Effects of a Prescribed Burn on Soil Microarthropod Populations at Nancytown, GA

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Abstract

In this study, the effects of a low-intensity prescribed burn were assessed on soil microarthropods by examining Collembola, Oribatid, Mesostigmata, and Prostigmata populations. Sampling was done for three consecutive years, including one year pre-burn. Mean microarthropod populations of all groups fluctuated over the three years, but further analysis indicated significant differences by date with population increases in 2006 for only Collembola and Oribatid populations. However, these significant differences were unrelated to the burn because the differences occurred at the control as well as burn site. Collembola and Oribatids also had significant differences by site; both suborders were more abundant at the burn site in all three years with no relation to the burn. These results detected no lasting effects on microarthropod populations, leading to the contention that other factors influenced population variations between years and not the prescribed burn. Environmental factors such as moisture probably contributed to the common trend in populations between the two sites. Environmental factors are density-independent, meaning their effects are constant over a large population which explains the significant increase of populations at both sites in 2006. These findings are significant because forest managers are more commonly using low-intensity prescribed fires to restore ecological health, and we have little information on how microarthropods respond to these fires.

1. Introduction

Resource managers recognize fire as an important element in protecting biodiversity and improving wildlife habitat. Low-intensity prescribed burning is often used by resource managers not only to improve ecosystem health but also for fuels reduction along interfaces of forested and urban areas, and this management strategy is increasing as managers gain understanding of fire ecology[12]. Studies suggest low-intensity prescribed burning is an effective method in restoring desirable species in pine-oak communities and has no adverse affects in nutrient cycling[6]. While much is known about the terrestrial and nutrient cycling benefits of low-intensity prescribed fire, information is lacking on the effects it has on the soil fauna in southern forests, and few studies examine soil communities before a prescribed burn and the response of the populations over subsequent years.

In the forest, microarthropods are among the most abundant organisms in the soil and play vital roles in the food web as decomposers. Microarthropods not only directly break down organic material but also feed on fungi and bacteria from organic material and in doing so release essential nutrients into the ecosystem. Because decomposition and nutrients are so closely linked, microarthropods greatly influence the quality of the soil. In addition to decomposing organic matter and releasing nutrients, some microarthropods are predators and control other soil organisms[9]. While much is known about the important role microarthropods play in the soil ecosystem, little is known on how microarthropod populations respond to fire disturbances.

The objectives of this research were to examine how microarthropod populations respond to a low-intensity prescribed burn. The populations of Collembola, Oribatida, Mesostigmata, and Prostigmata were examined from a burned site and from a nearby control site. Soil samples were taken a year before the prescribed burn, shortly after the burn, and one year following the burn. Since microarthropods are indicators of soil quality and also have great influence on the ecosystem, this study will help resource managers understand some ecological implications of prescribed burning.

2. Methods

2.1 site description

The research area is located in northern Georgia, at the Lake Russell Wildlife Management Area (USFS) in Habersham County. The area is about 480 m in elevation with a mean annual precipitation of 150 cm[8]. Vegetation is a mixed oak-hardwood forest with some pine. The canopy consisted of oak (*Quercus* spp), red maple (*Acer rubrum*), hickory (*Carya* spp), white pine (*Pinus strobus*), and shortleaf pine (*Pinus echinata*), with an understory of sourwood (*Oxydendrum arboretum*) and dogwood (*Cornus florida*).

2.2 experimental design

Sampling began in summer, 2004, at two sites in close proximity. In summer, 2005, one site was burned by the USDA Forest Service as part of a low-intensity prescribed burn that covered 810 acres. A post-burn evaluation found no bare soil exposed with 100% duff (layer between soil and leaf litter) intact and 80% of the understory vegetation consumed. The purpose of the burn was for fuels reduction along a wildland/urban boundary, and a secondary benefit included wildlife habitat improvement. Samples were taken again summer 2005 a few months following the burn, and again summer 2006 one year after the burn. The unburned was considered the control.

