J. Entomol. Res. Soc., 12(3): 29-37, 2010 ISSN:1302-0250

Effects of the 1988 Fires in Yellowstone National Park, USA, on the Ant Populations (Hymenoptera: Formicidae)

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ABSTRACT

Invertebrates play an important role in forest and grassland ecological processes, including nutrient cycling, decomposition, and seed dispersal. Litter-dwelling invertebrates may decline significantly where the forest floor or sagebrush litter layer is burned in wildfires. The 1988 Yellowstone National Park complex of wildfires in western Wyoming, USA, provided an opportunity to study fire effects on forested and sagebrush fire effects on soil/litter invertebrate community species richness, evenness, densities, similarities, and trophic levels. Based on 4500 pit fall traps samples collected one and two years after the wildfires, we identified 19 ant species from forested and sagebrush sites. Undisturbed forested sites contained 13 species, burned forested sites contained 14 species, edges of burned sites contained 6 species, undisturbed sagebrush sites contained 12 species, and burned sagebrush sites contained 4 species. *Formica* dominated in density and species. Ant species-richness did not change in forested areas after the fires but did decrease significantly in sagebrush litter after the fires. Community evenness significantly increased in fire affected forested areas and increased slightly in sagebrush burned areas as compared to non-burned areas. Forested community similarities declined in burned sites as compared to non-burned sites and declined only slightly in sagebrush burned areas.

Key words: fire, ant populations, Yellowstone National Park, USA

INTRODUCTION

Several studies have illustrated the roles of arthropods in the ecosystems processes, such as in nutrient cycling, litter decomposition and plant productivity (Schowalter *et al*., 1991; Christiansen *et al*., 1989; McBrayer, 1977). However, disturbance changes habitat structure, which in turn can affect arthropod community structure and function (Kirchner, 1977; Lavigne and Campion, 1978, 2001; Lavigne and Kumar, 1974; Morris, 1981). In this connection, the authors conducted a two-year study of the effect of the 1988 Yellowstone National Park (YNP) fires on litter arthropod communities (Christiansen *et al*., 1991). A portion of the collected data formed the basis for the present paper. An overview of the effect of the 1988 fires on the litter arthropod community in Yellowstone National Park has been published previously (Christiansen and Lavigne, 1996), but did not deal specifically with the ant fauna.

MATERIALS AND METHODS

Data Collection

Data were collected from early July to September, 1989 and from May to early September, 1990. Nine heavily burned forest sites (where fire did not leave any litter or logs) and nine unburned lodgepole pine forest sites were randomly established at locations throughout Yellowstone National Park. Three permanently placed 100 m transects were established in each site, from which five litter samples per transect were collected every 10 days. Samples also were taken from forest sites which were burned at the fringes only (logs blackened and lightly burned leaf litter present). One hundred sweep samples and incidental collections were also made at each site. Berlese funnels were used to isolate the litter arthropods. Three burned and three unburned sites were established and collected in sagebrush/grassland. Universal Transverse Mercator (UTM) grid numbers are used for many sites in YNP, especially those designating the original study sites, as per the request of the National Park Service and are map coordinates.

The ant specimens forming the core of this study were based on samples intermittently submitted to Drs. George C. Wheeler (deceased) and Jeanette N. Wheeler for identification. Because of the large numbers of ants collected in pit traps in the YNP fire study, it was impractical to submit all specimens to experts for identification. Additionally, where long series of an apparent single species occurred in pit traps, the majority of ants were discarded by our field assistants due to lack of sufficiently large storage containers.

Data Analysis

Data were collected to determine parameters including (1) richness, (2) density, (3) evenness, (4) diversity and dominance of ant populations in each site every ten days from June until mid September, 1989 and 1990. Analysis of variance and principal component analysis were used to correlate ant density and species composition with habitat data. Our general conclusions on pit trap data are verified by use of repeated measures analysis.

