Forest Ecology and Management 361 (2016) 346–357

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Community occupancy of herpetofauna in roadside ditches in a managed pine landscape

Jessica A. Homyack [a,*], Christopher J. O'Bryan [b], Jamie E. Thornton [c], Robert F. Baldwin [b]

[a] Weyerhaeuser Company, 1785 Weyerhaeuser Road, Vanceboro, NC 28562, USA
[b] Department of Forestry and Environmental Conservation, Clemson University, 132 Lehotsky Hall, Clemson, SC 29634, USA
[c] Weyerhaeuser Company, 32901 Weyerhaeuser Way South, Federal Way, WA 98001, USA

ARTICLE INFO

Article history:
Received 26 August 2015
Received in revised form 17 November 2015
Accepted 21 November 2015
Available online 7 December 2015

Keywords:
Amphibian
Ditch
Occupancy
Plantation
Reptile
Road

ABSTRACT

Aquatic habitat types embedded in managed forest can contribute ecological services and suitable conditions for numerous species despite departing from historical baselines. Although prevalent in the Atlantic Coastal Plain, roadside ditches adjacent to pine plantations have had few surveys of vertebrate diversity and little is known about local and landscape level effects of silvicultural activities on species assemblages. Our goal was to investigate richness and occupancy of amphibians and reptiles in an intensively managed forest landscape with a history of silvicultural alterations of aquatic habitat types, including ditching, draining, and periodic maintenance of ditches for optimizing loblolly pine (*Pinus taeda*) growth. We selected 15 roadside ditches that were maintained 3–17 years earlier and were embedded in a matrix of pine plantations in eastern North Carolina, USA. We conducted repeated, visual encounter surveys of roadside ditches during 2012–2013 and detected 25 species of amphibians and reptiles 447 times including five species of statewide conservation concern. We used a Bayesian, hierarchical, community occupancy model with group-specific hyper-parameters to estimate occupancy probabilities and species richness while accounting for imperfect detection. With our model, we examined effects of time since ditch maintenance, amount of nearby mature forest, and amount of adjacent wetlands on species richness and occupancy. We predicted species would respond positively to an intermediate period of time since ditch maintenance and positively to landscape covariates related to mature forest and wetlands. Our model estimated species richness of anurans from 0.9 to 7.4 species/ditch segment, snakes and lizards from 0.8 to 9.0 species/ditch segment, and turtles from 0.9 to 5.1 species/ditch segment. Contrary to our predictions, occupancy of herpetofauna showed no evidence of a relationship to time since ditch maintenance, and landscape metrics only influenced occupancy of one turtle species. Detection probabilities were influenced by season for several anurans, snakes, and lizards, but not turtles. Our results indicate that aquatic habitat types embedded in managed forests that were hydrologically and structurally altered for silviculture can support local occupancy of a relatively diverse herpetofaunal community and that temporal proximity to ditch maintenance had little effect on occupancy or richness.

1. Introduction

Understanding how aquatic features in managed forest support a diverse fauna is necessary for land managers to meet requirements of third-party forest sustainability certification, for states to understand the status of species in their boundaries, for meeting other conservation goals, and for ensuring recent policy changes regarding water quality are supported by scientific information (North Carolina Wildlife Resources Commission, 2005; Rissman et al., 2007; Jones et al., 2010; Acuña et al., 2014; Loehle et al., 2014). Forested wetlands support both local and landscape biodiversity, including numerous habitat specialists and endemic species of amphibians and reptiles (Gibbs, 2000; Leibowitz, 2003). Previous research in managed forest indicates that riparian buffers, wetlands, and vernal pools can serve as centers of biodiversity with diverse herpetofaunal communities (Russell et al., 2002; Gibbons et al., 2006). Consequently, intensive hydrological alteration and wetland loss can negatively affect biodiversity disproportionate to area covered, particularly in forested systems (Gibbs, 1993; Lehtinen et al., 1999). Wetlands that are not converted to uplands, but with altered hydrological regimes from silviculture or other activities, may still support biodiversity and other ecological services, but have received little research

* Corresponding author.
E-mail address: Jessica.homyack@weyerhaeuser.com (J.A. Homyack).

http://dx.doi.org/10.1016/j.foreco.2015.11.037
0378-1127/

(Herzon and Helenius, 2008). For example, altered aquatic habitats can support wetland functions, but their influence on species richness and occupancy of herpetofauna, an understudied group of organisms, is not well-understood, particularly in the spatial and temporal context of forest and wetland management (Rheinhardt et al., 1997; Herzon and Helenius, 2008; Christoffel and Lepczyk, 2012; Adams et al., 2013).

The mechanisms influencing herpetofaunal assemblages in both natural and altered aquatic habitats are complex, but available evidence indicates that a combination of local and landscape scale factors structure communities (Werner et al., 2007; Birx-Raybuck et al., 2009; Brand and Snodgrass, 2010). In general, natural wetlands or other aquatic habitat types embedded in forest support greater richness of amphibians than those surrounded by other cover types (Brand and Snodgrass, 2010; Walls et al., 2014b). Forest may provide a more permeable and suitable matrix for herpetofauna than aquatic habitat types surrounded by urban or suburban landscapes with impervious road surfaces that can contribute to mortality of individuals, alter hydroperiods, and increase pollutants in wetlands (Gibbs and Shriver, 2005; Rubbo and Kiesecker, 2005; Beaudry et al., 2008; Brand and Snodgrass, 2010). Further, landscape configuration of aquatic habitat types influences metapopulation dynamics and persistence by providing opportunities for dispersal of juveniles and gene flow among populations (Gibbs, 1993; Cushman, 2006; Compton et al., 2007). Therefore, management of forested landscapes to maintain a diverse and dense assemblage of wetlands and aquatic habitat types optimizes connectivity and colonization for many species.

