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Shrew response to variable woody debris retention: Implications for sustainable forest bioenergy

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ABSTRACT

Shrews are integral components of forest food webs and may rely on downed woody debris to provide microhabitats that satisfy high moisture and metabolic requirements. However, woody biomass harvests glean downed woody debris to use as a bioenergy feedstock. Biomass Harvesting Guidelines (BHGs) provide guidance on the amount and distribution of downed woody debris retained after harvest to ensure ecological sustainability of woody biomass harvesting and limit detrimental effects on wildlife. However, the success of Biomass Harvesting Guidelines at reaching sustainability goals, including conservation of wildlife habitat, has not been tested in an operational setting. Thus, we compared shrew captures among six woody biomass harvesting treatments in pine plantations in North Carolina, USA from April to August 2011–2014 ($n = 4$) and Georgia, USA from April to August 2011–2013 ($n = 4$). Treatments included: (1) woody biomass harvest with no BHGs; (2) 15% retention with woody biomass dispersed; (3) 15% retention with woody biomass clustered; (4) 30% retention with woody biomass dispersed; (5) 30% retention with woody biomass clustered; and (6) no woody biomass harvested. We sampled shrews with drift fence arrays and compared relative abundance of shrews among treatments using analysis of variance. Additionally, we used general linear regression models to evaluate the influence of downed woody debris volume and vegetation structure on shrew capture success at each drift fence for species with >100 captures/state/year. In 53,690 trap nights, we had 1,712 shrew captures representing three species, *Cryptotis parva*, *Blarina carolinensis*, and *Sorex longirostris*. We did not detect consistent differences in shrew relative abundance among woody biomass harvest treatments, but relative abundance of all species increased over time as vegetation became established. In North Carolina, total shrew capture success was negatively related to volume of downed woody debris within 50 m of the drift fence array ($P = 0.05$) in 2013 and positively related to bare groundcover in 2013 ($P = 0.02$) and 2014 ($P < 0.01$). In Georgia, total shrew capture success was negatively related to herbaceous groundcover ($P < 0.01$) and leaf litter groundcover ($P = 0.02$) and positively related to woody vegetation groundcover ($P < 0.01$) and vertical vegetation structure ($P = 0.03$) in 2013. Our results suggest that shrews in our study area were associated more with vegetation characteristics than downed woody debris and that woody biomass harvests may have little influence on shrew abundances in the southeastern United States Coastal Plain.

1. Introduction

Shrews are key components of forest food webs and have been used as indicators of the ecological effects of forestry practices (Hamilton, 1941; Van Zyll de Jong, 1983; Carey and Harrington, 2001; Ford and Rodrigue, 2001; Matthews et al., 2009). Shrews have high nutritional and moisture requirements; therefore shrews may be sensitive to forestry practices that change forest

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floor microhabitats and microclimate (Chew, 1951; Getz, 1961; Churchfield, 1990; Matthews et al., 2009). Specifically, shrew presence and abundance have been linked positively with canopy cover, leaf litter depth and cover, and available downed woody debris (Carey and Johnson, 1995; Lee, 1995; Butts and McComb, 2000; Hartling and Silva, 2004; Greenberg et al., 2007).

Downed woody debris is an integral ecosystem component, providing cover and food for shrews and other wildlife (Harmon et al., 1986; Lattimore et al., 2009; Evans and Kelty, 2010; Janowiak and Webster, 2010; Riffell et al., 2011). For example, downed woody debris retains moisture and provides microhabitats in a range of temperature and moisture regimes, with the temperature under and inside of logs often lower than ambient (Graham, 1925; Jaeger, 1980; Kluber et al., 2009). The high metabolic rate of shrews leads to increased evaporative water loss and potential desiccation (Churchfield, 1990; Ochocińska and Taylor, 2005). Hence, shrews may be dependent on downed woody debris because they are sensitive to changes in environmental moisture (Getz, 1961).

The availability of downed woody debris, particularly coarse woody debris (debris $\geqslant$ 7.62 cm in diameter for a length of at least 0.914 m, Woodall and Monleon (2008)), has been shown to influence shrew presence and abundance in some regions of the United States, though relationships in other regions are equivocal. For example, population sizes of Trowbridge's shrew (*Sorex trowbridgii*) and montane shrew (*Sorex monticolus*) in the Pacific Northwest of the United States are positively associated with abundance of coarse woody debris (Carey and Johnson, 1995; Butts and McComb, 2000). In the southeastern United States Coastal Plain, some shrew species have positive relationships with decay state of woody debris cover and amount of log cover, whereas relationships between other shrew species and coarse woody debris are inconsistent (McCay and Komoroski, 2004; Cromer et al., 2007; Moseley et al., 2008; Davis et al., 2010). In southeastern United States pine forests, capture successes of southern short-tailed shrews (*Blarina carolinensis*) and southeastern shrews (*Sorex longirostris*) were greater in areas with abundant volumes of retained downed woody debris; yet, capture success of least shrews (*Cryptotis parva*) may not be associated with downed woody debris (Loeb, 1999; Moseley et al., 2008; Davis et al., 2010). Thus, the relationships between downed woody debris and shrews may vary based on forest type, geographic region, and shrew species.

