THE SEASONAL EFFECTS OF VEGETATION COVER AND FOOD AVAILABILITY ON WHITE-FOOTED DEER MOUSE NEST BOX OCCUPANCY IN URBAN FOREST FRAGMENTS

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Bachelor of Science in Wildlife Conservation with Distinction

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ABSTRACT

White-footed deer mice (*Peromyscus leucopus*) are common inhabitants of urban forest fragments in Newark, Delaware, USA. Wooden nest boxes were used to study occupancy in 8 study sites characterized by small patch size and multiflora rose (*Rosa multiflora*) from September 2013 to May 2014. Microhabitat features including cover and food availability were measured around nest boxes using Nudds boards, a factor-10 wedge prism, and ground mast samples. Fall and winter occupancy were compared to seasonal vegetation density, hard mast biomass, and rose hip biomass in the software program PRESENCE. White-footed deer mouse nest box occupancy in fall was positively related to vegetation density measured in June. Winter occupancy was not related to cover or food covariates. Areas with dense summer vegetation cover, which provides refuge from predators, have greater occupancy of white-footed deer mice. Implications for other wildlife species should be considered before dense vegetation cover is managed in urban forest fragments.
Chapter 1

INTRODUCTION

The white-footed deer mouse (*Peromyscus leucopus*) is known for its opportunistic use of small wooded patches of land that have been fragmented by agriculture and human development. Human development and habitat degradation have broken large continuous forests into smaller sections known as forest fragments (Murcia 1995). Invasion by non-native plants is one ecological edge effect of forest fragments that usually results in dense vegetation growth (Murcia 1995; Dutra et al. 2011). Multiflora rose (*Rosa multiflora*) is a ubiquitous invasive plant found along forest edges and hedgerows that has spread across the United States (Schulz and Gray 2013). Urban forest fragments in Newark, Delaware have a high invasive plant species composition from continuous disturbance, with multiflora rose being especially abundant in most areas (Weinberg and Roth 1998).

Rose bushes produce fruit called rose hips that ripen in autumn and persist through winter (Chupp et al. 2013). Mice are attracted to the dense cover that woody plants such as multiflora rose provide, where they can forage on rose hips and other seeds (Stone and Cram 1902; Hamilton 1941; Meiners and LoGiudice 2003; Chupp et al. 2013). Rose hips may be additionally desirable due to their high vitamin C content (Barlow 1941). *R. multiflora* is also unique in that its foliage stays green later in the fall.
season and leafs-out earlier in spring, providing better cover for a longer period of time. White-footed deer mice are strongly influenced by dense shrubs and mouse activity has been positively related to densely-vegetated areas (Meiners and LoGiudice 2003; Chupp et al. 2013). White-footed deer mice use food resources such as hips and hard mast to survive through winter and reproduce during a spring breeding peak (Kesner and Linzey 1997; Vessey and Vessey 2007). Hard mast such as acorns, beech nuts, and hickory nuts are a desirable food source for white-footed deer mice (Hamilton 1941). Nuts are produced in autumn and can be cached through the winter in larders stored in or near mouse nests (Hamilton 1941).

Populations of white-footed deer mice in forest fragments are easily studied using wooden nest boxes that are affixed to trees in forested areas (Nicholson 1941; Barry and Francq 1980; Goundie and Vessey 1986; Wolff and Durr 1986; Rose and Walke 1988; Morris 1991; Kesner and Linzey 1997; Lewellen and Vessey 1999; Morris and Davidson 2000; Wilder et al. 2005; Vessey and Vessey 2007). Nest boxes are advantageous because they can be used throughout the year and have less negative impacts on survival than live traps (Nupp and Swihart 1995; Kesner and Linzey 1997; Lewellen and Vessey 1999; Vessey and Vessey 2007). However, population density estimates of mice using nest boxes are not consistent, and have found to be lower in summer months and higher in winter (Lewellen and Vessey 1999). White-footed deer mouse nesting locations shift vertically during autumn to areas closer to the ground (Nicholson 1941; Wolff and Hurlbutt 1982; Madison et al. 1984). Mice show preference for nesting in trees with larger DBH and in sites with more woody debris
and dense vegetation (Barry and Francq 1980; Wolff and Hurlbutt 1982; Rose and Walke 1988). Supplementation of nest boxes with food has been shown to increase signs of use by mice (Rose and Walke 1988). However, most researchers using only nest box stuffing were successful in attracting mice to survey occupancy (Nicholson 1941; Lewellen and Vessey 1999; Vessey and Vessey 2007).

