THE RANGE OF THE EASTERN PIPISTRELLES (*PIPISTRELLUS SUBFLAVUS*) IN SOUTHWEST NOVA SCOTIA AND AN ASSESSEMENT OF THEIR LOCAL DISTRIBUTION AS A FUNCTION OF ABIOTIC, AND SITE- AND LANDSCAPE-LEVEL FACTORS

A 2005 year-end report

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Lesley Corning, Masters of Applied Sciences Candidate, Saint Mary's University Department of Biology

Hugh Broders, Assistant Professor, Saint Mary's University Department of Biology, Halifax, NS, B3H 3C3, 902-496-8193, hugh.broders@smu.ca

Abstract

Fragmentation and loss of natural habitat are considered major threats to global biodiversity, with the impact of forest harvesting of particular concern in many regions. A reduction in the size and connectivity of natural habitats as a result of forest harvesting practices has the potential to fragment and isolate populations of organisms. Evaluation of the effects of disturbance on ecological patterns and processes can provide important information relevant to conservation and management decisions, and identification of species sensitive to environmental change may present opportunities for early indication of these disturbance effects. The eastern pipistrelle in Nova Scotia is restricted in its range, exhibits distinct behavioral and morphological characteristics, and is likely disjunct from conspecific populations and thus has the potential to be a significant population. They have very specific roosting requirements for clumps of *Usnea* lichen in mature spruce trees, potentially making them vulnerable to habitat alteration. The objective of the research project was to increase local knowledge of eastern pipistrelle ecology in Nova Scotia that will contribute towards their conservation and the forest habitat that they depend on. Specifically, we monitored the activity of eastern pipistrelles at forty river sites located throughout Nova Scotia to 1) determine the regional distribution of the population, 2) quantify the effects of landscape and site-level factors on species activity using a model selection technique and 3) assess the value of a systematic acoustic survey program to monitor the availability of landscape elements associated with eastern pipistrelle activity (likely mature spruce stands with an abundance of *Usnea* species). Activity of the species is concentrated in central southwest Nova Scotia where their distribution appears to be limited to the warmest area of the province. Average nightly temperature, area of water resources and mature spruce forest were important variables determining the presence or absence of the species at a site. These results support the contention that the eastern pipistrelle may be useful as an indicator of the availability and connectivity of mature forest associated with their activity, and a long term echolocation sampling protocol may be useful. To enhance the habitat availability for this species and species with similar habitat requirements, such practices as remnant tree retention, long rotations and designation of reserve areas may prove to be effective.

Introduction

Fragmentation of formerly continuous landscapes and the loss of natural habitat are considered to be major threats to biological diversity globally and central issues in conservation biology (Hagan et al. 1996; Monkkonen & Reunanen 1999). The expansion and intensification of human land use is the most important and large-scale cause of habitat loss and fragmentation (Andren 1994). The persistence of species and populations in today's world is increasingly dependent on the ability of individuals to disperse among remnant habitat in human-dominated landscapes (Daily & Ehrlich 1996). Of particular concern in many regions is the impact of forest harvesting on species and communities (Grindal & Brigham 1999). As forests become further fragmented by human disturbance, it is necessary to determine how factors such as the size, shape and connectivity of remaining forest patches affect animal populations and communities (Grindal & Brigham 1999).

One important consequence of land use change is a disruption in the spatial continuity, or connectivity, of natural habitat across a landscape (Freeman et al. 2003). Maintenance of connectivity allows for the movement of organisms and materials across landscapes between adjacent habitat or land-cover patches (Noss 1991). Intact forest patches are especially important for many organisms, including birds (Andren 1994; Uezu et al. 2005) and mammals (Law et al. 1999; Nupp & Swihart 2000). Connectivity in forests managed for wood production is important because forestry practices have the potential to eliminate wildlife from harvested areas and fragment and isolate populations in remnant habitat patches (Lindenmayer et al. 2000). The majority of the Maritimes provinces is characterized by the Acadian Forest Region however the past several hundred years of human occupation have seen the conversion of much of Nova Scotia's forest to early successional forest types (Mosseler et al. 2003). Remnants of old growth forest now occur only in small, isolate stands scattered throughout the province and limited data on the functional connectivity of old growth and mature forests in Nova Scotia is currently available (Mosseler et al. 2003).

To manage landscapes, biological indicators of landscape and habitat changes provide a useful approach and can potentially be used to monitor complex ecosystem and landscape processes that are otherwise not easily measured (Landres et al. 1988). Habitat disturbance is expected to affect organisms in a number of different ways, depending on the nature of the disturbance and on the ecology of the affected species (Grindal & Brigham 1999). Evaluation of the effects of disturbance on ecological patterns and processes can provide important information relevant to conservation and management decisions and identification of species sensitive to environmental change presents opportunities for early indication of disturbance effects (Medellin et al. 2000). In situations where there is interest in assessing the ecosystem integrity of managed land, indicator species represent an appropriate and useful approach (Fleishman et al. 2000). An ecosystem health indicator species is an organism that's viability is so ultimately associated with particular environmental conditions that its presence indicates the existence of those conditions (Lindenmayer et al. 2000; Simberloff 1998); species such as this may be useful for monitoring the availability of the habitat type that they depend on.

