Management strategies for optimal grazing distribution and use of arid rangelands[1,2]

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ABSTRACT: Application of existing and novel management techniques can alter traditional livestock grazing patterns and significantly improve the sustainability of arid rangelands. Livestock often congregate and heavily graze riparian areas and other sensitive rangeland, while abundant forage remains in other areas. Increasing the uniformity of grazing can help protect fisheries, wildlife habitat, and other vegetative and watershed resources. For years, managers have improved grazing distribution in extensive arid pastures by developing new water sources. In addition, strategic supplement placement can be used to lure cattle to graze areas that typically receive little use. Placement of low-moisture molasses blocks in steeper areas that were far from water increased forage use by 14% at distances up to 600 m from supplement in foothill rangeland. Recent research has examined the potential of breed and individual animal selection to improve grazing distribution patterns. Cattle breeds developed in mountainous terrain utilize rugged rangeland more uniformly than breeds developed in more gentle terrain. In pastures that were grazed by cattle identified as "hill climbers" (previously observed on rugged terrain), more residual vegetation was left on gentle slopes and areas closer to water than in pastures grazed by cattle identified as "bottom dwellers" (previously observed on gentle terrain near water). Cattle may use rugged rangeland more uniformly after weaning and during periods when temperatures are more moderate and the forage is more homogeneous (spring, early summer, and autumn). Herding shows great promise for protecting sensitive rangeland. Preliminary data show that residual riparian forage in pastures where livestock were herded was up to two times higher than in a control pasture. The integration of herding and strategic supplement placement seems to be more effective than herding alone. Many concerns associated with the sustainability of grazing on arid rangelands can be resolved by manipulating livestock grazing behavior through management.

Key Words: Beef Cattle, Behavior, Distribution, Grazing, Selection, Supplementation

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Introduction

Many concerns with livestock grazing in arid rangelands are the result of uneven grazing distribution. Pastures in the western United States are often large because of lower forage production and rough topography. In extensive and rugged pastures, livestock may need to travel long distances from water and up steep slopes to reach all available forage. Typically, cattle graze areas with gentle terrain near water more heavily than rugged terrain or areas far from water (Valentine, 1947; Cook, 1966). Cattle often prefer riparian areas and spend a disproportionate amount of time in these areas as compared to uplands (Smith et al., 1992). However, concentrated grazing, especially in riparian zones, may reduce vegetative cover and stream bank stability as well as increasing soil erosion (Kauffman et al., 1983).

Managers can increase uniformity of grazing and protect sensitive rangeland by changing attributes of the pasture or by modifying animal behavior. Most of the strategies currently used to improve grazing distribution have been known for over 45 yr (Williams, 1954). Water developments, salting, and fencing have been used successfully to improve livestock grazing distribution on both private and public lands. However, grazing distribution continues to be a major problem in the western United States (Holechek et al., 2001). Rangeland livestock producers and land managers are often reluctant to implement management to resolve concerns associated with localized overgrazing because of the high costs of some strategies. Innovative and cost-effective approaches to improve livestock grazing distribution are needed. Managers need more information on

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the effectiveness of distribution practices to determine whether implementation on a site-specific basis is economically beneficial (Stillings et al., 2003). The objective of this paper is to summarize the potential of new and existing grazing distribution strategies to resolve various resource concerns in arid rangelands.

Strategies That Change Pasture Attributes

Water Developments

Livestock are often reluctant to travel long distances to water (Valentine, 1947). For sustainable grazing, Holechek et al. (2001) concluded that calculated stocking rates for areas between 1.6 km and 3.2 km from water should be considered as half the value of areas less than 1.6 km from water; moreover, areas further than 3.2 km from water should be considered ungrazable. In mountainous terrain, vertical distance to water may be more important than horizontal distance to water (Roath and Krueger, 1982). In extensive arid pastures, availability of water is limited and areas far from water may not be grazed as heavily as areas close to water. Development of new water sources in areas that are further than 1 km from existing water sources usually increases forage use nearby and improves the overall uniformity of grazing. Cattle grazing patterns changed abruptly when the location of water was changed in eastern Oregon pastures (Ganskopp, 2001).

