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Macroarthropod response to time-since-fire in the longleaf pine ecosystem

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ABSTRACT

Fire is an important disturbance worldwide, and literature supports the use of prescribed fire to restore and maintain fire-dependent ecosystems. However, fire could alter the abundance and persistence of some arthropods, in turn influencing vertebrate taxa that depend on those arthropods as a food source. We used replicated prescribed fire treatments to evaluate macroarthropod response to time-since-fire in the fire-maintained longleaf pine (*Pinus palustris*) ecosystem. We sampled macroarthropod assemblages using vinyl gutter pitfall traps for 5 consecutive days in each month of the study (May-August 2014) in each replicate burn block. We identified macroarthropods to Order and dried and weighed the samples to determine biomass (g) of all taxa detected. We focused our analyses on 4 macroarthropod taxa important as food for wild turkey (*Meleagris gallopavo*): Araneae, Coleoptera, Hymenoptera, and Orthoptera. We used standard least squares regression to evaluate the effect of time-since-fire on total biomass of the 4 Orders (and we also evaluated those Orders independently). The analysis indicated that time-since-fire had no effect ($p = 0.2616$) on combined biomass of these 4 taxa. Analyzing the 4 Orders separately, biomass of Araneae ($p = 0.0057$) and Orthoptera ($p = 0.0004$) showed significant effects of time-since-fire, while Coleoptera ($p = 0.9465$) and Hymenoptera ($p = 0.1175$) did not. Parameter estimates (Araneae = 0.0084; SE = 0.0029; Orthoptera = 0.0137; SE = 0.0036) indicated that greater time-since-fire resulted in greater biomass for those 2 Orders. Overall, time-since-fire did not appear to have substantial effects on macroarthropod biomass. However, responses by Araneae and Orthoptera provided evidence that longer time-since-fire may result in greatest levels of biomass for some taxa. Our results indicate the use of frequent prescribed fire to restore and maintain longleaf forests is unlikely to pose risks to overall macroarthropod biomass, particularly if heterogeneity in fire frequency and spatial extent occurs on the landscape.

1. Introduction

Globally, fire is an important disturbance in many systems (Bowman et al., 2009), and literature supports the use of prescribed fire to restore and maintain fire-dependent ecosystems (Lashley et al., 2014b). Prescribed fire is used in the longleaf pine (*Pinus palustris*) ecosystem (LLPE) for restoration and maintenance of plant communities and fire-dependent fauna (Aschenbach et al., 2010; Beckage et al., 2005; Fill et al., 2012; Van Lear et al., 2005). It is well-documented that endangered red-cockaded woodpeckers (*Picoides borealis*) and Bachman's sparrow (*Aimophila aestivalis*; a species of management concern) respond favorably to frequent growing-season fire regimes that maintain needed structural requirements (Cantrell et al., 1995; Tucker et al., 2004). Similarly, important game species' responses to prescribed fire effects are well-understood (e.g., white-tailed deer [*Odocoileus virginianus*] space use [Lashley et al., 2015], wild turkey [*Meleagris gallopavo*] brooding cover [McCord et al., 2014]). However, little focus has been given to arthropod responses to fire in this ecosystem even

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though many young vertebrates, especially gamebirds (Healy, 1985; Hill, 1985; Palmer et al., 2001; Park et al., 2001) and songbirds (Duguay et al., 2000), forage on arthropods in the understory.

Whether in soils (Paoletti et al., 1991), streams (Cain et al., 1992), forests (Iglay et al., 2012; Pearce and Venier, 2006), or rangelands (Hoffmann, 2010), invertebrates have proven useful for understanding bottom-up trophic interactions (Loreau et al., 2001). Because most land birds, many mammals, and herpetofauna use invertebrates for food (Greenberg, 1995), invertebrates are suitable study organisms for evaluating management practices at local or landscape-scale (Arribas et al., 2012). Despite relatively few documented instances of extirpations, concerns about localized population extinctions (i.e., extirpation without natural recolonization) of arthropod species following fire are widespread (Swengel, 2001). Thus, more research is needed to elucidate invertebrate responses to prescribed fire, particularly in forested systems managed for vertebrate species of conservation or management concern.

Given the necessity for, and interest in, managing fire-maintained, open forest systems with prescribed fire (e.g., Lashley et al., 2014b), our goal was to contribute to the growing literature on invertebrate responses to fire. Swengel (2001) reviewed insect responses to fire in the context of managing open vegetation communities, but less is known about how time-since-fire affects invertebrates. Thus, we addressed this need by quantifying macroarthropod response to time-since-fire at Fort Bragg Military Installation, North Carolina, USA. Because restoration and management of the LLPE depends on mimicking historically frequent growing-season fire, understanding effects of the fire-return interval are needed. Knowledge of macroarthropod responses to prescribed fire may lead to better habitat management for those vertebrates that depend on them as food sources (Grodsky et al., 2015), particularly in systems where frequent growing-season fires are common. We sampled for macroarthropods and reported counts and biomass (g) of all taxa by treatment. We focused our analyses on 4 Orders (Araneae, Coleoptera, Hymenoptera, and Orthoptera) that are important foods of wild turkey (Hurst and Stringer, 1975; Healy, 1985; Iglay et al., 2005; McCord et al., 2014) and comprised the majority of the biomass in the study. We hypothesized that greater time-since-fire would correspond to greater available biomass of the 4 Orders.

