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The association of small mammals with coarse woody debris at log and stand scales

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Abstract

Coarse woody debris is an important structural element in forests. We empirically investigated the relationships between small mammals and coarse woody debris decay stage at two different scales: individual logs and forest stands. There were no significant relationships between small mammals and individual logs of different decay classes. We investigated the stand scale using areas with contrasting management intensities (a reference area and a more intensively managed area). No significant relationships were found between small mammal abundance (any species) and either mean decay class of logs in a stand, or overall abundance of logs. There was evidence of a landscape context effect. Red-backed voles, the most abundant microtine in the region, were significantly related to the abundance of the most decayed logs. This relationship was only significant on the intensively managed landscape, where highly decayed logs were rare. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

There is a growing awareness that it is critical to retain coarse woody debris (CWD) in managed forests as habitat for many species of animal, including small mammals (Harmon et al., 1986; Freedman et al., 1996). A number of studies empirically explore the relationship between small mammals and CWD, most often at a microhabitat scale. Several species, such as *Clethrionomys gapperi*, *C. californicus*, *Peromyscus maniculatus*, *P. leucopus*, and *Microtus pinetorum* use downed logs and stumps for traveling, foraging, and nesting (e.g. Miller and Getz, 1977; Hayes and Cross, 1987; Graves et al., 1988; Planz and Kirkland, 1992; Tallmon and Mills, 1994; McMillan and Kaufman, 1995; but see Barry et al., 1990; Mills, 1995).

While the distribution of woody debris is important for small mammals, it may be the decay stage of the CWD that determines its use. Maser et al. (1979), Ure and Maser (1982), and Maser and Trappe (1984) all indicate that there is an important relationship between fungi, decayed CWD, and mycophagous small mammals. Logs in an advanced stage of decay might provide microenvironments for small mammals

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to forage and nest (sensu Freedman et al., 1996). However, studies are few and results are not conclusive. For example, Tallmon and Mills (1994) find that *C. californicus* are associated with decayed logs, but Hayes and Cross (1987), also studying *C. californicus*, find no relationship with decayed logs. Gunderson (1959) demonstrates a positive association between rotting stumps and *C. gapperi*. Nordyke and Buskirk (1991) develop a predictive model directly relating log decay and *C. gapperi* abundance: 49% of variation in vole abundance is explained by the stage of log decay. Their study was at the forest stand scale, and did not address whether voles were actually associated with decayed logs within the stands.

We studied the relationship between decay stage of coarse woody debris and its use by small mammals. Use was assessed at two scales: (1) individual logs; and (2) forest stands. We predicted that small forest mammals would be closely associated with logs that were in an advanced stage of decay, as decadent logs should be good substrates for nesting, traveling, and foraging. We expected positive relationships between log decay and small-mammal abundance at both, log and stand scales.

2. Methods

The study took place on the Private Industrial forest of Fraser Papers, in the Appalachian forest of northwestern New Brunswick (47°22′ N, 67°25′ W). Upland sites were dominated by an overstory of sugar maple (*Acer saccharum*), yellow birch (*Betula allegheniensis*), and American beech (*Fagus grandifolia*). Lowland sites were dominated by black spruce (*Picea mariana*), white spruce (*Picea glauca*), and balsam fir (*Abies balsamea*).

2.1. Individual logs

Using a priori knowledge of the small mammal community gained during a concurrent study (Bowman et al., 1999), we selected three mature coniferous forest stands (primarily spruce and fir) with similar small mammal communities. Selected stands occurred in a forest with low management intensity (<15% recent plantations or clearcuts). Stand variability was minimized by selecting stands of equal age, tree species composition, location relative to drainage, and CWD distribution. In each of the three stands, line transects were conducted to select logs for small mammal sampling. Selected logs met the following requirements: (1) >10 m from adjacent log; (2) >3 m in length; and (3) >20 cm in diameter. We selected five logs in each stand from each of the five Maser scale decay classes (1 = sound, 5 = highly decayed; Maser et al., 1979). This approach left 25 logs around a central point in each stand, each log a minimum of 10 m from an adjacent log. Seventy-five logs were sampled over three stands.