Water developments have also been useful for protecting riparian areas. Porath et al. (2002) found that providing an off-stream water source decreased grazing pressure in the riparian zone, especially early in the grazing season when forage was plentiful. The researchers also found that providing off-stream water improved cow and calf weight gains. In another Oregon study conducted in the fall, Miner et al. (1992) observed that cows spent an average of 25.6 min/d in the stream when it was the only source of water. However, if an off stream tank was available, cows spent only 1.6 min/d in the stream.

New water sources are usually created by drilling wells, constructing ponds, building pipelines, or developing springs. These require a substantial capital investment. If the new water source allows sufficient forage to be harvested on a sustainable basis, the cost of construction would be justified. Workman and Hooper (1968) estimated that a new water development would annually provide 85 to 150 additional animal unit months (**AUM**) of forage. However, their estimate was based on the results obtained from one site in mountain rangeland. Development of off-stream water combined with strategic salt placement was economically beneficial for ranches with riparian grazing concerns (Stillings et al., 2003). Holechek (1992) estimated that providing water sources at intervals more frequent than 4 km would not be cost effective in arid rangelands. The conditions at each ranch and in each pasture are unique and analyses should be done on a site-specific basis.

Shade Structures

Livestock usually congregate in riparian areas during mid-day when temperatures are high (Porath et al., 2002). The shade that is often available in riparian areas may be part of the reason why they prefer these locations. For example, cows preferred to rest under trees during the hot periods in California foothill rangeland (Harris et al., 2002). In northeastern Nevada, Davison and Neufeld (1999) built structures to provide shade for cattle with the goal of reducing the time cattle spent in riparian areas. Cattle used the shade structures, but their construction did not significantly reduce cattle use of riparian areas. Providing shade structures increased live-weight gains of steers during the summer in Oklahoma (McIlvain and Shoop, 1971).

Fencing

Fencing is a direct method of altering livestock grazing patterns. Sensitive areas can be separated from other areas and managed differently. Bailey and Rittenhouse (1989) recommended fencing areas with similar forage and/or topography together to increase uniformity of grazing. Cattle often alternate among similar feeding sites in relatively homogeneous pastures (Bailey et al., 1990). In heterogeneous pastures, where forage quantity and quality are more variable, animals can select productive sites more frequently and avoid less-productive sites (Bailey, 1995). By grazing productive sites more often, cattle were able to spend more time in areas where there were greater quantities of higher-quality forage. Strategically placing fences could prevent livestock from choosing among diverse feeding sites and concentrating grazing in localized areas. For example, cattle are more likely to graze slopes uniformly if gentle terrain is not enclosed with rough terrain. If riparian areas are fenced separately from uplands, both types of terrain may be grazed more uniformly.

Stocking density has been suggested as a tool for increasing uniformity of grazing (Savory, 1988). Higher stocking densities are typically obtained by using fencing to create smaller pastures and rotating animals between pastures more frequently. It is important to separate the effects of stocking density (animals per hectare) from stocking rate (animals·hectare^{-1}·unit time^{-1}). Cattle will use steeper slopes and higher elevations and will travel further from water as the grazing season progresses and overall forage utilization increases (our unpublished data). Senock et al. (1993) reported that a 10-fold increase in stocking density (0.6 to 7 heifers/ha) improved uniformity of grazing in small pastures (33 to 35 ha) where the forage was almost a monoculture. In a Nebraska study with very small pastures (<1.5 ha), stocking density did not affect uniformity of grazing at similar stocking rates (Burboa-Cabera et al., 2003). Development of grazed patches in tall grass prairie vegetation was similar at stock

densities that varied from 9 to 54 steers/ha. The authors concluded that factors such as topography and distance to water rather than stocking density determined grazing patterns. In larger pastures (>200 ha) with a variety of forage species, stocking density did not reduce spatial variation in forage utilization (Kirby et al., 1986; Walker et al., 1989). Hart et al. (1993) found that pasture size and distance to water had a greater effect on cattle foraging activity than grazing system (continuous vs. rotational). These researchers suggested that rotational grazing systems were unlikely to improve animal performance over continuous grazing unless pasture size and distance to water were reduced below previous levels.

