RESEARCH ON NEW ENGLAND COTTONTAILS COMPLETED AT THE UNIVERSITY OF NEW HAMPSHIRE

Barbour, M.S., and J.A. Litvaitis. 1993. Niche dimensions of New England cottontails in relation to habitat patch size. ***Oecologia*** 95:321-327.

We examined physical condition, niche dimensions, and survival rates of New England cottontails (*Sylvilagus transitionalis*) that occupied 21 habitat patches of different sizes during winter. Rabbits on small patches (2.5 ha) were predominantly males, and both sexes had lower body mass than individuals on large patches (5.0 ha). Niche indices of habitat use where (ranges from 0 to 1, and values approaching 1 indicate generalized resource use) revealed that rabbits on small patches used a greater variety of microhabitats (based on understory stem density: (ßs = 0.81, and proximity to cover: (ßc = 0.79) than rabbits occupying large patches (ßs = 0.65, ßc = 0.66). Rabbits on small patches also consumed low quality forage more often and fed at sites farther from escape cover than rabbits on large patches. There were no significant correlations between rabbit densities and niche dimensions. Niche expansion was not a result of competitive release or relaxation of predator pressure. Rabbits on small patches apparently modified their niche dimensions in response to resource limitations. This response included occupying sites with limited understory cover that apparently resulted in rabbits on small patches having a lower survival rate (0.35) than rabbits on large patches (0.69) during a 10-week monitoring period. Skewed sex ratios and low survival rates among rabbits on small patches suggest that these habitats act as sinks to dispersing juveniles from large (source) patches. As a result, local populations of New England cottontails may become vulnerable to extinction if large patches of habitat are not maintained.

Brown, A.L., and J.A. Litvaitis. 1995. Habitat features associated with predation of New England cottontails: what scale is appropriate? ***Canadian Journal of Zoology*** 73: 1005-1011.

We examined habitat features at several spatial scales that were associated with predation of New England cottontails (*Sylvilagus transitionalis*) by mammalian carnivores. Fates (killed/survived) of marked cottontails were compared to characteristics of the habitat patch they occupied and composition of the surrounding landscape. Perimeter-to-area ratio of an occupied patch, amount of disturbed habitat within 0.5 km of a patch, and the amount of coniferous forest within 1 km of a patch were greater among killed rabbits than among those that survived. Amount of water within 1 km and an index of landscape evenness were greater among rabbits that survived. Habitat features in the vicinity of patches occupied by cottontails apparently influenced the distribution and movements of carnivores. Characteristics of patches likely influenced rabbit exposure and predator success. We propose that predation of cottontails was a multi-scaled process. Landscape composition (ca. 250 km^2) influenced the relative abundance of predators. The distribution of predators within a landscape was a function of the distribution of life requisites (multiple patches, ca. 250 ha). Predators then selected a patch to forage in based on its relative productivity in comparison to adjacent patches. Finally, once a predator entered a patch, vulnerability of a resident cottontail was dependent on the site (ca. 250 m^2) occupied by the rabbit. This hierarchical approach may help resolve the current debate on the risk of predation in fragmented landscapes.

Kovach, A. I., M.K. Litvaitis, and J.A. Litvaitis. 2003. Evaluation of fecal DNA analysis as a method to determine the geographic range of a rare lagomorph. *Wildlife Society Bulletin* 31:1061-1065.