The small mammal abundance at each log was sampled with a Sherman live trap. Traps were placed along the side of the log, in the ‘most likely runway’. Traps were prebaited for three days with a mixture of oats and sunflower hearts. We conducted two trapping sessions, on 17 July and 1 August, 1998. Traps were set for five consecutive days, and checked each morning and evening. Captures were weighed, identified as to sex and reproductive condition, marked with a 1-g monel ear tag (National Band and Tag, Newport, KA), and released at the same site.

We report trapping success for the log-scale study as number of captures/100 trap nights. The data did not appear normally distributed, so we analyzed for differences in small-mammal captures per log class using non-parametric Kruskall–Wallis analysis of variance. We only used small mammal species in analysis if the species was captured at a rate >1.0 capture per 100 trap nights.

2.2. Forest stands

We selected stands using a stratified systematic approach. We first selected two different study areas:

1. a reference area, with relatively low management intensity (recent clearcuts and plantations <15% of the landscape); and
2. an intensively managed area, where clearcuts, and softwood plantations covered >50% of the landscape.

Note that the log-scale study took place within the reference area. These two areas represent opposites in the continuum of management intensity. Both these areas were 4900 ha in extent. We placed sample points

1 km apart, in a square (8 × 8) grid: therefore, we had two square grids (reference and managed), each with 64 systematic sample points. In practice though, some points had missing data and for this analysis we had $N = 115$ different forest stands, representing a variety of stand types.

At each point we sampled coarse woody debris in six 20-m transects. Two paired transects were located at point center, while two other transects were located 70 m north and two more were located 70 m south of the center. All logs >8 cm in diameter and 1 m in length that crossed a transect were tallied. Different minimum diameters for CWD at the log and stand scales were chosen (8 cm vs. 20 cm); we wanted to characterize all the logs in the stand, and so we were more inclusive at this scale. There was no intention to quantitatively compare results from the two scales, so this difference should not be an issue. Logs were identified to species (where possible), and assigned a Maser-scale decay class. Logs from all six transects were summed from each sample point for statistical analysis.

We sampled the stands for small mammals from 10 May to 10 June, and from 15 August to 15 September, 1997. Five Victor Tin Cat repeating live traps (Woodstream, Lititz, PA) were used to survey each stand. One trap was placed at point center, and four other traps were placed in the cardinal directions at 35 m from center. All traps were placed in 'most likely runway' positions. All traps were prebaited for three days with oats and sunflower hearts. Traps were then set for four consecutive nights. Handling protocol was the same as at the log scale. The number of forest stands precluded us from trapping all the stations at once, so instead we prebaited and trapped all 115 stands within a four-week period.

Trapping success at the stand level was expressed as number of individuals per stand, considered a minimum estimate of abundance in each stand. Again, data did not appear normally distributed, so we proceeded with non-parametric analysis. Spearman rank correlations were used to explore the relationships between CWD variables and small mammal abundance. We only used small mammal species in analysis if the species was captured at a rate >1.0 individual per 100 trap nights. We conducted analyses on the reference and managed landscapes separately, and also on the combined sample.

3. Results

3.1. Individual Logs

A total of 741 trap nights at the log scale resulted in 142 captures of six species (Table 1). No significant relationships between any species of small mammal and the decay class of logs where they were captured were evident (Fig. 1). Further, there was no relationship between the total capture success of all species and log decay class (Fig. 1).

3.2. Forest Stands

A total of 5120 trap nights at the stand scale resulted in 1500 captures of 1015 individuals from eight species (Table 1). Spearman correlations demonstrated that there was no relationship between the mean decay class of logs from 115 different stands, and the number of individuals captured in those stands. This was consistent for all species and regardless of season or study landscape (Table 2; Fig. 2). Fig. 2 is representative of our results for the correlation of small mammal abundance and mean decay class. For simplicity, we present only results in Table 2 from our analysis of the combined study landscapes. The reference and managed landscapes were also analyzed separately, demonstrating no significant relationships. Using the same statistical approach, we detected no relationship between the abundance of