An important way of looking at the collected data is through species diversity, as indicated by Noss (1990), who defined the community ecosystem in terms of indicator variables, most of which we collected. Diversity is a function of the number of different species (richness) and the equitability of the abundance of individuals between the species (evenness). There are a number of indices which reflect these community parameters. We used a set of indices for richness (Morgalefs D), evenness (Heilp) and diversity (Shannon-Weaver index) that allow comparison to most other ecological studies (Pielou, 1975; Kotila, 1986). In any given community there are a finite number of species, limited by the number of the ecological niches available. A relatively small percent are abundant (represented by large numbers of individuals) and a large percent are rare (represented by a small number of individuals). Communities differ in the number of available ecological niches and this is reflected in the number of species collected from each community by any standardized collecting technique. It follows that the more techniques employed, the more species will be collected. In general, diversity increases as succession progresses although in some temperate systems climax communities have relatively low diversity (Brown & Southwood, 1983; Price, 1984). When stress is introduced into a natural community, diversity may be reduced even though the total number of individuals or the total productivity could conceivably remain unchanged or perhaps increased (Odum and Odum, 1959). In some cases disturbance may increase the variety of available niches and hence enhance diversity (Denslow, 1980). The effect of burning usually is to reduce the number of available ecological niches, but sometimes different niches are created which allow for the migration into an area of “rare” insects which subsequently become abundant. Since little is known regarding the effects of fire on arthropods in climax lodgepole pine communities, it is possible that insect diversity may be increased following an increase in floral diversity. Obviously this critical ecological issue is fundamental to any consideration of biological diversity and must be addressed empirically.

RESULTS AND DISCUSSION

Based on recent checklists, 54 species of ants have been recorded as occurring in YNP. We consider that this is a rich fauna for an area (3458.13 sq. miles) so far north (48E- 49EN) and at such high altitudes (6251 to 11,370 ft) (Lavigne and Tepedino, 1976; Wheeler & Wheeler, 1988; Wheeler *et al.*, unpublished manuscript).

However, we were only able to identify 18 ant species from forest and sagebrush research sites in 4500 pit trap samples collected during the two year fire effect study. For example, we were unable to separate species of the *rufa* group, and so had to ‘lump’ them. Undisturbed forest sites contained 13 species, burned forest sites contained 14 species, fringe burned forest sites contained 6 ant species, undisturbed sagebrush sites contained 12 species, and burned sagebrush sites contained 4 collected ant species (Table 1). Designation as to feeding behavior are based on the habits of ants in other environments (Wheeler & Wheeler, 1963, 1988). The genus *Formica* dominated in both numbers of species and density.

A range of ant community responses to fire resulted from plant community type (forest or sagebrush) and fire intensity (intense burns or burns that did not strongly alter the habitat) in our study. These ranges can affect ant community structure as well as ant life-histories (Siepel, 1993). Changes in ant community structure as seen in this study (diversity, richness, evenness and densities) can be viewed as changes in suitable habitat as they affect interaction of food sources, vegetation, life-histories and protection (New, 2007). We postulate that changes in ant community structure in intense burns in our study were probably due to the elimination of most of the vegetation and litter layer structures. Fringe burn areas had better ant survivability due to unburned or barely burned woody debris and patches of unburned vegetation which provided ant habitat as seen in similar more recent studies (Moretti *et al*., 2002; Ratchford *et al*., 2005; York, 2000). Forested fringed burned areas would have altered vegetation structure but there would be old niches as well as new niches created where ant populations and diversity could increase. An example would be the significant increase in *Formica* populations in fringe burns in forested areas as compared to nonburned areas.

Table 1. Species List [average densities (no/m$^{2)}$ of ants in YNP collected in pit traps].

Species*	Trophic Level	Habitat (avg/site)				
		F	FB	Fr	S	B
Aphaenogaster subterranea	P	3.3	3.0	0.6	2.0	2.0
Camponotus herculeanus	H	22.3	1.0	0.0	0.4	0.0
Formica lasioides	H	0.0	0.4	0.0	3.0	0.0
F. neogagates	H	0.0	1.2	2.8	0.0	0.0
F. neoclara	H, S	0.4	1.7	0.0	0.0	0.0
F. neorufibarbis	H	17.1	79.0	0.0	0.0	0.0
F. obscuriventris	H	0.2	0.0	0.0	0.0	0.0
F. oreas comptula	H	9.7	10.0	7.6	1.0	2.0
F. puberula	S	0.0	1.8	0.0	1.0	0.0
F. rufa group	-	0.7	1.3	0.0	2.0	0.0
F. subnuda	H, Se	5.3	2.3	7.8	1.7	3.3
F. subsericea	H, S	648.8	29.4	10.0	748.0	194.0
Lasius crypticus	H	0.0	0.0	0.0	2.7	0.0
Leptothorax muscorum	?	0.1	0.0	0.0	0.0	0.0
Manica hunteri	P	0.2	0.0	0.0	0.0	0.0
Myrmica incompleta	H, S	0.0	0.1	0.0	0.0	0.7
M. fracticornis	S	0.7	0.7	0.0	0.0	0.7
Polyergus breviceps	Sl	0.2	5.3	5.3	3.0	0.0
Tapinoma sessile	O	0.0	0.0	0.0	0.0	1.3

[a]H=Herder, S=Scavenger, Se=seed eater, O=Omnivore, Sl=Slaver, P=predator.

