GROUND-DWELLING ARTHROPOD ASSOCIATION WITH COARSE WOODY DEBRIS FOLLOWING LONG-TERM DORMANT SEASON PRESCRIBED BURNING IN THE LONGLEAF PINE FLATWOODS OF NORTH FLORIDA

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ABSTRACT

A 5-year study of long-term (40 years) study plots was conducted on the Osceola National Forest in northern Florida to determine how dormant-season fire frequency (annual, biennial, quadrennial, or unburned) affects ground-dwelling macroarthropod use of coarse woody debris in longleaf pine (*Pinus palustris* Mill.) forests. Pitfall traps were used to sample arthropods near logs or metal drift fences of equal length. Samples were identified to genus or the lowest practical taxonomic level. Overall, significantly more arthropods and more arthropod biomass were captured near drift fences than near logs. Similarity of arthropods captured near logs or drift fences ranged from 64.4% in annually burned plots to 69.2% in quadrennially burned plots, with no significant differences noted. Likewise, Shannon diversity, evenness, richness, and number of rare genera were the same for traps regardless of the trap location. Interaction between fires and trap location were observed in 31 of 932 arthropod taxa. Of those, 10 taxa had significantly higher numbers captured in traps near logs in some burn treatments but there was no consistent pattern between log use and fire frequency. In most cases, more were captured in log pitfalls in frequently burned plots but that was not the case for at least 4 taxa. Where interactions between trap location and fire frequency were not significant, arthropods in an additional 101 taxa were captured in higher numbers at 1 trap location or the other. Of those, 73 were captured in higher numbers in pitfalls near drift fences and 28 were captured in higher numbers near logs. Results showed no increase in log usage by general or more mobile ground-dwelling arthropods as more frequent burning reduced the herbaceous and woody under story. However, logs were clearly important to a wide variety of arthropods regardless of burn frequency.

Key Words: prescribed burning, coarse woody debris, habitat heterogeneity

RESUMEN

Una investigación de 5 años usando parcelas de estudio de largo plazo (40 años) fue realizado en el Bosque Nacional de Osceola en el norte del estado de la Florida para determinar como la frecuencia de los incendios en la estación latente (anual, bienal, cuadrienal o no quemada) afecta el uso de los escombros leñosos en bosques del pino, *Pinus palustris* Mill. por los macroartropodos que viven en el suelo. Se usaron trampas de caída para muestrear los artrópodos cerca de troncos o de postes metálicos de retensión de una misma longitud. Las muestras fueron identificadas al nivel de género o al nivel taxonómico más práctico. Sobretodo, se capturaron significativamente mas artrópodos con un mayor cantidad de biomasa cerca de los postes metálicos que cerca de los troncos. La similitud de los artrópodos capturados cerca de los troncos y los postes metálicos varia de 64.4% en las parécelas quemadas anualmente a 69.2% en las parcelas quemadas cuadrienales (cada 4 años) sin diferencias significativas anotadas. Asimismo, la diversidad Shannon, la igualdad, riqueza y el número de géneros raros fueron los mismos en las trampas a pesar de la ubicación de la trampa. Se observaron la interacción entre los incendios y la ubicación de las trampas en 31 de los 932 taxa de artrópodos. De estos, 10 taxa tuvieron un mayor número capturados en trampas cerca de los troncos en algunos de los tratamientos quemados pero no hubo un patrón consistente entre el uso de los troncos y la frecuencia de los incendios. En la mayoría de los casos, se capturaron más en las trampas de caída puestas cerca de los troncos en las parcelas quemadas frecuentemente pero esto no fue el caso en por lo menos 4 taxa. Donde las interacciones entre la ubicación de la trampa y la frecuencia del incendio no fueron significativas, los artrópodos en 101 taxa adicionales fueron capturados en números más altos en la 1 ubicación de trampa o la otra. De estos, 73 fueron capturados en números mas altos en trampas de caída cerca de los postes metálicos y 28 fueron capturados en números mas altos cerca de los troncos. Los resultados mostraron ningún aumento en el uso de los troncos por los artrópodos generales o los más móviles que viven en el suelo mientras que la quemada mas fre-

cuente redujo la vegetación herbácea y leñosa en las plantas bajeras. Sin embargo, los troncos fueron claramente importantes a una amplia variedad de artrópodos a pesar de la frecuencia de la quema.