Table 1
Species caught during a small-mammal research project in northwestern New Brunswick

Species	Logs[a] August 1998	Stands[b] May 1997	August 1997
Clethrionomys gapperi	5.4	4.6	9.4
Peromyscus maniculatus	1.9	2.8	14.7
Napaeozapus insignis	4.7	1.1	<1.0
Zapus hudsonius	—	—	<1.0
Microtus pennsylvanicus	3.7	<1.0	<1.0
Microtus chrotorrhinus	—	<1.0	<1.0
Synaptomys cooperi	—	<1.0	<1.0
Blarina brevicauda	2.0	1.7	9.7
Sorex spp.	<1.0	<1.0	<1.0

[a] Captures/100 trap nights.
[b] Individuals/100 trap nights.

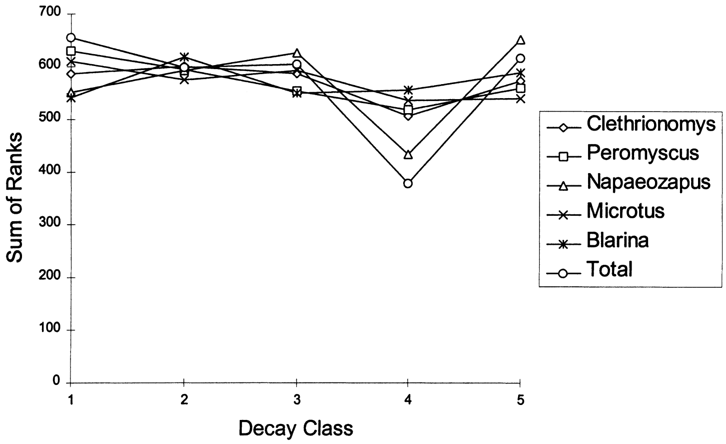

Fig. 1. Kruskal–Wallis rank sums for species captured adjacent to logs assigned one of the five different Maser et al. (1979) decay classes. No relationships were statistically significant ($p > 0.05$, $N = 75$).

CWD and the number of individuals captured in a stand (Table 2).

We also assessed whether relationships existed between small mammal species and the abundance of particular decay classes. Only class 5 logs (the most decayed) were significantly related to small mammal abundance, and so only class 5 logs will be discussed further here. When we considered the landscape context, we detected a positive relationship between the abundance of class 5 logs and the number of red-backed voles captured. On the intensively managed landscape, voles were significantly correlated with class 5 logs, both in spring ($r_s = 0.51$, $N = 58$, $p < 0.001$) and fall ($r_s = 0.40$, $N = 58$, $p < 0.01$). The relationship was not significant on the reference landscape in spring ($r_s = -0.07$, $N = 57$, $p > 0.05$) or fall ($r_s = 0.04$, $N = 57$, $p > 0.05$).

Table 2
Spearman correlation coefficients for relationships between small mammal abundance in 115 forest stands and (1) mean decay class of logs in the same stands, or (2) number of logs in the stands; no relationships were significant ($p > 0.05$, $N = 115$)

	Mean decay class		Number of logs	
Species	spring	fall	spring	fall
C. gapperi	−0.03	0.01	−0.03	0.12
P. maniculatus	0.02	0.06	−0.04	0.18
N. insignis	0.15	0.08	0.01	0.01
B. brevicauda	−0.11	−0.01	−0.05	0.04

4. Discussion

We detected no relationship between the decay stage of logs and the use of individual logs by small mammals. Thus, our work supports the conclusion of Hayes and Cross (1987) who find no relationship between small mammal activity at individual logs and log decay, using two classes of logs (hard vs.

