Bumblebee Resource Use in Rangelands Managed With Patch-burn Grazing

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We are evaluating the effect of a patch-burn grazing management strategy on bumblebee resource use and network assembly. Our treatment structure is four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-quarter of pasture) at a four-year return interval and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval. Here we present preliminary results following one year of study.

Introduction

Bumblebees are key components of temperate pollinator networks. They exclusively pollinate more than 20,000 plant species worldwide, and their large size and thermoregulatory ability uniquely permit foraging in climatic and weather conditions unavailable to most pollinators (De Luca and Vallejo-Marin, 2013; Sapir et al., 2017).

However, modern trends in agricultural intensification and rangeland management threaten this role. Most current cattle grazing practices focus on even grazing pressure and have homogenized vegetation structure and composition at broad scales (Fuhlendorf and Engle, 2001). The associated lack of floral diversity contributes to decreased abundances and diversity of bumblebees and other native pollinators while raising concerns for agriculture and biodiversity conservation (Öckinger and Smith, 2006).

The use of modern rangeland management techniques such as patch-burn grazing can enhance rangeland plant diversity and heterogeneity (Fuhlendorf and Engle, 2001). Within this management framework, the phenology of a patch is closely tied to its successional state (Devoto et al., 2013) and, thus, patch-burn grazing has the potential to stabilize the temporal availability of flowers through patch contrast (McGranahan et al., 2012).

One consequence of low flowering plant diversity is the accompanying lack of phenological diversity in the flower community (Wolf et al., 2017). Anthropogenic climate change also has the potential to alter flowering plant phenology, creating a mismatch between bee resource demands and resource availability (Papanikolaou et al., 2016; Arfin Khan et al., 2018)

The long active flight period of bumblebees outlasts the full flowering period of any one species. Thus, low diversity in grassland flora and peak flowering time can create periods of food resource limitation regardless of average seasonal floral abundance (Ebeling et al., 2008; Isbell et al., 2017).

Survival rates and resource availability of bumblebees are highly temporally variable (Goulson et al., 2010; Hemberger and Gratton, 2018). This variability depends on the season and colony life stage.

For example, in the spring, new queens provision most of the nectar for the colony, in addition to incubating eggs and building the nest, resulting in high colony vulnerability (Baer and Schmid-Hempel, 2003). Thus, queens select dense nectar sources during this critical period to increase foraging efficiency (Galpern et al., 2017).

Pollen and nectar restriction during this period has the most severe effects on colony growth, and colonies may be vulnerable to climate-induced asynchrony in plant-pollinator seasonal emergence (Rotheray et al., 2016; Schenk et al., 2017). Nectar and pollen resources also may be limiting to survival in late summer because colonies reach their period of maximum resource demand and many flowering plants have begun to senesce (Rotheray et al., 2016).

Bumblebees store limited amounts of pollen and honey, compared with other apian pollinators, and, thus, are particularly vulnerable to short-term resource shortages (Shelly et al., 1991; Williams and Christian, 1991; Pelletier and McNeil, 2003). In addition to managing for high total seasonal diversity, understanding how bumblebees use floral resources at fine temporal scales is essential to determine ecological "pinch points" and the temporal distribution of resources (Maron et al., 2015).

In addition to differences in floral availability, bee species turnover also is emerging as an important factor structuring seasonal networks (Winfree et al., 2018). Pollinator networks (i.e., the diagrammed associations of pollinator species and their host plants) allow researchers to document several traits known to preserve mutualistic plant-pollinator communities.

The modularity of pollinator networks (i.e., the tendency for the division of a network into subgroups that have densely connected nodes within but are sparsely connected to each other) recently emerged as an important factor for understanding resource availability for bees (Jha and Kremen, 2012; Spiesman and Gratton, 2016). Network plasticity grants pollinator communities resilience in the face of stochastic conditions across the course of the season, but pollinator research traditionally relies on averaged interaction networks during the course of the season.

These methods commonly are used because they are easy to work with and interpretable. However, resource use at a broad temporal scale may not accurately describe conditions that the organism is experiencing, much less the factors that are limiting to a species (Tanner et al., 2016). This mismatch may hamper grassland pollinator conservation efforts by focusing management on increased overall flower abundance and diversity without alleviating seasonal discontinuities in resources.

In this study, we will establish the relationship between bumblebee communities and prairie forbs at fine temporal scales, while also investigating how floral resources change during the course of a season. We then will investigate how a restored interacting fire and grazing disturbance regime regulates these changes. Rangeland fire can increase floral density and extend the late-season availability of flowers (Wrobleski et al., 2003). Increasing the temporal stability of resources for bumblebees will improve community diversity and reduce colony mortality.

