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The Influence of Prescribed Burning on Spiders and Pseudoscorpions: Known Predators of Woodland Litter Springtails

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ABSTRACT

To test the effect of prescribed burning on spiders and pseudoscorpions, leaf litter samples of invertebrates were collected from the East Woods of the Morton Arboretum. Of 162 samples extracted through modified Tullgren funnels, half were taken from previously burned areas and half from areas that had not been burned. Four years of data for each of three seasons within a span of 12 years were analyzed. Significantly fewer individual spiders were collected in burned areas than in unburned areas. Pseudoscorpions were present in approximately equal numbers in burned and unburned areas. Species diversity was greater for spiders than for pseudoscorpions with 12 families, 30 genera, and 22 species of spiders represented in the samples. Only 3 species of pseudoscorpions were collected. Results of this study suggest that to maintain or increase diversity of these invertebrates in natural environments where controlled burning is used as a management tool, frequency of burns should be changed from annual to every two or three years. In addition, several fire exclusion areas should be included that can serve as refuges for fire sensitive species to repopulate burned areas.

INTRODUCTION

Prescribed burning is used as a management practice to: 1) restore natural fire processes, 2) enhance growth of preferred native species of plants that evolved with fire as a natural component of the environment, and 3) eradicate or reduce non-native plant species. In one study of upland forests of the Chicago region, however, abundance of garlic mustard (a non-native plant)was enhanced in burned areas over unburned areas (Bowles et al, 2000). In addition to managing plant species, it is often desirable to investigate the animal components of the ecosystem to find out how such fires affect animal species (Greenslade, 1997; York, 1994). The physical structure of the litter of Heathland, a woody shrub habitat of the North York Moors in England, was studied to ascertain the effects of burning and cutting on the arthropod fauna (Usher and Smart, 1988). Results suggested in this study that fewer spiders in burnt areas might be due to more favorable open areas for bird predation than in the cut areas of heath. Species diversity information was limited as only one of 42 species of spiders was sufficiently abundant for statistical analysis. It has also been shown that the structural complexity of leaf litter significantly affected the abundances of some forest floor spiders, especially web building species (Bultman and Uetz, 1982; Duffey, 1978). Because prescribed fire affects the depth of leaf litter remaining, the epigeic fauna of a forest floor ecosystem in Australia had significantly lower numbers of spiders than adjacent unburnt areas (York, 1999). Successional changes in spider species after prescribed burning and decreases in total spider density were also reported in Finland with signs of recovery occurring only after 7-13 years (Huhta, 1971). However, in chestnut forests of south-facing slopes of the Alps, the numbers of spider species increased in areas of recurring fires over similar forests that had not been burned or burned only once (Moretti, 2000). Some studies on wildfires have shown that it may take 15-30 years for populations of linyphiid spiders to recover from wildfires (Buddle, et al., 2000).

Prescribed burning of woodland litter reduced springtail (Order Collembola) species richness as well as yearly and seasonal density (Brand, 2002). Because burning has been shown to affect springtail species richness and density, burning may also affect springtail predator diversity and density. Spiders prey on springtails in the litter layer of woodlands (Hallander, 1970). When spiders were removed experimentally, populations of springtails increase over those in control areas (Reichert and Bishop, 1990; Clarke and Grant, 1968). The purpose of my study at The Morton Arboretum in Lisle, Illinois, was to evaluate the effect of prescribed burning on spiders, pseudoscorpions, and the leaf litter in which they live. The effect of fire may be direct removal of predators or indirect if it reduces predator food supply.

Pseudoscorpions are common inhabitants of woodland leaf litter (Jones, 1970) and are known predators of springtails (Weygoldt, 1969). There are higher numbers of pseudoscorpions in less disturbed field margins than in those subject to mowing (Bell et al., 1999).

