The Relative Abundance of Eastern Red-backed Salamanders in Eastern Hemlock-dominated and Mixed Deciduous Forests at Harvard Forest

Brooks Mathewson*

Abstract - In anticipation of the loss of *Tsuga canadensis* (Eastern Hemlock) dominated forests due to infestation by *Adelges tsugae* (Hemlock Woolly Adelgid), this study assessed the relative abundance of the ecologically important terrestrial salamander, *Plethodon cinereus* Green (Eastern Red-backed Salamander), in five Eastern Hemlock-dominated stands and four mixed deciduous stands at Harvard Forest in Petersham, MA. Pooling data from four seasons (fall 2003–fall 2004; excluding winter), the relative abundance of *P. cinereus* as measured by the monitoring of artificial cover objects (ACOs) was significantly higher in Eastern Hemlock-dominated stands than in mixed deciduous stands (n = 444 *P. cinereus* observations). The relative abundance of *P. cinereus* was not significantly different in the two forest types as measured by natural cover object (NCO) searches over two seasons (fall 2003 and spring 2004), although sample sizes were small (n = 45 *P. cinereus* observations). This evidence that Eastern Hemlock-dominated forests provide equal or greater quality habitat for *P. cinereus* as mixed deciduous forests at Harvard Forest contrasts with studies from other areas of Eastern Hemlock's range, which have found the abundance of *P. cinereus* to be lower in this forest type. The conversion of Eastern Hemlock-dominated forest to mixed deciduous forest will have either have a negative impact or no impact on the relative abundance of *P. cinereus* at Harvard Forest.

Introduction

Plethodon cinereus Green (Eastern Red-backed Salamander), though small and not often seen, are a critical component of forest ecosystems (Burton and Likens 1975a). At Hubbard Brook Experimental Forest in Coos County, NH, terrestrial salamander biomass, of which *P. cinereus* accounts for 93.5%, is equivalent to that of small mammals and twice that of birds (Burton and Likens 1975a). *Plethodon cinereus* are ecologically important as both predator and prey (Welsh and Droege 2001). As predators of soil invertebrates that are important leaf fragmenters, *P. cinereus* potentially decrease litter decomposition rates, thereby decreasing the rate of CO_2 emission into the atmosphere (Burton and Likens 1975a, Hairston 1987, Wyman 1998). The prey of *P. cinereus* (by percentage of overall weight) include larval two-winged flies (23.7%), larval beetles (13.8%), adult beetles (8.5%), spiders (6.9%), and adult two-winged flies (6.5%) (Burton 1976). Sixty percent of the soil fauna consumed by *P. cinereus* is converted into new high-protein tissue, resulting in more annual tissue production than that of both birds and small mammals (Burton and Likens 1975b). Organisms that prey on salamanders include

*Harvard Forest, Harvard University, Petersham, MA 01366; bgmathewson@aol.com.

birds, such as *Catharus guttatus* Pallas (Hermit Thrush; Coker 1931), *Turdus migratorius* L. (American Robin; Fenster and Fenster 1996), and *Meleagris gallopavo* L. (Wild Turkey; Eaton 1992), and snakes, such as *Thamnophis sirtalis* L. (Garter Snake; Arnold 1982) and *Diadophis punctatus* L. (Ringneck Snake; Uhler et al. 1939).

In the past century, a number of dominant trees including *Castanea dentata* (Marsh.) Borkh. (American Chestnut), *Ulmus americana* L. (American Elm), and *Fagus grandifolia* Ehrh. (American Beech)have suffered severe declines in northeastern forests due to exotic pests and pathogens, yet the ecological impacts of these losses is largely unknown (Orwig 2002). *Tsuga canadensis* L. (Eastern Hemlock) is now another dominant tree species threatened throughout its range (McClure 1995, Orwig and Foster 1998). Since its arrival in Virginia in the 1950s, *Adelges tsugae* Annand (Hemlock Woolly Adelgid [HWA]) has been spreading along the east coast of North America and is now present in fifty percent of stands containing Eastern Hemlock in central Massachusetts (Orwig and Povak 2004). HWA causes mortality in Eastern Hemlock of all age classes within 4–10 years of infestation (Orwig and Foster 1998). Some sites in Connecticut, where HWA was first documented in 1985, have as high as 95% mortality (Orwig and Foster 1998). Eastern Hemlock-dominated stands in Southern New England are being replaced by mixed deciduous stands comprised of *Betula lenta* L. (Black Birch), *Acer rubrum* L. (Red Maple), and *Quercus rubra* L. (Red Oak) (Orwig and Foster 1998).