For our study, ten 1x2m plots were set up on north and south slopes at both sites. Each plot was randomly sampled. Ten samples were randomly taken from north and south slopes at each site. Soil cores, 5x5cm (60cm^3), with 1.5mm mesh screen on one end, were taken through the litter layer. The soil cores were then wrapped in aluminum foil and transported in a cooler back to the lab the same day where they were immediately placed screen-side down on modified Tullgren extractors[7]. The Tullgren extraction process involved applying a low amount of light over the top of the soil cores, and using a dimmer switch the light intensity was carefully increased every two days for one week. The increased light, temperature, and drying of the soil drove the microarthropods deeper into the soil core until they fell into a vial of 70% ethanol. Soil microarthropods were sorted in categories of order Collembola and suborders of mites; Oribatida, and Mesostigmata/Prostigmata. The suborders of Mesostigmata and Prostigmata were added together because they were less abundant than other soil taxa and have similar niches in the soil fauna as predators. The rest of the organisms were sorted into a category of “other” which included fauna such as thrips, pseudoscorpions, and ants. Soil temperatures were also taken at each plot using soil thermometers at depths of 3-5cm, and soil moisture readings were taken using a Hydrosense© (Campbell Scientific).

2.3 statistical analysis

Proc Genmod (SAS 9.1) was used to analyze differences among sites, dates, aspects, and all possible interactions. A Poisson distribution was followed because the microarthropod populations were not normally distributed. The analysis began with complete models and all possible interactions. Then the models were simplified by excluding insignificant and independent interactions until the most parsimonious models were achieved[3]. Since this procedure does not allow comparisons among means, a Tukey’s test was used for comparison purposes only. All data were analyzed using SAS 9.1[11].

3. Results

Mean microarthropod populations of all three groups fluctuated over the three years, but further analysis indicated significant differences by date for only Collembola and Oribatida populations (Table 1). Means of all populations especially Collembola and Oribatida show similar trends of decreasing in 2005 and increasing again in 2006 (Fig. 1, Table 2).

Analysis of Collembola populations indicates significant differences in site, date, and site*date*aspect interactions (Table 1). Table 2 shows the means of the site, date, and aspect variables for Collembola populations for comparison purposes. A comparison of these means shows Collembola populations at the burn site were significantly more abundant than at the control site over all three years, and Collembola populations significantly higher one year after the burn in 2006 than in the previous two years (Table 2).

The Oribatids were the most abundant taxon for each site, date, and aspect, and analysis indicates significant differences in their populations by site, date, and aspect (Table 1). A comparison of Oribatids shows the mean at the burn site to be significantly higher than the control site (Fig.2). Also, one year after the burn in 2006, Oribatid populations were significantly higher than the previous years (Fig. 1). Analysis indicates significant difference in aspects, and the mean comparison shows south slopes to have a higher mean in populations than north slopes (Fig. 3).

Prostigmata/Mesostigmata populations had no significant differences. Proc Genmod analysis showed Mesostigmata/Prostigmata difference by date to be P=0.0687 but not significant (Table 1). Also, soil moisture averaged 25% in 2005 and 11% in 2006, with no measurements available for 2004.

Table 1. microarthropod responses to site, date, and aspects, at Lake Russell Wildlife Management Area, 2004-2007.

Organism	*Log-Likelihood*	*Terms*	*Chi-square*	*df*	*P*
Collembola	169.38	site	6.41	1	**0.0113**
		date	17.87	2	**0.0001**
		aspect	1.63	1	0.2016
		site*date	1.93	2	0.3800
		site*aspect	3.47	1	0.0625
		date*aspect	0.05	2	0.9775
		site*date*aspect	13.15	2	**0.0014**
Oribatida	411.65	site	5.62	1	**0.0178**
		date	45.07	2	**<0.0001**
		aspect	4.61	1	**0.0318**
Prostigmata/ Mesostigmata	126.59	site	1.00	1	0.3171
		date	4.81	2	0.0902
		aspect	0.25	1	0.6143

Table 2. average numbers of Collembola were higher at the burn site over all three years. Collembola were also significantly higher in 2006 than in the previous two years. there was also a significant site*date*aspect interaction but Tukey's test does not distinguish where this was. (*) indicates where significant differences occurred.