Bats are small in size, mobile and long-lived with low reproductive potential (Fenton 1997; Findley 1993). These characteristics are thought to facilitate stable populations in unchanging landscapes, but may combine to make them especially sensitive to changes in environmental conditions (Fenton 1997), placing them at risk of population decline in the presence of habitat conversion or alteration. Growing evidence suggests that many bat species are declining around the world and habitat loss has been identified as the major contributor to these declines (Mickleburgh et al. 2002). In order to adequately protect bats and their habitats, we must have detailed knowledge and understanding of their patterns of habitat use (Fenton 1997).

Habitat selection is key to the survival and fitness of individuals and groups and is an important area of research in conservation biology and wildlife management (Veilleux et al. 2004). A thorough understanding of a species' natural history, in particularly their habitat requirements, is required for the development of effective management plans and conservation strategies (Fenton 1997). Also essential, is a good understanding of the habitat requirements of maternity groups, the reproductive component of the population (Veilleux et al. 2004). Habitat selection by bats is influenced by the interaction between their requirements for suitable foraging and roosting areas (Fenton et al. 1998; Kunz 1982). Roosts are a critical habitat component for bats (Kunz 1982) and, depending on roost type, the availability of roosts may be related to age and structural complexity (Crampton & Barclay 1998). Bats with specific tree-roost requirements are particularly vulnerable to disturbance created by forest harvesting which tends to eliminate old trees and reduce structural complexity. Forestry practices could have a negative impact on their roosting ecology by the direct loss of roosting sites (Grindal & Brigham 1999; Vonhof & Barclay 1996). Limited evidence suggests that some bats may be well-suited as indicators of habitat disturbance (Fenton et al. 1992; Medellin et al. 2000) and recently there has been a surge of interest in studying relationships between bats and their habitats by monitoring echolocation calls using bat detectors (Erickson & West 2003; Grindal & Brigham 1999; Humes et al. 1999; Patriquin & Barclay 2003; Zimmerman & Glanz 2000). This has been spurred by the technological improvements in relatively low-cost bat detectors (Hayes 1997).

The eastern pipistrelle (*Pipistrellus subflavus*) is a small (7-8g) (Fujita & Kunz 1984), microchiropteran bat species found throughout the eastern forests of North America (Veilleux et al. 2003). It is one of seven species of bats recorded in Nova Scotia (Broders et al. 2003; van Zyll de Jong 1985) which is at the northern extent of the known range for this species (van Zyll de Jong 1985). In 2001, Broders (2003) discovered an apparent concentration of eastern pipistrelles at Kejimkujik National Park. Subsequent ultrasonic monitoring throughout mainland Nova Scotia confirmed the presence of a significant population of this species in the province and indicated restriction of the population to southwest Nova Scotia in the summer (Rockwell 2005). This species occurs in very low numbers in southern coastal New Brunswick and is rare in southern Maine (Broders et al. 2001), suggesting that the Nova Scotia population of eastern pipistrelles may be a disjunct population, separated from conspecific populations further south. Given this isolation, the population may represent a nationally significant population, justifying special attention (Broders et al. 2003).

Current data suggests that the Nova Scotia population of eastern pipistrelles is also behaviourally and morphologically distinct from conspecific populations, lending further support to the significance of the population. Individuals of the Nova Scotia population are larger than conspecifics; the average mass of eastern pipistelles recorded in two populations to the south are 6.9 g and 7.1 g (van Zyll de Jong 1985; Veilleux et al. 2003), while in Kejimkujik National Park their mean mass is 8.2 g (Quinn & Broders, unpublished data). They also have very specific and unique roosting requirements. Conspecific populations of eastern pipistrelles have been observed roosting within a variety of roost types including live and dead tree foliage (Carter et al. 1999; Davis & Mumford 1962; Veilleux & Veilleux 2004; Veilleux et al. 2003, 2004), Spanish moss (Davis & Mumford 1962; Menzel et al. 1999), buildings (Whitaker 1998; Winchell & Kunz 1996) and rock crevices (Lacki & Hutchinson 1999), while in Nova Scotia females form colonies almost exclusively in clumps of *Usnea* lichen, typically in spruce trees found in mature stands (Quinn & Broders, unpublished data).

Studies on the foraging ecology of eastern bat species have noted a positive association of eastern pipistrelle activity with watercourses (Brack & Mumford 1984; Davis & Mumford 1962; LaVal et al. 1977) suggesting the importance of watercourses as foraging habitat for this species. In New Brunswick, Broders (2001) recorded eastern pipistrelle calls exclusively over lakes and rivers and successfully captured eastern pipistrelles only at river sites. Selection of roosts that are in close proximity to water resources may minimize energetic costs of commuting and provide an abundant prey source (Waldien et al. 2000). Therefore roost selection by this species may be limited by the proximity of suitable roosting areas to available water resources for foraging.

Epiphytic lichens play important ecological roles in many forest ecosystems (Price & Hochachka 2001), by contributing to structural complexity (Esseen et al. 1996), aiding nutrient cycling, and providing food, shelter and nest material for many animals. Lichen diversity and abundance have been shown to vary with forest age (Esseen et al.