Our specific objectives are to 1) monitor the abundance of floral resources at one-week intervals across a fire gradient and 2) use floral visitor surveys to construct fine temporal resolution plant-pollinator interaction networks and assess how best to characterize bumblebee use of available resources. Together, these results will be used to assist in bumblebee management and fine-tune knowledge of pollinator-habitat relationships during the course of a season. Knowledge of when flowers are limiting bee abundance and diversity, as well as how fire and grazing can manipulate resources at these times can help managers meet conservation objectives.

Procedures

Study Area

The Central Grasslands Research Extension Center (CGREC) is in Kidder and Stutsman counties, N.D., (46° 42’ 56” N, 99° 27’ 08” W) in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at the CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present.

The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago spp.*), yarrow (*Achillea millefolium*) and Flodman’s thistle (*Cirsium flodmanii*) (Rogers et al., 2005). The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 centimeters (cm) (15.9 inches) and average annual temperatures of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Landscape context is important for structuring pollinator communities and seasonal abundances, especially the amount and diversity of surrounding cropland (Rundlof et al., 2007; Persson and Smith, 2013). The surrounding landscape is primarily rangeland, with pastures of corn (*Zea mays*), soybeans (*Glycine max*), canola (*Brassica rapa*) and wheat (*Triticum aestivum*).

The study plots have a history of cattle grazing and limited exploratory agriculture. Additionally, the study plots do not have a recent history of burning. Thus, our treatments may incur a lag effect as we establish the treatment structure.

Treatment Structure

Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-quarter of pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval (PBG20).

Annual burn plots in treatment 3 will be two adjacent 20-acre subpatches. Growing-season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs will graze freely within pastures from May 1 to Oct. 1 each year at a moderate stocking rate designed to achieve 30 percent forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Methods

Assessing Pollinator Plant-Pollinator Networks

Within each 8-hectare (ha) subpatch, we will conduct a 20-minute visual encounter survey in two 50- by 50-meter (m) plots (128 plots/round, Devoto et al., 2013). Initially, the plot will be walked in three systematic transects. Each bumblebee visiting the reproductive parts of a flower will be collected, identified and subsequently released.

The species of plant that the bumblebee is visiting also will be recorded. If bumblebees cannot be identified to species in the field, they will be collected for identification in the laboratory using a dissecting scope.

Following the completion of a systematic walk-through, the remainder of the survey time will be spent performing a focused search for bumblebees, biasing search effort toward areas of dense floral resources. The length of time spent surveying is designed to approach an exhaustive sample of the plot, and will be adjusted if initial surveys demonstrate an abundance of unsurveyed bumblebees.

We will conduct surveys only between the hours of 9 a.m. and 5 p.m. on rain-free days (CaraDonna et al., 2017). Focused network surveys will not allow us to calculate pollinator densities among treatments, but because our treatment structure is small scale, we are more interested in the resources that our treatments provision within the greater foraging landscape of bumblebees (Knight et al., 2005).

To capture temporal changes in plant-pollinator networks, we will conduct a full round of network sampling every three to four weeks. This will allow us three sampling periods per season to capture a range of floral phenologies. Climate variables will be collected using an on-site North Dakota Agricultural Weather Network (NDAWN) weather station.

Analysis

We will use the R package bipartite to analyze plant-pollinator networks (Dormann et al., 2008; Peralda et al., 2017). Network generality and nestedness will be calculated for each sampling period, as well as the rate of species turnover and network switching during the course of the season for each time since the fire period.

Network nestedness is a measure of the extent to which specialist network interactions are a subset of generalist interactions (i.e, whether specialist interactions are unique). A nested network should be more resistant to stochastic perturbation.

Network nestedness has been shown to change with increased land use intensity and landscape degradation, and nestedness has been hypothesized to increase with active disturbance regimes (Burkle, et al., 2013; Moreira et al., 2015; Brown et al., 2016). Network specialization, as measured by the H2 index, measures the overall degree of specificity exhibited by pollinators and flowers in a network.

Robustness measures the extent to which network collapse will occur if random members are removed from the network.

Assessing Floral Availability

We will use floral surveys to plot the flowering period of forbs for a range of time since fire and assess resource discontinuities through time. Every week, we will perform floral resource surveys using 300 m belt transects centered within each one-eighth pasture subpatch (DeBano et al., 2016).

Along each transect, we will tally all flowering ramets within 1 m of the transect that are usable by bumblebees (Moranz et al., 2014). Although at a finer resolution than bumblebee surveys, floral abundance surveys will occur simultaneously to allow for comparison. Two transects in each subpatch will be sampled, for a total of 192 transect surveys per round.

