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Importance of forestry practices relative to microhabitat and microclimate changes for juvenile pond-breeding amphibians

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ABSTRACT

Balancing the goals of forest management and species conservation is a major challenge. Forestry practices could be refined with greater understanding of the importance of large-scale forestry practices versus smaller-scale microhabitat and microclimate variables in driving demographic vital rates for species of conservation concern. We examined the relative importance of forestry practices, microhabitat, and microclimate on juvenile anuran survival and growth. To do so, we examined three different species: wood frogs (*Lithobates sylvaticus*), American toads (*Anaxyrus americanus*), and southern leopard frogs (*Lithobates sphenocephalus*), in three different years using terrestrial enclosures. Terrestrial enclosures were placed in forestry treatment plots with unharvested forest, partial cut forest, early successional forest (ESF; i.e. 4–6 year old clearcut) with downed wood removed, and ESF with downed wood retained in central Missouri, USA. We ranked models using an information-theoretic approach to determine whether forestry treatment, microhabitat (logs, canopy cover, leaf litter depth), or microclimate (temperature and soil moisture) best predicted juvenile survival and growth. We found that microhabitat and microclimate, but not forestry practices, were important for survival and growth. However, small sample sizes may have limited our ability to detect forestry treatment effects. Most associations with growth and survival involved microclimate variables. Effects of microhabitat showed positive associations of survival with canopy cover and downed wood and of growth with leaf litter depth. All effects varied by species/year and season, as is common for studies on the effects of forestry practices on amphibians, indicating that it would be useful to maintain a variety of different microhabitats and microclimates to support a diverse anuran community. Because juvenile survival is a population-regulating parameter for many amphibians, it may be prudent to focus on creating favorable microhabitats and microclimates within areas under active forest management. However, it would be useful to repeat this type of study in different ecoregions with different species to determine the generalizability of these results.

1. Introduction

Forestry management practices include a suite of techniques for timber harvest, wildfire risk reduction (Agee and Skinner, 2005), and ecological restoration (e.g., Bailey and Covington, 2002). One of the biggest challenges of these techniques is balancing the primary goals with the maintenance of biodiversity (Simberloff, 1999). Broad-scale meta-analyses show that forest thinning tends to have positive effects for biodiversity (Verschuyl et al., 2011), while others, like clearcuts, tend to have negative effects for at least some taxa or life stages (e.g. juvenile amphibians, deMaynadier and Hunter, 1995; Semlitsch et al., 2009). However, there is a large amount of variability in responses to different forestry practices. Some of this variability is explained by the region of study or the focal taxa, but much is also unexplained. One reason for this may be a lack of understanding of the underlying habitat and climatic changes responsible for biodiversity responses.

Forestry practices alter the habitat as a whole, but also affect microclimate (e.g., Carlson and Groot, 1997) and microhabitat features, such as leaf litter depth, shading, and coarse woody debris (Riffell et al., 2011). These factors are known to be very important for a variety of taxa (Riffell et al., 2011) and are likely the mechanisms responsible for many of the effects of different forestry practices (deMaynadier and Hunter, 1995). To refine management practices, it is important to know which of these factors are most important and whether the local micro-scale conditions or the forestry practices themselves have a greater predictive power for focal taxa response variables. With such knowledge, forestry

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practices could potentially be adjusted to minimize negative effects on biodiversity or be tailored based on other factors related to the region, topography or target species (Sutton et al., 2014).

Amphibians are strongly affected by forestry practices. Particularly, clearcutting reduces amphibian abundance (e.g., Patrick et al., 2006), survival (deMaynadier and Hunter, 1995; Semlitsch et al., 2009), and alters behavior (Semlitsch et al., 2008; Pittman and Semlitsch, 2013; Osbourn et al., 2014). Previous work shows that microhabitat changes from forestry practices are very important for overall amphibian capture rates (including both adults and juveniles; deMaynadier and Hunter, 1995), as well as juvenile amphibian survival and desiccation (Rittenhouse et al., 2008). Amphibian capture rates tend to have positive relationships with downed wood, leaf litter depth, canopy closure, and soil moisture (deMaynadier and Hunter, 1995). Amphibian physiological adaptations (e.g., permeable skin) make them vulnerable to water loss (Jørgensen, 1997). Many species require particular microclimates and microhabitats that minimize desiccation (Peterman et al., 2013; Peterman and Semlitsch, 2013). However, it is unclear whether these microscale factors or larger-scale changes in landuse have higher predictive power for amphibian performance, as this comparison has not been made in previous studies for survival or growth (but see Blomquist and Hunter, 2009, 2010 for an assessment of adult habitat selection).

In our study, the goal was to assess the importance of habitat-level forestry practices relative to micro-scale (i.e. meters squared) variables (microhabitat and microclimate) in predicting amphibian performance. We focused on juvenile amphibian survival and growth in *in situ* terrestrial enclosures as part of a habitat-scale (i.e. hectares) experiment to evaluate the effects of forestry practices on amphibians (Semlitsch et al., 2009). We focused on juveniles, because their survival rates are especially important for amphibian population dynamics (Biek et al., 2002; Vonesh and De la Cruz, 2002). Forestry practices included unharvested forest (control), partial cut forest, early successional forest (ESF; i.e. 4–6 year old clearcut) with downed wood removed, and ESF with downed wood retained. We predicted that forestry practices would be most important for survival (Semlitsch et al., 2009) and that micro-scale variables would be most important for growth.