The objective of this research was to investigate the relative influence of food and cover on mouse nest box occupancy during fall and winter. Specifically, food and cover variables included multiflora rose hip biomass, hard mast biomass, hard mast basal area, and understory vegetation density. Null hypotheses stated the aforementioned factors would have no effect on mouse box occupancy. The working hypotheses of this research were that nest boxes with greater food availability, measured by multiflora rose hip biomass and hard mast biomass, would have greater occupancy. Greater occupancy was also predicted for areas with dense vegetation cover and more hard mast basal area surrounding nest boxes. Since use of nest boxes is influenced by season, the phenology of mast availability and vegetation density were thought to be the most influential microhabitat factors to result in nest box occupancy differences. Although prior studies have indicated that a dense understory is likely to host a large white-footed deer mouse population, other microhabitat characteristics in urban forest fragments have not previously been investigated to determine what influences occupancy of nest boxes by mice (Chupp et al. 2013).
Chapter 2
STUDY AREA

I conducted field research in 8 study sites in Newark, Delaware, USA. The sites included Ecology Woods (16.6 ha), Christina Creek (12.7 ha), Coverdale Farm (2,553.8 ha), Glasgow (75.6 ha), Iron Hill (150.1 ha), Reservoir (53.3 ha), Motorpool (5.9 ha), and White Clay Creek (163.6 ha). These urban forest sites represent the fragmented landscape around the city of Newark. Each fragment was surrounded by matrix including agricultural farms, mowed grass, residential areas, walking paths, pavement, roads, and fences (Weinberg and Roth 1998). The tree composition of all study sites was mainly sweet gum (*Liquidambar styraciflua*), maple (*Acer spp.*), oak (*Quercus spp.*), hickory (*Carya spp.*), tulip poplar (*Liriodendron tulipifera*) and beech (*Fraxinus americanus*). Midstory trees included ironwood (*Carpinus caroliniana*), black cherry (*Prunus serotina*), and cinnamon clethra (*Clethra acuminata*). The understory layer was composed of spicebush (*Lindera benzoin*), *Viburnum spp.*, multiflora rose (*R. multiflora*), greenbrier (*Smilax rotundifolia*), poison ivy (*Toxicodendron radicans*), sweet pepperbush (*Clethra alnifolia*), Japanese wineberry (*Rubus phoenicosius*), *Vaccinium spp.*., and blackberry (*Rubus fruticosus*). Ground-cover vegetation included mayapple (*Podophyllum peltatum*), Japanese pachysandra (*Pachysandra terminalis*), nettles (*Urtica dioica*), jack-in-the-pulpit (*Arisaema triphyllum*), and Japanese stiltgrass (*Microstegium vimneum*).
The study was conducted during a year with an unusually harsh winter.

