderate-to-below average tree growing conditions. Smaller fires were more difficult to predict from tree ring growth.

CONCLUSIONS

Western juniper chronology in the Chewaucan River Basin clearly showed major structural change across sagebrush community types since 1875. The most rapid period of establishment occurred between 1885 and 1925, a period of wetter than average conditions. Prior to 1875, fire played a major role in limiting juniper encroachment into these sagebrush communities. Mean fire return intervals of less than 22 years probably would have also limited the cover of sagebrush and allowed the herb layer to dominate the landscape. The time sequence of wet climatic conditions, introduction of livestock, and the reduced role of fire, support the thesis that these factors contributed to the postsettlement expansion of western juniper. All fires recorded were late summer or fall burns and nearly one half of the fires were large. Large fires generally followed 2 years of greater than average growth. The wetter than average conditions in the late 1800s and early 1900s should have promoted fire. However, high densities of domestic livestock during this period reduced fine fuels in the river basin to very low levels.

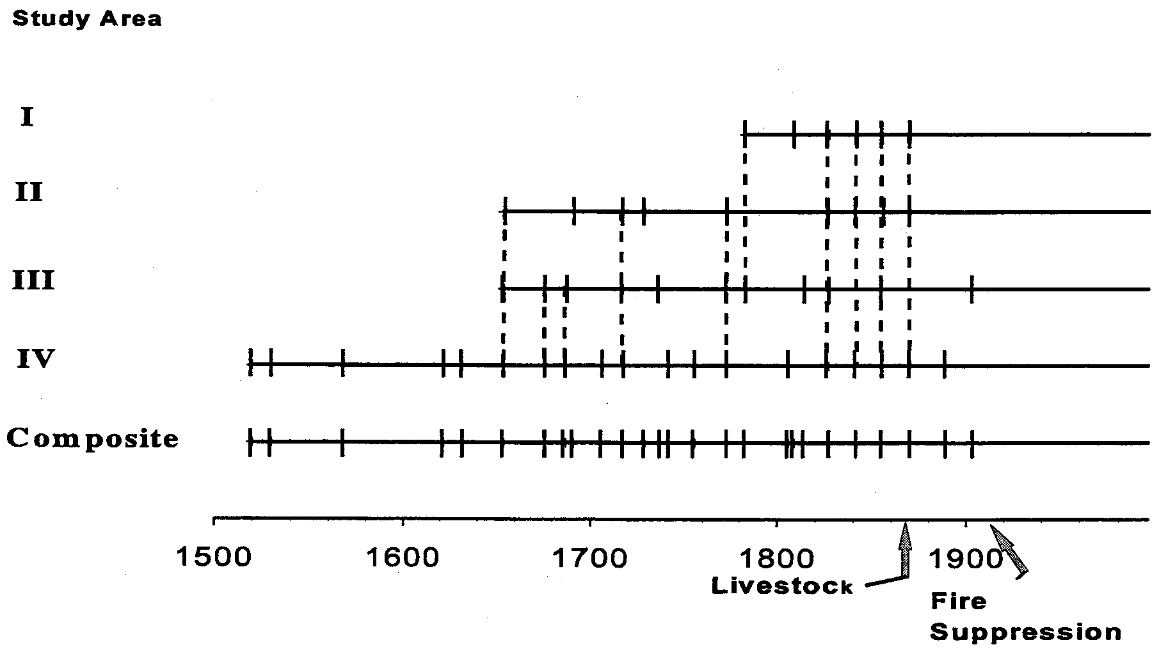

Figure 4. Master fire chronology for the *A. tridentata* ssp. *vaseyana* community type in the upper Chewaucan River basin. Fire history extends from 1520 to 1996. Each horizontal line represents a sample composite for each collection site with the bottom line being a composite for all fire scar samples across the four sites. Each vertical line designates a fire occurrence. Dashed lines connect collection sites where fires occurred in the same year.

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The Rangeland Carbon Flux Project

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INTRODUCTION

Global Change

The interest in and concern over climate change has never been greater than it is currently. In spite of extensive research, there is still considerable uncertainty about future global change. We know from long-term measurements (1958 to present) at the Mauna Loa Observatory in Hawaii that atmospheric CO_2 concentrations have been increasing at about 1.5 ppm per year (Amthor 1995). Atmospheric CO_2 levels are projected to double from current levels during the next century. However, the predictive capabilities of current global change models is open to debate. Rastetter (1996) has argued that models of ecosystem response to changes in climate and atmospheric CO_2 cannot be rigorously tested, and therefore fall outside the realm of science. Indeed, the complexity of most natural ecosystems makes modeling difficult even if climate is constant.

