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Fine-Scale Assessment of Habitat Characteristics of Two Cottontail Species in Southern New England

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FINE-SCALE ASSESSMENT OF HABITAT
CHARACTERISTICS OF TWO COTTONTAIL SPECIES
IN SOUTHERN NEW ENGLAND

BY
AMY E. GOTTFRIED

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
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2013

MASTER OF SCIENCE THESIS

OF

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2013

ABSTRACT

The changing landscape in New England over the past century has had a profound effect on the abundance and distribution of native wildlife species that prefer early successional habitat. In the mid 20th Century many of these species, including the New England cottontail (*Sylvilagus transitionalis*, NEC), experienced an increase in population numbers as abandoned agricultural fields matured into early successional habitats (ESH). However, as these ESH further matured into forests, populations of early successional wildlife species declined. Possibly as the result of this habitat loss, NEC has so declined that only one habitat patch has been identified that contains NEC in Rhode Island since 2005. The species is now a candidate for listing as an endangered species by the U.S. Fish and Wildlife Service. To identify sites currently occupied by NEC and eastern cottontail (*S. floridanus*, EC) in Rhode Island, I conducted an intensive statewide survey. I chose survey locations using three criteria: (1) the area is a known historic location for NEC; (2) the area revealed a high calculated habitat suitability index (HSI) value as determined by a model that was developed for NEC; and (3) the location was indicated by a model that generated a statewide cover map of early successional habitats. I also conducted intensive vegetation analyses at known locations of NEC and EC in Connecticut and Rhode Island to better describe their chosen habitat and identify any differences in preference between the two species. Sites in Rhode Island that were occupied by cottontails had more shrub cover, herbaceous cover, less canopy cover, and lower basal area than sites that were not occupied by cottontails. In Connecticut, sites that were occupied by NEC had more canopy cover, and greater basal area than sites

occupied by EC. In a comparison of site selection models, the map of early successional habitats identified more sites with cottontails present than a habitat suitability index.

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There are many people that I need to acknowledge for their help with my project. First, I must thank my major advisor, Dr. Thomas P. Husband for giving me the opportunity to further my education, and for his constant encouragement and support throughout my undergraduate and graduate career. I would also like to thank Principal Investigator on the project, Dr. T. J. McGreevy for his patience while I learned genetic techniques in the lab, and for assisting with the design and organization of the pellet survey effort.

Committee member and Principal Investigator Brian Tefft has also been a huge source of advice and support. His knowledge of all things rabbit was invaluable in planning the pellet and vegetation surveys. I must also thank my committee members, Drs. Scott McWilliams and Liliana Gonzalez, who both provided advice and guidance throughout all stages of my project.

I would still be in the woods collecting data right now if it were not for my field assistants Elena Albright and Keri Dyer. Their enthusiasm while working in less-than-ideal field conditions was incredible, and without that help I would not have been able to collect the amount of data that I did. Dr. Howard Kilpatrick and Travis Goodie from the Connecticut Department of Energy and Environmental Protection graciously provided me with thousands of telemetry points for cottontails in Connecticut. Without this information I would have not been able to collect data relating to New England cottontails and would have needed to shift the focus of my whole project. Additionally, Dr. Bill Buffum from URI provided me with incredibly useful information on the locations of shrub habitat in Rhode Island, which allowed us to collect what seemed like endless amounts of rabbit pellets. The undergraduate volunteers at URI were important

contributors to this project, collecting over 1,000 fecal pellet samples for the lab to analyze. I thank them for their enthusiasm and diligence in hunting for rabbit feces.

I need to thank my lab-mate Mary Sullivan for her friendship and sense of humor, which made the whole thesis writing almost enjoyable. I would also like to thank Cindy Maynard for her assistance in the field and for collaboration on the design of the vegetation survey protocols

On a personal note, I need to thank my family for their support in my decision to return to school, and for their encouragement along the way. Last but not least, I thank my husband for his computer wizardry, keen eye for editing, and support throughout this whole endeavor.

PREFACE

This thesis is written in manuscript format to be submitted to the Journal of Wildlife Management. All parts follow this format. I studied the habitat characteristics of 2 species of cottontails, the New England cottontail (*Sylvilagus transitionalis*) and the eastern cottontail (*S. floridanus*), in southern New England. I identified sites in Rhode Island that were occupied by cottontails using 3 survey site selection methods, 2 of which I compared for success at identifying areas inhabited by cottontails. I also selected sites in eastern Connecticut that were occupied by New England cottontails or eastern cottontails using previously collected telemetry data. At each of the sites in Rhode Island and Connecticut, I collected fine-scale habitat characteristics by recording shrub cover, stem density, herbaceous cover, basal area, and canopy cover. Site characteristics were compared by presence or absence of cottontails and by which species was present at each site using logistic regression modeling.

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MANUSCRIPT – I

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Fine-scale assessment of habitat characteristics of two cottontail species in southern New England

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INTRODUCTION

The historic range of the New England cottontail (NEC), *Sylvilagus transitionalis*, decreased by more than 80% over the past fifty years (Litvaitis 1993, Litvaitis et al. 1999, Litvaitis et al. 2006) while the distribution of the eastern Cottontail (EC), *Sylvilagus floridanus*, in southern New England increased over the same period of time (Johnston 1972, Probert and Litvaitis 1996). There are several theories behind the changes in abundance of these two species including ability to avoid increased predator populations (Smith and Litvaitis 1999; 2000), interspecific competition for resources (Fay and Chandler 1955, Barbour and Litvaitis 1993, Probert and Litvaitis 1996), and NEC habitat change and loss (Litvaitis 1993; 2001). Throughout New England, lands previously dominated by early successional forests have transitioned to mature forests (Askins 1993, Litvaitis 2001, Trani et al. 2001) and are becoming more fragmented by development and infrastructure (Villafuerte et al. 1997, Trani et al. 2001, Litvaitis et al. 2003). This affects many wildlife species that depend on large patches of early successional forests (Beckwith 1954) such as bobcat (*Lynx rufus*), ruffed grouse (*Bonasa umbellus*), American woodcock (*Scolopax minor*), and New England cottontail (Litvaitis 1993, Dessecker and McAuley 2001).

The U.S. Fish & Wildlife Service (USFWS) listed the New England cottontail as a candidate species under the Endangered Species Act in 2006 (United States Fish and Wildlife Service 2006). In Rhode Island, the last positive in-the-hand identification of NEC was in 2005 by the RI Department of Environmental Management (RI DEM). A 2006 range-wide survey (Litvaitis et al. 2006) identified 5 populations occupying western Connecticut, eastern Connecticut and Rhode Island, Cape Cod Massachusetts, southern

New Hampshire, and southern Maine. This study was large-scale and the search efforts were very broad and based largely on previously known locations of cottontails.

RI DEM has monitored cottontail populations in Rhode Island since 1950 and the USFWS since 2003, but due to the current status of NEC across their range, more in-depth and widespread surveys were initiated in 2010 in Rhode Island using a stratified random sampling design. This method can be used to target the areas immediately surrounding known locations and areas where the species is likely to occur based on additional environmental factors and the species' niche (Orrock et al. 2000, Guisan et al. 2006). This method is useful when the study area is large, but the distribution of a rare species is mostly unknown (Guisan et al. 2006, Rhodes et al. 2006). Specifically, a habitat suitability model can be used to target areas that have a higher probability of occurrence for the species of interest. Habitat suitability models based on presence data are a technique that can be applied to a variety of taxa at a variety of scales. These models have been used to predict the presence of rare plants on a fine scale (Gogol-Prokurat 2011), predict the spread of invasive plant species on a state and regional scale (Crall et al. 2013), to identify habitat selection in red-backed voles, *Myodes gapperi* (Orrock et al. 2000), and predict occurrence of terrestrial mollusks (Dunk et al. 2004), to name a few. While this technique has many applications, the scale (Dunk et al. 2004) and quality of the input variables (Le Lay 2010) are important considerations when testing the models. One benefit of habitat models, however, is they are usually adaptive and as more information is collected through testing, the models become better at predicting occurrences of a species (Crall et al. 2013).

In New England, a habitat suitability model was created specifically for NEC (S. G. Fuller, Wildlife Management Institute, unpublished report) and identifies parcels of land that presently have suitable habitat for NEC, and parcels that are capable of supporting NEC with proper management. The model is currently being used throughout the range of NEC to target focal areas for NEC conservation and management.

Most current NEC management strategies are focused on creating the ideal habitat because the most well established hypothesis for the decline of NEC is the loss of early successional habitat and habitat fragmentation (Litvaitis and Villafuerte 1996, Litvaitis et al. 2008). While there have been many habitat related studies focusing on NEC in the past, these studies either focused on the northern portion of the NEC's historic range (Barbour and Litvaitis 1993) where the vegetation can be very different both structurally and in species composition from other parts of its range, or in areas where EC is not present (Litvaitis et al. 2003). Recent studies on cottontail habitat that included southern New England focused on broad-scale analyses that often neglect key habitat variables such as shrub cover (Tash and Litvaitis 2007). Several past studies on cottontail habitat use in southern New England took place before DNA was used to identify species and before populations of EC had become so great (Eabry 1968, Nugent 1968, Johnston 1972). It is believed that the two species share similar habitats, but that EC may be able to thrive in a wider range of habitat types and areas with less understory cover (Probert and Litvaitis 1996, Smith and Litvaitis 2000).