Newark received 142.5 cm of snow from December 2013 to March 2014. The average high temperature was 28.7°C for summer and 16.4°C for fall. Winter and spring months (Feb-May) had an average of 13.6°C. For the entire study period, the maximum high temperature was 36.1°C and the minimum low temperature was −13.3°C (Lawrimore et al. 2011).
Chapter 3

METHODS

I deployed wooden mouse nest boxes within each study site in April and May 2013. I checked a total of 127 nest boxes divided among 8 sites from September–December 2013 and February–May 2014 (Table 1). Each mouse nest box was made of cypress and stuffed loosely with synthetic stuffing. They measured 15 x 15 x 15 cm in dimension, with a roof slanted toward the front face of the box and held onto the box by two screws. Circular holes measuring 2.5 cm in diameter were drilled on both the left and right sides of the boxes. I attached nest boxes to trees 1.5 m from the ground on hooks that were fastened around a tree using wire. I selected a tree to use by determining which tree was nearest to the grid point flag that was at least the width of the nest box in diameter. The points in each study site where boxes were deployed are on a square grid system; boxes were always at least 25 m away from the next nest box. I hung nest boxes in a direction facing the grid point flag.

When I checked each nest box, I first inserted rubber stoppers into the holes on each side. I loosened a screw on the roof of the box so that it could swivel open around the other screw, then checked each box for occupancy by moving the nesting materials gently. If a mouse was present, I emptied the nest box contents into a plastic bin and individual mice were counted. I weighed, sexed, and aged each mouse before returning it to its box for the months of September, October, November, and May. I followed the Institutional Animal Care and Use Committee protocol for mouse
handling (AUP number 1249-2013-0) for this data collection. I placed each nest box back on its original tree, removed the rubber stoppers from the side entrances, and screwed each roof shut before checking another nest box.

I visited each site a total of 11 times. I checked mouse nest boxes at each site once a month for a period of one year, from June 2013 to May 2014 (excluding January). I attempted to complete mouse nest checks within a period of 10 days for each month. For this study, only September 2013 to May 2014 occupancy data was used. September-December data was used for the “fall” season and February-May data was used for “winter.”

In October 2013, I measured food availability around each nest box by collecting ground samples of hard mast and multiflora rose hips. Hard mast included acorns, beech nuts, and hickory nuts. Soft masts other than rose hips, such as Berberis thunbergii berries and jack-in-the-pulpit fruit, were rarely encountered and not collected. Samples were taken using a 1-m² PVC sampling square 12.5 m north and south of each box. I gathered all potentially viable mast within the sampling square. I froze hard mast and rose hips in plastic bags after they were collected, then dried the viable samples for approximately one week in a laboratory oven at approximately 100°C. Samples were weighed once dry. Biomasses of hard mast and rose hips were averaged for each nest box.

I sampled vegetation density using Nudds boards at each cardinal direction 12.5 m from mouse nest boxes during summer leaf-out in June 2013 and during winter defoliation in March 2014. Nudds boards were two plywood panels 1 m x 0.3 m in dimension, with the top 0.5 m painted black and bottom 0.5 half painted white to create a checkerboard pattern when held vertically stacked (Nudds 1977). I held the
stacked boards for volunteer observers to obtain a measure of vegetation density of the
understory within 6 m of the ground. Volunteers quantified the observed amount of
vegetation that covered each panel as a percentage. Vegetation density measurements
were averaged around each box to create an estimate for overall vegetation density at
each box. Percent rose cover was estimated in June 2013 by assessing amount of *R.
multiflora* ground cover at each box point within a 12.5 m radius to represent the
approximate size of a mouse’s home range (Wolff 1985). Using a factor-10 wedge
prism, I quantified basal area and basal hard mast at each mouse box in March 2014.
Weather data were recorded in the field.

I assessed correlation between covariates using a correlation matrix in
Microsoft Excel before I generated occupancy models. Due to correlation between
some of the variables, the only covariates I used for box occupancy (Ψ) included
summer vegetation density, winter vegetation density, multiflora rose hip biomass, and
hard mast biomass.

