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Herpetofaunal Species Composition and Relative Abundance Among Three New England Forest Types

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ABSTRACT

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Drift fences and pitfall traps captured > 2000 reptiles and amphibians during 2 years; the most common species were wood frog (*Rana sylvatica*), American toad (*Bufo americanus*), and redback salamander (*Plethodon cinereus*). There were differences in species abundances among streamside and upland habitats within three forest cover types: northern hardwoods, red maple, and balsam fir. Among streamside stands, fewer ($P < 0.05$) individuals were captured in balsam fir. The two hardwood types supported the most species. Generally, more individuals were captured in upland than in streamside habitats. Both diversity (H') and evenness (J') were correlated with litter depth, and both were higher in hardwood than in balsam fir stands. *Rana sylvatica, B. americanus* and *P. cinereus* were more abundant in hardwood than in balsam-fir stands.

INTRODUCTION

The distributions and habitat associations of terrestrial amphibians and reptiles are poorly known compared with those of other forest vertebrates. Historical information exists on some species' distributions in New England (e.g., Allen, 1899; Speck, 1919; Oliver and Bailey, 1939), but there is relatively little quantitative information on habitat associations. Amphibians and reptiles are abundant vertebrates in many forest ecosystems. In the deciduous forests of the eastern United States, densities of redback salamanders alone can exceed 2 individuals/m^2 (Heatwole, 1962). The biomass of salamanders in the Hubbard Brook Experimental Forest in New Hampshire is twice that of birds and equal to that of small mammals; furthermore, annual production of biomass

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by salamanders there exceeds that of birds or mammals (Burton and Likens, 1975a,b). Although inconspicuous, salamanders and other amphibians and reptiles are important components of the energy flow of many forest ecosystems, especially in florest-floor decomposer food webs, where they are commonly upper-level consumers of prey too small to be utilized by birds or small mammals (Pough, 1983). Amphibians are abundant and important, but they are rarely considered in evaluations of forest management practices (Bury et al., 1980; Pough et al., 1987).

This study, the first to compare the herpetofaunas among three forest types in New England, was conducted to relate the general effects of watercourses and forest cover type with amphibian and reptiles. The specific objectives were to compare amphibian and reptile species composition among upland and streamside even-aged stands of three New England forest-cover types: northern hardwoods, red maple, and balsam fir.

MATERIALS AND METHODS

Study area

This study was conducted on the Kilkenny Wildlife Management Unit, the northernmost part of the White Mountain National Forest (WMNF) in Carroll and Coos Counties, New Hampshire. Soils of the region are typically stony, sandy, and acidic. Numerous permanent and intermittent streams drain the slopes. The forest present today resulted from the extensive fires of 1903 that followed widespread logging in the late 1800s. All selected stands were even-aged, 80–100 years old, and at least 25 ha in size; all were at elevation 396–762 m (1300–2500 ft), on slopes of $<24°$, and had NE, SE, W, or NW exposures. Streams flowing through study stands were <2 m wide, <40 cm deep, and lacked discernable floodplains.

Northern-hardwood stands contained American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and yellow birch (*Begula alleghanensis*), with sugar maple predominating. Dense canopies permitted few shrubs in the understory; shrubs present were primarily striped maple (*Acer pennsylvanicum*), mountain maple (*A. spicatum*), and hobblebush (*Viburnum alnifolium*). Early herbaceous plants included spring beauty (*Claytonia caroliniana*), trilliums (*Trillium* spp.), squirrel-corn (*Dicentra canadensis*), and trout-lily (*Erythronium americanum*). Later-appearing plants included wild oats (*Uvularia sessilifolia*), Canada mayflower (*Maianthemum canadense*), and false Solomon's-seal (*Smilacina* spp.).

The red-maple stands occupied wet sites. Beech was absent, and red maple (*Acer rubrum*) predominated. Associated species included yellow birch, paper birch (*Betula papyrifera*), and red spruce (*Picea rubens*). Understory species included mountain maple, serviceberry (*Amelanchier* spp.), viburnums (*Vi-*

burnum spp.), and dogwoods (*Cornus* spp.). Woodferns (*Dryopteris* spp.), Canada mayflower, trilliums, starflower (*Trientalis borealis*), Indian cucumber-root (*Medeola virginiana*), sarsaparilla (*Aralia nudicaulis*), grasses (Poaceae), and sedges (*Carex* spp.) were the common herbs.