Eastern Hemlock-dominated stands are structurally very different from mixed deciduous stands and consequently provide much different habitat for wildlife (Orwig and Foster 1998, Yamasaki et al. 2000). Eastern Hemlocks retain their lower branches, and forests dominated by this species have dense canopies limiting the amount of solar radiation penetration and resulting in little understory and herbaceous vegetation (Benzinger 1994a, Rogers 1980). Low levels of sunlight reaching the forest floor creates a darker and cooler microenvironment in Eastern Hemlock-dominated forests, and the soils in these forests are generally moister (Benzinger 1994a). In addition, soils in these forests have low pH and low levels of available "nitrate" nitrogen, both because Eastern Hemlock can thrive in these conditions, and because the needles of this species are acidic and have low nutrient content (Benzinger 1994a).

Ninety-six avian species and forty-seven mammalian species use Eastern Hemlock-dominated forests, but little is known regarding amphibian abundance in this forest type (Orwig and Foster 1998, Yamasaki et al. 2000). In Eastern Hemlock-dominated forests in Connecticut, *Dendroica virens* Gmelin (Black-throated Green Warbler), *Dendroica fuscus* Müller (Blackburnian Warbler), and Hermit Thrush are strongly associated with Eastern Hemlock-dominated forests during the breeding season, and the loss of Eastern Hemlock may lead to local extirpations of Black-throated Green Warbler (Tingley et al. 2002). Other bird species closely associated with this forest type include *Accipiter gentiles* L. (Northern Goshawk) and *Vireo solitarius* Wilson (Solitary Vireo) (Benzinger 1994b). *Odocoileus virgianus*

Zimmermann (White-tailed Deer) is also associated with Eastern Hemlock-dominated forests, especially in the winter when snow depth is less than in mixed deciduous forests (Yamasaki et al. 2000). The ant assemblages in Eastern Hemlock-dominated forests in Connecticut and Massachusetts are different from those in mixed deciduous forests in that the ant genus *Formica* is absent (Ellison et al. 2005). The avian brood parasite, *Molothrus ater* Wagler (Brown-headed Cowbird), is another ecologically important species that is absent in Eastern Hemlock-dominated forests (Tingley et al. 2002). Only one study, conducted in Albany County, NY, has assessed the relative abundance of *P. cinereus* in Eastern Hemlock-dominated stands (Wyman and Jancola 1992). In this study, the relative abundance of *P. cinereus* was lower in Eastern Hemlock-dominated stands than in stands dominated by American Beech, due to low soil pH (Wyman and Jancola 1992).

The first objective of my study was to compare the relative abundance of *P. cinereus* in Eastern Hemlock-dominated stands not infested with HWA and in mixed deciduous stands in anticipation of the future introduction of this invasive pest. My initial hypothesis was that the relative abundance of *P. cinereus* would be lower in Eastern Hemlock-dominated stands than in mixed deciduous stands, because of low soil pH. The second objective was to establish baseline data on the abundance of *P. cinereus* at Harvard Forest for use in assessing future changes in the relative abundance of this species. Finally, the third objective was to test for differences in the two forest types in two environmental variables–soil temperature and soil pH–which impact the distribution of *P. cinereus* (Heatwole 1962, Wyman and Jancola 1992).

Methods

Study sites

Five sites, within 15 km of each other and containing one Eastern Hemlock-dominated stand and one mixed deciduous stand separated by no more than 500 meters, were selected from four tracts of the Harvard Forest: Prospect Hill, Tom Swamp, Slab City, and Simes (2 sites) (Table 1). All stands are second-growth forest between 50–120 years old (Foster 1992). Sites in the Prospect Hill, Tom Swamp, and Slab City tracts were chosen using qualitative tree species composition data from the Harvard Forest Archives (Foster 1992). All Eastern Hemlock-dominated stands at these sites were qualitatively assessed in the field to be at least greater than 50% Eastern Hemlock. Quantitative tree species composition data for the two sites in the Simes tract was collected in 2005 (A. Barker-Plotkin, Harvard Forest, Petersham, MA, unpubl. data). Sixty-five percent of the total basal area in the Eastern Hemlock-dominated stands at the first Simes site was comprised of Eastern Hemlock. At the second Simes site, Eastern Hemlock accounted for 62% of total basal area. Data from the mixed deciduous stand at Tom Swamp were omitted from all analyses, as approximately 60% of the overstory basal area was removed in 1998. The abundance of *P. cinereus* has been found to be impacted by all types of forest harvesting, including selective harvesting (Harpole and Haas 1999).

