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Fire, mowing and soil moisture levels have no significant effects on underground arthropod population and diversity

MONIQUE PAIRIS, JULIE SUNDERMANN, and HANGHANG WANG
Biology Department, Grinnell College, Grinnell, IA 50112, USA

Abstract

Biologists use burning and mowing in prairie restoration to investigate their impacts on the prairie community, including plants and arthropods. Because underground arthropods play a crucial role in the prairie ecosystem as decomposers and bioindicators, it is important to understand how they are affected by burning and mowing. We conducted a study at CERA using 20 plots with a combination of burning and mowing, in order to examine the roles these treatments have on the diversity and population of underground arthropods. In addition, we analyzed the effects of soil moisture levels on underground invertebrates by manipulating this factor in a controlled lab experiment. Our results indicated that burning, mowing and their interaction had no significant effects on arthropods' population or diversity. We also found no significant effects of soil moisture levels on arthropod populations.

Introduction

Fire and mowing represent the most common disturbances to tall grass prairies. These disturbances, devastating at first, later may often enhance and increase the growth and flower production of plant species found throughout the prairie (Hulbert, 1969). Although the disturbances have positive effects on some plant species, they do not necessarily yield positive results for other populations living within the tall grass. In fact, some entomologists have expressed concern that burning and mowing are incompatible with the conservation of insects, the most bio-diverse populations of the prairie (Panzer, 2002). Known to be the major pollinators for prairie plants, insects play a vital role in the reproductive success of plant life (Dietrich et al., 1998). Underground arthropods especially contribute to the functioning of prairies, since most plant biomass is below ground (Panzer et al., 1995). Common underground arthropod taxa such as mites, Collembola, and nematodes, known as fungal feeders, speed the decomposition of the organic matter in the soil, therefore influencing nutrient cycling. In addition, these arthropods are found to help suppress plant pathogens by feeding on the fungi that cause root diseases (Curl 1988). In their study at CERA, Kutritiz and Melis asserted that the health and diversity of all prairie insects is essential to prairie success and maintenance (1999). Nevertheless, little research has been done on the effects of disturbances on prairie insects (Dietrich et al., 1998). Previous studies have suggested that soil moisture decreases as litter is removed in the process of burning (Hulbert, 1969), therefore negatively affecting certain populations such as collembolans (Anderson et al., 1989). On the other hand, another study conducted at CERA proposed that mowing provides a protective layer of litter to underground invertebrates therefore limiting evaporation of moisture (Cooper et al. 2003). Our study addressed whether underground arthropod populations continue to be affected by one or both of these disturbances, by comparing the effects of burning and mowing on invertebrates' populations and diversity. Moreover, the study examined how the environment, specifically soil moisture levels, affected underground invertebrate populations. This study helps scientists closer determine whether the management of prairies contributes to the success of the entire prairie community (Cooper et al, 2003).

Methods

We conducted our research at Conard Environmental Research Area (CERA), a reconstructed prairie located near Kellogg, Iowa. The project consisted of two experiments. The first experiment (10/8 and 10/13 2003) examined underground invertebrates' population and diversity found in plots with different disturbances. A set of 20 experimental plots (10m by 10m) located at CERA were used for research. There were four combinations of burning and mowing each located in 5 randomized blocks. The plots have been burned every spring since 1997, and they have been mowed each summer since 1999. In each plot, we used soil corers (29 cm long x 2.4 cm in diameter) to collect soil

Table 1. Total numbers in all samples from 4 treatments of field experiment.

T	Araneida	Collembola	Coleoptera	Diplopoda	Diplura	Nematode	Misc. Mite	Oribatid Mite	Psocoptera	Unknown	Total
BM	0	7	0	1	0	3	0	14	4	0	29
NBNM	2	3	1	4	1	3	4	18	1	0	37
BNM	0	0	6	0	0	0	0	8	0	4	18
MNB	0	7	0	0	1	2	0	10	0	0	20

T = Treatment B= Burned NB = Not burned M= Mowed NM=Not mowed

samples at 4 random points within the plot, and mixed them together to eliminate clumps of soil.

We used Berlese funnels to extract insects out of the soil and into a flask of 100 mL of 70% EtOH. The funnel was lined with cheesecloth to prevent a large amount of soil in the EtOH. We measured 473.2 cm^3 of the soil sample for each plot and placed them in the funnel. We kept the soil in the funnel for 1 week and then examined with microscopes the invertebrates found in the EtOH. With the "Key to Common Soil Animals" manual, we identified and classified invertebrates by orders.