For most natural ecosystems, competition among plant species is a major factor influencing the structure and function of these systems. The bulk of research on plant response to increasing CO_2 has focused on responses of individual species (Diaz 1995). This author points out that predictions based on single-species experiments often do not match the behavior of multi-species assemblages (Diaz 1995). There has been CO_2 enrichment work on native rangeland ecosystems (e.g., Owensby et al. 1993); however, the research is expensive and difficult to conduct over long time frames. Most studies have compared plant responses under current ambient and twice ambient CO_2 levels. The results are useful and provide interesting insights into CO_2 effects. However, questions remain about the response of plants and ecosystems to an immediate doubling of CO_2 compared to the gradual steady increase that has and will continue to occur.

Even if we don't worry about future changes, there has been difficulty explaining the global carbon cycle under current conditions. Sources of CO_2 (burning of fossil fuels, tropical deforestation) should be balanced by CO_2 sinks (oceans, atmospheric, and terrestrial biosphere). However, there is a substantial "missing sink" (Schimel 1995) that is still unaccounted for. Gifford (1994) has suggested that vegetation may already be responding to increased atmospheric CO_2 and thus is storing more C in soil and biomass than is being predicted.

Rangelands

Rangelands and grasslands combined constitute over 40 percent of the Earth's land surface (Stafford Smith 1995). In the U.S., rangelands and pasturelands are 34 percent and 10 percent, respectively of the total land surface (Barnes and Baylor 1995). Rangelands will certainly be influenced by changes in climate and atmospheric CO_2, and because of their global importance, rangelands may in turn influence atmospheric CO_2 and climate. Glenn et al. (1993) indicated that much of the Earth's arid rangeland is in need of improved management. They suggest that restoring arid rangeland may be a cost-effective method of sequestering atmospheric CO_2. The increasing CO_2 levels have the potential to increase plant productivity and as a result there may be more transfer of C from plants to soil (Amthor 1995). Lutze and Gifford (1995) suggest that grasslands have been responding to increasing CO_2 and may constitute a substantial part of the missing C sink. A number of studies suggest that permanent vegetation (rangelands, pastures, and forests) may be a considerable sink for C (Barker et al. 1996, Dixon et al. 1994, Ojima et al. 1993). However, the land must be in good condition if effective sequestration is to be expected (Glenn et al. 1993). In the U.S., permanent vegetation covers 73 percent of the land area (Barnes and Baylor 1995).

Impacts on Agriculture

What effects might we expect climate change and increasing CO_2 to have on agriculture? Sage (1995) has argued that immediately after the Pleistocene and atmospheric CO_2 was too low (about 200 ppm) to support the level of productivity necessary for successful establishment of agriculture. He suggests that the rise in CO_2 from below 200 to about 270, which occurred between 12,000 and 15,000 years ago was a prerequisite for agriculture. If he is correct, clearly CO_2 levels have impacted agriculture in the past, but what of the future? Hanson et al. (1993) used three general circulation models (GCMs) to simulate the effects of changing CO_2 and climate on rangeland livestock operations in the Great Plains. Unfortunately, the results were dependent on the specific GCM they used. In general, the results indicated there may be more forage production, but lower forage quality and thus decreased animal production under the climate change scenarios. The authors point out that management will influence animal production. Current knowledge may allow livestock producers to adapt to changes, if the changes can be clearly distinguished.

Research Approach

There are several potential research approaches that can be used to help elucidate responses to changing CO_2. Each approach will have strengths and weaknesses. Studying responses in elevated CO_2 environments provides important insights into what we might expect in the future. However, because of the expense and difficulty of this type of research, it is often focused on single species and is rather short-term in nature. There is also the question of whether responses to immediate increases in CO_2 will be comparable to gradual long-term increases. Models are valuable and allow researchers to compare different scenarios. Unfortunately, there is no rigorous way to test and validate the ecosystem-level climate change models. In fact, it has been suggested that the modeling approach falls outside of science because tests are not possible (Rastetter 1996).

