The Effects of Microsite (Logs versus Ground Surface) on the Presence of Forest Floor Biota in a Second-growth Hardwood Forest[1]

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Abstract

A study conducted in forests at the University of Connecticut investigated the value of logs for biodiversity in second-growth hardwoods. Forest floor microsite (log versus featureless ground surface [soil and leaf litter only]) was significant ($P < 0.001$) for the frequency of occurrence of representatives of all seven broadly defined life form groups examined. Algae, non-vascular plants, and fungi were found on logs, but not on the ground. Small mammal and bird perching was noted on logs, but not on the ground. Seedlings and non-seedling vascular plants occurred on both microsites, but were found in significantly greater frequency on the ground surface.

Introduction

Forest floor structure is the result of a variety of natural and anthropogenic processes that create features that persist for a wide variety of time periods. Features resulting from glacial activity (for example, erratic boulders or hard-packed soils underlying ephemeral ponds) are more or less permanent features. The pit and mound topography created when strong winds uproot trees may persist for centuries (Stephens 1956). The bare soil created when a tree is first uprooted is relatively soon covered by new vegetation or leaf litter while the trunks, stumps, and large branches of broken-off or uprooted trees may persist for decades or even centuries. Variation in forest floor structure results in habitat diversity for both plants and animals.

The habitat value of forest floor logs in particular has been recognized for many groups of species, including birds, small mammals, herpetofauna, insects and other invertebrates, vascular plants, non-vascular plants, and fungi (Bull and others 1997, Elton 1966, Harmon and others 1986, Maser and others 1979, McMinn and Crossley 1996, Samuelsson and others 1994). Logs contribute to forest biological diversity by providing animals and plants with substrate, e.g., for feeding, perching, or residence. Organisms that reside on, under, or in logs also may contribute to the diversity of ecological functioning that occurs in forest ecosystems. For example, log-related organisms are involved in nitrogen fixation (Hendrickson 1991, Larsen and others 1978), nutrient cycling (Harmon and others 1994), mycorrhizal fungal associations

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(Graham and others 1994, Molina and others 1993), and food chains (Maser and Trappe 1984).

Not every study from which the habitat value of logs has been inferred has involved quantitative, controlled comparisons of the value of log microsites versus other forest floor microsites. However, examples of such studies may be found for a variety of species and more broadly-defined life forms, for example, Barnum and others 1992 *(Peromyscus leucopus),* Bratton 1976 (herbaceous plants), Christy and Mack 1984 *(Tsuga heterophylla* [Raf.] Sarg.), Coney and others 1982 (land snails), Harmon and Franklin 1989 (conifer seedlings), Hofgaard 1993 (tree seedlings), Kruys and Jonsson 1999 (moss/liverwort/lichen/fungi), Minore 1972 (conifer [mostly] seedlings), Nakashizuka 1989 (woody plant seedlings), Olszewski 1968 (small mammals), Rambo and Muir 1998 (moss/liverworts), Steel and others 1999 (small mammals), Summers and Uetz 1979 (woodland centipedes), Szewczyk and Szwagrzyk 1996 (tree seedlings), Tallmon and Mills 1994 *(Clethrionomys gapperi),* and Thompson 1980 (herbaceous plants). In some cases, the extent to which logs are important microsites has been shown to be affected by log decay class.

The purpose of the present study was to compare statistically the use of logs to the use of the ground surface in a second-growth, eastern hardwood forest. Our goal was to evaluate the general significance of logs for a broad range of organisms that use logs in other forest cover types. The organisms we considered represented seven life forms: algae, non-vascular plants, fungi, seedlings, non-seedling vascular plants, small mammals, and birds. The specific study objectives were to determine the significance of forest floor microsite (log versus ground surface) for the frequency of occurrence of representatives of the seven broadly-defined life forms; and for logs only, to determine whether the frequency of representatives of each life form is affected by log species and decay class.

Study Area

The study was conducted in the summer of 1996 in forest on the North Eagleville Tract of the University of Connecticut (latitude 41^{o} 48' 30", longitude 72^{o} 17') located in the vicinity of Storrs, Connecticut. The forest, dominated by naturally regenerated, mature, second-growth oak *(Quercus* L.) stands, lies within the central broad-leaved region of the eastern deciduous forest (Duffield 1990). Annual precipitation averages 1,170 mm, spread more or less evenly throughout the year. The average mean January and July temperatures are -3^{o}C and 21^{o}C, respectively, with an average frost-free season of 156 days (Brumbach 1965). Soils in the North Eagleville Tract are primarily fine sandy loams developed from a glacial till derived from schist, gneiss, and granite. The soils are typically very stony with slopes ranging from 3-15 percent. However, soils with poor or very poor drainage as well as steeper (15-35 percent slope) shallow soils are also included within the area sampled (USDA Soil Conservation Service 1966).

