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Factors influencing herpetofaunal assemblages of aquatic systems in a managed pine forest

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ABSTRACT

Although >12 million ha of southeastern United States are intensively managed pine forest, we have little understanding of biological contributions of aquatic systems embedded in pine plantations. Further, the influence surrounding forest stand structure on assemblages of wetland-associated species in managed forests are poorly understood. To address these gaps, we investigated herpetofaunal assemblages across three ephemeral aquatic system types [unaltered sites (n = 16), altered sites (n = 18), and roadside ditches (n = 19)] embedded in an intensively managed pine landscape in eastern North Carolina, USA. These aquatic systems varied in their disturbance intensity and landscape context. Unaltered sites were avoided by silvicultural activities (set aside), altered sites were actively managed as part of the surrounding plantation, and ditches received maintenance as part of routine forest management. We examined amphibian and reptile species richness and assemblage composition at 53 aquatic sites surrounded by early-, middle-, or late-rotation aged pine plantations. During January–July 2013 and January–June 2014, we detected 34 amphibian and reptile species with visual encounter, dipnet, and call surveys at aquatic sites. We estimated species richness and used Analysis of Similarity to assess differences in species richness and assemblage structure by aquatic system type and stand age class. Amphibian species richness was greatest in unaltered and altered sites but was similar among stand age classes. Reptile species richness was similar among aquatic system types and stand age classes. Analysis of Similarity results revealed that amphibian assemblages were similar among stand age classes but were significantly different among all aquatic systems. Reptile assemblages also were similar among stand age classes but differed between altered sites and roadside ditches. Differences between richness and assemblage results may have been related to low detections of reptiles because our non-metric multi-dimensional scaling analysis, which only included species with >1 detection, revealed less obvious differences among reptile assemblages by aquatic system type. Despite dramatic variation in disturbance intensity and site-level environmental metrics, we did not find distinct herpetofaunal assemblages among aquatic system types or stand age classes. Our results suggest that aquatic systems in reconfigured landscapes not only support a range of herpetofaunal species, but that amphibian and reptile assemblages are similar across system types.

1. Introduction

Consideration of biodiversity is an integral component of sustainable forest management (Lindenmayer et al., 2000; Gardner, 2012). However, effects of forest management on biodiversity and the role of intensively managed plantations for wildlife habitat continue to be debated (Brockerhoff et al., 2008; Jones et al., 2010). Pine plantations in the southern United States are among the most intensively managed forests in the world. A typical silvicultural regime may include mechanical and chemical site preparation, fertilization, commercial thinning, clear-cut harvesting, and declining rotation lengths (Jokela et al., 2010). These silvicultural activities produce a landscape mosaic of forest patches varying in age and structural conditions, providing a range of habitat types that benefit many wildlife species (Wigley et al., 2000). Further, forest landowners often remove areas of ecological importance from intensive production, including aquatic habitat types, rare ecotypes, and riparian zones (Jones et al., 2010). The contributions of these managed forests to conserving biodiversity have been well described, including providing suitable habitat for imperiled species (Wigley et al., 2000; Hartley, 2002; Brockerhoff et al., 2008).

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Despite this, little is known about how managed forests contribute to shaping wetland associated herpetofaunal assemblages.

Habitat structure in intensively managed forest often is greatly altered from historical conditions, and in many areas of the Atlantic Coastal Plain, both aquatic and terrestrial features have been reconfigured to improve pine silviculture. For example, much of this region once was comprised of wet pine flats and pocosin wetlands. With human settlement and development, many wetland-dominated landscapes were ditched and drained to lower the water table to support forestry, agriculture, mining, and development (Cashin et al., 1992). As a result, managed landscapes often have extensive networks of interconnected roadside ditches that support amphibian and reptile occupancy (Fox et al., 2007; Homyack et al., 2014, 2016; O'Bryan et al., 2016), yet contributions of less altered aquatic habitat types to herpetofaunal assemblages are poorly understood.

Many amphibians and reptiles require aquatic habitats for all or a portion of their life history needs. Most amphibians depend on aquatic sites surrounded by adequate terrestrial habitat for breeding, larval development, and over-wintering. Semi-aquatic reptiles also depend on wetlands and the surrounding upland for foraging, nesting, hibernation sites, and other refugia (Burke and Gibbons, 1995). Small wetlands surrounded by uplands have important ecological roles for nutrient cycling and production of biomass and can have high species diversity and abundance of amphibians and reptiles (Russell et al., 2002; Semlitsch and Bodie, 2003; Gibbons et al., 2006).

Altered aquatic systems embedded in reconfigured managed forests can provide valuable habitat for amphibians and reptiles. For example, *Hyla* and *Pseudacris* were more abundant in harvested gaps relative to undisturbed bottomland wetlands (Cromer et al., 2002) and numerous herpetofaunal species used ditch systems in reconfigured landscapes (Mazerolle, 2004; Homyack et al., 2014, 2016; Johnson et al., 2016). Additionally, semi-aquatic turtles and snakes extensively use roadside ditches (Homyack et al., 2016) and small upland wetlands surrounded by managed forest (Russell et al., 2002). Forest management benefits some species by opening the canopy, which creates warmer microhabitats for reptiles and positively influences food and habitat quality for developing larval amphibians (Greenburg, 2001; Todd and Andrews, 2008; Hocking and Semlitsch, 2008; Skelly et al., 2014).

