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Grasshopper Responses to Fire and Postfire Grazing in the Northern Great Plains Vary Among Species

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ABSTRACT

Rangeland management practices such as burning and grazing may affect the development, survival, and reproduction of grasshopper populations. Experiments in the northern Great Plains that examine effects of fire and grazing utilization on grasshoppers are lacking. As part of a larger study examining vegetation responses to late summer fire and postfire grazing utilization in semiarid mixed prairie in eastern Montana to aid in postfire management decisions, we examined grasshopper responses to late summer fire and postfire grazing intensity. The experiment was repeated using adjacent blocks, with blocks receiving fire treatment in either 2003 or 2004 and grazing in the following year. Treatments were no fire and no grazing, and summer fire followed by grazing at 0%, 17%, or 50% forage utilization on a biomass basis. Grasshopper sampling was conducted before fire and for 2 years post fire. Fire reduced grasshopper density 36–53% across experiments, sampling periods, and postfire grazing treatments, but the effects of grazing and fire were species dependent. The two most abundant grasshopper species, *Ageneotettix deorum* (Scudder) and *Opeia obscura* (Thomas), were reduced 80% and 84% the first year after the 2003 fire, but only *O. obscura* was affected following the 2004 fire. Late summer fire appears to be a useful management tool to reduce populations of some grasshopper species in the northern Great Plains, while other species appear more responsive to food limitation from increased postfire grazing utilization. Fire effects were largely driven by two species, indicating that late-season fire impacts could be species dependent.

Introduction

Grasshoppers in the western United States often reach high densities and are economically important rangeland pests when abundant (Branson et al., 2006; Joern, 2000). During grasshopper outbreaks, grasshoppers often exceed livestock grazers in herbivore biomass and plant biomass removed (Belovsky, 2000; Belovsky and Slade, 2000; Branson and Haferkamp, 2014). The population dynamics of grasshoppers remain poorly understood (Joern, 2000). Although grasshopper outbreaks often lead to chemical control efforts, habitat management approaches to reduce grasshopper populations have received little attention (Branson et al., 2006). As grasshoppers are highly responsive to factors such as altered habitat structure and food availability (Joern, 2004; Onsager and Olfert, 2000), rangeland management practices may affect grasshopper populations by affecting development, survival, and reproduction.

Livestock grazing has been shown to positively and negatively affect grasshopper population densities, with relationships often differing between ecosystems in the western United States (reviewed in Branson et al., 2006; O'Neill et al., 2003). Foraging by livestock can directly reduce food availability for grasshoppers and indirectly affect populations through longer-term changes in plant community composition (Branson and Haferkamp, 2014; Fielding and Brusven, 1996; O'Neill et al., 2003, 2010). In addition, both grazing and trampling can affect a grasshopper's structural habitat and affect development and predation rates (Joern, 2004, 2005; Onsager, 2000; Pitt, 1999). For example, many pest grasshopper species in the northern Great Plains appear to increase in abundance when they can thermoregulate in microhabitats with habitat heterogeneity including bare soil (Onsager, 2000). Relationships between livestock grazing patterns and grasshopper populations in the northern plains remain unclear, although Onsager (2000), in a study lacking ideal replication, found grasshopper densities were five to nine times lower in rotational grazing pastures than in season-long grazing pastures.

Burning has been shown to frequently influence grasshopper densities and community composition in multiple ecosystems (Branson et al., 2006). Changes in grasshopper populations following fire can result from direct mortality of eggs, nymphs, or adults, as well as direct and indirect effects of vegetation and habitat changes (Bock and Bock, 1991; Joern, 2004, 2005; Porter and Redak, 1996; Vermeire et al., 2004). Although spring burning can positively affect grasshopper densities in tallgrass prairie (Joern, 2004), fall fire may be useful as a management tool to reduce populations of some pest grasshopper species in the northern Great Plains (Branson, 2005). In mechanistic laboratory

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studies, Branson and Vermeire (2007, 2013) showed that elevated soil temperatures associated with fire occurring under fuel loads typically found in the northern Great Plains could cause grasshopper egg mortality for species laying shallow egg pods but not for species laying deeper egg pods.

No experiments in the northern Great Plains have examined the combined effects of fire and postfire grazing utilization on grasshopper populations. Only one large-scale study has simultaneously examined fire and grazing management effects on grasshopper populations in the northern Great Plains, but low grasshopper densities combined with variability between replicate blocks limited the ability to detect treatment effects (Branson and Sword, 2010). We examined the responses of grasshoppers to late summer fire and postfire sheep grazing utilization. The objectives of the study were to examine if late-summer fire affected grasshopper densities and species composition and if postfire grazing utilization influenced the effect of burning on grasshopper densities and species composition. The grasshopper work was part of a larger set of studies examining vegetation responses to late summer fire and postfire grazing utilization to aid in postfire rangeland management (Vermeire et al., 2011, 2014).

Study Site

Research was conducted in semiarid mixed prairie, at the Fort Keogh Livestock and Range Research Laboratory located near Miles City, Montana (lat 46°24'N, long 105°56'W; 815 m above sea level). The freeze-free period ranges from 110 to 135 d. July is the hottest month, with an average maximum of 32°C, and January is coldest, with an average minimum of −14°C. The 30-yr average annual precipitation is 319 mm, with April to May precipitation being the greatest controlling factor for plant productivity (Heitschmidt and Vermeire, 2006; Vermeire et al., 2008, 2009).

