Grazing and Fire: Critical Components of Grasslands of the Eastern United States

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INTRODUCTION

Fire is a natural part of grassland ecosystems and has influenced plant communities with humans simply altering the role of fire (Scott 2000, Pausas and Keeley 2009). Similarly, herbivores have had a strong impact on plant communities (Johnson 2009). The combination of grazing, climate, and fire are particularly important in maintaining grassland ecosystems (Anderson 2006, Blair et al. 2014). Fire and grazing may be more critical as maintenance tools for grasslands that are in climates where precipitation can support development of forests (Bond 2005, 2008).

The warm, humid climate of the eastern United States is conducive to forest (Bond and Keeley 2005). However, grasslands and other fire-adapted communities have persisted in this region and were more prevalent in the past (Echols and Zomlefer 2010, Tompkins et al. 2010, Campbell and Seymour 2012, Johnson et al. 2013, Tompkins 2013). Here we review the role and importance of grazing and fire in the grassland ecosystems of the eastern United States. We also explore the more recent history and modern research of reintroducing these disturbances into eastern grasslands and highlight their importance for habitat management.

THE ROLE OF GRAZING IN GRASSLAND ECOSYSTEMS

Grasslands in the humid climate of the eastern United States receive enough precipitation, on average, to allow succession to forest in the absence of appropriate disturbance (Milchunas et al. 1988, Bond 2005, Bond and Keeley 2005). Historically, herbivores like deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), and American bison (*Bison bison*) were part of the open-habitat ecosystems in the eastern United States (Carroll et al. 2002). Explorers in the 1600s and 1700s reported seeing American bison (*Bison bison*) throughout the Southeastern Coastal Plain (Rostlund 1960). There are also accounts of bison in Indiana, Ohio, Illinois, Kentucky, and as far east as Virginia, New York, and Maryland (Belue 1996). Bison were considered a keystone species in native grasslands (Knapp et al. 1999). However, bison populations have been reduced drastically and may no longer play a significant role in grasslands (Shaw 1995, Belue 1996, Sanderson et al. 2008). Grazing by domestic livestock such as cattle (*Bos taurus*) may serve as a suitable alternative source of disturbance. Some even argue that livestock are a keystone species (Bock et al. 1993).

Grazing as a benefit to the individual plant has been the subject of some debate and may depend on the species of plant (Thompson and Uttley 1982, Verkaar 1986). In general, the act of defoliating a plant (like a grazing animal would) has a negative effect on the individual plant. Defoliation can reduce aboveground and belowground carbohydrate reserves, especially under intensive grazing (Owensby et al. 1977, Anderson et al. 1989). Intensive grazing may also reduce tiller replacement and decrease plant overwinter survival (Olson and Richards 1988). In particular, grazing during the late season or winter also may further decrease the survival of plants and spring regrowth (Owensby et al. 1970, Bullock et al. 1994). Tiller density might remain stable for some species, though (Hirata and Pakiding 2001). In some cases (e.g., less intensive grazing), plants may compensate their growth in response to defoliation (Georgiadis et al. 1989).

However, the effect of grazing on the overall production of the grassland system tends to be positive (Ferraro and Oesterheld 2002). When cattle grazed on native prairie, Hayes and Holl (2003) found that grazed sites had greater species richness and cover of native forbs compared to ungrazed sites. Other researchers have also found that grazing can increase species richness and diversity of plants. (Pykälä 2003, 2004, Bakker et al. 2006). In some situations, such as when there is standing dead biomass, grazing can increase the productivity of plants (Milchunas and Lauenroth 1993, Altesor et al. 2005).

The distribution and cycling of nutrients is also affected by grazers (Dubeux et al. 2007, Schnyder et al. 2010). Through ingestion and excretion, grazers may increase the rate of nutrient cycling (Rotz et al. 2005). Periods of rest may further promote nitrogen cycling (Sun et al. 2017). When nutrients are returned to the soil quickly, there may be a positive effect on soil biota leading to increased productivity at the ecosystem scale (Bardgett and Wardle 2003). However, the nutrients are typically deposited in concentrated patches near shade and water (Rotz et al. 2005). Urine deposits might have a positive effect on the abundance of forbs and warm-season grasses (Steinauer and Collins 1995). Excretion sites may serve as an important source of phosphorus, but may also facilitate the loss of nitrogen from the area via ammonia volatilization (Dubeux et al. 2007). Modifying the movements of livestock with portable shade or water sources may serve to re-distribute excretion sites (Rotz et al. 2005).