The objectives of my study were to: 1) identify sites occupied by NEC and EC in Rhode Island; 2) identify what habitat characteristics are important in predicting cottontail presence; 3) compare two methods for identifying existing habitat and examine

their ability to predict habitat patches occupied by cottontail species; and 4) compare the habitat use of NEC and EC on a microhabitat level using intensive on-the-ground vegetation measurements.

STUDY AREA

Winter fecal pellet and vegetation surveys took place in Washington, Kent, Providence, and Newport counties in Rhode Island (Fig. 1). These counties encompass 2,729 km². Rhode Island has a humid continental climate with warm, rainy summers and cold winters. Pellet collection, necessary for identification of cottontails through DNA analysis, is largely dependent upon snow and cold conditions during the winter months. According to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC), the average annual snowfall in Rhode Island is 90.2 cm, however the first field season (December 2010 to March 2011) received higher than average snowfall while the second field season (December 2011 to March 2012) received lower than average snowfall. According to the 2011 report (Butler et al. 2011a), Rhode Island's forests are dominated by mature trees (61-100 years of age) and the most common tree species include red maple (*Acer rubrum*), Eastern white pine (*Pinus strobus*), and Northern red oak (*Quercus rubra*).

Vegetation surveys also took place in the towns of Scotland and North Stonington, located in eastern Connecticut. This area has a similar climate and forest composition (Butler et al. 2011b) to Rhode Island.

METHODS

Survey Site Selection

Each survey location was chosen using one of three site selection methods: a habitat suitability index (HSI) developed specifically for NEC (S.G. Fuller, unpublished report); a Geographic Information Systems (GIS) data layer of all early successional habitats (ESH) in the state of Rhode Island (Buffum et al. 2011); and all historical known locations of New England cottontails from 1970 to 2005.

The NEC HSI was created using presence only data for NEC collected between 2000 and 2010. From these known locations, data from 24 habitat variables (S.G. Fuller, unpublished report) were used to model the habitat suitability throughout the range of NEC. While 5 components of the HSI were created for the purposes of NEC habitat conservation and management, for my study I used 2 of the components of the HSI to identify survey sites: 1) an index of current habitat suitability, and 2) a focal area analysis and ranking of parcels with high conservation value. For a parcel to be considered for site selection, it had to be highly ranked in the parcel analysis, have a suitability index ≥ 70 on a scale of 0 to 100, and be ≥ 2 ha. Larger parcel sizes were tried initially, but this eliminated too much habitat to be able to generate the required number of survey locations. From the areas that fit the above criteria, random survey points spaced ≥ 50 m apart were generated with the use of ArcMap 10 (Environmental Systems Research Institute, Inc., Redlands, CA).

The Rhode Island ESH is a map that identifies all shrubland habitat in Rhode Island based the Rhode Island Land Use dataset and the National Wetlands Inventory, as well as analysis of forest clear-cuts, and manual delineation based on high resolution

2008 digital imagery. For parcels to be considered using the ESH map, parcels had to be ≥ 4 ha, have a soil classification dryer than “very poorly drained” according to the Natural Resources Conservation Service (NRCS) soil survey for Rhode Island, and not overlap with a parcel that was identified using the HSI model. Random survey points that were spaced ≥ 50 m apart from each other and from HSI points were generated using the ESH criteria. All known historical locations for New England cottontails in Rhode Island from 1970 to 2005 were identified as sites for pellet surveys. These locations were provided by the R.I. Department of Environmental Management (RI DEM) and included 35 sites (B.C. Tefft, Rhode Island Department of Environmental Management, unpublished report).

The 2011 field season had a very broad focus with survey sites identified statewide. The 2012 field season survey sites were identified in two focal areas for the state. The first focal area included all areas in the Rhode Island towns of Coventry, West Greenwich, Exeter, Richmond, Hopkinton, and Westerly that were ≤ 8 km of the Connecticut border. The second focal area encompassed the Rhode Island towns of Tiverton and Little Compton. The same parameters were used for determining sites using the 2 selection methods, however sites were spaced ≥ 100 m apart from each other and ≥ 100 m apart from points that were surveyed during the first field season.

To determine which site selection method is most effective, survey sites were compared by selection method based on ability to predict the presence of cottontail rabbits at surveyed sites. I also compared the habitat variables measured at each site of these two site types using a 1-tailed t-test.

Pellet Surveys and Collection

Pellet surveys took place from December 2010 to March 2011 and from December 2011 to March 2012. Sites that were indicated by one of the three site selection methods above were surveyed at least three times during the two field seasons. Each survey period took place 24 to 72 hours after a snowfall and continued until temperatures rose above freezing or a rain event occurred. Collecting on snow provides a color contrast between the pellets and the substrate and aids in the detection of pellets. Furthermore, cold temperatures associated with snowfall keeps DNA on the pellet more stable thus ensuring better success rates for species identification when pellets are processed in the University of Rhode Island Regional Conservation Genetics Laboratory (URI RCGL). In the event of no snowfall during the field season, surveys took place when temperatures remained at or below freezing for at least 2 days.

University of Rhode Island (URI) student volunteers and RI DEM and USFWS personnel surveyed the selected sites. Prior to the beginning of each field season, training sessions were held to instruct all personnel on proper survey and fecal sample collection protocols. To ensure that all sites were surveyed in the same way, a 50 x 50-m search plot protocol was adopted with the assigned survey point acting as the center of the search plot. During each of the three survey periods the plots were searched for ≥ 1 hour. Any rabbit signs such as tracks, browse, and fecal pellets were documented and fecal pellets were collected following the collection protocol set forth by the URI RCGL. Pellet samples were identified to species using mitochondrial DNA extraction techniques at the URI RCGL.

Identifying Plots in Connecticut

Telemetry data collected by the Connecticut Department of Energy and Environmental Protection Wildlife Division from December 2008 to May 2012 (H. Kilpatrick and T. Goodie, Connecticut Department of Energy and Environmental Protection, unpublished report) were used to identify vegetation survey plots. Data were provided for 19 EC individuals and 11 NEC individuals across 4 properties. Properties were targeted for the telemetry study if rabbit sign (pellets, browse, tracks) was detected. Locations for individuals were collected 6 times a week, 3 evening points and 3 daytime points. Because differences in home range size between winter and breeding seasons were recorded for both cottontail species (H. Kilpatrick and T. Goodie, unpublished report) all data points for each individual were sorted into 2 seasons. Telemetry points collected from November to March were labeled as “winter season” and points collected from April to October were designated as “breeding season.” Using ArcMap 10 and the kernel density tool, areas with the highest density of points were identified for each individual during each season of available data. The mean center of all points in the high-density area acted as the center point for the vegetation plot. In the event that the identified center point for one individual was ≤ 10 m of another point, relating to the average size of the error polygon in the telemetry data, the average center of those center points combined was used as the new plot center and only 1 vegetation plot was completed. Only data points that were calculated to be independent (Swihart and Slade 1985) were used in determining the plot centers.

Vegetation Data Collection

I collected vegetation data at all completed pellet survey sites in Rhode Island and identified telemetry sites in Connecticut. Vegetation surveys were conducted within a 50 x 50-m plot. I took measurements on stem density, herbaceous cover, shrub cover, basal area, tree height, and canopy cover.

I estimated stem density by conducting stem counts in 1-m² quadrats at 12 random locations in each 50 x 50-m plot, 4 in each quadrant of the plot. Random locations were determined by choosing 2 numbers from a random numbers table that corresponded to values on the 50-m measuring tape, and placing the quadrat at the intersection of the random number on the tape in the first direction (North or South) and the random number on the tape in the second direction (East or West). Stems were counted if they were a woody shrub species that was rooted in the plot, ≥ 50 cm tall, and with a diameter at breast height (DBH) of ≤ 2.5 cm. I also estimated herbaceous cover within the same 12 quadrats and recorded the cover using a Daubenmire scale (Daubenmire 1959) to estimate total cover of plants < 50 cm tall.

Estimates of horizontal shrub cover were measured by using the line-intercept method (Canfield 1941) along 2 50-m transects in each plot, one in the North-South direction and one in the East-West direction. Species and heights of all shrub plants that intercepted the line that also were ≥ 50 cm tall with a DBH of ≤ 2.5 cm were recorded. During the second field season, I also measured visual obstruction by shrub cover using a modified Robel pole (Robel et al. 1970, Toledo et al. 2008). Measurements were taken at 4 random locations in the main plot, 1 in each quadrant. Random locations were chosen using the same method as described above. Visual obstruction was recorded from each

of the 4 cardinal directions at each location and the minimum height of the vegetation was recorded.

Basal area and canopy cover measurements were taken at the same locations as visual obstruction measurements and averaged to get a basal area and canopy cover of the plot. Canopy cover was measured using a convex spherical densiometer (Forest Densiometers, Rapid City, SD) (Lemmon 1957) and basal area was estimated using a 10-factor basal area prism (Cruise Master Prisms, Inc., Sublimity, OR). The distance to, DBH, and species of each basal area tree was recorded, as well. The height of 4 trees in the main plot were measured using a clinometer (Suunto, Vantaa, Finland) to give an estimate overall tree height in the plot.

A subset of 10 plots was measured 3 times throughout the second field season to monitor changes in plant growth. I recorded all habitat variables except for tree characteristics during the first week of June, July, and August to determine if there were significant differences in shrub and herbaceous measurements between the beginning and end of the field season.

Data Analysis

All survey locations and pellet collection sites were recorded using a handheld GPS unit (Garmin GPSMap 60CSx, Garmin International, Inc., Olathe, KS). Waypoints were plotted using ArcMap 10 and plots were identified by site selection method used and cottontail presence/absence.