Salamander sampling

Two sampling methods, both conducted by the author, were used to measure the relative abundance of *P. cinereus*. The first method was the installation and monitoring of artificial cover objects (ACOs). ACO stations, installed in the second and third weeks of September 2003, consistied of one cover board (1 m x 0.25 m x 2 cm green, untreated, rough-cut Eastern Hemlock board) and one asphalt shingle (1 m x 0.25 m) placed 3 meters apart, parallel to one another. Two materials were chosen for ACOs in order to compare observation rates under the two types. A coin toss was used to determine whether to place the shingle or the board to the left or right of each transect. Two ACO stations were installed 50 m apart along 2–6 transects in each stand, depending on stand size. The layout of transects varied depending on the shape of the stand. The latitude and longitude of all ACO stations was determined using GPS and recorded (Table 1). ACOs in both stands at a site were sampled an equal number of times and on the same day. The choice of which stand to sample first at a site was chosen randomly, as was the order in which to sample the sites. ACOs were monitored in fall 2003 (n = 3–6), spring 2004 (n = 5), summer 2004 (n = 3–4), and fall 2004 (n = 2). The interval between monitoring efforts was roughly two weeks, and never

Table 1. Description of study stands. Listed species comprise 75% or more of stands' basal area. FT indicates forest type (EH = Eastern Hemlock dominated; MD = mixed deciduous). Species codes are as follows: TSCA = *Tsuga canadensis* (Eastern Hemlock), PIST = *Pinus strobus* (Eastern White Pine), QUVE = *Quercus velutina* Lam. (Black Oak), QURU = *Quercus rubra* (Northern Red Oak), BEPO = *Betula populifolia* Marsh. (Gray Birch), ACRU = *Acer rubrum* (Red Maple), BELE = *Betula lenta* (Black Birch), and QUAL = *Quercus alba* L. (White Oak). AS indicates the number of artificial cover object (ACO) stations (each consisting of one cover board and one asphalt shingle) in each stand. CB reports the average number of *Plethodon cinereus* (Eastern Red-backed Salamander) observed per cover boards over four seasons (Fall 2003–Fall 2004 excluding winter). CS reports the average number of Eastern Red-backed Salamanders observed per cover shingles over four seasons (Fall 2003–Fall 2004 excluding winter). NCO reports the average number of Eastern Red-backed Salamanders observed per square meter during searches of natural cover objects. In each stand, forty 1-m^2 quadrats were searched over two seasons (Fall 2003 and Spring 2004).

Site	FT	Species composition	Size (ha)	Latitude	Longitude	AS	CB	CS	NCO
Prospect Hill	EH	TSCA–PIST	1.0	42°32.372'	72°10.750'	4	0.45	0.34	0.18
	MD	QUVE–QURU–BEPO	1.0	42°32.441'	72°10.819'	4	0.25	0.07	0.10
Slab City	EH	TSCA–QURU–PIST- ACRU	0.5	42°27.192'	72°10.197'	6	0.36	0.23	0.08
	MD	QURU–ACRU–BELE–TSCA	0.4	42°27.076'	72°10.098'	4	0.20	0.21	0.13
Simes 1	EH	TSCA–QURU	3.0	42°28.313'	72°13.025'	12	0.39	0.25	0.10
	MD	BELE–QURU–ACRU	1.0	42°27.956'	72°13.075'	4	0.18	0.13	0.20
Simes 2	EH	TSCA–BELE	3.0	42°28.511'	72°12.782'	12	0.41	0.16	0.10
	MD	PIST–BELE–QURU	1.0	42°28.758'	72°12.688'	4	0.25	0.19	0.08
Tom Swamp	EH	TSCA–PIST–ACRU	1.0	42°30.400'	72°12.886'	6	0.36	0.13	0.08

more frequent than weekly, other than one sampling round in fall 2003 which included sampling efforts that were within five days of the previous effort. Marsh and Goicocchea (2003) found no decrease in counts in weekly sampling efforts versus sampling which occurred every three weeks.

