Numerous studies of forest fragmentation have found a negative relationship between density of Peromyscus leucopus and forest fragment size. This relationship may be caused by both more food, and more cover from predation in smaller fragments, which have more structurally complex understory vegetation than larger fragments. However, we do not know the extent to which the proximity of understory vegetation affects selection of nesting sites within fragments. We hypothesized that nest boxes in highly vegetated areas would be utilized more often by P. leucopus than nest boxes in sparsely vegetated areas. We tested this hypothesis by measuring the amount of vegetation near thirty nest boxes in each of nine forest fragments. We also estimated the relative population density of P. leucopus in each fragment. We expected to find both a greater proportion of nest boxes occupied and a greater number of mice in nest boxes with a high amount of nearby vegetation. In our nine study sites in southwest Ohio, the structural complexity of understory vegetation was significantly greater in small forest fragments than in large and in edge habitat than interior. However, there was no relationship between any of the variables we measured, such as soil moisture and tree diameter, in the immediate vicinity of nest boxes and the density of mice. In edge habitat and larger fragments, the population density of mice was greater and nest boxes were more frequently occupied. Our results suggest that the complexity of vegetation immediately surrounding the nest box may not be as important to mice as vegetation at a larger scale (throughout an individual’s territory).

INTRODUCTION

Prior to the 18th century, forests covered most of the eastern half of the United States. However, since then, many parts of forests have been removed for farming and other purposes, leaving isolated forest fragments. Fragmentation can have a negative impact on the population dynamics of native species (Yahner, 1988). Decreased resource availability, decreased genetic diversity, and ultimately local or wide-range extinctions are some of the negative consequences of habitat fragmentation (Banks et al., 2007).

Interestingly, some species appear to be unaffected by forest fragmentation, and some seem to benefit from it (Yahner, 1988). Peromyscus leucopus, the white-footed mouse, is one species for which population density is inversely associated with the size of forest fragments (Anderson et al., 2003). This unusual relationship may be important, because white-footed mice fill several ecological roles in the forest, including those of prey, predator, and competitor (Fanson, 2010; Marcello et al., 2008). In addition to their integral role in the food web, P. leucopus is also useful as an indicator species for the health of the environment in which they reside, as they thrive in disturbed habitats (Phelps and McBee, 2009).

Several studies have shown that there is a negative relationship between the density of P. leucopus and forest fragment size; in other words, smaller fragments have more mice per hectare than larger fragments (Anderson et al., 2003; Nupp and Swihart 1996, 1998, 2000; Yahner, 1992). This is thought to be due, in part, to the fact that small forest fragments have a greater complexity of understory vegetation than do larger fragments (Anderson and Meikle, 2006). Vegetation plays a fundamental role in the survival of P. leucopus, as it provides both food-, in the form of nuts, fruits, and insects-, and shelter from predators (Anderson et al., 2003; Gehlhausen et al., 2000; Graves et al., 1988; Kaufman et al., 1983; Ranney et al., 1981). In fact, individuals tend to avoid areas of their home ranges that do not provide sufficient cover from predators (Barnum et al., 1992; Kaufman et al., 1983). Trees and shrubs provide covered pathways for travel, vertical escape routes from predators, and locations for nest construction (Barnum et al., 1992; Graves et al., 1988; Kaufman et al., 1983; Kaufman et al., 1985; Yahner, 1985), which results in a higher rate of reproduction and population density for P. leucopus in areas of greater vegetation complexity (Anderson et al., 2003; Wilder and Meikle, 2005, 2006).

In addition to living vegetation, coarse woody debris (e.g., fallen logs and stumps) are beneficial to P. leucopus. Mice tend to choose large (> 5 cm) logs for travel, because they can move without auditory detection by predators by avoiding leaf litter on the ground, and they can easily keep their balance on the wider logs (Barnum et al., 1992). Additionally, mice use coarse woody debris as orientation guides to navigate through the habitat (Barry and Francq, 1980). Coarse woody debris also can provide food in the form of insects and fungi (Greenberg, 2002). In general, the micro distribution of P. leucopus is positively influenced by the presence of coarse woody debris (Greenberg, 2002).
Because Anderson and Meikle (2006) argued that a greater complexity of understory vegetation leads to a greater relative density of mice, and since because previous research has indicated that microhabitat use by P. leucopus is related to the surrounding vegetation (Barnum et al., 1992; Kitchings and Levy, 1981), we hypothesized that the immediate surrounding vegetation would affect the occupancy rate of each nest box in our study sites. P. leucopus was utilized as the study subject as it is the major, if not only, mouse species in the study area. We predicted that more mice would be found in the nest boxes near the greatest amount of vegetation. We also predicted that more mice would be captured in nest boxes near the greatest amount of coarse woody debris.