I used SAS Software version 9.2 (SAS Institute, Inc., Cary, NC) to complete a logistic regression (PROC GENMOD, PROC LOGISTIC) to compare the probability of a

site being occupied by cottontails versus not being occupied based on the habitat variables present at the site. To choose which variables to include in the final model, I used a univariate logistic regression to identify significant variables ($P < 0.05$) (Nash and Bradford 2001). To exclude variables that showed signs of multicollinearity, I compared the tolerance (TOL) and variance of inflation factors (VIF) of each variable. If multicollinearity was detected, I used Akaike's Information Criterion (AIC) for goodness of fit to choose which variables to include in the multivariate logistic regression models. The same analysis was used to compare the probability of NEC presence versus EC presence in Connecticut.

To analyze the data collected 3 times throughout the second field season on the subset of plots, I used a general linear model with repeated measures (PROC MIXED) to test the null hypothesis that there was no difference in shrub cover, stem density, or herbaceous cover from the beginning of the field season to the end.

RESULTS

Pellet Survey – RI

A total of 110 sites were surveyed completely (surveyed at least 3 times over 2 field seasons) in Rhode Island: 38 from the ESH map, 54 from the HSI model, and at 18 historical locations. Cottontail presence was detected at 45 sites: 28 from the ESH map, 11 from the HSI model, and 6 at historical locations. At these sites, 658 fecal pellet samples were collected and an additional 679 haphazard samples from Washington, Kent, Providence, and Newport counties in Rhode Island were collected and analyzed. All of the samples collected at the survey sites were identified as EC. Two of the haphazard samples were identified as NEC.

Vegetation Survey in Rhode Island

For the subset of plots that were monitored 3 times throughout the summer, there were no significant differences in high shrub cover ($P = 0.161$), low shrub cover ($P = 0.319$), stem density ($P = 0.889$), herbaceous cover ($P = 0.672$), visual obstruction by low plants ($P = 0.668$) from the beginning of the field season to the end. There were significant differences in the average height of shrubs ($P = 0.014$), and the amount of visual obstruction from high plants ($P = 0.007$) from the beginning of the field season to the end, but because it was expected that there would be a change in plant height, I considered this change unimportant relative to habitat selection by cottontails.

Presence vs. Absence. - Vegetation surveys were conducted on all of the completed cottontail survey sites in Rhode Island ($n=110$). In a univariate logistic regression of presence versus absence of cottontails, the only variable that was not significant ($P >$

0.05) was stem density (Table 1) so it was excluded from the multivariate logistic regression model. Tree height also was excluded from the multivariate logistic regression model because while the variable had a significant P-value, this measurement was not recorded at every plot and should only be used for habitat characterization. In a test for multicollinearity, total shrub cover, low shrub cover, and high shrub cover all showed high VIF values (>10). Based on AIC values, high shrub cover fit best in the full model with all other habitat variables, so total shrub cover and low shrub cover were eliminated from the multivariate logistic regression model to prevent misinterpretation. Visual obstruction variables were only measured during the second field season so they were not included in the multivariate logistic regression model. However, all three variables (visual obstruction from high and low plants, and height of obstruction) were significant in a univariate logistic regression. The habitat variables that were included in the multivariate logistic regression model were high shrub cover, herbaceous cover, and basal area (Table 2). This model had the highest value of area under the curve (AUC) for explaining the variability, 0.834, and the lowest AIC value for goodness of fit. High shrub cover was the most important variable in the multivariate logistic model and had the highest odds ratio (Table 2).

Logistic regression plots were created for each individual significant variable (Figs. 2 to 11). Cover (total, low, and high), average herbaceous cover, visual obstruction (high, low, and height of obstruction) all showed a positive relationship with probability of cottontail presence (higher values = higher probability of cottontail presence), while canopy cover, tree height, and basal area showed a negative relationship with cottontail presence (lower values = higher probability of cottontail presence).

Shrub species composition was quantified for both the cover variables (high and low shrubs) and stem density. I observed some differences in shrub species composition between presence and absence sites (Tables 3, 4). Southern arrowwood (*Viburnum dentatum*), greenbrier (*Smilax rotundifolia*), and multiflora rose (*Rosa multiflora*) were the most recorded plants on sites where rabbits were present, while *Vaccinium* spp. and sweet pepperbush (*Clethra alnifolia*) were the most recorded species on sites where rabbits were absent. In comparison, while multiflora rose covered a high proportion of the total plots as both a high and low shrub (0.030, 0.026) at sites where cottontails were present, it was a much less common high and low shrub (0.004, 0.002) at sites where cottontails were absent.

Species present in stem counts and herbaceous cover estimations were quantified based on the average number of times the species was observed at a site. Small (<50 cm tall) *Vaccinium* spp. were the most common species detected in the herbaceous layer for absence sites, while various grasses (Family Poaceae) were the most common plants in the herbaceous layer at presence sites (Table 5). Similar to the shrub cover proportions, *Vaccinium* spp. were the most commonly detected species in the stem count measurements at absence sites, while oriental bittersweet (*Celastrus orbiculatus*) was most commonly detected at presence sites (Table 6).

Comparison of 2 Survey Site Selection Methods. - Of the 110 sites surveyed in Rhode Island, 38 were selected from early successional habitat sites, 54 were selected from the habitat suitability index sites, and 18 were historical locations for NEC. Eastern cottontail presence was recorded at 73% of ESH sites surveyed ($n=28$), 20% of HSI sites surveyed ($n=11$), and 28% of historical locations surveyed ($n=5$). NEC occurrence was

not detected at any survey sites. When comparing habitat variables between the sites, I only compared HSI and ESH sites. Over the course of the study, several of the coordinates for historical locations that were provided were found to be inaccurate (B. Tefft, personal communication). As a result, the habitat at historical location sites could not be compared to plots chosen by other site selection methods.

Results of a 1-tailed t-test showed that survey sites that were identified by the HSI method, as compared to ESH, on average had lower amounts of total shrub cover ($P \leq 0.001$), less high shrub cover ($P \leq 0.001$), less low shrub cover ($P = 0.001$), fewer stems ($P = 0.004$), less herbaceous cover ($P \leq 0.001$), and higher average canopy cover ($P = 0.003$) (Table 7). Values for visual obstruction, which were only measured during the second field season, also differed between the two models. Higher average visual obstruction by low vegetation ($P \leq 0.001$) and by high vegetation ($P \leq 0.001$) were observed at ESH survey sites compared to HSI sites.

Vegetation Survey in Connecticut

Vegetation surveys were completed for 36 plots (NEC $n=17$; EC $n=19$) representing 19 individual EC and 11 individual NEC. The individual sample size differs from the plot sample size because some of the calculated mean centers were ≤ 10 m from another calculated mean center point. Three of the EC plots were determined by combined mean center points because of their close proximity to one another, 2 of which were combined by the winter and breeding points of an individual. The 3rd combined plot contained points from both the winter and breeding points of 2 EC individuals. Three of the NEC plots were determined by combining the mean centers of multiple plots due to close

proximity to one another. One plot contained points from the winter season of 2 individuals, and the remaining 2 combined points contained points from both the winter and breeding points of an individual. When comparing the vegetation measurements for each species, breeding and winter plots were combined into a single data set. I used an ANOVA to compare differences between the measurements at the seasonal plots, and no significant differences were found. So while there may be spatial differences between the areas used by the 2 species in winter and breeding seasons, I believe that for further analysis data should be separated by species only.

In a univariate logistic regression, canopy cover ($P=0.01$) and basal area ($P=0.01$) were the only significant variables (Table 8), and thus the only 2 variables that remained in the multivariate logistic regression model (Table 9). All variables were tested in a backwards stepwise regression, and canopy cover and basal area were the variables most associated with NEC presence. While the AUC value for this model were high, 0.774, neither variable was significant ($P \geq 0.05$). A correlation analysis indicated very slight multicollinearity between the two variables, which may explain the reason why the AUC value was high (0.774) while the variables were not significant in the model.

Logistic regression plots show a positive relationship between probability of presence of NEC and amount of canopy cover and basal area (Figs. 12, 13). I observed positive relationship trends between probability of NEC presence and high shrub cover ($P=0.386$) and stem density ($P=0.057$) but these variables were not statistically significant, perhaps the result of a lack of power due to sample size (Fig 14; 15). Similarly, I observed a negative relationship between herbaceous cover ($P=0.058$) and the probability of NEC (Fig. 16), but this variable was not statistically significant, again

likely the result of lack of power due to low sample size. There was no relationship between the probability of NEC and visual obstruction, low shrub cover, or average tree height.

There was very little difference in the plant species compositions of plots occupied by NEC compared to plots occupied by EC. The top 3 high shrub species and the top 2 low shrub species recorded under shrub cover measurements were the same for both sets of plots (Tables 10, 11). The top 4 stem count species with the highest average occurrence were the same for both NEC and EC sites (Table 12), and both sites had various grasses (Family Poaceae) as the most common plant in the herbaceous layer (Table 13).

