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The Effects of Prescribed Burning on Macrofungal Species Richness in Upland, White Oak Forest

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Abstract

Fire provides an important disturbance to forest life and has been shown to affect a variety of aspects of forest ecology. We examined the effects of burning on macrofungal species richness in the upland, white oak forest at the Conard Environmental Research Area (CERA) in Grinnell, Iowa; we sampled macrofungi in six burned and six unburned plots and separated them into categories of macrofungi growing on wood and on the ground. The mean species richness was slightly higher in the burned plots than in the unburned plots, but not significantly. However, we found that woody macrofungi in the burned plots had a higher species richness than ground macrofungi in the burned plots. Our results did not support our hypothesis that there would be less species richness in burned plots and contradicts previous studies. This may indicate that in our study area, factors such as the intensity of the burning, fire's effects on moisture, carbon, and leaf litter may all increase macrofungal growth one year after fire disturbance.

Introduction

Macrofungi are integral to the study of the diversity of ecosystems. They affect the overall diversity of a community because they decompose biotic material which enables plants to reuse nutrients in a simpler form (Dix and Webster 1995). Macrofungi also make up a large part of forest diversity and species richness. The diversity of fungi in forests leads to the diversity of other forest organisms (Packham et al. 2002). Not many studies have been conducted on forest macrofungal diversity and most of the studies conducted on them come from Europe and Australia, so they may not necessarily be applicable to the United States and more specifically to the Midwest (Mueller 2004). In addition, most of the studies conducted on fungi to date focus on microfungi as opposed to macrofungi. Microfungi do not have fruiting bodies and are generally located in the soil, whereas macrofungi include larger above-ground fungi such as mushrooms, cups, parchments, and puffballs (Dix and Webster 1995). Our study focuses on the macrofungal species richness and how it is affected by burning.

Burning is an important aspect of forest maintenance and restoration because fire is a natural process which disrupts growth processes and destroys organisms. Over time, organisms have adapted to this disturbance and have become somewhat dependent upon it. Fire has been shown to greatly reduce shrub and sapling ground cover, but also generally has little effect on larger trees (Abrams 1988). In addition, Cairney and Bastias (2007) discovered that fire has the greatest effect on the first couple centimeters of soil in forest habitats and that fire's effects become more pronounced with more frequent burning.

Our study examines the effects of burning in an oak forest on species richness of macrofungi of two different types: those that grow on the ground and those that grow on wood. We hypothesized that burning would lower the species richness of both the ground fungi and the wood fungi. We based this on the fact that frequent fires decrease the amount of nitrogen, carbon, and other important nutrients in the soil, which are crucial for most fungal and plant growth. Fires typically decrease the moisture levels in the soil and, since fungi thrive in moist environments, this would not be conducive to fungal growth or richness (Neff et al. 2005; deRoman and deMiguel 2005). Finally, fires combust a portion of the available wood, which would leave less surface area for wood fungi to grow; the wood remaining after the burning might have less nutrients in it which would also inhibit fungal growth.

Methods

We conducted this study at the Conard Environmental Research Area (CERA) located in Grinnell, Iowa from October 5, 2009 through October 28, 2009. Our area of focus was the CERA upland white oak forest. The forest canopy is made up mostly of dominant white oak trees, the subcanopy consists of elms, hickories, and hackberry, and the ground cover is nearly shrubless. The forest contains 19 plots (Figure 1) from which we sampled the first 12. Since 1997, ten plots have been burned each fall (except when conditions were unsuitable in 2000 and 2005) and the remaining nine plots have been left unburned.

We collected macrofungal samples in the 25m by 25m burned and unburned plots in the oak forest at CERA. Each day, we sampled one burned and one unburned plot in order to account for temporal variation between sampling times. To establish collection points, we selected a random number and then created a belt transect from that point through to the opposite edge of the plot. We divided this 25m transect into 1m by 1m blocks (1m along the transect and ½ meter on either side of the transect line) and took macrofungi samples from every other block (odd or even numbered, determined randomly). When taking samples, we separated the fungi into two categories: those found on the ground and those found on wood. These samples were stored in a refrigerator before we identified them using a predetermined master list based on the appearance, smell and texture of the fungi. We also used the master list to determine the genus and species of the most commonly found fungi. To analyze our results, we compared the species richnesses using Minitab 15 to conduct an ANOVA test.