The second method used to sample *P. cinereus* involved searches of natural cover objects (NCOs). Twenty 1-m^2 quadrats at randomly selected points along the same transects that were used to establish ACO monitoring stations were sampled in each stand in both fall 2003 (the last week of September 2003 and the first week of October 2003) and spring 2004 (the third week of April 2004, second week of May 2004, and second week in June 2004). On all sampling days, an equal number of quadrats were searched in Eastern Hemlock-dominated and mixed deciduous stands at each site, except at one site (Simes 2) in fall 2003, in which different forest types were searched on successive days. In each quadrat, *P. cinereus* was searched for by the author within the leaf litter and under stones and coarse woody debris (CWD) for two minutes. After each search, NCOs were restored as closely as possible to their original positions.

Environmental sampling

Five soil samples were taken at random points along each transect from the organic layer of each stand just below the leaf litter, resulting in 10–30 samples per stand. A Thermo Orion model 290 pH meter (± 0.005) was used to measure the pH of a slurry of 2.0 g soil and 20 ml deionized water (Hendershot et al. 1993). Remote temperature sensors (1-Wire Thermochron iButtons, ± 1 °C) were placed on the surface of the soil in the center of each transect and were set to record temperature every half hour in spring 2004 (4/22/04–6/7/04) and every hour in fall 2004 (9/22/04–11/12/04).

Statistical analysis

Measurements from all seasons were collapsed into one average for the abundance of *P. cinereus* in each stand for both methods. ANOVA assumptions were tested on the following response variables: the abundance of *P. cinereus* as measured by monitoring of ACOs, the abundance of *P. cinereus* as measured by searches of NCOs, soil pH, and average daily low and high temperatures in spring 2004 (4/22/04–6/7/04) and fall 2004 (9/22/04–11/12/04). All assumptions of ANOVA were met for tests of abundance of *P. cinereus* as measured by ACO monitoring. However, the assumption that the samples were identically distributed was not met for abundance of *P. cinereus* as measured by NCO searches, soil pH, or average daily high temperatures in spring as these response variables were not normally distributed in Eastern Hemlock-dominated stands. In addition, the residuals were not normally distributed for average daily low temperatures in spring or low and high temperatures in fall. For all response variables that did not meet ANOVA assumptions, Wilcoxon Kruskal-Wallis Rank sum two-sample tests with normal approximation were used. ANOVA assumptions were met for tests of differences in abundance of *P. cinereus* under cover boards and cover shingles in all stands combined, as well as in Eastern Hemlock-dominated stands and mixed deciduous stands separately. JMP release 5.1.2 was used for all statistical tests.

Results

A total of 444 observations of *P. cinereus* were made during ACO monitoring (n = 1647 ACO observations) over four seasons. The abundance of *P. cinereus* as measured by ACOs was significantly higher in Eastern Hemlock-dominated stands than in mixed deciduous stands (one-way ANOVA: df = 8, $F = 9.38$, $P = 0.018$; Fig. 1). At least one *P. cinereus* was observed at every ACO station in the nine stands over the four seasons. NCO searches yielded 45 observations of *P. cinereus* in 360 1-m^2 quadrats searched. Most observations were made under coarse woody debris (CWD) or stones, although a few *P. cinereus* were also observed in the leaf litter. No difference was found in the abundance of *P. cinereus* in Eastern Hemlock-dominated stands (0.11 individuals/m^2 ± 0.04 SD) and mixed deciduous stands (0.13 individu-