DISCUSSION

Certain habitat variables can help to predict the presence of cottontails in southern New England. High shrub cover (>50 cm), herbaceous cover, and basal area were the variables that were most associated with presence of EC in Rhode Island. Although they did not fit in a logistic model, high proportions of low shrub cover, and lower canopy cover were associated with higher probability of cottontail presence. In the field, I observed that, due to the structure of many of the common shrub species found in the study area (e.g. *Rosa multiflora*, *Vitis* spp., *Celastrus orbiculatus*), stem density measurements were often not a good indicator of the amount of shrub cover in the area. While these plant species are known to provide food for cottontails (Eabry 1968, Rice 1978) and have the structure to provide a cover source, the manner in which the stems grow from the ground leads to low stem counts and high variability. Litvaitis et al. (2003) consider habitat suitable for NEC if the woody stem density was approximately >9,000 stems/ha, and Barbour and Litvatis (1993) found that NEC generally use patches with dense understory of >50,000 stems/ha. The stem density for NEC sites in Connecticut was 54,167 stems/ha (SE±7018), and while this number agrees with past studies, the variability is very high. This indicates that while stem density is an important habitat variable for NEC, given the structure of the plant communities in southern New England, stem density may not be the most accurate measure of cottontail habitat suitability, and stem counts should be used along with other habitat measurements in this region to evaluate cottontail habitat.

Based on my results, basal area also was an important factor in predicting the presence of cottontails in Rhode Island, and in predicting NEC sites in Connecticut. This

variable has not been reported in previous habitat studies relating to NEC, so I cannot make comparisons to values observed in other parts of the species' range. However, ideal basal area for early successional habitat management in the Southeastern US has been reported as 7-21 m²/ha (Natural Resources Conservation Service 1999), and in central US hardwood forests, basal areas >4.6 m²/ha on managed lands are found to have reduced stem density and are therefore considered poor quality habitat for early successional species (Thompson III 1997). Both of these values are lower than the average value observed in my study on sites with NEC present (53.6 m²/ha), and lower than sites with cottontails present in Rhode Island (57.5 m²/ha). My measurements include trees with DBH <10 cm, which are not often measured in traditional forestry surveys. As a result, my values for basal area may not be completely comparable to other studies, but the amount of difference is significant enough that the observed basal area values at NEC sites in my study were higher than the recommended values (Natural Resources Conservation Service 1999; Thompson III 1997) for early successional habitat. Even-aged timber management, or clear-cutting, on small patches of habitat is often recommended as a management tool to provide habitat for early successional species (Dessecker and McAuley 2001, Litvaitis 2001, Thompson III and DeGraaf 2001), including NEC, but my results indicate that tree characteristics are important variables for identifying NEC habitat and may be an important variable in managing for quality habitat.

In a comparison of the 2 site selection methods, the ESH map performed better than the HSI in that cottontails were found much more frequently on the former. The HSI model was developed as a management tool to identify sites for potential habitat

conservation and restoration. These sites are identified based on habitat variables at known locations for NEC. So while the HSI model was not created for the purpose of identifying sites that are occupied by NEC, the sites that it identifies as having a high suitability should have a higher likelihood of rabbit presence. However, the habitat variables that are included in this model are very limited due to the large scale of the model. The ESH map, on the other hand, is focused on Rhode Island and only identifies one variable – shrub habitat. While the ESH map was better at identifying sites where EC was present in Rhode Island than the HSI, neither of these site selection methods was able to identify locations where NEC was present given the parameters that were set initially, but that may be due to the incredibly small NEC population in the state. To further test the efficacy of the HSI at predicting NEC presence, it will need to be used in an area with a more stable, and widely distributed population of NEC.

While trends were recognized, there were few significant differences in the habitat characteristics of sites used by EC versus those used by NEC. Canopy cover and basal area were the only 2 variables that showed significant differences between the 2 species. Because the locations of the vegetation plots were determined by telemetry locations, and not based on a random survey, the plots were clustered on 4 distinct properties. These properties were targeted in trapping efforts because NEC was known to occur at each of the locations in the past. On 2 of the 4 properties, NEC and EC occurred in separate patches with little overlap. On the remaining properties, however, both species occupied the same patches of habitat. While the measured plots of the 2 species did not overlap, the vegetation characteristics of the entire properties were very similar. Had I surveyed more areas, there is a chance that significant differences in the habitat

characteristics between the 2 cottontail species would have been revealed, but with a steadily declining population of NEC, the opportunities for additional surveys of this nature are limited.

It is unclear whether the sites identified for NEC in Connecticut are what the species is choosing based on preference, or if these sites are being used because EC is pushing NEC to these potentially less desirable patches of habitat. My study was limited to habitat patches where the two species are sympatric, and also limited by a small sample size due to a declining population. It also is possible that the properties where these NEC were trapped are in transition from an ideal early successional habitat to a more forested habitat, and that the NEC may be using habitat patches that are not ideal. To be able to test what habitats are ideal for NEC in southern New England, habitat characteristics need to be measured on an allopatric NEC population to identify which habitats they are choosing based on preference.

MANAGEMENT IMPLICATIONS

The use of a range-wide method to identify patches of land for cottontail habitat management can be a useful tool, but in its current state, the scale is too large to capture the habitat variables that are important to cottontails. Models are an adaptive management tool and with the input of more data, a model may perform better at identifying currently suitable habitat as well as habitat that is suitable after management. Because the early successional habitat map performed well in identifying cottontail habitat in Rhode Island, I suggest incorporating regional early successional habitat maps into the range-wide habitat suitability model to create a more useful management tool. It is likely important to incorporate region-specific information in a range-wide model because the plant communities in the southern portion of NEC range are very different than those in the northern part of its range, and thus NEC habitat should be considered differently. While stem density may be an important habitat characteristic for identifying ideal NEC habitat in the northern part of its range, in southern New England a straightforward stem density measurement is not adequate for categorizing habitat where the plant structure in early successional habitats is dominated by vine-like shrub species. For southern New England, and perhaps elsewhere, a combination of shrub cover measurements, such as the line-intercept method or amount of visual obstruction using a Robel pole, should be considered to account for the high variability in stem density. Throughout the range of NEC, tree characteristics, specifically canopy cover and basal area, should be considered when identifying NEC habitat and when planning habitat management strategies. Additionally, if habitat management continues to be the main strategy of NEC conservation, standardized habitat measurements should be used to

allow accurate comparability and monitoring of habitat both on a regional scale and at a local level throughout the range of the New England cottontail. More research needs to be conducted to further characterize and compare the habitat preferences of NEC and EC. Without knowing if there are any true differences in habitat preference between these two species, there is no way to direct habitat management towards NEC only. If there are no true differences, and EC can colonize all of the habitats being created for NEC, steps may need to be taken to control the populations of EC to allow NEC to thrive.

Table 1. Description of habitat variables measured and the probability of each habitat variable predicting the presence of eastern cottontails (*Sylvilagus floridanus*) at survey sites throughout Rhode Island based on a univariate logistic regression.

Variable	Description	<i>P</i>
Total shrub cover	Proportion of total area covered by shrubs	≤ 0.001
High shrub cover	Proportion of total area covered by high shrubs (>1 m)	≤ 0.001
Low shrub cover	Proportion of total area covered by low shrubs (0.5-1 m)	0.035
Stems per m ²	Average number of stems per m ²	0.395
Herbaceous cover	Average percent of area covered by herbaceous plants	≤ 0.001
Canopy cover	Average percent canopy cover	0.017
Basal area	Average basal area (m ² /ha)	≤ 0.001
Tree height	Average tree height (m)	0.002
Visual obstruction low	Average percent visual obstruction by low vegetation (<1 m)	≤ 0.001
Visual obstruction high	Average percent visual obstruction by high vegetation (>1 m)	≤ 0.001
Visual obstruction height	Average height of visual obstruction (m)	0.002

Table 2. Results of logistic regression analysis of survey sites in Rhode Island where eastern cottontails (*Sylvilagus floridanus*) were present ($n=45$) versus sites where cottontails were absent ($n=65$). There were 3 habitat variables that best explained the variability in the model (AUC=0.834). Variables with odds ratios >1 are positively associated with cottontail presence, and those <1 are positively associated with cottontail absence.

Variable	Coefficient	Odds ratio	SE	<i>P</i>
Proportion of high shrub cover (>1 -2 m)	5.407	222.967	1.439	<0.001
Herbaceous cover (%)	0.017	1.018	0.013	0.190
Basal area (m^2/ha)	-0.014	0.986	<0.001	0.035

Table 3. Composition of high woody plant species (>1-2 m) at survey sites in Rhode Island where no cottontail was detected ($n=65$), and where eastern cottontails (*Sylvilagus floridanus*, EC) were detected ($n=45$). Survey locations were identified by a habitat suitability model, early successional habitat map, or historical New England cottontail (*S. transitionalis*) location.

