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The effects of clearcuts and forest buffer size on post-breeding emigration of adult wood frogs (*Lithobates sylvaticus*)

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ABSTRACT

The establishment of terrestrial buffer zones around vernal pools has been recommended to provide upland habitat for pool-breeding amphibians in areas where forestry practices occur adjacent to breeding sites. However, few studies have empirically tested the effectiveness of buffers. We assessed post-breeding emigration behavior (net emigration distance, rate of movement, proportionate use of available habitats) of radio-tagged adult wood frogs (*Lithobates sylvaticus*) at nine vernal pools with experimental forest buffer treatments in central Maine, USA. Buffer treatments were either 30-m ($N = 3$) or 100-m ($N = 3$) forest buffers surrounded by a 100-m wide clearcut; pools surrounded by uncut forest served as reference sites ($N = 3$). We tracked 33 individuals in 2004 and 2005, for an average of 41 days, as they emigrated from breeding pools. Recently clearcut habitat was permeable to emigrating adult wood frogs, particularly females. A higher proportion of frogs at 30-m buffer sites than at 100-m buffer sites traveled through the clearcuts to reach intact forest beyond, suggesting that 30-m buffers may not provide sufficient upland habitat to support adult wood frog populations. There was high variability in emigration behavior among frogs, regardless of buffer treatment, and males and females tended to exhibit differential responses to different buffer sizes and to clearcut habitat. Although wood frogs in this study utilized both 30-m and 100-m forest buffers, variability between sexes and density-dependent effects could render small buffers (e.g., 30 m or less) inadequate to support these populations.

1. Introduction

Vernal pools are common throughout northern New England forest ecosystems and constitute vital habitat for several amphibian species (Gibbs, 1993). Amphibians utilize pools for breeding and larval development, yet most species spend the majority of their adult lives in the terrestrial environment (Berven, 1990; Hunter et al., 1999). The spatial arrangement of breeding sites within a matrix of suitable upland habitat permeable to amphibian movement is of critical importance to their survival (Dunning et al., 1992; Pope et al., 2000; Semlitsch and Bodie, 2003; Hocking and Semlitsch, 2007), particularly in landscapes subject to disturbance (Semlitsch et al., 2009). Current federal wetland regulations, however, do not protect these isolated wetlands or the adjacent upland habitat from land-use practices such as timber harvesting (Gibbons, 2003; Burne and Griffin, 2005). Protection of suitable terrestrial habitat through the use of forested buffer zones is integral to effective conservation of vernal pool-breeding amphibians (Calhoun and deMaynadier, 2004; Harper et al., 2008).

Intensive forest management can degrade terrestrial habitat by reducing amphibian microhabitat provided by leaf litter and coarse woody debris (McLeod and Gates, 1998; Semlitsch, 2000). Additionally, canopy removal by means of clearcutting eliminates shade, increases ground surface temperatures, and reduces soil moisture, thereby making such areas inhospitable or less suitable for many amphibian species (Semlitsch, 2000). Wood frogs (*Lithobates sylvaticus*) and spotted salamanders (*Ambystoma maculatum*) tend to be less abundant in clearcuts than in uncut forests (deMaynadier and Hunter, 1999) and clearcuts are associated with decreased juvenile survival for a number of amphibians (Patrick et al., 2006, 2008; Rothermel and Semlitsch, 2006; Todd and Rothermel, 2006).

The effects of clearcuts on amphibian movement are not well understood. The creation of open areas by timber harvesting can disrupt amphibian migration routes between breeding pools and upland habitat (deMaynadier and Hunter, 1995; Todd et al., 2009). Adult wood frogs have been found to travel hundreds of meters from breeding pools during post-breeding emigration, with maximum migration distances of approximately 395 m and

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340 m reported by Rittenhouse and Semlitsch (2007) and Baldwin et al. (2006), respectively. Because moving through open habitat increases the risk of desiccation and predation, forest clearcutting over a broad landscape area may significantly alter amphibian migration behavior (Rittenhouse and Semlitsch, 2009; Rittenhouse et al., 2009).

The short life span, high fecundity, and long migration distances of wood frogs make them especially sensitive to habitat loss and alteration (Harper et al., 2008). One method designed to protect important upland amphibian habitat surrounding vernal pools is the implementation of terrestrial buffer zones. Recommended buffer zone widths range from 30 to 290 m from the pool edge, and their efficacy has recently been tested through the use of simulation models. These models showed that regulations protecting 30 m or less of surrounding terrestrial habitat are inadequate to support viable populations of pool-breeding amphibians (Harper et al., 2008). To our knowledge, there has been no prior field experiment designed specifically to test whether wetland buffers provide sufficient protection for vernal pool-breeding amphibians, or to compare buffers of different widths. We conducted a large-scale field experiment with the following objectives: (1) to determine whether wood frogs will migrate through clearcuts; (2) to determine whether buffer size affects wood frog post-breeding emigration behavior (use of clearcuts, rate of movement, and emigration distance); and (3) to determine whether male and female wood frogs exhibit differential post-breeding emigration behavior.