2. Material and methods

2.1. Study system

Our study was conducted in central Missouri, USA at Daniel Boone Conservation Area (DBCA), Warren County. The terrestrial habitat is primarily natural, second-growth oak-hickory forest, and there are many permanent, constructed wildlife ponds that support several species of amphibians. DBCA is the site of experimental forestry plots constructed in late 2004 and early 2005 to investigate the effects of forestry practices on amphibians (Semlitsch et al., 2009). Briefly, the four, circular plots (164 m radius) had a small pond in the center, and the surrounding terrestrial area was divided into four quadrants (Fig. 1). Each quadrant received one of four forestry treatments: unharvested forest (control), partial cut forest (thinned to 60% stocking level by removing or girdling low quality trees), clearcut with downed wood removed (trees greater than 25 cm in diameter were removed and trees under 25 cm were girdled and left standing), and clearcut with downed wood retained (as in removed treatment except trees under 25 cm were felled). The two clearcuts were opposite each other in all plots (Semlitsch et al., 2009). Our study occurred during the 4–6 years after timber harvest, and the vegetation in former clearcuts had grown to be successional, shrubby vegetation (Earl and Semlitsch, 2013). Thus, we refer to the former clearcuts as early successional forest (ESF).

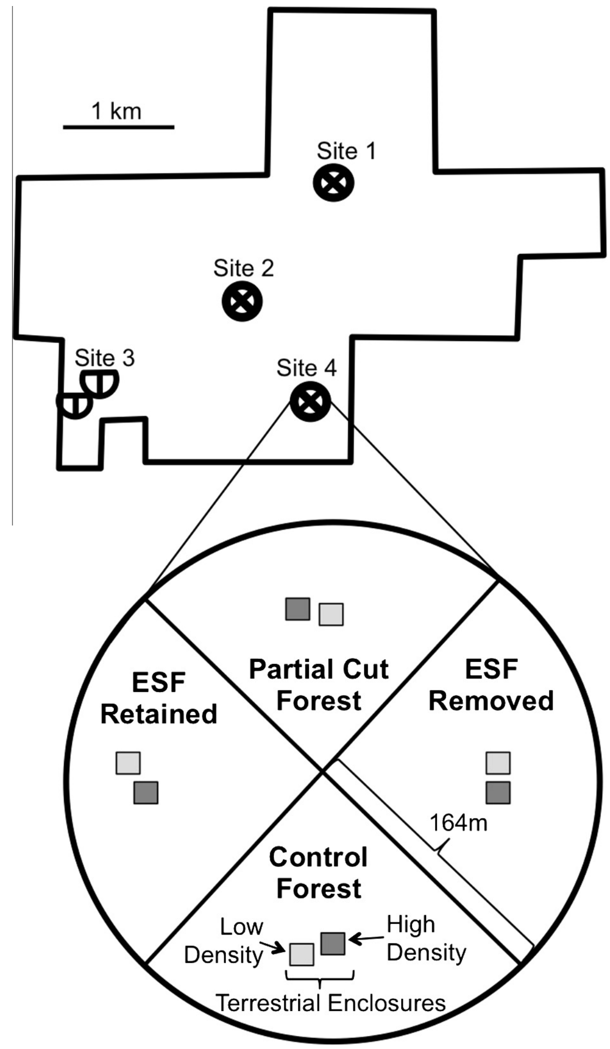

Fig. 1. Layout of circular, experimental forestry plots, forestry practice treatments, and terrestrial enclosures at Daniel Boone Conservation Area, Warren County, Missouri, USA. Note that terrestrial enclosures (3 m × 3 m) are not to scale, and site three consists of two half circles due to previous forest cutting nearby that prevented the placement of a full circular plot. ESF removed = Early Successional Forest (i.e. 4–6 year old clearcuts) with downed wood removed. ESF retained = ESF with downed wood retained.

We evaluated the impacts of long-term forest management on three anuran species in different years: wood frogs (*Lithobates sylvaticus*) in 2008/2009, American toads (*Anaxyrus americanus*) in 2009/2010, and southern leopard frogs (*Lithobates sphenocephalus*) in 2010/2011. These species were chosen, because they have large geographic ranges and are relatively common, potentially making our results relevant to areas beyond our study site. In Missouri, all species breed in ponds during spring (March, April). Wood frogs generally breed about one month earlier than the other two species. All three species have larval periods lasting several months, after which they metamorphose and emigrate to the adjacent terrestrial habitat during summer (Hocking et al., 2008). Wood frogs and American toads typically overwinter terrestrially (Green, 2005; Redmer and Trauth, 2005), whereas leopard frogs overwinter in permanent bodies of water (Butterfield et al., 2005).

2.2. Experimental design

To examine the importance of forestry practices, microhabitat and microclimate on juvenile survival and growth, we used *in situ* terrestrial enclosures within experimental forestry plots at