High woody plant species (>1-2 m)	Proportion of total plots covered by woody plant species	
	Cottontails absent	EC present
<i>Acer rubrum</i>	<0.001	0.002
<i>Amelanchier canadensis</i>		0.002
<i>Berberis thunbergii</i>	<0.001	<0.001
<i>Betula</i> spp.		0.001
<i>Betula alleghaniensis</i>		<0.001
<i>Betula lenta</i>	<0.001	0.001
<i>Betula populifolia</i>		0.001
<i>Carpinus</i> spp.	<0.001	
<i>Carya</i> spp.		0.001
<i>Carya tomentosa</i>	<0.001	
<i>Celastrus orbiculatus</i>	0.002	0.006
<i>Clethra alnifolia</i>	0.020	0.029
<i>Comptonia peregrina</i>		<0.001
<i>Cornus</i> spp.		<0.001
<i>Cornus amomum</i>	<0.001	0.001
<i>Corylus cornuta</i>		<0.001
<i>Crataegus</i> spp.		<0.001
<i>Elaeagnus umbellata</i>	0.005	0.012
<i>Euonymus alatus</i>		0.001
<i>Fagus grandifolia</i>	0.003	0.001
<i>Gaylussacia</i> spp.		<0.001
<i>Hamamelis virginiana</i>	0.001	<0.001
<i>Ilex</i> spp.	0.001	0.002
<i>Ilex glabra</i>	0.001	
<i>Ilex verticillata</i>		0.002
<i>Juniperus virginiana</i>		0.001
<i>Kalmia latifolia</i>		0.011
<i>Kalmia latifolia</i>	0.013	
<i>Ligustrum vulgare</i>		<0.001
<i>Lindera benzoin</i>	0.001	
<i>Lonicera</i> spp.	<0.001	0.021
<i>Lonicera japonica</i>		<0.001
<i>Lonicera morrowii</i>	<0.001	0.003

Table 3. *Continued*

High woody plant species (>1-2 m)	Proportion of total plots covered by woody plant species	
	Cottontails absent	EC present
<i>Morella pensylvanica</i>		0.004
<i>Myrica</i> spp.		<0.001
<i>Nyssa sylvatica</i>	0.001	0.001
<i>Parthenocissus quinquefoila</i>	<0.001	
<i>Picea</i> spp.		<0.001
<i>Pinus strobus</i>	0.012	0.002
<i>Prunus</i> spp.	0.001	0.001
<i>Prunus pennsylvanica</i>		<0.001
<i>Quercus</i> spp.	<0.001	
<i>Quercus alba</i>	0.006	<0.001
<i>Quercus prinus</i>	<0.001	
<i>Quercus rubra</i>		<0.001
<i>Quercus velutina</i>	<0.001	0.001
<i>Rhamnus</i> spp.		0.004
<i>Rhamnus frangula</i>	<0.001	
<i>Rhododendron</i> spp.		0.006
<i>Rhododendron viscosum</i>		0.001
<i>Rhus copallina</i>		0.001
<i>Robinia pseudoacacia</i>		<0.001
<i>Rosa multiflora</i>	0.004	0.030
<i>Rubus</i> spp.	<0.001	0.012
<i>Salix</i> spp.		<0.001
<i>Salix uva ursi</i>	<0.001	
<i>Sassafras albidum</i>	<0.001	0.002
<i>Smilax</i> spp.	0.003	0.016
<i>Smilax glauca</i>	<0.001	0.002
<i>Smilax rotundifolia</i>	0.001	0.025
<i>Spiraea</i> spp.	0.001	
<i>Spiraea alba</i>		<0.001
<i>Spiraea tomentosa</i>	<0.001	
<i>Toxicodendron radicans</i>		<0.001
<i>Vaccinium</i> spp.	0.017	0.022
<i>Vaccinium corymbosum</i>	0.003	
<i>Viburnum acerifolium</i>	<0.001	0.001
<i>Viburnum dentatum</i>	0.002	0.064
<i>Vitis labrusca</i>	0.002	0.023
Dead stems	0.003	
Unknown species	0.002	0.006

Table 4. Composition of low woody plant species (0.5-1 m) at survey sites in Rhode Island where no cottontail was detected ($n=65$), and where eastern cottontail (*Sylvilagus floridanus*, EC) was detected ($n=45$). Survey locations were identified by a habitat suitability index, early successional habitat map, or historical New England cottontail (*S. transitionalis*) location.

Low woody plant species (0.5-1 m)	Proportion of total plots covered by woody plant species	
	Cottontails absent	EC present
<i>Acer rubrum</i>		<0.001
<i>Alnus</i> spp.		<0.001
<i>Amelanchier canadensis</i>		0.002
<i>Berberis thunbergii</i>	0.001	0.001
<i>Betula</i> spp.		0.002
<i>Betula lenta</i>	<0.001	<0.001
<i>Betula populifolia</i>		0.001
<i>Carya</i> spp.	<0.001	0.001
<i>Carya tomentosa</i>	<0.001	
<i>Castanea dentata</i>	<0.001	
<i>Celastrus orbiculatus</i>	0.003	0.009
<i>Clethra alnifolia</i>	0.016	0.018
<i>Comptonia peregrina</i>	<0.001	<0.001
<i>Cornus amomum</i>		0.002
<i>Corylus</i> spp.	<0.001	
<i>Elaeagnus umbellata</i>	0.001	0.002
<i>Fagus grandifolia</i>	0.001	<0.001
<i>Frangula alnus</i>	<0.001	
<i>Gaylussacia</i> spp.	0.009	0.003
<i>Gaylussacia baccata</i>	<0.001	
<i>Hamamelis virginiana</i>	<0.001	0.001
<i>Ilex</i> spp.	<0.001	<0.001
<i>Ilex glabra</i>	<0.001	
<i>Ilex verticillata</i>		<0.001
<i>Juniperus virginiana</i>		0.003
<i>Kalmia</i> spp.		<0.001
<i>Kalmia latifolia</i>	0.007	0.007
<i>Lonicera</i> spp.	<0.001	0.016
<i>Lonicera japonica</i>		<0.001
<i>Lonicera morrowii</i>	0.001	0.002
<i>Lyonia ligustrina</i>	0.008	
<i>Morella pensylvanica</i>	<0.001	0.005

Table 4. *Continued*

Low woody plant species (0.5-1 m)	Proportion of total plots covered by woody plant species	
	Cottontails absent	EC present
<i>Nyssa sylvatica</i>	<0.001	
<i>Pinus rigida</i>		<0.001
<i>Pinus strobus</i>	0.005	0.002
<i>Prunus</i> spp.	<0.001	0.001
<i>Prunus serotina</i>		<0.001
<i>Quercus</i> spp.	<0.001	<0.001
<i>Quercus alba</i>	0.003	0.001
<i>Quercus rubra</i>		<0.001
<i>Quercus velutina</i>	<0.001	0.001
<i>Rhamnus</i> spp.		0.003
<i>Rhamnus frangula</i>	<0.001	
<i>Rhododendron</i> spp.		0.001
<i>Rhododendron viscosum</i>		<0.001
<i>Rhus copallina</i>		<0.001
<i>Robinia pseudoacacia</i>		<0.001
<i>Rosa multiflora</i>	0.002	0.026
<i>Rosa rugosa</i>		0.002
<i>Rubus</i> spp.	<0.001	0.015
<i>Salix uva ursi</i>	<0.001	
<i>Sassafras albidum</i>	<0.001	<0.001
<i>Smilax</i> spp.	0.011	0.013
<i>Smilax glauca</i>	<0.001	0.001
<i>Smilax rotundifolia</i>	<0.001	0.026
<i>Spiraea</i> spp.	0.002	
<i>Spiraea alba</i>		<0.001
<i>Spiraea tomentosa</i>		<0.001
<i>Thuja occidentalis</i>		<0.001
<i>Toxicodendron radicans</i>		<0.001
<i>Tsuga canadensis</i>	<0.001	
<i>Vaccinium</i> spp.	0.045	0.010
<i>Vaccinium corymbosum</i>	0.006	
<i>Viburnum acerifolium</i>	<0.001	0.001
<i>Viburnum dentatum</i>	<0.001	0.017
<i>Vitis labrusca</i>	<0.001	0.012
Dead stems	0.001	
Unknown species	0.001	0.006

Table 5. Herbaceous layer plant species (herbaceous species and others <50 cm tall) composition was recorded in 12 quadrats per survey plot. In Rhode Island, percent of occurrence of each plant species was determined for plots where no cottontail was detected ($n=65$), and plots where only eastern cottontail (*Sylvilagus floridanus*, EC) was detected ($n=45$).

Herbaceous layer plant species	Percent occurrence of herbaceous layer species per plot ($\pm$ SE)	
	Cottontails absent	EC present
<i>Acer</i> spp.	1.99 (0.69)	3.08 (0.87)
<i>Acer rubrum</i>	12.56 (2.08)	4.35 (1.63)
Family Asteraceae	0.12 (0.12)	1.81 (0.86)
<i>Athyrium filix femina</i>	4.73 (1.85)	6.52 (1.99)
<i>Calystegia</i> spp.		1.63 (1.46)
<i>Carex</i> spp.	1.49 (1.26)	
<i>Celastrus orbiculatus</i>	2.24 (1.41)	10.14 (2.59)
<i>Chelidonium majus</i>	0.12 (0.12)	1.27 (1.27)
<i>Clethra alnifolia</i>	11.44 (3.10)	9.78 (3.47)
<i>Dennstaedtia punctilobula</i>	2.74 (0.84)	0.18 (0.18)
<i>Elaeagnus umbellata</i>	1.37 (0.84)	1.09 (0.61)
<i>Fagus grandifolia</i>	1.00 (0.55)	0.54 (0.54)
<i>Galium</i> spp.	5.35 (1.53)	3.80 (1.81)
<i>Gaylussacia</i> spp.	1.74 (1.23)	1.09 (1.09)
<i>Impatiens</i> spp.	1.62 (1.15)	2.36 (0.81)
<i>Kalmia latifolia</i>	2.86 (1.17)	3.08 (1.93)
<i>Ligustrum</i> spp.		1.27 (1.10)
Family Liliaceae	1.12 (0.73)	1.45 (1.45)
<i>Lonicera</i> spp.	0.50 (0.50)	9.78 (3.26)
<i>Lonicera morrowii</i>	0.75 (0.75)	1.63 (1.06)
<i>Lycopodium</i> spp.	12.69 (2.64)	4.35 (1.86)
<i>Lyonia ligustrina</i>	1.49 (1.49)	
<i>Maianthemum canadense</i>	13.93 (2.33)	6.88 (1.47)
<i>Mitchella repens</i>	1.49 (0.87)	0.36 (0.25)
<i>Monotropa uniflora</i>	0.62 (0.41)	0.36 (0.25)
<i>Onoclea sensibilis</i>	0.87 (0.36)	7.43 (2.11)
<i>Osmunda cinnamomea</i>	3.36 (1.23)	1.63 (0.80)
<i>Parthenocissus quinquefolia</i>	2.36 (1.24)	11.41 (2.92)
<i>Pinus strobus</i>	6.22 (1.66)	1.27 (0.58)
Family Poaceae	22.89 (3.14)	28.26 (4.52)
<i>Quercus</i> spp.	5.72 (1.15)	2.54 (0.85)
<i>Quercus alba</i>	4.35 (1.08)	3.26 (1.59)