Comparison of Average Numbers of Collembola Per Soil Core

	Site	**Date**	**Aspect**
Burn	8*		
Control	5		
2004		6	
2005		5	
2006		9*	
North			6
South			7

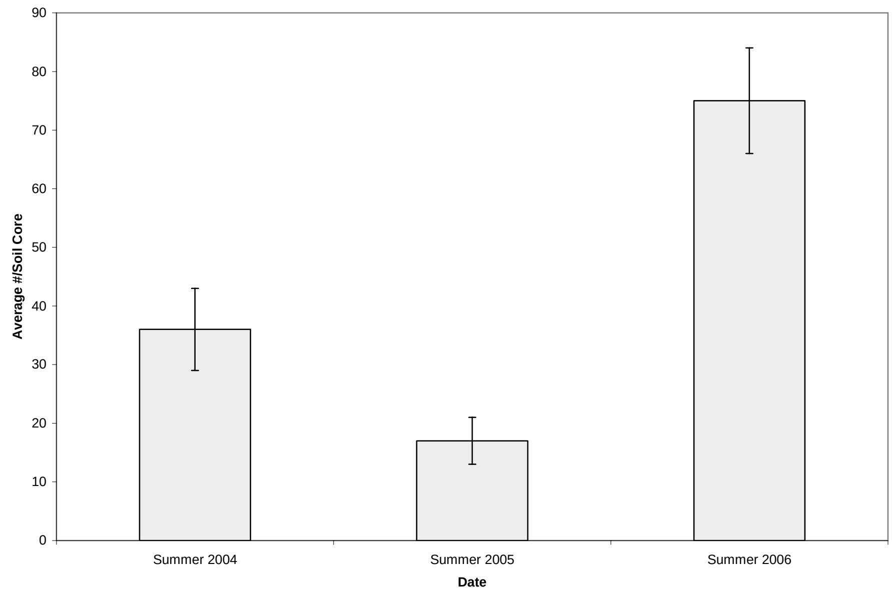

Figure 1. Oribatid populations by date at Nancytown, GA.

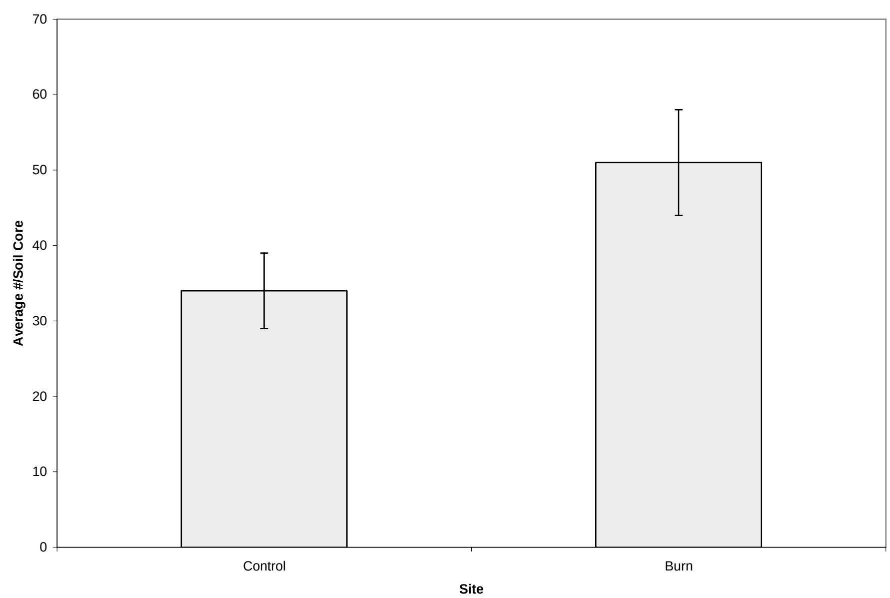

Figure 2. Oribatid populations by site at Nancytown, GA.