Perhaps the most important function of grazers is their ability to alter the structure of the vegetation (Sala et al. 1986, Derner et al. 2009). Through foraging, grazers can reduce the height of the plants and shift the distribution of leaves closer to the ground (Sala et al. 1986, Hayes and

Holl 2003). The presence of grazers may also help to reduce the depth of litter and increase the amount of bare ground (Hayes and Holl 2003). The reduced cover of grass and litter and the resulting increase in bare ground may facilitate the introduction of woody seedlings (Archer et al. 2017). Left unchecked, these woody plants have the potential to outcompete grasses. To counter the encroachment of woody plants in a grassland, fire is considered an important tool (Bond 2008, Archer et al. 2017).

FIRE IN THE EASTERN UNITED STATES

The pre-settlement eastern United States has frequently been depicted as a vast, unbroken forest (Day 1953). However, some have argued against this claim (Askins 1999), the idea even being dubbed "erroneous" by Maxwell (1910). Alternatively, large parts of the eastern United States were not forested but subject to extensive agriculture by Native Americans (Doolittle 1992). Possessing only stone tools to clear and maintain open areas, they relied heavily on fire (Doolittle 1992). Open habitats were not only the result of agriculture. There were barrens and shrublands, both on the coast and on inland plateaus, or "knobs" (Latham 2003, Litvaitis 2003).

Apart from Native American agriculture, forested areas of the eastern United States were dominated by oak, pine, and hickory (Fralish et al. 1991, Landers et al. 1995, Delcourt et al. 1999, Hanberry and Nowacki 2016). There were also vast tracts of pine savanna (Askins et al. 2007). Disturbance-dependent forests like these were maintained by a mix of lightning-induced fire and regular fires set by the Native Americans (Delcourt et al. 1999, Carroll et al. 2002, Askins et al. 2007). These fires even extended into the Appalachian Mountains (Van Lear and Waldrop 1989).

Early European explorers in the mid-1600s and early 1700's report that Native Americans would frequently set ring fires to encircle game or use fire and natural barriers to funnel game (Hammett 1992). Similarly, there are mentions of the use of fire to clear forest to create cropland or stimulate early successional vegetation (Hammett 1992). These reports often originate from observations near Virginia and the Carolinas, but there is also evidence from the interior of the Southeast (Delcourt 1987, Hammett 1992). The use of fire by aboriginal people to influence game habitat has been documented in various other places as well (Lewis and Ferguson 1988).

There are various estimates on the population of Native Americans prior to European discovery.

Regardless of the estimate, there were probably millions of individuals using fire to maintain early successional habitat for the purposes of agriculture or to encourage game (Van Lear and Harlow 2002).

By evaluating pollen core data (Delcourt 1987, Delcourt and Delcourt 1997, Delcourt et al. 1999), historical accounts, and considering the remnants of fire-adapted communities we can conclude that fire has played a major role in shaping the eastern United States. Clearly, the landscape that the first European explorers witnessed, and some since have described as an untouched wilderness, was actually the result of 10,000 years of active management by Native Americans with fire (Lewis and Ferguson 1988, Denevan 1992, Carroll et al. 2002).

THE NEW LANDSCAPE

By the time the above-mentioned explorers had witnessed bison in the Southeast, the population of Native Americans had been reduced dramatically. The open habitats created or maintained by the Native Americans had already begun to reforest (Denevan 1992). Bison were eliminated from much of their range by the 19th century. Even today, restored populations do not have the ability to fully express their ecological role and provide sufficient disturbance on the landscape (Sanderson et al. 2008).

The patchwork agriculture and land clearing that was common in the 19th and 20th centuries may have helped to temporarily re-open some of the forest. But, the public's view on fire as well as the intensification of row-crop agriculture have together drastically changed the landscape in the eastern United States. Attitudes towards fire were largely influenced by federal policies and associated anti-fire campaigns (e.g., Smokey Bear, Dixie Crusaders) initiated in the late 1800s and early 1900s (Stephens 2005). Fencing laws, the timber industry, and a skewed perspective on pre-colonial American wilderness all further contributed to a reduced role of fire as a major disturbance factor (Hayter 1963, Wade and Lewis 1987, Dods 2002, Donovan and Brown 2007).

