Conservation Grazing Practices for Prairie Habitat Protection in Western Washington

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March 1st 2024

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1. Introduction

Conservation grazing has emerged as a term used in various parts of the world as an assemblage of concepts and practices for utilizing grazing for conservation outcomes. While this approach is apparently without specific definition, it bears resemblance to targeted grazing for vegetation management; but more broadly, it is situated in recent discussions promoting a transition from a utilitarian approach to grazing land management focused on production of livestock and forage to an ecosystem management approach focused on provision of these ecosystems goods in addition to other ecosystem goods and services, such as wildlife habitat (Fuhlendorf et al. 2012; Havstad et al. 2007, Freeceet al. 2014)). This Extension Bulletin compiles scientific concepts, theoretical principles, and practices to apply a conservation approach to grazing by private landowners, conservation reserve managers, and others.

The goal of this Bulletin is to provide landowners and managers with practical recommendations and examples for conservation grazing. It seeks to translate some current and recent technical science on grazing for habitat enhancement into an accessible and applicable format. The approach we have taken is to group practices along the lines of common ecological principles, because fundamentally grazing with conservation in mind requires an understanding of these relationships.

Socio-Economic and Cultural Considerations

In developing practices and recommendations in this emerging field, it is important to be take a multi-disciplinary perspective. Much of the content in this bulletin is informed by science and experience-based concepts and practices, yet the success of their application will depend on cultural and socio-economic conditions in specific places. For example, private land managers are rational actors and business decisions must support profitability. As of yet, many conservation objectives work at cross-purposes with current market signals and, as a result, financial incentive mechanisms must be considered to successfully advance conservation on private lands. This is important not merely for the success of conservation, but also for the business success of private landowners, who are critically important partners in this work. As one landowner we know has said, “If you pay us to grow grass, we’ll grow grass. If you pay us to grow butterflies, we’ll grow butterflies.”

Similarly, many grasslands are owned or managed by indigenous, farming, and otherwise deeply rooted multi-generational families. Based on past experiences of these populations, “conservation” or “grazing” can variously be associated with land displacement, loss of cultural values, lost access, costly regulatory burden, and uncompensated policy changes. Conservation and food production have not always been allies or compatible, but with appropriate cultural approaches and knowledge, policy, financial incentives, and market structure, they can and must be, as there is not land enough to achieve either of them independently.

Grasslands Overview

Grassland ecosystems cover approximately 26% (8.6 billion ac) of the global land surface. With savannas, shrubland, semi-forested rangeland, arid and tundra habitats included, these ecosystems cover approximately 40% of terrestrial land surface. Grass-dominated ecosystems are dispersed across a variety of elevations, topographies, and latitudes, and develop due to conditions that limit closed tree cover. These limits include environmental factors such as rainfall, disturbance such as from wildfires or other natural disruptions, cold temperatures, cultural maintenance through shrub and tree removal and use of fire, and herbivory.

Grasslands are typically classified as natural, semi-natural, or "improved". A closed tree canopy in natural, or primary, grasslands is predominantly prevented by low rainfall or cold temperatures. Intact grasslands of the Great Plains, Australia, the Arctic, Antarctic and alpine tundra (from "treeless plains" in Finnish), pampas of Argentina, African savanna, and steppe regions of Russia, Mongolia, and China, among others, are exemplary of natural grasslands.

Semi-natural, or secondary, grasslands are those in which succession to tree canopy closure is or has been restricted by human activities, typically through the use of fire, but also potentially in combination with moisture-limiting edaphic (soil) conditions.

Grass-dominated prairie ecosystems of western Washington are a type of semi-natural or secondary grassland. Maintenance of these ecosystems for habitat and natural function in addition to mere forage production distinguishes a 'semi-natural' from a 'secondary' classification. So-called 'improved grasslands' are those managed with high-producing forages that are the result of intensive breeding programs, such as a seeded orchard grass (*Dactylis glomerata*) and white clover (*Trifolium repens*) pasture or hay field. These grasslands are often but not always managed with increased fertility and irrigation inputs.

Social and Ecological Importance of Grasslands

Globally, grasslands support human livelihood and ecological function on a massive scale. Grassland management constitutes 70 percent of total global agricultural land area, sustaining two billion people (25 percent of the world population; Robinson et al. 2019). Ecologically, grasslands play an important role in global climate regulation, exhibit greater vascular plant biodiversity than any other ecosystem in the world (in numbers per patch areas <1,000 ft2; Habel et al. 2013), and provide many ecosystem services in terms of pollinator resources and water regulation (Benngsston et al. 2019).

Decline in extent of global grasslands diminishes opportunities to sustain rural livelihoods, meet food and fiber needs from these perennial-based agro-ecosystems, and sustain grassland biodiversity and ecological function generally.

Geographic Extent of Grasslands in Western Washington

Prairie ecosystems of western Washington are semi-natural grasslands, the word "prairie" being derived from the French word "praierie", which in turn is derived from the Latin term "pratum".

These grass-dominated ecosystems have been roughly mapped based on the geographic distribution of prairie and grassland soils in the region as described by the Natural Resource Conservation Service (Noland and Carver 2011). These soils extend in patches from the Columbia River in the south near Camas, WA to the tip of Orcas Island (San Juan Islands) in the north, with a patch of prairie-soils in eastern Whatcom County. The three primary semi-natural grassland regions in western Washington are the islands of San Juan and Island Counties, areas of Pierce and Thurston Counties in South Puget Sound including substantial areas in Lewis County, and southern Clark County near Camas.

Loss of Grassland and Grassland Species Globally and Locally

Both around the world and locally in western Washington, grasslands and grassland species have experienced dramatic declines. In western Washington it is estimated that, from a historical extent of 150,000 acres, over 90 percent of natural and semi-natural grasslands have been converted to agriculture (improved pastures or crop production) or development or converted to shrublands or forest due to fire exclusion.

Examples of global grassland loss or degradation includes the 60% (360 million ac) loss of North American grassland , 90% loss of northern European semi-natural grassland, 106 million acres loss of Eurasian steppe to cropland, and 60-80% degradation of South American grassland (Bengtsson et al 2019).

Grassland species losses and extinctions can be illustrated by the decline of grassland birds. In North American, the overall abundance of birds (in total numbers) declined by 29% since 1970, amounting to the loss of approximately 3 billion birds. Across biomes, grassland species specifically exhibit the greatest losses, with 74% of species overall in decline for a total estimated loss of 700 million breeding individuals across 31 species (Rosenberg et al. 2019).

In Western Washington, grassland species losses are illustrated by the listing of several federally threatened or endangered species in 2014, including the Tayler's checkerspot butterfly (*Euphydryas editha taylori*), Mazama pocket gopher (*Thomomys mazama*), Oregon Vesper Sparrow (*Pooecetes gramineus*), and Oregon spotted frog (*Rana pretiosa*).

2. Conservation Grazing for Habitat Conservation

Conservation grazing has emerged as a concept and set of practices. No set definition exists for conservation grazing, but it is referred to here as grazing principles and practices that aim to conserve and enhance habitat for wildlife. Conservation grazing contrasts with grazing management approaches that focus solely on livestock or forage production objectives. It is part of an expanded view of how grazing animals can be used to support ecosystem services. In this sense, grazing for ecosystem services can provide food and fiber for humans as well as other services such as carbon sequestration (climate regulation), pollination, water infiltration and storage, wildlife habitat, and other (Goodwin et al. 2023). Here we focus on conservation grazing as supporting habitat and wildlife.

For context, recent scientific literature has described the transition from a "utilitarian" approach to grazing management (focused on forage and livestock products) to an "ecosystem management" approach as a paradigm shift (Fuhelendorf et al. 2012). Characteristics of this paradigm shift are described in Sidebar 1.

Sidebar 1. Characteristics of the Shift from a Utilitarian Approach to Grazing Management to an Ecosystem Management Approach

Transition from livestock-centered management to biodiversity-centered management (Freeceet al. 2014)

Embrace of "…an expanded view of rangelands as complex ecosystems that support multiple land use objectives and provide a full suite of ecosystem services including biodiversity (Fuhlendorf et al. 2012, Havstad et al. 2007)

Response to new demands from society for a wider range of goods and services from grazing lands (Svjecar and Havstad 2009)

Opportunity to promote pastoral communities and economies for production of livestock products as well as to conserve biodiversity in collaboration with ecologists and conservation biologists (Havstad et al. 2007)

Opportunity to develop "lucrative markets" (Havstad et al. 2007) and supportive regulatory conditions (Westoby et al. 1989) that "free managers to intervene positively" and flexibly to enhance ecological services on managed grasslands.

Expansion of the focus of grazing management from forage production to include or even prioritize ecological and amenity goals such as improving water quality, conserving endangered species, and creating open space (Havstad et al. 2007).