Field Procedures

Following the guidelines of Harmon and Sexton (1996), logs were defined as pieces of coarse woody debris (CWD) at least 1.5 m long. Length was measured from the large end to the point where the log diameter tapered off to less than 10 cm. To locate logs for sampling, a line intersect method was used (Ringvall and Ståhl

1999) with randomly located transects laid out within the hardwood forest. Log diameter was measured at the base, mid-point, and upper end of each log intersected by the transect. Each log was identified as "oak" or "non-oak" (Panshin and de Zeeuw 1980) and assigned to one of five hardwood log decay classes (Pyle and Brown 1998). The presence of under-log habitats (leaf litter and soil) was tallied.

Seven broadly defined "life forms" *(table 1)* were chosen to enable quick categorization of organisms into groups that reflected their taxonomy and/or function. We did not explore the relationship of the species included in our life form groups to typical indices of diversity (Swindel and others 1991). For each life form, the presence or absence of any representative species (or, for small mammals and birds, the presence or absence of evidence of perching by any representative species) was tallied for each log. Presence/absence observations of representatives of each life form also were tallied for under-log habitat when it occurred.

Table 1—*Life forms used to categorize the diversity of biota.*

Life form	Description
Algae	Only those visible to the unaided eye
Non-vascular plants	Including mosses, liverworts, lichens
Fungi	Fungal fruiting bodies and hyphae visible to the unaided eye without disturbance of the microsite; and slime molds
Seedlings	Trees $\leq$0.50 m tall; other species with cotyledons
Vascular plants	Excluding seedlings and grass-like plants (Poaceae, Cyperaceae, Juncaceae)
Small mammals	Perching use assessed by presence of scat or nuts/seeds with tooth marks
Birds	Perching use assessed by presence of guano, nests, or proliferations of seeds

The ground surface adjacent to each log was sampled at a distance of 3 meters from the log. For each log, an equivalent area of featureless ground surface (equal to the length times the mid-point diameter of the log) was sampled for the presence/absence of the seven life forms by ground surface substrate (decaying leaf litter and soil). The ground surface samples were taken on alternating sides of the transect and were relocated as needed to avoid forest floor features such as other pieces of CWD or rocks and fine woody debris that might have a different habitat value than leaves and soil.

Data Analysis

For each life form, the significance of microsite type (log versus ground surface) was analyzed using a Haber-corrected chi-square test (Zar 1999) for a 2 X 2 contingency table of microsite type and presence/absence. For each life form, chi-square goodness of fit analysis (Zar 1999) was used to test the significance of log decay class and log species. For decay classes I-IV, the null hypothesis was that the frequency of the j^{th} life form on logs of the i^{th} decay class is proportional to the occurrence of logs in the i^{th} decay class within the sample. With reference to vascular plants, expected values of less than 5 were deemed acceptable for testing extreme departures from a uniform distribution at alpha values of 0.01 because the average expected value (of 7.5 in the case of vascular plants) was at least 4.0 (Zar 1999). For log species (oak or non-oak), a Yates-corrected chi-square goodness of fit (Zar 1999) was applied to the null hypothesis that the frequency of the j^{th} life form on logs of i^{th} species is proportional to the occurrence of logs of the i^{th} species within the sample. The independence of log species and log decay class (for decay classes I-IV) was tested with the log-likelihood ratio (G statistic; Zar 1999). For all statistical tests, *P*-values of less than 0.01 were considered significant. The quadratic mean diameter for the basal end of the logs was calculated as the square root of the average squared diameter.

Results

Two hundred seventy-seven logs and an equal number of adjacent forest floor areas were sampled. The quadratic mean diameter at the basal end of the logs was 31 cm; the median basal diameter was 22 cm. The majority (156) of the 277 logs were decay class II, while 15, 64, 39, and 3 logs were decay classes I, III, IV, and V, respectively *(table 2).* Two hundred nine logs (75 percent) were identified as oak. Nearly half the total sample (46 percent) was class II oak logs *(table 2).* The null hypothesis that log species is independent of decay class was rejected ($P < 0.0001$).

Table 2—*The occurrence of oak and non-oak logs by decay class in the North Eagleville Tract of the forests at the University of Connecticut.*

	Decay class					
Log group	**I**	**II**	**III**	**IV**	**V**	**Total**
Oak	6	128	50	22	3	209
Non-Oak	9	28	14	17	0	68
Total	15	156	64	39	3	277

Strong microsite preferences were found *(table 3).* Algae, non-vascular plants, fungi, and signs of small mammal and bird perching were found on logs, but not on the leaf litter or soil of the adjacent, featureless forest floor. Vascular plants and seedlings were found significantly more frequently on the forest floor samples than on logs. More than 99 percent of the forest floor observations of seedlings and vascular plants involved plants rooted in soil (usually with the roots first going through leaf litter). Under-log habitat also provided shelter for seedlings and to a lesser extent for vascular plants and small mammals *(table 3).*

Seedlings and vascular plants were the only life forms for which decay class was significant ($P < 0.01$). With increasing decay, a larger proportion of the logs in a decay class supported seedlings and vascular plants *(table 4)*. Both seedlings and vascular plants occurred in lower (but not significantly lower) proportions than expected on oak logs. This did not alter the trend in the effect of decay class *(table 4)*. Log species was not statistically significant for any of the life forms.