The second experiment involved controlling a specific environmental factor that may affect underground invertebrates: soil moisture. On October 27, 2003, we collected 15 samples of soil (473.2 cm^3each) from a grassland section that was neither burned nor mowed at CERA, using the same methods as the first experiment. On October 29, we mixed all samples together and divided the soil into 17 pots. Initially two pots were saturated to determine the average amount of water needed for full saturation. With the 15 remaining pots, we fully saturated 5 pots, half saturated 5 and quarter saturated 5. Due to the rapid decomposition rate of underground arthropods, we expected to determine the effects of soil moisture levels on underground arthropod by comparing the number of arthropods left in the EtOH. We repeated the saturation process four times every other day between October 29 and November 3 before extracting the samples using the Berlese funnels for 48 hours. We counted and classified all invertebrates by order.

We calculated the taxon diversity using the Shannon-Wiener index and used the General Linear Model (ANOVA) to test the effects of burning and mowing and their interaction on species diversity and population. We also used the General Linear Model (ANOVA) to determine the effect different levels of soil moisture have on underground arthropod populations.

Results

We found a total of 18 orders of arthropods in the 20 plots. Too few individuals were sampled to facilitate the ANOVA test on several orders, therefore, only the 10 most abundant orders were analyzed (Table 1). We also excluded ants (Hymenoptera Formicidae) due to its excessive number in one sample that would otherwise affect our analysis. The ANOVA showed no significant effect of burning, mowing and no significant effect on the interaction of the two treatments on arthropod population and diversity (Figures 1 and 2).

Moisture levels also had no significant effect on total arthropod population (F= 0.32 P=0.729; Fig 3). Similar to the first experiment, we eliminated orders that did not have any organisms.

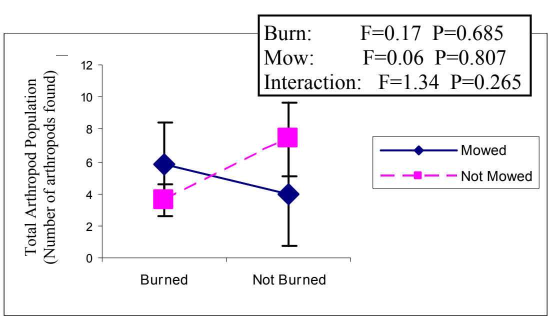

Figure 1: Total arthropod population (number of arthropods found) in the 20 plots of different treatments (+/- S.E.).

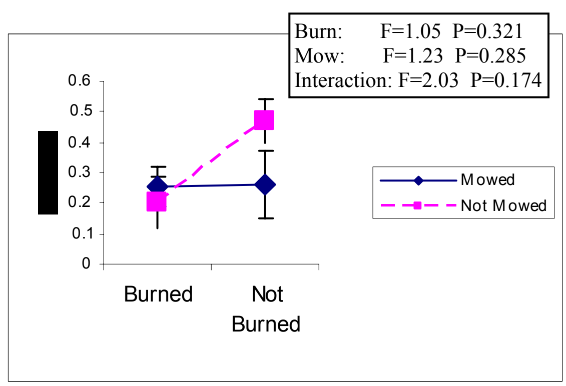

Figure 2: Species diversity in the 20 plots of different treatments (+/- S.E.).

Table 2. Total numbers in all samples from 3 treatments in soil moisture experiment.

T	Araneida	Collembola	Coleoptera	Diplopoda	Diplura	Hymenoptera Formicidae	Misc. Mite	Oribatid Mite	Staphylinidae	Total
QS	1	3	0	1	1	1	0	11	1	19
HS	0	2	1	0	0	0	2	10	0	15
S	0	1	2	0	0	0	0	8	0	11

T= Treatment QS= Quarter Saturated HS= Half Saturated S= Saturated

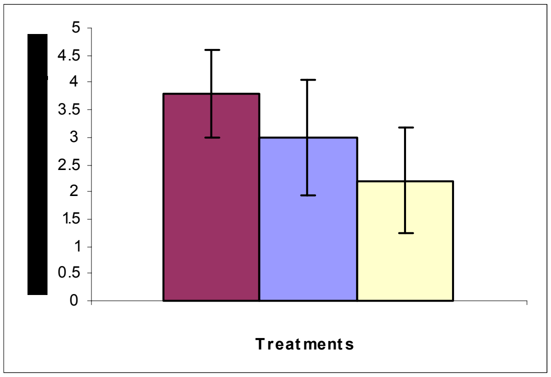

Figure 3: Total number of arthropods found in different saturated moisture levels, Quarter saturated, half saturated, fully saturated from left to right. (+/- S.E)