Balsam-fir (*Abies balsamea*) stands occupied flats on sandy glacial till. Balsam fir was dominant; associates included red spruce, quaking aspen (*Populus tremuloides*), red maple, and yellow birch. Beaked hazelnut (*Corylus cornuta*), mountain maple, hobblebush, and raspberry (*Rubus* spp.) were common understory plants. Herbaceous species included Canada mayflower, foamflower (*Tiarella cordifolia*), common wood-sorrel (*Oxalis montana*), bunchberry (*Cornus canadensis*), wild oats, bluebead (*Clintonia borealis*), trilliums, starflower, and a variety of mosses. Bracken (*Pteridium aquilinium*), whorled wood aster (*Aster acuminatus*), sedges, clubmoss (*Lycopodium* spp.), and sarsaparilla were abundant where there were openings in the canopy.

Herpetofaunal sampling

Herpetofaunal surveys were conducted in six stands (one streamside stand and one upland stand for each cover type) using drift fences with 48 pitfall traps for amphibians and 12 modified funnel traps for snakes in each stand (Fitch, 1951; Vogt and Hine, 1982). Drift fences constructed of fiberglass screen, approximately 40 cm high with the bottom 10 cm buried, were attached to wires and anchored to trees. Wooden stakes attached by wire 20–30 cm from the fence provided lateral stability and eliminated any type of 'escape ladder' for captured individuals.

Pitfall traps were constructed from two No. 10 (3.2-l) cans joined end-to-end. A 'funnel' made from a plastic bowl was placed in each trap to prevent captured specimens from escaping. Funnel traps for snakes were constructed of hardware cloth.

In upland stands, drift fences were arranged in a rectangle (Vogt and Hine, 1982) >100 m from the stand boundary (Fig. 1a). In streamside habitats, the total length of fencing and numbers and types of traps were the same as in the upland habitats, but instead of a rectangular configuration fences were set parallel to and at varying distances from streams in order to intercept species or individuals moving toward or away from water (Fig. 1b).

Traps were operated during April, June, and July in 1981 and May through September in 1982. Traps were opened when rain was predicted within 24 h. Traps were checked at least every other day in periods without rainfall and daily during rainfall and for 1 day after rain. Trapping periods varied from 2 to 7 days. Trapped specimens were marked, then released on the opposite side of the fence, approximately 3 m from the fence. Data on species movement are reported elsewhere (Rudis, 1984). Other survey methods used to detect species

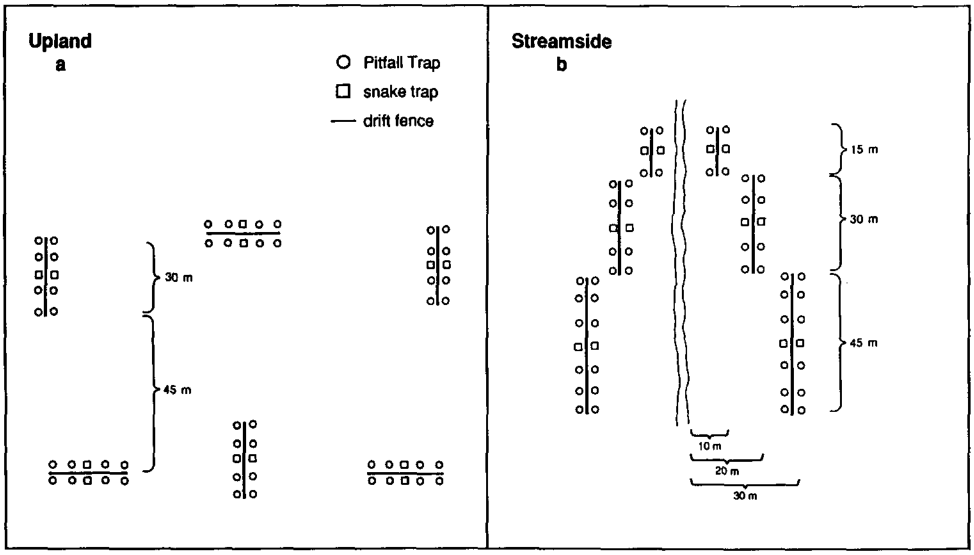

Fig. 1. Trap and drift-fence configuration for herpetofaunal sampling in (a) upland and (b) streamside stands, White Mountain National Forest, New Hampshire.

presence after trapping included turning logs, stones and litter and electroshocking in streams (Gunning and Lewis, 1957).

