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Influence of Canopy Closure and Shrub Coverage on Travel along Coarse Woody Debris by Eastern Chipmunks (Tamias striatus)

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ABSTRACT.—We investigated relationships between canopy closure, shrub cover and the use of coarse woody debris as a travel path by eastern chipmunks (*Tamias striatus*) in the north central United States. Fine scale movements of chipmunks were followed with tracking spools and the percentage of each movement path directly along coarse woody debris was recorded. Availability of coarse woody debris was estimated using line intercepts. We predicted that, if chipmunks used coarse woody debris to reduce their risk of predation, movement along coarse woody debris would be greater for animals tracked at sites with open canopies and thick shrub cover. Travel along coarse woody debris was negatively associated with canopy closure and positively associated with the percent of coarse woody debris available at a site and the percentage of shrub cover at a site. Sex and age of eastern chipmunks did not appear to influence the amount of use of coarse woody debris. Our results suggest that coarse woody debris is more important to chipmunks in areas with open canopies and thick shrubs and are consistent with the hypothesis that coarse woody debris provides chipmunks with some protection from predators.

INTRODUCTION

Coarse woody debris, such as fallen logs, snags, pieces of wood and branches, provides an important resource for many forest-dwelling small mammals (Harmon *et al.*, 1986). Indeed, positive associations have been established between the quantity of coarse woody debris and the abundance of several species of small mammals, including Richardson and Oregon voles (*Microtus richardsoni* and *M. oregoni*—Doyle, 1987); western red-backed vole (*Clethrionomys californicus*—Hayes and Cross, 1987); white-footed mouse (*Peromyscus leucopus*—Planz and Kirkland, 1992). Investigations on the importance of coarse woody debris have been conducted at a variety of spatial scales including both the forest stand (Clough, 1987; Carey and Johnson, 1995; Loeb, 1999; Butts and McComb, 2000) and micro site level (Doyle, 1987; Hayes and Cross, 1987; Graves *et al.*, 1988; Butts and McComb, 2000). Most of this work has occurred in the western United States and studies from other regions are limited (Loeb, 1996). For example, we are aware of only one study that investigated associations between coarse woody debris and eastern chipmunks (*Tamias striatus*—Dueser and Shugart, 1978). In that study, quantities of coarse woody debris did not differ between sites where chipmunks were captured and sites where no chipmunks were captured. However, work on western

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species such as townsend's chipmunk (*T. townsendii*—Carey, 1995) has demonstrated positive associations between chipmunk densities and levels of coarse woody debris.

Studies testing mechanistic hypotheses about the use of coarse woody debris provide insight into its functional role at the microhabitat level. Potential mechanisms for the use of coarse woody debris by small mammals include its importance as a foraging site (Ure and Maser, 1982; Tallmon and Mills, 1994), nesting site (Loeb, 1999), travel route (Douglas and Reinert, 1982), territorial marker (Zollner *et al.*, 1996) or refuge from potential predators (Doyle, 1987; Loeb, 1999). Mechanistic work on the use of coarse woody debris by small mammals in the eastern United States has focused on mice of the genus *Peromyscus* (McCay, 2000). Studies have demonstrated that white-footed mice use fallen logs and branches as landmarks for orientation and navigation (Barry and Franq, 1980; Drickamer and Stuart, 1984) and as pathways for travel (Graves *et al.*, 1988; Planz and Kirkland, 1992). Other investigators have suggested that mice travel along logs to reduce predation risk because movement on logs is more difficult for auditory predators to detect (Fitzgerald and Wolff, 1988; Barnum *et al.*, 1992; Roche *et al.*, 1999; McCay, 2000). Furthermore, the use of logs as landmarks and travel routes by mice may speed their movements between locations, reducing their risk of predation (McMillan and Kaufman, 1995). Such studies improve our understanding of relationships between small mammals and crucial habitat components and ultimately our ability to manage habitat for these species.

