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Quantifying multi-scale habitat use of woody biomass by southern toads

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ABSTRACT

Woody biomass extraction for use as a feedstock for renewable energy may remove woody debris that provides suitable micro-climates for amphibians. We examined habitat use of the southern toad (*Anaxyrus terrestris*) as an indicator of relationships between amphibians and woody biomass in pine plantations of the southeastern United States using a controlled enclosure experiment and a field-based radio-telemetry study. In the enclosure experiment, we recorded toad selection among four 16-m^2 treatments that varied in area of ground surface covered by coarse woody debris (CWD) and spatial allocation of CWD. Treatments were: (1) ≈100% of the ground area covered by CWD in one large pile (volume of CWD = 1.10 m^3, 100CWD); (2) ≈50% of the ground area covered with CWD in one large pile (volume of CWD = 0.60 m^3, 50PILE); (3) ≈50% of the ground area covered with CWD dispersed throughout the treatment (volume of CWD = 0.25 m^3, 50DISP); and (4) no CWD (0CWD). In the radio-telemetry study, we identified southern toad daytime refuge locations and compared habitat characteristics to paired random locations. From May to August 2013, toads ($n = 47$) did not use enclosure treatments randomly during nocturnal hours ($P < 0.01$), and ranking of treatments from most to least selected was 0CWD, 100CWD, 50DISP, 50PILE. When no rain events occurred, toads spent a greater proportion of time during nocturnal hours in 100CWD as temperature increased ($P = 0.03$). Toads used 100CWD 75% of the time for diurnal refuge. Radio-marked toads ($n = 37$) avoided grass ($P < 0.01$) and bare ground ($P < 0.01$) as diurnal refuge sites. Although radio-marked toads used CWD, other cover sources also were used as refuge sites and toads did not select CWD cover ($P = 0.11$) over other diurnal refuge types. Our results suggest woody biomass in recently harvested pine plantations is not an essential habitat characteristic during nocturnal hours and therefore may not be important for foraging. Yet, woody biomass may provide diurnal refuge for southern toads, and likely other amphibians, when desiccation risk is high (i.e., temperatures are high and rain does not occur). Additionally, southern toads may use woody biomass for diurnal refuge when other cover sources are not available, but can exhibit behavioral plasticity when cover sources such as vegetation are accessible.

1. Introduction

Habitat degradation is a major cause of amphibian declines (Delis et al., 1996; Davidson et al., 2002; Stuart et al., 2004; Becker et al., 2007; Harper et al., 2008). The National Wildlife Federation and the Southern Environmental Law Center suggested woody biomass extraction for use as a renewable energy feedstock could contribute to degradation of habitat for many wildlife species (Evans et al., 2013). Although woody biomass has been harvested for energy production for decades (Stuart et al., 1981; Watson et al., 1986; Puttock, 1987), operational harvests in southeastern United States pine plantations can decrease downed woody debris by ≈81% compared to sites with only a roundwood harvest (Fritts et al., 2014). Despite the benefits of replacing nonrenewable energy with woody biomass, reductions of downed woody debris following woody biomass harvests could alter ecosystem services and impact wildlife populations (Perschel et al., 2012; Evans et al., 2013).

Sustainability of woody biomass harvests is of particular importance in the southeastern United States, which is considered a "wood basket" and currently is the largest exporter of wood pellets

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in the world (Hanson et al., 2010; Evans et al., 2013; Goh et al., 2013). Growth of forest-based bioenergy production facilities is most rapid in the southeastern United States and use of woody biomass for power, heat, and liquid biofuels has been increasing in recent years (Mendell and Lang, 2012, REN21, 2013). However, this region is a global center of amphibian diversity (IUCN, 2013), and amphibians use downed woody debris for thermoregulation, protection from desiccation, reproduction, and as a feeding substrate (Jaeger, 1980; Hassinger, 1989; Whiles and Grubaugh, 1996; Butts and McComb, 2000). Previous studies in the southeastern United States have documented varying amphibian responses to experimental manipulations of downed woody debris (Owens et al., 2008; Davis et al., 2010; Homyack et al., 2013; Fritts, 2014), but conclusions often were based on relative abundance and species richness estimates from large-scale sampling studies. Although large-scale studies are useful, they often rely solely on count data and fail to identify individual-based behaviors that could better inform the mechanisms underlying population response (Schmidt, 2003; Muths et al., 2006). Individual movement behavior studies are particularly useful because results can be scaled up from the individual to the population level and can help predict amphibian habitat requirements (Lima and Zollner, 1996; Gibbs, 1998; Haddad, 1999; Graeter et al., 2008). Therefore, combining large-scale sampling to estimate abundance and species richness with fine-scale studies that identify underlying mechanisms responsible for population changes following a habitat disturbance can aid in developing sound management protocols.