Noninvasive genetic sampling of animal populations provides many potential benefits to wildlife biologists over traditional field methods that require trapping, handling, and repeated visits to the same study site. Noninvasive genetic methods can be time- and cost-effective and are pertinent to the study of rare, elusive, and threatened or endangered species. We evaluated the utility of fecal mtDNA analysis as a method to inventory the range of New England cottontails (*Sylvilagus transitionalis*), a species of conservation concern. We were able to consistently extract high quality DNA from the fecal pellets of 3 species of lagomorphs, New England cottontails, eastern cottontails (*S. floridanus*), and snowshoe hares (*Lepus americanus*). We found that season, sample age, and source species influenced extraction success. We amplified a 565 base portion of the mitochondrial genome, using the polymerase chain reaction (PCR), and identified species-specific restriction sites. We used this technique in a pilot field study to distinguish among 140 fecal samples of the 3 sympatric lagomorphs. Unequivocal species identification was possible for 98% of the 133 samples that amplified successfully. Therefore, we conclude that mtDNA analysis of fecal pellets is an efficient and reliable method to inventory and monitor lagomorph populations during the winter. Our approach can easily be extended, with minor modifications, to the monitoring of other herbivore species.

Litvaitis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. ***Conservation Biology*** 7:866-873.

Unlike other regions of North America, forested habitats in New England have increased substantially in the past 100 years. The proportion of land in New Hampshire covered by forests was 47% in 1880 and 87% in 1980. This increase was largely the result of a region-wide abandonment of farms and the subsequent colonization of these lands by second-growth forests. I examined the sequence of farm abandonment, forest colonization, and forest maturation that occurred in New Hampshire in relation to changes in the abundance and distribution of a group of forest mammals and birds that have undergone substantial declines. A modeled pattern of secondary succession resulted in the availability of approximately 195,000 ha of early seral habitats (10-25 years after abandonment) from 1905 to 1940. These habitats then matured into closed-canopy forests by ca. 1960. Concurrent to the loss of early successional habitats, populations of New England cottontails (*Sylvilagus transitionalis*) decreased from an apparent continuous distribution throughout 60% of New Hampshire to fragmented populations that occupy <20% of the state. Bobcats (*Felis rufus*) responded functionally (*S. transitionalis* in diet: 1951-54 = 43% versus 1961-64 = 10%) and numerically (mean annual harvest of bobcats: 1951-54 = 350, 1965-69 = 36) to changes in cottontail abundance. Eighteen of 26 species of migratory passerines that nest in the forests of northern New England also declined during the period their populations were monitored (1934-1987). Eight (44%) of the species that declined are associated with early successional habitats, and these species consistently exhibited population declines during the 1950s. The reduction of early successional species may be extended (in space and time) by current land uses that fragment and isolate patches of habitat. Ownership patterns of forest lands in New England (excluding Maine, 88% privately owned with an average holding of 10 ha) suggest that large tracts of early successional habitats will be

restricted to industrial and state/national forests. Although even-aged management of a portion of these forests may be perceived as incompatible with area-sensitive and interior species, clustering of clearcuts and maintaining large tracts of mature habitats could sustain diverse populations of forest vertebrates.

Litvaitis, J.A. 2003. Are pre-Columbian conditions relevant baselines in managed forests of the northeastern United States? ***Forest Ecology and Management*** 185:113-126.

Populations of a number of taxa associated with shrublands, early-successional forests, and other disturbance-generated habitats (collectively referred to as "thickets") are declining in the northeastern United States. To assure that species dependent on thicket habitats persist, intervention is warranted. However, conservationists concerned with the status of thicket-dependent species are confronted with two important questions. How much habitat is needed? And how should these habitats be distributed? Natural disturbance regimes have been recommended as a baseline that managers should consider while providing thicket habitats. Within the Northeast, historic disturbance regimes varied substantially among forest types. Coastal regions were characterized by extensive barrens where regular and often times large-scale disturbances that resulted in >15% of the area being covered by regenerating forest stands. Among inland forests, natural disturbances were usually small and resulted in seedling-sapling stands and beaver (*Castor canadensis*) impoundments covering <6% of the area. Under these conditions, thicket-affiliated species were probably distributed in small, disjunct populations that shifted in space and time. Current efforts to maintain thicket habitats must deal with a range of current land uses and a legacy of historic uses. Additionally, the effectiveness of management protocols that mimic natural disturbances is limited among many forests. Increasing ownership parcelization, a relatively young forest, and landscape fragmentation substantially reduce the practicality and suitability of small-scale disturbances for generating thicket habitats. Large, clustered patches may be more practical and beneficial, especially in urbanized landscapes. In rural areas, silvicultural manipulations should be applied on a "sliding scale" relative to forest age. Timber harvests that emulate the range of variability of natural disturbances may become appropriate in these areas as forest stands mature. Addressing the needs of thicket-dependent species in the northeastern United States will require creativity, a willingness to explore a variety of solutions, and public support.

