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A review of Characteristics of Burns Conducted Under Modified Prescriptions to Mitigate Limited Fuels in a Semi-Arid Grassland

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INTRODUCTION

In the semiarid shortgrass steppe region of the Great Plains, interest in prescribed fire as a management tool is rising. A growing body of literature from this region highlights the utility of fire in controlling undesirable species, managing habitat structure, and improving forage, but few seek to directly examine the mechanisms by which burning alters the ecosystem. Research in more mesic grasslands suggests that heat induced plant mortality as well as fire's indirect effects on soil moisture and temperature (through litter removal and blackening of the soil surface) are the primary mechanisms for change. Augustine et al. 2014 focused on relationships between fuel load, weather, fire temperatures, and heat dosage in semiarid grasslands.

Augustine et al. 2014 stress that the need for a more thorough understanding of fire characteristics in areas with low fuel loads will aid in formulating prescriptions that lead to the desired management outcomes. The authors examined measures of heat production over 7 years of dormant season burns in grazed and ungrazed shortgrass steppe of northeast Colorado. Thermocouples were used to measure fire temperature at the soil surface, near plant meristems, under a wide range of weather conditions, fuel loads, and seasons. In order to understand and help predict the direct effects of fire (heat) on the plant community, the authors set out to 1) identify fuel and weather conditions that impede fire spread and effectively prevent implementation of prescribed burns, and 2) evaluate the relative influence of fuel loads, air temperature, wind speed, and relative humidity on peak temperatures, heat duration, and heat dosage near the ground surface.

FUEL LOAD, WEATHER, AND FIRE CHARACTERISTICS

Under the appropriate weather conditions, fuel load can be a predictor of success for prescribed fires. In shortgrass prairie as well as other grassland systems, maximizing fire characteristics such as burn completeness, peak temperature, heat duration, and heat dosage under a range of fuel loads is a key consideration in fire planning. Appropriate ranges of weather conditions such as wind speed, air temperature, and relative humidity are not only vital to safety, they can also influence short and long term fire effects on the plant community. Prior research in desert grasslands suggests safe and effective burning can be conducted in as little as 450 lb/acre with air temperatures of 72-82 ^{0}F, relative humidity of 10 - 20%, and wind speeds of 7-18 mph.

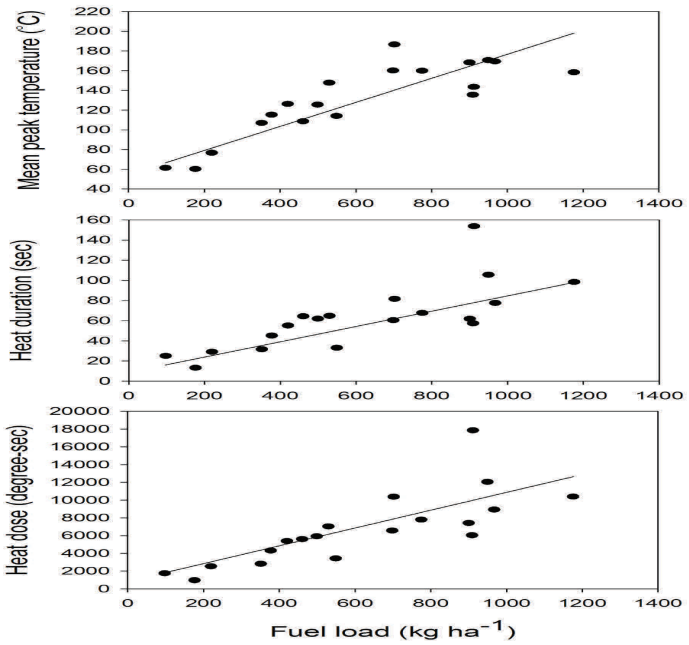

Figure 1. Mean peak temperature (^{0}C), mean heat duration (sec. above 60^{0}C), and heat dose (^{0}C*sec, base 0^0) measured 1 cm above ground level as a function of variation in fuel loads for burns in shortgrass steppe of NE Colorado during 2007 to 2013. Lines show predictions based on the fuel load coefficient in fitted models (see Augustine et al. 2014, Fig. 2). *Reprinted with permission.*

In blue grama-dominated shortgrass steppe, fuel loads of 300-500 lb/acre are typical of years with average precipitation and moderate cattle stocking rates. In this range of fuel loads, Augustine et al. 2014 found that burns could be conducted successfully (+ 80% completeness) with air temperatures as low as 52^{0}F, wind speeds from 9-25 mph, and rel-

ative humidity from 9 - 15%. Burning in fuel loads of 300 lb/acre resulted in fire completeness < 60%. For all burns, mean peak temperature, heat duration, and heat dosage (calculated as area under the time-temperature curve using a baseline of 0^0C) were all most strongly correlated with fuel load (See figure 1).