Large dead wood in terrestrial forest habitats is an important resource for a number of arthropods and other animals that use it for food, oviposition sites, protection from environmental extremes, and foraging habitat (Elton 1966; Harmon et al. 1986; Grove 2002). Within this habitat saproxylic arthropod communities vary with species of tree, stage of decomposition, types of fungal colonists, and location (aquatic to xeric) of dead wood in the landscape (Harmon et al. 1986; Speight 1989; Økland et al. 1996; Grove 2002). In addition to direct contribution to forest diversity, saproxylic arthropods are an important part of the food web supporting a variety of predators and parasites (Harmon et al. 1986). Considerable research on coarse woody debris and its function in forests has been done in North America but most of the emphasis has been in the Pacific Northwest and Canada (Harmon et al. 1986; Woldendorp et al. 2002). Within North America there is a large body of literature on the Scolytinae (Curculionidae: Coleoptera) and their associates but relatively little work on other saproxylic species or those that occur in later stages of decay (Savely 1939; Howden & Vogt 1951; Hammond et al. 2001, 2004), and less is known about how dead wood affects the distribution of arthropods that may be associated with it but not totally dependent on it (Irmler et al. 1996; Marra & Edmonds 1998; Andrew et al. 2000; Buddle 2001). Despite the growing interest in this topic, interactions between woody debris and arthropod communities in the Southeastern United States have received little attention (McMinn & Crossley 1996) and this is particularly true for longleaf pine (*Pinus palustris*) forests.

Longleaf pine once occupied about 30 million hectares in the Southeastern region of North America (Frost 1993). Today <1.3 million hectares remain as small, isolated parcels (Outcalt & Sheffield 1996) resulting in longleaf pine and associated communities being classified as the third most endangered ecosystem in the United States (Noss et al. 1995). Conservation and restoration of these communities is a priority for forest management and conservation groups throughout the region (Van Lear et al. 2005).

Prior to European arrival in North America, longleaf pine communities were maintained by frequent fires (1-3 year intervals) started by lightning or Native Americans (Landers 1991) but this is no longer the norm. An unanticipated result of reduced fire frequency is the increased accumulation of fuels which foster fires that are significantly more likely to damage both the environment and stand improvements, and pose a much greater threat to human health and safety (Oultcalt & Wade 2004). A number of remedies are available and, although prescribed burning is the only alternative that addresses the full suite of ecosystem components, other alternatives are commonly chosen to achieve short-term results (Van Lear et al. 2005). Even when fire is used, these remaining longleaf pine communities are often not managed under the appropriate fire regime (Brose & Wade 2002).

A number of studies and reviews have looked at effects of fire on arthropods but no clear general trends have emerged (Rice 1932; Heyward & Tissot 1936; Pearse 1943; Buffington 1967; Ahlgren 1974; Hurst 1971; Warren et al. 1987; Muona & Rutanen 1994; Buddle et al. 2000; Niwa & Peck 2002; Hanula & Wade 2003). However, despite the lack of a general trend, fire has a significant effect on many epigaeic arthropods and this is particularly true for the longleaf pine flatwoods ecosystem where it reduces diversity, community similarity and populations of many taxa (Hanula & Wade 2003). In addition to direct mortality, fire alters the forest habitat and community structure resulting in either positive or negative effects on a given species. For example, by reducing predators (spiders, centipedes, ground beetles, etc.) some species may experience population increases or, conversely, reductions in prey may reduce predator populations. Fire may also reduce food for detritivores (e.g., termites) and cover for other species. By removing refuges such as litter or low growing shrubs, fire may increase susceptibility to predation, temperature extremes or desiccation.