Downed woody debris is gleaned as woody biomass, which is a major feedstock of bioenergy worldwide (Perlack et al., 2005; Hillring, 2006; Mantau et al., 2010). The southeastern United States is the largest exporter of wood pellets and is experiencing the most rapid growth of forest bioenergy production facilities in the world (Mendell and Lang, 2012; Goh et al., 2013). Domestic and foreign policies that encourage bioenergy production drive demand for forest bioenergy, which could involve increasing levels of woody biomass extraction with unknown effects on functionality and sustainability of forests in the southeastern United States (Evans et al., 2013). Further, demand for woody biomass is expected to continue to increase as renewable energy mandates are implemented in the European Union, which is supplied in great part by wood pellets produced from forests in the southeastern United States (Goh et al., 2013). Based on 2013 estimates, pellet production may increase by 87% in 2014 over the 2012 production level in the United States alone (Forisk Consulting, 2013). Woody biomass also is a feedstock of second generation biofuels, and the United States Department of Agriculture (USDA) predicts that approximately 50% of second generation biofuels needed to meet United States biofuel mandates will originate from the Southeast region by 2020 (USDA, 2010). Woody biomass harvests glean forest harvest residues, including treetops, limbs, slash, and felled small trees, generally in tandem with harvest of roundwood products. Although woody biomass has been harvested for energy production for decades (Stuart et al., 1981; Van Hook et al., 1982; Watson et al., 1986; Puttock, 1987), current levels of extraction decreased downed woody debris by up to 81% compared to sites without a woody biomass harvest in southeastern United States pine plantations (Fritts et al., in press).

Concerns about potential effects on wildlife habitat and other ecological consequences of harvesting woody biomass from decreasing volumes of downed woody debris have prompted the development of voluntary Biomass Harvesting Guideline (BHG) implementation by managers on operational forestlands (MFRC, 2007; Röser et al., 2008; PADCNR, 2008; KYDOF, 2011; Perschel et al., 2012). Because of the ecological value of downed woody debris for wildlife, nutrient cycling, and erosion control, Biomass Harvesting Guidelines typically focus on a target volume of woody biomass to be retained on the forest floor to maintain biological diversity and site productivity (Harmon and Hua, 1991; Ranius and Fahrig, 2006). Biomass Harvesting Guidelines have been created under the idea that "more" downed woody debris is better than "less," but minimum volumes and spatial arrangements of downed woody debris needed to sustain wildlife populations are not understood. Biomass Harvesting Guidelines often recommend retaining volumes of both coarse woody debris and fine woody debris (debris smaller than coarse woody debris) to meet sustainability goals; however, suggested volumes, sizes, and spatial arrangements of downed woody debris vary among Biomass Harvesting Guideline documents and have little empirical support. Thus, research is needed to determine the effects of woody biomass harvests and implementation of Biomass Harvesting Guidelines on sustainability, particularly for shrews and other wildlife species associated with downed woody debris.

Lack of consensus on associations between shrews and downed woody debris in the southeastern United States, coupled with an absence of operational-scale research on woody biomass harvesting, warrant investigation of shrew response to variations in downed woody debris retention following woody biomass harvests. Because dead wood decays relatively quickly in the Southeast (Moorman et al., 1999), the first 3–4 years post-harvest is the appropriate time to detect shrew responses. Our objectives were to: (1) evaluate the effects of different levels of woody biomass harvests on shrew relative abundance; and (2) quantify the relationships between shrew capture success and downed woody debris volume, vegetation structure, and vegetation composition.

2. Methods

2.1. Study area and design

We conducted our study on eight replicate clearcuts (i.e., unit of replication) in the Coastal Plain Physiographic Region of the southeastern United States: four in Beaufort County, North Carolina (-077°0′0″W to -076°53′50″W and 35°34′0″N to 35°38′20″N); three in Glynn County, Georgia (-081°44′40″W to -0.81°40′42″W and 31°07′31″N to 31°11′14″N); and one in Chatham County, Georgia (-081°11′26″W to -081°10′37″W and 32°18′46″N to 32°19′21″N), USA. All study sites were in intensively managed loblolly pine (*Pinus taeda*) plantations. North Carolina sites were managed for sawtimber production, had two commercial thinning entries before the final harvest, and were 32–39 years old at time of clearcut harvest. Georgia sites were managed for chip-and-saw and pulpwood production and were 25–33 years old at time of final harvest. Three Georgia sites had one commercial thinning entry and one site had two commercial thinning entries before clearcut harvest. North Carolina soils were predominately loam and silt loam. Georgia soils were predominantly loam, clay loam, and fine sandy loam.