Litvaitis, J.A., M.S. Barbour, A.L. Brown, A.I. Kovach, J.D. Oehler, B.L. Probert, D.F. Smith, J.P. Tash, R.Villafuerte, and M.K. Litvaitis. 2006. Testing multiple hypotheses to identify the causes of the decline of a lagomorph species: the New England cottontail as a case study. Pages ##-## in Paulo Alves and Klaus Hackländer, editors. ***Biology of lagomorphs - evolution, ecology and conservation.*** Springer-Verlag, Berlin.

The distribution and abundance of New England cottontails (NEC, *Sylvilagus transitionalis*) have declined by > 75% in the last 40 years. Habitat loss via forest maturation and fragmentation, competition with expanding populations of eastern cottontails (*S. floridanus*), and hybridization between NEC and eastern cottontails have been proposed as the causes of this decline. This review summaries a series of experiments that evaluated these explanations and recommends specific conservation actions. A model of forest succession showed that a "successional wave" that followed the abandonment of agricultural lands in New England had a

profound effect on NEC. Populations of NEC initially expanded and then retracted as second-growth forests matured. Current populations are disjunct and structured in a series of induced metapopulations that include patches of habitat from < 0.5 to > 20 ha. We found no evidence of interference competition between NEC and eastern cottontails; however, eastern cottontails have behavioral and morphological adaptations that enable them to exploit small patches of habitat more effectively than NEC. A survey of mitochondrial DNA from *Sylvilagus* collected throughout the northeastern United States did not reveal any evidence of hybridization between species of cottontails. Preliminary results also indicate that genetic diversity of remaining populations of NEC is geographically structured, with one population (eastern Massachusetts) diverging from all other subpopulations. Available information does not clarify if current genetic diversity is a consequence of natural barriers to gene flow or recent reductions in population sizes and habitat continuity caused by human land uses. Although NEC likely evolved to exploited small patches of habitat, in contemporary landscapes they are confronted by intense predation by generalist carnivores, especially on small patches (< 2.5 ha). Therefore, efforts to enhance long-term viability of NEC should include maintaining large patches (> 10 ha) of habitat in a landscape network. Such efforts would be most successful if complimented by existing land uses that sustain early-successional habitats or native shrublands.

Litvaitis, J. A., B. Johnson, W. Jakubas, and K. Morris. 2003. Distribution and habitat features associated with remnant populations of New England cottontails in Maine. ***Canadian Journal of Zoology*** 81:877-887.

We investigated the distribution and habitat associations of New England cottontails (*Sylvilagus transitionalis,* NEC) at the northern edge of their historic range (state of Maine) during the winters of 1999-2000 and 2000-2001. We compared features of *regions* (≥100 km^2), *landscapes* (multiple home ranges of NEC, within 1 km of suitable habitat), and *patches* (usually <0.1 km^2) among sites that were occupied by NEC, occupied by a potential competitor [snowshoe hares (*Lepus americanus*)], or vacant. The current range of NEC in Maine is approximately 1,600 km^2 versus a recent historic range of 9,400 km^2 (83% decline). Loss of early-successional forests may explain the decline in abundance but did not explain the pattern of range contraction. Patches occupied by NEC were larger, had a greater density of understory vegetation, and were more frequently associated with idle agricultural lands than vacant patches. Habitats occupied by snowshoe hares were characterized by a greater proportion of forest and a lower density of roads in the surrounding landscape, were more often associated with recent clearcuts, and had a lower density of understory vegetation than sites occupied by NEC. Based on current land-use patterns, remaining populations of NEC in Maine are vulnerable to extirpation.