Analysis

The lengths of flowering periods, as well as the diversity and abundance of flowers, will be compared among treatments using generalized linear models using the lmer package in R (R Core Development Team). Prior research demonstrates that fire can prolong the flowering period of rangeland forbs, as well as enhance the flower set of individual plants (Wroblenski and Kaufmann, 2003; Mola et al., 2018).

Results

Assessing Pollinator Plant-Pollinator Networks

In 2018, our networks included nine bumblebee species, 28 flower species and 1,319 plant/flower interactions (Figure 1). Season-long grazing pastures had nine bumblebee species and 16 flower species. PBG40 pastures had nine bumblebee species and 21 flower species, while PBG 20 pastures had seven bumblebee species and 25 flower species.

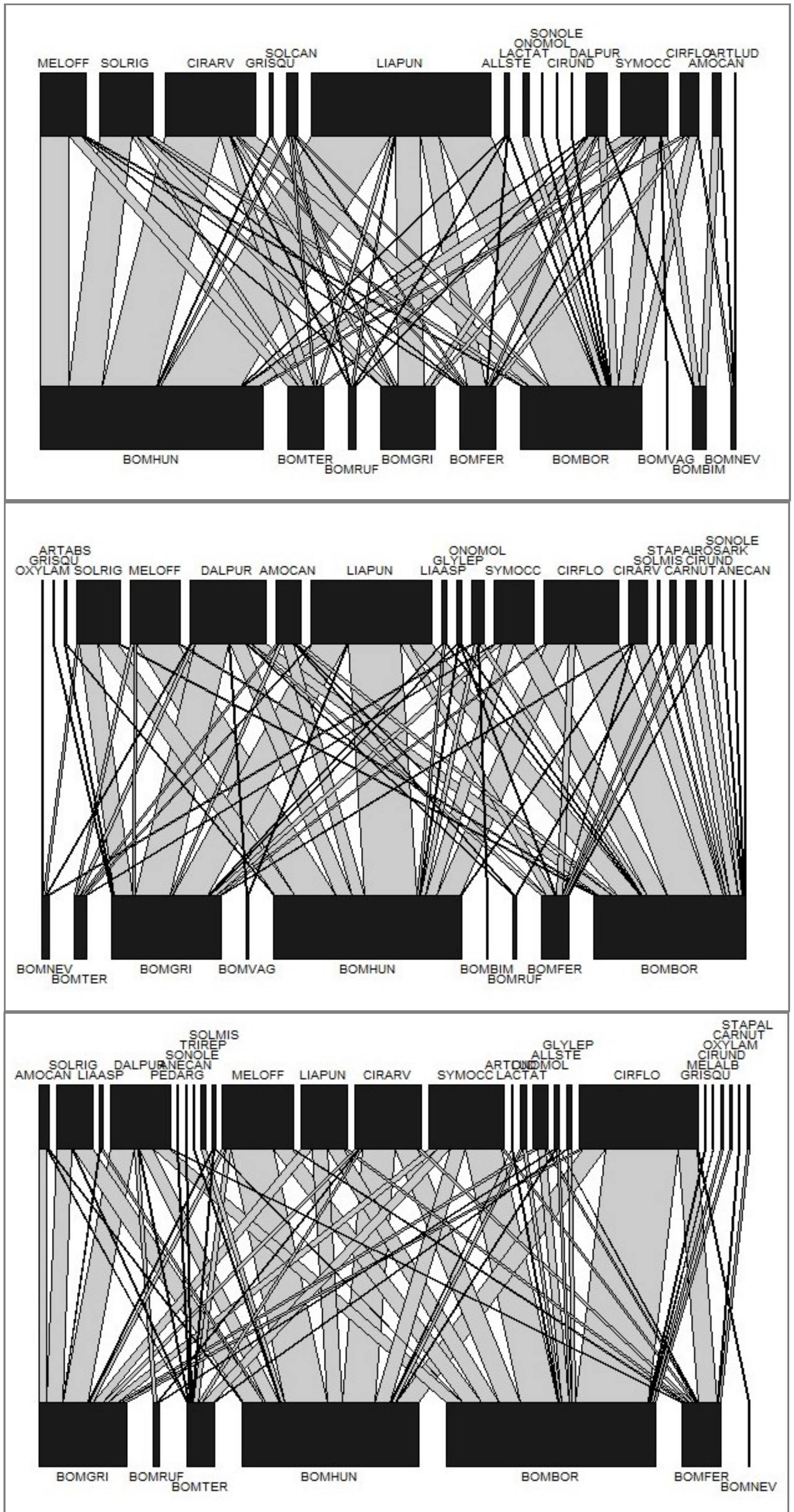

Figure 1. Bumblebee-flower network interactions under three management paradigms at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018. Top: Season-long grazing (SLG); Middle: Patch-burn grazing with spring fires (PBG40); Bottom: Patch-burn grazing with spring and summer fires (PBG20).