1996; Lesica et al. 1991; Neitlich & McCune 1997; Price & Hochachka 2001), a relationship likely a result of slow growth rates and inefficient dispersal, making lichens particularly sensitive to environmental change, including habitat alteration (Esseen et al. 1996). Forest management practices alter forest landscapes in ways that limit opportunities for lichen growth and dispersal and Price & Hochachka (2001) found lichens to be less abundant in young, managed stands compared to mature forest. As a result of this sensitivity, lichens have been useful as bio-indicators, reflecting forest continuity (Rose 1976) and old-growth conditions (Esseen et al. 1996). In a study of epiphytic lichen associations in Nova Scotia, Cameron (2002) found *U. trichodea* abundance to be greatest in old growth forests, indicating an association between this lichen growth and older forests. One of the distinguishing characteristics of the Acadian Forest Region found throughout Nova Scotia is a high proportion of red spruce (*Picea rubens*), a long lived, shade tolerant species adapted to high atmospheric moisture (Mosseler et al. 2003). The historical abundance of this tree species may have lead to the development of the apparent association between roosting eastern pipistrelles and spruce stands.

Evidence also suggests that in Nova Scotia, individuals remain faithful to small roost areas both within and between years (Quinn & Broders, unpublished data). Females of most temperate North American bat species form maternity colonies during late spring and early summer, within which gestation, parturition and weaning of young occur (Kunz 1982). The majority of bat species, particularly those that form maternity colonies, require a relatively large number of roost trees within a given season, which they switch on a regular basis. The fidelity of bats to a particular roost structures varies greatly depending on the species, roost type and time of year (Veilleux & Veilleux 2004). Veilleux & Veilleux (2004) also provide evidence for female eastern pipistrelle fidelity to relatively small roost habitat areas during a single summer. It is important from a conservation perspective to study and understand roost fidelity and roost area relationships because they reveal the minimum habitat requirements of maternity colonies, and therefore the area that is needed to maintain populations of bats (Lewis 1995; Veilleux & Veilleux 2004).

All of the current data in Nova Scotia support the contention that the province's population of eastern pipistrelles is small, distinct and disjunct from conspecific populations. Within Nova Scotia, the eastern pipistrelle appears to have specific roosting habitat requirements for mature spruce stands. Therefore, the viability of this species may be related to the availability and connectivity of this forest type. If their patterns of activity are related to changes in the amount and distribution of this forest type in a predictable manner, then changes in their activity may reflect changes in the availability of this type of forest. Activity of this species is also relatively cheap and easy to monitor. Therefore the study of this species may have value for monitoring and assessing changes in landscape structure and connectivity at the landscape level, with a decrease in activity indicating a loss of landscape elements associated with eastern pipistrelles (e.g. mature spruce stands with conditions appropriate for the growth and persistence of *Usnea* species). Further research is necessary to increase our knowledge of local habitat requirements of the eastern pipistrelle and determine the conservation status of the population. An assessment of the value of a monitoring program is necessary as this would contribute towards the conservation of this species and the forest habitat that they depend on, and also provide land managers with better information to create and implement management plans to ensure the viability of naturally occurring populations within protected and working landscapes.

The goal of this research project was to increase local knowledge of eastern pipistrelle ecology in Nova Scotia that will contribute towards their conservation and the forest habitat that they depend on. Specifically, the objectives were:

1) to determine the regional distribution of the population;

2) to quantify the effects of landscape and site-level factors on species activity;

3) to assess the value of a systematic acoustic survey program to monitor the availability of landscape elements associated with eastern pipistrelle activity (likely mature spruce stands with an abundance of *Usnea* species).

Methods

Field Methods. Forty forested river sites were selected throughout southwest Nova Scotia using GIS and topographic maps. Sites were selected on major waterways accessible by vehicle and were periodically acoustically sampled from June to August 2005 using six echolocation detection systems. Each system consisted of an Anabat II detector interfaced to a CF Storage ZCAIM, calibrated to reduce variability in sensitivity (Larson & Hayes 2000). The systems automatically turned on prior to sunset (19:00) and shut down following sunrise (07:00) to conserve power. They were suspended from trees such that the microphone was unobstructed by surrounding vegetation, maximizing the quality of the recorded calls by reducing interference. A HOBO Temp/Humidity data logger (Pro Series by Onset) was also deployed with each system and recorded temperature and absolute humidity on an hourly basis over each sample period. Due to the large spatial extent of the sampling area, sites were systematically sampled to reduce commute time. Each site was sampled three times for three days each over the entire sampling period. At each site, the average of three measurements (at the site, 25 m upstream and 25 m downstream) of river width and forest canopy height were recorded to control for the effects of these variables on foraging behaviour.

Lab Methods. Field identification of many bat species is possible because of the distinctive nature of their echolocation calls (Fenton & Bell 1981; O'Farrell et al. 1999) and in Nova Scotia, eastern pipistrelle calls are distinctly different from those of all sympatric species and can be identified relatively easily (Macdonald et al. 1994). Call sequences of eastern pipistrelles were visually identified using frequency-time graphs using ANALOOK Software (C. Corben, www.hoarybat.com) and the presence or absence of the eastern pipistrelle on each night of sampling was determined.