Fertilization and Burning

Livestock prefer to graze in areas with higher forage quality and quantity (Senft et al., 1987; Bailey et al., 1996). For example, Senft et al. (1985) found that cattle spent more time in plant communities with higher levels of standing nitrogen (kilograms of N per hectare). Ganskopp and Bohnert (2002) found that cattle spent more time in areas where the forage had been intensively grazed the previous year than in areas that had been rested, not grazed, during the preceding year. Forage in areas that had been grazed during the previous year had higher crude protein concentrations than in areas that had been rested. Forage quality and quantity can be improved by burning and fertilization (Holechek et al., 2001). In tall grass prairie, bison prefer to graze in areas that have been recently burned (Coppedge and Shaw 1998, Biondini et al. 1999). Hooper et al. (1969) suggested that fertilization could be used as a tool to improve grazing distribution. Livestock are attracted to fertilized forage and could be lured to underutilized rangeland that had been treated. The authors concluded that fertilization would only be profitable if livestock grazed both the treated areas and untreated nearby forage; however, they did not sample sufficiently to demonstrate whether cattle did use adjacent forage more heavily after treatment.

Season of Use

Determining the season during which pastures are grazed is important for manipulating grazing patterns. In mountain rangelands, upland forage quality is typically higher during early summer. During late summer, upland forage becomes mature and lower in quality as soils dry, whereas the quality of riparian forage remains relatively higher because of greater availability of soil moisture (Vallentine, 1990). If forage quality within a pasture is relatively homogeneous, it is likely that livestock will graze more uniformly (Bailey, 1995). Parsons et al. (2003) found that forage utilization of uplands was higher and utilization of riparian vegetation was lower during early summer as compared to late summer. The researchers recommended early-summer grazing over late-summer grazing for improving riparian areas in mountain rangeland. During autumn and winter, all forage is dormant and uniformly lower in quality. Correspondingly, uniformity of grazing may be greater in rugged terrain in mid autumn through early winter.

Other Factors

In rough topography and in heavy timber, some authors have recommended developing trails to improve uniformity of grazing (Williams, 1954; Holechek et al., 2001). In Oregon, Ganskopp et al. (2000) analyzed the location of cattle paths in an extensive rugged pasture. Cows established paths that were very similar to simulated least effort routes between distant points (Ganskopp et al., 2000). In canyon areas of New Mexico, development of trails greatly improved uniformity of grazing (R. Hartley, personal communication, Roy, NM). Trails allowed cows to easily travel to areas far from water before grazing steep and rocky slopes. Logging roads in mountainous Oregon rangeland increased grazing use of nearby areas in steep and rugged terrain (Roath and Krueger, 1982). However, roads did not appear to be an important factor in distribution in gentle terrain.

In prairies and desert areas with few trees or shrubs, cattle seek out power poles and other structures to scratch on. In central Nevada, cows have been lured to underutilized areas by providing posts or other objects that animals can use to rub against (J. Fallini, personal communication, Tonopah, NV).

