Small Mammal Community Dynamics in an Oak Forest in the Northeastern United States

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ABSTRACT

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Mammals are important ecosystem indicators because their abundance and distribution often reflect a number of environmental variables that can be used to infer the health of an ecosystem. Where predators thrive, prey must also be abundant, and ecosystem health must be sufficient to support complex community level dynamics. In order to gain baseline data on small mammal community dynamics, a mark-recapture study was undertaken from July through September 2008 in an oak-dominated forest near Cornwall, New York. I initiated an examination of whether the loss of tree species in an ecosystem impacts community dynamics and foraging habits of small mammals. In order to test the impact of oak trees on structuring small mammal communities, a series of 12 experimental plots with differing proportions of oaks girdled were used as trap sites for three consecutive nights each month for a total of 2160 trap nights. In the months immediately following the girdling of oaks, small mammal abundance and distribution did not vary between treatments or between duplicate plots. A total of nine species of small mammals were captured. Small mammal populations resemble those in other typical northeastern oak forests, with *Peromyscus leucopus* (white-footed mouse; 35.5%) and *Tamias striatus* (eastern chipmunk; 54.2%) comprising the majority of the small mammal species composition. I examined 658 scats from nine species and found that small mammal species diet did not significantly vary within species between plot types. Future years of trapping data may show effects from oak death, and it is expected

that habitat with substantial loss of oak will experience a change in small mammal species composition compared to oak-dominated habitat. This study is important because the data may contribute to a better understanding of trophic interactions within an ecosystem, especially those interactions involving small mammals.

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Table 5. The number of unique captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to month. A one-way analysis of variance (ANOVA) was used to detect significant differences in captures between months (total number of captures and differences within species). The ANOVA indicated that the total number of captures of all species did not vary over the three-month field season. Month did have a significant effect on the number of captures within two species, *Blarina brevicauda* and *Tamias striatus*, whose numbers significantly increased over time. The number of *Peromyscus leucopus* captures decreased as the season progressed, but this change was not significant. A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the monthly capture means and look for significant differences between number of captures each month within species. A Tukey's HSD test indicated a significant increase in capture numbers between July and August in *T. striatus* and a significant increase in capture numbers between July and September and between August and September in *B. brevicauda*. (All species captured were accounted in comparisons for all species. Only species with more than four captures were compared with ANOVA.)

Table 6. The number of unique captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to plot type. One-way analysis of variance (ANOVA) did not detect any differences in captures within species between plot types. The one exception was *Clethrionomys gapperi*, which was found more frequently in the control and non-oaks girdled plots. A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the unique capture means of each plot type, and no significant differences were found in the number of unique captures between plot types. (Only those species captured more than four times are included.)

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Figure 5. Of all species captured in Black Rock Forest, New York in 2008, *Blarina brevicauda* was one of two species that significantly increased in captures as the season progressed.

Figure 6. The percentage of total captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to month. The number of *Peromyscus leucopus* captures decreased as the season progressed, and the number of *Tamias striatus* captures increased as the season progressed, however neither of these changes are significant.

Figure 7. Diet distribution of species in Black Rock Forest, New York in 2008.
a) *Peromyscus leucopus* diet distribution. b) *Tamias striatus* diet distribution.
c) *Blarina brevicauda* diet distribution.

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DEDICATION

I dedicate this master's thesis to my parents;

they made everything possible for me.

INTRODUCTION

The forests of the northeastern United States are either currently affected or at risk of numerous threats such as habitat loss, degradation, and fragmentation. These threats come in the form of invasive species, pollution, agriculture, livestock management, road construction, recreational use, other anthropogenic developments, climate change, and pest and pathogen invasions, amongst many others (Peters 1992; Houghton 1994; Cole 1996). It is essential to study a range of levels of disturbance in order to fully understand the effects of potential ecological change and the potential outcomes of these changes.

Many ecosystems have a single species, the foundation species, that controls population and community dynamics and regulates ecosystem processes by acting as a stabilizer for those processes (Ellison 2005). Foundation species are those in low trophic levels and that are abundant in their communities but common across a region. These species stabilize ecosystem processes and regulate ecosystem dynamics (Ellison 2005). Trees are often foundation species because they define their ecosystem's structure and microclimate (Ellison 2005). Subsequently, the loss of a foundation species can severely alter ecosystem structure and stability. The loss may drastically impact the dynamics of that ecosystem's energy and nutrient cycles, hydrology, food webs, and biodiversity (Ellison 2005). Removal of a fundamental species will inevitably impact species diversity across many trophic levels, including birds and mammals dependent upon mast and all their associated predators, parasites, and pathogens (Loo 2009). North American forests are currently losing many of their foundation species, including eastern hemlock, Port-Orford cedar, whitebark pine, and many species of oaks, to pathogens, parasites, and anthropogenic threats (Orwig 2002; Hansen 2000; Kendall 2001; Garbelotto 2001; Knight 2002).

On a landscape scale, rapid loss of trees can significantly affect forest ecosystems, even if the trees are not foundation species. One main research area that is critical in understanding ecosystem-level losses of species and their respective impacts on food webs and ecosystem processes is the aspect of trophic interactions between influential species (Mack 2000; Loo 2009). In cases where the affected species is a fundamental, dominant species in an ecosystem, the ecosystem will be fundamentally changed, as in the case of *Castanea dentata* (American chestnut) (Loo 2009). Chestnut blight, caused by the pathogen *Cryphonectria parasitica*, eliminated adult American chestnut from forests where it was the dominant tree species (Anagnostakis 1987).

Non-indigenous invasive pathogens, in addition to insect pests, are currently one of the most serious threats to eastern North American forests (Lovett 2006). Non-native pathogens have caused considerable changes in forest structure in North America, affecting food webs, nutrient cycling, seed crop success, photosynthesis and productivity, microclimate, light conditions, and tree species composition (Webb 1995; Jenkins 1999; Lovett 2002; Loo 2009). One disease of particular interest is sudden oak death (SOD), caused by the aerially-dispersed pathogen *Phytophthora ramorum*, which is currently a severe problem in the western United States, causing extensive and substantial tree mortalities (Werres 2001; Knight 2002; Rizzo 2002; Davidson 2003; COMTF 2008). The United States Department of Agriculture (USDA) considers New York as a state with favorable climatic suitability for the establishment of *P. ramorum*

(Venette 2006). With the current threats to northeastern forests and the possibility for more severe ecosystem change, it is vital to understand how these systems will react to potential intensive and extensive damage.

The impact of species loss is most considerable when the target species is a foundation species, creating far-reaching cascades of effects that impact the host and associated species, including alterations in availability or quality of nutrients, food sources, and abiotic factors (Jones 1994; Loo 2009). The loss of oaks and other over story trees and shrubs may cause cascading effects in their ecosystems including increased risk of fire, soil erosion, and loss of habitat and food resources for wildlife (McPherson 2000; Garbelotto 2001).

Oak species provide indispensable ecosystem functions: they regulate small mammal populations; they function as important food sources and habitat for many other species; and they play important roles in nutrient cycling and retention (Orwig 2002). The northeastern United States has a significant proportion of oak-dominated ecosystems, and understanding the elements of a naturally functioning oak-dominated forest can serve as a baseline for studies on the loss of these intact ecosystems, which seems likely given the numerous threats that northeastern forests currently face.

Oak forests support a number of small mammal species (Healy 1988; Brooks 1998). Small mammals may be good species to study in oak forest ecosystems because they may be sensitive to changes in their habitat and food sources, which is directly related to oak populations. As a result, small mammals are ideal study subjects for studying community dynamics: they directly impact community structure, interact with other trophic levels, and are sensitive to ecosystem changes (Elkinton 1996; Ostfeld

1996). Understanding the dynamics and structure of the small mammal community can serve as a way of understanding how an ecosystem reacts to change (Ostfeld 1996).

Small mammals typically have high population abundances and therefore play an important role in trophic webs. They may alter food resource abundances and are able to significantly change the population dynamics of their prey items (Elkinton 1996; Ostfeld 1996). Species whose diets consist largely of seeds and fruits serve important roles as seed transporters and distributors for many plant species (Janzen 1971). Small mammals are commonly associated with predator-prey population dynamics and help determine the population dynamics of their predators (May 1973; Krebs 1974). Due to their interactions with many trophic levels and their sensitivity to environmental change, small mammals can serve as proxies for ecosystem health; fluctuations in abundances and foraging ecology can reveal changes in the forest environment (Ostfeld 1996).