Specific to western Washington, a conservation grazing approach is useful and even necessary due to widespread loss of grassland habitat in the region, a trend reflected nationally and globally. Western Washington prairies are considered a priority habitat by the State of Washington because they have been reduced to approximately 2% of their historic range (Crawford and Hall 1997). Most native prairies have disappeared through conversion to cropland or urban uses or invasion by trees or non-native herbaceous species.

Rethinking Grazing from the Perspective of Ecosystem Management

This Extension Bulletin describes practices that can be used to implement a conservation approach to grazing. Effective conservation grazing plans are based on established grazing principles but also adaptations of these principles to manage forage resources, grazing animals, and other ecosystem processes as part of a larger ecosystem (see Sidebar 2). Established grazing principles described by Reece et al. (2008) that remain pertinent to conservation grazing include, among others:

- Goal-setting,
- Inclusion of production and natural resources objectives,
- Adapting management to seasonal variation in the ability of plants to recover from grazing,
- Understanding the basic principles of "balancing total forage requirements of the herd with available forage resources",
- Evaluating forage availability and potential stocking rates across the landscape, and
- Applying specific practices to specific conditions and goals.

With regards to applying grazing in the context of ecosystem management, some practices will need to be modified, with the aim of re-establishing ecosystems processes and specific ecological conditions on the landscape. This Extension Bulletin describes these practices, grouped in the following categories:

- Plant response to grazing
- Grassland species succession
- Grazing distribution
- Stocking rate
- Grazing systems
- Grazing integration with fire

This approach emphasizes the integrated application of ecological *processes* such as grazing, fire, water cycling, and nutrient cycling to re-establish important ecological *patterns* on the landscape (diverse vegetation structure, for example) "…with the objective of ultimately maintaining the full suite of biodiversity." (Fuhlendorf et al. 2012).

Sidebar 2. An Ecosystem Management Paradigm for Grazing Management

The ecosystem management paradigm, in the context of range or grassland management, aims to re-integrate grazing into landscape-scale ecological processes with the goal of restoring habitat functionality. With re-establishment of ecological processes as the long-term goal, it follows that specific grazing management practices will be guided by different objectives than have long structured and guided range science topics. At the least, a distinct variation on how accumulated knowledge of grazing principles is applied in practice is needed to achieve outcomes (i.e. habitat and species conservation) that go beyond forage and livestock production.

3. Plant Response to Grazing: Manage Grazing to Guide Plant Community Composition

Theory

Livestock producers and other grazing land managers use knowledge (theory) of how plant species respond to grazing when they select practices to encourage specific plant communities. One way plants have been grouped in their response to grazing is as "increaser", "decreaser", and "invader" species (Dyksterhius 1949). The practical question is, what grazing practices should be used, and how, to retain desirable species likely to disappear, manage those with a propensity to increase, and resist invasions of undesirable species? For the conservation grazing land manager, managing for desired sward species is supported by understanding species' capacity to "resist" grazing through either avoidance or tolerance (Briske et al. 1991; Sidebar 3).

Sidebar3 . Grazing Avoidance + Grazing Tolerance = Grazing Resistance

Grazing avoidance is achieved through plant form (morphology) adaptations and biochemical compounds that reduce palatability. Plant form adaptations include modified tiller length and angle that make the plant more difficult to consume, mechanical deterrents including spines, awns, and waxes, and potentially more numerous, finer leaves to avoid herbivory. Biochemical defenses include storage of "secondary compounds" (alkaloids, glucosinolates, cyanogenic compounds, tannins, lignins and resins) in plant parts to deter grazing and/or interfere with digestion. ***Grazing tolerance*** is achieved also through plant form strategies, but also biological function adaptations (physiology). Tolerance based on plant form adaptations includes high leaf replacement potential (e.g. regrowth points lower on the plant) and rapid regrowth from these low growth points. Tolerance based on plant function includes increased rate of photosynthesis (compensatory photosynthesis) and rapid leaf tissue replacement following grazing, and competitiveness at accessing water and nutrients relative to less grazing tolerant plants.

Concepts like these that describe plant resistance to grazing can be used, over time, to accumulate ecological knowledge about the interaction of grazing with the form, function, and "chemical toolbox" (secondary compounds) of specific grassland plant species. This is critical to retain sensitive species and reign in over-zealous ones (see Figures 1 and 2). For example, which practices select against upright growth form, which support target forb species, and which support sensitive native species (Admin 2017)? Numerous down-stream decisions flow from this knowledge, including grazing intensity and timing prescriptions, selecting grazing systems and livestock type and breed, applying coordinated disturbance actions, managing soil, and restoration such as seeding to increase plant diversity.

Table 1. Plant Response to Grazing Practices and Intended Outcomes

Goal/intended outcome	Practices
Knowledge gained of which species increase, which decrease, and which are invaders	Document/observe the grazing preferences of different plant species (increasers, decreases, invaders)
Knowledge gained of potential biochemical benefits or 'avoidance mechanisms' of plant species	Increase ecological knowledge of different species by researching or obtaining analyses of plant secondary compounds present in species of interest

Prevalence of increaser species is suppressed in specific locations or at specific times	For “increaser” species, graze from floral initiation to seed set where possible
Grazing-sensitive or key species (such as native forbs) are allowed to complete reproduction from flowering to seed set	For target species, periodically or annually defer grazing from floral bud initiation through seed maturity. These are season- and species-specific deferments. May not be critical every year; monitor to track changes
Vigor of decreaser species is maintained: those that are sensitive and may benefit from periodic or prolonged relief from grazing pressure	Remove 1 or 2 paddocks from rotation yearly (i.e. “rest rotation”, see Grazing Systems) to provide periodic full-season grazing deferment spring growth to first hard frost
The most vigorous, fastest-growing, and palatable plant material (cool-season grasses in the Pacific Northwest) are preferentially used while less palatable forbs and sensitive grasses are grazed lightly or not at all. Some patches are avoided while “grazing lawns” develop at preferred sites	Calculate and apply low and medium stocking rates that allow for grazing selectivity. This can be applied in large continuously grazed paddocks and rotational paddocks (See: Stocking Rate); avoid uniform, complete application of high stocking densities in all paddocks that encourage non-selective use
Short-statured wet grassland habitat is created for amphibians and other wildlife	Graze over-dominant species in summer and fall after ground has dried to halt development to closed canopy

Plant Response to Grazing – Examples

Figure 1. Many plant species that provide important wildlife habitat resources (many natives but not all) are intolerant of repeated, close grazing or even repeated moderate grazing (Drovers et al 2017). Species that are prone to being grazed by ruminants to the extent they are replaced by other species (“species replacement”) are referred to as “decreasers”. Those that tolerate grazing and replace other species are “increasers”. Decreasers require grazing rest periodically. Golden paintbrush (Photo A) is palatable and has been observed in South Puget Sound to be grazed readily by cattle. While the grazing resistance of golden paintbrush has not been studied to our knowledge, it has no apparent mechanisms to avoid or tolerate grazing and will be grazed out if not managed appropriately with a spring deferment. Common yarrow (Photo B), on the other hand, contains volatile plant secondary compounds including alkaloids and glycosides that generally limit its overall intake (a grazing avoidance mechanism). Additionally, note yarrow’s ability to tolerate grazing (a grazing tolerance mechanism) through production of side shoots. Yarrow photo taken in July after June grazing followed by rest.

Figure 2. This photo illustrates high grazing pressure that has led to the replacement of species lacking grazing resistance (decreasers) with highly grazing resistant species (increasers or invaders). Lack of grazing resistance among many preferred native plant species (and many preferred forage species) results in the dominance in many western Washington grasslands by Colonial bentgrass (*Agrostis capillaris*), Sweet vernalgrass (*Anthoxanthum ordoratum*), Annual brome (*Bromus hordaceous*), Rattail fescue (*Vulpia myuros*), Early hairgrass (*Aira praecox*) and others. Increaser forbs include, among others, Subterranean clover (Trifolium subterranean), Sheep sorrel (Rumex acetosella), Oxeye daisy (Leucanthemum vulgare), Hairy cat's ear (*Hypochaeris radicata*), and Common yarrow (*Achillea millefolium*).

Sidebar 3. Grazing Resistant Species in Western Washington

Grazing resistant species in western Washington tend to be short-lived, short-statured, exhibit reproductive strategies that resist grazing (annual reproduction, vegetative reproduction such as rhizomatous root systems or spreading by stolons), leaf out and set seed early in the season, and summer dormancy. They may present fine and short-lived leaf blades, hold axillary meristems (re-growth points) close to the ground to avoid grazing, and contain volatile compounds that limit livestock intake, such as cyanogenic compounds in Subterranean clover (*Trifolium subterraneum*). Plants that grazing animals avoid benefit from "interspecific competition", or in other words, these grazing resistant species benefit from the sunlight, fertility, and moisture available when more preferred and grazing intolerant species diminish. Little may be known about the grazing resistance or tolerance of target native species of interest. An example source of information is provided by the Scottish Forestry agency. This agency provides information on grazing resistance of native grass and forb species (Scottish Forestry n.d.) and is useful for developing grazing plans based on grazing resistance. The inventory ranks species on a 1-5 scale of grazing resistance for 36 species plus additional grazing response information for ten other species. Additionally, land managers can search out information on individual species regarding composition of plant secondary compounds, tolerance to grazing, leaf replacement potential, and competitive ability in terms of resource acquisition.

