Adaptive Grazing Management for Recovery

Know why you're moving from paddock to paddock

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On the Ground

- To condition plant communities for desired event-driven change, plants should not be defoliated during critical periods of their life cycle year after year.
- Because animal preferences cause heterogeneous plant use patterns, sufficient time between defoliations is needed for preferred plants to recover sufficiently to maintain themselves and reproduce.
- Adequate levels of recovery between defoliations for individual plants generally requires that they go through their rapid growth phase and elongation of the apical meristem, or they may need to set seed, establish desired structure, germinate, and establish seedlings or some other measure of growth/regrowth, depending on management goals.
- Because of the inherent variability of precipitation in most rangeland environments, achieving adequate recovery will require adaptive management that includes variable recovery periods that may be a full growing season or more in some years, depending on weather, level of defoliation, and timing of defoliation.

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Plant community change is inevitable, and grazing management strongly affects how change occurs. Heavy or frequent defoliation reduces individual plant vigor and productivity.[1] Animal preferences for particular pasture locations and plant species reduce the benefits of moderate *average* stocking rates in continuously grazed paddocks with diverse vegetation and topography, because a few high-quality, palatable plants often receive the majority of the defoliation.[2] These nonrandom defoliation patterns constantly change interplant relationships.[3] As productivity and diversity of preferred plants declines, animals shift to other places and plants. Thus, frequently visited plant communities can become focal points of grazing-induced degradation that expands over time,[4] and makes the community more susceptible to extreme events.

As early as 1956, Gus Hormay asked, "How can grazing be regulated so as to prevent close use of these plants?" to which he answered, "It can't."[5] Therefore, if grazing management is to make plant communities more resilient in the face of uncertain conditions: 1) managers must change the timing, frequency, and distribution of defoliation compared to continuous stocking on landscapes; 2) these changes must be sufficient to provide preferred, heavily defoliated plants adequate physiological recovery—that is, recovery that allows defoliated plants to maintain or increase their proportional representation on the landscape through vegetative or seedling recruitment; 3) these changes must be based on physiological responses of preferred, heavily defoliated plants; and 4) management strategies must adapt to changes in animal behavior and weather. If defoliation patterns and plant recovery don't change, one grazing "system" is like another from the plant's perspective. Likewise, if rotational movement of livestock among paddocks does not change defoliation patterns enough to maintain existing plants and enable recruitment of new desirable plants, the rate of degradation may slow, but results are inevitably undesirable.

Many managers think of rest as any time a paddock is not grazed, without considering growing conditions during the interval between grazing periods. But a nongrazing period may or may not allow plants to meet their physiological needs. For instance, unsuccessful *rotational grazing systems* traditionally measure nongrazed "rest" periods by a calendar. In contrast, adaptive grazing managers choose to return livestock to a location based on plant development that occurs when environmental conditions allow plants to meet critical physiological needs. They practice deferment in the strict sense: "a delay of grazing to achieve a specific management objective. A strategy aimed at providing time for plant reproduction, establishment of new plants, restoration of plant vigor, a return to environmental conditions appropriate for grazing, or the accumulation of forage for later use."[6]

Ecological processes and relationships among organisms during deferment move a plant community toward or away from management objectives. In the most general sense, adequate recovery is the point at which the re-introduction of livestock will either enhance, or not impede movement toward management's ecological objectives. Some processes involve individual plants—for instance, the regrowth and reproduction of defoliated plants. Others may occur at the paddock scale—for instance, accumulation of root mass to enhance the soil ecosystem or accumulation of above ground biomass to enhance water capture, decrease evaporation, and stabilize soils. Managers may also have ranch-scale goals—for instance, to create species and structural heterogeneity within and among paddocks. Hence, adequate recovery encompasses a *value judgment* by management in defining ecological goals and an ecological judgment that the return of livestock will facilitate goals.

We focus on plant regrowth and reproduction after defoliation because that process is common to all perennial grassland systems. Our discussion of recovery assumes that management values plant diversity and wants to recruit underrepresented species, typically highly palatable species that decrease with repeated, severe defoliation. In our experience, allowing a grass to go through its rapid growth phase and elongation of the apical meristem is essential to maintain preferred plants on a landscape.[7,8] Regular *deferment* that achieves *recovery* of heavily defoliated plants generally enables recruitment of new plants, thus promoting regeneration of degraded plant communities over time.