Elton (1966) recognized the importance of woody debris as a source of forest diversity and he noted that as wood decomposes it is increasingly colonized by generalists that do not require specific tree species or even depend on woody debris as their sole habitat. For example, Irmler et al. (1996) found that the increasing variety of wood-dwelling species as dead wood aged was due largely to immigration of litter dwelling species to dead wood and to species using dead wood for overwintering. Likewise, Cárcamo & Parkinson (1999) reported that decomposed coarse woody debris was a major factor in shaping ground beetle assemblages, and Evans et al. (2003) and Jabin et al. (2004) reported that proximity to logs was an important factor in shaping litter-dwelling invertebrate communities. These studies demonstrate the role dead wood can play in shaping epigaeic arthropod communities, which can in turn affect a variety of ecological processes (Evans et al. 2003; Jabin et al. 2004).

While planning a study on the long-term effects of frequent dormant-season burning on epigaeic arthropods (Hanula & Wade 2003) we hypothesized that the presence of coarse woody debris would be more important to these arthropods on annually burned plots where much of the leaf litter, understory vegetation and structure is sparse and has little time to recover between burns. To address this hypothesis, we conducted a study over a 5-year period to examine whether the presence of woody debris influenced pitfall trap captures under varying burn frequencies in a longleaf pine forest. In addition, we measured the amount of coarse woody debris and other habitat variables to determine how long-term frequent burning interacted with these variables to shape the epigaeic arthropod community.

Materials and Methods

Study Site and Prescribed Burn Treatments

The study was conducted in the Osceola National Forest in Baker County, Florida. Study plots were established in 1958 to examine effects of burning frequency on fuel reduction for wildfire prevention. At that time the overstory trees were 45-year-old longleaf pines that were 20 m tall and 29 cm diameter (DBH) with a few slash pine (*P. elliottii*) of similar size. The presence of remnant "boxed" longleaf pine trees from past turpentine operations suggest that the area was never cleared for agriculture. The understory consists of typical flatwoods vegetation dominated by saw palmetto (*Serenoa repens*), gallberry (*Ilex glabra*), *Vaccinium* sp. and wiregrass (*Aristida beyrichiana*). The study was a randomized complete block design consisting of 24, 0.8-ha plots arranged in 6 blocks of 4 treatments. Initial treatments were winter burns applied every 2, 4 or 6 years and unburned controls. However, in 1964 the 6-year interval treatment was replaced with annual winter burns. The entire site was burned in 1958 to initialize the study area, and treatments have been applied as scheduled since then between Dec and early Mar. Fire intensity varied from year to year depending on weather conditions, dead fine-fuel moisture content (which typically ranged from 7-20%), and firing techniques. Our study, superimposed on this long-term winter burn study, started in fall, 1994 just before the application of annual burns in the winter of 1994-1995. The study continued for the full cycle of burn treatments (annual, biennial, and quadrennial) ending after the quadrennial plots were again burned the winter of 1999-2000. Control plots had been unburned for 42 years at the close of our study.

We sampled the naturally occurring large dead wood on the plots in Dec 2003, three years after the study. Small dead wood was not affected by fire frequency on our plots (Hanula & Wade 2003), so it is unlikely that large dead wood was, and there was no evidence of increased tree mortality following our study so the delay in measuring this attribute did not result in significant changes in dead wood volumes between the time insects and dead wood were sampled. We estimated large dead wood volume by measuring the end diameters of all down woody debris in five 10-m wide transects which resulted in sampling approximately 50% of the plot surface. In addition, we conducted a 100% survey of standing dead wood. We used Huber's equation (volume = $m \times l$; where, m = mid-point cross-sectional area and l = length) to estimate volume of dead wood (Avery 1975). The mid-point diameter of downed wood was estimated by taking the average of the end diameters. The mid-point diameter of standing dead wood was estimated using taper equations for coastal plain longleaf pine (Clark et al. 1991).