Table 5. *Continued*

Herbaceous layer plant species	Percent occurrence of herbaceous layer species per plot ($\pm$ SE)	
	Cottontails absent	EC present
<i>Quercus veluntina</i>	1.49 (0.90)	0.54 (0.31)
<i>Rhamnus frangula</i>		1.09 (0.92)
<i>Rosa multiflora</i>	1.12 (0.50)	2.72 (0.78)
<i>Rubus</i> spp.	2.61 (0.85)	12.86 (3.44)
<i>Rubus flagellaris</i>	7.84 (1.74)	13.04 (2.55)
<i>Sassafras albidum</i>	1.37 (0.72)	0.36 (0.25)
<i>Smilax</i> spp.	3.36 (1.20)	3.99 (1.73)
<i>Smilax rotundifolia</i>	0.25 (0.17)	1.81 (0.89)
<i>Solidago</i> spp.	1.74 (0.78)	17.75 (3.72)
<i>Symplocarpus foetidus</i>	1.49 (0.77)	2.72 (1.35)
<i>Toxicodendron radicans</i>	5.60 (1.81)	22.64 (3.95)
<i>Trifolium</i> spp.	0.75 (0.55)	1.27 (0.68)
<i>Uvularia sessilifolia</i>	3.11 (1.15)	1.81 (0.97)
<i>Vaccinium</i> spp.	40.80 (4.19)	9.06 (2.87)
<i>Vaccinium angustifolium</i>	1.87 (1.51)	
<i>Viburnum dentatum</i>	1.24 (0.51)	3.26 (0.99)
<i>Woodwardia</i> spp.	0.12 (0.12)	2.17 (1.20)
Unknown species	10.82 (2.01)	9.42 (2.55)

Table 6. Woody plant species composition was recorded in 12 quadrats per survey plot. In Rhode Island, percent of occurrence of each plant species was determined for plots where no cottontail was detected ($n=65$), and plots where only eastern cottontail (*Sylvilagus floridanus*, EC) was detected ($n=45$).

Woody plant species	Percent occurrence of woody plant species per plot ($\pm$ SE)	
	Cottontails absent	EC present
<i>Acer rubrum</i>	0.25 (0.17)	1.45 (0.70)
<i>Amelanchier</i>		1.09 (0.80)
<i>Celastrus orbiculatus</i>	2.11 (0.99)	12.32 (2.53)
<i>Clethra alnifolia</i>	11.19 (3.15)	9.60 (3.41)
<i>Elaeagnus umbellata</i>	0.50 (0.39)	1.45 (0.60)
<i>Fagus grandifolia</i>	1.12 (0.47)	0.36 (0.36)
<i>Gaylussacia</i> spp.	1.74 (1.33)	1.09 (0.80)
<i>Juniperus virginiana</i>		1.27 (0.68)
<i>Kalmia latifolia</i>	2.24 (1.00)	2.90 (1.76)
<i>Lonicera</i> spp.	0.50 (0.39)	10.33 (3.23)
<i>Lonicera morrowii</i>	0.62 (0.62)	1.99 (1.10)
<i>Lyonia ligustria</i>	1.37 (1.37)	
<i>Pinus strobus</i>	6.84 (1.72)	2.17 (1.17)
<i>Quercus</i> spp.	0.62 (0.32)	1.27 (0.68)
<i>Quercus alba</i>	3.11 (1.05)	0.72 (0.44)
<i>Rhamnus frangula</i>		1.99 (1.54)
<i>Rosa multiflora</i>	1.00 (0.45)	7.43 (2.39)
<i>Rubus</i> spp.	0.62 (0.32)	8.51 (1.96)
<i>Smilax</i> spp.	5.60 (1.78)	8.33 (2.60)
<i>Smilax glauca</i>	1.74 (0.93)	1.63 (1.06)
<i>Smilax rotundifolia</i>	2.36 (1.17)	11.78 (4.04)
<i>Toxicodendron radicans</i>	0.62 (0.51)	1.09 (0.42)
<i>Vaccinium</i> spp.	30.10 (3.58)	7.97 (2.10)
<i>Vaccinium angustifolium</i>	1.37 (1.37)	0.18 (0.18)
<i>Vaccinium corymbosum</i>	1.74 (1.22)	0.18 (0.18)
<i>Viburnum dentatum</i>	1.49 (0.68)	10.51 (2.20)
<i>Vitis labrusca</i>	0.12 (0.12)	5.25 (1.25)
Dead stems	2.61 (0.78)	2.17 (0.98)
Unknown species	1.74 (0.63)	2.90 (1.22)

Table 7. Comparison of habitat variables for cottontail survey sites identified by an early successional habitat map (ESH) ($n=38$), a habitat suitability index (HSI) created specifically for New England cottontail (NEC) ($n=64$), and known locations of eastern cottontail (EC) ($n=19$) and NEC ($n=17$) in Connecticut. Sites that were identified by the ESH map have habitat values more similar to sites in Connecticut that have EC and NEC than sites identified by the HSI model.

Variable	ESH value ($\pm$ SE)	HSI value ($\pm$ SE)	EC value ($\pm$ SE)	NEC value ($\pm$ SE)
Proportion total shrub cover	0.288 (0.029)	0.113 (0.014)	0.295 (0.049)	0.337 (0.046)
Proportion high shrub cover	0.346 (0.039)	0.106 (0.016)	0.321 (0.054)	0.384 (0.047)
Proportion low shrub cover	0.230 (0.032)	0.119 (0.017)	0.268 (0.048)	0.291 (0.048)
Stems per m ²	7.415 (0.951)	4.411 (0.521)	3.535 (0.580)	5.417 (0.702)
Herbaceous cover (%)	41.452 (3.507)	25.103 (2.639)	54.660 (6.269)	36.887 (6.029)
Canopy cover (%)	71.071 (4.512)	86.288 (2.749)	45.280 (7.041)	73.664 (6.001)
Basal area (m ² /ha)	57.506 (7.013)	97.949 (5.280)	29.473 (5.366)	53.603 (6.615)
Tree height (m)	11.576 (1.101)	18.541 (0.679)	14.073 (1.990)	13.842 (2.149)
Visual obstruction low (%)	51.399 (4.189)	32.320 (2.604)	65.231 (4.648)	67.094 (7.538)
Visual obstruction high (%)	32.507 (4.505)	16.709 (1.884)	44.778 (7.379)	44.490 (9.034)
Visual obstruction height (m)	0.606 (0.074)	0.294 (0.028)	0.791 (0.114)	0.765 (0.170)

Table 8. Description of habitat variables measured and the probability of each habitat variable predicting the presence of New England cottontail (*Sylvilagus transitionalis*) at locations in eastern Connecticut based on a univariate logistic regression.

Variable	Description	<i>P</i>
Total shrub cover	Proportion of total area covered by shrubs	0.521
High shrub cover	Proportion of total area covered by high shrubs (>1m)	0.386
Low shrub cover	Proportion of total area covered by low shrubs (0.5-1m)	0.732
Stems per m ²	Average number of stems per m ²	0.057
Herbaceous cover	Average percent of area covered by herbaceous plants	0.058
Canopy cover	Average percent canopy cover	0.010
Basal area	Average basal area (m ² /ha)	0.013
Tree height	Average tree height (m)	0.937
Visual obstruction low	Average percent visual obstruction by low vegetation (<1m)	0.812
Visual obstruction high	Average percent visual obstruction by high vegetation (>1m)	0.979
Visual obstruction height	Average height of visual obstruction (m)	0.885

Table 9. Results of logistic regression analysis of survey sites in Connecticut where eastern cottontail (*Sylvilagus floridanus*, EC) was present ($n=19$) versus sites where New England cottontail (*S. transitionalis*, NEC) was present ($n=17$). There were 2 habitat variables that best explained the variability in the model (AUC=0.774). Variables with odds ratios >1 are positively associated with NEC presence, and those <1 are positively associated with EC presence.

Variable	Coefficient	Odds ratio	SE	<i>P</i>
Canopy cover (%)	0.024	1.024	0.019	0.222
Basal area (m ² /ha)	0.017	1.017	0.021	0.420

Table 10. Composition of high woody plant species (>1-2 m) at survey plots in Connecticut where eastern cottontail (*Sylvilagus floridanus*, EC) ($n=19$) and New England cottontail (*S. transitionalis*, NEC) ($n=17$) were present, respectively. Positive locations were identified by a previous radio telemetry study and vegetation surveys took place at the mean center of telemetry locations within an individual's core use area.