Masting by oak species increases abundances of generalist small mammals such as *Peromyscus leucopus* (white-footed mouse), *Peromyscus maniculatus* (deer mouse), and *Tamias striatus* (eastern chipmunk) (Elkinton 1996; Ostfeld 1996; Wolff 1996; Jones 1998; McCracken 1999; Schnurr 2002). Other species such as *Clethrionomys gapperi* (southern red-backed vole), however, show no effect in abundance from oak mast crop (Schnurr 2002).

Numerous studies have suggested that small mammal survival is influenced by the magnitude of seed production (Bergstedt 1966; Hansen 1978; Gilbert 1981; Jensen 1982; Ostfeld 1996; Wolff 1996; McCracken 1999; Schnurr 2002). In particular, species such as *P. leucopus* had populations which positively correlated with crop sizes and seed fall of *Quercus rubra* (red oak), *Pinus strobus* (white pine), and *Acer rubrum* (red maple) (McCracken 1999). Years of high oak acorn production have also been positively associated with higher weights of *P. leucopus* (McCracken 1999). Other species such as *Clethrionomys glareolus* (bank vole) are also known to positively respond (i.e. increased reproduction and population densities) to mast seed production by *Fagus sylvatica* (European beech) (Jensen 1982).

A study on the effects of oak removal is currently underway at Black Rock Forest, in the Hudson Valley region of New York State. The study hopes to observe the effects of killing oak trees in relatively undisturbed habitat, looking at different components of the ecosystem. Due to its location, Black Rock Forest is naturally susceptible to *P. ramorum* and other causes of oak loss. The goal of my study is to study the effects of oak removal on small mammal community structure. As part of a larger study examining the different components of a northeastern oak ecosystem, this study investigated the preliminary state of the small mammal community in a typical oak-dominated forest in the northeastern United States in order to establish the condition of a naturally functioning small mammal community. It is important to understand the natural preliminary state of the small mammal community prior to or close to any significant changes in the environment. Ecosystem effects of massive disease-induced mortalities of tree species or landscape-scale mortalities from other threats to biodiversity are not well known, and rapid deaths of large numbers of plant and tree species could produce significant changes in small mammal community structure. This may be especially true in systems in which the plant serves as a major food source or as an important feature of the community (Jones 1998). The first summer of trapping coincided with the girdling of oak trees, and thus this study will serve as a baseline for abundance, distribution, and foraging habits of common mammal species for future years of trapping.

I expect that the relative abundances of small mammal species will vary depending on the degree to which habitat has been altered in the experimental design. Specifically, if a major food source is removed (via girdling), I expect that small mammals that heavily rely upon those food sources will be affected. This project is an important ecological study because the abundance and foraging ecology data will contribute to a better understanding of the complex trophic interactions between plant and animal species in eastern forest ecosystems.

METHODS

Study Area

Trapping was conducted at Black Rock Forest, a nature reserve approximately 50 miles north of New York City, in Cornwall, New York. The forest is approximately 16 km^2 of northern hardwoods in the Hudson Highlands. Sudden oak death was simulated on a total of 12 plots (6.75 ha) by girdling oak trees, causing either immediate or impending death while still leaving a standing tree. Plots were divided into four experimental plot types: 1) 100% oaks girdled (three plots); 2) 50% oaks girdled (three plots); 3) 100% non-oaks girdled (three plots); 4) control (three plots) (i.e., unmodified natural habitat) (Figure 1). Plots measured 75 m x 75 m and the entire plots were treated with girdling. A centered 25 m x 25 m subplot was located within each 75 m x 75 m plot.

Small Mammal Trapping

Small mammal trapping was conducted from July through September 2008 using Sherman live-traps (3 x 3.5 x 12"; H. B. Sherman Traps; Tallahassee, FL). Twenty traps were placed in each of the 12 experimental plot types.

Traps were placed within each 25 m x 25 m subplot to avoid edge effects, and the subplots were 30 m apart. Specifically, traps were placed in concentric circles in a web design from the center of each plot (Figure 2). Approximately 10 traps made up each concentric circle from the center of the plot. Traps were placed 10 m apart, and concentric rings were also 10 m apart. Study plot size (0.5625 ha) and trap placement was deemed appropriate for the expected mammals with home range sizes within the treatment plot size (ASM 2004); the home ranges of most of the expected small mammals fall well under the treatment plot size of 0.5625 ha.

I trapped during nine consecutive nights/ten consecutive days of each month. Each of the four plot types was surveyed for three consecutive trap nights. Traps were closed and collected at the end of the fourth day and rotated amongst different cells in the experimental plots (n = 12). Plots A1, A2, A3, and A4 were trapped the first three nights. On the evening after the third night, traps were moved to plots B1, B2, B3, and B4 for the next three nights. On the evening after the third night of trapping on the B plots, the traps were moved to plots C1, C2, C3, and C4.

Traps were checked in the morning (between 7 and 9 A.M.) and evening (between 5 and 7 P.M.) with a maximum possible capture time of 14 hours. Traps were baited with oats and peanut hearts. To prevent prolonged exposure to sun and rain, traps were placed under ample canopy cover and in the shade, and during colder months, cotton was placed in traps.

Sherman traps were used rather than the track tubes method used in the pilot study (Cords and Burns 2007) due to the need for mark-recapture of captured subjects. This enabled observation of potential movement patterns between plots. Live traps also allowed a more accurate estimate of population abundance than track tubes. Any potential differences in age demographics between the plots could also be detected. Track tubes would not have allowed me to differentiate between age classes (juveniles, subadults, and adults).

Data Collection

The following data were collected from each captured individual: species; gender; age class (adult, subadult, or juvenile); mass (g); and body length and tail length (mm). Sex was determined by the distance of the anus from the genital opening, which was visually estimated, and by presence/absence of enlarged nipples. Age was determined based on pelage and relative size. For white-footed mice, which are the most abundant and commonly-caught species with Sherman traps, adults are large in general size and have brown dorsal fur; juveniles are small and have gray dorsal fur; subadults are moderate in size and the dorsal fur is brown in some parts and gray in others. All body measurements were measured with a flexible ruler (mm). Mass (g) was determined with a hanging scale (300g x 2g; model #40300; Pesola; Baar, Switzerland); individuals of small-sized species, such as mice and voles, were hung by the base of the tail. Larger species, such as chipmunks and squirrels, were weighed while still in the trap. Mass (g) of the trap was measured after the individual was released, and the difference of the two weights was taken as the mass of the individual. Total body length (mm) was calculated by adding the body and tail length measurements. Ear length (mm) was measured for white-footed mice, from the bottom lobe of the ear to the farthest tip of the ear tissue. For chipmunks and shrews, pelage is the same between adults and subadults, therefore distinguishing between the age stages was not attempted. Juvenile chipmunks were those that weighed 30g or less (Allen 1938). Captured animals were tagged with numbered ear tags (model #1005-1; National Band and Tag Co.; Newport, KY), which were placed near the bottom of the ear, outside of the ear cartilage. Tags were cleaned with alcohol before application and were placed in both ears when possible, in the case that one tag was torn off in between recaptures. If ticks were observed on the ears or fleas or any other ectoparasites were visible on the body, samples of these ectoparasites were taken and stored in ethanol. Approximate total handling time for each individual was 5-8 minutes. After all necessary data were collected and individuals were tagged, captured animals were promptly released in the same locations they were captured.

Scat samples were collected from live traps and the restraining bag after individuals were sampled and released. Each sample was stored in a refrigerator before processing. Refrigerated scat samples were prepared and analyzed in a laboratory of the Department of Ecology, Evolution, and Environmental Biology at Columbia University. Prior to examination, the scats were emulsified for 30-45 minutes in a mixture of 8 parts water and 2 parts general detergent and then sorted manually using a sieve with mesh size 250 μm (model #1303; H&C Sieving Systems; Columbia, MD). Approximately two scat pellets from each individual were emulsified and examined. Scats were dried overnight at room temperature in a petri dish. Prey items were identified using a dissecting microscope and classified as presence/absence in three general categories: vegetation, seeds, or insects. Data were recorded for each individual's scat as presence/absence of individual food categories. Feeding habits were only analyzed for those species captured in all plot types.