4. Manage Species Succession and Transitions to Improve Vegetative States

Theory

Grazing land managers use knowledge of how grassland plant communities change over time to influence these changes. Accumulated knowledge of plant community change in moist and more dry grass and arid-land environments have identified two main types of change. These are known as the succession and state-and-transition models (Clements 1936; see Sidebar 4).

Sidebar 4. Succession and State-and-Transition Theories to Plant Community Change

The ***succession theory*** (Clements 1936) describes plant community change as rather steady and predictable change from fast-growing, weedy pioneer plants to more complex and stable communities of desirable climax plant species. For practical purposes for management, change in the community is continuous (one condition leads to the next), reversible, and linear. Decrease in disturbance or increase in precipitation is thought to support higher climax communities. This theory better explains more moist environments or sites. The ***state-and-transition theory*** (Westoby 1989), by contrast, describes plant community change as less predictable. Change between states is abrupt, difficult or impossible to reverse, and often dramatic, leading to multiple different possible steady states after a transition. For practical purposes, the state-and-transition model recognizes that degraded or altered states may only be changed with intensive intervention, and better explains change in more arid environments or sites.

The usefulness of these concepts is to understand how plant communities may change to improved conditions, and to create or seize those opportunities; and likewise to avoid conditions or actions that will lead to degraded conditions. A key approach to being successful is developing ecological knowledge of the possible successional steps or ecological states possible at a site, and possible transitions between them.

Table 2. Successions and State Transitions Practices and Intended Outcomes

Goal/intended outcome	Practices
Gain knowledge to manage transitions and use “opportunistic management” to drive transitions	Develop a catalogue of possible ecological states
Increase awareness of strategies that prevent state declines and support state improvement	On-farm trials to develop and test transitions between ecological states
Allow tall-stature species to set seed	Mid-season or periodic season long rest (Figure 3)
Succession to shrubs or woodland is arrested and reversed to achieve a desired mid-successional ecological grassland condition	Appropriate disturbance is applied (e.g. fire or paired with grazing); heavy disturbance is applied in a specific season to eliminate dominance (Figure 5)
Transition to an improved state is supported by introducing seed or other propagules to sites where these desirable species have disappeared	Opportunistically introduce seed or seedlings (plugs, starts), or other propagules; intensity of disturbance is matched with difficulty of the transition

Habitat patches are introduced that have high percent native/preferred (forb or other) percent cover	Seed and protect disturbed micro-sites (consider exclusion cages strategically)
Invasive species replaced with preferred grass and forb	Burn-graze
Suppress “increasers” by creating open space for forbs, preferred forage or other habitat	Graze moderately to decrease dominant successional or state species cover (Figure 4)
“Decreasers” supported with carefully timed disturbance relief	Decrease grazing pressure under conditions favorable to the increase of sensitive species
“Decreasers” supported with carefully timed and located seed establishment	Seed under conditions or at microsites that are beneficial to seed establishment
Avoid dominant invasive weedy forbs	Avoid close, continuous grazing, instead generally moderate grazing with varying rest periods
Allow light penetration to new shoots	In historically undergrazed areas with some (> 20%) preferred species, graze to decrease thatch
Increase percent cover of native species	During growing season: low grazing intensity or periodic deferment
Arrest and reverse woody encroachment	High-intensity, localized disturbance (Figure 6)

Manage for Species Succession and Transitions – Examples

Figure 3. Tall stature species allowed to set seed. Orchardgrass (Dactylis glomerata), Sweet vernalgrass (Anthoxanthum odoratum), Tall fescue (Festuca arundinaceae)

Figure 4. Transitions from preferred or historical habitat “states” or conditions to less-preferred states can be driven by natural events (fire, weather) or by changing management (stocking rate, burning, fertilization, elimination of plant populations, or introduction of invasive plants; Westoby 1989) and are often not easily reversible. Photo A depicts seasonally wet grasslands in western Washington that can become invaded by Reed canary grass, which eliminates the short-statured vegetation needed by the endangered Oregon Spotted Frog for egg laying. Intensive grazing by a contracted cattle herd may be used over many seasons to reduce biomass, slow the invasion of Reed canary grass, and create Oregon Spotted Frog habitat. Photo B shows water depth monitoring work by Ecostudies Institute to monitor Spotted Frog habitat improvements as the result of summer grazing vegetation management. Photo C: Oregon Spotted Frog egg mass found in February waters in the summer-grazed Reed canary grass stubble. Photo credits: Ecostudies Institute.

Figure 5. Some degradations to optimum grazing and wildlife habitat can be reversed more easily, and this is sometimes referred to as plant succession. In more mesic (moist) environments, increased or decreased disturbance and/or precipitation tends to change plant communities along a succession continuum. In this photo, a derelict field is being invaded by Scotch broom and exotic cool-season grass species, with residual presence of native forbs including Common Camas (*Camassia quamash*, green shoots). The natural typical succession at this site (pm Spanaway gravelly-sandy loam soils) without any human management would be to proceed to shrubs and finally afforestation by Douglas Fir. Maintaining open grassland can be achieved by increasing the disturbance regime through grazing and/or fire, mechanical, or chemical treatments to maintain a mid-successional, open grassland plant community containing native forbs. This site is in early restoration, and a combination of grazing, fire, mechanical controls, and seeding will be used to reduce thatch, eliminate Scotch broom, and generate heterogeneous vegetation structure while maintaining forage resources for grazing animals. Natural succession may need to be augmented with forb seeding to more significantly shift the existing state (or condition) of this site, a state improvement that is not possible without external restoration work at many altered grassland sites in the region.

Figure 6. High-intensity prescribed fire managed by Loess Canyon Rangelands Alliance to combat Eastern Red Cedar encroachment in the Nebraska Loess Canyon region. Reversal from shrubland to grassland requires intensive disturbance but is successfully reversing bird biodiversity loss in this region. Recent research by U.S. Geological Service documented increased bird species richness on a 90,000 acre management unit.

5. Manage Grazing Distribution to Increase Habitat Heterogeneity

Theory

Managing grazing to generate uneven, or *heterogeneous*, landscapes contrasts rather surprisingly with long-held objectives in the range and pasture sciences to manage grazing for *even* forage use (Toombs et al. 2009). Following historical overuse of many grazing lands in the 19th century, and with a focus primarily on livestock and forage production, the goal in range and pasture sciences has been to develop practices that maximize yield of palatable species at peak digestibility while minimizing bare ground (Freese et al. 2014, Fuhlendorf et al. 2012). As noted, this focus has been described as utilitarian, and the resulting landscape as lacking in variability, or heterogeneity, that is required to support biodiverse wildlife populations by providing habitat niches. So important might heterogeneity be for habitat value (for arthropods, birds, mammals, amphibians, reptiles, and other wildlife) that it has been described as a "keystone structure" critical to maintaining species diversity (Tews et al. 2003).

While managing for uneven use, or heterogeneity, of grazing lands truly is a paradigm shift (and is likely to require financial incentives for livestock producers) the practices and conservation concepts for implementing it are somewhat straightforward. Landscape heterogeneity can be generated by natural processes (climate, soils, topography) and management impacts/ disturbances (grazing, fire, wildlife). Tools at the managers disposal include stocking rate, grazing systems, disturbance regimes, and livestock type and breed selection. Objectives, among others, of managing grazing for heterogeneity are to:

- Create "variability in structure and composition of plant communities over space and time" (Allison et al. 2017)
- Develop different vegetation structures and compositions to support different life cycles of individual species over short time-frames
- Provide patch sizes at different successional states (disturbed, undisturbed, transitional) that are preferred by different species, or the same species at different life stages
- Focus on ecological processes rather than individual species or target habitat or condition due to inherently conflicting needs of multiple target species on the same landscape
- Combine disturbance regimes, such as fire and grazing, to generate out-of-sequence shifting mosaics of disturbed, undisturbed, and transitional patches

A primary wildlife conservation premise of heterogeneity-based grazing is that wildlife requirements are too varied to manage for individually. Rather management must do its best to emulate variable disturbance regimes with the goal of creating diverse habitat niches.