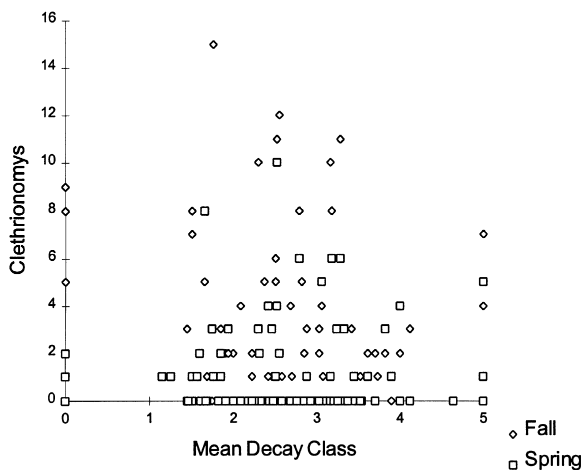

Fig. 2. Relationship between mean decay class of logs and abundance of *Clethrionomys gapperi* in 115 different forest stands in New Brunswick. The relationship was not significant in spring ($r_s = -0.03$, $N = 115$, $p > 0.05$) or fall ($r_s = 0.01$, $N = 115$, $p > 0.05$).

soft). Although we found that logs of all decay stages were used with equal intensity by small mammals, we suggest that the reasons for small mammals using logs would vary with decay stage. For example, red-backed voles will nest in rotted logs, while using the surface of sound logs as runways (Bowman, personal observations). Our study design did not tease apart these differences. We restrict our interpretation to say that the overall use of logs was consistent regardless of decay stage.

We have considered that small mammals were attracted artificially to logs by baited traps. However, small mammals are generally only attracted to traps from a small radius (e.g. Hayes and Cross, 1987) and in most cases this would mean they were already associated with the log.

At the stand scale, our study demonstrated no relationship between the abundance of any small-mammal species and either the abundance or mean decay class of logs, regardless of season or landscape (Table 2). Most studies that link the distribution of small-mammal species to the distribution of downed logs (e.g. Gunderson, 1959; Doyle, 1987; Tallmon and Mills, 1994) have dealt with microhabitat, whereas the stand-scale component of our study provided a broader view. Microhabitat associations may not translate across scales (Wiens et al., 1993). The results of our stand-scale study reflected the notoriously broad niches and the variable response to forest management of many small-mammal species (e.g. Martell and Radvanyi, 1977; Clough, 1987; Steventon et al., 1998).

Red-backed voles are linked to old-growth conditions, including decayed logs, by Nordyke and Buskirk (1991) and our findings at the stand scale add to their study. Nordyke and Buskirk model *Clethrionomys gapperi* abundance as a function of mean CWD decay stage in forest stands. We cannot support their model outright, based on our findings. However, we did detect an interesting relationship between *Clethrionomys* and decayed logs that may add to our understanding. Highly decayed logs were abundant in our reference landscape (Table 3). We believe that this abundance is why we found no relationship between *Clethrionomys* and log decay (sensu Nordyke and Buskirk 1991) in the reference area, either at the log or stand scales: CWD decay was not a limiting factor. On the intensively managed landscape highly decayed logs were rare (i.e. possibly limiting; Table 3). This is a result of silviculture practices which reduce the amount of mature forest and protective overhead cover, characteristics associated with highly decayed CWD (Gore and Patterson, 1986; Sturtevant et al., 1997). In particular, the practice of scarification removes a lot of CWD (Freedman et al., 1996). Many planted sites in the managed landscape were scarified. When class 5 logs were rare, a relationship with red-backed voles became apparent. In other words, the model of Nordyke and Buskirk (1991) may only apply to contexts where decayed CWD is relatively rare.

Table 3
The abundance of highly decayed logs (Maser scale class 5; Maser et al., 1979) in reference and intensively managed forests; the distributions were significantly different ($p < 0.001$; two sample Kolmogorov–Smirnov test)

Forest	Mean No. class 5 logs	SD
Reference	3.06	3.35
Managed	0.76	1.30

It is possible that the relationship between *Clethrionomys* and decayed logs is related to moisture balance. Red-backed voles have demanding water requirements (Getz, 1968) and this is believed to be a major reason why they are associated with mature forests, which are often high in moisture content (Franklin et al., 1981). These areas are also the last areas in a managed forest to have an abundance of decayed logs (Maser, 1990).

We suggest that future work could explore the causality of relationships at both, the log and stand scales. By isolating managed forests, where decayed logs are rare due to silviculture activities, the relationships between red-backed voles and class 5 logs could be explored experimentally.

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