We also collected soil samples for a percent carbon and percent moisture analysis from each plot. We froze these samples and then weighed them before drying them for more than 24 hours at 60 degree Celsius to determine percent moisture. We then removed the large pieces of organic matter from the soil using a sieve, and weighed the soil again. We combusted the samples in an oven at 400 degrees Celsius for one hour to burn off all of the carbon from the soil itself and we then used the residual ash weight to calculate the percent of carbon lost on ignition, using the following formula:

% Carbon Lost on Ignition=
((Dry Weight- Ash Weight)/ Dry Weight) x100

We used Minitab 15 to conduct t-tests to determine the effects of burning on species richness, carbon content, and moisture content; an ANOVA test to determine the effects of burning between woody and ground species richness. Also, we performed regression analyses to determine variance due to the day and correlations of species richness to percent moisture and carbon in soil.

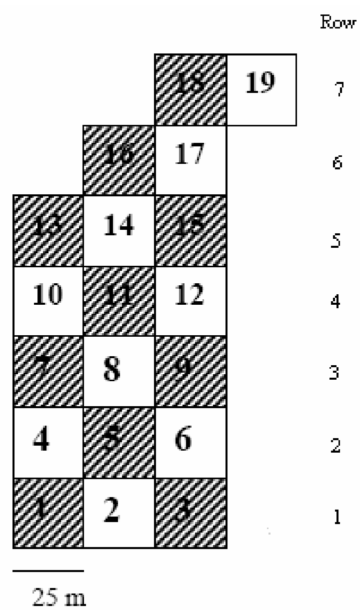

Figure 1. Map of the forests plots, with shaded plots burned and unshaded plots unburned.

Results

Temporal Variance:

Since the growth of macrofungi is often affected by the outside temperature, we compared the number of species found each day in order to examine temporal variance using a regression analysis (Figure 2). The number of species found on any given day showed a general downward trend, however, the regression analysis showed that the relationship between species richness and sampling date was not significant ($f = 1.36$, $p = 0.255$, $r^2 = .058$).

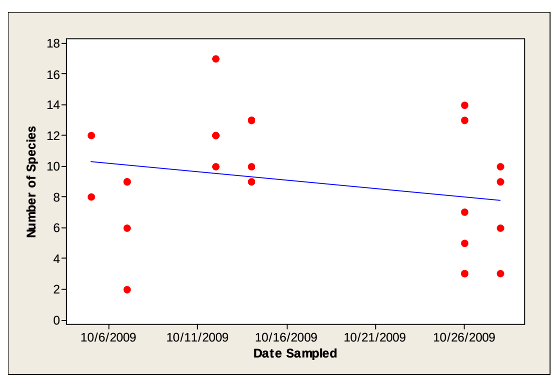

Figure 2. Number of species found on all plots (n=12) from each sampling day. $f = 1.36$, $p = 0.255$, $r^2 = .058$.

Overall Species Richness:

We found a total of 79 species in the burned plots and 52 species in the unburned plots; of these, 49 were unique to the burned plots and 22 were unique to the unburned plots. However, the average species richness was not statistically different for burned and unburned plots (t = 0.87, p = 0.395).

Woody and Ground Species Richness Results:

We found that burning had a non-significant effect on the difference between woody and ground species richness, with woody species richness increasing with burning and the other three data points remaining similar (Figure 3). Even though the type of fungus (woody or ground) p-value was near significant (f= 3.04, p = .092), the interaction p-value for fungus type (woody or ground) and treatment (burned or unburned) (f = 2.54, p = 0.321) and the effect of the treatment (f = 0.13, p = 0.373) were less significant.

The woody and ground species that we found in the plots were generally unique to their substrate, with the exception of three species: Dark Cup, Grey Mycena, and Stalkless Puffball (we created these names for the species, but we could not identify their genus and species). All of these species were found both on the ground and on wood.

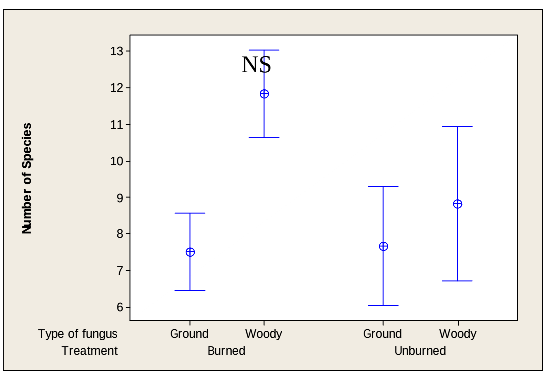

Figure 3. Number of species in burned (n=6) and unburned (n=6) plots divided between woody and ground macrofungi species. Treatment p = 0.373 and f = 0.13, type of fungus f = 3.04 and p = 0.092, and interaction f = 2.54 and p = 0.321. Error bars represent 1 standard error from the mean.