[b]F=Forest, FB=Forest burn, Fr=Fringe burn, S=Sagebrush, SB=Sagebrush burn.

There was a very low percent similarity between undisturbed and fringe burn areas probably due to both an increase in niches in which uncommon species could occupy and a decrease in niches for other ant species which could not survive well in the new habitat structure. Sagebrush areas ‘ similarities were high in comparing burn and unburned areas probably due to a less complicated original plant community structure which would not have been as altered as a forest community structure.

Ant species-richness in forested sites did not change due to fire (Table 2). This result was found in other studies (Barrow *et al*., 2007 & Parr and Anderson, 2008).

However, unlike what Barrow et.al (2007) found in the burned habitats they studied, community density, evenness and diversity were significantly (P<0.05) influenced by fire in YNP. Ant community density was drastically lower (92%) in both fringe forest fires and in intensively burned forests one year after fire events. Community evenness significantly (P<0.05) increased in fire affected forest sites. Ant litter community diversity was low in unburned sites but significantly (P<0.05) increased in fire sites.

Parr *et al*. (2007) found functional disruption may occur in a burned area. We also found (Table I) that ant functional structure was changed in burned areas. Parr *et al*. (2008) found that predator richness usually increased in burned areas, we found that predator richness remained the same in all burned areas except for a decline in richness in fringed burned areas. One slaver species densities dramatically increased in forested burn areas.

Table 2. Ecological parameters of ant populations in forest sites, YNP (avg/m2).

Parameter	Fire Disturbance		
	None	Fringe	Intense
Richness	1.56a	1.40a	1.78a
Density	1709.78a	134.80b	139.00b
Evenness	0.08a	0.86b	0.52c
Diversity	0.09a	0.73b	0.63b

*Means in the same row followed by the same letter are not significantly different at the 5% level of confidence, Duncan=s multiple range test.

Sagebrush ant litter community richness significantly (P<0.05) declined in burned sites, unlike in forest sites which saw increases in community richness (Table 3). Parr *et al*. 2004 and Barrow *et al*. 2007 found ant assemblages in burned habitats were resilient to burning with fire generally not having significant effects on ant richness, composition or structure. However, the ant assemblage in sagebrush in YNP showed community density declined 73% in fire sites. Evenness did significantly (P<0.05) increase in sagebrush burned sites. Community diversity increased slightly in burned sites but not to a significant level.

Table 3. Ecological parameters in YNP sagebrush habitats (avg/m^2).

Parameter	Fire Disturbance		
	None	Fringe	Intense
Richness	3.67a	NA	2.33b
Density	767.00a	NA	204.00b
Evenness	0.07a	NA	1.42b
Diversity	0.07a	NA	0.12a

*Means in the same row followed by the same letter are not significantly different at the 5% level of confidence, Duncan=s multiple range test.

The ant genus *Formica* was an important litter ant component in forest populations (Table 4). Although overall ant community richness did not change due to fire, richness of *Formica* was affected by forest fires. Richness increased significantly by more than five times in fringe burned forest sites. Ant richness increased in intensively burned sites but not to a significant level. Community density declined 93% in fire affected forest sites. Community evenness significantly increased in both fringe fire sites and in more intensively forest fire sites with fringe sites increasing more than community evenness in intensively burned sites. *Formica* diversity was low in nonburned sites, but increased in fire sites.

The genus *Formica* was the most important litter ant component in sagebrush sites. Community richness significantly ($P<0.05$) declined by more than half in fire sites (Table 5). A density decline of 74% occurred in *Formica* species in fire sites. Community evenness did increase ($P<0.05$) in sagebrush fire sites one year after the fire event. *Formica* diversity remained unchanged comparing unburned and burned sites.

Table 4. Ecological parameters of *Formica* populations in YNP forested sites (avg/m2).