Table 3. Grazing Distribution/Heterogeneity Practices and Intended Outcomes

Goal/intended outcome	Practices
The correct sizes of resource niches are created based on the needs of target species; landscape-scale management adapted for multiple target species	Maintain different patch sizes; some large, homogenous patches; others different (Figure 8)
Grazing livestock make selective use of available grasses and forbs, preferentially consuming high-biomass, palatable grass	Apply low to intermediate stocking rates to allow livestock grazing selectivity (see Stocking Rate)

species, consuming only small (<10-15%) of forb species, and creating open space for remaining forbs and small-stature species	
Suitable habitat is available for grassland birds at the extremes of the vegetation structure gradient	Create patches along the full range of the disturbance gradient
Diverse habitat is available in close proximity to meet different habitat needs during different life stages of a species	Maintain vegetation structure of varying heights in near proximity (high, low, medium nearby connected by edges, Figure 7) Create variable stages of disturbance at small scales with adjoining edges
Habitat is provided for species that prefer short, intermediate, and long time since last disturbance (usually weeks/months to several years)	Distribute grazing to create patches of varying time since disturbance (See Integrating Fire with Grazing)
"Ecological stability" is achieved by expressing the full spectrum of ecological patterns simultaneously on the landscape, providing habitat for multiple species with vastly diverging habitat preferences	Represent all stages of disturbance (time since disturbance and multiple ecological conditions, i.e. undisturbed/ transitional/ disturbed) at medium and large scales on the landscape (Figure 9)
Appropriate use in time releases (relief from disturbance is provided) target species at optimal moment	Provide patch, pasture, and landscape variability thoughtfully with knowledge of target species needs
High-quality forage regrowth is available for livestock or wild ungulates, which require higher-quality resource patches in the winter for survival	Remove old forage and thatch: graze areas heavily that have been neglected with large quantities of undisturbed, ungrazed, and over-mature forage (Figure 5)
Prolonged relief allows recovery of sensitive species, if available for recruitment from propagules or seed	Reduce or eliminate grazing pressure on areas that have been heavily disturbed/grazed in the past
Disturbance gradients are created based on distance from high-use areas and resource-rich locations; these are moved periodically to create a shifting pattern	Strategically use and move water ("piosphere effect") and supplement placement to draw disturbance
Within-pasture and among-pasture scales of heterogeneity are expressed where possible (within-pasture heterogeneity is challenging to express practically)	Select water and feed placement to create within-pasture and among-pasture variation
The full range of conditions (ie. disturbed/ transitional/undisturbed; not necessarily degraded/pristine) are identified for specific	Use herding, fencing, fire, or other to represent these conditions (Figure 10)

habitat-types and represented as a full suite on the landscape	Avoid over-representation of any one species or community across space and time
Wildlife forage resources are maintained on the landscape	Manage for unpalatable shrub components known to be utilized by wildlife
Grazing management is integrated with natural landscape variability	Utilize topo-edaphic features including uplands and lowlands, slopes, presence/absence of fossorial species soil disturbance, and seasonal differences in forage composition

Grazing Distribution to Increase Habitat Heterogeneity – Examples

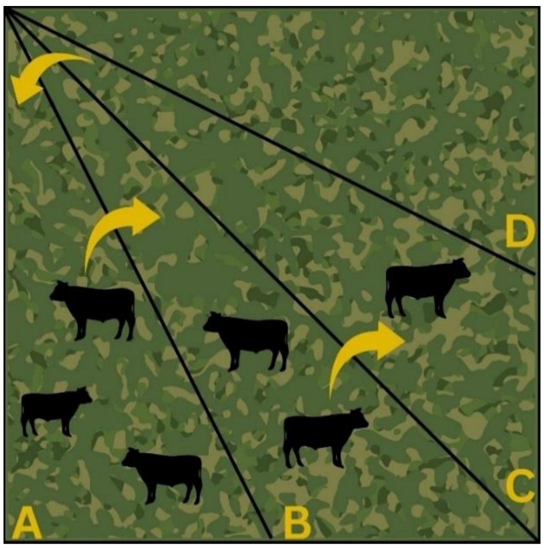

Figure 7. Schematic illustrating application of multiple different stocking rates to different paddocks to increase heterogeneity of vegetation structure. This system is adapted from Clark et al. (2024) and referred to as Modified Twice-Over Rest-Rotation Grazing. At the beginning of the grazing season, target utilization rates are identified for each paddock. For example, 70-80% utilization in paddock A, 40-50% utilization in paddock B, 20-30% utilization in paddock C, and 0% utilization in paddock D. Most practically, the targeted utilization rate is achieved by varying the amount of time that the same number livestock (or AUs) spend in each paddock. Time in each paddock needs to be determined by monitoring forage utilization rates through pre- and post-grazing biomass estimations using a pasture stick or other method. The "twice over" component refers to rotating cattle through this system arrangement twice per season, applying the same utilization rate each time. Additional paddocks can be added, using multiples of the same utilization rates, or different.

Figure 8. Streak horned lark populations typically occupy sites greater than 150 acres and preferably 100s of acres in the Puget Lowlands, Lower Columbia, and Willamette Valley; populations on smaller sites are exceptional, or border water bodies that expand effective/perceived area ….. Streaked horned lark nest in bare rocky ground adjacent to a tuft of dead vegetation (Photo credit: Dr. Randy Moore, Oregon Department of Fish and Wildlife; WDFW n.d.)

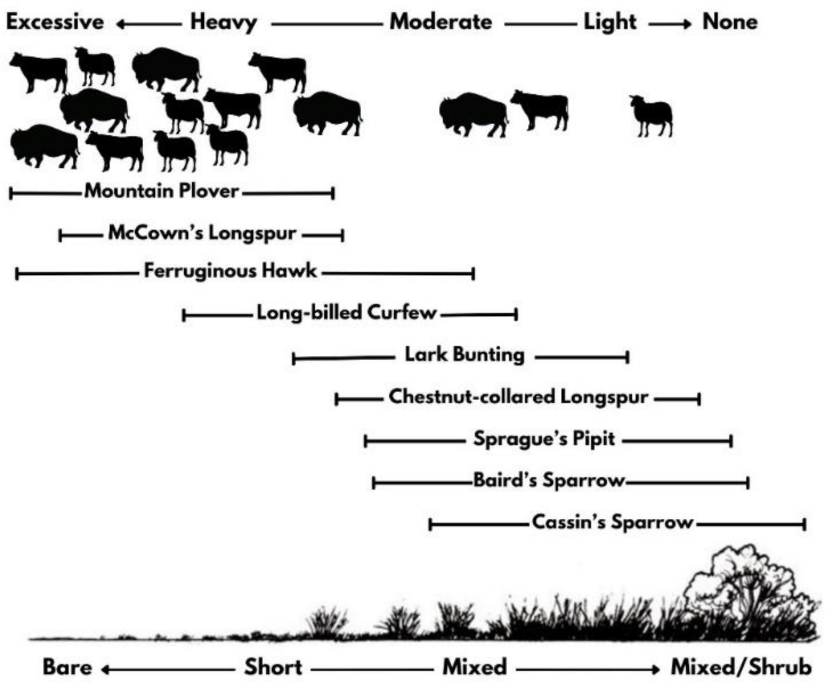

Figure 9. Disturbance intensity preferences of several grassland bird species. Habitat for target species can be created by varying time since disturbance (in months or years) and representing a variety of times since disturbance simultaneously from year to year. Figure modified from Derner et al. (2009), who refer to this as a vegetation structure gradient. Species listed here are typical to North American Great Plains. A vegetation structure gradient for Puget Prairie and example grassland bird species with associated preferences are, from high to low disturbance: Streaked horned lark (150 to 300+ acre patches, sparsely vegetated grassland, >60% bare ground), Western Meadowlark (7-15 acre patches, low-stature vegetation, 3-6% bare ground + tall structure >25 cm), Oregon Vesper Sparrow (10-20 acre patches, grassy edge habitat, grasses 15-30 cm + woody vegetation and patches of bare ground), and Western bluebird (10-20 acre patches, open woodland savanna with snags, fruiting shrubs, moderate disturbance to maintain open woodland structure).

Figure 10. This image shows a continuously used grazing lane next to a rotationally grazed paddock. These areas with greatly varying utilization allows for contrasting vegetation structure in close proximity.

6. Manage Disturbance Regimes: Integrate Grazing and Fire to Restore Ecological Processes and Patterns

Theory

Until recently, dominant conservation theory has held that landscape disturbance is unnatural, and that the most effective approach for restoration is homogenous, moderate disturbance (Fuhlendorf et al. 2009). The failure of these homogenous, moderate disturbance regimes to staunch grassland ecosystem degradation, as exhibited by globally distributed woody encroachment (Roberts 2024), has revealed shortcomings of this approach. While policy and public perception lags, research has demonstrated the importance of spatially and temporally heterogenous disturbance regimes, generating large areas each of no- to low-disturbance combined with areas of intense disturbance in a random pattern with varying time since disturbance (see Figure 2).

To effectively implement heterogeneous disturbance regimes using livestock to generate habitat, livestock producers and conservation land managers each must overcome entrenched practices. Producers must avoid 'managing to the middle': uniformly grazing to generate even forage height and utilization.