Population Analysis

Minimum population sizes (k) were calculated by taking the number of unique captures (not including recaptured individuals that both have ear tags or evidence of torn tags/missing tags) for each species. For species that had fewer than ten captures, minimum population size was not calculated due to the small sample size of that species. To show that the majority of individuals were captured, the cumulative proportion of marked individuals was plotted over time for *P. leucopus* and *T. striatus*. Only species that had a sufficient number of ear-tagged captures were plotted. One-way analysis of variance (ANOVA) in SPSS (version 16.0; Statistical Program for the Social Sciences, Inc.; Chicago, IL; 2008) was used to examine for any variance in k between plots and between species. A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the k of each plot type and look for significant differences in the k between plot types.

Density estimates were calculated by dividing the total number of unique captures for all species in each plot for each month by the plot size, averaging for each plot type, and extrapolating for the density in one hectare. Density estimates were reported as the number of unique individuals per hectare and the total number of captures per hectare. A one-way ANOVA was used to detect any variance in densities between plots. Results were considered significant at the $p < 0.05$ level.

A one-way ANOVA was used to detect any significant differences between plot types and trapping success. Overall trapping success was calculated as a percentage of the total number of captures out of the total number of trap nights. A one-way ANOVA was also used to detect differences between the number of individuals of each species trapped, but only those species captured more than four times were included. One-way ANOVA was also used to examine for temporal variability (morning versus afternoon) in species trapping success, for those species with more than four captures.

A one-way ANOVA was used to detect significant differences between plot types in species diversity, evenness, and richness. Species diversity was calculated using the Simpson's Diversity Index (*D*), and the species evenness was calculated using the Simpson's Measure of Evenness (*E*) (Simpson 1949). Small mammal capture frequencies were examined for variation by trapping session, age, and sex, using a one-way ANOVA. Due to low sample sizes, data sets from replicate plots were combined (i.e. all captures from control plots will be analyzed together).

A one-way ANOVA was used to detect significant differences in captures between months (total number of captures and differences within species). A Tukey's HSD test was used to compare the monthly capture means and look for significant differences between number of captures each month within species.

Feeding habits were examined by comparing percent occurrence of the three main food types between plots, within each species that had more than four captures (*P. leucopus*, *T. striatus*, *Blarina brevicauda* (northern short-tailed shrew)). The Levins's measure of niche breadth (*B*) was calculated for each species based on plot type, month of capture, gender, and age (Levins 1968). Calculated *B* values were then standardized from 0 to 1, and a one-way ANOVA was used to detect significant differences within species between plot type, month of capture, gender, and age.

RESULTS

Trapping

During 2160 trap nights, 381 individuals, representing a total of 659 captures, were captured from nine different species. The most frequently captured species were the white-footed mouse (35.5%; *Peromyscus leucopus*) and the eastern chipmunk (54.2%; *Tamias striatus*). Less frequently captured were the northern short-tailed shrew (*Blarina brevicauda*), the southern red-backed vole (*Clethrionomys gapperi*), the masked shrew (*Sorex cinereus*), the northern flying squirrel (*Glaucomys sabrinus*), the southern flying squirrel (*Glaucomys volans*), the woodland vole (*Microtus pinetorum*), and the long-tailed weasel (*Mustela frenata*) (Figure 3).

Captures of *G. sabrinus*, *G. volans*, *M. pinetorum*, *M. frenata*, *S. cinereus* were too rare to perform statistical analysis. Captures of *B. brevicauda*, *C. gapperi*, *P. leucopus*, and *T. striatus* were ample enough to perform statistical analysis.

For these four species, a total of 381 unique individuals were captured, of which 278 (73%) were recaptures. Of those species with recaptured individuals, 27.2% of *C. gapperi* were recaptures, 33.6% of *P. leucopus* were recaptures, and 11.1% of *T. striatus* were recaptures (Table 1). Trapping success was significantly affected by whether the trap was available during the night or day for some species. A one-way ANOVA showed that *P. leucopus*, *B. brevicauda*, and *C. gapperi* were significantly more likely to enter a trap during the overnight trapping session (ANOVA $F_{1,50} = 181.6$, $p < 0.05$; $F_{1,50} = 7.692$, $p = 0.008$; $F_{1,50} = 11.83$, $p = 0.001$), and *T. striatus* was significantly more likely to enter a trap during the daytime trapping session (ANOVA

$F_{1,50} = 5.715$, $p = 0.021$). The mean trapping success of all species was 30.5% for the entire field season. Trapping success did not change over the course of the trapping season. A one-way ANOVA did not detect any significant differences between trapping success by plot types (ANOVA $F_{3,8} = 0.327$, $p = 0.806$), although significant differences were detected for trapping success of different species (ANOVA $F_{3,204} = 42.4$, $p < 0.05$) with *P. leucopus* and *T. striatus* being the most commonly caught species.

Plots of the cumulative proportion of marked individuals over time indicated that a majority of *P. leucopus* individuals in the study area were captured (Figure 4a). In the last ten days of the trapping season, approximately 68% of the total number of captures were marked individuals (Figure 4a). It is unclear whether a majority of *T. striatus* individuals were captured (Figure 4b), which may be due to numerous captures escaping before an ear tag was applied during the first month of capture.

Population Structure

A greater number of males were captured relative to females for nearly all species. *Blarina brevicauda* captures consisted of a 7:3 male-female sex ratio. *Clethrionomys gapperi* captures were approximately 8:2 male-female. *Peromyscus leucopus* captures were approximately 6:4 male-female. *Tamias striatus* captures were roughly 1:1 male-female.

Age structure of all species was predominantly adult, with very few juvenile and subadult captures. Both *B. brevicauda* and *T. striatus* captures consisted of all adults. Ninety-two percent of *C. gapperi* captures were adults. A total of 7 percent of *P. leucopus* captures were juveniles, 19.1% subadults, and 73.4% adults.

A one way ANOVA did not detect any variation between plots for the minimum population size (*k*) for any species (Table 2a). A Tukey's HSD test did not find significant differences in *k* between plot types (Table 2b). A one way ANOVA did not detect any variance between plots for density (Table 3).

Species Diversity, Species Evenness, Species Richness

The Simpson's Diversity Indices (*D*) and the Simpson's Measure of Evenness (*E*) for all plot types were similar (Table 4). The diversity indices for the plot types ranged from 0.522 in the 50% oaks girdled plot type to 0.610 in the control and non-oaks girdled plots. The evenness measures for the plot types ranged from 0.114 in the control, all oaks girdled, 50% oaks girdled, and non-oaks girdled plot types to 0.115 in the all oaks girdled plots. An ANOVA did not detect any significant differences between plots for species diversity or species evenness (Table 4). Species richness ranged from five in the control and 50% oaks girdled plot types to six in the all oaks girdled and non-oaks girdled plot types, and an ANOVA showed that species richness did not significantly vary between plots (Table 4).

Temporal Effects

An analysis of variance (ANOVA) indicated that the total number of captures of all species did not vary over the three-month field season (Table 5). Month did have a significant effect on the number of captures within two species, *B. brevicauda* and *T. striatus* (Table 5; Figure 5), whose numbers significantly increased over time. The number of *P. leucopus* captures decreased as the season progressed, but this change was not significant (Table 5; Figure 6). A Tukey's HSD test indicated a significant increase in captures between July and August in *T. striatus* ($p = 0.051$; Table 5) and a significant increase in captures between July and September and between August and September in *B. brevicauda* ($p < 0.050$; $p = 0.001$; Table 5). A one way ANOVA did not detect any differences in captures within species between plot types (Table 6a). The one exception was *C. gapperi*, which was found more frequently in the control and non-oaks girdled plots ($p = 0.037$; Table 6a). A Tukey's HSD test did not indicate any significant differences in pairwise comparisons between plot types within any species (Table 6b).

Feeding Habits

Scat was collected from all nine species. A total of 658 scat samples were analyzed. Under magnification, the following food items visible in the processed scat samples were: whole insects, insect fragments, seeds, and small fragments of vegetation/leaves.

Based an analysis of fecal remains, the majority of the diets of *P. leucopus, T. striatus,* and *B. brevicauda* were insects and vegetation. The average *P. leucopus* diet consisted of 47% insect, 38% vegetation, and 15% seed (Figure 7a). The average *T. striatus* diet consisted of 54% insect, 36% vegetation, and 10% seed (Figure 7b). The average *B. brevicauda* diet consisted of 40% insect, 52% vegetation, and 8% seed (Figure 7c).