In general, bumblebee/flower network statistics were similar among the three treatments. All bumblebee networks were unspecialized. They also were moderately nested, and plant and bumblebee halves were robust to extinction events (Table 1).

	PBG20	PBG40	SLG
Bee Species	7	9	9
Flower Species	25	21	16
H2	0.21	0.20	0.18
Nestedness	0.58	0.69	0.49
Robustness Flowers	0.85	0.82	0.84
Robustness Bees	0.69	0.74	0.73

Table 1. Network characteristics of a flower/bumblebee interaction network across three management treatments at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018. PBG20 = Patch-burn grazing with two seasons of fire, PBG40 = Patch-burn grazing with one season of fire. SLG = Season-long grazing with no fire.

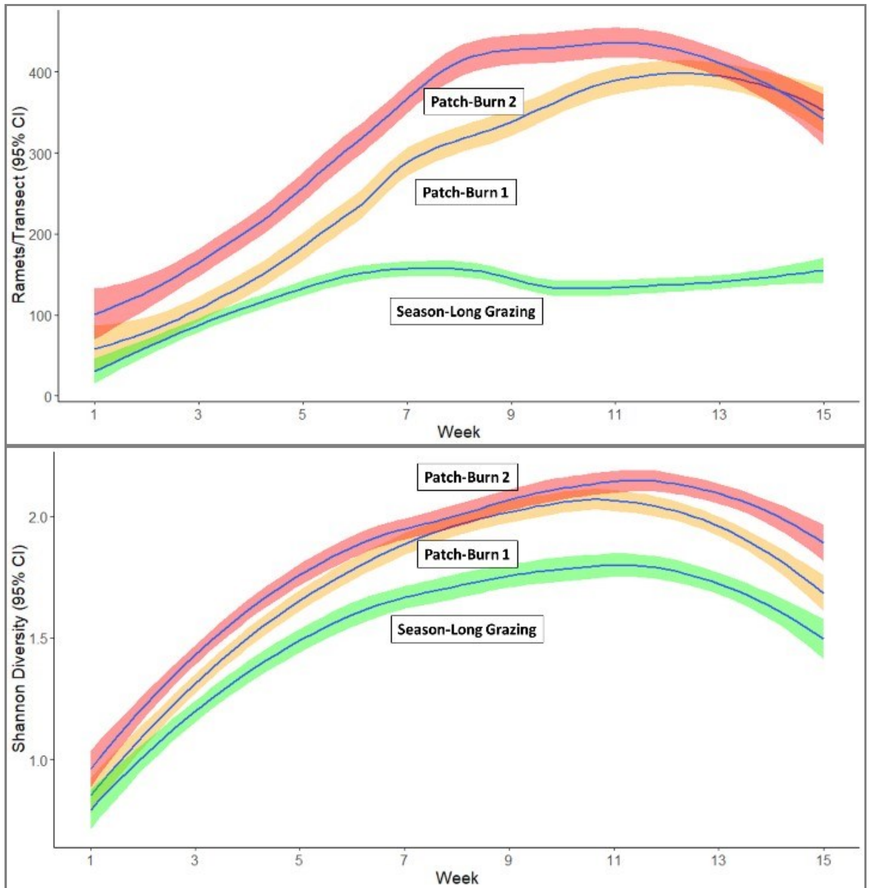

Figure 2. Total flower abundance (top) and Shannon diversity (bottom) of pastures managed with season-long grazing, patch burning with one season of fire, and patch burning with two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018.

Assessing Floral Availability

Our weekly surveys culminated in 15 rounds from May 21 to Sept. 3, 2018. We documented 120 flowering plant species and 658,182 flowering heads. We found that flowering plant abundance and diversity was higher in both patch-burn grazing treatments, compared with season-long grazing (Figure 2).

Additionally, we found differences in species-specific flowering plant phenology among treatments. For example, rigid goldenrod (*Solidago rigida*) reached its peak abundance more than two weeks later, compared with season-long grazing (Figure 3, next page).

Among fire-age classes, western snowberry (*Symphocarpos occidentalis*) reached peak flowering more than three weeks later in new burns, compared with unburned patches and one year-since-fire patches (Figure 3).

