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LOG DIAMETER INFLUENCES DETECTION OF EASTERN RED-BACKED SALAMANDERS *(PLETHODON CINEREUS)* IN HARVEST GAPS, BUT NOT IN CLOSED-CANOPY FOREST CONDITIONS

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Abstract.—**We tested for relationships between the size of coarse woody debris and its use by Eastern Red-backed Salamanders (*Plethodon cinereus*) in harvest-created gaps and closed-canopy forest of central Maine. Searches of 231 logs indicated that the probability of finding a salamander beneath small diameter logs was low in harvest-created gaps; whereas, the probability of finding a salamander was both higher overall and constant among log diameter sizes in closed-canopy forests. We did not detect a correlation between salamander length or mass and log diameter in either forest canopy condition. Our model shows the probablility of detecting salamanders under logs in harvest-created gaps is similar to the probability of detecting salamanders in closed-canopy forests if log diameter is approximately 35 cm. Forest harvesting practices that leave larger-sized residual woody material on the forest floor may mitigate the unfavorable habitat conditions for Red-backed Salamanders associated with reducing canopy cover.**

Key Words. —amphibians; coarse woody debris; habitat; harvesting; silviculture

INTRODUCTION

Coarse woody debris (CWD) is an important component of forest ecosystems, providing water storage, nutrient cycling, carbon storage, and habitat for many species (Harmon et al. 1986). The Eastern Red-backed Salamander (*Plethodon cinereus*) is a forest-dwelling, lungless salamander that requires microhabitats sufficiently moist for respiration, and uses logs for refuge, foraging areas, and nesting habitat (Heatwole 1962; Feder 1983; Petranka 1998). Essential surface activities, such as foraging and mating, may be restricted by hot, dry conditions. Because logs dry out much more slowly than the leaf litter layer of the forest floor (Heatwole 1962), they provide salamanders foraging opportunities and shelter to avoid desiccation during dry periods (Jaeger 1980). Young-of-the-year plethodontid salamanders are rarely encountered in leaf litter, but are associated with rotting logs in the soil. The presence of logs may be vital to young-of-the-year development (Wyman 2003). Openings in the forest canopy result in more variable temperature and moisture regimes on the forest floor (Chen et al. 1999), including dry conditions that potentially limit salamander activity (Jaeger 1980; Harpole and Haas 1999; Herbeck and Larsen 1999; Karraker and Welsh 2006; Reichenbach and Sattler 2007; but see Messere and Ducey 1998). Limited activity of salamanders presumably affects not only reproduction and recolonization, but also alters the nutrient cycling of the forest floor. As predators of leaf litter fragmenters, salamanders active in leaf litter indirectly lower the rate of leaf litter decomposition (Wyman 1997). Leaving residual material, such as CWD, scattered across the forest floor is a forest management practice that may facilitate the persistence or reestablishment of salamander activity after harvesting (deMaynadier and Hunter 1995).

Salamander abundance has been positively correlated to CWD volume and density (Mathis 1990; Petranka et al. 1994; deMaynadier and Hunter 1995; Morneault et al. 2004; McKenny et al. 2006). Size of CWD also has a role in providing habitat for Eastern Red-backed Salamanders, especially in disturbed, open-canopy areas. Mathis (1990) found a positive association between cover object (logs and rocks) size and body size of Eastern Red-backed Salamanders under broken canopy conditions, and higher occupancy rates of large cover objects than of small cover objects (pine boards). Larger salamanders are assumed to be more successful competitors for preferred resources, such as large cover objects.

However, Gabor (1995) assessed Eastern Red-backed Salamander populations in a closed canopy forest and did not find a relationship between cover object size (logs and rocks) and snout-vent-length (SVL) or mass. These studies suggest that forest canopy conditions influence the size of cover objects used by salamanders, which in turn may be related to salamander abundance and fitness, especially post-harvest. We assessed whether Eastern Red-backed Salamander (Fig. 1) detection and body size were related to CWD size under both open- and closed-canopy conditions. We expected

FIGURE 1. Eastern Red-backed Salamander (*Plethodon cinereus*) in the Penobscot Experimental Forest, Maine, USA. (Photographed by Carol Strojny.)

to detect more and larger salamanders under large logs than under small logs, and we expected this relationship to be stronger in harvest gaps where a relatively dry microenvironment made large logs more suitable than in closed-canopy forests where a small log might provide sufficient shelter.