Litvaitis, J.A., J.P. Tash, M.K. Litvaitis, M.N. Marchand, A.I. Kovach, and R. Jenkins. In review. A range-wide survey to determine the current distribution of New England cottontails. ***The Wildlife Society Bulletin.***

The abundance and distribution of New England cottontails (NEC, *Sylvilagus transitionalis*) have been declining for several decades. Remnant populations in some regions are known to be vulnerable to extirpation but little is known about the status of populations in most areas. We conducted a survey of the historic range (circa 1960) of NEC to determine the current distribution and relative status of extant populations. Because NEC were sympatric with eastern

cottontails (*S. floridanus*) and snowshoe hares (*Lepus americanus*) in much of their historic range, identity of resident lagomorphs was based on DNA extracted from tissue of captured rabbits or from fecal pellets of free-ranging individuals. We searched 2,333 patches of suitable habitat and detected NEC in 154. Five disjunct populations were identified in approximately 14% of the historic range. Forest maturation and fragmentation are the most plausible explanations for the widespread decline of NEC. Contraction of the historic distribution was toward eastern and southern edges where a variety of anthropogenic disturbances (e.g., brushy edges of highways and railroad corridors and idle portions of agricultural fields) provided habitat. Efforts to enhance long-term viability of New England cottontails should include responses at two spatial scales. At the population or landscape scale, existing land uses should guide habitat manipulations. At the regional scale, some consideration should be given to increasing dispersal among remnant populations, possibly by generating "steppingstones" of suitable habitat.

Litvaitis, J.A., J.P. Tash, and C.L. Stevens. 2006. The rise and fall of bobcats in New Hampshire: relevance of historical harvests to understanding current patterns of distribution and abundance. ***Biological Conservation*** ###: In press.

Harvest records reveal that populations of bobcats (*Lynx rufus*) in New Hampshire have undergone substantial changes during the past 200 years. In the 1800s, a nearly continuous bounty program resulted in annual harvests that averaged ~30 bobcats. Harvests increased in 1915, and fluctuated from 100 to 400 bobcats during the 1920s through the 1950s. In 1959, harvests peaked at 421 and then rapidly declined. By 1970, payment was made on only 10 bobcats, and legal status was changed from nuisance animal to game species in 1973. In 1989, trapping and hunting seasons were closed and bobcats were designated a protected species. After 15 years of protection, populations of bobcats seem to be remaining at modest levels. To understand what factors may have contributed to the remarkable rise and fall of bobcat populations, we compared the temporal distribution of harvests to comments by early naturalists, legislation to control bobcat abundance, and historical changes in land use. We then used two approaches with a geographic information system to identify the environmental features that may affect present-day populations. The empirical approach relied on a comparison of landscape characteristics associated with recent (1990 – 2004) observations of bobcats to characteristics found at a comparable set of random locations. We also examined the characteristics of townships that yielded the majority of historical bobcat harvests (1931 – 1965) and developed a process-oriented model to rank present-day habitat suitability. The irruption of bobcat populations coincided with the availability of early-successional habitats as abandoned agricultural lands reverted to second-growth forests during the first half of the 20th century. Likewise, bobcat populations rapidly declined as these forests matured and no longer supported abundant prey, especially New England cottontails (*Sylvilagus transitionalis*). Our efforts to identify habitat features associated with present-day populations had mixed results. The empirically-derived model correctly classified only 52% of recent bobcat locations, whereas the process-oriented model indicated that nearly 88% of recent bobcat observations were associated with sites that were ranked at high suitability. The results of this study demonstrate the utility of information on historical harvests when addressing questions on the status of contemporary wildlife populations.