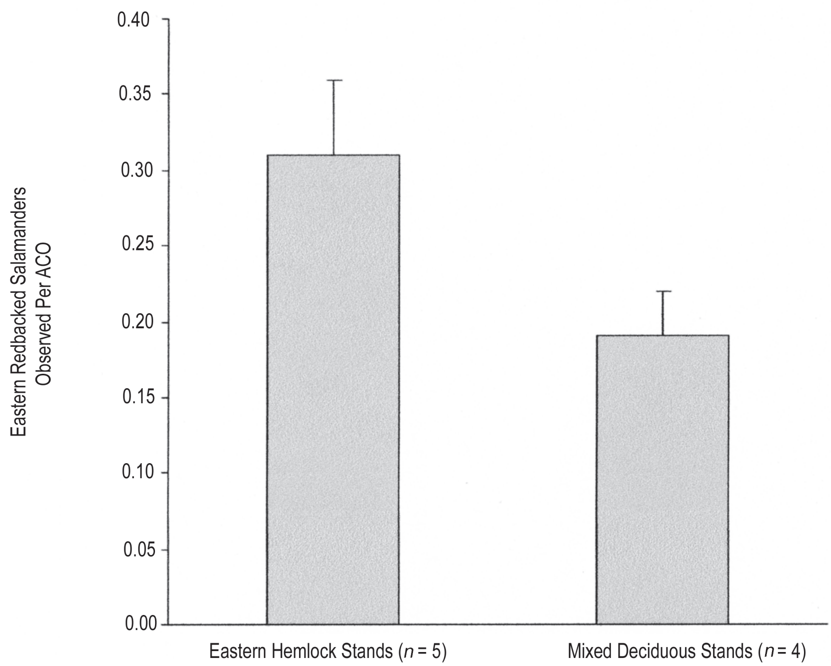

Figure 1. The relative abundance of Eastern Red-backed Salamander (*Plethodon cinereus*) in five Eastern Hemlock (*Tsuga canadensis*) dominated stands and four mixed deciduous stands at Harvard Forest over four seasons (Fall 2003 to Fall 2004 excluding winter) as measured by the monitoring of two types of artificial cover objects (ACOs), 1-m x 0.25-m x 2-cm green, untreated, rough-cut Eastern Hemlock cover boards and 1-m x 0.25-m asphalt shingles. Error bar indicates one standard deviation from the mean.

als/m^2 ± 0.05 SD) using this method (Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 23, z = 0.634, P = 0.526; Fig. 2). Again, at least one *P. cinereus* was observed in each stand.

Observation rates of *P. cinereus* were higher under cover boards than under cover shingles in all stands combined (one-way ANOVA: df = 17, F = 9.07, P = 0.008). However, in mixed deciduous stands, the difference was not significant (one-way ANOVA: df = 7, F = 3.72, P = 0.105). In Eastern Hemlock-dominated stands, observation rates of *P. cinereus* were significantly higher under cover boards than cover shingles (one-way ANOVA: df = 9, F = 18.04, P = 0.003).

Soil pH in Eastern Hemlock-dominated stands (4.0 ± 0.1 SD) was lower than in mixed deciduous stands (4.3 ± 0.1 SD) (Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 30, z = 2.367, P = 0.018). In spring 2004 (4/22/04–6/7/04), there was not a statistically significant difference in the average daily low temperatures in Eastern Hemlock-dominated stands (7.4 °C ± 0.2 °C SD) compared to mixed deciduous stands (7.3 °C ± 0.2 °C SD)

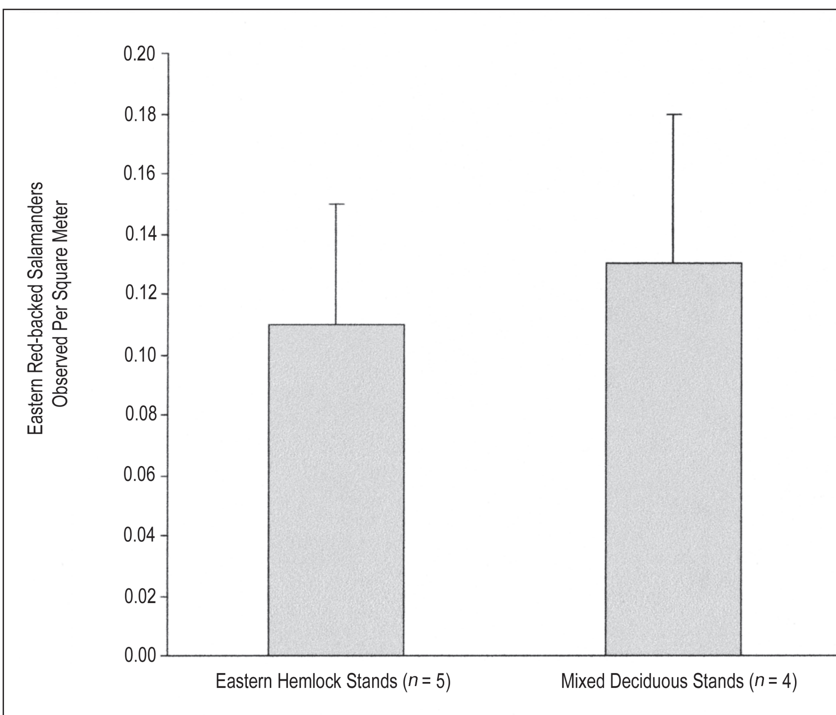

Figure 2. The relative abundance of Eastern Red-backed Salamanders (*Plethodon cinereus*) in five Eastern Hemlock (*Tsuga canadensis*) dominated stands and four mixed deciduous stands at the Harvard Forest as measured by searches of natural cover objects in square meter quadrats. Forty 1-m^2 quadrats were searched in each stand over two seasons (Fall 2003 and Spring 2004). Error bars indicate one standard deviation from the mean.

(Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 17, z = -0.646, P = 0.519). Average daily high temperatures in spring 2004 were significantly lower in Eastern Hemlock-dominated stands (20.3 °C ± 2.6 °C SD) than in mixed deciduous stands (21.6 °C ± 2.5 °C SD) (Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 29.5, z = 2.214, P = 0.027). In fall 2004 (9/22/04–11/12/04), average daily low temperatures were significantly lower in Eastern Hemlock-dominated stands (5.2 °C ± 0.3 °C SD) than in mixed deciduous stands (5.8 °C ± 1.2 °C SD) (Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 29.5, z = 2.214, P = 0.027). There was not a statistically significant difference in the average daily high temperatures in fall 2004 in Eastern Hemlock-dominated stands (11.5 °C ± 0.3 °C SD) and mixed deciduous stands (12.8 °C ± 1.0 °C SD) (Wilcoxon Kruskal-Wallis rank sum two-sample tests: s = 22, z = 1.626, P = 0.104).

Discussion

The observation of at least one *P. cinereus* in all nine stands using both methods indicates that this species is distributed throughout both the Eastern Hemlock-dominated and mixed deciduous forest types at Harvard Forest. The relative abundance of *P. cinereus* is not lower in Eastern Hemlock-dominated stands than in mixed deciduous stands, although it is unclear whether it is higher or equal. Therefore, the conversion of Eastern Hemlock-dominated stands to mixed deciduous stands at Harvard Forest should have either a neutral or a negative impact on the relative abundance of *P. cinereus*. Higher soil pH in Eastern Hemlock-dominated stands at Harvard Forest than in Albany County, NY, where *P. cinereus* is less abundant in Eastern Hemlock-dominated stands than in stands dominated by American Beech, may explain the differences in the results from the two studies (Wyman and Jancola 1992). Average soil pH in the Eastern Hemlock-dominated stands at the Harvard Forest is 4.0, which while less than the average soil pH in mixed deciduous stands (4.3), is still above the threshold that impacts the distribution of *P. cinereus* (3.8; Wyman and Jancola 1992). In Albany County, humus pH is 3.40 and mineral soil pH is 3.21 in Eastern Hemlock-dominated stands, while humus pH ranges from 3.85 to 5.50 and mineral soil pH ranges from 3.67 to 5.29 in American Beech-dominated stands (Wyman and Jancola 1992). Another difference in the two studies is that the mixed deciduous stands in my study were primarily dominated by oak species as opposed to American Beech.

The conflicting results from the two methods of measuring the relative abundance of *P. cinereus* makes it unclear whether this species is equally or more abundant in Eastern Hemlock-dominated stands as in mixed deciduous stands. Only 45 salamanders were observed during NCO searches in my study, and a larger sample size could reveal a higher abundance of *P. cinereus* in Eastern Hemlock-dominated stands as seen using ACOs. However, it is also possible that a higher percentage of the populations of *P. cinereus* might be being sampled in Eastern Hemlock-dominated stands than in mixed deciduous stands using ACOs, while NCO searches are sampling the same percentage of the population in both forest types. One reason for this could be that there are fewer NCOs in the Eastern Hemlock-dominated stands in this study, making ACOs more attractive in this forest type. In the stands in which I have data on the volume of CWD—the four at the two Simes sites—mixed deciduous stands had 63% more CWD than Eastern Hemlock-dominated stands (A. Barker-Plotkin, unpubl. data). Interestingly, the stand with the highest volume of CWD (85% greater than the next highest)—the mixed deciduous stand at Simes 1—also had the highest relative abundance of *P. cinereus* as measured by searches of NCOs, and the lowest relative abundance of *P. cinereus* as measured by ACOs (A. Barker-Plotkin, unpubl. data). Houze and Chandler (2002) had higher encounter rates of plethodontid salamanders under ACOs relative to NCOs in stands with fewer NCOs. Surface searches of NCOs (n = 645 salamanders observed) have been found to be highly correlated with estimates of absolute population size (Smith and Petranka 2000); however, no study has assessed whether there is a relationship between observation rates under ACOs and absolute population size. If the percentage of the population of *P. cinereus* sampled using ACOs varies between different forest types, ACO data may be more valuable in evaluating temporal changes in the abundance of this species rather than spatial differences.