MATERIALS AND METHODS

Our research took place in the Penobscot Experimental Forest of Penobscot County, Maine, which comprises 1,540 ha of predominately mixed coniferous-deciduous forest. The approximate coordinates for the center of this experimental area are 44˚ 50′ 9.66″ North and 68˚ 36′ 19.31″ West. We conducted our research in 30 ha of mature forest that included 22 harvested gaps (mean ± 1 SE = 1328 ± 113 m^2). Gaps were cut once between 1995-1997 and some trees (ranging from 4-25 m^2/ha of basal area) were left in each gap. Thus, the cutting represented a light partial harvest (an "irregular group shelterwood with reserves" in forestry terminology). The closed-canopy areas had a mean basal area of 32 m^2/ha (Schofield 2003).

We used log searches to determine if Eastern Red-backed Salamander distribution was affected by CWD size in harvest gap or closed-canopy areas (sites in the same stand as the gaps, but at least 30 m from any gaps). In closed-canopy areas, we walked marked transect lines that formed a 50 m grid system within the forest management areas. We searched beneath logs that were within 10 m of either side of the transect line. There were 15 closed-canopy transects totaling 1200 m (transect length range of 30-100 m). In gap areas, we walked north-south transects that passed through the gap center. There were 22 gap transects totaling 844 m (transect length range of 25–80 m). We sampled for a total of 15 days in June and July of 2003. Because the number of salamanders found under logs increases as the leaf litter dries (Heatwole 1962; Jaeger 1980), we waited at least 24 hours after a rainfall event that moistened the forest litter before searching for salamanders. Large logs were relatively less available within our research area (Fraver et al. 2002). To balance sampling units (logs) across the range of log diameters, we randomly selected one log every 6 m along the transects in the following order of priority: large logs (>31 cm diameter), medium logs (21-30 cm), and small logs (10-20 cm). We categorized logs by their large-end diameter. Sampled logs had at least 0.5 m of their length resting on the ground, a minimum diameter of 10 cm, and belonged to decay class II or III (Maser et al. 1979). When a suitable log was identified, it was rolled or lifted. Two people searched for salamanders beneath the log and in the organic horizon (approximately 7 cm depth) directly below the log. We measured salamander snout-vent length (SVL) and total length using a metric ruler and mass (± 0.01g) using a digital platform field scale.

We tested for a difference in proportion of logs with Eastern Red-backed Salamanders between harvest-created gaps and closed-canopy areas using a Chi-square goodness of fit test, with the proportions observed in the closed-canopies as expected values. Logistic regression was used to estimate the probability of detecting an Eastern Red-backed Salamander as log diameter increased under both canopy conditions. We used the predictive variables of log diameter, habitat type (gap or closed-canopy), and an interaction term (log diameter x habitat type) for the logistic model. Spearman Rank Correlations were applied to examine the relationship between mass or SVL of salamanders to log diameter. Because previous capture rates of Eastern Red-backed Salamanders in the area from a concurrent study were lower than expected (Strojny 2004), combined with a limited area and log population, an alpha value of 0.10 was selected instead of 0.05 to improve detection of an inequality of proportions between our two treatments, if one exists.