High woody plant species (>1-2 m)	Proportion of total plots covered by woody plant species	
	EC plots	NEC plots
<i>Acer</i> spp.		0.001
<i>Acer rubrum</i>	<0.001	0.025
<i>Acer saccharum</i>		<0.001
<i>Alnus</i> spp.	0.002	
<i>Berberis thunbergii</i>	0.004	0.002
<i>Betula alleghaniensis</i>		0.001
<i>Betula lenta</i>		0.002
<i>Carya</i> spp.	0.001	<0.001
<i>Carya ovata</i>	0.001	
<i>Carya tomentosa</i>		0.001
<i>Celastrus orbiculatus</i>	0.018	0.016
<i>Cirsium</i> spp.	0.001	
<i>Clematis virginiana</i>	0.002	
<i>Clethra alnifolia</i>	0.006	0.006
<i>Cornus</i> spp.	0.001	0.003
<i>Cornus amomum</i>	0.007	<0.001
<i>Corylus</i> spp.	0.001	0.002
<i>Corylus cornuta</i>	<0.001	0.003
<i>Elaeagnus umbellata</i>	0.072	0.049
<i>Euonymus alatus</i>	0.001	0.003
<i>Fagus grandifolia</i>	0.009	0.020
<i>Hamamelis virginiana</i>	0.001	0.003
<i>Juniperus virginiana</i>		0.002
<i>Ligustrum vulgare</i>		0.001
<i>Lindera benzoin</i>	0.002	
<i>Lonicera</i> spp.		<0.001
<i>Lonicera japonica</i>	0.001	
<i>Lonicera morrowii</i>	0.008	0.007
<i>Ostrya virginiana</i>	0.001	0.003
<i>Parthenocissus quinquefoila</i>	0.002	<0.001
<i>Prunus</i> spp.	0.001	

Table 10. *Continued*

High woody plant species (>1-2 m)	Proportion of total plots covered by woody plant species	
	EC plots	NEC plots
<i>Prunus serotina</i>		0.005
<i>Quercus</i> spp.	<0.001	
<i>Quercus alba</i>		<0.001
<i>Quercus velutina</i>	0.001	
<i>Rosa multiflora</i>	0.126	0.133
<i>Rubus</i> spp.	0.016	0.015
<i>Smilax</i> spp.		0.011
<i>Smilax glauca</i>	0.001	0.001
<i>Smilax rotundifolia</i>	0.007	0.019
<i>Toxicodendron radicans</i>		<0.001
<i>Vaccinium</i> spp.	0.003	0.005
<i>Vaccinium corymbosum</i>		
<i>Viburnum acerifolium</i>	0.001	0.007
<i>Viburnum dentatum</i>	<0.001	
<i>Vitis labrusca</i>	0.021	0.028
Dead stems	0.001	0.004
Unknown species	0.002	0.003

Table 11. Composition of low woody plant species (0.5-1 m) at survey plots in Connecticut where eastern cottontail (*Sylvilagus floridanus*, EC) ($n=19$) and New England cottontail (*S. transitionalis*, NEC) ($n=17$) were present, respectively. Positive locations were identified by a previous radio telemetry study and vegetation surveys took place at the mean center of telemetry locations within an individual's core use area.

Low woody plant species (0.5-1 m)	Proportion of total plots covered by woody plant species	
	EC plots	NEC plots
<i>Acer rubrum</i>		0.001
<i>Berberis thunbergii</i>	0.003	0.015
<i>Betula alleghaniensis</i>		<0.001
<i>Betula lenta</i>		<0.001
<i>Carya</i> spp.	<0.001	<0.001
<i>Carya ovata</i>	<0.001	
<i>Celastrus orbiculatus</i>	0.031	0.021
<i>Clematis virginiana</i>	<0.001	
<i>Clethra alnifolia</i>	<0.001	0.003
<i>Cornus</i> spp.		<0.001
<i>Cornus amomum</i>	0.007	<0.001
<i>Corylus</i> spp.	0.002	
<i>Corylus cornuta</i>		0.007
<i>Elaeagnus umbellata</i>	0.018	0.009
<i>Euonymus alatus</i>	0.001	
<i>Fagus grandifolia</i>	0.003	0.004
<i>Hamamelis virginiana</i>		0.003
<i>Kalmia latifolia</i>		0.001
<i>Ligustrum vulgare</i>		0.001
<i>Lindera benzoin</i>	0.003	
<i>Lonicera</i> spp.	<0.001	
<i>Lonicera japonica</i>		0.001
<i>Lonicera morrowii</i>	0.016	0.009
<i>Parthenocissus quinquefolia</i>	0.002	
<i>Pinus strobus</i>		<0.001
<i>Prunus</i> spp.	<0.001	
<i>Prunus serotina</i>	<0.001	
<i>Quercus</i> spp.	<0.001	
<i>Rhododendron</i> spp.		<0.001
<i>Rosa multiflora</i>	0.145	0.167
<i>Rubus</i> spp.	0.019	0.014

Table 11. *Continued*

Low woody plant species (0.5-1 m)	Proportion of total plots covered by woody plant species	
	EC plots	NEC plots
<i>Smilax</i> spp.		0.005
<i>Smilax glauca</i>		0.001
<i>Smilax rotundifolia</i>	0.004	0.010
<i>Solanum dulcamara</i>	<0.001	0.001
<i>Toxicodendron radicans</i>	<0.001	
<i>Vaccinium</i> spp.	0.001	0.001
<i>Viburnum acerifolium</i>	<0.001	0.002
<i>Viburnum dentatum</i>	<0.001	<0.001
<i>Vitis labrusca</i>	0.010	0.010
Dead stems		0.004
Unknown species	0.002	0.001

Table 12. Woody plant species composition was recorded in 12 quadrats per survey plot. In Connecticut, percent of occurrence of each plant species was determined for plots where eastern cottontail (*Sylvilagus floridanus*, EC) ($n=19$) and New England cottontail (*S. transitionalis*, NEC) ($n=17$) were present, respectively.

Woody plant species	Percent occurrence of woody plant species per plot ($\pm$ SE)	
	EC plots	NEC plots
<i>Acer rubrum</i>	0.88 (0.60)	2.94 (1.59)
<i>Berberis thunbergii</i>	0.44 (0.44)	4.41 (3.04)
<i>Betula lenta</i>		1.96 (1.14)
<i>Carpinus caroliniana</i>		1.47 (0.79)
<i>Carya</i> spp.	1.32 (0.72)	
<i>Celastrus orbiculatus</i>	19.30 (4.81)	23.53 (6.20)
<i>Clethra alnifolia</i>	2.63 (2.63)	3.43 (3.43)
<i>Cornus amomum</i>	1.32 (0.96)	
<i>Corylus cornuta</i>	0.44 (0.44)	3.92 (1.91)
<i>Elaeagnus umbellata</i>	3.95 (1.61)	0.98 (0.98)
<i>Fagus grandifolia</i>	0.88 (0.88)	1.96 (1.52)
<i>Kalmia latifolia</i>		1.47 (1.07)
<i>Lonicera morrowii</i>	4.82 (1.84)	0.49 (0.49)
<i>Rosa multiflora</i>	24.12 (4.63)	31.86 (6.90)
<i>Rubus</i> spp.	5.26 (1.59)	9.31 (3.34)
<i>Smilax rotundifolia</i>	5.70 (4.86)	18.14 (7.54)
<i>Toxicodendron radicans</i>	1.32 (0.72)	
<i>Viburnum acerifolium</i>	1.75 (1.21)	5.88 (2.34)
<i>Vitis labrusca</i>	3.07 (1.14)	5.88 (2.23)
Unknown species	0.44 (0.44)	1.47 (1.07)

Table 13. Herbaceous layer plant species (herbaceous species and others <50 cm tall) composition was recorded in 12 quadrats per survey plot. In Connecticut, percent of occurrence of each plant species was determined for plots where eastern cottontail (*Sylvilagus floridanus*, EC) ($n=19$) and New England cottontail (*S. transitionalis*, NEC) ($n=17$) were present, respectively.

Herbaceous layer plant species	Percent occurrence of herbaceous layer species per plot ($\pm$ SE)	
	EC plots	NEC plots
<i>Acer</i> spp.	0.44 (0.44)	4.41 (2.49)
<i>Acer rubrum</i>	1.75 (1.02)	5.39 (1.88)
<i>Arisaema triphyllum</i>	3.95 (2.73)	6.86 (3.52)
<i>Artemisia vulgaris</i>		1.47 (1.47)
<i>Asclepias</i> spp.	2.63 (1.57)	0.98 (0.67)
Family Asteraceae	2.63 (1.11)	2.45 (1.56)
<i>Athyrium filix femina</i>	3.95 (2.66)	8.82 (3.68)
<i>Berberis thunbergii</i>	0.44 (0.44)	2.94 (2.14)
<i>Boehmeria cylindrica</i>	1.32 (1.32)	1.96 (1.96)
<i>Celastrus orbiculatus</i>	13.60 (4.33)	18.14 (6.40)
<i>Chelidonium majus</i>	3.95 (2.73)	
<i>Clethra alnifolia</i>	2.19 (2.19)	3.43 (3.43)
<i>Commelina communis</i>	3.51 (2.65)	
<i>Corylus americana</i>	1.32 (1.32)	
<i>Corylus cornuta</i>	0.44 (0.44)	2.45 (1.56)
<i>Dennstaedtia punctilobula</i>	2.63 (1.81)	
<i>Digitaria</i> spp.	1.75 (1.36)	
<i>Eupatorium</i> spp.	0.88 (0.60)	1.47 (1.47)
<i>Galium</i> spp.	21.05 (5.19)	11.76 (3.12)
<i>Impatiens</i> spp.	14.04 (5.10)	20.10 (5.90)
<i>Lonicera</i> spp.		1.47 (1.07)
<i>Lonicera morrowii</i>	3.07 (1.45)	
<i>Maianthemum canadense</i>	5.26 (3.67)	25.00 (8.81)
<i>Mikania scandens</i>	1.75 (0.80)	0.49 (0.49)
<i>Onoclea sensibilis</i>	2.19 (1.07)	8.82 (4.49)
<i>Parthenocissus quinquefolia</i>	11.40 (2.86)	7.35 (2.76)
<i>Phytolacca americana</i>	3.95 (2.73)	0.49 (0.49)
<i>Plantago</i> spp.	2.63 (1.81)	1.47 (1.47)
Family Poaceae	47.81 (6.46)	28.43 (6.19)
<i>Polygonum</i> spp.	1.75 (1.21)	0.98 (0.67)
<i>Polygonum sagittatum</i>	2.19 (2.19)	2.94 (2.01)
<i>Potentilla</i> spp.	1.32 (0.72)	1.47 (0.79)