Pre-burn live and dead plant biomass (dried) was estimated on each plot from eight 1-m^2 subplots. Details of sampling procedures for live and dead plant material can be found in Hanula & Wade (2003). Sampling methods were adapted from Shea et al. (1996). Two clusters of 8 transect lines were established in each plot. We ran 15 m long transects from the center of each cluster in the 4 cardinal directions and 4 additional 15-m long transects were established at 90° from the ends of the original transects. Sampling frames (1 m^2) were placed on the ground 4 m from the starting point of each transect. All stems <1.9 cm basal diameter were collected by category from each sample point, bagged, oven-dried at 42°C for a minimum of 48 h, and weighed. Plant biomass was separated into 11 categories consisting of (1) live palmetto, (2) dead palmetto, (3) live gallberry, (4) live pine needles (seedlings), (5) live grasses and forbs, (6) litter layer (O1 or L layer), (7) humus (O2 and O3 or F and H layers), (8) pine cones, (9) 0-0.6 cm dead branches, (10) 0.6-2.5 cm dead branches, and (11) other dead woody material.

Arthropod Sampling

We hypothesized that logs could function in two ways to increase trap captures of arthropods: (1) they could be a preferred habitat resulting in concentrations of arthropods around them, or (2) they could act as drift fences concentrating and directing arthropods normally wandering across the forest floor into traps near them. To determine if large dead wood was a preferred habitat or acted as a drift fence, we placed 3-m long logs of longleaf pine (20-25 cm diameter) in the center of each plot and installed pitfall traps along them immediately after felling. Four pitfall traps constructed from 480-mL capacity plastic cups (Hanula & Franzreb 1998) were installed near the log at plot center (2 on each side 0.5 m from each end)

TABLE 3. (CONTINUED) MEAN (±SE) NUMBER OF INDIVIDUALS OF ARTHROPOD TAXONOMIC GROUPS CAPTURED IN SIGNIFICANTLY ($P < 0.05$) HIGHER NUMBERS IN PITFALL TRAPS NEAR EITHER DRIFT FENCES OR LOGS PLACED IN STUDY PLOTS IN A LONGLEAF PINE FOREST IN NORTH FLORIDA UNDERGOING DIFFERENT CONTROLLED BURN FREQUENCIES, 1994-2000. ANALYSES OF VARIANCE WERE CONDUCTED BY SAS GLM PROCEDURE (SAS 1985).