Amphibians may indicate the ecological sustainability of woody biomass harvests because their physiology makes them particularly susceptible to forest disturbances and manipulations that alter forest-floor temperature and moisture regimes. As poikilothermic ectotherms, temperature affects nearly all physiological processes of amphibians (Gatten et al., 1992; Rome et al., 1992), including behavior and growth. Therefore, habitat selection can have direct physiological and functional consequences (Huey, 1991). Metabolism in ectotherms increases with environmental temperature and can account for more of the overall energy budget than the other components (i.e., growth, reproduction, and storage) combined (Pough, 1980; Spotila and Standora, 1985; Gatten et al., 1992). When surface temperatures are high, amphibians may decrease above-ground activities to avoid increased metabolic costs which could decrease energy available for growth or reproduction and consequently lead to population declines (Congdon et al., 1982). Further, amphibians risk desiccation because their skin does not prevent evaporative water loss (Jørgensen, 1997).

Thermoregulation coupled with the risk of desiccation may make downed woody debris particularly important to amphibians. Hence, amphibians often use downed woody debris, which provides micro-habitats in a range of temperature and moisture regimes, with the temperature under and inside woody refugia often lower than ambient (Graham, 1925; Whiles and Grubaugh, 1996; Butts and McComb, 2000; Kluber et al., 2009). Other than protection from desiccation and thermoregulation, amphibians use downed woody debris for reproduction and as a feeding substrate (Hassinger, 1989; Whiles and Grubaugh, 1996). Therefore, amphibian populations may be sensitive to reductions of downed woody debris associated with harvesting woody biomass.

We employed two methods to assess selection of downed woody debris by southern toads (*Anaxyrus terrestris*) in southeastern United States Coastal Plain loblolly pine (*Pinus taeda*) plantations following clearcut and woody biomass harvests: (1) a manipulative enclosure experiment that compared nocturnal habitat selection and diurnal refuge site selection among treatments with varying areas of ground covered by coarse woody debris (CWD; defined here as downed woody debris $\geqslant$ 7.62 cm in diameter for a length of at least 0.91 m; Woodall and Monleon, 2008) in different spatial allocations of CWD (i.e., piled or dispersed); and, (2) a radio-telemetry study that investigated diurnal microhabitat selection in relation to availability of downed woody debris. We used the southern toad as an indicator of amphibian response to woody biomass harvests because southern toads are less susceptible to forest canopy removal than other amphibians and, therefore, are among the most abundant species in regenerating clearcuts (Homyack et al., 2013; Fritts, 2014). Southern toads are capable of storing and reabsorbing large quantities of water in their bladders and tolerate higher temperatures and desiccation risks than other amphibians (Thorson and Svihla, 1943; Hillyard, 1999). Hence, southern toads have been used as a conservative metric for examining potential impacts of silviculture on amphibians (Todd and Rothermel, 2006). We also examined relationships between environmental variables (i.e., rainfall and temperature) and selection of downed woody debris to assess how climatic conditions may affect the importance of woody biomass to amphibians. We predicted that toads would select downed woody debris for nocturnal activity and for diurnal refuges in both the enclosure and radio telemetry experiments, particularly during hot and dry weather conditions. Further, we hypothesized that piled CWD would provide cooler microclimates than CWD dispersed evenly across the same amount of ground area and predicted that toads would select piled CWD over dispersed CWD.

2. Methods

2.1. Study area

We examined habitat selection of southern toads in a regenerating loblolly pine stand in the southeastern Coastal Plain Physiographic Region in Beaufort County, North Carolina. The project was part of a large-scale study to evaluate wildlife response to woody biomass harvesting. The radio-telemetry study was conducted on a 75.4-ha site that contained six woody biomass treatments each with varying volumes of retained downed woody debris (Fritts et al., 2014). The enclosure was located in the same regenerating stand, but outside of the aforementioned treatment boundaries. The stand was clearcut for roundwood and woody biomass and had treatment implementation winter 2010–2011. The site received two post-harvest herbicide applications with Chopper© (BASF Corporation, Research Triangle Park, North Carolina): a broadcast application year one post-harvest and a banded application year two post-harvest (i.e., after re-planting). Following clearcut and woody biomass harvests but before our study, the site was V-sheared to prepare a planting surface. The site was bedded and replanted fall 2011-winter 2012 (i.e., year two post-harvest and before sampling) at a density of ≈1100 trees/ha. Parallel drainage ditches occurred throughout the sites to improve pine growth and survival.

2.2. Data collection

2.2.1. Enclosure trials

We compared southern toad habitat selection among treatments with varying ground area coverage and spatial distributions of CWD using an enclosure experiment during May–August 2013. In 2012 (after bedding and planting), we constructed an 8-m × 8-m (i.e., 64 m^2) enclosure $\geqslant$ 50 m from the nearest ditch or road. We randomly assigned four 16-m^2 treatments to the four quadrants of the enclosure: (1) ≈100% of the ground surface area covered by CWD in one large pile (volume of CWD = 1.10 m^3, 100CWD); (2) ≈50% of the ground area covered with CWD in one large pile (volume of CWD = 0.60 m^3, 50PILE); (3) ≈50% of the ground area covered with CWD dispersed throughout the