GIS Analysis. Land-use cover data of southwest Nova Scotia was obtained (Nova Scotia Department of Natural Resources Forestry Inventory Data) and forest and freshwater resource characteristics within commuting distance of each site were determined using GIS. Commuting distance was assumed to be 5 km, which is the greatest distance an eastern pipistrelle has been observed to travel from trap site to roost site at Kejimkujik National Park (Quinn & Borders, unpublished data). Specifically we determined the area of water resources (including lakes, rivers and wetlands) and the area of mature spruce forest within each buffer area. For the purpose of this research, mature spruce forest was defined as any forest patch with a composition of spruce species equal to or greater than 50% and a canopy equal to or greater than 11m, the minimum roost tree height recorded for maternity colonies of eastern pipistrelles at Kejimkujik National Park (Quinn & Broders, unpublished data).

Statistical Analysis. Preliminary statistical analysis involves a logistic regression model selection technique to determine the quantitative effects of a number of variables (Table 1) on the probability of presence of the eastern pipistrelle at a given site. In the global model the probability of presence is believed to be a function of site-level and landscape-level factors, phenology and weather. Nights where at least one eastern pipistrelle call sequence was recorded were coded as 1 and nights with no eastern pipistrelle activity were coded as 0. A set of nine *a priori* candidate models to explain the variation in their presence at sites was compiled based on the known biology of the species and on the expected results (Table 2). Binomial family generalized linear models with a logit link in S-PLUS 2000 were used (Hosmer & Lemeshow 2000).

The models were ranked using the small sample variant of Akaike's Information Criterion (AIC_c, Table 2) (Burnham & Anderson 2001; Burnham & Anderson 2002), calculated using the 'extractAIC' command in the MASS library in S-PLUS 2000. The AIC approach allows for the best model in the candidate set (the model for which AIC is minimized) to be identified, and the remaining models to be ranked (Burnham & Anderson 2002). Akaike weights (w_i, the probability that the *i*-th model is actually the best among the candidate set of models, given the data) (Burnham & Anderson 2002) were also calculated. For the set of models comprising the 95% confidence set based on Akaike weights, the difference between the AIC of each model and that of the best approximating model was calculated (Δ_i). The larger the Δ_i, the less plausible it is that model *i* is the best approximating model in the set (Burnham & Anderson 2001).

To determine which variables were most important in differentiating sites where the eastern pipistrelle was present from site where it was not, multi-model inference was used rather than basing conclusions on only the best approximating model in the candidate set, thus reducing bias. To do this, relative importance weights (Nw_i, the sum of the normalized Akaike weights for all of the models containing the given variable) were calculated for the variables present in the 95% confidence set of models (Table 3) (Burnham & Anderson 2002). This method is particularly useful when a number of the models are nearly as well supported as the best model (Burnham & Anderson 2001).

Variables with a Nw_i > 0.60 (arbitrarily chosen *a priori*) were considered to be important. For all the important variables, the model-average parameter estimate (β_i) with estimated unconditional standard error (Burnham & Anderson 2002) was calculated (Table 3).

Results

We recorded a total of 6759 eastern pipistrelles echolocations calls making up 601 call sequences at 21 of the 40 river sites. Their activity was concentrated in the central area of southwest Nova Scotia around the Mersey and Medway River watersheds, with smaller concentrations with lower levels of activity detected in the Gaspereau River valley and the Annapolis River valley. The sites with the highest levels of activity were located on the Mersey River. Sites where eastern pipistrelle calls were recorded were identified and from this we have made general conclusions about the extent of the distribution of the eastern pipistrelle in southwest Nova Scotia and delineated the range of the species (Figure 1).

The 95% confidence set of models consisted of 2 of the 9 candidate models (Table 2). The top ranking model (model 6) contained the variables: area of water resources, average nightly temperature and area of mature spruce forest (w_i = 0.93). Only these three variables were included in the 95% confidence set of candidate models and all were considered to be important given the considerable weight of the best approximating model. The second best supported model contained the variables: area of water resources and area of mature spruce forest (w_i = 0.06); these variables were included in both of the models of the 95% confidence set and, as a result, had a relative importance weight of 1.0 (Table 3) indicating that they are very important factors to consider in differentiating between sites with recorded eastern pipistrelle activity, and sites with no activity.

The logistic curves for the important variables show that they each have a positive relationship with the probability of presence of the eastern pipistrelle (Figure 2 a, b and c) meaning that as the variables increase at a site, the probability that the eastern pipistrelle will be recorded increases as well. The combined effect of the three variables increases the probability of presence of the eastern pipistrelle from around 10% to approaching 100% through the minimum to maximum values for each variable (Figure 3).

Discussion

Thorough knowledge of a species' distribution is of prime importance to their conservation in any region (Cowley et al. 2000). Previous echolocation sampling of mainland Nova Scotia indicated that the range of the eastern pipistrelle is restricted to the southwest region in the summer (Rockwell 2005). The low sampling intensity of the study, however, left many questions regarding the distribution of the species in the region unanswered. Based on the results of intensive echolocation sampling in the current study, we now have a more comprehensive understanding of their distribution and have delineated the range for the eastern pipistrelle in southwest Nova Scotia. Within this region, the eastern pipistrelle is distributed over a relatively wide geographic area, mostly inland, with the highest activity recorded in central southwest Nova Scotia. There is a general lack of activity along the southern shore of the province and to the far southwest.