2. Methods

2.1. Study site

This study was conducted on industrial forest land owned and managed by International Paper Company/Sustainable Forest Technologies, totaling 120,646 ha (289,552 acres) in Penobscot and Washington counties, Maine. Forests were mixed hemlock- (*Tsuga canadensis*) northern hardwood (*Fagus grandifolia*, *Acer saccharum*, *Betula alleghaniensis*), with a network of vernal pools and dirt access roads throughout.

2.2. Buffer width manipulations

To examine how post-breeding movement of wood frogs is influenced by forest buffer width surrounding vernal pools, we completely encircled nine vernal pools with drift fences. Study pools were selected based on several criteria. All vernal pools were: (1) initially surrounded by at least a 1000-m radius of relatively undisturbed forest (logging > 60 years ago); (2) similar in hydroperiod (holding water at least five months post ice-out the year prior to the study); and (3) between 0.1 and 0.3 ha (which is typical of vernal pools in the region) (Gibbs, 1993). Because of the complex landscape, we were not able to standardize the distance from our study pools to the nearest neighboring vernal pool or dirt road.

We randomly assigned pools to one of three treatments: reference (i.e., uncut treatment; $N = 3$), clearcut with 100-m buffer ($N = 3$), or clearcut with 30-m buffer ($N = 3$). Between September 2003 and March 2004, International Paper Company created experimental buffers by clearcutting forest (removed all merchantable trees ≥5 cm dbh) around specified vernal pools. Pools in the 30-m and 100-m buffer treatments had a 100-m wide concentric band of forest clearcut around the forest buffer zone (Fig. 1). Experimental buffer widths were based on the range provided by current recommendations (Semlitsch, 1998; Richter et al., 2001) and our 30-m buffer treatment is similar to more recent buffer recommendations for vernal pools (Calhoun and deMaynadier, 2004). We mapped vernal pool, buffer, and clearcut perimeters using a Trimble Pathfinder Pro XR GPS unit (Trimble Navigation Limited, Sunnyvale, CA; accurate to 0.5 m). Red pine (*Pinus resinosa*) and spruce (*Picea* spp.) were planted in the experimental clearcuts post-harvest.

Table 1
Number of adult female (F) and male (M) wood frogs radio-tracked at each buffer treatment ($N = 33$).

	2004		2005		Total
	F	M	F	M	F + M
Reference	2	2	5	1	10
100-m buffer	2	3	4	3	12
30-m buffer	3	2	6	0	11

2.3. Post-breeding movement

In April 2004 and April 2005, we collected adult wood frogs at drift fences as they emigrated from the nine study pools (Tables 1 and 2). Radiotransmitters (model BD-2; Holohil Systems Ltd., Carp, Ontario, Canada) with expected battery life of five weeks were externally attached to the frogs' waists using belts made of Teflon tubing (Bartelt and Peterson, 2000). The belt was positioned on the waist of the frog by sliding it over the extended hind legs. The transmitter-belt package was approximately 8% of the average frog mass (7.2 ± 0.9 g). The cotton thread used to hold the tubing together was susceptible to moist conditions and deteriorated over time, allowing unrecovered radios to fall off the frogs (Waye, 2001). Transmitter belts were attached in the field and frogs were handled as little as possible. Once the belt was attached, the frog was released approximately 2–3 m from the drift fence on the opposite side of the fence from the point where it was captured.

Our target tracking period was from spring post-breeding through summer; however, depredation and battery failure events resulted in reduced tracking times for some frogs (Table 2). We located each animal every other day from capture until termination using an Advanced Telemetry Systems Challenger 2000 receiver and a hand-held three-element Yagi antenna. Animals still being tracked after four weeks were captured and reoutfitted with new transmitters ($N = 13$). Frogs were checked for skin abrasions each week, and if present, a topical antibiotic/antiseptic (e.g., Bactine®) was applied to the skin. If severe abrasions were present, the transmitter was removed and the animal was released in order to prevent unnecessary injury or fatality ($N = 6$). When an individual was located, we determined its position by direct overhead localization (Madison, 1997), marked the location with a labeled flag, recorded the location using a Trimble Pathfinder Pro XR GPS, and subsequently plotted the location on a Geographic Information System map of the site. We categorized the location of each frog into one of three habitat types: buffer, clearcut, or forest (wooded area beyond the clearcut).

2.4. Data analysis

For each frog, we calculated the final straight-line distance from the breeding pool edge at the end of the tracking period (from pool edge to final location) using ArcViewGIS 3.3 (Environmental Systems Research Institute, Inc., Redlands, CA). This distance value (hereafter "net emigration distance") may not reflect the total distance traveled, including lateral movements and backtracking for example, but rather reflects the distance of the frog's final location from the breeding pond. We used the net distance value to calculate the mean rate of movement during the tracking period (meters per day). Because no individual frogs were tracked in both 2004 and 2005, and because preliminary analyses suggested no effect of year tracked ($P = 0.437$), for all subsequent analyses we combined data across years to increase error degrees of freedom.