In this article, we describe 1) adequate physiological recovery following defoliation to maintain plant vigor, 2) the importance of *adequate* physiological recovery to promote positive plant community changes, 3) positive ecological and physiological effects resulting from adequate recovery, 4) how the collective effects of adequate recovery on individual plants condition resources for positive change in response to episodic favorable events and increase resilience during unfavorable conditions, and 5) guidelines to help managers implement and adjust deferment periods based on variable conditions in perennial grass dominated rangelands.

What is Adequate Recovery from Defoliation?

Recovery of photosynthetic capacity between defoliations is critical for productive, palatable species to maintain or increase in abundance.[7] Preferred plants are often grazed severely before optimum paddock utilization is achieved,[9] so moderate stocking rates alone are of limited value to maintain these plants. Multiple defoliations during critical points in the growing season, within and across years, should also be avoided to maintain preferred plants.[8,10,11,12] However plant species may respond differently to defoliation, have different critical physiological periods during the growing season, different reproductive mechanisms, seasonal variations in palatability, and may respond differently to intermittent weather events.

Adequate recovery, therefore, depends on the species, size, general health and condition of the plants being managed, the intensity of defoliation, as well as whether seed production and/or recruitment of new individuals are a management need. The time required to achieve any of these targets is variable and depends on growing-season moisture. Torell and coworkers, in southern New Mexico shortgrass dominated rangeland, found growth rates on days with soil moisture > 30% to be > four times that on days with soil moisture between 20% and 30%. Days with soil moisture < 20% resulted in almost no growth.[13] On average, less than 45 days, dispersed over a 180-day growing season, provided most of the growth in that semiarid shortgrass environment, indicating that most or all of a growing season would normally be required to achieve adequate physiological recovery for heavily defoliated plants, and longer periods during drought (*see Grissom and Steffens as well as Barnes and Howell, this issue*).

Long deferment periods that allow vegetative or seedling recruitment in most years may be desirable if vegetative or seedling recruitment of rare, desired plants is necessary for desired plant community compositional change (Fig. 1). Monitoring regrowth of defoliated desirable species to ensure they have reached desired physiological targets (e.g., seed set, vegetative reproduction, or rapid growth and elevation of the apical meristem) before being regrazed can help determine

Figure 1. Long deferment may be desirable if vegetative or seedling recruitment of rare, desired plants is desired. Near this water point, adequate deferment has been provided to the plants in the paddock in the foreground to accomplish replenishment of photosynthetic capacity of existing plants, seed maturity, and recruitment of new plants from vegetative propagules or seedlings, even when levels of defoliation on individual plants are high in preferred parts of the paddock during a grazing period (midground with manure deposition). In the background is a paddock that is partially recovered after similar levels of defoliation.

the required recovery between defoliations in a specific environment.

When managers target specific desirable species, they should consider differences in growth periods, seasonal palatability, interplant competition, and reproductive mechanisms among species. For example, a paddock may contain a cool-season plant that is palatable and actively growing only in spring and fall, but is not palatable in comparison to actively growing warm-season plants in summer. Such a paddock might be grazed in midsummer, and again in the dormant season while providing a full season of growth for cool-season plants.

Adequate recovery is ultimately a management judgment based on the timing of critical points in the growth cycle of desired species. Multiple paddocks grazed intermittently at different seasons provide managers the opportunity to observe the response of desired species to management decisions including length of deferral. The iterative adaptation of management decisions to observations is the only path to defining adequate recovery for a specific management situation. The companion case study to this article (*see Grissom and Steffens, this issue*) provides examples of how adaptive management to provide extended deferment periods increased recruitment of desirable cool-season midgrasses and palatable shrubs in a semiarid environment.

Recovery Period Affects Plant Recruitment

Changes in plant composition are often event driven as plant communities react to changing weather. Survival and recruitment of desired species in drier environments have been found to be sporadic, unpredictable, and responsive to moisture and grazing; can vary among years as much as 60 fold; and can be as high as 6–700 plants/ha gain or loss annually for perennial species.[14,15] Deferment that allows increased vegetative reproduction and seedling recruitment can increase the likelihood of recruitment events.