RESULTS

We completed two to four transects, each ranging from 25 m to 100 m, each sampling day, balancing the length of harvest-created gap transects with closed-canopy transects. Total sampling area was approximately 2 ha of harvest-created gap (22 gaps) and 3 ha of closed-canopy forest. To achieve a similar number of logs searched in both conditions, we searched more area in closed-canopy forest because log density was lower. We detected Eastern Red-backed Salamanders more frequently under logs in closed-canopy forests (45 of 116 logs) than in harvest gaps (16 of 115 logs) ($X^2 \geq$

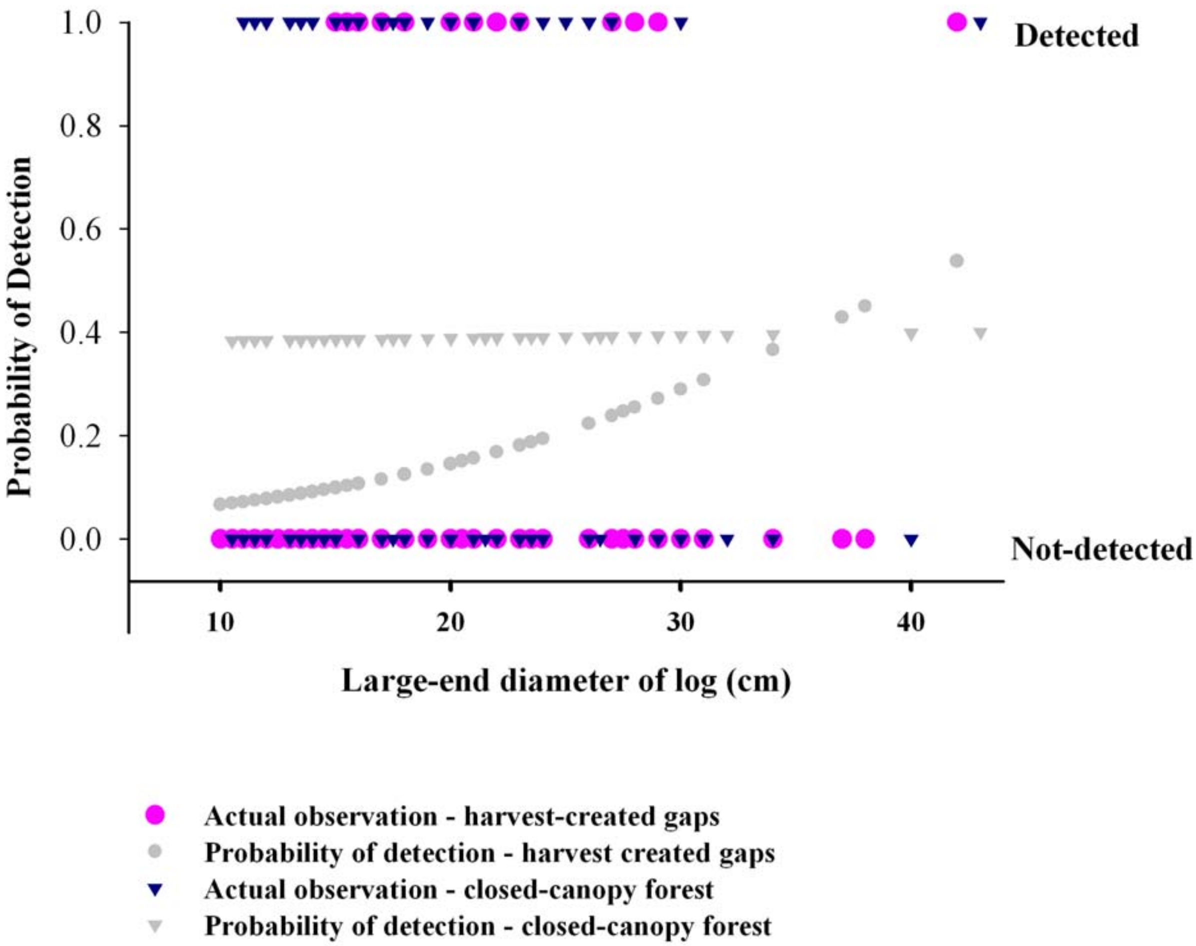

FIGURE 2. Logistic regression function based on the observations of logs found with Eastern Red-backed Salamanders in harvested gaps (16 of 115 logs) and closed-canopy areas (45 of 116 logs) related to log size (diameter).