The waters of the Atlantic Ocean and the Bay of Fundy are relatively cold (8 to 12 ºC) and have a strong influence on average air temperatures over southwestern Nova Scotia in spring and summer. Along the coast, temperatures are frequently 4 to 6 ºC cooler than inland in the summer (Environment Canada 2006; http://www.atl.ec.gc.ca). Average summer temperatures are greatest in the range where the eastern pipistrelle is found. Cooler temperatures along the coast may restrict the range of the eastern pipistrelle to these inland areas that are less influenced by the cooling effects of the marine environment.

The general distribution of the eastern pipistrelle in southwest Nova Scotia is characteristic of the distributions of greater than 60 other southern affiliated species

(Davis & Browne 1996; Lavers 2004). These species have been effectively isolated from the main part of their ranges, likely caused by a period of climatic cooling, causing them to become disjunct and restricted to the warmest area of the province in the interior southwest (Davis & Browne 1996).

The results of the logistic regression and model selection analysis suggest that the presence of the eastern pipistrelle at a given site is strongly influenced by average nightly temperature, demonstrating the sensitivity of this species to low temperatures. This result lends further support to the above contention that the distribution of the eastern pipistrelle in southwest Nova Scotia may be limited by cool average summer temperatures along the coast. It was expected that average nightly temperature would be an important variable to consider when differentiating between sites with eastern pipistrelle activity, and sites with none for at least two reasons. First, overall insect abundance on a given night has been shown to vary with temperature, with a greater abundance of insect prey on relatively warm nights (Taylor 1963). Foraging bouts usually account for the largest proportion of an individual’s daily energy budget (Kurta et al. 1989) and on cool nights with little active prey, the energetic costs of foraging may be too great for the given food rewards.

Additionally, maintaining high body temperatures during exposure to cool temperatures is energetically costly (Willis et al. 2006). One response by bats to low temperatures is the use of torpor, which are controlled reductions in body temperature and metabolism (Altringham 1996). Torpor results in enormous energy savings, however, it may represent a disadvantage for pregnant females because it slows the development of offspring, extending the period of gestation (Racey 1973; Racey & Swift

1981). For temperate species of bats, the costs of prolonged gestation may be especially important because offspring have only a short warm season in which they must grow quickly to build sufficient reserves of fat to survive the winter.

The landscape variables area of water resources and area of mature spruce forest within commuting distance of the site were found to be important in the analysis, suggesting that the availability of habitat types considered to be important to serve the foraging and roosting requirements of this species are important variables determining their presence or absence at a site. This was expected because waterways likely represent important foraging habitat for eastern pipistrelles and as the area of lakes and rivers increases, there will be a greater number of foraging opportunities for individuals. Additionally, evidence has shown that colonies of eastern pipistrelle females are found in stands of mature spruce, typically in low lying wet areas. Therefore, an increase in overall lakes, rivers and wetlands will likely increase the probability of encountering suitable roosting areas with conditions appropriate for the growth of *Usnea*.

It was also expected that the area of mature spruce forest within commuting distance of the sites would be an important variable influence the presence or absence of eastern pipistrelles. Roosting habitat requirements represent a critical component of the ecology of bats (Kunz 1982) and this result indicates that the distribution of the eastern pipistrelle is influenced by the availability of suitable habitat for roosting colonies of females. Larger areas of mature spruce forest should support a greater number of colonies which would be expected to increase foraging activity along rivers in the vicinity. The fact that both of these landscape variables are considered to be important and as their area increases, the probability of the presence of eastern pipistrelles increases, suggests that areas in which there is an abundance of roosting opportunities in close proximity to suitable foraging areas represent favorable conditions for colonies of eastern pipistrelle.

The results of this investigation support the contention that the eastern pipistrelle may have value as an indicator of the abundance and connectivity of mature spruce forest in southwest Nova Scotia. Through the analysis, we have shown that the presence or absence of this species is related to the area of mature spruce forest, and therefore, their viability in the region may be dependent on the continued availability of these mature forests. Landscapes intensively managed for timber production are often characterized by young, even-aged forests with low densities of large live or dead trees (Waldien et al. 2000), and future forestry practices in the region may further limit the availability of this forest type.

Echolocation monitoring of eastern pipistrelle activity presents an opportunity for us to monitor the availability and connectivity of mature spruce forest over the large spatial scale of southwest Nova Scotia. By monitoring a series of sites over the long term we can detect changes in the activity patterns of this species. The area of wetlands is easily determined and could reasonably be expected to remain relatively constant over the time scale of monitoring. Therefore changes in eastern pipistrelle activity would be expected to indicate changes in the availability of the mature spruce forest they depend on for roosting and reproduction. Following completion of a second field season of echolocation monitoring from late May to mid August 2006, we will consider the magnitude of activity of eastern pipistrelles at sites in a model selection analysis in place of the presence or absence of the species. The magnitude of activity is easily quantified by calculating the number of calls per call sequence using ANALOOK Software (C. Corben, www.hoarybat.com). By quantifying the magnitude of activity and once again analyzing the models, we will have a good understanding of the quantitative relationship between eastern pipistrelle activity and the landscape variables that we are interested in. This will also allow us to monitor connectivity over time by determining if new areas of activity are sufficient in size and proximity to other patches to replace the areas where activity has been reduce by forest resource extraction.