Using software program PRESENCE, I ran single-season models for
occupancy with rose hip biomass, hard mast biomass, and vegetation density as
covariates for both fall (Sept-Dec) and winter (Feb-May) occupancy (PRESENCE
September 2014). I used each visit’s average temperature, Julian date, and time of day
as covariates to model detection probability (P) using PRESENCE software.
PRESENCE is a free program provided by the U.S. Geological Survey that is able to
use binomial and multinomial occupancy data to estimate patch occupancy rates and
detection probability. Models with low AIC values are the best models, out of all
models run by PRESENCE in each set, to predict occupancy (Aikaike 1974).
Additional analyses must be conducted to determine the amount of variance each covariate is able to explain.
Chapter 4

RESULTS

The number of mice detected in each site per month varied greatly over the course of the study period. October had the greatest occupancy, and April the lowest. More mice were detected overall in Christina Creek, and this site also had the highest average nest box occupancy. White Clay Creek had the second-highest average nest box occupancy; it was equal to Christina Creek for maximum number of mice detected per nest box. Motorpool, the smallest study site, had the lowest occupancy (Figure 1).

Vegetation density on average was highest for both fall (74.57%) and winter (32.07%) in Christina Creek (Figure 2). The lowest vegetation density was in Reservoir in fall (21.53%) and Iron Hill in winter (6.95%). Rose hip biomass and rose cover percent were both greatest in Christina Creek. Iron Hill was the site with the greatest hard mast basal area (40.17 m²/ha). White Clay Creek had the greatest hard mast biomass from ground samples. I noticed food caches of rose hips inside nest boxes during the study period, ranging from a few hips to several dozen. Acorns, beech nuts, and hickory nuts were also cached in larders in sites where hard mast was more abundant.

No covariates were found to have influenced detection probability, so detection probability was held constant in all models. After creating a correlation matrix in Microsoft Excel, I found fall vegetation density measurements to be correlated (> 0.45) with basal area, hard mast basal area, and rose cover. Vegetation density in
winter was correlated with basal area and hard mast basal area, but not rose cover. 
Vegetation density and rose cover were positively correlated (0.459) in fall (Figure 3). Rose hips and rose cover were correlated (0.375); rose hip biomass and hard mast biomass were not correlated (-0.07). No correlated variables were run in the same model set, which is why vegetation cover, rose hip biomass, and hard mass biomass were the covariates selected to model in PRESENCE.

The best model to predict fall occupancy used fall vegetation density (Table 2). Mouse abundance was also positively correlated with vegetation density in both fall and winter (Figure 4). However, vegetation density was not related to occupancy in winter based on PRESENCE analysis (Table 3). Fall vegetation density, which used summer Nudds board measurements, explained 26.93% of variance in fall abundance (Figure 4). In winter, rose hip biomass and hard mast biomass were not strongly related with occupancy. Rose hips explained 12.65% and hard mast 2.18% of variability in winter mouse abundance. Additionally, neither rose hips nor hard mast was a good predictor for occupancy since their model AIC values were similar to the null model (Table 3).
Table 1  Number of boxes deployed per study site with landscape metrics associated with each site.

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Boxes (#)</th>
<th>Study Site Size (ha)</th>
<th>Nest Box Sampling Area (ha)</th>
<th>Rose Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christina Creek (CC2)</td>
<td>17</td>
<td>12.7</td>
<td>8.2</td>
<td>57.67%</td>
</tr>
<tr>
<td>Coverdale (CD)</td>
<td>15</td>
<td>2,553.8</td>
<td>6.2</td>
<td>45.69%</td>
</tr>
<tr>
<td>Ecology Woods (EW)</td>
<td>20</td>
<td>16.6</td>
<td>16.2</td>
<td>13.48%</td>
</tr>
<tr>
<td>Glasgow (GG2)</td>
<td>15</td>
<td>75.6</td>
<td>4.7</td>
<td>0.00%</td>
</tr>
<tr>
<td>Iron Hill (IH2)</td>
<td>15</td>
<td>150.1</td>
<td>5.1</td>
<td>0.07%</td>
</tr>
<tr>
<td>Motorpool (MP)</td>
<td>15</td>
<td>5.9</td>
<td>5.1</td>
<td>41.13%</td>
</tr>
<tr>
<td>Reservoir (RE)</td>
<td>15</td>
<td>53.3</td>
<td>5.0</td>
<td>3.16%</td>
</tr>
<tr>
<td>White Clay Creek (WC1)</td>
<td>15</td>
<td>163.6</td>
<td>5.2</td>
<td>0.80%</td>
</tr>
</tbody>
</table>