Percent Carbon and Percent Moisture Results

We found that the soil from the burned plots had slightly higher overall percentages of moisture and carbon, but neither amount is statistically significant (t = 1.45 and p = 0.185 for carbon; t = 0.253 and p = 0.413 for moisture; Figures 4 and 5). There was a non-significant positive regression between percent carbon and species richness ($f = 1.51$, $p = 0.232$, $r^2 = .064$) and between percent soil moisture and species richness ($f = 2.03$, $p = 0.168$, $r^2 = .085$).

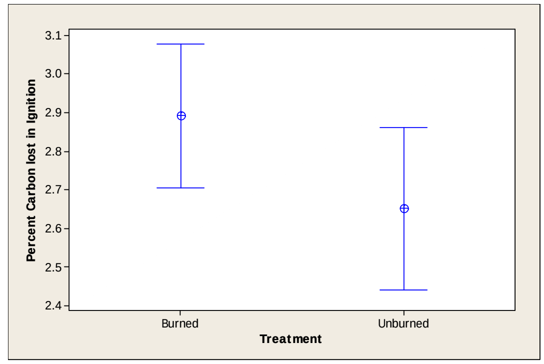

Figure 4. Percent carbon lost in ignition. Samples taken from burned (n=6) and unburned (n=6) plots. t = 0.86 and p = 0.413. Error bars are one standard error from the mean.

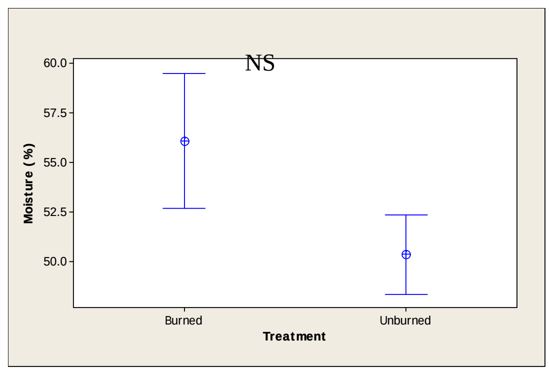

Figure 5. Percentage of moisture in soil. Samples taken from burned (n=6) and unburned (n=6) plots. t = 1.45 and p = 0.185. Error bars are one standard error from the mean.

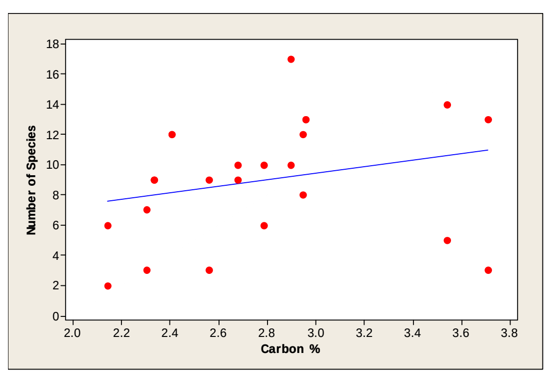

Figure 6. Relationship between number of species and percent carbon in soil from burned (n=6) and unburned (n=6) plots. $f = 1.51$, $p = 0.232$, $r^2 = .064$.

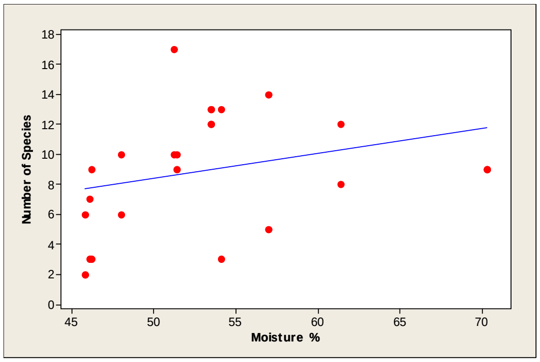

Figure 7. Relationship between number of species and percent moisture in soil from burned (n=6) and unburned (n=6) plots. f = 2.03, p = 0.168, r^2 = .085.