Strategies That Change Grazing Behavior

Selection

Breed Selection. Livestock producers and land managers may be able to improve uniformity of grazing by selecting breeds that were developed in more rugged terrain. Tarentaise cattle developed in the French Alps consistently climbed higher ($P < 0.05$) and used higher elevations (greater vertical distance to water) than Herefords on northern Montana rangeland (Bailey et al., 2001a); in 1 of the study's 2 yr, Tarentaise used steeper slopes ($P < 0.05$) than Herefords. There were no differences among breeds in the use of slopes during the other year of the study ($P > 0.10$). Additional research compared the terrain use of cows sired by Angus, Charolais, Piedmontese, and Salers bulls. Cows sired by Piedmontese bulls used higher terrain ($P < 0.05$) than cows sired by Angus bulls (Bailey et al., 2001c). Piedmontese cattle were developed in the foothills of the Italian Alps, whereas Angus cattle were developed in eastern Scotland. Although breeds may differ in terrain use when they are grazed together in the same pasture, additional research was needed to verify that overall herd grazing patterns could be changed by selection. Social interactions and other factors could overwhelm any dif-

ferences in terrain use that result from genetic factors such as breed (Mosley, 1999).

Individual Animal Selection. Selecting livestock based on their grazing patterns and terrain use has the potential for improving livestock grazing distribution (Roath and Krueger, 1982; Howery et al., 1996). If animals have preferences for certain areas of pastures or types of terrain, uniformity of grazing could be improved by choosing animals that prefer upland slopes, higher elevations, and distances further from water and by culling animals that use areas that are typically overgrazed (e.g., gentle slopes near water). For selection to be effective, terrain use must be a repeatable trait, and there must be variation among individuals. In addition, selecting or culling cows based on their grazing patterns must not adversely affect performance of the herd (i.e., weaning weights and pregnancy rates). Ideally, terrain use should be heritable so that genetic improvement could be made through sire selection. Genetic selection can be made through culling, but genetic progress is typically much slower than through sire selection. Culling also can change the behavior of the herd directly even if the trait is not heritable because cows with undesirable grazing patterns are removed. Culling may also affect grazing patterns of replacement heifers because grazing patterns are affected by early learning. Howery et al. (1998) found that cows grazed in the same areas of mountain pastures as did their biological or foster dam.

In foothill pastures at our laboratory in northern Montana, observers on horseback have recorded the locations of individual cows two to three times per week for five consecutive years (1997 to 2001). Large variations in terrain use were observed within and between breed types. For example, the average vertical distance traveled to water during 1997 to 2001 by one Tarentaise cow was over 1.5 times greater (41 vs. 68 m) than another Tarentaise cow (our unpublished data), which was the largest difference observed between any two cows irrespective of breed type. Sufficient variability appears to exist both between and within breeds for selection to be effective.

To evaluate whether selection would improve uniformity of grazing, herds from two ranches in northern Montana were observed and were ranked on terrain use (Bailey et al., 2001b). Based on previous observations, half of each herd was classified as "hill climbers." Hill climbers were cows that spent more time grazing steeper slopes and higher elevations during previous observations. Cows in the other half of each herd were classified as "bottom dwellers" and included cows that used gentler slopes and areas closer to water. At each ranch, hill climbers and bottom dwellers grazed in separate, but similar, pastures during 1999 to 2001. Cows in each pasture were observed simultaneously using horseback observers and GPS (global positioning system) collars. Forage utilization was measured after grazing in each set of pastures. Eight paired comparisons of hill climbers and bottom dwellers were completed (replicated in time and space). Stubble height in riparian and other sensitive areas (coulee bottoms) was greater ($P < 0.01$) when grazed by hill climbers than when grazed by bottom dwellers. Using a ratio that combined three attributes of terrain use (slope, distance to water, and elevation), data collected from GPS tracking collars and horseback observers showed that cows previously classified as hill climbers used rougher terrain ($P < 0.05$) than those classified as bottom dwellers when they grazed in separate but similar pastures. These results demonstrate that selection for grazing distribution has the potential to improve conditions of riparian and other sensitive areas that have been heavily grazed in the past and to increase the uniformity of grazing on rugged rangeland.