Parameter	Fire Disturbance		
	None	Fringe	Intense
Richness	0.89a	5.00b	1.22c
Density	1682.89a	125.00b	128.89b
Evenness	0.06a	0.93b	0.50c
Diversity	0.05s	0.65b	0.52b

*Means in the same row followed by the same letter are not significantly different at the 5% level of confidence, Duncan=s multiple range test.

Ant community similarities were analyzed among burned and unburned forest and sagebrush sites (Table 5). The forest ant community in intensively burned sites declined 77% as compared to unburned forest sites. A further decrease (91%) occurred in fringe burned forest sites. Sagebrush community similarities were not affected as much as in forest communities. There was only a 4% difference in community similarity of burned versus unburned sagebrush sites.

Forests and sagebrush habitats which were not inflicted with fire contained almost the same communities (Table 6). However, fire disturbance in both forest and sagebrush ant communities decreased similarities by 74%. Even lower community similarities occurred among burned sagebrush and fringe burned forest litter ant communities. Intensively and fringe burned forest ant communities contained only 8% of the community structure as opposed to that found in unburned sagebrush ant communities. The majority of ant species and community densities collected in pitfall traps were aphid herders and honeydew consumers. Only four ant species, three *Formica* and one *Aphaenogaster*, were found in all forest and sagebrush sites. Two of these species, *Formica subnuda* and *Formica subsericea*, are omnivores which would enable them to change to available food resources in disturbed sites. The species, *Formica oreas comptula*, also was found in all sites. This is a thatching ant which will herd aphids on sagebrush and lodgepole pines in various regions of the country (Wheeler and Wheeler 1986). Collections of this species in burned sites could indicate foraging parties from nearby unburned sagebrush or pine habitats. *Aphaenogaster subterranea* are carnivorous ants which would not require vegetation in order to survive in burned sites.

There were six species found only in forest habitats and two species found only in sagebrush habitats. Forest habitats contained five species of aphid herders and one predator. The predator, Manica hunteri, was a rare species (only two specimens were collected in pit traps). Ant species found only in forest sites would appear to be adapted to cooler, shaded sites as opposed to the two specimens found only in more open sites as found in sagebrush habitats. Also, the aphids, with which herders and honeydew collectors are correlated, may be specific to forest or sagebrush habitats. The only obligatory slaver, Polyergus breviceps, was found in forest sites with the highest community density located in fringed burn sites.

Table 5. Ecological parameters of *Formica* populations in YNP sagebrush habitats.

Parameter	Fire Disturbance		
	None	Fringe	Intense
Richness	2.33a	NA	1.00b
Density	760.00a	NA	199.33b
Evenness	0.06a	NA	0.13b
Diversity	0.05a	NA	0.06a

*Means in the same row followed by the same letter are not significantly different at the 5% level of confidence, Duncan's multiple range test.

Table 6. YNP ant population similarities (per m^2) in fire zones vs undisturbed sites.

Comparison		Percent Similarity
Forest	Undisturbed vs intense burn	23.45
	Undisturbed vs fringe burn	8.48
	Intense burn vs fringe burn	24.25
Sagebrush	Undisturbed vs intense burn	95.71
	Undisturbed vs undisturbed forest	90.24
	Undisturbed vs intense burned forest	6.45
	Undisturbed vs fringe forest burn	8.24
	Burned vs fringe burned forest	6.24
	Burned sagebrush vs intensively burned forest	7.27

ACKNOWLEDGMENTS

This study was supported in large measure by two grants (1989/1990) provided by the University of Wyoming/National Park Service (UWNPS) Research Center Research was conducted in Yellowstone National Park under auspices of Permit #01322. We express appreciation to the staff of UWNPS Research Center for providing research facilities, supplies and lodging during the two year study. Mr. Glen Stanley, a graduate student, monitored and collected the pit trap and litter samples which provide the basis for this study. We are grateful to Dr. Scott Shaw for constructive criticism of an earlier draft of this manuscript. We express appreciation to members of the University of Wyoming statistics department for their input in the data analysis. Thanks also go to

Dr. Jeffrey Lockwood for his input on the statistical treatment of data relating to the effect of the 1988 fires on the ant population. We also thank two outside reviewers Dr. Paul B. Kannowski and Dr. Steven W. Rissing for their comments, suggestions and corrections. Any errors are ours and not theirs.

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Received: February 26, 2010 *Accepted: November 11, 2010*