METHODS/STUDY SITE

The East Woods of The Morton Arboretum was used for my study that extended over 12 years with collections in the 4 years 1987,1989,1997, and 1998. Of the 680 hectares at the Arboretum, about 110 hectares are covered by the East Woods and 20 hectares have been burned annually in the spring after snow melt since 1987. Prescribed burning has been used at the Arboretum as a management technique to restore fire processes of the past and encourage the growth of diverse, hardwood deciduous species. Two known predators of springtails, spiders and pseudoscorpions, were collected in litter samples and extracted using modified Tullgren funnel techniques. Although the screen mesh was designed specifically for small arthropods, the large openings at the junction of screen and funnel permitted all but the largest spiders to be collected. Specimens were collected in a bottle of Van Torne's preservative (Christiansen and Bellinger, 1980) at the base of each funnel. Spiders and pseudoscorpions were sorted using a Bausch & Lomb 7-30X microscope and stored in individual vials of 70% isopropyl alcohol for future identification. Litter was not weighed in 1987, but was weighed for the other three years. To study the effect of fire, an experimental design was established in which 126 random samples (0.2 m^2 area) of woodland leaf litter from 13 one acre plots distributed throughout the East Woods were collected in 3 different seasons (excluding winter) over four years. An equal number of samples (63) were collected from previously burned areas and from areas that had not been previously burned. Litter was placed in plastic bags and transported to the extraction funnel location in insulated coolers. Details concerning vegetation of the site and collection methods were published earlier (Brand, 2002). Data were gathered on species richness, frequency and density of spiders and pseudoscorpions, and dry weight of leaf litter. The software program Statistix 7 (Analytical Software 2000) was used to perform ANOVA or nonparametric Kruskal-Wallis ANOVA tests on data for all samples from previously burned and unburned areas. The Kruskal-Wallis test was used if the variances were heterogeneous and the distributions non-normal.

RESULTS

Results of the overall study are provided first, followed by the effect of fire on spiders, pseudoscorpions, and leaf litter. Taxonomic placement of genera and species of spiders by family is provided in Table 1.

Spiders

Many of the 419 spiders collected were immature, thus taxonomic identification to family, genus, or species was restricted to 322 specimens (Table 1). Of the immature specimens, 55 were spiderlings for which only identification to family was possible. The remaining 42 were juveniles for which only genus could be identified. Of the twelve families represented in the study, two families, Agelenidae and Uloboridae, were not represented in collections from unburned areas and the family Dictynidae (web builders) was not sampled in burned areas. Specimens from 30 genera were collected in the study. Of these, 7 genera were not represented in unburned areas and 7 genera were not represented in burned areas. The number of specimens identified to species was insufficient to compare effects of burning at the species level. A few spiders were identified as new species but these have not yet been described.

The number of spiders per $0.2m^2$ sample ranged from 0 to 38 with a mean (x_m) of 2.59 and a standard error (S.E.) of 0.30. Density per square meter ranged from 0 to 204 with a x_m of 13.93 ± S.E. of 1.63. Mean density varied significantly over the 4 years with the highest mean density in 1998. Seasonal density for the 3 seasons (winters excluded) also varied significantly (Table 2).

Density of spiders per square meter in burned areas was significantly lower than in unburned areas (Table 3). However, for any given year there was no difference in spider density from burned versus unburned areas. There were significantly more spiders in unburned areas in spring than in burned areas, but no difference in density due to fire for summer and autumn seasons (Table 3).

Pseudoscorpions

Three species of pseudoscorpions (*Microbisium parvulum*, *Chthonius (Ephippiochthonius) tetrachelatus*, and *Hesperochernes canadensis*) were identified in the 193 specimens collected (Table 4B). Individuals of *M. parvulum* were most numerous (186), followed by *C. tetrachelatus* (6), and *H. canadensis* (1). It is the first time this latter species has been reported from Illinois (M. Harvey, pers. comm.). The number of pseudoscorpions per $0.2m^2$ ranged from 0 to 9 with xm of 1.2 ± 0.14. Density per square meter ranged from 0 to 45 with x_m of 6.0 ± 0.70. Mean density varied significantly over the 4 years with highest mean density occurring in 1998, the same year in which the spiders had the highest density (Table 4A). Seasonal variation in density was not significant (Table 4A). No significant effect of prescribed burning on pseudoscorpion density was demonstrated (Table 5). However, there were more pseudoscorpions from unburned areas (108) than burned areas (85), and 4 of 6 specimens of *C. tetrachelatus* and the single specimen of *H. canadensis* were from unburned areas. Density was significantly different only in 1987 with lower density in burned areas. No differences in density were demonstrated for any of the seasons as a result of prescribed burning (Table 5).

Litter

In 1989,1997, and 1998 litter was collected, dried, and weighed. For 126 samples, the mean and standard error was 2.13 kg/m. and ± 0.09. There was no significant difference in annual variation in mean litter weight over three years, but seasonal variation was highly significant with spring having the highest litter weight (Table 6). A significant effect of burning was demonstrated with more litter present in the unburned areas than burned areas. The same effect was seen in each year of the study but there were no differences of the effect of burning on mean litter weight within any of the 3 seasons (Table 7).