A conceptual question for livestock producers and conservation land managers is how to implement heterogeneous disturbance regimes.

Table 4. Integrating Disturbance Regimes Practices and Intended Outcomes

Goal/intended outcome	Practices
Biomass is reduced and nutrient-rich patches are created that draws grazing animals and reduces disturbance elsewhere; nutrient availability is increased to forages	Integrate patch burning with grazing (i.e. "pyric herbivory") as a single disturbance sequence, and move this combination around the landscape to create out-of-sequence mosaics; use fire to draw grazing to specific sites and reduce at other sites
A combination of highly disturbed (high grazing pressure) and undisturbed (light to no grazing pressure) habitat patches is created (Figure 11)	Manipulate grazing pressure with pyric herbivory and, if scale does not permit natural livestock distribution, fencing/paddocks to mimic natural movement (Figure 11)
Capacity is developed to apply fire safely on a range of scales, including smaller-scale landowners burning 5-10 acre patches	Collaborate with local burn partners (such as conservation organizations, Department of Fish and Wildlife, or tribes) or join or create a Prescribed Burn Association
Habitat is provided for grassland birds that prefer habitat from zero to 36 months and more since focal disturbance	Represent the "…the entire gradient of vegetation structure" generated by patch burning and grazing (Figure 12)
"Pyrodiversity"	Manage fire specifically with different fuel loads to generate variable burn intensities at different positions on the landscape

Fire interacts with: variable fuel load to generate uneven burn intensity; grazing to generate uneven forage utilization; uneven grazing to variably distribute fertility; with burn frequency to vary between-fire forage composition	Be alert to integrating fire with other disturbance processes such as fuel load, mowing, grazing, manure distribution, and fire frequency, and others

Integrating Disturbance Regimes – Examples

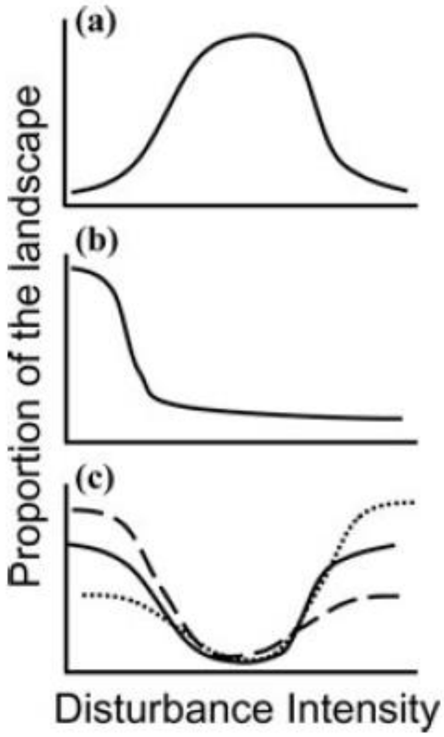

Figure 11. Conceptual models of the proportion of the landscape receiving different disturbance intensities. In grassland ecosystems, (a) represents the agricultural land-management model and the intermediate-disturbance hypothesis in which the majority of the landscape is moderately disturbed, (b) represents a protectionist model in which disturbance is minimized across the entire landscape, and (c) represents the landscape disturbance pattern expected from a fire and grazing interaction that creates a shifting-mosaic landscape (Fuhlendorf et al. 2009).

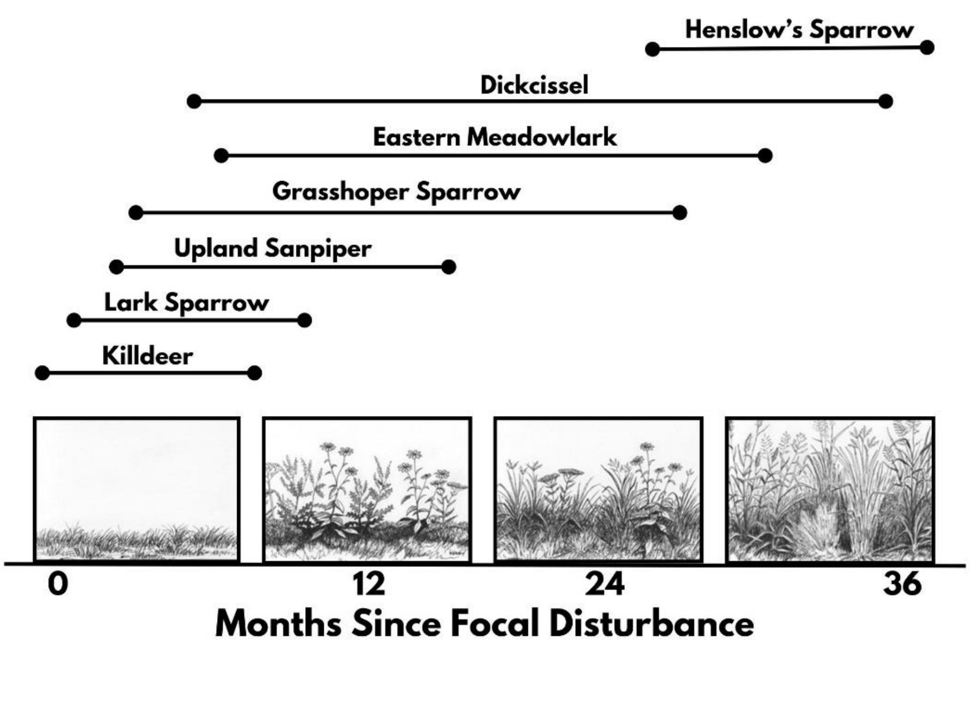

Figure 12. Response of grassland birds to time since focal disturbance by fire and grazing at the Tallgrass Prairie Preserve from 2001 to 2003. Art work in the figure courtesy of Gary Kerby. From Fuhlendorf et al. (2009)

7. Soil Management

Theory

Understanding the difference between extensive as compared to intensive land management is central to managing soil fertility on grasslands for habitat and biodiversity (see Sidebar 5).

Sidebar 5. Extensive versus Intensive Grazing Systems

Many of the world's grasslands evolved to some degree in conjunction with extensive grazing, along with other disturbances such as fire. In extensive grazing systems feed for livestock is sourced from natural grasslands, shrublands and woodlands, in contrast to intensive systems where food is sourced from seeded and fertilized pastures (FAO 1991).

Agricultural intensification over the 20th century, in conjunction with atmospheric nitrogen (N) and phosphorous (P) deposition has led to grassland soil nutrient enrichment. The impact on grassland species richness (SR) has generally been negative (Stevens et al. 2010, Lyons et al. 2023, Soons et al. 2017). This is compounded by species loss due to landscape fragmentation, decrease in seed distribution associated with livestock transhumance (and thus population isolation), and competition with fast-growing introduced species (Walker et al. 2004, Soons et al. 2017), among other factors.

Grazing managers can manage soil fertility to increase habitat and species biodiversity by guarding against nutrient enrichment. When working on private lands or contracting with private producers where nutrient-limited conditions may negatively affect livestock and forage production, measures need to be considered to compensate producers for habitat services in addition to food production ecosystem services. Otherwise conservation will work against active market disincentives, and weaken the economic viability of critical private lands partners.

The general observation regarding soil fertility for species-rich grasslands is that high nutrient levels preference generalist (typically "increaser") over specialist (typically "decreaser") species because generalists respond most rapidly to elevated nutrients, a degree of disturbance, and resource abundance (McKinney and Lockwood 1999). Common Eurasian grasses introduced to Puget Prairies including Kentucky bluegrass (*Poa pratensis*), Colonial bentgrass (*Agrostis stolonifera*), Rattail fescue (*Vulpia myuros*), Quackgrass (*Elymus repens*), and Perennial ryegrass (*Lolium perenne*) fall into this category. In particular, species richness can be supported by avoiding simultaneous addition or enrichment of multiple nutrients, such as N + P, or N + P + potassium (K), as multiple elevated nutrients negatively affect native plant biodiversity the most (Scotton et al. 2024).

Managers must also be aware of the impact of soil fertility enrichment on soil biological communities, which will significantly impact success in re-establishing late-successful grassland forbs and other target species (see Sidebar 6).

Sidebar 6. The Role of Soil Biological Communities in Grassland Restoration

Soil biological communities and dynamics are also impacted by intensive versus extensive management, with higher fungi:bacteria ratios in the latter. Arbuscular mycorrhizal (AM) fungi may be a critical "missing link" in successful establishment of higher successional grassland species (Kozial et al 201&). Grazing land managers can consider options to culture and reintroduce AM from sites references grassland sites known to extant AM populations and a higher fungi:bacteria ratio (Kozial et al. 2022). Robust AM fungal populations are likely essential to efficient below-ground distribution of essential nutrients (e.g. N, P, and water), with more efficient transfers supporting late-successional “stress tolerator” species; whereas nutrient enrichment depresses growth of often rare stress tolerator species and preferences introduced generalist and colonizer species (including fast-growing perennials and weedy plants; Bardgett et al. 2007). Improved outcomes for increasing plant biodiversity in grazed systems thus calls for lower nutrient levels (in particular soluble N). Resulting enhanced mycorrhizal networks have been shown to support ‘herb’ or flowering plant (forb) species and suppress fast-growing grasses (Grime et al. 1987, Van der Heijden et al. 2004, Chomel et al. 2022).