Adding to this change is the 14 million ha that have been planted to the non-native cool-season grass, tall fescue (*Schedonorus arundinaceus*) which dominates grasslands agriculture across the Fescue Belt (Kallenbach 2015). These grasslands are grazed by domestic cattle (*Bos taurus*). However, tall fescue has negative effects on wildlife (Applegate 2005, Barnes et al. 2013) and cattle via an endophytic fungus that infects the majority of tall fescue plants (Ball et al. 1991, Rudgers and Clay 2007, Mays et al. 2013, Kallenbach 2015, Saikkonen et al. 2016).

Similarly, there are approximately 12 million ha of non-native bermudagrass (*Cynodon spp.*) used as cattle forage in the Atlantic and Gulf Coastal Plains (Taliaferro et al. 2004). Bermudagrass rapidly colonizes new areas and forms a thick carpet. Consequently, this reduces plant diversity, quality of wildlife habitat, and has other negative ecological impacts (Barnes et al. 2013).

Grasslands are one of the most endangered biomes on Earth (Hoekstra et al. 2005). Consequently, many species of grassland-associated wildlife, particularly birds, are also declining (Brennan and Kuvlesky 2005, McCracken 2005). There has been renewed interest and promotion of native warm-season grasses for both livestock production and wildlife habitat (Ryan and Marks 2005). Converting exotic grass pastures in the eastern United States to native warm-season grasses has the potential to positively affect both cattle production and grassland-associated wildlife (Keyser et al. 2019). However, there is a need for more research to provide information on issues such as establishment, farm-scale effects, species-specific wildlife effects, the benefits of adding prescribed fire, the effects of landscape-scale habitat composition, and government cost-share opportunities (Keyser et al. 2019).

RECENT RESEARCH, NEW IDEAS, AND FINDING A MIDDLE GROUND

Bison and cattle may have differing habits, but some researchers have concluded that the foraging ecology of cattle and bison is comparable (Van Vuren 2001, Allred et al. 2011). In general, bison and cattle prefer differing proportions of grasses and forbs, with bison selecting more grasses and cattle selecting more forbs (Dodd and Plumb 1993, Steuter and Hidinger 1999). Bison also tend to use larger areas, while cattle prefer to stick closer to water sources (Kohl et al. 2013). However, some researchers consider the differences between bison and cattle to be slight, and that grazing management probably has more influence on the vegetation (Fuhlendorf and Engle 2001, Towne et al. 2005, Tastad 2014). If this is true, cattle production should provide disturbance that is comparable to the disturbance provided historically by bison (Towne et al. 2005, Tastad 2014). Here, we attempt to provide information related to native grasses, burning, and the existing non-native cool-season grasses in the eastern United States and how it pertains to cattle production and wildlife. There are relatively few recent studies in the eastern states (Scasta et al. 2016b, Keyser et al. 2019), so we will also include some examples from the Midwest.

Walk and Warner (2000), working in Illinois, found that low intensity grazing was important when creating habitat for grassland birds. Compared to exotic pastures, grazed native pastures may also encourage nesting productivity for some birds (Monroe et al. 2016). In Tennessee and Kentucky, various types of native grass production stands (CRP, biofuel, grazing, etc.) demonstrated the ability to provide habitat for grassland birds (West et al. 2016). Grazing is particularly important for maintaining near-ground structure for birds like northern bobwhite (Harper et al. 2015). Further, some models based on numerous sites in Missouri predicted greater counts of birds in grazed native grasses in comparison to other grassland types (Jacobs et al. 2012).

Grazing alone may provide some benefits for certain wildlife. However, adding fire may extend benefits to both wildlife and cattle. Wade and Lewis (1987) summarized some of the earlier studies of burning rangeland in the Southeast and reported that fire increased forage quality, forage quantity, and cattle weight gains. However, many of these earlier studies passively mention that burning rangeland is also beneficial to wildlife. Recent studies provide more insight to the additional benefits for wildlife.

In a trial of patch-burn grazing in an old field (16 ha) in Tennessee, McGranahan et al. (2013, 2014) found that burning increased the crude protein of broomsedge (*Andropogon virginicus*) and the spatial heterogeneity of the vegetation in the field. Additionally, the burned patches were also grazed more frequently than the unburned patches suggesting an increase in forage quality. This is important because broomsedge is commonly thought of as low-quality forage. The burned patches also had more bare ground, less litter cover, and shorter plant heights than the unburned areas. This spatial heterogeneity provides benefits for wildlife by providing a variety of cover types and foraging areas among burned and unburned patches. This trial may be a good example because the study area was representative of many working-lands cattle farms in the eastern United States: mostly tall fescue, broomsedge, and scattered trees.