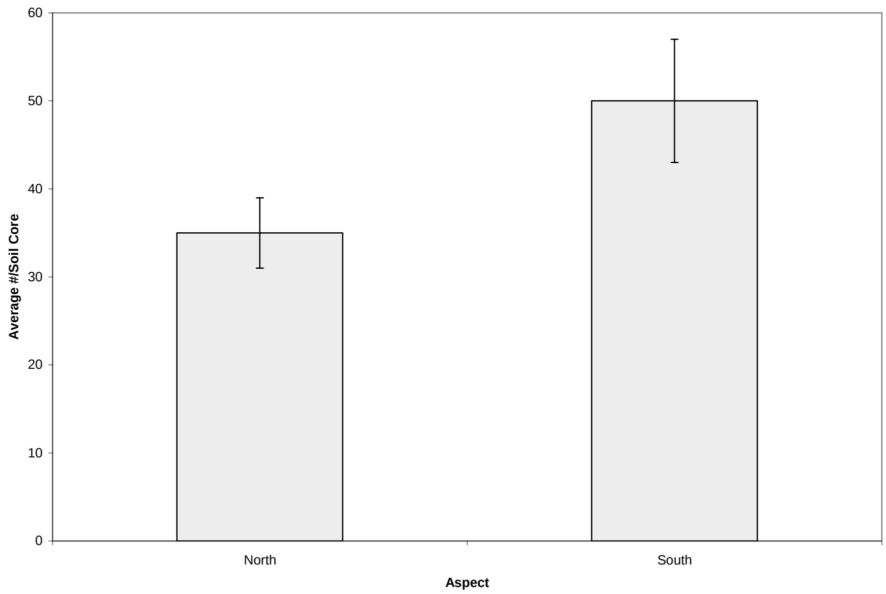

Figure 3. Average oribatid populations by aspect at Nancytown, GA.

4. Discussion

The results indicated a general trend with all three groups of microarthropods, which involved a decline of populations in 2005 and an increase in 2006, significantly so for Collembola and Oribatids (Fig.1, Table 2). While the non significant declines in 2005 coincided with the year of the prescribed fire, they were apparently unrelated because the declines occurred at the control as well as burn site. It is important to reiterate the significant differences among Collembola and Oribatid populations were found with the increase in 2006 and are by date with no interaction, meaning the increase of populations in 2006 occurred at both sites in the same year.

Collembola and Oribatids also had significant differences by site. This shows that both groups were more abundant at the burn site with no interaction with date; the means of all three years were significantly higher at the burn site. Collembola also had a significant site*date*aspect interaction in the results (Table 1). However, the Tukey's test is not able to tell where this significant difference occurred. The effects were likely related to increased abundance in populations among south facing aspects.

The results detected no lasting negative effects on microarthropod populations, leading to the contention that populations were not affected by the prescribed burn. A similar study conducted by Coleman and Reiske found an initial significant decrease in litter arthropod populations with negative effects in abundance lasting for two years following a prescribed burn. The other study also concluded there were no effects after two years, and no long term effects from the prescribed burn[2]. The different lasting effects from the burn in the results between the Coleman and Reiske experiment and the study of this paper probably reflects differences between soil and litter fauna.

Some soil invertebrates such as microarthropods dwell deep enough in the soil horizon to be insulated from even high-severity fire, and some populations may escape effects from fire by moving deeper in response to soil temperatures[4]. However, it is possible that microarthropods were initially negatively affected by the fire, but nutrient inputs from the fire compensated for any negative effects.