Table 5. Soil Management Practices and Intended Outcomes

Goal/intended outcome	Practices
Establishment of species sensitive to elevated levels of nitrogen (esp. inorganic) and phosphorous, which reduce species richness in native grasslands over time	Limit or eliminate nitrogen (N) and phosphorous (P) additions, and potassium if in combination with N and P
Limited soil inorganic nitrogen increases the soil fungi-bacteria ratio	Less intensive management is applied focused on low external-input practices, in particular soluble inorganic fertilizers
Less competitive native grass, native forb, and legume species establish, increasing species richness	Manage for higher soil fungi:bacteria by modifying soil fertility management, as above (Figure 13)
	Manage to decrease nutrient-enriched topsoil; consider removing topsoil, plowing at depth, and burying upper layers by inverting with a plow (Figure 14)
A “staged colonization” restoration scheme increases species richness, fungi:bacteria, and establishment success	Early in restoration sow plant functional groups/species such as legumes (*Trifolium pratense*, *Trifolium repens*) and yellow rattle (Rhinanthus minor) to condition soil for subsequent species establishment; experiment with others such as
Dominance of introduced cool-season grass species such as perennial ryebrass (*Lolium perenne*), and others that preferentially use inorganic N, are suppressed	Introduce and support legumes in the sward, and rely on soil biological networks for “…interplant transfers of nutrients via hyphal links” and decomposition/soil nutrient cycling
	To the extent possible manage against and limit introduction of ruderal (weedy) non-native species that outcompete native
Native seed restoration and overall biodiversity is improved, in particular for late-succession native species that are difficult to establish	Use native arbuscular mycorrhizal fungi in grassland restoration; specific AM species may need to be locally cultured to be effective and of sufficient concentration

Soil Management – Examples

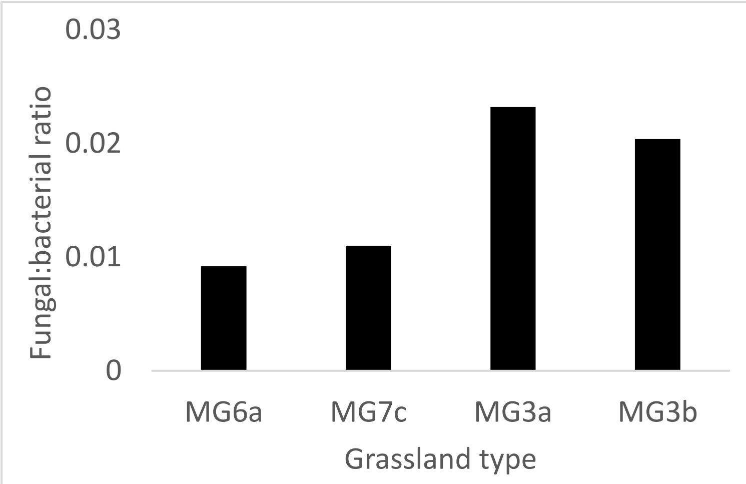

Figure 13. Effects of management intensity on fungal-to-bacterial biomass ratios. Gradient of management intensity in the Yorkshire Dales: (i) improved (MG6a); (ii) Very modified meadow (MG3a/MG7c); (iii) Slightly modified meadow (MG3a), and; (iv) Unmodified meadow (MG3b). Figure recreated from Bardgett and McAlister (1999).

Figure 14. Volunteers at a Scottish Wildlife Trust site taking an aggressive approach (full sod removal) to reducing competition and likely reducing soil fertility enrichment. Photo credit: Clare Toner. https://scottishwildlifetrust.org.uk/2020/06/making-room-for-meadows/

8. Grazing Systems

Theory

A variety of grazing systems are available to manage animal impact. These include continuous grazing, rest-rotation grazing, deferment grazing, and management-intensive grazing (or variations on rotational grazing), among finer gradations of each, and these are described in Figure EE. The strengths and weaknesses of different grazing systems vary, among other ways, in terms of:

- Suitability to enhance habitat
- Suitability to improve pasture or range condition (from a livestock production perspective)
- Affordability (infrastructure required)
- Management knowledge and time

Attempts have been made to score grazing systems regarding the likelihood of achieving specified management objectives. For example, Reece et al. (2008) note the following: continuous systems require the least labor and infrastructure while providing some vegetation heterogeneity; rest rotation systems well-designed offer good season-long nesting cover and are moderately affordable and complex; deferred rotation systems supports range improvement and some nesting cover while requiring only moderate management, and; intensively managed systems optimize grazing distribution and livestock management but reduce nesting cover and can be costly (Table 6).

Table 6. Suitability of Four Grazing Systems to Achieve Various Management Objectives, Ranked from 1 (least likely) to 5 (most likely). Adapted from Reece et al. (2008)

	Continuous	Rest Rotation	Deferred Rotation	Intensively Managed
Provide nesting cover	3	5	3	1
Improve grazing distribution	1	3	3	5
Minimize fence and water expense	5	3	3	1
Facilitate livestock management	1	4	4	5

Grazing land managers should be inclusive in their selection of grazing systems. Grassland bird researchers, for example, have noted that diverse disturbance regimes generate "…patchiness across the landscape, contributing to a shifting mosaic that presumably enhances biodiversity" (Fuhlendorf et al. 2006). A mix-match approach to grazing systems can contribute to landscape patchiness, thus arguing against a strict subscription to any one grazing systems (Figure Q). Just as with stocking rate, no single grazing system is likely to be appropriate for the suite of wildlife habitat patches needed on the landscape. Remaining flexible is appropriate when applying grazing systems on the basis of restoring diverse ecological processes and resulting patterns.

Table 7. Grazing Systems Practices and Intended Outcomes

Goal/intended outcome	Practices
Creation of variable vegetation structure and wildlife habitat at the with-pasture scale; high bite size, daily intake, and rate of gain due to selectivity	Season-long continuous grazing system at low to moderate stocking rate (Reece et al. 2008, Figure 15)
Creation of between-pasture heterogeneity on the landscape, sensitive species receive periodic rest, and forage evenness increased in grazed paddocks; bird nesting cover provided in rested paddocks	Take one or two paddocks out of rotation each year, and rotate livestock once/season through the remaining paddocks in a rest-rotation grazing system (Reece et al. 2008, Figure 15)
Distribute forage use somewhat evenly, allow rest, and provide bird nesting cover for specific seasonal time period; can vary sequence of use; 50-70% of area rested at any one time; bite size, intake, and gain will decrease in last grazed paddocks with over-mature forage	Rotate livestock once through each of 4-6 or more paddocks over the course of the growing season in a deferment grazing system (Reece et al. 2008, Figure 15)
Most even forage use; frequent rotation can minimize nesting cover and reduce habitat quality; forage palatability is often optimized; bite size, intake, and rate of gain can decline if forage availability becomes limited at high SRs	Divide pastures up into the greatest number in a Management-Intensive Grazing (MiG) system, apply high grazing pressures, and rotate frequently according to target utilization rates, typically leaving 3-4" even stubble heights (Reece et al. 2008, Figure 15)
Combinations of tall-stature, low-stature, and mixed habitat niches achieved in a "mix-match" approach to grazing systems; attributes of all above grazing systems integrated at a single ranch site	Integrate different grazing systems on different pastures, and rotate these systems across pastures over the years (Figure 16)
Variation in vegetative structure between pastures is created	Vary season and intensity of pasture use with deferment or rest-rotation (potentially in combination with variable SR)
"The capacity of managers to detect [and] learn" is supported	Set goals for utilization, heterogeneity, habitat niches, etc by pasture, and monitor in order to manage adaptively; recruit monitoring partners
High grazing efficiency is achieved to the extent possible, even after deferment or rest-rotation of some paddocks; livestock return is	Use high stocking rate for post-deferment grazing (Figures 17 and 18))

timed with fledging or specific bloom times for target plant species	
Purposeful application of different grazing systems in time and space, achieving specific forage and natural resources objectives	Understand the key differences in forage utilization and habitat of different grazing systems (see the next four rows, and Figure 19)
Low grazing efficiency, mix-stature vegetation structure, and uneven grazing in post-deferment paddocks is achieved	Use low to moderate stocking rate for post-deferment grazing
Rest at key times in phenological development (i.e. flowering) is provided to prevent competitive disadvantage that would result from season-long grazing of species of importance	Use season of grazing (and rest) thoughtfully to balance competition between forage species (Figure 20)

