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Effects of annual fire on the litter fauna populations and soil compositions of an upland white-oak forest

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Abstract

Studies have shown that arthropod populations require 2-3 years to recover from forest fires. However, many traditional forest management practices include annual prescribed burns. Our study sampled the litter-dwelling organisms in the annually-burned upland white-oak forest at CERA to see if their populations are negatively affected by annual fire. In addition, we sampled the soil moisture and carbon content as well as litter mass to determine relationships between fire, litter, litter fauna, and soil. We found that overall neither the populations nor the physical aspects of the soil and litter varied significantly between treatments. We did find some meaningful differences and some trends in our data. For example, ant abundance and order richness were significantly higher in unburned plots and there was an overall trend of higher litter-fauna abundance in unburned plots. However, these results were not enough to demonstrate a negative effect of annual fire. We still suggest, based on other studies and research, that forest management include fire every 2-3 years rather than every year to allow populations to recover. Or, rather than changing the fire frequency, forest management could employ a patchwork burning pattern to aid quick litter fauna recovery in the burned areas.

Introduction

Periodic burning has been shown to benefit forest habitats in many ways, including the reduction of litter. This results in greater light penetration to the forest floor, warmer soils, and uncluttered forests which prevent out-of-control fires, which all in turn aid plant growth (Rieske-Kinney 2005). Although fire is often beneficial to forest habitats in these ways, fire can harm litter fauna populations, specifically in the short-term. Insects and other organisms living in the ground litter of a forest are an integral part of maintaining forest health by helping to decompose the litter, reduce the size of organic particles, and add nutrients to the soil (Wiezik et al. 2007 and Rieske-Kinney 2005). For example, nematodes, commonly found in forest litter, are associated with bacterial-based decomposition (Yeates 2007). Studies of woodland fires suggest, however, that it takes forest arthropods a few years to recover from fire (Camann et al. 2008). Though fire can be considered beneficial, it is possible that the frequency, scale, and season of fire can negatively affect aspects of the forests such as soil moisture and composition and flora and fauna succession rates.

We examined the effects annual burning has on the ground cover, litter-dwelling organisms, and soil of the white-oak upland forest at Conard Environmental Research Area (CERA). As found in other similar studies, we expected that the amount of ground litter in the annually burned areas would be reduced compared to the unburned plots (Brand 2002). Because these plots are burned annually, we hypothesized that the insect populations do not have enough time to recover each year and that the soil composition of the burned plots then suffers from the lack of insects decomposing the litter. We tested the average amount of litter, the average number of insects, the order richness and diversity of insects, and the soil carbon content of each plot. Higher levels of carbon are associated with increased soil fertility (Rice 2002).

Methods

The Conard Environmental Research Area (CERA) is a 365-acre protected prairie and lab facility near Kellogg, Iowa, acquired in 1968 by Grinnell College. Of these 365 acres, 125 are reconstructed prairie. The remaining acres are made up of a variety of different habitats—our study took place in the upland white oak forest and focused on the forest burn plots. There are 19 plots, 10 of which are burned every year in the fall or winter, and 9 of which are left unburned (Figure 1). The burned plots have been burned once each fall since 1997, with the exception of fall 2000 and fall 2005, when only half the plots were burned due to unsuitable conditions. Prior to 1997, the forest area was unmanaged and ungrazed.

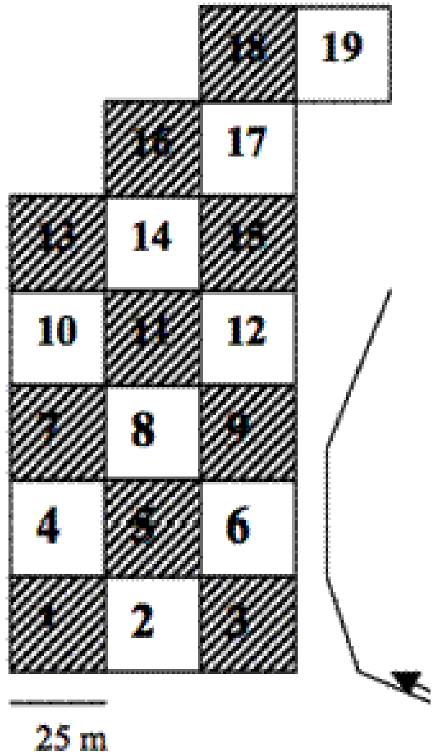

Figure 1. Layout of forest burn plots at CERA. Shading designates annually burned plots.