Litvaitis, J.A., D.L. Verbyla, and M. K. Litvaitis. 1991. A field method to differentiate New England and eastern cottontails. ***Transactions of the Northeast Section of the Wildlife Society*** 48:11-14.

We used morphological characteristics and discriminant analysis to develop a field technique that distinguishes between New England cottontails (*Sylvilagus transitionalis*) and eastern cottontails (*S. floridanus*). Using ear length, body mass, presence/absence of a black spot between the ears, a white spot on the forehead, and a black line on the anterior edge of the ears, we correctly classified 95% of the calibration data set and 94% of a test data set. We recommend that biologists using this method restrict their application to rabbits collected during winter.

Litvaitis, J.A., and R. Villafuerte. 1996. Factors affecting the persistence of New England cottontail metapopulations: the role of habitat management. ***Wildlife Society Bulletin*** 24:686-693.

The distribution and abundance of New England cottontails (*Sylvilagus transitionalis*) have declined dramatically in response to land-use changes and expanding human populations. Remnant populations of cottontails are fragmented and likely to decline further unless conservation agencies intervene. We used computer simulations in the context of metapopulation theory to understand the effects of environmental correlation, habitat loss, and habitat management on remaining populations of New England cottontails. Environmental correlation (based on increased vulnerability to predation during periods with snow) and habitat loss (based largely on forest maturation) can each affect the persistence of cottontail metapopulations. The synergistic effect of these 2 parameters can cause a rapid decline in rabbit populations or local extinctions. However, these effects may be countered by a management program that maintains a network of suitable habitats. Patches (15-75 ha) of early successional habitat that are maintained with a regime of periodic disturbances (burning, cutting, or mowing) may be sufficient to sustain local populations of New England cottontails. Current theory on spatially structured populations and computer simulations are useful for developing management guidelines for a species that is declining in human-altered landscapes.

Litvaitis, J.A., D.L. Wagner, J.L. Confer, M.D. Tarr, and E.J. Snyder. 1999. Early successional forests and shrub-dominated habitats: land-use artifact or critical community in the northeastern United States. ***Northeast Wildlife*** 54:101-118.

Prior to European colonization, early-successional and shrub-dominated habitats (collectively referred to as thickets) were widely distributed throughout the northeastern United States. Fires (including those intentionally set by aboriginal people), wind storms, and beavers (*Castor canadensis*) were likely the major forces that set back succession and perpetuated thicket habitats. More recently, abandonment of agricultural lands has had a profound effect on the abundance of these habitats throughout the Northeast. In the first half of this century, early-successional habitats and many of the species that exploited them were widespread. The vast majority of these lands have since matured into mid-successional stands. Additionally, native shrublands that are characterized by dry, sandy soils (especially scrub oak [*Quercus ilicifolia*] and pitch pine [*Pinus rigida*] barrens) have been lost to succession, development, and agriculture. As a result, populations of insects, birds, mammals, and reptiles that are obligates of

thicket habitats are among the most threatened taxa in the Northeast. Current efforts to maintain these communities are not sufficient; therefore, we advocate an aggressive approach to increase the acreage of early-successional habitats and shrublands, and to restore disturbance regimes necessary to maintain them. In northern areas where forests dominate, efforts should be directed toward enhancing thicket habitats in a pattern that resembles natural disturbances. In landscapes that are dominated by human activities (especially agriculture and urbanization), thicket habitats should be large, clustered, and consolidated with existing habitats such as powerline corridors. In all regions of the Northeast, efforts to acquire, restore, and manage native shrublands should increase.

Litvaitis, M.K., and J.A. Litvaitis. 1996. Using mitochondrial DNA to inventory the distribution of remnant populations of New England cottontails. ***Wildlife Society Bulletin*** 24:725-730.