To enhance roosting habitat availability for the eastern pipistrelle and other organisms with similar requirements for mature spruce forest with an abundance of *Usnea* and other associated characteristics, current forestry practices could be altered in a number of ways. Structural diversity is an important component of mature and old growth forest, compared to relatively monotonous even aged young forests (Neitlich & McCune 1997). Species diversity and frequency of late successional species could be enhanced by introducing methods into current forestry practices that enhance structural diversity in managed forests. Management techniques such as structural retention of remnant trees, long rotations or creation of reserves could potentially reduce the impacts of disturbance created by forestry practices (Price & Hochachka 2001).

Individual remnant trees or groups of trees left standing are immediately available for use as wildlife trees by a range of organisms and also enhance the development of lichen (Neitlich & McCune 1997; Peck & McCune 1997; Price & Hochachka 2001). Groups of remnant live and dead tress and reserve areas sufficient in size to provide roosting areas for colonies of reproductive eastern pipistrelle will provide habitat for a range of other species that share similar habitat requirements for mature forest or more specifically, mature spruce forest. Cameron (2002) has also suggested that the retention of remnant live and dead trees in Nova Scotia is useful for the development of diverse lichen communities. The dispersal ability of *Usnea* and other lichens may be limited and establishment and re-growth of this genus following disturbance may be aided by the retention of remnant trees. Remnant trees facilitate lichen community development in at least two ways. First, they retain the epiphytic lichens present on those trees, making them immediately available to wildlife following disturbance, and second, they provide a source of propagules for future lichen crops (Peck & McCune 1997). Many lichens are dispersal limited and provision of a source of propagules to an area recently disturbed by forestry practices should enhance the abundance and diversity of future lichen communities in that area. Support for this was provided by Peck & McCune (1997) who demonstrated that biomass of lichens was significantly greater in second growth stands with remnant tree retention than those without remnant trees.

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Table 1. Seven variables identified as potentially important factors for differentiating between sites with recorded eastern pipistrelle activity and sites with no activity recorded for the forty river sites throughout southwest Nova Scotia, 2005.

Variable	**Abbrev.**	**Description**
Average Temperature	temp	The average of hourly temperature readings over each sample night (from 19:00 to 06:00) (°C)
Hours of 100% Humidity	humid	The number of hourly readings over each sample night with a relative humidity of 100% (from 19:00 to 06:00) (hrs)
River Width	rwth	The average of three canopy height measurements: at each site, 25 m upstream and 25 m downstream (m)
Canopy Height	rcht	The average of three river width measurements/estimates: at each site, 25 m upstream and 25 m downstream (m)
Area of Mature Spruce	amsp	The area of forest dominated by spruce species (> 50% composition) with a height greater than 10 m within a 5 km buffer of the site (h)
Area of Water Resources	awet	The area of lakes, rivers and wetlands found within a 5 km buffer of the site (h)