Significant differences were found between: the proportion of *P. leucopus* individuals and the proportion of *B. brevicauda* individuals that showed insects in their diet ($p = 0.0006$); the proportion of *B. brevicauda* individuals and the proportion of *T.*

striatus individuals that showed insects in their diet ($p = 0.0008$); and the proportion of *P. leucopus* individuals and the proportion of *T. striatus* individuals that showed vegetation in their diet ($p = 0.01$).

An analysis of the Levins's measure of niche breadth (*B*) with a one-way ANOVA found no significant differences in *B* within species between plot type, gender, and age (Tables 7a, 7c, 7d). One-way ANOVA found significant differences in *B* between months in *P. leucopus* and *T. striatus* ($p < 0.050$; $p = 0.018$; Table 7b). Both *P. leucopus* and *T. striatus* showed a more specialized feeding niche over time (Table 7b); both species showed increased specialization towards insects in their respective diets.

Mortalities

Mortalities included those of *B. brevicauda*, *P. leucopus*, *S. cinereus*, and *T. striatus*. Sixty-one percent of *B. brevicauda* captures resulted in mortality and 50% of *S. cinereus* captures resulted in mortality ($n_{\text{Blarina}} = 14$; $n_{\text{Sorex}} = 1$); the high frequency in mortality in these species is due to the high metabolic rates of shrews (George 1986; Whitaker 2004). Other mark-recapture studies that include *Blarina* spp. and *Sorex* spp. have similar mortality rates (Anthony 2005; Hammond 2006; Wiewel 2007).

Trap mortality for *P. leucopus* was 1.7% and 0.33% for *T. striatus*. White-footed mouse mortalities appeared to be due to cold overnight temperatures, even though cotton was placed in traps for nesting. The sole *T. striatus* mortality was due to consumption by a long-tailed weasel (*M. frenata*) that had also entered the trap.

DISCUSSION

Trapping

According to the findings of this study, the small mammal community in the study area was composed of nine species. Species diversity did not vary between treatment types, nor did species diversity vary temporally between treatment types. Other studies in northern hardwoods and oak ecosystems reported a range of 4 to 16 species of small mammals (Healy 1988; Brooks 1998; Cords 2007). Compared to a recent small mammal study in the same area of Black Rock Forest, where track tubes were used, this study reported an additional five species that were not previously detected: *C. gapperi*, *G. sabrinus*, *G. volans*, *M. pinetorum*, and *M. frenata* (Cords and Burns 2007). In addition, this study captured a majority of the *P. leucopus* individuals in the study area, which was not previously possible with the track tubes method in the earlier study.

Peromyscus leucopus, *B. brevicauda*, *T. striatus*, and *C. gapperi* were more likely to enter traps during the overnight trapping sessions, which reflects the nocturnal nature of these species (Lackey 1985; George 1986; Snyder 1982; Merritt 1981). An improvement to this study could be to increase the frequency of trap checks during the overnight trapping sessions in order to allow for these more frequently captured species increased opportunities to enter the traps. A better picture of the species diversity of the area may be acquired through increased captures of these species.

Other studies also reported *P. leucopus* and *T. striatus* as the most abundant small mammal species in eastern oak ecosystems (Dueser 1978; Kitchings 1981; Brooks

1998). The presence of *P. leucopus* in such large numbers in all plot types reflects studies that show that the species is less selective than others, such as *C. gapperi*, in its microhabitat use (Yahner 1986).

Clethrionomys gapperi showed a significant difference in population abundance between plot types, specifically with higher numbers in the control and non-oaks girdled plots. This species is known to prefer habitats with many opportunities for refugia and nest sites, such as stumps, rocks, logs, and exposed roots. In northern hardwood habitats, the southern red-backed vole prefers recently clear-cut habitats, which provide extra material for refugia (Lovejoy 1973; Kirkland 1977; Merritt 1981; Yahner 1986). Plots with higher frequencies of *C. gapperi* had, from general visual observation, more rocks, exposed roots, logs, and other places for refugia and nest sites.

Population Structure

More males were captured relative to females for nearly all species, with the exception of *T. striatus*. The male-female capture ratios reflect other small mammal studies in which more males are captured relative to females. Studies that have live-trapped natural populations of *P. leucopus* have found higher male to female ratios (Townsend 1935; Burt 1940; Snyder 1956; Stickel 1960). Other studies have found that the deer mouse (*Peromyscus maniculatus*), another small mammal species closely related to *P. leucopus* that typically occurs in the same areas, have also recorded significantly more male captures than females, and many other *Peromyscus* species show the same trend (Terman 1967; Hansen 1974; Morton 1980). An analysis of the North American Census of Small Mammals also shows a male-biased gender ratio in *P.*

maniculatus (Terman 1967). This male-biased ratio is possibly to due males "wandering" more and traveling over larger areas than females, increasing trap exposure and the probability of capture (Burt 1940; Townsend 1935).

Age structure of captured individuals shows predominantly adult age structures in all species. This may be a reflection of the warmer months and that the breeding season had previously passed and all previous juveniles are now adults (Burt 1940). In northern populations of *P. leucopus*, individuals are considered fully developed 6 to 10 weeks after birth, the breeding seasons occur during the spring and late summer, and the gestation period varies between 22 to 37 days (Burt 1940; Svihla 1932; Lackey 1978). The predominance of adult captures in the *P. leucopus* population likely reflects this timing. The breeding seasons of *T. striatus* are from late February to early April and then again from late June to early July, the gestation period lasts between 31 to 32 days, juveniles emerge between five to seven weeks old, and individuals reach adult size three months after birth (Allen 1938; Burt 1940; Pidduck 1973; Smith 1972; Yerger 1955). According to these studies, juveniles and subadults are present in the population between July and September, but this age structure was not reflected in the trapping results.

Temporal Effects

Month had a significant effect on the number of captures within *B. brevicauda* and *T. striatus* species. *Blarina brevicauda* capture numbers increased while *T. striatus* capture numbers increased and then decreased. Shrew activity varies by season, and shrew species are most active during spring and late fall (Briese 1974). The increase in

B. brevicauda capture numbers towards the end of the trapping period reflects this reported increase in activity towards the autumn season. The results also reflect that *B. brevicauda* females are also more active during pregnancy and lactation, which occurs around the breeding seasons of spring, late summer, and early autumn, and this increase in activity is likely due to the increased nutritional demands of reproduction and natal care (Martin 1982; Blair 1940; Hamilton 1929).

The significant increase in *T. striatus* captures during the August trapping session is due to the high number of recaptures because after the first capture, individuals become trap-happy (the probability of capture increases with trap experience). The increase in captures may also reflect a general higher abundance of the species during the warmer August month, and the decrease in captures during the end of the trapping season may reflect the colder September temperatures.

Feeding Habits

The diets of *P. leucopus* and *T. striatus* reflect previous studies on the species' diets (Hamilton 1941; Elliott 1978; Wrazen 1978; Snyder 1982; George 1986). During the spring and summer months, the majority of the diet are known to be insects, fruit, acorn mast, and other seeds (Hamilton 1941). Analysis of the Levins's measure of niche breadth (*B*) of *P. leucopus* and *T. striatus* found that both species increased niche specialization over the trapping season; both species showed an increase in insects in their diets. This may be an indication of a lower availability of food items over time, possibly due to colder temperatures.

While food limitation appears to play an important role in regulating *P. leucopus* populations, even under different environmental and demographic conditions (Bendell 1959), this study did not detect any differences in foraging habits or population numbers. Effects of oak removal on diet were not seen during this trapping season because girdled oaks were still dropping acorns even after girdling. Future years of trapping may detect responses from the small mammal community after the treated oaks are fully deceased and unproductive.

Time-Delayed Responses

Response of the small mammal community specifically to oak removal may not have been detected during the first year of experimental plot treatment and trapping due to the time-delayed response of small mammal species to significant changes in their habitat. Most of the species captured in the study have a lifespan longer than the trapping period (*B. brevicauda*, ~4.5 months; *P. leucopus*, ~14.7 months; *S. cinereus*, ~15 months; and *T. striatus*, ~16 months), and therefore any population changes that may occur may not appear for another year or more (Pearson 1945; Buckner 1966; Roberts 1976; Merritt 1981; Snyder 1982; Lackey 1985; George 1986; Schug 1991). Studies on predator-prey population dynamics of small mammals have also reported time-delayed responses (May 1973; Krebs 1974). In future years, populations reliant on oak species will most likely decrease in abundance in areas with fewer oaks. This prediction is based on other studies which have found 25-68% smaller bird populations in habitats affected with sudden oak death compared to populations before sudden oak death infection (Monahan 2006).