Grazing Systems – Examples

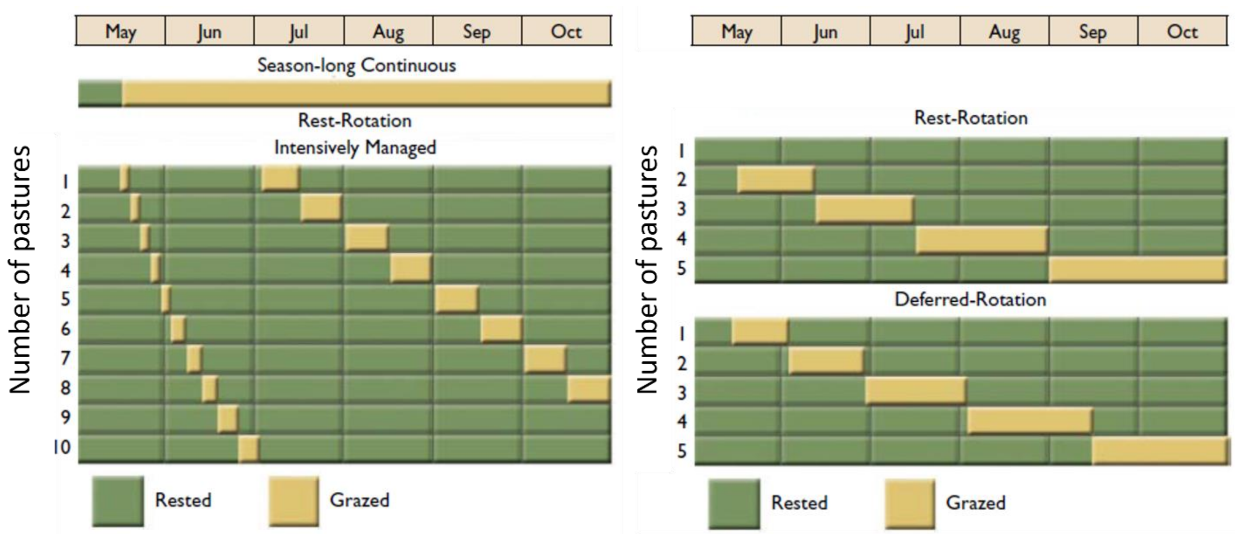

Figure 15. Grazing systems have different, and sometimes surprising, affects on livestock production and habitat quality. Heterogeneous patchiness can be obtained with season-long continuous grazing at low to moderate stocking rates, but sites must be managed to prevent degradation at heavy use areas. Intensively managed rotational systems generate the most even use (and can maximize forage production/area) but tend to eliminate habitat patchiness and can damage nesting cover. One or two paddocks per year are set aside in rest-rotation systems, which has been described as "…the most effective way to maintain high levels of vigor in key plant species" (Reece et al. 2008). Deferment grazing is flexible, but generally means rotation of livestock one-time through each paddock over the year. It can be designed to provide rest at critical periods, such as known nesting seasons, and sequence of use can be varied across years. Multiple systems can, and generally should, be combined to optimize conservation and production values across the landscape (see Figure Q). Figure modified from Reece et al. (2008).

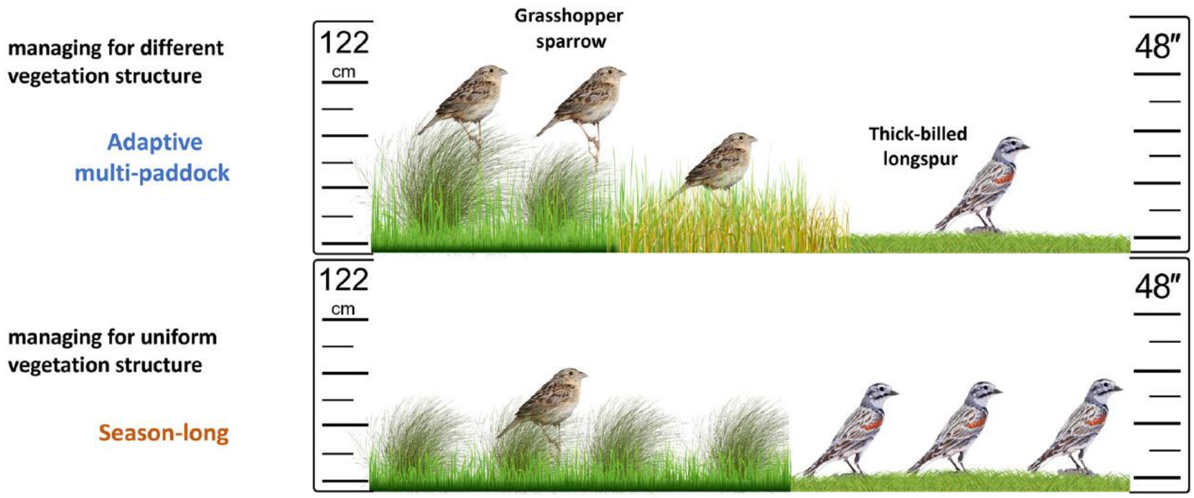

Figure 16. Heterogeneous vegetation structure can be achieved by integrating different grazing systems on different pastures and rotating these systems among pastures over the years. This project in northeastern Colorado on shortgrass steppe shows how adaptive multi-paddock grazing (top panel) is most effective at creating habitat for bird species that prefer tall and medium-height vegetation stature (Grasshopper sparrow; Song sparrow preferences approximately equivalent in Puget prairies), but less effective at creating habitat for species preferring short-stature (Thick-billed longspur. Season-long continuous grazing on productive soils (bottom left panel) is moderately effective at creating habitat for bird species that prefer tall and medium-height vegetation stature, while the same season-long grazing on low-productivity soils was highly effective at creating habitat for bird species preferring short-cropped vegetation. In the diagram, more birds indicates better habitat outcomes. Combined, these two grazing systems are more effective than when used alone, in creating habitat for bird species with divergent preferences. Figure from Raynor et al. (2022).

Figure 17. Adequate use can be made of mature forages of mixed palatability if grazed at a sufficient density as illustrated in figures X and Y. Here a mixed stand of Tall fescue (*Festuca arundinaceae*), Orchardgrass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), Colonial bentgrass (*Agrostis capillaris*), Subterranean clover (*Trifolium subterraneum*), and various forbs including a considerable cover of Oxeye daisy (*Leucanthemum vulgare*), all species in the reproductive phase, were grazed following a spring deferment period at a stocking rate of 45 head per acre (~50 AUM/ac). Residual stubble heights after grazing ranged from 3-8 in. depending on the species and location, including use of numerous palatable and less palatable forbs (see Figure U).

Figure 18. Forage consumption during post-deferment grazing in June, from top left clockwise: A: fescue (Fesctuca sp.), B: Oxeye daisy (*Leucanthemum vulgare*), C: Common Yarrow (*Achillea millefolium*), and D: Horsetail (Equisetum sp).

Figure 19. A deferment (A) versus a continuous grazing system with high grazing pressure (B) on the same pasture in the same month (April) in two sequential years. In 2021 (A) a deferment system was used to withhold grazing in April and May for spring-blooming forbs. In 2022 (B) the ranch ran out of hay due to economic and supply chain issues. The pictures illustrate the interaction of grazing system, stocking rate, and grazing resistance on the use by livestock of Common camas (*Camassia quamash*), a native forb. Continuous access to the plant, high stocking rate and lack of avoidance mechanisms resulted in high percent use of this forb, but also created low-stature and patchy bare ground. Continuous grazing paired with high grazing pressure resulted in non-selective use of all available forage, including forbs, in spring of 2022.

Figure 20. Deferment grazing systems can be coordinated to match reproductive stage of specific species or be time-controlled as described by Reece et al. (2008, Figure ZZ). Pictured here is a April-early June deferment timed to spring-blooming native forbs. (A) Immature seedpods of Common Camas (*Camassia quamash*). (B) Nearly mature seedpods that grazing livestock are likely to avoid at this stage; grazing can commence when pods begin to show signs of wrinkling and drying. (C) Fully mature, dry seedpods of shedding clusters of small black seeds. (D) Fully dried Camassia Quamash and (E) Plectritis congesta. Goals for a deferment may include getting to the post-bloom stage, going all the way to viable seed, or other, which will determine when to end the deferment.