In October and November 2009 we collected soil and litter samples from 3 random points within each of the 19 plots using a .25 m by .25 m quadrat. Burlese funnels and heat lamps were used to extract the litter fauna from the litter samples. Each sample was in the Burlese funnel for 48 hours, after which we identified the litter fauna. Most of the litter fauna we identified to order based on identifiable characteristics. Some we were able to identify more specifically to family. Others we identified only to class or phylum based on our limited ability to distinguish differences between certain litter organisms.

We used a soil auger to collect 3 soil samples, each one 5 cm deep, from every plot for moisture and carbon testing. To measure the soil moisture we weighed the soil before and after drying it in an oven at 60 degrees Celsius for three weeks**.** These soil samples were then measured for carbon content, or organic matter, using the Loss-On-Ignition Method. To do this, we pounded the dried soil and then passed it through a 2-mm sieve to remove large fragments of organic and inorganic material. We weighed a small amount of the sifted soil in a small crucible, ashed it for 1 hour in a muffle furnace at 400 degrees Celsius, and weighed it again. To determine the organic matter, or LOI (Loss-On-Ignition), we used the formula

% = Dry weight – Ash weight/Dry weight x 100

We used Minitab 15 to analyze our data and conduct descriptive statistics. We compared the differences between treatments in carbon content, litter mass, and insect order in burned and unburned plots, using t-tests. To determine order diversity, we used Simpson's Diversity Index:

$$D= 1/[\sum(n/N)^2]$$

(n=number of individuals per order, N=number of total individuals)

Results

The mean carbon content of the soil in burned and unburned plots was not significantly different (2.652 vs. 2.654%; t= -0.01, p=0.993). There were also no significant differences in soil moisture between the two types of plots (burned 34.11% vs. unburned 31.66%; t=1.19,p= 0.255). Mean litter mass per meter squared in burned plots was 1.9% greater than in unburned plots, a non-significant difference (t=0.07,p=0.944).

The average total number of litter-dwelling organisms per meter squared in the unburned plots was 46.7% greater than in the burned plots (t=-1.21, p=0.248). There were a few individual orders that showed significant (or marginally non-significant) differences between burned and unburned plots. Unburned plots had eight times more ants than unburned plots (t=-2.58,p=0.033) (Figure 2). No other litter fauna showed a significant difference, but nematodes (t=2.29, p=0.051), Diptera (t=-1.48,p=0.176), and Collembola (t=-1.17,p=0.277) all had higher means in the unburned plots (Figure 3). Spiders showed the opposite trend (though not significant), with 57.5% higher mean numbers of spiders in the burned plots than the unburned plots (Figure 2).

The order diversity between plots did not differ significantly. Diversity in burned plots averaged 3.9% greater than in unburned plots. (5.92 vs. 5.87 on Simpson's diversity scale; t=0.08,p=0 .934) However, the unburned plots had a significantly higher average order richness per plot than burned plots (12.7 vs. 9.6 orders per plot; t=-3.43,p=0.004).

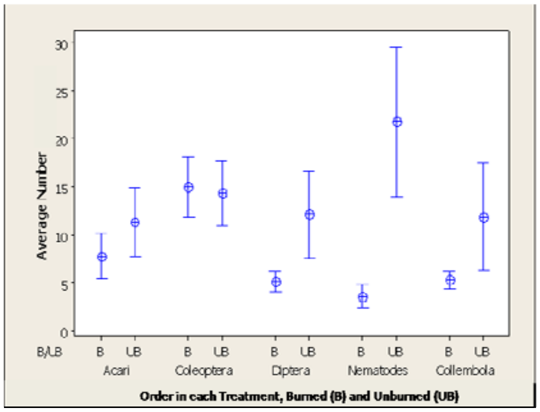

Figure 2. Difference in average number of litter animals from each identified order between burned and unburned plots. Bars are one standard error from the mean. n=19 (* means p< .05).

