Forest Ecology and Management 334 (2014) 217–231

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Anuran assemblages associated with 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] School of Agricultural, Forest, and Environmental Sciences, 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 12 June 2014
Received in revised form 20 August 2014
Accepted 23 August 2014

Keywords:
Amphibian
Anuran
Ditch
Forest management
Occupancy
Plantation

ABSTRACT

Managed forests support a diverse assemblage of herpetofauna. However, less is known about how aquatic features embedded in intensively managed landscapes, particularly modified aquatic habitat types, influence biodiversity. Further, whether additional anthropogenic disturbances to modified aquatic habitats affect occupancy of amphibians has not been studied, but has important ramifications for ongoing policy debates regarding water quality regulations in the United States. We examined species diversity and occupancy of anuran assemblages in an intensively managed forest landscape with a history of ditching, draining, and periodic maintenance of ditches. During 2012–2013, we conducted repeated aural surveys for calling male frogs and toads across 16 roadside ditch segments that were maintained from 3 to 17 years earlier. Across 12 survey events, we detected 15 species of frogs and toads 555 times. We used a community occupancy model to estimate occupancy for multiple anurans and to examine associations between species occupancy for roadside ditches and the time since drainage ditch maintenance, amount of nearby mature forest cover, and metrics describing adjacent depressional wetlands. We predicted a quadratic relationship between both species richness and probability of occupancy for individual species with time since ditch maintenance because we hypothesized anurans would respond positively to intermediate vegetation structure and canopy cover when selecting calling and oviposition sites. Based on previous studies, we also predicted positive relationships between anuran occupancy and diversity with proportion of the surrounding landscape in mature forest or in depressional wetlands, and negative relationship with increasing distance to nearest wetland. Contrary to our prediction, we did not find evidence of a positive response (95% credible intervals included 0) by the community or individual species to time since ditch maintenance or the forest or wetland covariates, but we did observe a diverse assemblage of frogs and toads associated with roadside ditches in managed pine forest. Estimated richness ranged from 5.5 to 11.5 species/site and probabilities of occurrence ranged from 0.01 to 1.00 by species and site. Detection probabilities by species within a season ranged from 0 to 0.93 and were positively influenced by rainfall for several species and differed across months for many species. Our results indicate that reconfigured aquatic habitat types embedded in managed forests can support local and regional occupancy of anurans, but the current anuran community likely differs from what occurred historically.

1. Introduction

The contributions of intensively-managed forests to maintaining landscape-scale biodiversity are well documented. The matrix of forest of various ages interspersed with other land uses and unmanaged forest provide a wide range of structural conditions for wildlife (Hartley, 2002; Miller et al., 2009). Within managed forest landscapes, stands are adjacent to and intermixed with riparian buffers, wetlands, vernal pools and other unmanaged areas (Russell et al., 2002a; Jones et al., 2010; Leonard et al., 2012). These embedded natural aquatic features serve as centers of biodiversity for a myriad wildlife species that require aquatic habitat types to meet life history needs for foraging, breeding, or overwintering (Semlitsch and Bodie, 1998; Russell et al., 2002a; Gibbons et al., 2006). Among aquatic associates, amphibians may be particularly sensitive to habitat alteration because many species have a biphasic lifestyle that links them to composition and structure of aquatic habitat types for breeding and overwintering and surrounding uplands for other requirements (Semlitsch, 2003). Despite the extensive body of work describing relationships between herpetofauna and forest management (deMaynadier and

* Corresponding author. Tel.: +1 252 633 7525.
E-mail address: Jessica.homyack@weyerhaeuser.com (J.A. Homyack).

http://dx.doi.org/10.1016/j.foreco.2014.08.035
0378-1127/

Hunter, 1995; Semlitsch et al., 2009), as a taxonomic group, amphibians have been subjected to significantly less integrative research than birds or mammals (deStefano, 2002; Christoffel and Lepczyk, 2012). Numerous knowledge gaps regarding their status and relationships with forest management and other anthropogenic habitat alteration remain (deStefano, 2002). Further, large-scale monitoring in the United States has indicated declines in abundance or occupancy for amphibians, prompting concerns that amphibian declines may be occurring at a broader geographic scope and at a steeper rate than recognized previously (Walls et al., 2011; Adams et al., 2013). Although amphibian diversity is often greater in natural habitat types compared to those without anthropogenic alteration (Guerry and Hunter, 2002; Scott et al., 2008; Walls et al., 2014), a growing body of literature has recognized the value of human-altered wetlands for herpetofauna. For example, borrow pits and ponds and upland habitat types associated with golf courses and retention ponds provide basking, feeding, and reproductive habitat for aquatic turtles to meet life history needs (Harden et al., 2009; Glorioso et al., 2010). Additionally, both permanent and seasonal ponds on golf courses can support diverse amphibian communities, with fish-free ephemeral wetlands having the greatest number of species (Scott et al., 2008). Stormwater retention ponds in suburban developments can sustain occupancy and breeding of anurans despite catching pollutants and being embedded in fragmented landscapes (Birx-Raybuck et al., 2009; Brand and Snodgrass, 2009). Drainage ditches in peat mines provide movement corridors for anurans (Mazerolle, 2004). It is understood that landscape context surrounding wetlands influences occupancy (Kolozsvary and Swihart, 1999; Guerry and Hunter, 2002; Mazerolle et al., 2005), but most studies of altered aquatic habitats have occurred in suburban environments (but see Walls et al., 2014). Little information exists describing how reconfigured aquatic features in a primarily forested matrix support occupancy and species richness of herpetofauna.