It has been demonstrated that small mammals use physical cover to reduce their risk of predation when in areas where they are more susceptible to predators (Lima, 1998; Kotler and Brown, 1988; Longland and Price, 1991; Smith, 1995). Coarse woody debris can serve this function for small mammals by providing a refuge when they are attacked by large predators such as birds of prey (Doyle, 1987; Loeb, 1999). Finally, small mammals that are elevated on coarse woody debris may have an improved ability to be vigilant for potential predators (Whitaker and Abrell, 1986). Thus, the purpose of this study was to assess the use of logs as travel routes by eastern chipmunks and examine the role of predation avoidance as a mechanism underlying this phenomenon. Chipmunks are known to be more vigilant (Mahan and Yahner, 1999), forage less (Bowers and Ellis, 1993) and more likely to be attacked by predators (Bowers, 1995) in sites with open canopies and thick shrub layers. Thus, we predicted that, if eastern chipmunks travel on coarse woody debris to reduce their risk of predation, then the use of coarse woody debris should be negatively associated with canopy closure and positively associated with shrub coverage.

METHODS

Our study was conducted in Oneida County, Wisconsin, during May–August 1999. Fifty-two chipmunks were tracked along three roadsides situated in northern hardwood forests of 30-to-50-y old trees with ground cover layers of ferns (*Pteridium*) and asters (*Aster*). At each roadside we established a transect of live-traps paralleling the road approximately 10 m into the woods. Transects at the three sites had different spacing among traps because of limited quantities of similar northern hardwood forests at each site. The first transect contained 13 trap stations with approximately 25 m between traps. The second contained 14 stations with approximately 50 m between traps and the third consisted of 16 trap stations with approximately 100 m between traps. The three transects were within 3 km of each other.

Chipmunks were captured using Sherman and Tomahawk live-traps baited with black oil sunflower seeds. Traps were open between 0600–1100 h. Upon capture, chipmunks were sexed and classified as adult or juvenile based upon body size and pelage. Then they were outfitted with a tracking spool and released at the site of capture. Tracking spools (1.7 g, 180 m, denier two-ply nylon No. 2 quilting bobbin; Barbour Threads Inc., Anniston, Al.)

were inserted into a balloon and glued to the back of the neck. This insured that the animal did not meet any resistance when it reached the end of the spool and that the animal was only left with a balloon glued to its fur for a few days (Zollner, 2000). The loose end of the thread from the tracking spool was tied to a permanent structure next to a release mechanism and the animal was placed inside the release mechanism through its open end, which was then closed. All releases were accomplished using a release mechanism constructed from a piece of PVC pipe that was 30 cm long and 6.5 cm in diameter. One end of the pipe was permanently sealed with opaque tape. The other end was capped and could be opened by pulling on a string from a distance of 10 m away. The thick forest environments allowed a successful release to be accomplished from a distance of only 10 m away. However, pilot work indicated that chipmunks usually remained within the mechanism for at least one hour after the cap was removed so the researchers presence should not have influenced these animals' movements.

Each tracking spool left a trail of thread recording the animal's movements after it exited the release mechanism. The day following release, we returned to the site and placed surveyor's flags at every point along the trail of thread where the animal changed directions and at 2 m intervals along straight stretches of movement. We followed all trails until they ended (either where the chipmunk entered a burrow or where the string ended or broke). A retractable tape measure and sighting compass were used to determine distance and bearing between successive flags. These measurements were then used to map the movements of the chipmunk. In turn, we used these maps to calculate the distance from each flag in the movement path to the site where the chipmunk was captured/released. When chipmunks were tracked to burrows, we calculated the distance from each flag along the movement pathway to the burrow. For each chipmunk we calculated the average distance (using each flag as a point) along its movement pathway from its release site. For animals that entered a burrow, we calculate the average distance from their burrow to each flag along the movement pathway.

While tracking chipmunks we noted all segments of the tracking thread that lay directly over logs and downed branches as movement along coarse woody debris. We also recorded the diameter of all coarse woody debris along which chipmunks traveled. These values were used to calculate the percentage of each path that occurred on coarse woody debris (size criteria >5 cm). We did not consider travel perpendicular to coarse woody debris as direct travel on it.