Habitat sampling

In each of six stands, two circular 0.04-ha plots were randomly located. All live and dead trees > 10 cm in diameter were tallied by species. Diameter at breast height (D_{bh}) and total height were measured in the field; stem density and basal area were calculated.

Canopy closure was measured with a spherical densiometer at 10 points 3 m apart along each of 2 random diameters of each circular plot; ground-cover density was estimated using a sighting tube at the same points. Litter depth was measured with a metric rule at each of these points. Along the perimeter of the 0.04-ha plot, four circular 28-m^2 subplots were located at cardinal compass coordinates; all understory (2.5–10 cm D_{bh}) trees and the number of shrubs > 1.5 m in height were tallied as either deciduous or coniferous.

Herbaceous and low-woody stem densities were recorded on 24 1-m^2 plots at 10-m intervals along a random transect through each stand. All herbaceous stems and woody stems < 1.5 m in height were tallied. Fallen logs > 1 m long and 8 cm in diam., rocks, and stumps > 30 cm diam. were counted along a 100-m random transect through each stand. Stream width, gradient, and pH were measured at the midpoint in the trap configuration (Fig. 1b).

Data analysis

Numbers of species and individuals were pooled for 2 years; recaptures were not included. Because trapping effort was related to periods of rainfall, comparisons among stands were made using catch-per-unit-effort. The Shannon-Weaver (1949) index, H', was used as a measure of species diversity; Pielou's (1966) J' was used to calculate the evenness with which individuals were distributed among the species captured. Chi-square was used to test the null hypotheses that there were no differences in herpetofauna captures per unit effort among forest types within streamside habitat, among forest types within upland habitat, or among forest types (pooled upland and streamside). Bonferroni's inequality (Byers and Steinhorst, 1984) was used to construct simultaneous confidence intervals to determine if actual and expected utilization were significantly different.

Range tests were used to test differences among stands for canopy closure, litter depth, ground cover, and herb and woody stem density.

RESULTS

Ten amphibian and one reptilian species were captured, including 455 salamanders, 1615 anurans, and 10 snakes (Table 1). The same 11 species were found in both years. Four species occurred in all stands: wood frog (*Rana sylvatica*); American toad (*Bufo americanus*); redback salamander (*Plethodon cinereus*); and red-spotted newt (*Notophthalmus viridescens*). Three species occurred in all streamside stands: two-lined salamander (*Eurycea bislineata*); green frog (*Rana clamitans*); and garter snake (*Thamnophis sirtalis*). Two uncommon species were restricted to streamside stands: spring salamander (*Gyrinophilus porphyriticus*); and dusky salamander (*Desmognathus fuscus*) (Table 1). Turning logs, rocks, and litter in these stands did not produce any additional species. Electroshocking a 100-m length of each stream produced four larval dusky salamanders. The greatest total number of individuals was captured in the red-maple streamside stand and the fewest in the balsam-fir streamside stand. There were no differences in total captures among upland stands, but among streamside stands there were fewer ($P < 0.05$) captures/unit effort in the balsam-fir stand (Table 1).

Among forest types (streamside and upland stands pooled), there were fewer total captures/unit effort ($P < 0.05$) in the balsam-fir than in the hardwood stands; hardwood types each yielded approximately twice as many individuals as the balsam-fir type. Upland stands yielded significantly fewer ($P < 0.05$) individuals than did streamside stands, but mean species diversity was not different. Both species diversity and evenness were higher in hardwood than in balsam fir stands (Table 2).