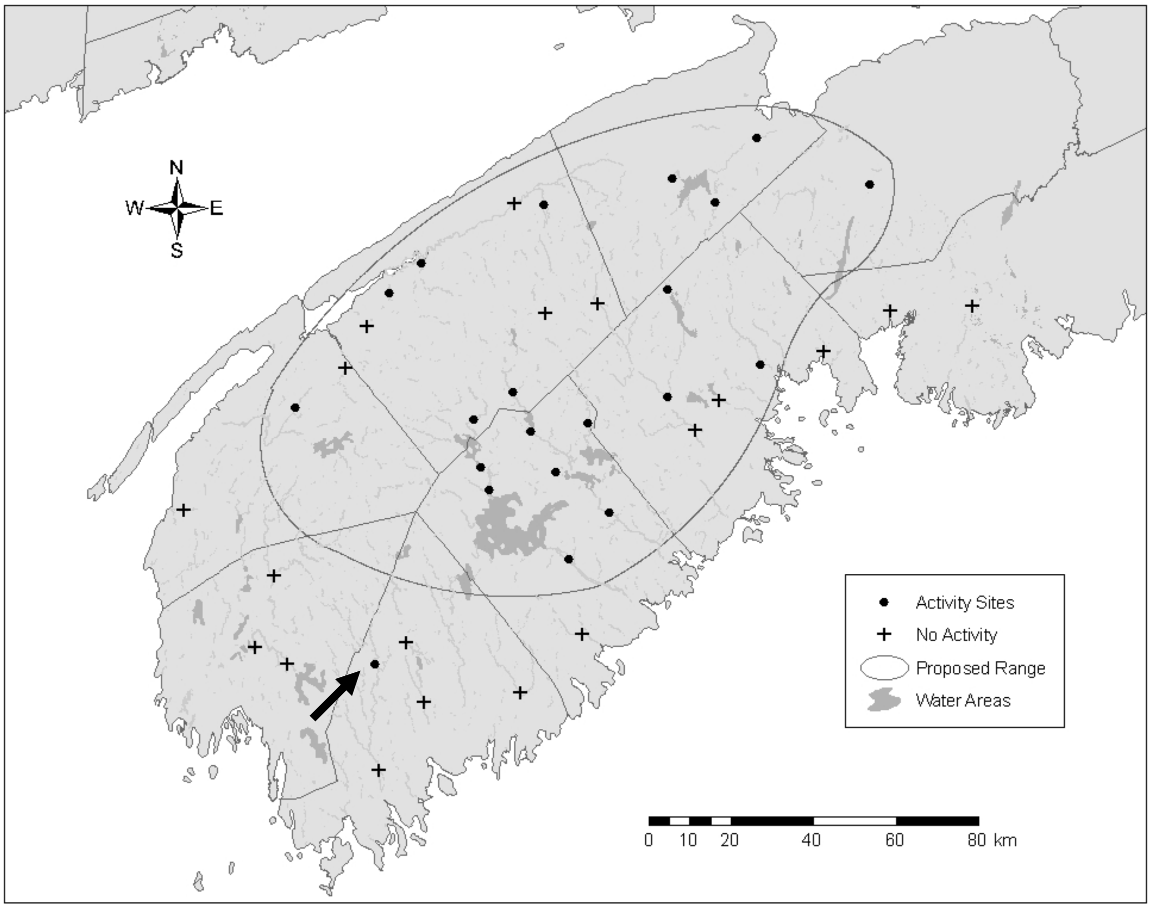


Figure 1. The location of the forty river sites in southwest Nova Scotia and the proposed range for the eastern pipistrelle in the region based on echolocation monitoring from June to August 2005 at these sites. At activity sites (●) a minimum of a single eastern pipistrelle call sequence was recorded, while at sites with no activity (+), no call sequences recorded were attributed to the eastern pipistrelle. There is one positive site for eastern pipistrelle activity (●) that lies outside of the proposed range for the species (marked with an arrow). A single eastern pipistrelle sequence, made up of eight calls, was recorded over nine nights of sampling at this site and the site is otherwise surrounded

by sites where no activity of the eastern pipistrelle was recorded. We therefore choose to exclude this site from the delineated range.

Table 2. Candidate *a priori* logistic regression model set for differentiating between sites with recorded eastern pipistrelle activity and sites with no activity based on the seven variables identified as potentially important factors and recorded for the forty river sites throughout southwest Nova Scotia, 2005.

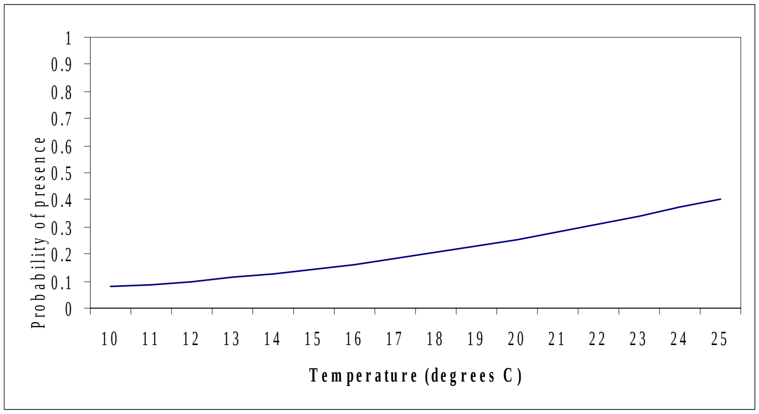
Model	**Terms**	**AIC_c**	**w_i**	**Rank**
1	awet	240.72	0.002	4
2	amsp	244.03	0.000	7
3*	**awet + amsp**	**233.65**	**0.062**	**2**
4	temp + humid	243.88	0.000	6
5	rwth + rcht	253.83	0.000	8
6*	**awet + temp + amsp**	**228.22**	**0.930**	**1**
7	rwth + rcht + humid	255.87	0.000	9
8	rwth + awet	242.67	0.001	5
9	amsp + temp + humid	238.46	0.006	3

* models included in the 95% confidence set of models (based on w_i)

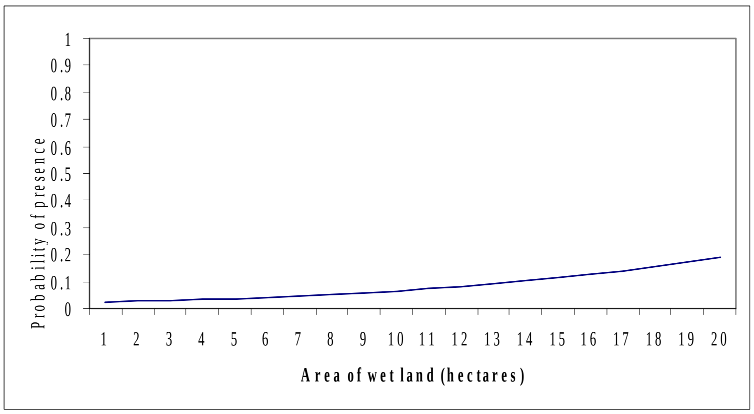
Table 3. Normalized weights (Nw_i) and model-averaged parameter estimates (β_I) with associated unconditional standard error (SE) for the variables considered to be important (Nw_i > 0.60) in differentiating between sites with recorded eastern pipistrelle activity and sites with no activity for the forty river sites throughout southwest Nova Scotia, 2005.