Limitations and Future Improvements

Limitations of this study include that there was only one season of trapping and the lack of prey specificity in fecal analysis. Future improvements should include multiple seasons of trapping to view the effect of oak girdling over the course of multiple years and thus over the course of numerous turnovers of the small mammal populations.

Fecal analysis can be improved by a more specific and targeted method of analysis. Identifying food items through tissue collection and stable isotope analysis will provide more thorough and detailed results for prey items, as well as providing a longer time scale for feeding habits. Fecal analysis will only provide days of feeding habits, whereas stable isotope analysis will provide months of feeding habits.

More specific identification of food items, such as acorn mast, can be achieved by creating a reference collection of possible resource species available during the trapping season. Under a microscope, fragments of food items can be identified through comparison to photomicrographs taken of the reference collection specimens. A previous small mammal study was successful in identifying food items to the species level using this method (Vazquez 2004).

Another limitation of the study was the identification of *Peromyscus* by pelage and ear length, rather than the more demanding examination of salivary amylase, which would be a more accurate way to distinguish *P. leucopus* and the deer mouse, *Peromyscus maniculatus*, a less common species of *Peromyscus* that has been previously reported in the area, so it is possible that some *P. maniculatus* were captured (Parren 1985).

Future improvements to the study should include additions to the trapping methods in order to target a wider range of small mammals. Changes should be made to the bait, the frequency of trap checks, and the trap types used during the study. Increased diversity in the bait may help to attract a larger number and diversity of small mammals. Increasing the frequency of trap checks would allow more individuals an opportunity to enter traps, as well as lower the incidences of mortality, especially in shrew species.

Including additional trap types in different sizes may trap a wider diversity and higher number of small mammals. Using larger-sized Sherman traps may help to attract the larger small mammal species, therefore capturing a more diverse range of small mammal species that are known in the area. The incorporation of pitfall traps may trap and detect additional shrew species that are known in the area but were not captured in this study. Pitfall traps are more effective than live traps in capturing shrews, can capture other small mammals species, and are able to capture more than one individual at a time (Hudson 1959; Brown 1967; Pucek 1969; Briese 1974). Pitfall traps may also help to decrease mortality rates in shrew species, due to live bait being placed at the bottom of the trap.

CONCLUSIONS

The results show that the small mammal community at the study site is typical of northern hardwoods and oak ecosystems in the northeastern United States. This study has provided a baseline for future years of trapping data for the experimental plots in Black Rock Forest. It has given an indication of the small mammal community's species composition and species' current habitat and diet preferences in the area.

In future years of trapping, I predict that habitat with a substantial loss in oak species will experience a change in small mammal species composition compared to oak-dominated habitat, and species that heavily rely on oak species as food sources will show diet shifts. Small mammal composition may change in altered oak habitat (i.e. plots with removed oak) as some species supplement their diets with other forage while other species move elsewhere. The change in vegetative composition may affect the diet of some small mammals by changing insect composition. Species relying more on oaks (i.e. *Peromyscus* spp.) may have lower abundances in plots with no oaks. Change may be detected in future years after the small mammal populations have had sufficient time to respond to the changes in their environment.

Limitations of this study were having only one trapping season, using only fecal analysis for analyzing feeding habits, and using one method of trapping. Improvements can be made by increasing the number of trapping seasons, including stable isotope analysis in diet analysis, using a more rigorous method of food item identification, and including more diverse methods of small mammal trapping.

TABLES AND FIGURES

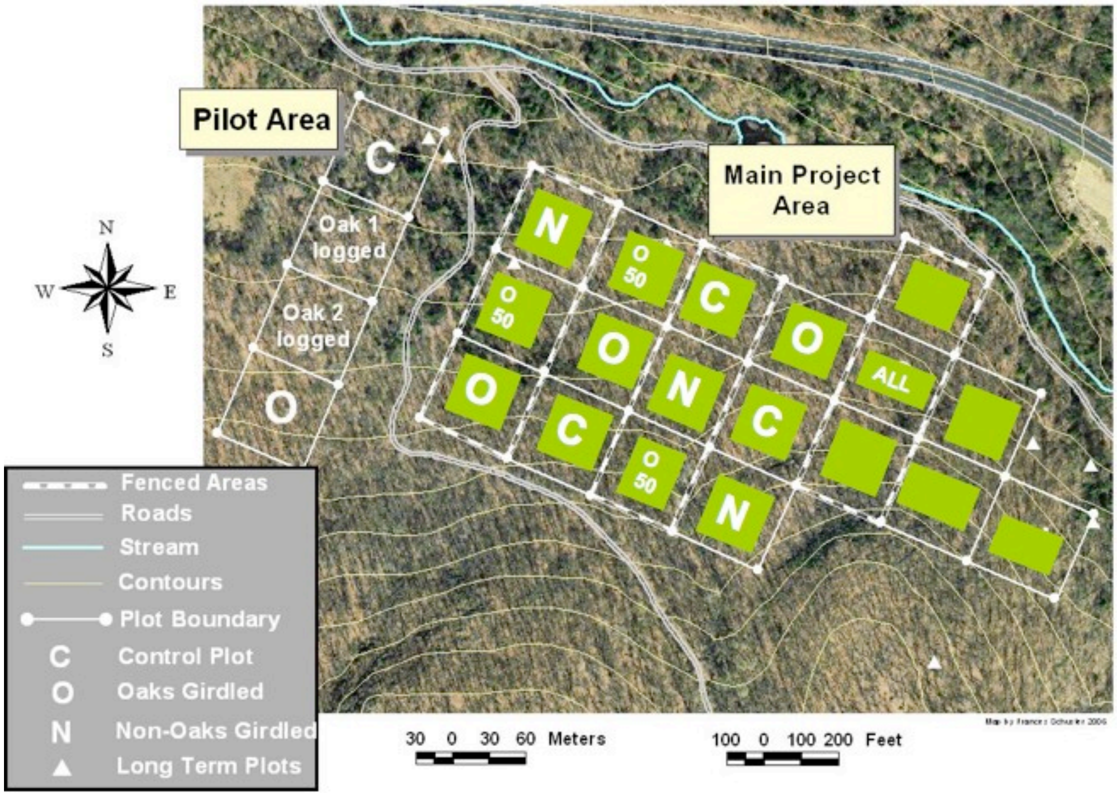


Figure 1. Plots on the North Slope of Black Rock Forest in New York were divided into four experimental plot types: 1) "O": 100% oaks girdled (3 plots); 2) "O 50": 50% oaks girdled (3 plots); 3) "N": 100% non-oaks girdled (3 plots); 4) "C": control (3 plots) (i.e., unmodified natural habitat). Plots measured 75 m x 75 m and the entire plots were treated with girdling. A centered 25 m x 25 m subplot was located within each 75 m x 75 m plot. (Image courtesy of Frances Schuster, Black Rock Forest Consortium.)

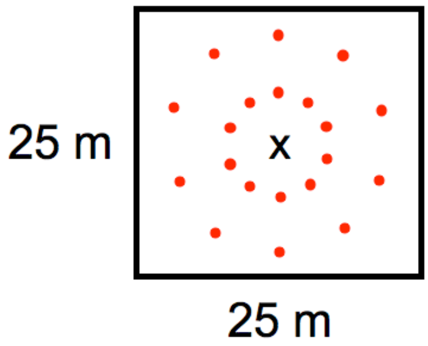


Figure 2. Plots on the North Slope of Black Rock Forest in New York were divided into four experimental plot types: 1) “O”: 100% oaks girdled (3 plots); 2) “O 50”: 50% oaks girdled (3 plots); 3) “N”: 100% non-oaks girdled (3 plots); 4) “C”: control (3 plots) (i.e., unmodified natural habitat). Plots measured 75 m x 75 m and the entire plots were treated with girdling. A centered 25 m x 25 m subplot was located within each 75 m x 75 m plot. To avoid edge effects, I placed traps (red dots) in concentric circles in a web design from the center (x) of each plot, staying within the 25 m x 25 m subplot.