When new recruits are defoliated before establishing enough photosynthetic capacity and root biomass to survive, relatively rare and palatable plants are unlikely to increase in the plant community. Mortality was high for seedling midgrass plants defoliated at less than 10 weeks development under ideal greenhouse conditions with no competition.[16] These findings provide an estimate for a *minimum* deferment period when seedling recruitment is desired in subhumid, temperate environments. Under field conditions, this period would likely be much longer, even in relatively mesic conditions. When a seed bank is not available, desired plants may need to set seed regularly. In Missouri, when paddocks were deferred for most or all of a growing season between grazing periods of < 2 days at very high stocking densities (100–300 AU of cattle per acre), warm-season tallgrasses and desirable legumes established in virtual monocultures of tall fescue (*Festuca arundinacea*) without mechanical seeding (Greg Judy, personal communication, 2007).

Conditioning Resources for Change

Grazing deferral is one tool to condition resources for response to the next favorable weather event.[17] For example, abrupt increases in desirable plants after several years of grazing strategies with regular, adequate physiological recovery (*see Grissom and Steffens, this issue*) may occur as a result of sporadic events that exceed some environmental or physiological threshold that allows recruitment of new plants.[14,15] The time-lag between management actions (the season, intensity, and recovery characteristics of grazing) and weather-related response make grazing records a critical tool for adaptation. Our experience suggests that such conditioning entails: 1) allowing plants to mature to increase propagule availability and root mass of existing plants to make full use of available moisture; 2) leaving high residuals to increase surface litter, capture drifting snow, and thus increase soil moisture which may, in turn, promote reproduction and establishment; 3) managing plant structure to decrease surface wind velocity, and thereby stabilize soils and decrease evaporative losses; and 4) changing animal distribution, and severity and frequency of defoliation, on critical areas to influence interplant competition.

Guidelines for Providing Adequate Recovery

Grazing strategies designed to provide sufficient recovery between defoliations should plan for and *focus on desired responses of preferred species or functional groups on preferred parts of the landscape*. The following should be considered:

1) How long is required for target plants to achieve target physiological development after being defoliated to the observed intensity under good growing conditions, and when are these growing conditions likely to occur? This would be the *minimum* period required between defoliations.
2) The number of days available in a "normal" year for rapid growth is then used to assess how much time is *actually* needed. This assessment should take into account moisture, optimum temperature, and photoperiod requirements for the species of concern; the degree to which it was defoliated; and the period of potential growth still available for the plant to recover.[11]
3) If a desired plant species decreases in palatability during the year, a paddock may be available for grazing more often than the required period between defoliations would indicate, as that plant species may be ungrazed in a subsequent grazing period if it is less palatable than alternatives.
4) Longer deferment may be required for target plants that reproduce vegetatively, as establishment of new individuals from tillers, stolons, or rhizomes will likely take more time and require more resources than simply replacing tillers to maintain the plant.
5) To avoid defoliation during germination and seedling establishment, further increases in length of deferment may be necessary.

6) With an adequate seedbank, seed production may not be necessary. However, if seeds of species that do not reproduce vegetatively are not common in the seedbank—particularly desirable plants like winterfat (*Krascheninnikovia lanata*) or fourwing saltbush (*Atriplex canescens*) that have short periods of seed viability—plants may need to set seed regularly.
7) The frequency with which conditions conducive to recruitment occur may have some bearing on the length of planned recovery, but will certainly give some indication of how often notable changes in plant composition are likely.

Grazing "System" vs. Adaptive Grazing Strategy

Mark Westoby and colleagues, in a seminal paper on the state and transition model of rangeland ecology wrote, "Under the state and transition model, range management . . . would see itself as engaged in a continuing game, the object of which is to seize opportunities and to evade hazards as much as possible. The emphasis would be on timing and flexibility rather than on establishing a fixed policy."[18] Nevertheless, little has been done in the intervening years to identify specific components of such an approach, and how decisions should be evaluated, selected, monitored, and adapted to change rangeland resources in desired ways.

For just these reasons, *planning* will be essential to have some idea of what to expect, but will need to be continually revised when observations indicate unexpected conditions. In the same way, named grazing "systems" will often be of little value, as optimum management approaches will be context specific based on goals, abilities, opportunities, constraints, and constantly changing climatic and economic conditions.[19]

Launchbaugh and Walker conceptualized such an approach when they defined targeted grazing as the application of a particular kind of grazing animal at a specified season, duration, and intensity *to accomplish specific vegetation management goals*.[20] Without a goal, we cannot measure progress, identify opportunities, or avoid hazards. Therefore, goal-based strategies that use knowledge of ecosystem processes and their inter- and intra-annual variability are essential. Adaptive grazing management as we describe here can be thought of as consistent targeted grazing on a ranch scale.