We evaluated the utility of mitochondrial DNA extracted from tissue samples and fecal pellets as a possible method to track declining populations of New England cottontails. The most consistent amplifications among the fecal pellets were obtained from fresh samples of eastern cottontails (about 50% success rate) using the final method described. DNA extractions from New England cottontail fecal pellets were successful in <10% of the attempts. The major problem encountered were plant pigments that purify along with the DNA and act as strong inhibitors of the PCR. Once amplified, species distinctions were easily made using the restriction enzyme Bfa I. However, due to the low success rate of extracting New England cottontail DNA from fecal pellets, we suggest that a large scale application of this method be postponed until a more efficient purification technique is developed. We recommend that biologist rely on tissue samples as an effective, noninvasive technique to sample the distribution of New England cottontails. Hunters and other cooperators could be supplied with agency-addressed envelopes to submit small cuts from ears or portions of a carcass. Samples should be large enough (ca. 5 x 10 mm) to permit subsampling and therefore avoid any contamination. We suspect that participation in such a survey would be substantially greater than surveys that request the entire head. Additional samples (especially vehicle mortalities) would enhance geographic coverage and could be collected throughout the year. Exposure to temperature and weather extremes will not degrade tissue samples.

Litvaitis, M.K., J.A. Litvaitis, W.-J. Lee, and T. D. Kocher. 1997. Variation in the mitochondrial DNA of the Sylvilagus complex occupying the northeastern United States. ***Canadian Journal of Zoology*** 75:595-605.

We compared the variation in mitochondrial DNA among species of cottontail rabbits in the northeastern United States to i) assess the effects of historic transplants of eastern cottontails (*Sylvilagus floridanus*) on subspecific status, ii) examine the extent of hybridization between invading eastern cottontails and declining populations of endemic New England cottontails (*S. transitionalis*), and iii) evaluate the recent reclassification of *S. transitionalis* into two sister species, New England cottontail and Appalachian cottontail (*S. obscurus*). Sequence variation in the tRNAPro and the first 310 base pairs of the control region supported a separation of the two species, *S. floridanus* and *S. transitionalis*/*S. obscurus*. However, geographic structuring of haplotypes was not detected for either group. Genetic similarity among populations of *S. floridanus* indicated that subspecific designations are not warranted for this species in the

northeastern United States. Comparisons of sequence information from populations of *S. transitionalis/S. obscurus* that were never sympatric (Maine), recently sympatric (New Hampshire), or sympatric with eastern cottontails since the last glaciation of eastern North America (Virginia, West Virginia, Maryland, North Carolina) indicated that hybridization is not occurring between eastern cottontails and New England or Appalachian cottontails. Limited variation in mtDNA does not support the recent reclassification of *S. transitionalis* into sister species. However, karyotypic and morphological differences between northern and southern populations should be considered during any efforts to restore declining populations of this species.

Oehler, J.D., and J.A. Litvaitis. 1996. The role of spatial scale in understanding responses by medium-sized carnivores to forest fragmentation. ***Canadian Journal of Zoology*** 74:2070-2079.

Increased predation has been suggested as a proximate factor causing the decline of vertebrate diversity in many human-altered landscapes. Previous studies on this topic have provided conflicting results, perhaps as a consequence of the limited spatial scale used in these investigations. We incorporated a multiscaled approach (using site, plot (1.44 km^2), and landscape (54 km^2) to investigate the distribution of activity of medium-sized carnivores relative to habitat edges and the numeric responses of these predators to habitat diversity. Among the taxa surveyed, raccoons (*Procyon lotor*) did not show an affinity for habitat edges at any spatial scale. However, raccoons were more abundant in landscapes characterized by a diversity of cover types. Free-ranging domestic dogs (*Canis familiaris*) and cats (*Felis domesticus*) did not respond to proximity of habitat edges in summer but showed a strong affinity for edge habitats (especially those associated with human dwellings) during winter. Wild canids (*Vulpes vulpes* and *Canis latrans*) also selected sites in close proximity to edges in winter and were more abundant in diverse landscapes. Although human-dominated habitats (agricultural areas, grass-brushland, and developed sites) represented only 7 – 27% of the three landscapes studies, populations of generalist predators (raccoons and wild canids) increased as landscapes became more diverse. As a result, even moderate levels of habitat fragmentation may elevate predation rates and subsequently alter the composition of prey communities.