Although both amphibians and reptiles are associated with aquatic habitats and are vulnerable to habitat alteration, responses to habitat alteration can vary between taxa. For example, amphibians have permeable skin that causes greater sensitivity to chemicals and water loss relative to reptiles (Gibbons et al., 2000). Further, reptiles typically are more vagile and often make extensive movements, whereas some amphibians may travel <100 m over a lifetime (Semlitsch and Bodie, 2003). Despite the valuable roles amphibians and reptiles have in nutrient cycling and production of vertebrate biomass (Campbell and Campbell, 2001; Gibbons et al., 2006), we have little understanding of how forest management and aquatic systems embedded in reconfigured landscapes contribute to herpetofaunal assemblages (Cushman, 2006; Semlitsch et al., 2009).

Improved understanding of how aquatic systems in managed forests contribute to biodiversity is critical to meet sustainability objectives in addition to economic or silvicultural targets. Specifically, three broad categories of aquatic systems exist in many intensively forested landscapes. In order of increasing disturbance intensity, they include: (1) unaltered sites that are avoided during forest management activities, (2) altered sites that are managed in conjunction with the surrounding forest stand, and (3) roadside ditches that improve pine silviculture. These broad habitat categories contribute to different environmental conditions (Johnson et al., 2016), and we investigated how structural conditions alter amphibian and reptile assemblages within an intensively managed pine landscape in the Atlantic Coastal Plain of North Carolina, USA. Our objective was to assess and compare herpetofaunal species richness and assemblage composition as a function of aquatic system type, stand age class, and local-scale environmental metrics. We hypothesized that species richness would be greatest for both amphibians and reptiles in unaltered sites and sites surrounded by mid-successional (mid-rotation) stands. Unaltered sites receive fewer disturbances relative to other aquatic systems, and mid-successional stands were predicted to have intermediate effects of forest management relative to recently harvested stands and late-aged stands with greater canopy cover.

2. Materials and methods

2.1. Study area and aquatic systems

We conducted our study in an intensively managed forest landscape in the Coastal Plain of North Carolina (Fig. 1). Loblolly pine (*Pinus taeda*) plantation silviculture involved clear-cutting mature stands (25–35 years old), followed by mechanical (V-shearing and bedding) and chemical (banded or broadcast herbicide prescribed at the stand-level) site preparation, loblolly pine seedlings planted at approximately 1100 trees/ha, fertilization, and typically one commercial thinning entry (Homyack et al., 2014). Approximately 86% of the study area was pine plantations, and the remaining area was comprised of ecological or cultural areas removed from production including streamside management zones and forested wetlands. The landscape surrounding the study area was a mixture of forest, agriculture lands, and low-density residential housing.

We selected 16 unaltered sites (0.50 ha ± 0.16), 18 altered sites (0.20 ha ± 0.06), and 19 roadside ditches (0.05 ha ± 0.003) after examining GIS data and imagery (altered and unaltered sites) and local forestry records (roadside ditches) to identify potential sites. From this pool of potential sites, we visited sites in a random order to determine if wetland characteristics (e.g., aquatic vegetation, water) were present and excluded those that would be harvested during the study and or those <500 m from the nearest site. Additional details regarding site selection can be found in Johnson et al., 2016. Because ditches were continuous linear habitats, we randomly selected a point within the ditch and then sampled 75 m on either side of that point. Sites were also stratified based on the age of the surrounding planting. Early rotation stands (n = 18) were recently planted sites (2008–2013) with open canopies (mean age = 2.4 years, SE = 0.3). Mid-rotation stands (n = 17) were 15.5 yrs old on average (SE = 0.9 yrs), and late rotation stands (n = 18) were 28.1 yrs old (SE = 1.4 yrs). A previous analysis characterized environmental variation among the sampling sites evaluated in this study from the perspective of both aquatic system type and stand age class (Johnson et al., 2016). Unaltered sites (size range = 0.05–2.25 ha) were characterized as mostly fishless sites with high canopy cover and correspondingly little grass cover. These sites had an average hydroperiod that lasted approximately three-quarters of the spring and summer seasons. Altered sites (size range = 0.02–0.86 ha) are also mostly fishless but were shallower and had lower canopy cover than unaltered sites. As a result, grass cover was higher. These sites had an average hydroperiod that lasted two-thirds of the spring and summer seasons. Roadside ditches typically had a permanent hydroperiod, which facilitated the presence of fish at most of these sites. Canopy cover was lower relative to unaltered sites, and these sites had less cattail (*Typha* spp.) and cane (*Arundinaria gigantea*) than the other habitat types. The effect of stand age often varied depending upon the aquatic system, but in general the most pronounced effects were on vegetation. Older stands had less aquatic vegetation in non-ditch habitats. Additional