Figure 1  Box plot of mouse abundance per nest box in each study site for fall and winter. Boxes in the figure represent the first quartile, median, and third quartile of mice detected. Whiskers show the minimum and maximum number of mice.
Figure 2  Vegetation density for fall and winter at each study site. Nudds board measurements were averaged around each nest box.

Figure 3  Correlation between rose cover and fall vegetation density. The correlation between the two covariates is 0.4593. Heteroscedasticity of data prevented regression analysis; Spearman’s rank correlation is 0.47.
Correlation between vegetation density and mouse abundance for fall and winter. Mouse abundance was summed and divided by number of boxes in each study site. For fall, R-squared is 0.1676. Winter R-squared is 0.1240.

Fall occupancy modeling results using fall vegetation density, rose hip biomass, and hard mast biomass as covariates. The model set includes a null and global model. AIC, ΔAIC, AIC weight, number of parameters, and twice the negative log likelihood are provided in the table for each covariate model.

<table>
<thead>
<tr>
<th>Covariate</th>
<th>AIC</th>
<th>ΔAIC</th>
<th>AIC Wgt.</th>
<th>No. Par.</th>
<th>-2* LogLike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall vegetation density</td>
<td>559.65</td>
<td>0.00</td>
<td>0.8177</td>
<td>2</td>
<td>555.65</td>
</tr>
<tr>
<td>Global (all covariates)</td>
<td>563.48</td>
<td>3.83</td>
<td>0.1205</td>
<td>4</td>
<td>555.48</td>
</tr>
<tr>
<td>Null</td>
<td>564.88</td>
<td>5.23</td>
<td>0.0598</td>
<td>2</td>
<td>560.88</td>
</tr>
<tr>
<td>Rose hip biomass</td>
<td>573.00</td>
<td>13.35</td>
<td>0.0010</td>
<td>2</td>
<td>569.00</td>
</tr>
<tr>
<td>Hard mast biomass</td>
<td>573.26</td>
<td>13.61</td>
<td>0.0009</td>
<td>2</td>
<td>569.26</td>
</tr>
</tbody>
</table>
Table 3  Winter occupancy modeling results using winter vegetation density, rose hip biomass, and hard mast biomass as covariates. The model set includes a null and global model. AIC, ΔAIC, AIC weight, number of parameters, and twice the negative log likelihood are provided in the table for each covariate model.

<table>
<thead>
<tr>
<th>Covariate</th>
<th>AIC</th>
<th>ΔAIC</th>
<th>AIC Wgt.</th>
<th>No. Par.</th>
<th>-2* LogLike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rose hip biomass</td>
<td>379.25</td>
<td>0.00</td>
<td>0.3661</td>
<td>2</td>
<td>375.25</td>
</tr>
<tr>
<td>Hard mast biomass</td>
<td>379.39</td>
<td>0.14</td>
<td>0.3413</td>
<td>2</td>
<td>375.39</td>
</tr>
<tr>
<td>Null</td>
<td>379.7</td>
<td>0.45</td>
<td>0.2923</td>
<td>2</td>
<td>375.70</td>
</tr>
<tr>
<td>Winter vegetation density</td>
<td>393.52</td>
<td>14.27</td>
<td>0.0003</td>
<td>2</td>
<td>389.52</td>
</tr>
<tr>
<td>Global (all covariates)</td>
<td>397.52</td>
<td>18.27</td>
<td>0.0000</td>
<td>4</td>
<td>389.52</td>
</tr>
</tbody>
</table>
Chapter 5