Relationship Between Terrain Use and Animal Performance. The relationship between performance traits and observed movement patterns of cows grazing Montana foothill rangeland was also examined (Bailey et al., 2001a). Attributes of the cow (weight, hip height, and body condition score) were not consistently related to terrain use. Weaning weight of their calves and calving date were also not consistently related to terrain use. Grazing patterns of pregnant and nonpregnant cows were also similar, which suggests that reproductive performance may not be related to terrain use. Results reported by Bailey et al. (2001a) indicate that selecting or culling cows based on terrain use should not adversely affect performance of the herd.

Animal Age and Status

Managers have recognized that yearling steers, yearling heifers, and nonlactating cows typically utilize extensive pastures more evenly than cow-calf pairs (Bell, 1973). Nonlactating cows used steeper slopes and higher elevations than lactating cows in northern Montana during the summer (Bailey et al., 2001a). DelCurto et al. (2003) suggested that producers consider early weaning calves to help protect riparian areas. After weaning, nonlactating cows would spend more time in uplands and less time in riparian areas. In contrast to expectations, Bryant (1982) reported cows used mountain rangeland in Oregon more evenly than yearlings. This apparent inconsistency may be explained by prior experience with the pastures (Vallentine, 1990). Older cows with more knowledge of the terrain may graze more uniformly than inexperienced animals, such as yearlings or younger cows. In an Oregon study, older cows spent less time in riparian areas than did 2-yr-old cows (DelCurto et al., 2003), and, in Montana (our unpublished data), older cows (5+ yr) used rugged terrain more uniformly than younger cows (3 to 4 yr).

Strategic Supplementation

Most commercially available supplements fed to cattle are palatable and have the potential to lure animals to underutilized rangeland. Low-moisture block supple-

ments are available in containers (blocks weighing up to 113 kg) that can be readily transported to rough terrain and then self-fed. Manufacturers often recommend placing one container for every 20 to 25 cows. When fed at this rate, larger containers of low-moisture molasses blocks (e.g., 113 kg) usually provide supplement for about 2 wk, which decreases the labor and expenses required to deliver the product. Bailey and Welling (1999) showed that cattle spent more time and grazed more forage in pasture areas where low-moisture supplement was provided than in similar control areas where no supplement was provided. Although it was more effective in moderate terrain (10 to 20% slopes), strategic supplement placement noticeably changed livestock grazing patterns in steeper terrain (15 to 30% slopes) at greater distances from water.

To quantify the effectiveness of low-moisture blocks for modifying livestock grazing patterns, the distance that grazing distribution was affected by supplement placement was estimated. A series of studies conducted in northern Montana (Bailey et al., 2001d) measured forage utilization at incremental distances from supplement. Bailey and Welling (1999) found that forage use was similar at distances of 20 to 200 m from supplement. In a subsequent study (Bailey et al. 2001d), forage utilization was measured at distances of 50 to 600 m from supplement. Again, forage use was similar at all distances measured. Forage utilization was then measured at distances from 200 to 3,000 m from supplement. In this data set, grazing use decreased linearly at greater distances from low-moisture molasses blocks, and the effective distance that supplement affected grazing use was estimated to be 600 m. At distances further than 600 m, the effect of supplement placement diminished rapidly.

Global positioning system tracking collars were used to assist with the forage utilization measurements. Collared cows spent about 16% of their time within 200 m of supplement and spent 33 to 40% of their time within 600 m of supplement sites (Bailey et al. 2001d). Strategic supplement placement appears to be effective for increasing the uniformity of grazing in the fall and winter. Supplement was placed on steep slopes far from water that cattle typically avoided, and, as a consequence, cows spent a great deal of time nearby. After supplement is consumed or moved, animals spend less time in the area and move to new supplement placement sites or to other parts of the pasture. New supplement placements should be located at least 300 m from previous placements to avoid excessive grazing in nearby areas.