An alternate approach is to do intensive CO_2 flux research at a variety of sites to define the current situation. The research will help provide answers about the global carbon cycle as it exists today, and will serve as a baseline for future evaluation. With the current rate of change of atmospheric CO_2 at 1.5 ppm per year, there will be a 15 ppm change in only a decade. The precision of current instrumentation will allow detection of subtle shifts in both CO_2 fluxes and sequestration of C in plant and soil pools. Rastetter (1996) suggested that responses to continued changes in climate and CO_2 in the future will likely be sufficient to be detectable with current technology. The sort of ecosystem-level approach we propose here will provide information useful beyond just assessment of global change impacts. A full understanding of rangeland structure and function will be important in assessing rangeland health and implementing ecosystem management. Decisions about management require an understanding of how a system functions.

STUDY DESIGN

Scientists at a dozen ARS locations across the central and western U.S. have established a coordinated plan to directly measure rates of CO_2 exchange between the atmosphere and rangeland vegetation. The locations represent most major rangeland ecosystems of the U.S. (Table 1). The larger part of the project is based on Bowen-ratio technology. The Bowen-ratio unit looks very much like a portable weather station, but the systems are instrumented with infrared gas analyzers that allow us to evaluate fluxes of both CO_2 and H_2O. The units have two arms that draw in air just above the plant canopy and at about 1 m above the canopy. An energy-balance approach is used to calculate fluxes of CO_2 and H_2O at 20 minute intervals continuously. The units can operate the entire growing season, but there are problems with winter measurements at some of the colder locations.

At each location we measured an array of variables that will help characterize each specific rangeland. Carbon and nitrogen pools were measured in soils, aboveground vegetation, roots, and litter. We also measured microclimate, soil moisture, leaf area index, plant species composition, and plant biomass.

The participating locations span the western U.S. and encompass a wide diversity of rangelands (Table 1). Some locations are also using 1 m^3 chambers and portable photosynthesis systems to measure CO_2 flux on small plots. The small-plot work allows comparison of specific treatments, such as grazing or burning, or comparison of different species and plant communities. The Bowen-ratio and chamber measurements are conducted in close proximity to each other, which will also allow a comparison of techniques.

RESULTS-TO-DATE

For some locations 1996 was the second complete year of data collection, but every location now has at least one growing season of CO_2 flux data. Most locations have completed the descriptive measurements although some analyses remain to be done.

EXPECTED OUTCOME

There are a number of major questions we hope to answer with the results of this project:

1. What role do U.S. rangelands play in the carbon cycle? Are they a sink for

atmospheric CO_2?
2. Is CO_2 flux correlated to climatic or ecosystem characteristics, and are the relationships strong enough to allow extrapolation?
3. What role do specific land management activities, such as grazing and burning, have on rangeland CO_2 flux?
4. Do direct measurements of CO_2 flux provide an accurate assessment of primary productivity?

Because of the extensiveness of the project there are also many ancillary benefits of the data sets. The descriptive comparisons of the various ecosystems will be useful to land managers, policy-makers, and modelers. In the past, there have been few studies that employed consistent sampling techniques to compare diverse rangeland ecosystems.

The data will also serve as an important baseline against which to judge future measurements of CO_2 flux. Many of the ARS land bases already have extensive long-term data sets on climate, soil moisture, plant species composition, and productivity. Given that rangelands are generally evaluated based on species composition, it will be necessary to identify species changes that are a result of climatic or CO_2 change. The type of data collected from this project will be critical in guiding future evaluation of our nation's rangelands.

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Table 1. ARS locations involved in CO_2 flux network.

Location	Rangeland type	Technology in use
Burns, OR	arid sagebrush steppe	Bowen-ratio; chambers
Du Boise, ID	mesic sagebrush steppe	Bowen-ratio
Logan, UT	mesic sagebrush steppe	Conduct chamber studies at Du Bois
Tucson, AZ	desert grassland	Bowen-ratio
Las Cruces, NM	desert grassland	Bowen-ratio
Ft. Collins, CO	C_4-dominated shortgrass prairie	Bowen-ratio; chambers
Cheyenne, WY	C_3-dominated shortgrass prairie	Bowen-ratio; chambers
Miles City, MT	arid midgrass prairie	Bowen-ratio; chambers
Mandan, ND	mesic midgrass prairie	Bowen-ratio
Woodward, OK	arid tallgrass prairie	Bowen-ratio
El Reno, OK	mesic tallgrass prairie	Bowen-ratio
Temple, TX	mesic southern tallgrass prairie	Bowen-ratio