9. Stocking Rate

Theory

Livestock producers exert a great deal of control over grazing impact on plants and plant communities by determining the number of animals to graze, the size of the grazing area, and the duration of grazing time. Together these variables determine the stocking rate. Importantly, when managing grazing lands for livestock production and ecosystem management, there is no "right" stocking rate; rather, there will be numerous appropriate stocking rates to achieve multiple and often quite different ecosystem landscape objectives (Fuhlendor et al. 2012; Campbell et al. 2006). For example, herding, as a profession itself, represents an aggregation of nuanced skill and knowledge by which the herder and herding dog interact with a flock to apply specific grazing pressures (through number of sheep applied to a specific area over a period of time) to generate any number of forage management outcomes (see Figure BB). In the context of grazing for habitat, these may include:

- Using a high to very high stocking rate to encourage even use of all available forage, including grasses, legumes, forbs and shrubs, creating open and low vegetation structure and potentially areas of bare ground
- Using a moderate stocking rate to apply sufficient grazing pressure to create separation in use between grasses and legumes on the one hand and forbs and shrubs on the other
- Using a light stocking rate to support growth and reproduction of upright grassland species, many of which due to elevated growing points can be grazed out

A substantial body of literature is available evaluating the effect of stocking rate on forage use, vegetation heterogeneity, and biodiversity and can be explored in Further Reading.

To reliably achieve conservation outcomes with grazing, stocking rate is combined with a chosen approach to monitor forage use. Options include utilization (percent of forage consumed or wasted), harvest efficiency (percent of forage consumed), residual dry matter (amount of forage remaining at the end of the grazing season), and grazing pressure index (see Sidebar 7). For reference, moderate stocking rate corresponds approximately with 50% utilization and 25% harvest efficiency (Smart et al. 2010)

Sidebar 7. Grazing Pressure Index

Managing stocking rate and density for a heterogeneity regime will require multiple rates and use of the Grazing Pressure Index (GPI) may be useful (Smart et al. 2010). The GPI can be applied as an objective means of quantifying grazing pressure to achieve high and low grazing pressure needed to create heterogeneous vegetation structure. In landscapes managed for patch-mosaic patterns, for example, GPI can be utilized to calculate animal units to deploy in a pasture in relation to available forage. Based on work by Smart et al. (2010), a pasture or patch receiving heavy disturbance to generate low-stature forage would be stocked at 36 AU/ton (1.2 AUM/ton), and a pasture or patch receiving light pressure for relatively undisturbed structure would be stocked at 13 AU/ton (0.43 AUM/ton). Variation and modification of these figures in practical application is inevitable and necessary, but they can serve as a starting point. Available forage estimation is required to use this approach, whether with a pasture stick, rising plate meter, or cut and weight methods.

Table 8. Stocking Rate Practices and Intended Outcomes

Goal/intended outcome	Practices
Different utilization rates is achieved in different paddocks and maintained over the entire grazing season	Set specific utilization rate targets for each paddock across available paddocks in rotational systems
Inadvertent preferencing of grazing-tolerant species is prevented by avoiding SRs that lead to high harvest efficiency (i.e. non-selective grazing)	Manage grazing intensity and timing to offset competitive exclusion by dominant grass species of less-competitive sward elements such as native forbs and bunchgrasses (Figure 21)
The competitive exclusion by tall-stature grasses of forbs and other low-growing target species is eliminated	Apply sufficient (typ. moderate) grazing pressure to create separation in use between grasses/legumes and forbs/shrubs, but not so much that forbs are used overmuch
Forage species with tall-stature (height) and upright growth-form prevail in the sward	Apply consistently low SR to grazed areas over long periods of time, preferencing tall, upright species.
Forage species with low-stature (height) and prostrate or sprawling growth-form prevail in the sward	Apply consistently high SR to grazed areas over long periods of period, preferencing short, prostrate species
Forb grazing is minimized	Low SRs tend to maintain low forb use as an overall percent of intake
Full (complete removal), minimal (nearly no removal), and selective use of forage is achieved strategically; different SRs support a combination of heterogenous and homogenous grazing pressures.	Calculate and apply low, medium, and high SR to achieve varying utilization rates. Apply low to medium SRs for high grazing selectivity, and the opposite for low grazing selectivity (See Sidebar 7, Figure 22)
Overall sward biodiversity increases	Moderate grazing to increase species richness
Grazing selectivity is achieved in large continuously grazed and rotationally grazed paddocks; even (non-selective) use is avoided where uneven forage use is desired (e.g. separation between grass/legume and forb/ shrub use)	Use low SR; avoid uniform, complete application of high stocking densities in all paddocks
Specific vegetation uses are achieved, such as pressure on shrubs, protection of medicinal are rare plants, use of over-mature forage, and so on	Close herding, management intensive grazing (MiG), or other careful management of site forage for specific goals (Figure 23)

Stocking rate – Examples

Figure 21. The key to understanding how to apply proper stocking densities is to have clear goals. Whereas high stocking rate and utilization rate can negatively affect regrowth and thus reduce overall forage productivity, this same effect can be applied purposefully to reduce the competitive exclusion by cool-season grasses of native forbs. In the photo above, high stocking rate was applied in February-March prior to a peak native forb bloom to purposefully set back non-native perennial grasses and allow light and room for Spring gold (*Lomatium utriculatum*) and Common camas (*Camassia quamash*, picture above as clumps of thick, grass-like leaves). The process has sometimes been referred to as "managed over-grazing", but that is perhaps a misnomer, as the high grazing pressure is set on purpose to match the habitat objective, and thus is not excessive. A deferment began in mid-March, 2022 (photo taken March 28th) following heavy grazing. Under continued deferment through May or early June, this field will become a carpet of Camas and Spring gold blooms and produce substantial seed.

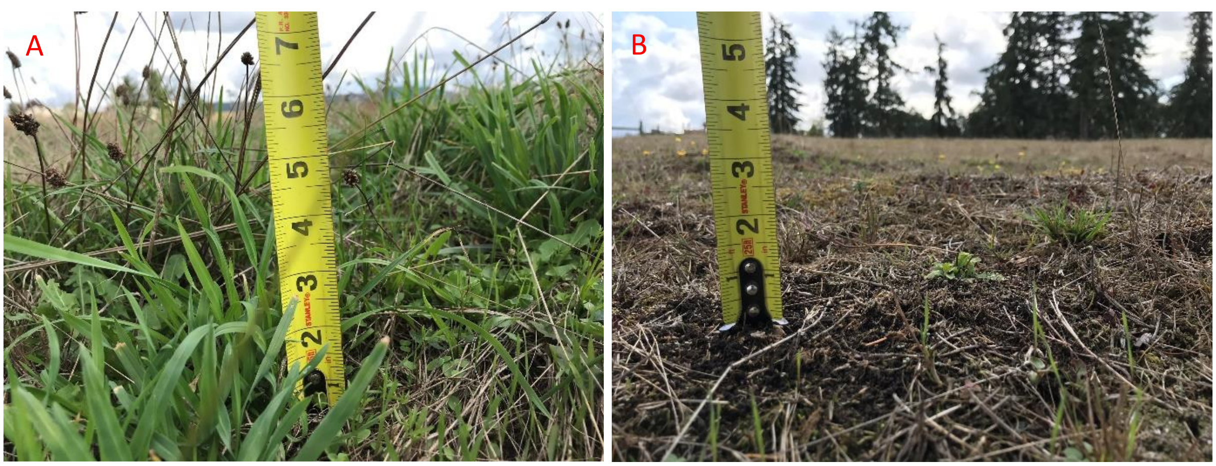

Figure 22. Stocking rate can be used to apply full, partial, or no forage removal. Over time high stocking densities applied under continuous grazing will affect plant species composition through replacement of grazing intolerant with grazing tolerant species (species replacement). While stocking rate is generally (and in most cases should) be set to leave forage residual (2-4 inches, roughly optimizing carrying capacity), higher densities can be set to achieve more complete or full removal for specific habitat purposes (exceeding typical carrying capacity). Above are photos of two grazed sites taken fall 2019 and illustrate the effect of stocking rate and grazing system on vegetation structure as well as fall regrowth. The stocking rate of site A was determined to retain 4-6 inch summer stubble height with periodic rest. Stocking rate at site B resulted in consistent <1-2 inch stubble height with limited to no rest. Photos were taken on September 13th and 18th, respectively (2019), are both on Nisqually gravelly sandy loam and within 20 miles of each other.

Figure 23. "Close herding" is a term that has been used to describe active, close-proximity management of a grazing herd. Many traditional herders in Hungary have used this approach, and it has been adopted from there to a ranch in Idaho as well. The intent is to manage grazing time and animal numbers on the various pastures available to the shepherd; in other words, stocking rate. Goals can be to reserve areas where new growth is tender, exert greater pressure on over-mature or less-preferred forages, maintenance of rare or medicinal plants in the sward, use of shrubs to prevent encroachment, and to utilize particular forages before they become too mature, among others (Molnar et al. 2016). The herder pictured here describes the herding process as "the whole afternoon involves them starting off and me walking out to head them off". With such close attention, forage use or protection can be managed much more carefully and precisely with close herding than even high-intensity rotational grazing; although the objectives may be similar in terms of managing grazing pressure in specific areas for specific purposes (Molnar et al. 2022).

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