Comparison of Low-Moisture Blocks to Other Supplements. The effectiveness of using low-moisture blocks and conventional dry mineral mixes for manipulating cattle grazing patterns and delivering as supplemental trace mineral on rugged rangeland pastures were compared in Montana (Bailey and Welling, 2002). Cows were tracked with GPS collars to record cattle grazing patterns and to determine how often they visited supplement sites (position within 10 m of supplement). Cows spent more time ($P < 0.05$) within 100, 200, 400, and 600 m of low-moisture blocks than within similar distances from dry mineral mix. The proportion of collared cows that did not visit low-moisture molasses blocks (26%) tended to be less ($P = 0.07$) than for dry mineral mix (45%). Other preliminary research suggests that low-moisture blocks were more effective than pressed blocks for manipulating cattle grazing patterns. Forage utilization was greater ($P < 0.05$) near low-moisture blocks than pressed blocks in a study that we conducted in New Mexico. In a Montana study, grazing patterns of cows fed range cake (supplement cubes) in accessible terrain were compared to cows fed low-moisture blocks placed in higher terrain that would not normally be accessible for feeding range cake. Cows fed low-moisture blocks used higher elevations ($P = 0.06$) than cows fed range cake. Although cows readily travel to the areas where cake is fed, they do not stay in the area after the supplement is consumed. Cows that were fed low-moisture blocks (self-feeding) spent almost 5 h/d within 100 m of the feeding site, whereas cows fed range cake spent less than 1 h.

Herding

Although herding has been used to manipulate livestock grazing distribution for centuries, its use on rangeland cattle operations has been limited. Herding requires additional labor, and its effectiveness has been questioned (Rhodes and Marlow, 1997). Some producers believe that herding cattle away from riparian areas is futile, because animals often return to streams shortly after being moved. Others suggest that regular herding is a very effective practice to protect riparian areas (Skovlin, 1957; Butler, 2000). An ongoing research project in central Montana is evaluating herding and the integration of herding and strategic supplementation. We hypothesized that the integration of herding and strategic supplementation would be more effective than either practice used alone. Three treatments (control, herding, and herding combined with strategic supplementation) are being evaluated in a 3-yr study using three 550-ha pastures in a Latin square design. Cattle grazing patterns are being recorded using GPS collars, horseback observers, and forage utilization and stubble height measurements. Preliminary results (yr 1) suggest that herding and the combination of herding and strategic supplementation were very effective in protecting the stream that flowed through the center of these pastures. Stubble heights in riparian areas in the pastures where cows were herded were greater ($P < 0.05$) than in the control pasture. In addition, stream bank stubble heights (<0.5 m from the largest stream) were higher ($P < 0.05$) in the pasture that combined herding and supplementation than in the pasture where cattle were only herded.

Integration of Strategies to Optimize Grazing Distribution

Integrating several strategies appears to have the greatest potential to solve critical resource issues associated with poor livestock grazing distribution. Preliminary research suggests that combining strategic supplement placement with herding has synergistic benefits. Strategic supplement placement appeared to help train cattle to use a new water development at a Montana ranch (S. Roth, personal communication, Big Sandy, MT). Anecdotal observations from the Red Canyon Ranch, in Wyoming, suggest that the combination of herding and culling problem cows (individuals that frequent riparian areas or that are difficult to herd) improved grazing patterns and helped protect riparian areas (Budd, 1999). The strategies for increasing uniformity of grazing discussed above do not appear to be antagonistic and in several cases appear to be complementary based on preliminary evaluations. More research is needed to develop "integrated systems" of management strategies to resolve critical resource issues and increase the sustainability of grazing on arid rangelands.

Implications

Ongoing research holds promise to give livestock producers and land managers new tools to improve the sustainability of grazing on arid rangelands. Behavior of beef cattle and other livestock seems to be very malleable and can be modified to meet management goals. Several tools are available for manipulating livestock grazing patterns, including season of use, selection, strategic supplement placement, and herding. The integration of these practices along with other well-established practices, such as off-site water development, has the potential to significantly improve uniformity of grazing and give managers an alternative to livestock exclusion to protect sensitive rangelands.

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