Heterogeneity may also be extended to include a complete change from grass-dominated to forb-dominated areas (Vermeire et al. 2004). Although the dominance of forbs may be temporary, it still represents a shift towards heterogeneity and habitat for some wildlife species. Vermeire et al. (2004) also demonstrated that burned patches are desirable enough that they could be used to manipulate cattle activity away from some areas.

The effect of burning and grazing on heterogeneity of vegetative structure was also studied in northern Missouri and southern Iowa. Scasta et al. (2016) found that it was important to reduce cattle stocking to moderate levels (2.4 AUM/ha) to produce the largest range of plant structure and biomass between recently burned patches and 2-year post burn patches. However, the definition of moderate stocking can be variable depending on the productivity of the site. They posited that moderate stocking is optimal because too few cattle would not consume enough of the post-burn growth. Cattle stocked at heavy rates would have to move beyond the post-burn patch to find enough forage. At any rate, a bird study conducted on the same site showed that grassland-obligate bird diversity could be increased by following Scasta et al.'s recommendations (Duchardt et al. 2016). Similarly, in southwest Missouri, patch-burn grazed areas had higher density of grasshopper sparrow and eastern meadowlark (Stroppel 2009).

Reduced stocking rates may not be practical to many cattle farmers. Under certain conditions, it may not be necessary. A long-term study in Oklahoma suggested that patch-burn grazing was a good way to re-introduce fire to the landscape without reducing stocking rate (Limb et al. 2011). This study also showed that cattle grazed in patch-burn areas required less supplemental feed and gained more weight every year after the fire rotation was completed. In light of this, it may be possible for stocking rates to remain at traditional levels in a patch-burn grazing system as long as the fire rotation has been well established.

The possibility of maintaining stocking rates should be interesting to working-lands cattle producers who previously thought that native forages and patch burning required a reduced stocking rate. Pastures that have 2 or more patches might not only stabilize annual weight gain for cattle, it may also reduce dependency on regular precipitation (Allred et al. 2014). This is encouraging when facing the uncertainties of climate change.

CONCLUSIONS

There are a number of benefits of burning for cattle farmers and wildlife managers. Burning has the potential to increase and stabilize the weight gain of cattle, provide a buffer against unpredictable precipitation patterns, and reduce supplemental feed requirements. Patches of wildlife habitat can also be created and maintained without having to exclude cattle from dedicated wildlife areas. By simulating the native ecosystem we can expect that wildlife will respond positively. The only way we might do this is to create a new fire regime appropriate for the altered landscapes that now dominate the eastern United States.

The encroachment of woody stems in grasslands has many causes, but grazing patterns among domestic cattle are likely one of the major factors (Briggs et al. 2005). To prevent woody stems, prescribed burning is usually suggested. However, prescribed burning may not be the ultimate solution to preventing woody encroachment (Pendergrass et al. 1998, Hartman and Heumann 2001, Ansley and Castellano 2006, Valkó et al. 2014). This may be due to the reduction in fuel loads caused by chronic grazing, which prevents fires from becoming hot enough to kill woody invaders (Van Langevelde et al. 2003, Briggs et al. 2005). Similarly, a balance of fire and grazing pressure may be required to prevent woody encroachment and maintain grasslands (Van Langevelde et al. 2003, Briggs et al. 2005, Midgley et al. 2010, Raffaele et al. 2011).

The role of fire and grazing has had such a strong influence on the grassland ecosystem that some have considered the two a single disturbance process (Fuhlendorf et al. 2008). Considering the importance of grazing and fire, it may be more appropriate to say that they are a single ecological driver for grasslands (Evans et al. 1988, Askins et al. 2007).

The case we have presented here is based on the field research and review of others that have largely been in the midwestern and western United States, as well as Africa, Australia, and South America. Grasslands in the eastern United States are subject to unique factors (e.g. annual precipitation, proximity to forest, endemic woody species, smaller pasture sizes, etc.). Similarly, the interaction of fire frequency and grazing intensity may be important for specific management considerations (Fuhlendorf and Smeins 1997). Given the lack of field research specific to the eastern United States, it may be worthwhile to consider research on patch-burn grazing and its implications on grassland-associated wildlife.

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