For each chipmunk released the percentage of ground covered by coarse woody debris was estimated from five transects. The first transect extended from the release site to the furthest point of movement away from the release site. The other four transects extended 40 m away from the release site in ordinal directions. Along each transect, we recorded the segments directly over coarse woody debris greater than 5 cm in size. We divided the sum of the segments that intersected coarse woody debris by the total length of transects to estimate the percent cover of coarse woody debris in the vicinity where each chipmunk was tracked.

We estimated the percentage canopy closure and the percentage of the ground cover at each release site. Percentage canopy closure was estimated as the average value of spherical densiometer measurements (Vora, 1988) while facing 90, 180, 270 and 360 degrees at each release site. Percentage of ground cover was estimated as the proportion of a 10-m north south transect centered on each release site that was covered by a herb/shrub layer of vegetation.

The influence of availability of logs at a site, canopy closure, herb/shrub cover, sex and age of chipmunks trapped on percent of travel along logs were examined with regression analyses. We used a stepwise variable selection procedure with a significance level of 0.15 for

TABLE 1.—Summary of parameter estimates and their tests for significance from the best linear regression model to explain the percent of chipmunk travel paths along coarse woody debris

Variable	Parameter	*F*	P =
Intercept	13.57	1.14	0.2921
Logs available	1.01	9.88	0.0030
Canopy closure	−0.23	3.39	0.0721
Shrub coverage	0.08	2.37	0.1308

entry into the model to determine the variables that best described the variation in the use of logs during travel by chipmunks. Studentized residuals, dffits and dfbetas values were used in influence diagnostics to identify and eliminate outlying observations. Pearson's correlation coefficient was used to determine if canopy closure and shrub cover were correlated and to determine if canopy closure and logs available were correlated. Variance inflation factors were used to determine if correlations between regressor variables caused problems with multicollinearity in the regression analysis. All percentages were arcsine transformed prior to analysis to insure homogeneity of variance and normally distributed data (Zar, 1999).

RESULTS

Fifty-two chipmunks were tracked at 30 release sites for an average of 107.2 ± 8.0 (SE) m. The average location of a chipmunk along a movement path was 18.7 ± 0.2 m from the site where the animals was captured and released. On average, 4.6 ± 0.7% of movements were along coarse woody debris (>5 cm in diameter). The average cover of coarse woody debris (>5 cm in diameter) was 4.2 ± 0.3% of the sample transects. We observed direct chipmunk movement along woody debris as small as 2 cm in diameter. However, movements along fine woody material (<5 cm) composed less than 5% of all movements along woody debris. Thus, we defined coarse woody debris as only material greater than 5 cm in diameter and excluded all measurement on woody material less than 5 cm in diameter from estimates of both use and availability. Twenty-three chipmunks were tracked to their burrows. Paths that reached burrows averaged 71.8 ± 7.8 m long and position of chipmunks along these paths averaged 15.1 ± 0.4 m away from the animal's burrow. At the first road site, 22 chipmunks (7 adult females, 3 juvenile females, 10 adult males and 2 juvenile males) were captured at 11 of the 13 trap stations. At the second site, 11 chipmunks (4 adult females, 2 juvenile females, 3 adult males and 2 juvenile males) were captured at 8 of the 14 trap stations. At the third site, 19 chipmunks (5 adult females, 6 juvenile females, 6 adult males and 2 juvenile males) were captured at 11 of the 16 trap stations.

The regression model that best fit the data indicated that use of coarse woody debris was positively associated with percent cover of logs and shrubs and negatively associated with percent canopy closure (Table 1). Sex and age were not included in the best model and were not good predictors of travel along coarse woody debris. Influence diagnostics conducted on the best model caused four observations to be discarded as outliers. These four observations had studentized residuals that exceeded a value of two, dffits that exceeded a value of 2*sqrt(p/n) and dfbetas greater than 2*sqrt(n) (SAS, 1988). The exclusion of these outliers improved the fit of the model but did not change the variables selected for the best model. The slope of the variables included in the regression model differed in the degree to which their estimates were statistically different from zero (Table 1), but the overall model composed was statistically significant and explained nearly 40% of the variation in chipmunk travel along logs ($F = 8.73$; $d.f. = 3$; $P < 0.0001$; $R^2 = 0.3731$).