Table 13. *Continued*

Herbaceous layer plant species	Percent occurrence of herbaceous layer species per plot ($\pm$ SE)	
	EC plots	NEC plots
<i>Quercus</i> spp.	0.88 (0.88)	1.47 (0.79)
<i>Rosa multiflora</i>	4.82 (1.95)	7.84 (4.97)
<i>Rubus</i> spp.	9.21 (2.84)	15.69 (3.77)
<i>Rubus flagellaris</i>	2.63 (1.81)	12.25 (4.58)
<i>Smilax rotundifolia</i>	0.88 (0.60)	2.45 (1.39)
<i>Solanum dulcamara</i>	2.63 (1.43)	0.49 (0.49)
<i>Solidago</i> spp.	34.65 (5.85)	24.02 (5.62)
<i>Symphyotrichum novi belgii</i>	1.75 (1.75)	
<i>Thelypteris noveboracensis</i>	0.44 (0.44)	5.88 (5.38)
<i>Toxicodendron radicans</i>	14.47 (3.05)	17.65 (4.94)
<i>Trifolium</i> spp.	9.65 (2.72)	1.96 (1.14)
<i>Urtica dioica</i>	7.89 (2.74)	4.90 (2.27)
<i>Uvularia sessilifolia</i>	2.19 (1.25)	3.92 (1.45)
<i>Vaccinium</i> spp.	0.88 (0.88)	3.92 (2.16)
<i>Viburnum acerifolium</i>	3.95 (3.15)	7.84 (3.31)
<i>Viola</i> spp.	3.07 (2.23)	
<i>Vitis labrusca</i>	2.63 (1.11)	1.47 (1.07)
<i>Woodwardia</i> spp.		2.45 (1.99)
Unknown species	3.95 (1.33)	4.41 (2.38)

Figure 1. Map of study area with vegetation survey locations. Survey points in Rhode Island represent sites that were surveyed for cottontail (*Sylvilagus* spp.) presence, and sites where vegetation measurements were collected. Points in Connecticut represent vegetation survey locations based on previous telemetry studies for New England cottontail and eastern cottontail.

Figure 2. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on the proportion of total shrub cover measured in a 50 x 50-m plot.

Figure 3. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on the proportion of high shrub cover (shrub species >1-2 m tall) measured in a 50 x 50-m plot.

Figure 4. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on the proportion of low shrub cover (shrub species 0.5-1 m tall) measured in a 50 x 50-m plot.

Figure 5. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average percentage of herbaceous cover measured in a 50 x 50-m plot.

Figure 6. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average percentage of canopy cover measured in a 50 x 50-m plot.

Figure 7. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average basal area (m^2/ha) measured in a 50 x 50-m plot.

Figure 8. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average tree height (m) measured in a 50 x 50-m plot.

Figure 9. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average percentage of visual obstruction caused by low vegetation (0.5-1 m).

Figure 10. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average percentage of visual obstruction caused by high vegetation (>1-2 m).

Figure 11. Logistic regression of the probability of a survey site in Rhode Island being occupied by cottontails based on average height (m) of visual obstruction by vegetation.

Figure 12. Logistic regression of the probability of New England cottontail presence versus eastern cottontail presence based on average percentage of canopy cover measured in a 50 x 50-m plot.

Figure 13. Logistic regression of the probability of New England cottontail presence versus eastern cottontail presence based on average basal area (m^2/ha) measured in a 50 x 50-m plot.

Figure 14. Logistic regression of the probability of New England cottontail presence versus eastern cottontail presence based on proportion of high shrub cover (shrub species >1-2 m tall) measured in a 50 x 50-m plot.

Figure 15. Logistic regression of the probability of New England cottontail presence versus eastern cottontail presence based on stem density (stems per m²) measured in a 50 x 50-m plot.

Figure 16. Logistic regression of the probability of New England cottontail presence versus eastern cottontail presence based on average herbaceous cover.

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APPENDIX I. Literature Review

Due to their current conservation status as a candidate species (U.S. Fish and Wildlife Service 2006), the New England cottontail (NEC), *Sylvilagus transitionalis* (Chapman 1975), has been the subject of many habitat-focused studies in recent years. These studies aim to get a better understanding of the specific habitat requirements of this species.

Over the past 50 years, the range of the New England cottontail has declined significantly (Litvaitis 1993, Litvaitis et al. 1999, Litvaitis et al. 2006), while populations of EC have increased and their range has expanded during this same period of time (Johnston 1972, Reynolds 1975). Theories on the cause of the decline in populations of NEC include habitat loss caused by forest maturation and fragmentation (Litvaitis 1993;2001), and competition for resources with an introduced species, the eastern cottontail (EC), *Sylvilagus floridanus* (Fay and Chandler 1955, Barbour and Litvaitis 1993, Probert and Litvaitis 1996). In many states, EC were introduced as a game species, possibly in response to already declining NEC populations (Jackson 1973). While direct aggressive and interference competition have not been documented as explanations for increased EC range, it has been suggested that EC colonization of a habitat patch may establish “prior rights,” influencing NEC to avoid the colonized patch (Probert and Litvaitis 1996).

Eastern cottontails are considered habitat generalists and can live in a wide variety of different habitats including woodlots, fencerows, cultivated fields and roadsides as long as there is a source of woody vegetation for food and a cover source, either natural or artificial (Swihart and Yahner 1982). Winter habitat is considered a limiting factor for

EC; areas are considered suitable during winter if percent shrub crown closure is 20-50% and percent tree canopy closure is 25-50% (Allen 1984). Early habitat studies in Connecticut did not document any measurable differences in certain habitat, but found that EC were more often associated with “open land” plant species while NEC were associated with forested plant species (Eabry 1968). Additionally, NEC was never trapped in open, mowed, or pastured field habitats, while EC were often found in these habitats (Eabry 1968). Smith and Litvaitis (1999) found that the eye size of EC is larger than NEC, leading to higher probability of predator detection. This may explain the EC’s apparent ability to occupy a wider variety of habitats with differing cover types than NEC.

In a captive study, Dalke and Sime (1941) found that EC and NEC had nearly identical food habits and preferences, consuming woody stems in the winter months and herbaceous species in the summer months. In a study of food preferences of wild cottontails on a patch where only NEC were present (Rice 1978), no clear plant species appeared to be preferred – in all cases the most abundant shrub species was the plant species most often consumed. Haugen (1942) notes that food availability is seldom a limiting factor in suitable habitat for EC; they will often select habitats with more cover over those with abundant food sources if the two are not found together. The foraging strategies of EC and NEC differ according to a captive study (Smith and Litvaitis 2000), which showed that NEC consumed more food in cover than EC, who depleted available food at the same amounts regardless of amount of cover. These studies further support the claims that EC is a generalist that can adapt to a wide variety of habitats with differing food sources and cover amounts.

While EC has thrived throughout southern New England, NEC populations have declined. Changes in habitat are the most commonly studied reason behind the decline of NEC populations across their native range. The abandonment of farmland in New England led to an abundance of early successional habitat, and thus high population levels of NEC, but as these habitats have matured into forests, the populations of NEC have declined (Litvaitis 1993). Linkkila (1971) documented a shift in species composition of a early successional habitat in Connecticut from mixed population of NEC and EC in 1960 to a population of only EC by 1970. More recently, a 2006 study on the current distribution of NEC throughout their native range identified 5 populations occupying western Connecticut, eastern Connecticut and Rhode Island, Cape Cod Massachusetts, southern New Hampshire, and southern Maine, representing a >80% decrease in their historic range (Litvaitis et al. 2006). Additionally, the remaining suitable early successional habitats that are available to NEC are becoming increasingly fragmented (Villafuerte et al. 1997, Litvaitis et al. 2003). Barbour and Litvaitis (1993) found that patches of suitable habitat >5 ha were consistently occupied while smaller patches had an occupancy rate of 60%. Occupying smaller patches implied extinction vulnerability due to limited food resources and increased predator interaction. A recent study characterized the habitat characteristics of the remaining populations of NEC on a large scale and found that all remaining populations are associated with human-dominated landscapes and areas of sparse forest coverage, further highlighting the importance of early successional habitats and the effects of fragmentation on this species (Tash and Litvaitis 2007).

While there have been many studies on the habitat characteristics of both eastern cottontails and New England cottontails in the past, the scale and techniques used need to be considered when making comparisons of the results of each. Earlier studies looked at habitat comparisons on a small scale, but the species identification techniques used were not reliable, and the habitat characterization techniques used were often unable to identify subtle differences between the habitat characteristics of EC and NEC. More recent studies have tried to characterize NEC habitat on a range-wide scale, which often excludes important variables, such as shrub cover, due to limitations in data availability at large scales. To better manage the declining NEC populations, more information is needed on the habitat characteristics that are important to both species and whether habitat differences between the two species can be identified at any scale.

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