DISCUSSION

Information about invertebrate components can provide an essential link to improve management of woodland ecosystems (Naeem, S. et al, 1995, Hunter, M.D. et al, 2003, Reynolds, B.C. et al, 2003). Recent studies of decomposition rate in a forest ecosystem showed that spiders influence the chemistry of decomposition (Hunter M.D. et al, 2003). Although the present study could not be replicated in detail at other sites, a preliminary investigation of the effect of burning on similar predators was conducted in 1997 and 1998 at the oak-hickory wooded knolls of Lincoln Marsh, Wheaton, Illinois. Of the 54 samples collected over 3 seasons, 27 each from previously burned and unburned areas, the numbers of these predators (spiders and pseudoscorpions) were insufficient to demonstrate significant differences of the effect of fire (unpublished data). Over the four years of the present study there was a significant difference in the density of spiders with increasing density over time (Table 2). Similarly, pseudoscorpions also had a significant increase in density with the exception of the third year, 1997 (Table 4). In a previous study of springtails in this area (Brand, 2002), the same pattern of significantly increased density occurred. In 1998, the final year of the study, all three invertebrate species (springtails, spiders, and pseudoscorpions) showed their highest densities. This year also had the highest precipitation (Morton Arboretum weather station records) for periods prior to sampling (Brand, 2002). However, litter weight did not follow this pattern and was not significantly different in the three years that litter weight was measured. There was a significant difference in litter weight by season with more litter in the spring prior to increased decomposition at higher temperatures in the summer and autumn (Table 6). The effect of fire on litter was evident in each year of the study with significant variation in dry weight for each year (Table 7). Reduced density of spiders in the spring from burning was statistically significant but this seasonal effect of burning was not significant for pseudoscorpions or litter (Tables 3, 5, and 7).

When prescribed burning is a part of the management protocol, understanding the effects of fire on density and diversity of invertebrate populations can contribute to more successful ecological restorations. In my study spiders and pseudoscorpions responded differently to fire. Spiders were significantly less dense in areas that were burned whereas pseudoscorpions showed no difference in density between burned and unburned areas. This may reflect a behavioral difference in which larger, mobile spiders are more active on the surface of litter and subject to higher mortality from fire than smaller pseudoscorpions closer to the ground surface. Despite availability of some safe havens under logs, stones, and exposed tree roots during prescribed burning, diversity of invertebrate and plant species would be enhanced if prescribed burns occurred every two or three years rather than annually. A reduced frequency of burning may more adequately reflect the historical occurrence of naturally occurring fires than the regular annual burns often used in current management practice.

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Table 1. List of spiders.

Family	Genus and species	Family	Genus and species
Agelenidae	*Agelenopsis* sp.	Linyphiidae	*Meioneta evadens*
Anyphaenidae	*Anyphaena* sp.		*M. unimaculata*
	Hibana		*Microneta viaria*
	Oxysoma		*Walckenaeria sprialis*
Clubionidae	*Clubiona* sp.	Lycosidae	*Schizocosa (oscota)**
	Clubionoides		*S.* sp.*
Corinnidae	*Phruokripus alarius*		*Picuta*
	Scotinella madisonia	Salticidae	*Bianor*
	Castianeira sp.		*Neon*
Dictynidae	*Tricholathys* sp.	Theridiidae	*Endoplognatha ovata*
Hahniidae	*Neoartistea* sp.		*E. (tecta)**
Linyphiidae	*Bathyphantes alboventris*		*E.* sp.**
	Centromeris cornupalpis		*Theridion* sp.
	Corammorota sp.	Thomisidae	*Misunenops* sp.
	Eperigone autumnalis		*Ozyphila monroensis*
	E. maculata		*O.* sp.**
	E. sp. undescribed		*Xysticus fraternis*
	Gnathonaroides pedolis		*X.* sp.**
	Kaestneria sp.	Uloboridae	*Uloborus* sp.

( )* - most likely this species
** - different but unknown species than listed for genus

Table 2. Density of spiders for all samples plus annual and seasonal variation. (X_m/m^2)

Annual Variation: KW = 67.1, $p < 0.001$**

Year	N	X_m	S.E.
1987	36	1.89	0.64
1989	36	7.42	1.59
1997	54	19.35	4.03
1998	36	24.33	2.37
All Samples	162	13.93	1.63

Seasonal Variation: KW = 7.81, $p < 0.03$*

Season	N	X_m	S.E.
Spring	54	15.74	0.31
Summer	36	15.92	1.13
Autumn	72	11.57	0.31

N = number of samples; X_m = mean of individuals, S.E. = standard error

Table 3. Effect of fire on spiders (X_m/m^2).