30.70, df = 1, $P < 0.001$). Our logistic model showed a significant effect for log diameter ($P = 0.017$), habitat type ($P = 0.003$), the interaction between log diameter and habitat type ($P = 0.073$), and the overall model likelihood-ratio test ($P = 0.000$). Detection probability was related to log diameter in the harvest-created gaps, but not in the closed canopy. In harvest-created gaps, salamander detection probability increased with log diameter (Fig. 2). The predictive ability of the model was relatively weak, with an overall correct prediction rate of 64.8%. We did not find correlations between SVL and log size ($P = 0.80$, df = 1,16 in harvest gaps, and $P = 0.54$, df = 1,43 in closed-canopy forests) or mass and log size ($P = 0.35$, df = 1,16 in harvest gaps, and $P = 0.60$, df = 1,43 in closed-canopy forests).

DISCUSSION

The probability of detecting Eastern Red-backed Salamanders under logs was related to both canopy condition and log size. In closed-canopy areas, observations of salamanders were higher overall and constant across log size. In harvest gaps, the probability of finding a salamander was lower than that of closed-canopy areas until log diameter was 35 cm. In harvest-gaps no salamanders were found beneath logs with diameters $\leq$ 15 cm. Consistent with our model, Mathis (1990) observed higher occupancy rates of large cover objects than small cover objects by Eastern Red-backed Salamanders in broken-canopy conditions. We did not find evidence to support a correlation between size of log and body size (length or mass) of salamanders. This lack of a relationship between log size and salamander body size in both gap and closed-canopy conditions was similar to the results of Gabor (1995; research conducted in closed-canopy conditions in Virginia), but different from Mathis (1990; research conducted in broken-canopy, natural forest conditions in Virginia). Because open-canopy conditions limit forest floor moisture more than closed-canopy conditions do, we expected larger logs to be more ‘in demand,’ and thus occupied by larger salamanders. Considerations that may explain why our observations differ from those of Mathis include if forest floor conditions were more moist in Maine (present study) or if lower salamander population size (present study) reduced demand. Research by Moore et al. (2001) suggest that seasonality might be a factor; they found a positive relationship between cover-object size and Red-backed Salamander body size in the fall, but not spring or summer. The robustness of our model was restricted by the limited number of larger logs in the forest and the low number of observations within gaps. Also, by using an alpha level of 0.10 instead of the conventional 0.05 level, our model may have falsely identified a significant interaction between log size and canopy type. Because coarse woody material surveys in this experimental forest show that large-diameter logs are limited (Fraver et al. 2002), more study should be done to explore this relationship. Manipulative experiments with placement of large cover objects would strengthen the predictability of our model, and further clarify any relationship between salamander body size and log sizes in open and closed-canopy forest.

Leaving residual material such as down wood and snags can have an influential role in post-disturbance forest development by allowing organisms to persist in disturbed areas or facilitating their re-colonization (Franklin et al. 1997, 2000; Spence 2001). The ability of downed wood to retain moisture in dry summer months (Maser et al. 1988; Fraver et al. 2002) is of ecological importance to animals that depend on moisture. In our study, Eastern Red-backed Salalmanders were infrequently detected under smaller diameter logs in the harvested gaps, suggesting that smaller diameter logs do not provide adequate habitat. However, larger logs, which were relatively scarce, did show a higher probablility of sheltering a salamander in harvested gaps. Large logs persist longer and provide more area than smaller logs (McComb and Lindenmayer 1999), and may increase the survival rate of salamanders by reducing movement, water loss, and exposure to predators (Moseley et al. 2004). Furthermore, given changes in climate patterns and other disturbances such as invasive earthworms reducing available leaf litter (Bohlen et al. 2004; Hale et al. 2005), downed wood may have an increasingly important role in habitat structure. The total quantity of post-harvest CWD is one measure of residual material, but forest managers should also take into account the ecological value of retaining larger diameter (>35 cm) classes of downed wood.

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