Three species made up 90% of all captures (Table 1). Wood frog was the

TABLE 1

Numbers of individual amphibians and reptiles captured in forest stands, White Mountain National Forest, New Hampshire, 1981 and 1982

Species	Red maple		Northern hardwoods		Balsam fir		Total
	Upland	Stream-side	Upland	Stream-side	Upland	Stream-side	
Wood frog	121	297	205	224	186	167*	1200
American toad	20	98	100	94	16	24*	352
Redback salamander	98	101	65	37	8	6*	315
Two-lined salamander	0	4	0	25	26	1	56
Spring peeper	5	10	28	0	3	2	48
Spotted salamander	2	14	21	1	3	0	41
Red-spotted newt	4	10	9	2	6	1	32
Green frog	0	5	1	4	2	3	15
Garter snake	1	3	0	2	1	3	10
Spring salamander	0	2	0	6	0	0	8
Dusky salamander	0	1	0	2	0	0	3
No. individuals	251	545	429	397	251	207*	2080
No. trap nights	2508	2596	2544	2494	2832	2854	15828

*Captures by forest cover type are different ($P<0.01$).

TABLE 2

Species richness, total captures, diversity (H') and evenness (J') of amphibians and reptiles, White Mountain National Forest, New Hampshire

Habitat or cover type	No. of species	N	H'	J'
Upland stands	9	931	$\bar{x}=1.18$ (range 1.03-1.39)	$\bar{x}=0.54$ (range 0.47-0.63)
Streamside stands	11	1149	$\bar{x}=1.12$ (range 0.77-1.33)	$\bar{x}=0.47$ (range 0.32-0.56)
Forest type				
Red maple	11	796	1.23	0.54
Northern hardwoods	11	826	1.33	0.58
Balsam fir	11	438	0.90	0.40
All stands	11	2080	1.33	0.56

most common species, being 57% of all captures and 48–80% of the captures in each stand. American toad constituted 17% (6–24%) of total captures. Redback salamander constituted 15% of all captures, and was found in lower numbers ($P<0.05$) in balsam-fir stands (Table 1).

Eight additional species varied in frequency and abundance among the six stands. Of these, spring peeper (*Hyla crucifer*), two-lined salamander, and spotted salamander (*Ambystoma maculatum*) were trapped in sufficient numbers ($n>40$) to support analysis. Two-lined salamanders were more abundant than either American toads or redback salamanders in the upland balsam-fir stand: 11% of captures compared to 9.5% for the last-named 2 species combined. Spring peepers and spotted salamanders were both most abundant in the northern-hardwood upland and red-maple streamside stands.

Wood frogs were more abundant ($P<0.05$) in the streamside red-maple stand and less abundant ($P<0.05$) in the upland stand than would be expected by chance. American toads were more abundant ($P<0.05$) in northern-hardwood stands than would be expected, while both redback salamanders and American toads were less abundant ($P<0.05$ in the balsam-fir stands than would be expected by chance (Table 3). Bonferroni intervals could not be used to test habitat use by any of the other amphibian species trapped because some stands yielded fewer than 5 captures.

Mean trapping success over 2 years was 15% for pitfall traps and <3% for snake traps. The overall recapture rate for salamanders was 3.9%. Trap mortality over 2 years was 17.8% for *R. sylvatica*, 18.5% for *B. americanus*, and 33% for *P. cinereus*.

Vegetation structure, composition, and microhabitat variables differed significantly between streamside and upland habitats, including differences in tree species composition, basal area, number of shrubs, ground cover, canopy closure, litter depth, and number of stems in the understory (Table 4). The last three variables also differed significantly between balsam fir and the two

TABLE 3

Habitat use by three amphibian species as evaluated by Bonferroni simultaneous confidence intervals in New England forest types, White Mountain National Forest, New Hampshire

Stand	Species			
	Rana sylvatica	*Plethodon cinereus*	*Buffo americanus*	Total
Red maple upland	–[1]	+[2]	–	–
Red maple stream	+	+	+	+
Northern hardwood upland			+	+
Northern hardwood stream			+	+
Balsam fir upland		–	–	–
Balsam fir stream		–	–	–

[1]Forest type is used significantly less than is expected by chance ($P<0.05$).
[2]Forest type is used significantly more than is expected by chance ($P<0.05$).