In millions of acres of low-relief ecosystems in the Southeastern United States, wetlands were altered by ditching and draining of wetlands, channelizing streams, and filling, which produced dryer uplands suitable for agriculture, forestry, mining, and development (Richardson, 1983). Historically, much of the Atlantic Coastal Plain was dominated by pocosin, wet pine (*Pinus* spp.) flats, and other wetland types (Richardson, 1983). By the 1980s, however, a large proportion (e.g., 41% in North Carolina) of the palustrine forested wetlands in the Atlantic Coastal Plain were altered to support agriculture and forestry, important contributors to the state economy (Cashin et al., 1992; Wear and Greis, 2013). Hydrological alterations accompanied conversion to pine plantations, and concomitant development of a system of ditches running parallel to forest roads and into forest stands, which improved ability for machinery to operate year-round and survival of planted pines (DeBell et al., 1982; Miwa et al., 2004).

Environmental regulations, such as the passage of the "Swampbuster" Provisions of the Food Security Act of 1987 provided disincentives for draining additional wetlands, but forest and agricultural landowners could maintain existing ditches and canals to their original configuration. Thus, as part of normal silvicultural practices in this region, ditches periodically are scoured with an excavator and spoils are deposited alongside ditches. Maintenance activities remove most aquatic vegetation and organic matter and disturb the area immediately adjacent to the ditch. Ditch maintenance is often conducted a few years prior to harvesting of adjacent stands, to ensure adequate drainage for regeneration of pines. Following ditch maintenance and with succession, herbaceous and woody vegetation reestablishes along and inside of ditches, shade increases, and ditches become shallower. Therefore, this intermittent disturbance creates a spatially and temporally dynamic mosaic of ditches in various successional stages across the landscape that may influence species that use these features (Herzon and Helenius, 2008).

Approximately half of North American amphibian and reptile species occur in the southeastern United States, including many endemics and species of conservation concern (Gibbons et al., 2000; Stuart et al., 2004; Jenkins et al., 2015). Thus, examining species richness and occupancy of herpetofauna in altered aquatic habitats of managed forests in the Atlantic Coastal Plain is necessary to fill an expansive data void and inform management decisions. We aimed to investigate species richness and examine influence of ditch maintenance and landscape characteristics describing mature forest and adjacent wetlands on occupancy of roadside ditches by of herpetofauna. We used a hierarchical Bayesian approach to multi-species occupancy modeling that accounted for detection, estimated the probability of occurrence for amphibians and reptiles at roadside ditches across a range of years following maintenance, and examined for effects of local and landscape descriptors. Habitat preferences of wetland-associated herpetofauna vary, but intermediate levels of canopy cover and aquatic vegetation may support feeding and reproduction of the greatest diversity of amphibians (Porej and Hetherington, 2005; Skelly et al., 2005, 2014), and may provide an optimal combination of foraging habitat and basking opportunities for reptiles (Blouin-Demers and Weatherhead, 2001). Thus, we predicted that species richness and site occupancy of herpetofauna in roadside ditches would be highest at an intermediate period of time since maintenance because this was when vegetation structure would be at intermediate levels. Further, we predicted that occupancy and species richness would be positively associated with amount of mature forest and adjacent wetland cover. This study complements previous research that examined patterns of use of roadside ditches by calling anurans (Homyack et al., 2014), and is the first study that we are aware of that examined a broad herpetofaunal assemblage.

2. Materials and methods

2.1. Study area

We examined herpetofaunal communities associated with roadside ditches in a large (≈24,000 ha) tract of relatively contiguous matrix of pine plantations located in the Atlantic Coastal Plain, eastern North Carolina, USA (Fig. 1). Weyerhaeuser Company owned and managed the tract primarily for loblolly pine (*Pinus taeda*) sawtimber production, and the surrounding area included agriculture, forest, and limited rural housing. The study area primarily was a matrix of pine plantations of various ages (86%) and also included streamside buffer zones, ephemeral pools, forested wetlands, and other land not cultivated due to ecological or cultural significance (Leonard et al., 2012). Silvicultural activities in pine plantations included mechanical (shearing of stumps and bedding to create a raised planting surface) and chemical site preparation (banded or broadcast herbicide prescribed at the stand level), planting of loblolly pine seedlings, fertilization, commercial thinning operations, and a final clearcut harvest at 25–35 years.

In the early 1900s, publically funded drainage districts and the Civilian Conservation Corps began developing a drainage system of parallel, drainage ditches entering stands and flowing into larger ditches running parallel to forest roads. Additional roads and ditches were constructed into the 1970s (Joseph H. Hughes, Weyerhaeuser, retired, personal communication). Because forest roads in the privately-owned study area were gated with limited access, relatively few vehicles traversed roads in the study area. The ≈735 km of roadside ditches flanking unimproved forest roads were disturbed by maintenance activities approximately every 25 years to return them to their original dimensions as part of normal forestry activities to support pine growth.

With existing georeferenced data, we were unable to randomly select ditch segments (study sites) from the landscape, so we used an approximate chronosequence approach to choose 15 roadside ditch segments based on time since maintenance. We defined