Providing the soil is not prohibitively acidic, many characteristics of Eastern Hemlock-dominated stands are favorable to *P. cinereus*. Like other plethodontid salamanders, *P. cinereus* lacks lungs and respires through its skin, which must remain moist (Feder 1983). In Eastern Hemlock-dominated stands, where less solar radiation reaches the forest floor, cool, moist microhabitats may be more common than in mixed deciduous stands (Benzinger 1994a, Heatwole 1962). Lower average daily high temperatures in spring 2004 and lower average daily low temperatures in fall 2004 on the surface of the forest floor support the characterization of Eastern Hemlock-dominated stands being cooler. Eastern Hemlock-dominated stands may also contain a higher abundance of *P. cinereus* prey. In Saltonstall Ridge, CT, the relative abundance of nine of eleven groups of soil organisms was higher in Eastern Hemlock litter than in mixed deciduous litter from a stand comprised of *Acer saccharum* L. (Sugar Maple), Red Maple, and American Beech (Hartman 1977). Amongst these soil organisms were larval and adult Diptera (two-winged flies) as well as adult Coleoptera (beetles), groups which have been found to comprise 38.7% of the diet of *P. cinereus* (Burton 1976). However, in oak-pine, oak-hickory, mixed mesophytic, and northern hardwoods in the southern Appalachian Mountains, invertebrate densities were not found to have an impact on the abundance of salamanders (Harper and Guynn 1999).

Results from NCO searches can be used to roughly estimate the absolute abundance of *P. cinereus* at Harvard Forest remembering that only between 2% and 32% of a population of *P. cinereus* is located at the surface of the soil at any one point in time (Taub 1961). At Hubbard Brook, daytime forest floor searches in the summer yielded only 21% of the total population as measured by searches during wet rainy, summer nights (Burton and Likens 1975a).

Since I conducted searches of NCOs on the surface of the soil in the fall and spring when the encounter rate of *P. cinereus* is higher than in the summer (Bonin and Bachand 1997), it is likely that a higher percentage of the overall population was observed in my study than in Burton and Likens' (1975a) study. Using a conservative assumption that 32% of the population was on the surface of the soil in both forest types, the estimate of overall abundance of *P. cinereus* is 0.33 individuals/m^2 in Eastern Hemlock-dominated forests and 0.39 individuals/m^2 in mixed deciduous forests. Both estimates slightly exceed the estimate of overall abundance of *P. cinereus* at Hubbard Brook (0.25 individuals/m^2; Burton and Likens 1975a).

Plethodon cinereus is an excellent indicator of environmental change due to its abundance and position in the middle of the food web and its sensitivity to environmental stressors (Frisbie and Wyman 1992, Welsh and Droege 2001, Wyman and Jancola 1992). Highton (2005) reports that 180 of 205 populations of *Plethodon* species in twenty-two states from Oklahoma to North Carolina and from Pennsylvania to Florida, have declined from pre-1990 levels. Of these declines, only 22 can be attributed to habitat destruction (Highton 2005). One of the potential causes of these declines is soil acidification caused by acid rain (Frisbie and Wyman 1992, Wyman and Jancola 1992). Another factor that could potentially lead to declines in the abundance of *Plethodon* species is global climate change, which could cause warmer, drier conditions on the forest floor. Declines in the abundance of *P. cinereus* could lead to increases in the abundance of soil fauna on which they prey, and subsequent increases in decomposition rates and emission of CO_2 into the atmosphere (Wyman 1998). In addition, the species which prey on *P. cinereus* may be negatively impacted. The baseline data on the relative abundance of *P. cinereus* at Harvard Forest presented here will allow future studies to determine the population stability of this ecologically important organism as the forests it occupies undergo both local vegetative changes, such as the potential conversion of Eastern Hemlock-dominated forests to mixed deciduous forests due to HWA, as well changes in environmental conditions due to global factors.

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