Table 3—*The frequency of representatives of seven life forms by forest floor microsite.*[1]

		Microsites			
	Log	Ground surface[2]		Under log[3]	
Life forms		Soil	Leaf litter	Soil	Leaf litter
Algae	218	0	0	0	0
Non-vascular plants	246	0	0	1	0
Fungi	261	0	0	0	0
Seedlings	145	[4]267	1	71	2
Vascular plants	30	[4]265	1	10	0
Birds	17	0	0	0	0
Small mammals	31	0	0	3	0

[1]A total of 277 logs and corresponding areas of ground surface was sampled.
[2] The ground surface sample areas that included seedlings and vascular plants on leaf litter also included these life forms on soil; thus, the tally for ground surface as a whole is equal to the tally for soil.
[3] The under log tallies were neither statistically analyzed alone nor included in the log tallies.
[4] Almost all the seedlings and vascular plants tallied under "soil" grew out of leaf litter but were found to be actually rooted in soil after the leaf litter was moved to inspect the rooting medium.

Table 4—*The proportion of available oak and non-oak logs on which seedlings and vascular plants occurred.*

	Seedlings		Vascular plants	
	Log species group		Log species group	
Decay Class[1]	Oak	Non-Oak	Oak	Non-Oak
I	0.33	0.33	0	0
II	0.41	0.50	0.04	0.14
III	0.54	0.64	0.10	0.14
IV	0.91	0.88	0.32	0.41

[1] Decay class was significant ($P<0.01$) for both seedlings and vascular plants, and log species group was not independent of decay class; however, the differences in occurrence of seedlings and vascular plants by log species group (oak versus non-oak) were not significant.

Discussion

We found a wide range of differences among the seven life forms with regard to the importance of log habitat. We cannot quantify the absolute importance of forest floor logs because we did not quantify the proportions of the forest floor area occupied by logs and by featureless zones. Further, we did not sample all available types of forest floor microsites. Non-vascular plants, for example, were encountered only on logs in our study, but during sampling they were observed to be common on unsampled forest floor microsites, particularly rock surfaces. Similarly, another unsampled microsite, fine woody debris, provides an additional forest floor microsite for algae, non-vascular plants, and fungi in our study area (Kruys and Jonsson 1999).

Forest floor logs and buried wood have been cited as important substrates for tree seedlings in a wide variety of locales, for example, in the Cascade Mountains (Christy and Mack 1984), the Adirondacks (McFee and Stone 1966), and the Great Smoky Mountains (White and others 1985). Our results, which show a lesser importance of logs as habitat for vascular plant seedlings, contrast with these reports.

Some seed characteristics, seedbed conditions, seed sources, and the climatic conditions typical of second-growth, eastern hardwood forests may explain why we found more seedlings and vascular plants on the forest floor than on logs. Our study area is dominated by large- or medium-seeded species, for example oaks and maples. This contrasts with the small-seeded western hemlock *(Tsuga heterophylla* [Raf.] Sarg.) of Christy and Mack (1984), the red spruce *(Picea rubens* Sarg.), Fraser fir *(Abies fraseri* [Pursh] Poir.), and yellow birch *(Betula alleghaniensis* Britt.) studied by White and others (1985), or the studies involving spruce seedlings in Canada cited in support of the notion of foresters' frequently-voiced belief in the significance of decaying trunks and stumps for conifer seedlings (McFee and Stone 1966). Large seeds are less likely to lodge on a log (Szewczyk and Szwagrzyk 1996). The likelihood of seeds lodging on a log is promoted by surficial fissures (Goder 1961), such as those found on large trees, particularly rough-barked conifers. The eastern deciduous forest of North America is typically second-growth where the average overstory tree diameter is much less than that of old-growth forests (particularly those old-growth forests of the moist Pacific Northwest). Further, the microclimate of oak-dominated forests is considerably drier than that of moist coniferous forests. Thus, in comparison to moist old-growth conifer forests, the regeneration of vascular plants on logs in the eastern deciduous forest may be hampered by a combination of a less moist microclimate, larger seeds, and typically smaller logs.