The study site is rolling upland on Pinehill loam soil (fine, montmorillonitic Typic Eutroboralfs) with some patches of a Pinehill-Absher complex. Absher soil is a clay loam (fine, smectitic, frigid Leptic Torrertic Natrustalfs). The site had a decades-long history of moderate grazing by cattle until May 2003, when livestock were excluded. Vegetation was dominated by perennial graminoids, with *Hesperostipa comata* (Trin. & Rupr.) Barkworth, *Pascopyrum smithii* (Rydb.) A. Löve, *Carex filifolia* Nutt., *Bouteloua gracilis* (Willd. Ex Kunth) Lag. ex Griffiths, and *Poa secunda* J. Presl contributing most to biomass. Annual grasses *Bromus japonicus* Thunb., *B. tectorum* L., and *Vulpia octoflora* (Walter) Rydb. were always present and variable in abundance. *Artemisia frigida* Willd. occurred frequently, whereas *Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young was common but widely spaced. The most common forbs were *Plantago patagonica* Jacq., *Logfia arvensis* (L.) Holub, *Alyssum alyssoides* L., *Sphaeralcea coccinea* (Nutt.) Rydb., and *Phlox hoodii* Richardson.

There are three main subfamilies of rangeland grasshoppers in the area of the study, slant-faced (Gomphocerinae), band-winged (Oedipodinae), and spur-throated (Melanoplinae). The majority of species in the slant-faced and band-winged subfamilies are grass feeders, whereas the spur-throated subfamily includes grass, mixed, and forb feeders (Pfadt, 2002). Although all grasshoppers found in the area of the study are univoltine, the four most abundant grasshopper species at the study site differ in phenology and egg-laying habits (Pfadt, 2002). *Ageneotettix deorum* (Scudder), the white-whiskered grasshopper, is a small-bodied early hatching species laying small egg pods of three to five eggs just below the soil surface. It is a common economic species in the slant-faced subfamily and is a grass generalist. *Opeia obscura* (Thomas), the obscure grasshopper, is another small-bodied slant-faced species that is later hatching. It lays egg pods of ~eight eggs and typically prefers blue grama *(Bouteloua gracilis)*. *Melanoplus sanguinipes* (Fabricius), the migratory grasshopper, was the most common spur-throated species. It begins hatching after *A. deorum* and lays much larger egg pods up to 4 cm deep. It is a highly polyphagous feeder on grasses and forbs and is a dominant economic species in the spur-throated subfamily. *Trachyrhachys kiowa* (Thomas), the kiowa grasshopper, is an intermediate hatching species in the band-winged subfamily that feeds on grasses and sedges and lays vertical egg pods up to 3 cm deep.

Methods

Thirty-two 0.75-ha plots (75 × 100 m) were randomly assigned four treatments, with four replications within each of two fire treatment years. The experiment was repeated using two adjacent blocks of 16 plots, with blocks receiving fire treatment in either 2003 (Experiment 1) or 2004 (Experiment 2) and grazing treatment in 2004 or 2005, respectively. The repeated experiments are described as Experiments 1 and 2, following Vermeire et al. (2011, 2014). Treatments were no fire and no grazing, and summer fire followed by grazing the next year at one of three levels of forage utilization on a biomass basis (0%, 17%, or 50%), hereafter referred to as fire-grazing treatments.

Fires were applied to individual plots 29 August 2003 and 24 and 25 August 2004. Plots receiving grazing treatments were stocked during late June and early July of the first growing season after fire using 3 or 9 sheep *Ovis aries* in 2004 and 6 or 18 sheep in 2005 to achieve 17% and 50% utilization, respectively, by mid-July. Resulting stocking rates for 17% and 50% utilization were 4.3 and 12.2 animal unit days·ha^{-1} (1 AUD = 9.08 kg dry-matter forage) during 2004 and 25.4 and 77.7 AUD·ha^{-1} during 2005 because of differences in forage production between years. Additional details of fuel loads, fire weather, sheep management, and plant response to treatments were reported by Vermeire et al. (2011, 2014). The on-site U.S. Department of Agriculture Livestock and Range Research Laboratory Institutional Animal Care and Use Committee considered sheep handling in this study as a standard management practice requiring no official approval for experimental procedures.

Grasshopper sampling was conducted before each fire and for 2 years after each fire treatment. As the study was designed to generate grazing utilization recommendations in the year following fire, livestock grazing occurred only during the first year post fire. Grasshopper populations were sampled for an additional year after livestock grazing to determine if fire and grazing impacts were persistent, given grasshoppers univoltine life cycles. Total grasshopper population density was estimated every 2–4 weeks by counting the number of grasshoppers within 40, 0.1-m^2 aluminum wire rings between ~late May and August (Belovsky and Joern, 1995; Joern, 2004; Onsager and Henry, 1977). Rings were permanently placed in three or four transects in each replicate plot and were spaced about 5 m from each other. Grasshopper sampling periods varied between years on the basis of the timing of grasshopper hatching and population declines (Table 1). Sampling took place on days when air temperature was above 23°C. Grasshopper community composition was determined through random catch samples of ~50–60 individuals taken two or three times each summer. Low grasshopper population densities of < 2 per m^2 in all plots during the study limited the number of grasshoppers that could be removed from plots without potentially depleting populations. Individuals

Table 1
Sampling dates by assessment period for Experiment 1 (fires applied 29 August 2003) and Experiment 2 (fires applied 24 and 25 August 2004) on silty ecological sites in southeastern Montana.

Period	Sampling Dates	
	Experiment 1	Experiment 2
Prefire	28 Jul, 26 Aug 2003	14 Jul, 4, 18 Aug 2004
Postfire	3 Sep 2003	31 Aug 2004
Pregraze	27 May, 16 Jun 2004	20 Jun 2005
Graze	29 Jun, 13 Jul 2004	30 Jun, 18 Jul 2005
2 yr postfire	30 Jun, 8, 29 Jul, 22 Aug 2005	6, 22, 28 Jun, 19 Jul 2006