Discussion

The combination of the burning and mowing treatments had no effect on either underground arthropod population size or diversity. Due to the rapid reproduction rates of prairie arthropods, disturbances such as fire may wipe out arthropod populations initially, but they recover quickly as soon as the habitat is partially restored to its original state (McCullough et al, 1998). Rapid reproduction is also promoted by the influx of nutrients after a fire, when fresh, young plant growth becomes available (Robbins and Myers, 1992, cited in Lyon et al. 2000). In 2003 Cooper et al. investigated the immediate response of underground arthropods to burning and mowing at CERA at midsummer. The litter that accumulated from mowing sheltered the insects' underground environment, allowing the soil moisture and underground arthropods to remain unaffected. The fire treatment eliminated plant biomass therefore allowing more sun to dry the soil and increase its temperature. Most insect populations were not affected by the fire treatment, but some taxa such as mites and Collembola were negatively affected by burning because they reside in the top layers of the dried soil. Our results differ from this study because we collected data the fall after the spring burn rather than midsummer (two weeks after mowing). The longer interval between burning and mowing and data collection may have allowed the few insects that survived in-situ enough time to reproduce and recreate large populations comparable to those in unburned plots.

The depth of our core samples may also help explain our lack of significant results when the different treatments were applied. Soil protects many insects from burning, and the level of protection depends on the depth of the organism in the soil and heat penetration (Schimid et al. 1981, cited in Lyon et al. 2000). Previous studies by Hulbert in 1969 have suggested that at the depth of approximately 8 cm or more, underground soil conditions, specifically moisture and temperature, will not be altered by the burning and mowing aboveground. Since the soil samples we took were 29 cm deep, it is possible that the soil provided enough protection to the arthropods to leave them unaffected by the disturbances aboveground.

A final possible explanation for our results is recolonization, or migration from adjacent undisturbed plots. The treated plots located in CERA are open, providing ample sources for arthropod colonists. Studies by Harper et al (2000) showed that both above- and underground populations will re-enter disturbed areas after the effects of fire have been reduced and the environment becomes hospitable.

Studies have also suggested that insect population are depressed immediately during the first prescribed fires but will increase gradually after consistent annual fires, once burn-sensitive species are eliminated. A study conducted by Anderson et al. in 1989 found that total insect biomass decreased after the first year burn, but was not affected after being burned more times. The burning at CERA has taken place since 1997. It is possible that our data showed no significance because the arthropods we found in burned plots at CERA have adapted to the changes in the environment. Our study conflicts with a similar study conducted at CERA (Kustritz et al, 1999), which concluded that the combination of burning and mowing yielded a decrease in the population of underground arthropods. However, due to the early time of their study, when only 2 annual burns and one mowing treatment were applied, many burn-sensitive arthropods may have still existed on the burned plots in the CERA area.

The presence of insects is affected by numerous variables, such as season, weather fluctuations, and timing of disturbances. Prairie arthropod populations are highly variable and unpredictable (Reed, 1997). This study may have been affected by the drought that occurred the summer before we collected our data. Due to this environmental condition, there was no significant difference on soil moisture of the plots from which we collected our data (Edwards et al, 2003). During our own study, the weather fluctuated markedly and may have also influenced the data we collected.

The second experiment testing the importance soil moisture has on underground invertebrates showed no significant variation of insect populations among different saturation levels. The main reason for this outcome may be in part due to our own assumption that one variable can control the abundance of a population of insects. Although many studies (Anderson, 1982 and Amburg et al, 1981) state that mowing and burning decrease soil moisture levels, therefore decreasing overall insect populations, the interaction of other variables beside soil moisture may also have a large influence on these results. Furthermore, the short duration of our soil moisture manipulation experiment may have also limited the significance of differences between treatments.

Our study has showed that burning and mowing have been compatible with the conservation of arthropod biodiversity, and in this way supporting the annual fire-managed and mow-managed model of prairie management. Future studies onthe burning/mowing effect may include isolating in-situ reproduction from migration by preventing arthropod movements from undisturbed plots. In the soil moisture experiment, since arthropods environment consists of more than soil, future studies may include roots in the soil content from prairie plants to accurately reproduce an arthropod's environment. This would entail growing plants in the soil, with the assumption that the experiment would take a much longer time to perform.

Species in the prairie adapt and react to conservation tools in different ways. In the case of burning, species such as Big Blue Stem (Hulbert, 1969) and certain species of grasshoppers (Anderson et al, 1989) are positively affected by this disturbance, while other populations of species as *Zizia aurea* (Howe, 1969) are depressed. In prairie management, it is important for us to consider the effects of treatments on different communities, such as the plant and the arthropod community. It is also equally important to see the prairie as an integrated ecosystem, taking into account that each community has interactions with others and influences on the entire ecosystem.

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