Probert, B.L., and J.A. Litvaitis. 1996. Behavioral interactions between invading and endemic lagomorphs: implications for conserving a declining species. ***Biological Conservation*** 76:289-296.

New England cottontails (*Sylvilagus transitionalis*) were the only rabbits indigenous to the extreme northeast portion of the United States. However, following massive introductions that began in the 1930s, eastern cottontails (*S. floridanus*) expanded their range into this region. Concurrent to the range expansion by eastern cottontails, the abundance and distribution of New England cottontails declined. Because these two species utilize similar habitats, competition has been suggested as an explanation for the decline of *S. transitionalis*. To test this hypothesis, we examined the dominance relationship between these two rabbits in confined arenas, and evaluated interference competition in large enclosures where cover and food were manipulated to create good and poor sites. New England cottontails were dominant in 42% of the behavior dyads where there was a clear winner. No differences were detected in habitat selection trials.

These results do not support the hypothesis that interference competition has affected the decline of New England cottontails. However, we suggest that scramble competition for disturbance patches of habitat may be influential in determining the distributions of these rabbits in New England. Populations of *S. transitionalis* may be sustained by maintaining occupied patches of early-successional habitat (10-25 years post disturbance) rather than attempting to restock habitats occupied by *S. floridanus*.

Smith, D.F., and J.A. Litvaitis. 1999. Differences in eye size and predator-detection distances of New England and eastern cottontails. ***Northeast Wildlife*** 54:55-60.

In the northeastern United States, New England cottontails (*Sylvilagus transitionalis*) and eastern cottontails (*S. floridanus*) substantially overlap in their use of habitats. However, populations of eastern cottontails have remained relatively stable whereas populations of New England cottontails have declined substantially. In previous experiments, eastern cottontails were able to exploit open habitats whereas New England cottontails sacrificed food for safety by remaining in cover. Furthermore, eastern cottontails had a greater survival rate than did New England cottontails. In this paper, we examined whether eastern cottontails had an ability to detect predators at greater distances than did New England cottontails. We found that the exposed surface area of the eyes of eastern cottontails was larger than among New England cottontails, and eastern cottontails could detect an approaching predator at greater distances than New England cottontails. We suggest that as landscapes become fragmented and vulnerability to predation increases, eastern cottontails will likely persist while populations of New England cottontails will continue to decline.

Smith, D.F., and J.A. Litvaitis. 2000. Foraging strategies of sympatric lagomorphs: implications for differential success in fragmented landscapes. ***Canadian Journal of Zoology*** 78: 2134-2141.

In recent decades, the distribution of New England cottontails (*Sylvilagus transitionalis*) has declined substantially in response to forest maturation and fragmentation. Populations of eastern cottontails (*S. floridanus*) have expanded into the range of *S. transitionalis*, apparently less affected by the consequences of habitat modifications. We suspected that *S. floridanus* was able to exploit small patches of habitat where *S. transitionalis* was vulnerable to intense predation and evaluated this explanation within large enclosures where we manipulated the quality and distribution of food in relation to escape cover. In trials with low-quality food in cover and high-quality food in open areas, *S. transitionalis* sacrificed food quality for safety by remaining in close proximity to cover. *S. floridanus* avoided low-quality food in cover and foraged at sites away from cover that contained high-quality food. When food was removed from cover, *S. transitionalis* was reluctant to forage in the open, lost a greater proportion of body weight, and succumbed to higher rates of predation than did *S. floridanus*. We applied these results to foraging patterns by free-ranging rabbits in a fragmented landscape and estimated that *S. transitionalis* could successfully exploit only 32% of the available habitat without experiencing elevated rates of predation, whereas *S. floridanus* could exploit 99% of the habitat. Thus, the consequences of habitat fragmentation (especially elevated predation risk) may not be as detrimental to *S. floridanus*, and this species will likely persist whereas populations of *S. transitionalis* will continue to decline.