Named grazing systems evaluated in the scientific literature have often been applied with little flexibility to account for variability in growing conditions within and across years.[19] Ever-changing conditions characteristic of complex adaptive systems *almost always* preclude *every* part of a ranch being managed for maximum benefit *every* year. Animals must always be somewhere, so plants in some area(s) will be affected negatively each year. The key is to identify these areas, ensuring that the same area is not negatively impacted every year and that management responds to changing conditions and tries to benefit desired species and communities most years. The smaller the area occupied and the shorter the graze period, the smaller the area that should be negatively impacted because of multiple defoliations without physiological recovery, the greater the proportion of the year available for recovery, and the more management flexibility that is possible.

Information *Needed* for Adaptive Management

Assessing rangeland resources for management purposes is not necessarily gathering quantitative data, but rather acquiring information, often qualitative, that infers cause–effect relationships and that can be used to modify management actions for desired outcomes. Therefore, desired outcomes and limiting processes must be identified before appropriate assessment criteria can be selected (*see Grissom and Steffens, this issue*).

Detecting early plant community changes where they occur can help managers unravel their causes and, in turn, adjust management actions. Records of rainfall events and amounts, grazing events, and photo points in areas likely to respond to changes in defoliation patterns that show plant structure and species composition are helpful for short-term assessments.

Because of the sporadic and event-driven nature of plant community changes, useful qualitative assessment methods will likely focus on rangeland health and provide managers with a feel for their starting point and current situation as well as to assess whether management is generally moving in the right direction. Rangeland health focuses on factors associated with hydrologic function, biotic integrity, and soil stability—all of which are necessary to condition resources for positive plant community change. Regularly evaluating factors such as litter amount and movement, bare ground and soil stability, plant community structure, plant mortality, decadence and recruitment, and species reproductive capacity in heavily used parts of the landscape using more permanent methods to track changes over time (i.e. repeated photo points paired with written comments and/or numeric values associated with these factors) will provide information that facilitates decisions and track progress over a period of years. Quantitative monitoring methods may help managers understand and quantify how the landscape responds to particular management decisions. Where management decisions have the potential to be legally challenged, quantified monitoring has high credibility.

Short-term monitoring should examine animal behavior and defoliation patterns on desired plants to identify possible reasons for long-term trends, and formulate logical ways to address deviations from expectations. Short-term monitoring methods will be context specific, but should contain common elements—that is, some measure of the frequency, timing, and intensity of defoliation of desired plants, and the opportunity for adequate physiological recovery based on the level of defoliation from which desired plants must recover and the climatic factors influencing growth.

Two methods have been used successfully—Grazing Response Index (GRI)[21] and the Sandhills Defoliation Response Index System (SANDRIS). The full array of leaves described in the GRI as a measure of opportunity for regrowth is useful in field-level monitoring to predict future outcomes from present conditions, and is repeatable within the limits of the index. These methods can be combined with additional measures like utilization maps, moveable exclosure cages, photo points, and observations of livestock diet selection through the season, which can be used to obtain information on changing patterns and processes needed for adjustments to grazing management plans.

Adaptive Management and Infrastructure for Recovery

We have seen successful and unsuccessful management using levels of infrastructure development that range from minimalist approaches with herders to intensive management using temporary fencing, portable watering facilities, extremely high stocking densities, and multiple moves per day. Animal distribution and timing of grazing can also be managed with patch burning, limiting access to water, supplemental feeding stations, and fencing.

Infrastructure should facilitate *management*. There is nothing magical or critical about the number, type, or orientation of paddocks. Water and permanent fencing only have value if they provide necessary control and flexibility of the distribution and timing of grazing. We suggest that managers adaptively arrive at a definition of adequate recovery for species of concern in a given environment and then practice adaptive grazing management with existing paddocks before increasing paddock numbers. Paddock numbers should be increased as an adaptive response to monitoring information that indicates a need for more control of defoliation patterns to achieve desired results.