Depending on the severity of the fire, nutrient cycling can be dramatically affected. Nitrogen is often the most limiting nutrient in ecosystems, but there is often an increase in nitrogen available to the soil directly after a low-intensity fire with no long-term loss of nitrogen when fire temperatures are below 200°C[4, 6]. This is important to consider because nitrogen is especially exploited by fungi, a food source for microarthropods[10]. Perhaps this initial increase of nitrogen gave a temporary boost to microarthropod populations.

In the event of severe fire, nitrogen can be lost from the ecosystem, leading to the lack of food sources. However, restriction to one food source is uncommon among soil organisms such as microarthropods, thus starvation among adult microarthropods is uncommon, supporting that starvation is uncommon in any event of fire. The flexibility of microarthropods in regard to food sources means food availability is more influential on population regulation over time than on direct mortality[10]. This supports that fluctuation among populations, as seen in this study, is the result fluctuating food availability due to factors other than fire because of the similarity between the burn and unburned sites (Fig. 1, Table 2).

The feeding habits of microarthropods are also opportunistic, meaning litter quality and microhabitat change can lead to variable populations which help in explaining the uneven distribution of microarthropods within the ecosystem. Studies suggest that specific plant litter affects spatial variation among microarthropod populations. Studies also suggest that losses of nitrogen over time from a low-intensity fire are easily replenished through nitrogen deposition from the atmosphere and by litter fall within the next year if the canopy remains intact[4, 6]. It must be added, this study does not support that populations benefited from nutrient input from the prescribed fire because there were no significant site*date interactions which favor the burn site in the results.

One or multiple environmental factors are likely responsible for the variation in populations by date for the burn and control sites (Fig.1, Table 2). Environmental factors are considered to be density-independent, meaning their effects are constant over a large population range[10]. Changes in environmental factors such as temperature and soil moisture affect rates of microarthropod development particularly in immature stages. In addition, environmental factors can have lasting effects because development may take up to three years in some species[1].

In this study the only measured environmental factor with any difference was soil moisture, and at both sites the soil moisture averaged 25% in 2005 and 11% in 2006. Soil moisture is the most direct environmental factor influencing the abundance of microarthropods because it changes the structure and oxygen content of the soil by altering pore spacing between soil particles[1]. Structure of a soil describes the way soil particles combine to form the texture; for example, crumbs and clods are two types of structure in which there are different sized pieces of soil. These different sizes allow for different sizes of pores, which in turn, influence the aeration of the soil and retention of water[10]. Aeration is important for respiration and water retention is important because the amount and duration of moisture greatly influences the activities of organisms such as microarthropods by influencing the activity of food sources. For example, certain bacteria such as saprotrophs have adapted to become active only in dry microhabitats. The results from this study support the possibility of increased saprotroph activity in 2006 because the average soil moisture was lower at both sites in 2006 compared to 2005. Soil fauna ecosystems are so interconnected that once organisms such as bacteria become active, it sets a chain reaction for the activity of microarthropods that rely on bacteria as their food source[1].

5. Conclusion

This study examined the effects of a prescribed fire on microarthropod populations. The results detected no lasting negative effects on microarthropod populations from the prescribed burn. Microarthropods were either able to escape from fire or the populations were resilient to the effects of fire. Environmental factors such as soil moisture could have contributed to the common trend in populations between the two sites and explained the significant increase of populations at both sites in 2006, although other factors which this study did not measure could have played a role, such as pH and other food resources[1]. Future research should further examine the effects of environmental factors on microarthropods, perhaps in settings where factors can be controlled and precisely measured. It also should be added that future research should examine how more severe fire impacts the soil fauna. This study showed not only how microarthropods respond to a prescribed fire but also suggested soil ecosystems are so interrelated that environmental factors have great influence on microarthropod populations.

6. References

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