Smith, D.F., P.J. Pekins, R.N. Coup, M.D. Tarr, P.G. Jensen, and K.S. Smith. 1996. Metabolic rates of New England and eastern cottontails during winter. ***Northeast Wildlife*** 53:25-33.

In New England, two species of cottontail rabbits are sympatric. Populations of the endemic New England cottontail (*Sylvilagus transitionalis*) are declining, whereas the introduced eastern cottontail (*S. floridanus*) has a relatively stable distribution. We measured basal metabolic rates, conductance, and lower critical temperatures of these cottontails to assess whether energetic differences may help explain their population trends. Metabolic rate ($\bar{x}$ = 0.86 and $\bar{x}$ = 0.77 ml $O_2 \cdot g^{-1} \cdot h^{-1}$ for New England and eastern cottontails, respectively) and conductance (0.03 ml $O_2 \cdot g^{-1} \cdot h^{-1} \cdot {}^{\circ}C^{-1}$ for both New England and eastern cottontails) did not differ between species, but the lower critical temperature of New England cottontails ($\bar{x}$ = -0.3°C) was 7°C higher than that of eastern cottontails. Analysis of published data revealed that basal metabolic rates among lagomorphs of northern latitudes do not differ ($\bar{x}$ = 0.74 ml $O_2 \cdot g^{-1} \cdot h^{-1}$, 1 df , F = 1.23, P = 0.30), suggesting their metabolic capacities and energetic demands are not different. We conclude that the difference in population trends of the two sympatric cottontails in New England is probably not a result of any difference in their metabolic capacity.

Smith, D.F., W.J. Smith, J.R. LaCourse, and J.A. Litvaitis. 1997. A data logging system using optical sensing techniques to determine foraging strategies of cottontail rabbits. Pages 39-41 in ***Proceedings of the IEEE 23rd Annual Northeast Bioengineering Conference***. University of New Hampshire, Durham.

Adaptive foraging decisions yield information on how animals view their environment. These decisions allow researchers to know how foragers rank habitats. We used a data logging system using infrared break-beam circuitry to evaluate these decisions. The data from this system revealed differences in behaviors between two species of cottontail rabbits in outdoor enclosures where obtaining food incurs predation costs (probability of mortality).

Villafuerte R., J.A. Litvaitis, and D.F. Smith. 1997. Physiological responses by lagomorphs to resource limitations imposed by habitat fragmentation: implications to condition-sensitive predation. ***Canadian Journal of Zoology*** 75:148-151.

Human land uses have resulted in landscape mosaics with habitat patches that vary in quality. Patch quality (including the abundance of food and risk of predation) can affect the survival of animals that are sequestered to remnant patches of habitat. Recent investigations on the demography of New England cottontails (*Sylvilagus transitionalis*) have shown that cottontails on small (resource poor) patches were in poor physical condition (based on body weight) and often foraged at sites with limited cover. This resulted in a higher mortality rate than among rabbits occupying large (resource rich) patches. To gain additional insight on the consequences of habitat fragmentation, we tracked the physiological condition of rabbits occupying small and large patches during winter. Physiological condition of rabbits was based on urinary urea nitrogen:creatinine (UN:C) ratios, and was compared to similar indices obtained from captive rabbits. Consistent with our expectations, UN:C ratios indicated that rabbits on small patches were nutrient limited for a longer period than rabbits on large patches. Transmitter-equipped rabbits on small patches had a lower survival rate and died earlier than rabbits on large patches. All mortalities were predator-related. Using these data, we developed a simple model that

supports the role of "condition-sensitive predation" as a major factor limiting populations of New England cottontails. Our results also demonstrate the utility of sampling physiological condition as an index to habitat quality of lagomorphs in human-dominated landscapes.