Because of animal preferences, palatable plants in preferred areas of the landscape are susceptible to severe and repeated use (Fig. 2) with long grazing periods, even at relatively light stocking rates. Therefore, there is some minimum number of paddocks and movements required to reduce repeated defoliations during a grazing period to an acceptable level *and* provide adequate recovery between defoliations (Fig. 3). Large numbers of paddocks with frequent livestock moves may require more labor, but many managers find that labor for checking and moving livestock actually decreases, as animals are easier to find and become more tractable as they adapt to the routine.

With high fencing costs, the optimum number of paddocks will be relatively small. Using one- or two-wire permanent power fencing, with or without further subdivision with temporary fencing, often makes large numbers of paddocks economically feasible. Potential advantages of higher paddock numbers per herd include increased proportions of the year when growth can occur on a given part of the landscape without the risk of defoliation by livestock; more timely ad-

Figure 2. Even when overall stocking rate is moderate, animals will selectively use preferred plants in preferred areas selectively, and often severely. Western wheatgrass plants in the foreground have been severely defoliated in the spring, while blue grama plants in the background have been almost untouched.

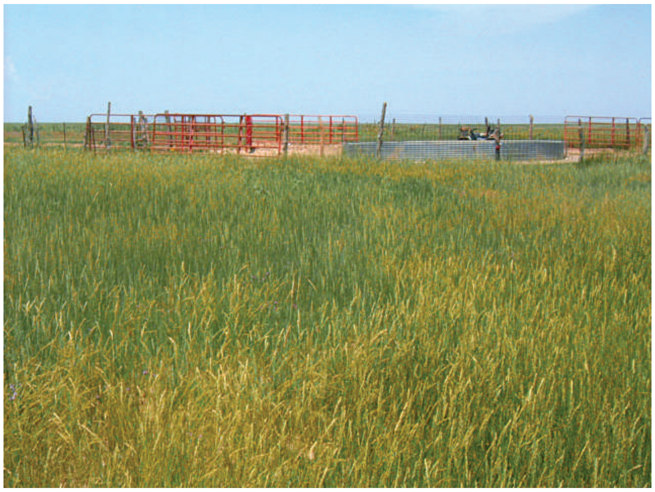

Figure 3. When infrastructure facilitates proper management that provides adequate physiological recovery between defoliations, even preferred plants in preferred areas can maintain or increase their proportional composition and productivity in the plant community. Here western wheatgrass within feet of a water point of a grazed paddock is showing a high degree of vigor as a result of regular, adequate recovery between defoliations.

Figure 4. Deferment periods should be timed to favor desired plants on the greatest part of the landscape possible and may need to be all or most of a growing season. Pictured are the fruits of regular, extended growing-season deferment. Winterfat was a rare plant prior to implementing this type of management.

justments of forage demand to forage availability (*see Frasier and Steffens, this issue*); distribution that more closely matches forage quality and quantity on the landscape, including more control and precision regarding the *average* level of defoliation at smaller spatial scales (*see Norton et al. and Barnes and Howell, this issue*); and increased control of structural heterogeneity and diet quality, including wider selection of plant species.

Conclusions

Plant community change is inevitable. Grazing management strongly influences the changes that occur. Changes in plant composition are sporadic and weather dependent.[14,15,17] Management should, therefore, be centered on creating conditions that enable desired plant and community responses to favorable weather events and resilience in unfavorable periods.[17,18] Management of animal distribution in time and space allows defoliated plants to re-establish sufficient photosynthetic capacity and prevents growing centers of degradation in preferred areas.

Regular deferment to allow adequate recovery from defoliation should be timed so that desired species can maintain or increase their proportional representation in the plant community after these events. In semiarid environments, because of the sporadic nature of growth, adequate recovery often requires most of the growing season (*see Grissom and Steffens as well as Barnes and Howell, this issue*). When moisture is below normal, or recruitment of new plants is necessary to achieve plant community goals, deferment periods required for plant community recovery may be a year or longer (Fig. 4).

Extended deferment embraces, and even encourages, plant community changes. Allowing existing plants to express more fully their potential, and allowing new plants to come into the system, enhances diversity and resilience in the face of uncertainty. Such management reduces risk and conditions plant communities to respond favorably, may decrease environmental thresholds required for positive change, and increases resource resilience.

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