DISCUSSION

Occupancy of mouse nest boxes in urban forest fragments is best explained in the fall season using vegetation density. However, I measured the fall vegetation density covariate in June 2013, when understory vegetation had reached peak foliage growth. The data collected from June Nudds boards does not fully represent vegetation density during the September-December sampling period, at which time foliage began falling from the understory plants. Nevertheless, occupancy of white-footed deer mouse nest boxes from September-December was positively correlated with vegetation cover measured during June. The relationship between dense cover and higher occupancy could show that mice prefer to nest in areas that are more protected from predators and weather (Matlack 1993; Murcia 1995; Meiners and LoGiudice 2003). Summer foliage may remain on plants long enough to provide cover in early autumn while ambient temperatures are decreasing in fall. Nest boxes provide shelter and a more stable nest temperature than areas outside of boxes (Nicholson 1941; Wolff and Hurlbut 1982; Madison et al. 1984). In winter, mouse nest boxes were occupied less often and had fewer individuals in all of the study sites. Reduction in occupancy compared to fall could have been due to winter mortality or preferential use of underground nests, since Madison et al. (1984) found mice to nest close to the ground during the coldest winter months.
White-footed deer mouse box occupancy is not predictable through food availability of hard mast or rose hips. Hard mast production varies annually, and the autumn of 2013 was a low mast year for oak trees in Delaware. Using mast-colling methods other than ground sampling would help reduce sampling error in the future. Predation of hard mast before it is collected is one of the largest hurdles for getting accurate ground-sample biomasses. Rose hips were difficult to sample in ground plots as well due to white-tailed deer (*Odocoileus virginianus*) browse on multiflora rose stems, resulting in a lack of available hips to collect. Increasing sample size and collecting hard mast in different mast production years would likely provide a better understanding of the relationship of mast to nest box occupancy.

All of the study sites were intrinsically different from one another other. The variables tested were used in an attempt to quantify the qualitative differences between the 8 forest fragments. I used simple covariates to measure the landscape. However, additional covariates such as study site size, human development, distance to edge, proximity to an agricultural field, distance to a stream, and others could all be influential to occupancy. To illustrate this point, Christina Creek had the greatest vegetation cover and mouse box occupancy per box. On average, 0.73 mice occupied a box from September-May, and there was a maximum of 1.47 mice. Similarly, White Clay Creek had an average of 0.71 mice per box and a maximum of 1.47. The comparable occupancy of mouse next boxes between the two sites is contrasted by the difference in understory vegetation composition. Christina Creek’s change in vegetation density from fall to winter was 42.49% and had a rose ground cover of 57.67%. White Clay Creek’s vegetation density change was 19.25% and had 0.80% rose cover. The site with greatest multiflora rose structure, Christina Creek, and
highest summer vegetation density measurements had the greatest occupancy of white-footed deer mice. White Clay Creek had the second-greatest occupancy of white-footed deer mice with the third-lowest rose cover and percent vegetation density change. The juxtaposition between Christina Creek and White Clay Creek indicates factors other than just vegetation cover and multiflora rose composition are important to predict the amount of boxes that will be occupied.

Although mouse nest box occupancy between Christina Creek and White Clay Creek shows occupancy is influenced by covariates other than solely vegetation cover, the fall PRESENCE models showed dense vegetation cover to be a good predictor out of the covariates I tested. Similar research by Meiners and LoGiudice (2003), Dutra et al. (2011), and Chupp et al. (2013) support this finding. Edge habitats dominated by dense vegetation provides cover and refuge to white-footed deer mice. Dense vegetation structure is commonly found around residential areas due to increased levels of disturbance. Homeowners living near fragmented forests with a dense understory, characterized often by invasive plants, may have a greater need for pest management. White-footed deer mice also serve as a reservoir for Lyme disease (Donahue et al. 1987). The cascading effects of human development may therefore give rise to increased prevalence of Lyme disease in urban areas, where mice inhabit the dense understory of forest patches.