Weather conditions also influenced these fire characteristics, but the influence of fuel load was 3.4 times (for peak temperature) to 5.6 times (heat dosage) greater than the influence of any weather element. The most important weather parameters for both peak temperature and heat duration were wind speed followed by air temperature. Conversely, air temperature followed by wind speed most influenced heat dosage. Relative humidity had only a minor influence on heat production measurements. This study suggests that prescribed fire in semi-arid grasslands with fuel loads below 900 lb/acre) can be safely and effectively conducted with relative humidity from 10% to 20% combined with air temperatures above 61^0F. The authors also indicate that peak temperatures can be maximized by burning under wind speeds of 18-22 mph, while heat duration and heat dosage are maximized at wind speeds of 4-9 mph.

PREDICTING MANAGEMENT OUTCOMES

Controlling undesirable species with prescribed fire is a common management strategy in rangelands. Quantified relationships between fuel load, weather, and fire characteristics can help improve land managers' ability to predict fire's effects on target and non-target species. Augustine et al. 2014 compared fire effects linking heat duration and heat dosage to plant mortality on two species of concern (broom snakeweed and prickly pear cactus) also studied in mixed-grass prairie and desert grasslands . First, broom snakeweed experiences significant mortality when heat dose > 8900^0F*sec. Based on the results of this study, in shortgrass steppe, this heat dosage could likely be achieved by burning in fuel loads > 600 lb/acre with wind speeds of 4-9 mph, ambient air temperatures > 61^0F, and relative humidity < 30%. Second, prickly pear cactus mortality rates have been shown to increase as heat duration increases from 60 - 360 sec. Based on the authors' results, heat duration > 60 sec in shortgrass steppe can occur with fuel loads > 500 lb/acre, and are optimized in weather conditions similar to those described for broom snakeweed control. As to fire effects on non-target species, Augustine et al. 2014 add that past studies in shortgrass steppe have shown that prescribed burning under these conditions does not threaten the productivity of dominant grass species, provided that burns occur in their dormant season.

Another common use for prescribed fire in grasslands is the manipulation of habitat structure and function for wildlife. Grassland birds that require at least some degree of low vegetative structure for breeding and foraging benefit from a post-fire landscape. The authors discuss the importance of fire in shortgrass steppe for increasing suitable breeding and nesting habitat for mountain plover, a bird species of conservation concern. This species requires large homogenous tracts of low vegetation and exposed bare soil. Based on their results, Augustine et al. 2014 suggest that to achieve this goal using prescribed fire in shortgrass steppe, burns should be conducted at a minimum fuel load of 300 lb/acre providing wind speeds are near 9-11 mph, relative humidity of 8 - 15%, and air temperatures > 60^0F. At fuel loads > 400 lb/acre, homogenous burns can be achieved under a wider range of weather conditions.

CONCLUSIONS

This study provides useful quantitative relationships between fuel loads, weather conditions, and heat characteristics for predicting fire's effect on habitat structure, function, and composition in blue grama-dominated shortgrass steppe. The authors illustrate the potential usefulness of these models by providing fire prescription thresholds for broom snakeweed and prickly pear cactus reduction as well as mountain plover habitat improvement. In conclusion, Augustine et al. 2014 suggest that fire prescriptions allowing for higher air temperatures and lower relative humidity than were previously recommended for low-volatile fuels, should mitigate incomplete burn coverage, low heat dosage, low heat duration, and peak temperatures in typical shortgrass steppe fuel loads. They do, however, emphasize caution against extrapolating model predictions to semi-arid grasslands dominated by plant species that differ in canopy structure and fuel connectivity from the shortgrass steppe.

REFERENCES

Augustine, D.J., J.D., Derner, and D.P. Smith. 2014. Characteristics of Burns Conducted Under Modified Prescriptions to Mitigate Limited Fuels in a Semi-Arid Grassland. Fire Ecology 10(2): doi: 10.4996/fireecology.1002036

GETTING HELP

David Augustine's home page has a wealth of research from the shortgrass steppe. You may also want to view our webinar recording on fire ecology in that region. The Great Plains Fire Science Exchange has resources on fire, fire effects, monitoring, and more at http://GPFireScience.org. We can also locate experts to address your fuels questions.

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