Discussion

What should be noted is that we are unable to make statistical comparisons among treatments with our networks statistics after only one year of data collection. However, patch-burn grazing does not seem to be disruptive to bumblebee resource use and network assembly.

At the same time, patch-burn grazing increases floral availability and diversity. Even in species that did not extend their phenology under patch-burn grazing, a diversification of phenology within a species increases temporal stability of that resource under patch-burn management (Figure 3).

In light of these conclusions, patch-burn grazing appears to be an effective conservation tool for those seeking to increase resource availability for native rangeland pollinators.

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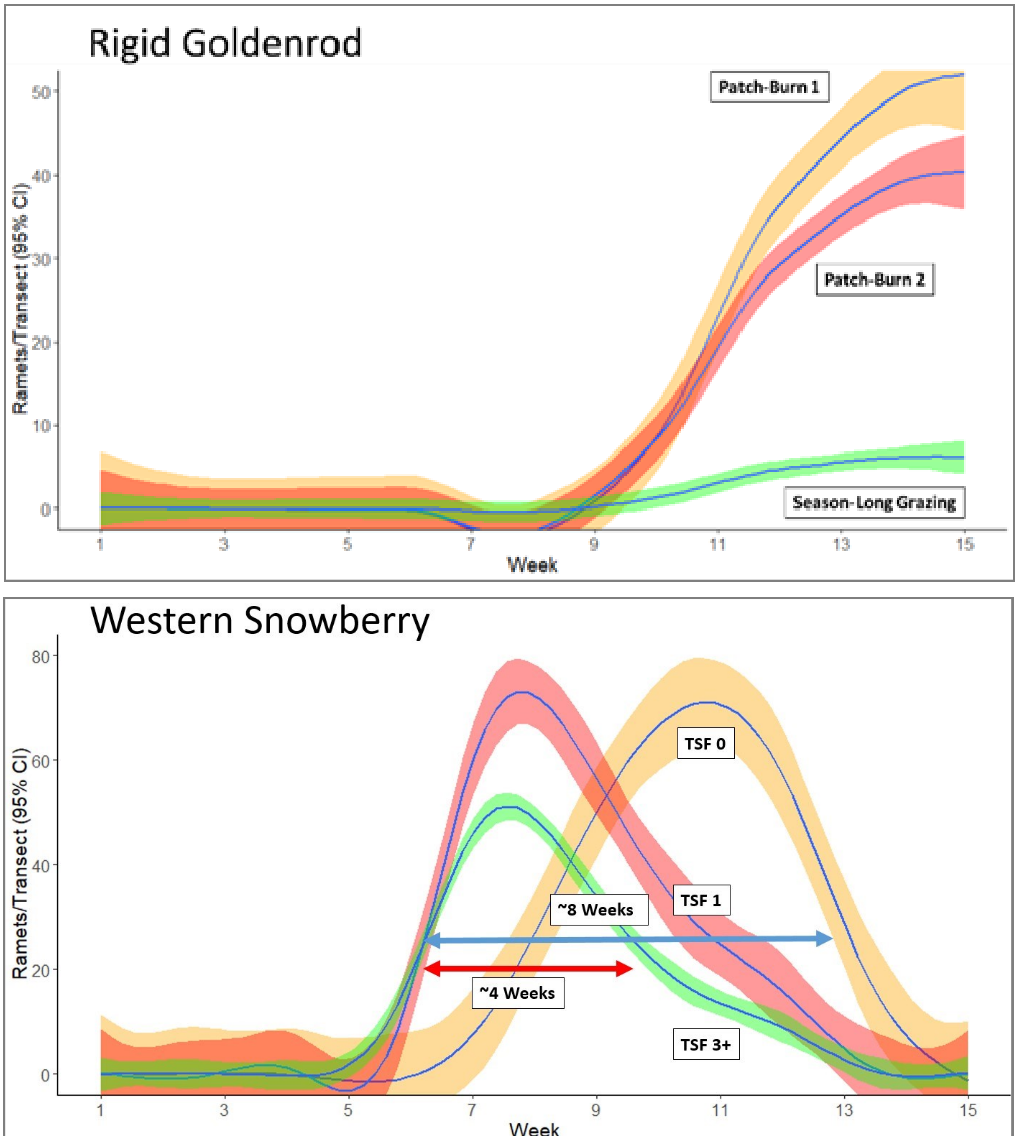

Figure 3. (Top) Rigid goldenrod abundance among season-long grazing, patch burning with one season of fire, and two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018. (Bottom) Western snowberry flower expression among season-long grazing, patch burning with one season of fire, and two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018, illustrating the resource benefits provided by patch-burn grazing via phenological heterogeneity.

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