MATERIALS AND METHODS

Study site
Nine fragments of secondary-growth deciduous forest within 25 km of Oxford, Ohio, U.S.A. were used for the study. The trees in the forest patches were of similar age, as estimated by mean basal area of trees among patches (Anderson et al., 2006). As a part of another study, the fragments were designated as either large (>100 ha) or small (~1-2 ha), and were separated from the nearest study fragment by at least 1 km and from other forested areas by at least 50 m (Marcello et al., 2008). We compared the small fragments against the large.

Relative population density of mice
Each fragment had fifteen nest boxes in the edge and fifteen nest boxes in the interior, for a total of 270 boxes for the nine fragments. Edge habitat was defined as being within 15 m of the field/forest transition and was based on differences in the complexity of the understory vegetation (Anderson et al., 2003; Marcello et al., 2008; Wilder and Meikle, 2005). The nest boxes were approximately 15 m apart, and each was hung on a tree at a height of ~1.5 m. Nest boxes (15 x 15 x 15 cm) were made of wood with two 2.5 cm openings. In addition, nest boxes were filled with a polyester fiberfill for mouse bedding (Marcello et al., 2008). The use of nest boxes allowed the capture of mice with a minimum of stress to the animals (Wild and Meikle, 2005).

Censusing and collection of data on mice were performed as outlined in Marcello et al. (2008). Mice were captured individually in a plastic bag and scanned for the presence of a passive integrated transponder (PIT tag; AVID®). Data for each mouse included weight, body and tail length, sex, and reproductive status. New captures (if ≥ 8 g, no PIT tag present) were lightly anesthetized with isoflurane and injected with a PIT tag subcutaneously in the interscapular area (see Anderson et al., 2003; Marcello et al., 2008; Wilder and Meikle, 2005). Animals less than 8 g were not tagged or included in the census. Instead, their collective weight was recorded with the data of the reproductive female found in the same nest box (Marcello et al., 2008). Censuses were taken from the nest boxes from April 2008 until November 2008, for a total of six censuses.

The Institutional Animal Care and Use Committee of Miami University had approved these methods (protocol number 726).

Complexity of understory vegetation
The vegetation measurement used in our study was performed in August 2008. For each nest box, four measurements were obtained 2 m from the nest box (to the north, south, east, and west) in a method similar to Anderson and Meikle (2006). A 2 m vertical rod marked at half-meter intervals was placed at each of the four compass points around the nest box tree. The number of the four sections on the pole that were contacted by vegetation was recorded for a possible total of four. For example, a vegetation score of two meant that the pole was contacted by vegetation somewhere in two of the four half-meter sections. If one of the standard measured points was in the matrix (e.g. corn, soybeans, pasture), the measurement was not included in the average score for that nest box. Vegetation scores for each nest box were averaged to obtain a total vegetation score for each nest box for comparison with scores of other nest boxes. Coarse woody debris was also recorded at each compass point by counting all woody debris greater than 1 cm in a six-centimeter radius around the bottom of the vegetation pole. It was then summed for the four points the rod was placed. In addition, diameter at breast height was obtained for each tree that contained a nest box, and a soil moisture measurement was taken using a Lincoln soil moisture meter at the base of each nest box tree.

RESULTS

The relationship between microhabitat characteristics and relative density of mice was tested in two ways. In the first analysis, only data from the two population censuses immediately before and after the vegetation check were used (a census in July and a census in August). In this analysis, we assumed that the vegetation only remained during a narrow window of time encompassed by censuses before and after the vegetation measurement. In the second analysis, data from all six P. leucopus censuses were used. For the second analysis, it was assumed that the values for the single measurement of vegetation complexity were representative of the relative complexity of vegetation throughout the year.

The relative density of mice (for two censuses and for six censuses) was analyzed using an analysis of variance (ANOVA) with fragment size, habitat type (edge or interior), coarse woody debris, diameter at breast height, mean vegetation score, mean soil moisture, and number of mice in the habitat as factors all in the same model (ANOVA: PROC MIXED, SAS Institute). A logistic regression was performed (PROC GENMOD, SAS Institute) to determine whether any of the above factors influenced the probability of each box being occupied. Mean vegetation score, coarse woody debris, diameter at breast height, and mean soil moisture were individually analyzed using an ANOVA with fragment size, habitat type (edge or interior),
and number of mice in the habitat as factors in the model. Only statistically significant interactions are reported.