TABLE 4

Mean values[1] of habitat variables measured on two 0.04-ha plots in each of six stands, White Mountain National Forest, New Hampshire

Habitat variables	Red maple		Northern hardwoods		Balsam fir	
	Upland	Stream-side	Upland	Stream-side	Upland	Stream-side
Tree D_{bh} (cm)	24.8a	21.3b	21.0b	26.0a	19.9b	23.8a
Basal area (m^2/ha)						
coniferous	5.0b	0.0b	0.0b	1.9b	15.0a	23.7a
deciduous	34.0a	36.5a	30.0a	23.6a	0.0b	10.0b
Canopy closure (%)	89a	84a	94a	87a	69b	75b
Litter depth (mm)	27a	24a	34a	32a	18b	12b
Small trees (1000 stems/ha)	1.96a	3.30a	3.21a	1.83a	11.88a	0.45b
Shrubs (1000 stems/ha)	0.49b	0.93b	0.40b	3.84b	11.25a	8.26a
Ground layer						
herbs (stems/m^2)	128a	102a	20b	59b	76b	113a
woody (stems/m^2)	16	16	30	20	25	21
moss cover (%)	10b	3b	1b	2b	20a	22a
Slope (%)	<1	9	14	10	4	7
Aspect	NE	NE	NE	NW	W	NW
Elevation (m)	500	400	650	550	500	500

[1]Duncan's new multiple range test (Steel and Torrie, 1960, p. 107); values followed by different letters are significantly different ($P<0.001$).

hardwood types ($P<0.01$). Streamside habitats, however, did not yield significantly more species than upland habitats. Litter depth was the only variable that was related to herpetofaunal community measures: both H' and J' were correlated ($r=0.82$) with litter depth.

DISCUSSION

Forest stands without apparent water courses support herpetofaunal communities that are as rich and diverse as corresponding New England stands containing permanent water courses. Most of the species encountered in this study require water for breeding, so it is evidently available in inconspicuous pools and trickles. The major community distinction is apparently between deciduous and coniferous rather than between upland and streamside habitats. This difference likely reflects soil/litter pH differences. Soil pH influences the density and distribution of *P. cinereus* — the species was excluded from 27% of forest habitat in Delaware County, New York by low soil pH (Wyman and Hawksley-Lescault, 1987). In our study, *P. cinereus* was found in lower numbers ($P<0.001$) in balsam-fir stands, only 13 individuals trapped vs. 202 in red-maple and 105 in northern-hardwood stands.

Total herpetofaunal captures per unit effort in balsam-fir stands were half those in either of the deciduous forest types. Soil humus-layer pH was 2.4 in balsam-fir stands in the study area, more acidic than in the northern-hardwood or red-maple stands, which ranged between 3.4 and 3.9 (Hoyle, 1973). However, streamwater pH was not low in any stand, ranging between 6.5 and 7.2 during the trapping period. Such levels would not likely affect survival of amphibian larvae.

Low pH has been implicated in reducing amphibian population levels in several ways. Low pH depresses sodium uptake and increases sodium loss in amphibian larvae, with death occurring after loss of approximately 50% of body sodium content (Freda and Dunson, 1984 1985). Low soil pH may also affect productivity of salamander prey species (Haagvar and Amundsen, 1981). The LD_{50}s of three food items of redback salamanders (the isopods *Oniscus assellus* and *Armadillium vulgare* and the millipede *Diploidus* sp.) range between 3.0 and 3.5. Lower prey populations could result in lower salamander populations. Also, redback salamanders can sense the pH of the substrate and may move away from low-pH conditions, likely resulting in females depositing fewer eggs in low-pH soils (Wyman and Hawksley-Lescault, 1987). Other salamander species may likewise sense substrate pH and move away.

The litter layer was significantly thinner under balsam-fir stands in this study, and although percent canopy closure was higher, shrub stem density was greater. Above-ground activity by redback salamanders and red-spotted newts was positively correlated with the density of understory vegetation and depth of leaf litter in forest stands in New York. Furthermore, conifer plantations contained few salamanders (Pough et al., 1987). The inhospitality of conifer stands to salamanders reported from New York (Pough et al., 1987) and South Carolina (Bennett et al., 1980) is supported by results of this study.

Salamander numbers have been shown to be related to stand disturbance; their numbers are lower in recent clearcuts and areas of small-scale disturbances, but by stand age 60 numbers do not differ from those of old stands (Pough et al., 1987). Cover type also has an important effect in that balsam fir, and perhaps conifer types in general, have poorer herpetofaunal communities due to lower soil pH and litter depth.

Plethodontids are the most abundant forest salamanders (Burton and Likens, 1975a). The influences of soil pH and litter depth changes, resulting from changes in the proportion of conifer stands, could change the forest-floor decomposer food web, of which amphibians and reptiles are upper-level consumers.

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