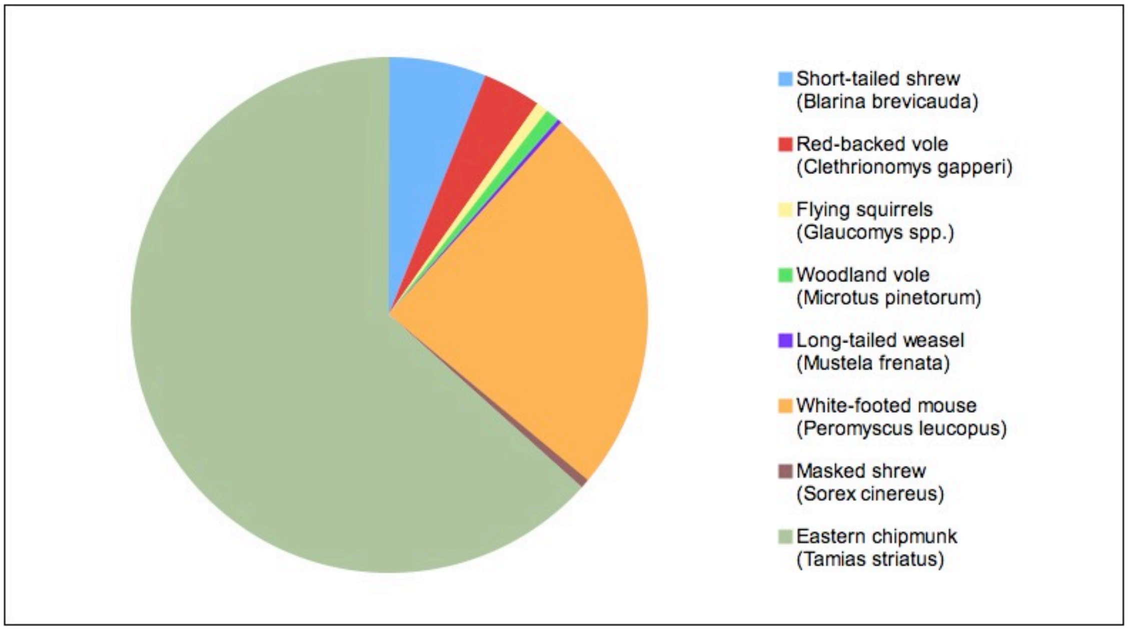
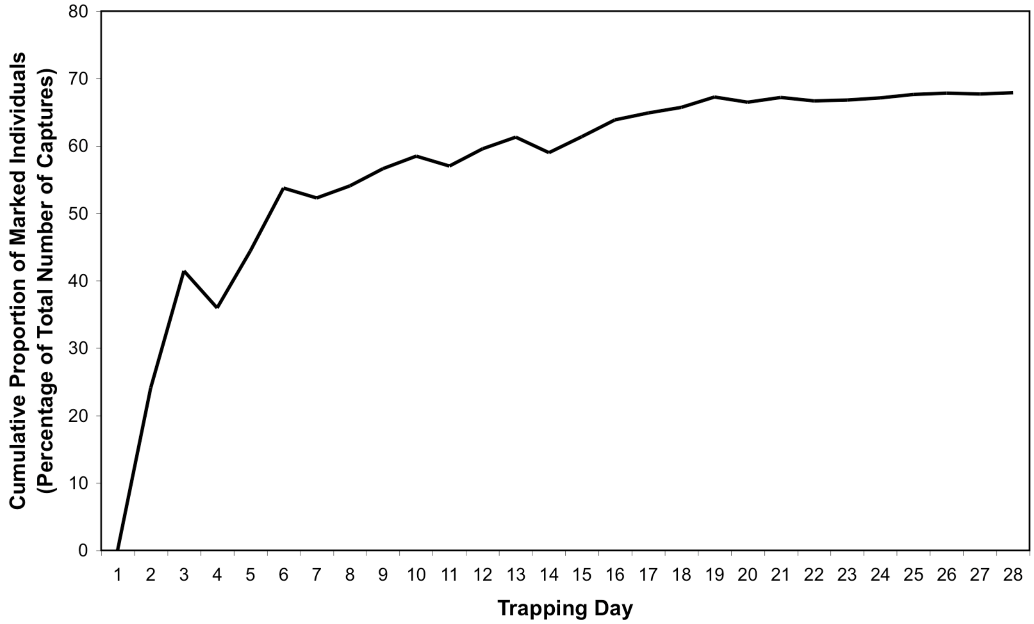


Figure 3. The dominant species in the North Slope community of Black Rock Forest, New York in 2008 were the white-footed mouse (*Peromyscus leucopus*) and the eastern chipmunk (*Tamias striatus*).

Table 1. Number and percentages of unique and recaptured small mammal individuals captured at Black Rock Forest, New York in 2008.

SPECIES	TOTAL CAPTURES	NO. UNIQUE CAPTURES	% UNIQUE CAPTURES	NO. INDIVIDUALS RECAPTURED	% INDIVIDUALS RECAPTURED	MEAN NO. CAPTURES PER SESSION
Blarina brevicauda	23	23	100%	0	0%	10
Clethrionomys gapperi	22	14	63.6%	6	27.2%	9
Glaucomys sabrinus	1	1	100%	0	0%	0
Glaucomys volans	3	3	100%	0	0%	0
Microtus pinetorum	3	3	100%	0	0%	1
Mustela frenata	1	1	100%	0	0%	0
Peromyscus leucopus	295	94	31.9%	99	33.6%	92
Sorex cinereus	2	2	100%	0	0%	0
Tamias striatus	307	240	78.2%	34	11.1%	116

a)



b)

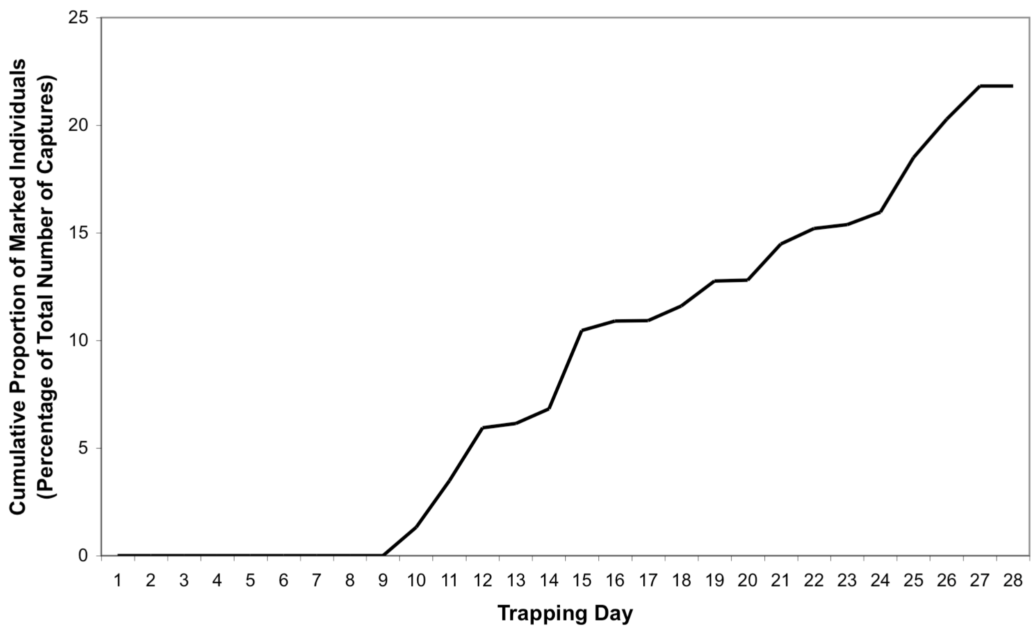


Figure 4. To show that the majority of individuals in the North Slope community of Black Rock Forest, New York in 2008 were captured, the cumulative proportion of marked individuals was plotted over time for a) *Peromyscus leucopus* and b) *Tamias striatus*. The cumulative proportion of marked individuals is shown as the percentage

of the total number of captures. Figure a shows that a majority of *P. leucopus* individuals in the study area were captured, as indicated by the plateau occurring around 68%. It is unclear whether a majority of *T. striatus* individuals were captured due to the lack of a distinct plateau in Figure b. This may be due to numerous captures escaping before an ear tag was applied during the first month of trapping.