The relative population density census data immediately before and after the vegetation measurement indicated that nest boxes in habitats (edge or interior) with a greater population density of *P. leucopus* were more likely to be occupied ($X^2 = 4.75, df = 1, p < 0.0001$) and were occupied by more mice simultaneously ($F(6, 244) = 3.14, p = 0.006$). However, there was no relationship between any of the other variables we measured (vegetation, coarse woody debris, diameter at breast height, or soil moisture) and the relative density of mice in relation to the nest box (all $p > 0.1$). Likewise, none of the variables we measured were related to the probability of the nest box being occupied (all $p > 0.1$). The structural complexity of understory vegetation was significantly greater in small forest fragments than in large ($F(1, 253) = 4.64, p = 0.03$) and in edge habitat than interior ($F(1, 253) = 35.11, p < 0.0001$; Figure 1).

**Figure 1.** A comparison of the structural complexity of understory vegetation in nine forest fragments outside of Oxford, OH. Vegetation is significantly greater in small fragments than large fragments and in edge habitat than interior habitat.

When we pooled the data from all six censuses in relation to the vegetation measurement, we obtained similar results. Nest boxes in habitats (edge or interior) with a greater population density of *P. leucopus* were more likely to be occupied ($X^2 = 8.24, df = 1, p = 0.004$). Additionally, there was no relationship between any of the other variables we measured (vegetation, coarse woody debris, diameter at breast height, or soil moisture) and the relative density of mice in relation to the nest box (all $p > 0.1$). Likewise, none of the variables we measured were related to the probability of the nest box being occupied (all $p > 0.1$).

**DISCUSSION**

The greater complexity of understory vegetation in the edge versus the interior found in this study is consistent with previous findings (Anderson et al., 2003; Anderson and Meikle, 2006; Burke and Nol, 1998). Although understory vegetation complexity was related to both fragment size and habitat type (Figure 1), the population density of *Peromyscus leucopus* was not related to the structural complexity of understory vegetation, either in the forest fragment overall or specifically near the nest box. No relationship was found between the population density, the nest box occupancy, and the other variables tested, such as coarse woody debris. There could be several explanations for these findings.

One factor that may have contributed to the lack of relationship between nest box occupancy and the relative density of *P. leucopus* may be that the 2 m area around each nest box tree was too small an area to determine if the vegetation in the immediate area surrounding the tree had any effect on occupancy rates. The home ranges of *P. leucopus* are much bigger than the area sampled (averaged around 590m²; Wolff, 1985), and *P. leucopus* is known to travel throughout its territory to find food. Perhaps the vegetation immediately surrounding where *P. leucopus* nests is not indicative of its nesting choices; instead, there may be other factors influencing the choice of nest placement, such as specific species of vegetation or a particular location within an individual’s territory.

Research by Barnum et al. (1992) indicates that *P. leucopus* prefer logs that are greater than 5 cm in diameter for path selection. This could have implications for the current project in two ways. When measuring coarse woody debris in this study, all logs and sticks that were at least 1 cm in diameter were counted, and we found no relationship between our coarse woody debris measurements and the population density of *P. leucopus*. In future studies, only logs greater than 5 cm should be enumerated, as those are of the most importance to *P. leucopus* (Barnum et al., 1992). In addition, we found that there was no influence of the diameter of the nest box tree on the distribution of mice. Perhaps *P. leucopus* prefers all woody vegetation greater than 5 cm in diameter, and as all of the nest box trees were much greater in diameter than this, we did not see an effect.

Another factor influencing these results could be that our estimate of vegetation complexity is based on one measurement of vegetation. This measurement was done in August, when the growing season is coming to an end in the study area. Vegetation is likely to vary over the course of the growing season and may influence the choice of microhabitat over a longer time period (e.g., spring to fall). Various herbaceous species are present at different times over the growing season, and cover utilized as protection may change. In future studies, vegetation should be measured at each population census for *P. leucopus*, in order to test for a correlation between the nest box occupancies and the amount of vegetation at each check.

Our results indicate that future studies should focus on the effects of vegetation in close proximity to nesting sites over a
longer time period. This would provide a better estimate of the effects of each aspect of the environment on densities of *P. leucopus* and of preferential nest box locations. Observing nest box occupancies over time in relation to variable vegetation growth, soil moisture, and coarse woody debris would eliminate possible biases created by a single check. Overall, in the 270 nest boxes, we found that mice appear to be influenced by vegetation, but possibly at a larger scale than the small area immediately adjacent to their nesting sites. The vegetation located in their entire home range may be more influential than that in the immediate area.

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**REFERENCES**