Variable	**Nw^i**	**β**	**SE**
intercept	-	-3.86	1.04
temp	0.94	0.13	0.05
awet	1	0.12	0.04
amsp	1	0.12	0.05

a)



b)



c)

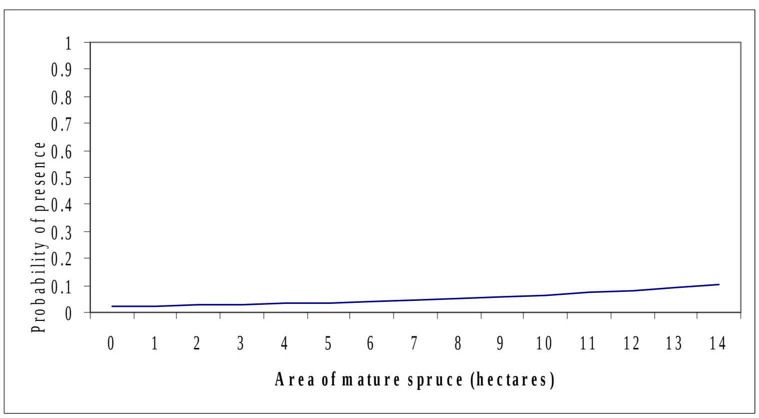


Figure 2. Univariate logistic curves ($P(Y_i) = e^{\beta 0 + \beta 1 x1} / 1 + e^{\beta 0 + \beta 1 x1}$) showing the probability that the eastern pipistrelle will be recorded at a given site in southwest Nova Scotia as a) the average nightly temperature increases, b) the area of water resources within the 5 km buffer increases and c) the area of mature spruce forest increases through the minimum to maximum values recorded for each variable.

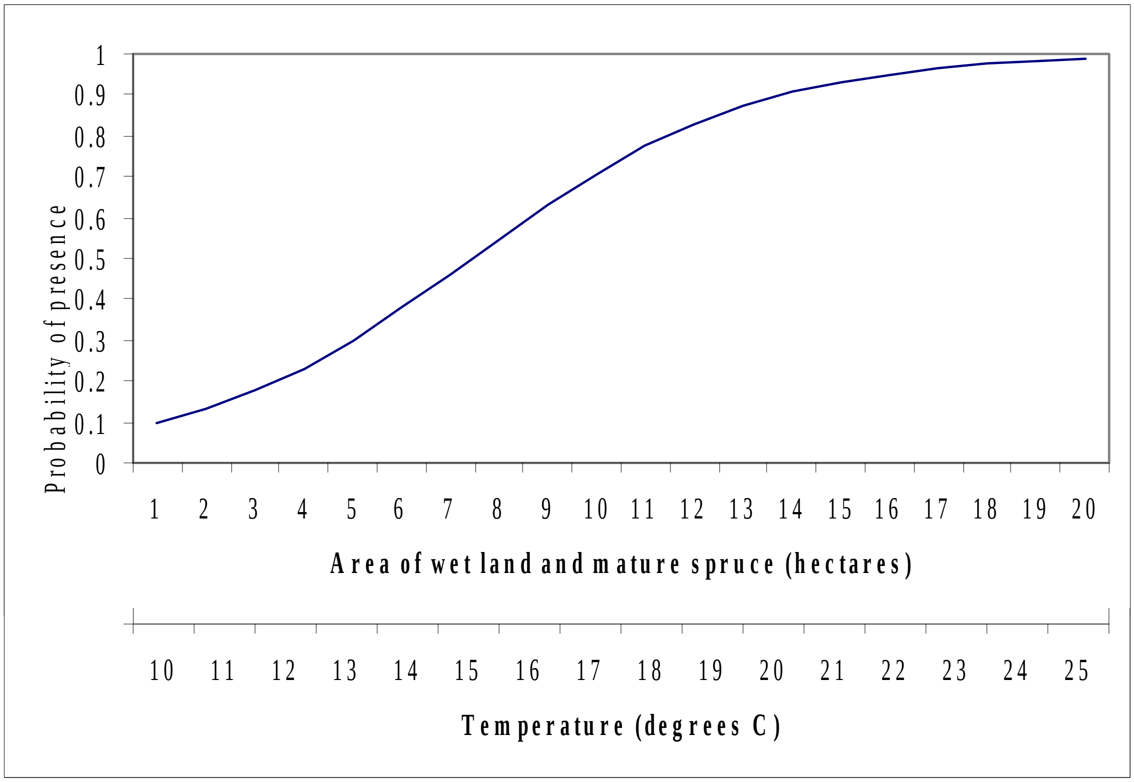


Figure 3. The combined logistic curve ($P(Y_i) = e^{\beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3} / 1 + e^{\beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3}$) showing the probability that the eastern pipistrelle will be recorded at a given river site in southwest Nova Scotia as the important variables: average nightly temperature, the area of water resources and the area of mature spruce forest (hectares) in a 5 km buffer increase through the minimum to maximum values for each variable.

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