Removal of dense vegetation cover in urban forest fragments may accommodate for the social carrying capacity of white-footed deer mice, but ramifications to other wildlife species would require additional consideration. Invasive plants are a major component of dense vegetation cover in most fragments. By removing invasives such as multiflora rose, Amur honeysuckle (*Lonicera mackii*),
Japanese barberry (*Berberis thunbergii*) or any similar dense shrubs, a forest fragment would have a drastically altered ecosystem. Several researchers have investigated ecosystem implications of understory management. Ward et al. (2013) studied the effects of removing Japanese barberry to reduce blacklegged tick (*Ixodes scapularis*) habitat, but found managing barberry to be ineffective in restoring native plant species unless white-tailed deer browse was also controlled. Cover by Amur honeysuckle was more influential to mouse activity than the presence of honeysuckle fruit when Dutra et al. (2011) experimentally removed honeysuckle bushes. Meiners and LoGiudice (2003) also found seed predation by *P. leucopus* to be highest in areas with close proximity to multiflora rose, rather than in open areas.

Overall, multiflora rose serves many ecological purposes and provides resources to more species than just *P. leucopus*. Cover provided by multiflora rose thickets benefits bird species such as Gray Catbird (*Dumetella carolinensis*), Song Sparrow (*Melospiza melodia*), and Eastern Towhee (*Pipilo erythrophthalmus*) for nesting and refuge in forest fragments (Keller and Yahner 2007). Small mammals other than white-footed deer mice may also use rose bushes as shelter (Dutra et al. 2011; Chupp et al. 2013). White-tailed deer often browse on multiflora rose stems and consume rose hips growing in forest fragments. Perhaps one of the most important aspects of multiflora rose is its role in maintaining bottom-up ecosystem processes. Dense foliage shades soil from sunlight, maintaining soil moisture and humidity for reptiles and land snails (Cowie 1985; Nazdrowicz et al. 2008). Snail species protected from desiccation by rose are a key source of calcium for breeding birds and also serve a food resource for white-footed deer mice (Hamilton 1941; Cowie 1985; Hames et al. 2006).
Protection from predators is of paramount importance to white-footed deer mice. Mice face a significant amount of predation pressure from generalists such as raccoons (*Procyon lotor*) and have higher populations where raccoons are removed (Eagan et al. 2011). Mice also have higher populations where dense cover provides refuge from predators, even when predator populations are high (Chupp et al. 2013). Predator abundance and annual variation in mouse populations could play a part in determining occupancy. Anecdotally, raccoon predation may have influenced mouse box occupancy in the Coverdale study site. Synthetic nest box stuffing was often found on the ground or partially pulled through the box holes; the reason for this was never discovered, but it is possible to have been caused by a predator.

Since many carnivores depend on white-footed deer mice as a food source, predator populations would either be reduced if dense understory vegetation was removed or switch predation pressure to a different prey species. Examples of mouse predators include raptors, owls, mammalian mesocarnivores, and snakes; black rat snakes (*Elaphe obsolete*) were sometimes found inside mouse nest boxes during box checks. Instead of predating wild mice, these carnivores may kill squirrels or songbirds instead. Songbirds would also be influenced by the lack of dense understory cover, and bird species that prefer early-successional areas would have less nesting habitat. Most importantly, simply removing invasive shrubs would not be an effective means of managing the vegetation of a forest fragment. Without excluding white-tailed deer from management areas, native herbaceous plants and tree saplings would be browsed. White-tailed deer damage would prevent a forest patch from being restored to a desired native species composition (Ward et al. 2013). Although white-footed deer mouse occupancy is predicted by dense vegetation cover, pursuing a
management strategy to remove it as a way to limit mouse populations would have high costs – not only for land managers, but for ecosystems of urban forest fragments as well.
LITERATURE CITED


Schulz, B. K., and A. N. Gray. 2013. The new flora of northeastern USA: Quantifying introduced plant species occupancy in forest ecosystems. Environmental Monitoring and Assessment 185:3931-3957.