Discussion

Our results indicated that the average species richness of the macrofungi was non-significantly higher in the burned plots and that burning may favor woody species more than ground species. The results of our percent moisture and carbon tests indicate that, overall, the burned plots had non-significantly more moisture and more carbon, both important factors in the growth process of macrofungi. These results do not verify our hypothesis that there would be greater woody and ground species richness in unburned plots, but they may indicate beneficial effects of burning on macrofungal species richness.

The macrofungi samples that we took illustrate a possible difference between species richness in burned and unburned plots, although this difference was non-significant. We hypothesized that there would be decreased species richness in burned plots, because fire destroys the wood that fungi grow on and the fruiting bodies of the fungi themselves. An alternative hypothesis is that fire acts as a stimulus for certain species of macrofungi. A study in Western Australia that examined macrofungal succession after wildfires found that appearance and then dramatic disappearance of some macrofungal species may suggest that some species are stimulated by environmental changes that are caused by fire (Robinson et al. 2008). This same study discovered that fire resulted in an immediate decrease in species richness, but over five years after a single burning, the macrofungal richness in burned and unburned areas equaled out. Our research area was burned about one year prior to our sampling so over that year of succession it is possible that species richness already began to increase. Succession after recurring annual burns may be affected by the frequency of the treatment (Robinson et al. 2008).

In addition to certain species thriving on fire, fire's effect on competition between macrofungal species may have led to higher species richness. This was found in a study by Penttilä and Katiranta (1996) on the effects of prescribed burning on wood-rotting fungi in Finland. They discovered that most of the species that were abundant after burning were species that had been absent before the area was burned. They interpreted this to mean that by destroying dominant species, fire gives some species the change in environment that they need to establish themselves since competition with dominant species has been lessened.

Our results did not support our hypothesis that there would be fewer ground and woody macrofungal species in the burned plots. The average number of ground species remained similar between the burned and unburned plots, suggesting that burning makes little difference in the numbers of macrofungi on the ground. The main effect of burning is that it removes litter, yet most fungi grow in the soil, on wood but not on leaf litter (with some exceptions). Therefore, lower amounts of litter in the burned plots should have little effect on the amount of ground fungi.

The unexpected rise in woody species richness after burning disagrees with the study by Penttilä and Kotiranta (1996) which found that species richness of woody fungi decreased dramatically with burning because of an increase of certain dominant species and a loss of some of the rarer species. Our contradictory findings might be explained by our sampling methods—we only examined wood on our established transects, whereas Penttilä and Kotiranta (1996) looked at all wood in their plots. Another factor contributing to the greater woody species richness in burned plots is the low intensity burning that occurs in CERA. This means that trees and logs are not destroyed and the forest also may take less time to recover and grow back from this slight disturbance. Therefore, the amount of woody species destroyed by the fire was less than those with high intensity fires.

Other factors to consider in our experiment are percent soil moisture and percent carbon. Trudell and Edmonds (2004) show that increasing these factors in the soil increases fungal growth. Our findings somewhat support this study because our burned plots had slightly higher percent soil moisture, percent carbon and species richness than in the unburned plots. However, our regression analyses showed that these two factors were not necessarily correlated with species richness. This might be explained by the fact that both percent soil moisture and carbon were similar between burned and unburned plots.

Our study investigated the effects of burning on macrofungal species richness in an oak forest. We found that fire may be a necessary disturbance for oak forests, because it increases species richness of macrofungi which are integral organisms in the overall health of a forest. These results were different from many other studies that have been conducted to examine the effects of prescribed burns on fungi, so it is important to further examine the factors that could have led to our results. Some ideas for future studies would be to look at the long term effects of fire on succession of macrofungal species richness in oak forests. This would mean having larger intervals between fires to allow longer periods of succession from the disturbance. Similarly, one could investigate the effects of random intervals between burns to allow a more natural representation of the effects of burning on species richness. These studies could allow for a more detailed comparison with the Robinson et al. (2008) study in western Australian forests. The effects of burning in a different season instead of late fall could show whether the time of year of burning may correlate with fungal growth cycles. In addition to examining the percent carbon and moisture in the soil it would also be interesting to compare the percent nitrogen in the soil of burned and unburned plots to see what effect nitrogen changes caused by burning has on the growth of macrofungi. Trudell and Edmonds (2004) found that nitrogen abundance correlated negatively with species richness. These studies would help make more concrete claims about the effects of fire on macrofungal species richness. Although our results disproved our hypothesis and contradicted previous studies, it shows that fire is a potentially important disturbance to macrofungal species richness.

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