TABLE 2.—Summary of statistics generated by the stepwise variable selection procedure when determining which variables produced the best model to predict percent of travel along coarse woody debris by chipmunks

Variable	Partial R^2	Model R^2	F	P =
Logs available	0.2619	0.2619	16.32	0.0002
Canopy closure	0.0775	0.3393	5.28	0.0263
Shrub coverage	0.0338	0.731	2.37	0.1308

Examination of the partial R^2 values (Table 2) revealed that percent coarse woody debris cover at a site explained most of the variation in travel along logs by chipmunks followed by canopy closure and finally shrub coverage. Correlation analyses revealed that canopy closure was correlated with shrub coverage ($r = -0.33698$, $P = 0.0146$) and that canopy cover was correlated with the availability of coarse woody debris ($r = -0.22217$, $P = 0.0333$), but variance inflation factors were less than 2 for all variables in the final model indicating that multicollinearity was not a concern in the regression model.

DISCUSSION

Our results demonstrated that eastern chipmunks travel on coarse woody debris more in areas where more coarse woody debris is present. Beyond the obvious influence of availability, our results suggest that open canopies and thick shrub layers result in higher use of coarse woody debris as travel pathways. These observations are consistent with an anti-predatory role for the use of coarse woody debris. Of course, the risk of predation a chipmunk faces at any point on the landscape is a complex function of both the animals state and numerous environmental characteristics including but not limited to the extent of local canopy closure and shrub coverage. Furthermore, coarse woody debris undoubtedly serves several functions for eastern chipmunks and, thus, we are not surprised that the significant regression model for canopy closure did not explain all of the variation in travel along coarse woody debris.

Our results suggest a relationship between travel along coarse woody debris by eastern chipmunks and canopy closure that has implications for the response of chipmunks to forest management practices. Coarse woody debris is a feature that can be easily manipulated during forest management for the benefit of wildlife (McCay, 2000). Our results suggest that eastern chipmunks may benefit most from prescribed levels of coarse woody debris in forests with open canopies and thick shrub layers. Thus, coarse woody debris is likely to be most important for chipmunks immediately following even aged harvests. Clear cuts are known to influence the behavior of individual chipmunks (Mahan and Yahner, 1999) and our results suggest that levels of residual coarse woody debris in a stand may affect important demographic parameters such as survivorship.

Several factors may have influenced our results. Seasonal and annual fluctuations in factors such as the intensity of intra-specific interactions, lushness of ground cover vegetation or quantity of leaf litter on the forest floor also may have influenced the use of coarse woody debris by our study subjects. However, trapping sites were placed systematically and animals were tracked as they were captured at these sites so there should not have been any bias associated with the timing of our data collection relative to canopy closure. We also could have used a more liberal (>2 cm diameter) or conservative (<10 cm diameter) definition of coarse woody debris. However, preliminary analyses indicate that as long as we used the same criteria to define used and available coarse woody debris our results were not

sensitive to the level used. Additionally, we could have included (perpendicular) movements across coarse woody debris in our estimates of use. This may have improved the significance of the statistical associations we observed but it would not have changed our interpretation of the data. Thus, we elected to limit our inference to clear travel along coarse woody debris by chipmunks. Finally, tracking spools only record where an animal travels and not how much time it spends on coarse woody debris. Thus, we cannot distinguish between chipmunks using coarse woody debris as resting sites and those traveling along it quickly.

It is also possible that the tracking spools influenced the behavior of the chipmunks and caused them to act atypically. However, numerous authors have suggested that tracking spools provide an excellent means to assess habitat selection by small mammals (Boonstra and Craine, 1986; Key and Woods, 1996). If our use of this technique affected the chipmunks negatively, we expect that they would have returned to their burrows immediately and groomed the spools off. Instead, many of the chipmunks we tracked never entered burrows. Furthermore, we tracked all of the chipmunks for long distances with no indication that they were moving atypically.

By examining fine scale movements of individual animals, we have provided mechanistic insight not available through larger scale phenomenological studies. Our results are consistant with the hypothesis that coarse woody debris is less important to eastern chipmunks in forests where their risk of predation is lower. We suggest that the benefit of leaving residual coarse woody debris will be greatest for eastern chipmunks following management practices that create open canopy conditions.

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