The low-relief landscape of the Atlantic Coastal Plain experienced significant hydrologic modification during the 19th and 20th century via ditching, channelization of streams, and filling of wetlands primarily to support agriculture and development (Richardson, 1983; North Carolina Wildlife Resources Commission, 2005). Historically, this region was dominated by pocosin, wet pine (*Pinus* spp.) flats, and other wetland types, but prior to the "Swampbuster" Provisions of the Food Security Act of 1985, a substantial land area was drained by a network of parallel, linear ditches flowing into larger roadside ditches (Richardson, 1983; Rheinhardt et al., 1997). This ditch network reduced surface waters and lowered the water table to support agriculture and forestry operations, which continue to be economically important industries in the southeastern United States (Wear and Greis, 2013). Along with other improvements in silvicultural site preparation, the altered water table from ditching improved operability, provided opportunities for year-round harvesting, and increased survival of planted pines in managed forests (DeBell et al., 1982; Miwa et al., 2004). Although environmental regulations provided economic disincentives for draining additional wetlands for agricultural purposes, forest and agricultural landowners retained the ability to maintain existing ditches and canals to original dimensions. Ditch maintenance currently is integrated into the prevailing silviculture regime of many regions. Reconfiguration of wetlands, including ditching, and some silvicultural practices have been identified as contributing to wetland losses, particularly in the Atlantic Coastal Plain (Dahl and Stedman, 2013). Additionally, the U.S. Environmental Protection Agency (USEPA) has proposed a rule to clarify the definition of Waters of the U.S. under the Clean Water Act, which could incorporate many perennially flowing ditches as jurisdictional tributaries (United States Environmental Protection Agency, 2014). The USEPA proposed rule has ignited debate about potential effects of implementation and highlights the need for water quality policies to be supported by current science (Acuña et al., 2014; Loehle et al., 2014).

During maintenance of existing roadside ditches, operators scour bottom sediments with an excavator and deposit spoils alongside ditches. In this process, most aquatic vegetation and organic matter are removed and adjacent areas of upland habitat types are disturbed by heavy equipment and spoil piles. Thus, ditches and neighboring uplands provide a constantly changing matrix of aquatic systems of varying stages of vegetative succession across a landscape. Scouring of ditches for maintenance removes most aquatic vegetation so that amphibians initially may have limited availability of oviposition sites or foraging opportunities for larvae (Egan and Paton, 2004; Porej and Hetherington, 2005; Gorman and Haas, 2011) and may also alter important factors, such as available food resources or the invertebrate predator community (Werner et al., 2007). As vegetative succession occurs, roadside ditches become shallower and have increased shading from extensive woody vegetation, which may negatively affect some species of aquatic breeding amphibians (Skelly et al., 1999; 2014). Thus, there may be an intermediate period of time post-ditch maintenance with intermediate levels of vegetation that supports the greatest diversity of breeding anurans. Despite the prevalence of drainage systems on the Atlantic Coastal Plain, little is known about either the community composition of organisms associated with roadside ditches or influence of ditch maintenance activities on occupancy (North Carolina Wildlife Resources Commission, 2005).

A diverse assemblage of anurans occurs in the southeastern United States, including numerous species of toads, true frogs, treefrogs, small hylids, and a microhylid (Dorcas and Gibbons, 2008). These species vary in their dependency on aquatic habitats, but all require standing water for successful reproduction. Previous research has described positive effects of surrounding forest area (Knutson et al., 1999; Guerry and Hunter, 2002), which provides connectivity between breeding and terrestrial habitats (Semlitsch and Bodie, 2003), on amphibians. Amphibians can operate in a metapopulation structure, with individuals dispersing from wetlands and colonizing adjacent breeding sites, so that groupings of aquatic habitat types may facilitate population persistence (Marsh and Trenham, 2001; Compton et al., 2007; Semlitsch, 2008). To understand the contribution of roadside ditches to regional biodiversity in a managed forest landscape and whether periodic disturbance influences occupancy, we surveyed the anuran community in roadside ditches at various years since maintenance. Our goals were to investigate species richness of the anuran community and to evaluate effects of ditch maintenance and landscape characteristics describing mature forest cover and nearby wetlands on occupancy of managed roadside ditches by frogs and toads in a matrix of southern pine plantations in eastern North Carolina, USA. Using a hierarchical Bayesian approach to multi-species occupancy modeling that accounted for detection, we examined patterns of species richness and occupancy for both local-scale (time since ditch maintenance) and landscape-scale (proportion of mature forest, proportion of depressional wetland, distance to nearest depressional wetland) influences. We predicted that roadside ditches supported a diverse anuran community, that species richness would peak at an intermediate time since maintenance, and that area of mature forest and nearby wetlands surrounding sampling locations would be positively associated with both species occupancy and richness.

2. Materials and methods

2.1. Study area

We examined anuran occupancy of roadside ditches on a ≈24,000 ha tract of contiguous intensively-managed pine forest