			Drift Fence		Log		
Order	Family	Genus or Lowest Taxa	Mean	SE	Mean	SE	$P > F$
		Sphenophorus	4.1	0.6	1.5	0.4	<0.0001
Mecoptera	Panorpidae	*Panorpa*	6.9	1.5	3.7	0.9	0.009
Diptera	Tipulidae*		0.4	0.1	4.3	0.5	<0.0001
	Mycetophilidae	*Unidentified*[a]*	0.9	0.2	5.2	0.8	—
		Orfelia [a]	5.7	1.3	0.5	0.1	—
	Sciaridae		205.5	30.2	86.0	19.5	<0.0001
		*Bradysia**	0.3	0.1	2.6	1.0	0.04
		Corynoptera[a]	198.3	30.5	77.8	19.3	—
		Epidapus	5.2	1.0	0.6	0.3	<0.0001
		*Pseudosciara**	0.6	0.2	2.2	0.6	0.01
		Sciara[a]*	0.08	0.06	2.0	0.8	—
	Culicidae		6.5	1.0	1.8	0.4	0.0003
		Culex	6.1	0.9	1.2	0.3	0.0001
	Chironomidae*		0.6	0.2	2.8	0.9	0.03
	Empididae		1.1	0.2	3.8	1.2	0.04
		*Drapetis**	0.5	0.1	1.3	0.2	0.004
	Dolichopodidae*		11.4	1.3	25.3	1.7	<0.0001
		*Medetera**	6.8	1.0	19.8	1.8	<0.0001
	Phoridae	*Megaselia*	108.5	16.5	59.6	14.5	0.03
	Sphaeroceridae	*Leptocera*	14.5	4.6	3.7	1.0	0.03
Lepidoptera	Arctiidae	*larvae*	9.0	1.1	6.0	0.8	0.02
	Noctuidae	*larvae*	3.3	0.5	5.6	0.7	0.0009
Hymenoptera	Diapriidae		6.6	1.0	1.5	0.3	<0.0001
	Mutillidae		7.0	0.9	2.8	0.4	<0.0001
		Dasymutilla	2.7	0.5	0.5	0.2	0.0003
		Timulla	3.6	0.5	1.6	0.3	0.001
	Pompilidae	*Priocnemella*	1.8	0.3	0.5	0.1	0.0003
	Formicidae		978.7	75.3	764.4	37.5	0.02
		Formica	24.1	5.0	13.5	2.9	0.007
		Leptothorax	3.8	1.3	0.3	0.2	0.007
		Monomorium	4.5	1.7	0.9	0.5	0.04
		Odontomachus	364.8	33.8	339.0	33.9	0.05
		Pheidole	353.4	35.3	263.3	33.4	0.02

Asterisks (*) denote groups that were captured in higher numbers near logs.
Taxa followed by an "a" had a significant interaction of trap location with burn frequency.

near drift fences while 28 different arthropods were captured in higher numbers near logs. We plotted the numbers captured by year to see if there was evidence of depletion from pitfall trapping for a long period of time or competition between traps. Fig. 3 shows 6 examples of those plots. Four years of trapping did not affect the abundance of arthropods in the vicinity of our traps nor did we see evidence of declining trap captures in one trap type as the other increased.

DISCUSSION

Prescribed burning over a 40-year period significantly changed the understory vegetation and litter layer of the study plots (Hanula & Wade 2003; Glitzenstein et al. 2003). Despite reduced litter and less shrub cover on annually burned plots, we saw no increased use of logs as habitat by ground dwelling arthropods. Andrew et al. (2000) reported similar results for ants although they suggested that a few rare species may benefit from the presence of logs in areas where frequent low intensity fires are commonly used. We found community similarity, diversity, and richness were the same for the 2 trap locations regardless of the frequency of winter burning. Likewise, we saw no increase in overall arthropod abundance or biomass near logs but instead we captured more in traps near metal drift fences.