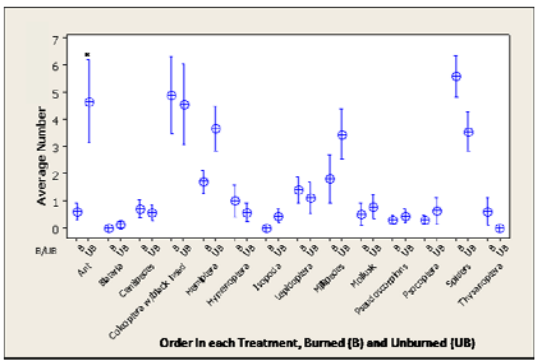

Figure 3. Difference in average number of litter animals from each identified order between burned and unburned plots. Bars are one standard error from the mean. n=19 (All p values> .05.)

Discussion

We found that the average number of litter fauna per square meter was slightly lower in burned plots, but it was not a significant difference. Our results also show that most orders did not vary significantly in number of individuals between treatments. With the exception of spiders, orders tended to have fewer individuals in the burned plots. Only ants showed significantly lower numbers in the burned plots, but Hemiptera and nematodes showed marginally non-significant trends in this direction. This trend of lower numbers in burned plots could be due to direct mortality in the fire and/or the fire's destruction of litter fauna habitats (Rieske-Kinney 2005). Without many significant differences, however, we do not have strong evidence to conclude that fire negatively affects litter-dwelling organisms besides ants. Also, this similarity in litter fauna data between treatments could be caused by the patchwork nature of our experiment. For example, all of the organisms we studied are free-moving and thus not constrained to their respective 25 meter by 25 meter plots.

Overall we found that the physical aspects of the forest's litter and soil are not significantly affected by the annual fall burns. The average soil moisture was not significantly different between the treatments. Because we gathered our data in the fall before this year's burn treatment, the two plots could have been similar because the moisture levels had almost an entire year to recover and stabilize since the last fall burn in 2008. Iverson and Hutchinson (2002) found similar results with soil moisture and fire. In their study, soil moisture levels evened out two months after a prescribed spring burn.

We found little to no difference in carbon content between the two treatments. We know that organic matter levels in the soil are affected by decomposition rates and soil moisture (Rice 2002). Thus, since we found no significant difference in soil moisture and very few significant differences in litter fauna populations between treatments, it is not surprising that the carbon content in both plots is virtually the same. The average litter mass per meter squared did not differ between treatments (p-value=0.944). This makes sense because though fire greatly reduces ground litter, so much time passed since the last burn in the fall of 2008 that the burned forest plots had time to recollect litter over the year. In addition, we collected our litter samples in the fall, just after all of the leaves had fallen over all of the plots.

The order diversity was not significantly different between the two treatments. However, the order richness did vary significantly between plots. Orders that were absent in burned plots were orders that existed in the unburned plots but in low numbers. It could be that orders with fewer individuals to begin with just have a lower chance at surviving fires simply due to a lack of numbers. Thus, the burning treatment reduces the number but not the evenness of orders present in the litter.

Based on other studies and research, we suggest that fire frequency be reduced to every 2-3 years rather than every year, even though our results did not indicate that the forest's litter fauna populations were in dire need of a greater recovery period between fires. We do not think that less-frequent burning would be harmful to the plant life by choking the forest in litter because we found that unburned plots did not have much more litter mass. Additionally, we suggest that forest management mimic the patchwork nature of our experiment, as this seems to have been a factor that allowed litter fauna to survive fire rather well. Burning smaller portions of a forest rather than a widespread area seems to allow for quicker recovery in burned areas, as the organisms can more easily move from the unburned plots to re-colonize in the burned plots.

To further investigate fire's effect on a forest ecosystem, it would be beneficial to perform the same study with bigger plot sizes to determine if the patchwork nature did indeed affect our study. Also, we suggest testing nitrogen levels in the soil. Litter-dwelling organisms are known to add nitrogen to the soil through decomposition, and nitrogen levels are also a good measure of soil fertility (Wiezik et al. 2007). Finally, we would examine the differences in plant life between unburned and burned treatments, as this would be another factor that affects litter-dwelling organism populations.

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