Table 2. The minimum population sizes of the four most commonly captured small mammal species did not vary by plot for any of the main species. Minimum population sizes (*k*) were calculated by taking the number of unique captures (not including recaptured individuals that both have ear tags or evidence of torn tags/missing tags) for each species. For species that had fewer than ten captures, *k* was not calculated due to the small sample size of that species. a) One-way analysis of variance (ANOVA) was used to examine for any variance in *k* between plots and between species. A one way ANOVA did not detect any variation between plots for *k* for any species. b) A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the *k* of each plot type and look for significant differences, and no significant differences were found.

a)

SPECIES	Average minimum population size of each **control** plot	Average minimum population size of each **all oaks girdled** plot	Average minimum population size of each **50% oaks girdled** plot	Average minimum population size of each **non-oaks girdled** plot	**ANOVA**
Peromyscus leucopus	2	3	1	4	$F_{3,32} = 2.61$, $p = 0.069$
Tamias striatus	6	8	7	6	$F_{3,32} = 0.321$, $p = 0.810$
Blarina brevicauda	1	1	1	1	$F_{3,32} = 0.433$, $p = 0.731$
Clethrionomys gapperi	1	0	0	1	$F_{3,32} = 2.64$, $p = 0.066$

b)

	ANOVA PAIRWISE COMPARISONS (Tukey's HSD)					
SPECIES	**CONTROL – ALL OAKS GIRDLED**	**CONTROL – 50% OAKS GIRDLED**	**CONTROL – NON OAKS GIRDLED**	**ALL OAKS GIRDLED – 50% OAKS GIRDLED**	**ALL OAKS GIRDLED – NON-OAKS GIRDLED**	**50% OAKS GIRDLED – NON-OAKS GIRDLED**
Peromyscus leucopus	p = 0.963	p = 0.907	p = 0.204	p = 0.661	p = 0.429	p = 0.053
Tamias striatus	p = 0.908	p = 0.924	p = 1.00	p = 1.00	p = 0.873	p = 0.891
Blarina brevicauda	p = 0.905	p = 0.803	p = 1.00	p = 0.996	p = 0.905	p = 0.803
Clethrionomys gapperi	p = 0.137	p = 0.137	p = 0.944	p = 1.00	p = 0.355	p = 0.355

Table 3. Density (number of unique individuals per hectare) was estimated for all species at Black Rock Forest, New York in 2008. Density estimates were calculated by dividing the total number of unique captures for all species in each plot by the plot size, averaging for each plot type, and extrapolating for the density in one hectare. Density estimates were reported as the number of unique individuals per hectare and the total number of captures per hectare. A one-way analysis of variance (ANOVA) did not detect any variance between plots for density.

PLOT TYPE	AVERAGE DENSITY ESTIMATE (NUMBER OF UNIQUE INDIVIDUALS PER HECTARE)	NUMBER OF TOTAL CAPTURES PER HECTARE
Control	17	31
All oaks girdled	20	34
50% oaks girdled	18	29
Non-oaks girdled	20	36
ANOVA	$F_{3,32} = 0.262$, $p = 0.852$	$F_{3,32} = 0.506$, $p = 0.681$

Table 4. One-way analysis of variance (ANOVA) was used to detect significant differences between plot types in species diversity, evenness, and richness. Species diversity was calculated using the Simpson's Diversity Index (*D*), and the species evenness was calculated using the Simpson's Measure of Evenness (*E*). For small mammals captured at Black Rock Forest, New York in 2008, *D*, *E*, and species richness for all plot types were similar.

PLOT TYPE	SIMPSON'S DIVERSITY INDEX (*D*)	SIMPSON'S MEASURE OF EVENNESS (*E*)	SPECIES RICHNESS
Control	0.610	0.114	5
All oaks girdled	0.545	0.115	6
50% oaks girdled	0.522	0.114	5
Non-oaks girdled	0.610	0.114	6
ANOVA	$F_{3,8}$ = 0.052, p = 0.983		$F_{3,8}$ = 1.27, p = 0.349

Table 5. The number of unique captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to month. A one-way analysis of variance (ANOVA) was used to detect significant differences in captures between months (total number of captures and differences within species). The ANOVA indicated that the total number of captures of all species did not vary over the three-month field season. Month did have a significant effect on the number of captures within two species, *Blarina brevicauda* and *Tamias striatus*, whose numbers significantly increased over time. The number of *Peromyscus leucopus* captures decreased as the season progressed, but this change was not significant. A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the monthly capture means and look for significant differences between number of captures each month within species. A Tukey's HSD test indicated a significant increase in capture numbers between July and August in *T. striatus* and a significant increase in capture numbers between July and September and between August and September in *B. brevicauda*. (All species captured were accounted in comparisons for all species. Only species with more than four captures were compared with ANOVA.)

	MONTH (TOTAL NUMBER OF UNIQUE CAPTURES)			**ANOVA**	**ANOVA PAIRWISE COMPARISONS (Tukey's HSD)**		
SPECIES	**JULY**	**AUGUST**	**SEPTEMBER**		**JULY-AUGUST**	**JULY-SEPTEMBER**	**AUGUST-SEPTEMBER**
All species	186	256	217	$F_{2,33} = 0.386$, $p = 0.683$	$p = 0.671$	$p = 0.963$	$p = 0.823$
Peromyscus leucopus	117	111	68	$F_{2,33} = 3.20$, $p = 0.054$	$p = 0.154$	$p = 0.057$	$p = 0.874$
Tamias striatus	60	128	119	$F_{2,33} = 3.31$, $p = 0.049$	$p = 0.051$	$p = 0.148$	$p = 0.864$
Blarina brevicauda	1	3	19	$F_{2,33} = 13.3$, $p < 0.050$	$p = 0.861$	$p < 0.050$	$p = 0.001$
Clethrionomys gapperi	2	9	11	$F_{2,33} = 0.951$, $p = 0.397$	$p = 0.894$	$p = 0.376$	$p = 0.642$

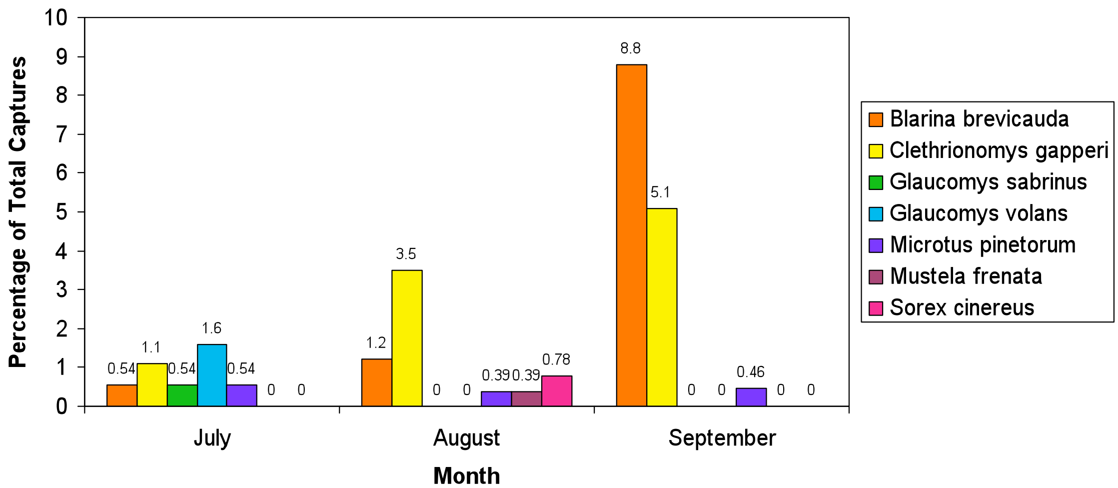


Figure 5. Of all species captured in Black Rock Forest, New York in 2008, *Blarina brevicauda* was one of two species that significantly increased in captures as the season progressed.

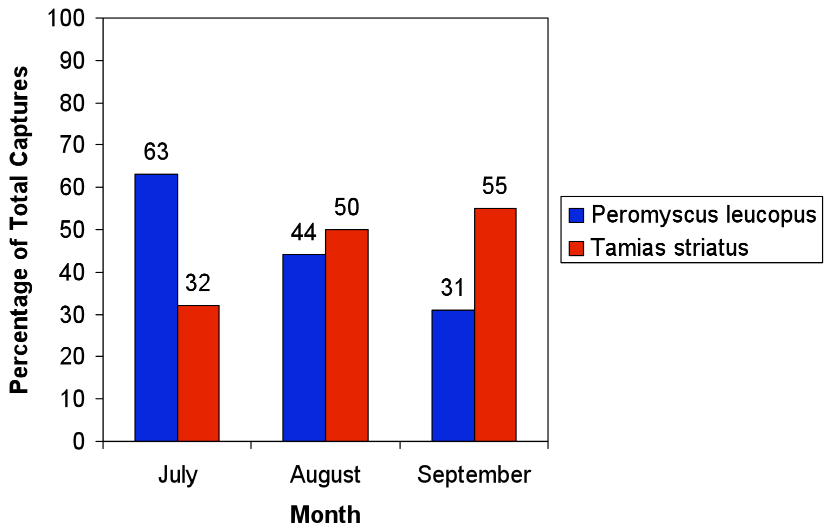


Figure 6. The percentage of total captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to month. The number of *Peromyscus leucopus* captures decreased as the season progressed, and the number of *Tamias striatus* captures increased as the season progressed, however neither of these changes are significant.