2. Material and methods

2.1. Study area

We conducted our study at Fort Bragg Military Installation (Fort Bragg), which was owned by the U.S. Department of Defense and located in the Sandhills physiographic region of central North Carolina. Fort Bragg comprised 73,469 ha in the LLPE, and uplands were dominated by longleaf pine forests and managed with growing-season prescribed fire on a 3-yr fire-return interval (Lashley et al., 2014b). Fort Bragg defined growing-season as April-September and dormant-season as October-March. During our study, burn blocks averaged 43 ha (Lashley et al., 2015). Burn blocks missed during their targeted growing-season were burned in the following dormant season (usually December-March), which resulted in a small area of Fort Bragg (~15% during the study period) being burned greater than 3 years prior and during the dormant season (Lashley et al., 2015). Drainages were dominated by blackgum (*Nyssa sylvatica*), with a densely vegetated understory stratum composed primarily of *Lyonia* spp. and *Ilex* spp.; drainages burned infrequently because of moist conditions (Lashley et al., 2015).

2.2. Prescribed fire treatments

In 2013 and 2014, we applied 4 prescribed fire treatments to 12 burn blocks (i.e., 3 replicates in each treatment) with known burn history and similar overstory and understory structure (Fort Bragg Forestry Branch). The 4 treatments were: (1) 1yrG: previous growing-season fire (i.e., replicates burned growing-season 2013); (2) 0yrD: previous dormant-season fire (i.e., replicates burned dormant-season 2013–2014); (3) 0yrEarlyG: same year early growing-season fire (i.e., replicates burned April 2014); and 4) 0yrG: same year growing-season fire (i.e., replicates burned June-July 2014). The 3 blocks selected for "previous dormant-season fire" (Treatment 2) had been burned every year in December-February since 1985; these blocks were burned annually, but not during the growing season, due to proximity to anthropogenic structures. The 9 blocks selected for the 3 treatments associated with previous or same-year growing-season fire were burned every 3 years since Fort Bragg initiated the growing-season fire regime in 1989; all 9 blocks had at least 4 consecutive rotations where fires were set in May-June. For each replicate block, we calculated time-since-fire in months (range: 0–24), relative to macroarthropod sampling (all of which was conducted in 2014; see next section) and the month the block was burned during its treatment window (or in previous years). For example, if a replicate block from the 1yrG treatment was originally burned in May 2013, then time-since-fire at the May 2014 macroarthropod sampling would be 12 months and at the June 2014 sampling it would be 13 months. Similarly, if a replicate block from the 0yrG treatment was originally burned in May 2012, then time-since-fire at the May 2014 macroarthropod sampling would be 24 months; however, when the "same-year" burn occurred in June 2014 for this treatment, then time-since-fire at the June 2014 sampling would be 0 months and at the July 2014 sampling it would be 1 month.

2.3. Macroarthropod sampling

We sampled macroarthropod assemblages using gutter pitfall traps for 5 consecutive days in each month of the study (May-August 2014) in each replicate burn block (see previous section). We chose gutter traps (Pausch et al., 1979) over conventional circular pitfalls because of increased sampling area (length), which should improve resolution. Additionally, suction sampling can introduce bias by damaging invertebrate samples (Iglay et al., 2005). We randomly assigned the gutter locations; however, to avoid potential bias associated with edge effects or military traffic, we constrained the random points to be $\geq$50 m from firebreaks (i.e., the edge of the burn block). At each point, we buried 2 10-ft vinyl gutters (fitted with watertight end caps) flush with the ground, leveled them, and replaced the disturbed litter layer to avoid biasing the captures. We buried the gutters 10–30 m apart, with 1 oriented north-south and the other oriented east-west. We filled the gutters approximately half-full with water and added several drops of dishwashing detergent to break surface tension. We checked traps daily to make sure water levels did not get too low from evaporation or too high following rain events. We left gutters open day and night from the time of deployment until sampling was complete 5 days later. We acknowledge that pitfall trap features influence their efficiency at capturing arthropods (Luff, 1975) and that our use of gutter traps is biased toward mobile, ground-dwelling macroarthropods. We acknowledge that a single method cannot sample all taxa important to the diet of birds or other vertebrates; however, gutter traps effectively capture taxa available to ground-foraging species like wild turkey and allow for standardized comparisons among treatments.