	Burned			Unburned				
	N	X_m	S.E.	N	X_m	S.E.	Analysis	p Value
All samples	81	12.61	2.89	81	15.21	1.53	KW =7.44	p < 0.01**
Annual Variation								
1987	18	2.06	0.89	18	1.72	0.95	F = 0.07	p = 0.80
1989	27	5.56	1.34	9	13	4.62	KW = 3.3	p = 0.07
1997	27	21.31	7.78	27	17.4	2.35	KW = 1.84	p = 0.18
1998	9	28.89	5.85	27	22.82	2.5	F = 1.24	p = 0.27
Seasonal Variation								
Spring	18	7.78	1.72	36	19.72	2.03	KW =12.3	p < .001**
Summer	27	16.9	7.99	9	13	4.62	KW = 1.28	p = 0.26
Autumn	36	11.83	2.44	36	11.31	2.37	F = 0.02	p = 0.88

N = number of samples; X_m = mean of individuals, S.E. = standard error

Table 4. Annual/season variation density (X_m/m^2) and identification of pseudoscorpions.

A) Annual and seasonal variation density

	N	X_m	S.E.		N	X_m	S.E.
Annual Variation				Seasonal Variation			
F = 3.34 p < 0.03*				F = 0.41 p = 0.66			
1987	36	5.17	1.36				
1989	36	6.11	1.71	Spring	54	6.91	1.51
1997	54	4.43	1.201	Summer	36	5.06	1.64
1998	36	10.8	1.96	Autumn	72	6.63	1.07
All samples	162	6.37	0.781				

N = number of samples; X_m = mean of individuals, S.E. = standard error

B) Identification of pseudoscorpions

Family	Genus and species
Chemetidae	*Microbisium parvulum*
Chthoniidae	*Chthonius tetrachelatus*
Neobisiidae	*Hesperochemes canadensis*

Table 5. Effect of fire on pseudoscorpions (X_m/m^2).

	Burned			Unburned				
	N	X_m	S.E.	N	X_m	S.E.	Analysis	p Value
All samples	81	5.6	1.09	81	7.11	1.12	F = 0.99	p = 0.32
Annual Variation								
1987	18	3.78	1.28	18	6.56	2.36	KW = 19.4	p < .001**
1989	27	6.15	2.07	9	6.01	3.06	KW = 0.01	p = 0.18
1997	27	5.7	2.21	27	3.15	0.92	KW = 0.07	p = 0.80
1998	9	7.22	3.01	27	11.93	2.41	F = 1.08	p = 0.31
Seasonal Variation								
Spring	18	7.72	2.82	36	6.5	1.8	F = 0.14	p = 0.71
Summer	27	4.74	1.96	9	6	3.06	F = 0.11	p = 0.74
Autumn	36	5.17	1.39	36	8.08	1.62	F = 1.87	p = 0.18

N = number of samples; X_m = mean of individuals, S.E. = standard error

Table 6. Dry weight of litter for all samples plus annual and seasonal variation (kg/m^2).

	N	X_m	S.E.		N	X_m	S.E.
Annual Variation				Seasonal Variation			
KW = 2.21 p < 0.33				KW = 57.0 p < 0.01**			
1989	36	2	0.2	Spring	54	2.8	0.1
1997	54	2.3	0.2	Summer	36	1.3	0.1
1998	36	1.9	0.1	Autumn	72	1.9	0.1
All samples	126	2.1	0.1				

N = number of samples; X_m = mean of individuals, S.E. = standard error

Table 7. Effect of fire on litter (X_m/m^2).

	Burned			Unburned				
	N	X_m	S.E.	N	X_m	S.E.	Analysis	p Value
All samples	72	1.92	0.11	54	2.39	0.15	KW = 7.22	p < 0.01*
Annual Variation								
1989	18	1.51	0.23	9	2.22	0.21	KW = 4.81	p < 0.03*
1997	27	1.81	0.21	27	2.85	0.21	F = 12.83	p < 0.001*
1998	27	1.53	0.11	27	2.12	0.15	KW = 5.88	p < 0.02*
Seasonal Variation								
Spring	18	2.8	0.19	36	2.79	0.18	F = 0.0	p = 0.98
Summer	27	1.35	0.16	9	1.32	0.12	KW = 0.49	p = 0.49
Autumn	18	1.98	0.2	36	1.79	0.13	F = 0.61	p = 0.44

N = number of samples; X_m = mean of individuals, S.E. = standard error