Table 6. The number of unique captures of species groups in Black Rock Forest, New York in 2008 were analyzed according to plot type. One-way analysis of variance (ANOVA) did not detect any differences in captures within species between plot types. The one exception was *Clethrionomys gapperi*, which was found more frequently in the control and non-oaks girdled plots. A Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the unique capture means of each plot type, and no significant differences were found in the number of unique captures between plot types. (Only those species captured more than four times are included.)

a)

	TOTAL NUMBER OF UNIQUE CAPTURES					
SPECIES	CONTROL	ALL OAKS GIRDLED	50% OAKS GIRDLED	NON-OAKS GIRDLED	ALL PLOT TYPES	ANOVA
Peromyscus leucopus	41	43	32	61	177	$F_{3,32} = 2.61$, $p = 0.069$
Tamias striatus	63	75	75	57	270	$F_{3,32} = 0.321$, $p = 0.810$
Blarina brevicauda, Sorex cinereus	4	8	9	4	25	$F_{3,32} = 433$, $p = 0.731$
Clethrionomys gapperi	11	0	0	10	21	$F_{3,32} = 4.61$, $p = 0.037$

b)

	ANOVA PAIRWISE COMPARISONS (Tukey's HSD)					
SPECIES	CONTROL – ALL OAKS GIRDLED	CONTROL – 50% OAKS GIRDLED	CONTROL – NON OAKS GIRDLED	ALL OAKS GIRDLED – 50% OAKS GIRDLED	ALL OAKS GIRDLED – NON-OAKS GIRDLED	50% OAKS GIRDLED – NON-OAKS GIRDLED
Peromyscus leucopus	p = 0.963	p = 0.907	p = 0.204	p = 0.661	p = 0.429	p = 0.053
Tamias striatus	p = 0.908	p = 0.924	p = 1.00	p = 1.00	p = 0.873	p = 0.891
Blarina brevicauda, Sorex cinereus	p = 0.905	p = 0.803	p = 1.00	p = 0.996	p = 0.905	p = 0.803
Clethrionomys gapperi	p = 0.137	p = 0.137	p = 0.944	p = 1.00	p = 0.355	p = 0.355

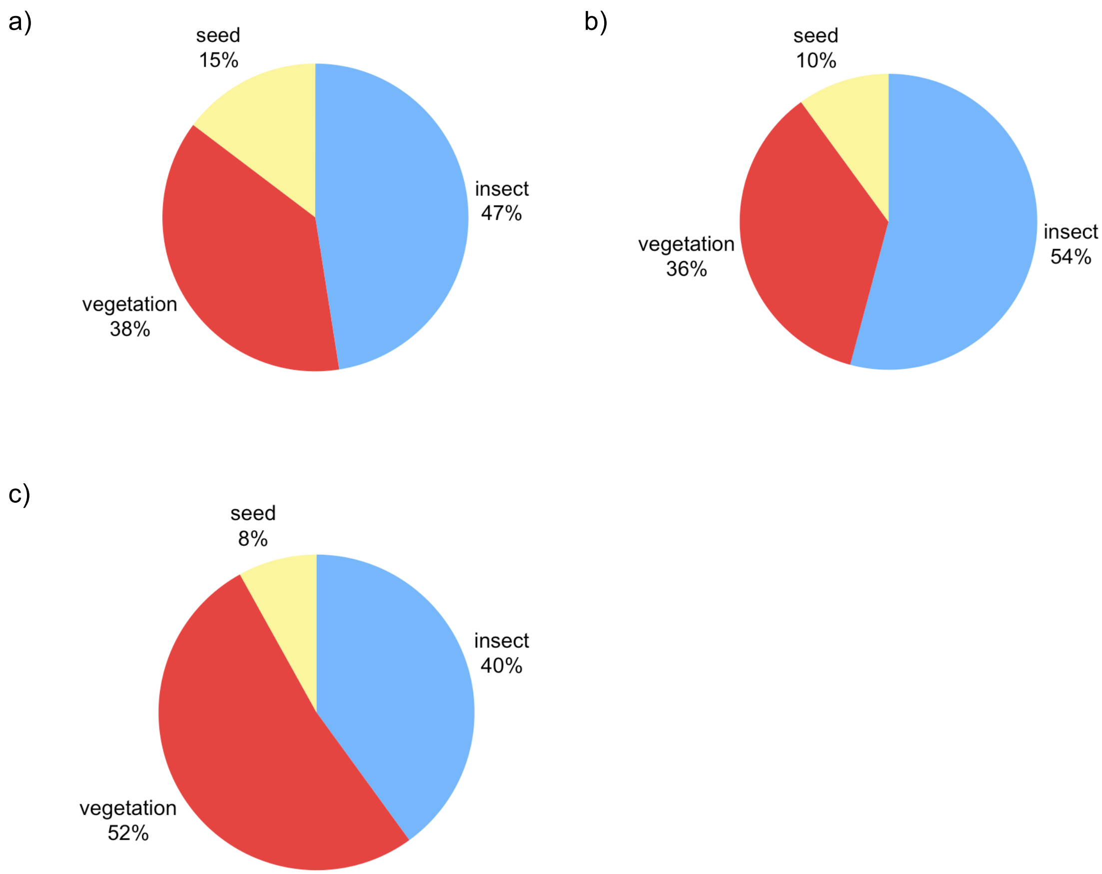


Figure 7. Diet distribution of species in Black Rock Forest, New York in 2008. a) *Peromyscus leucopus* diet distribution. b) *Tamias striatus* diet distribution. c) *Blarina brevicauda* diet distribution.

Table 7. The Levins's measure of niche breadth (*B*) was calculated for each species trapped in Black Rock Forest, New York in 2008 based on a) plot type, b) month of capture, c) gender, and d) age. Calculated *B* values were then standardized from 0 to 1, and a one-way analysis of variance (ANOVA) was used to detect significant differences within species between plot type, month of capture, gender, and age. One-way ANOVA found significant differences in *B* between months in *Peromyscus leucopus* and *Tamias striatus*, where both species became more specialized in their feeding niche over time. (Only species with more than four captures were analyzed. Only *P. leucopus* had enough fecal samples for the three age groups to compare *B* values.)

a)

SPECIES	CONTROL	ALL OAKS GIRDLED	50% OAKS GIRDLED	NON-OAKS GIRDLED	ALL PLOT TYPES	ANOVA
Peromyscus leucopus	0.7480	0.5345	0.7881	0.7376	0.7893	$F_{3,28} = 1.13$, $p = 0.355$
Tamias striatus	0.5797	0.5420	0.4648	0.6131	0.6596	$F_{3,8} = 0.336$, $p = 0.800$
Blarina brevicauda	0.3000	0.6613	0.5000	0.7857	0.6447	$F_{3,7} = 0.857$, $p = 0.506$

b)

SPECIES	JULY	AUGUST	SEPTEMBER	ANOVA
Peromyscus leucopus	0.6918	0.5376	0.4456	$F_{2,29} = 14.9$, $p < 0.050$
Tamias striatus	0.7576	0.5744	0.3655	$F_{2,30} = 4.58$, $p = 0.018$
Blarina brevicauda	0.5000	0.8333	0.5090	$F_{2,10} = 0.571$, $p = 0.583$

c)

SPECIES	MALE	FEMALE	ANOVA
Peromyscus leucopus	0.6711	0.7071	$F_{1,58} = 0.010$, $p = 0.919$
Tamias striatus	0.5519	0.5002	$F_{1,20} = 2.39$, $p = 0.138$
Blarina brevicauda	0.8333	0.5000	$F_{1,13} = 0.001$, $p = 0.977$

d)

SPECIES	ADULT	SUBADULT	JUVENILE	ANOVA
Peromyscus leucopus	0.6704	0.7822	0.5800	$F_{2,51} = 0.845$, $p = 0.436$

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