The seedbed conditions provided by logs in second-growth, eastern deciduous forests are less conducive to seedling germination and establishment than the conditions found on the forest floor or on logs in other locales. Seedling germination and establishment on logs requires moisture that may be provided by duff collected on the log surface (Goder 1961) or by decayed wood. The leaves of broad-leaved, deciduous forest trees are much less likely to remain on top of logs to decay into duff than are leaves of small-needled conifers, such as hemlock, spruce, or fir. Further, in our study area (and elsewhere in the eastern deciduous forest), the pool of available logs is dominated by a cohort of hard-surfaced, decay class II oaks believed to be the result of widespread mortality related to heavy infestations by the introduced gypsy moth *(Lymantria dispar* L.).[3] In addition, on the forest floor of oak-dominated forests, there is little competition from moss or herbaceous plants compared to

[3] Unpublished data on file, C. Pyle, Storrs, Connecticut.

conditions found in other forest cover types (Harmon and Franklin 1989). Thus, even where seedlings on logs are quite numerous (e.g., in canopy gaps), forest floor seedlings also are likely to be equally or more numerous.

Although oak seed source is plentiful, the presence of oak seedlings on logs is largely curtailed by factors that affect seedling placement and establishment. Squirrels bury acorns in soil rather than in logs. Further, the establishment of oak seedlings depends upon the development of a tap root (unlikely to be successful on logs in the early stages of log decay).

Despite these reasons for logs as likely to provide less suitable habitat than that found on the forest floor, some logs in our study area did support the growth of seedlings and vascular plants. We did not tally seedlings by species, but we did observe that in the vicinity of the occasional eastern hemlock *(Tsuga canadenis* [L.] Carr.) trees, certain logs had high concentrations of hemlock seedlings. In areas where the forest floor is covered by a thick layer of oak-dominated litter, the roots of newly germinated hemlock seedlings are unable to send roots through the forest floor litter to the soil. Eastern hemlock regeneration is typically restricted to CWD except where the forest floor has been disturbed (by mixing of organic and mineral soil or by fire) to expose a "partially decomposed layer" (Godman and Lancaster 1990). We speculate that in oak-dominated forests, logs may be found to be more important than the featureless forest floor for the regeneration of other small-seeded species in addition to hemlock.

Our results corroborate the importance of logs for small mammals and birds. Because we used evidence of log use *(table 1),* rather than field sightings of small mammals and birds, our results for these two life forms address the habitat quality of logs only in the context of their preferred use as perches.

Small mammals, seedlings, and vascular plants were observed under, as well as on, logs. Because not every log had habitat under it, our observations of the occurrences of organisms in this type of habitat *(table 3)* were not included in the statistical analysis of log use. However, the deterrent to browsing provided by logs situated above seedlings (Graham and others 1992) may be noteworthy in Connecticut and other locales where ungulate browsing is extensive.

Log decay class was less frequently significant than expected. The state of log decay previously has been found to be important for a great variety of organisms (Crites and Dale 1998, Goder 1961, Hofgaard 1993, Kruys and others 1999, McCullough 1948, Muhle and LeBlanc 1975, Rambo and Muir 1998, Seastedt and others 1989, Szewczyk and Szwagrzyk 1996, Tallmon and Mills 1994). Stronger relationships to decay class might have been found had we used less broadly defined groups of organisms. Finally, it is worth considering that there are multiple decay classes present within most logs of a given decay class classification (Pyle and Brown 1999). In our study, the degree of habitat differences among logs of different decay classes may have been obscured with the tallying of presence/absence, rather than percent cover estimations for life forms, such as algae, fungi, and non-vascular plants.

In contrast to other features of the forest floor (such as rock surfaces and fine woody debris), logs are a relatively long-lasting substrate that may be subject to control through forest management activities. The number, the decay class distribution, and the size of forest floor logs may be strongly influenced by management decisions in commodity forests. As knowledge increases concerning the effects of log-related habitat on biological diversity, managers will be better prepared to make decisions concerning the desired characteristics of the woody debris to be left on the forest floor in logged areas.

Summary and Conclusions

Forest floor logs are an important and manageable habitat component for the promotion of biological diversity. In our study of the frequency of occurrence of seven broadly-defined forms of life on logs as compared to the featureless forest floor, logs were found to be better habitat for non-vascular plants, fungi, and algae, and preferred for perching by small mammals and birds. Further study is needed to quantify the importance of other forest floor features and the importance of the various microsites relative to the proportion of the forest floor they occupy.

Although the frequency of logs with an observed presence of vascular plants and seedlings was significantly less than that for corresponding areas of ground surface, some seedlings and vascular plants did occur on logs in the second-growth hardwood forest study area. The presence of seedlings and vascular plants on logs was independent of log species (oak vs. non-oak), but not of decay class. The more decayed a log, the greater the likelihood that seedlings and vascular plants were present.

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