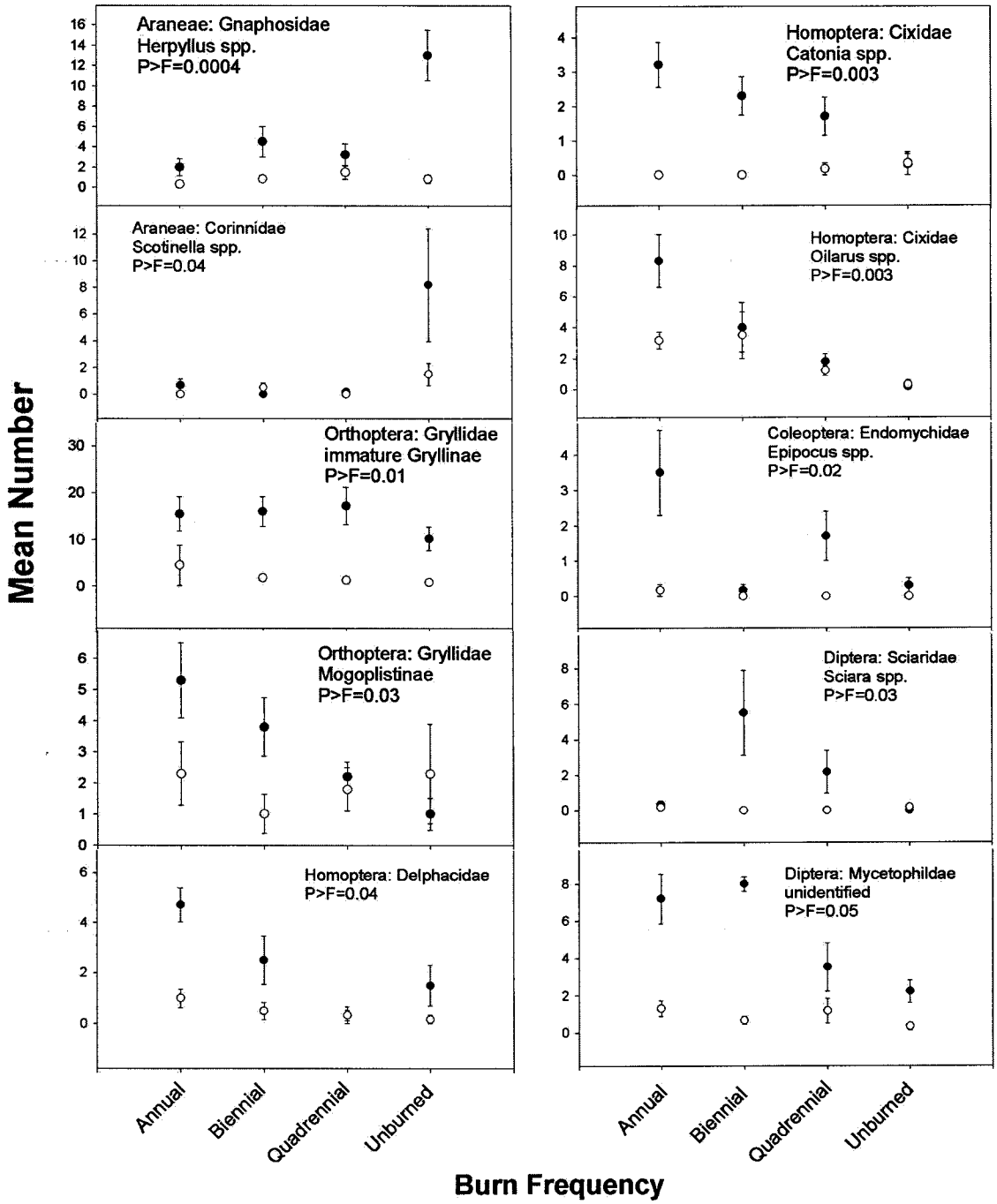

Fig. 1. Mean number (±SE) of individual arthropod taxa collected in pitfall traps near logs (●) or drift fences (○) between 1994 and 2000. Trapping occurred in study plots in a north Florida longleaf pine forest, undergoing different controlled burn frequencies. Graphs are for taxa in which fire frequency significantly affected trap captures and captures near logs were greater than those in traps near metal drift fences. Probabilities ($P > F$) are for the trap location × fire frequency interaction term in analyses of variance (Proc GLM, SAS 1987).

Habitat heterogeneity and structural diversity are considered important factors in determining community richness and diversity (Hutchinson 1959; Southwood et al. 1979; Tilman & Pacala

important for maintaining overall forest diversity (Elton 1966; McMinn & Crossley 1996; Braccia & Batzer 2001; Grove 2002; Grove & Hanula 2006). Experience in European forests demonstrates that without it a number of saproxylic species could go extinct or be reduced to critically low levels (Berg et al. 1994). We found that relatively few non-saproxylic macroarthropods were captured more frequently near logs even on plots where forest structure was greatly simplified by annual burning. Arthropod community structure might have been affected by the overall volume of logs on frequently burned plots but the effect was weak in comparison to the impact of fire frequency. Detailed studies are needed to clearly understand how deadwood contributes to the habitat needs of those species or groups found associated with it in longleaf pine communities.

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