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ENVIRONMENTAL FEATURES INFLUENCING *MYOTIS* BAT PRESENCE IN THE
PENOBSCOT EXPERIMENTAL FOREST IN CENTRAL MAINE, USA

by

Emily K. Anderson

A Thesis Submitted in Partial Fulfillment
of the Requirements of a Bachelor's Degree with Honors
(Ecology and Environmental Sciences)

The Honors College

The University of Maine

May 2016

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Abstract

Bat populations in the eastern U.S. continue to decline due to white-nose syndrome (WNS), a fungal pathogen known to produce abnormal behavior and tissue damage in bats. As a result, the composition of bat communities has changed significantly, in part due to the dramatic decrease of cave hibernating bat species. These species rely on forests for summer roosting sites and foraging. Maine is a heavily forested state where timber harvesting is a large source of revenue; therefore it is necessary to understand the factors influencing the presence of vulnerable bat species. However, little is currently known about suitable habitat for these species in Maine. This study had two main objectives: (1) to identify habitat features that influence *Myotis* bat presence across a range of environmental conditions; and (2) to document bat species present at our study site, the Penobscot Experimental Forest (PEF) in Bradley Maine. During the summer of 2015, we placed ten AnaBatTM acoustic detectors at a total of 46 locations throughout the PEF, stratified by four cover types: open, closed canopy, small canopy gaps, and large canopy gaps. Detectors were moved to new locations on a weekly basis. We analyzed nine potential predictor variables, creating a separate logistic regression model for each. The models were evaluated using Akaike's corrected information criterion (AICc), assuming that the model with the lowest AICc score was the most influential. We found that the number of trees per hectare (in quadratic form) was the best predictor of *Myotis* species presence, with proportion of canopy openness and gap size also contributing to variation among sites. In total, we detected eight bat species at the PEF representing the full set of species occurring in Maine. Our expectation is that findings from this study will provide a foundation for future investigations into forest use by threatened bats in this region.

Acknowledgements

First and foremost, I thank Shawn Fraver for his excellent guidance and support throughout the entire thesis process. I thank Erik Blomberg for his guidance in data collection and analysis, and overall support to me and the project. I thank Elias Ayrey for his time and effort producing the LiDAR layers we used. I thank Lara Katz for her assistance in data collection and field work. I thank Nicholas Jenkins, Sarah Nelson, and Lindsay Seward for their help and support with reviewing my thesis and being a part of this process. I thank the PEF Research Operations Team for providing the funding that made this work possible. I thank Trevor Peterson for his help with identifying acoustic signatures. Furthermore, I thank Trevor Peterson and Stantec Consulting for loaning us the detectors. I thank Bob Seymour and Paul Szwedo for providing the AFERP GIS data layers.

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Introduction

Bat populations in the eastern United States (U.S.) continue to decline due to white-nose syndrome (WNS), a fungal pathogen that affects hibernating bats. Since its first documentation in New York in 2006, WNS has spread throughout the north-eastern and mid-Atlantic regions of the U.S., as well as Ontario and Maritime provinces of Canada (Frick et al. 2010). WNS is caused by the fungus *Pseudogymnoascus destructans* and can produce abnormal behavior, including premature arousals from hibernation and depletion of stored fat, both of which apparently weaken infected individuals, thereby increasing mortality risk (Blehert et al. 2009, Reeder et al. 2012). Infected bats also exhibit wing damage and fuzzy white fungus on their nose and muzzle. Fungal hyphae destroy hair follicles, as well as the nearby sweat and sebaceous glands. They penetrate the basement membrane and infect surrounding tissues, ultimately causing erosion of the ear and wing epidermis. WNS is fatal for almost all infected bats (Blehert et al. 2009).

As a result of widespread mortality and population declines, the composition of bat communities in northeastern North America has changed dramatically in recent years (Langwig et al. 2012). WNS affects hibernating species, which in this region include the big brown (*Eptesicus fuscus*), little brown (*Myotis lucifugus*), northern long-eared (*Myotis septentrionalis*), Indiana (*Myotis sodalis*), eastern small-footed (*Myotis leibii*), and tricolored (*Perimyotis subflavus*) bats (Gargas et al. 2009, Francl et al. 2011). Demographic simulation models show that little brown bat populations, irrespective of the population starting size in all scenarios, dropped to a minimum population size <1.5% of the original, in the years following WNS infection (Russel et al. 2015). Empirical

studies have shown similar results: *Myotis* species declined by 72% between 2004-06 and 2010 (Brooks 2011).

Northern long-eared bats in particular have suffered significant declines throughout their range, which covers much of central and eastern North America. Recent work reveals that northern long-eared bats are subject to a significantly higher extinction probability than either little brown or big brown bats, and that they are no longer present at 69% of their previously occupied hibernacula (Frick et al. 2015). In the U.S., the northern long-eared bat has recently been federally listed as a threatened species under the Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS, 2015).

Because Maine is heavily forested and supports an active forest industry, forest-dwelling bats, such as *Myotis* and related species mentioned above, have recently become a conservation issue. WNS was first confirmed in Maine during the winter of 2010-2011. Although previous studies have evaluated habitat features that affect bat presence or absence at roosts in other regions (Johnson et al. 2015, Pauli et al. 2015, Divoll 2013), few studies have evaluated the features that potentially influence bat presence across a range of conditions within Maine's forested landscapes.

Thus our primary objective was to better understand which habitat and environmental features influence *Myotis* and *Perimyotis* (referred to collectively as “cave-hibernating” in this paper) bat presence at a particular forested location. Due to the importance of the forest industry to Maine's economy, we placed particular emphasis on forest structural features across a range of long-term silvicultural treatments, all located within the Penobscot Experimental Forest of central Maine (Fig. 1). We hypothesized

that cave-hibernating bat presence would differ among the treatments due to differences in forest structural attributes. Forest characteristics such as stand density, and proximity of wetlands have been shown to influence bat activity (Grindal and Brigham 1999, Broders et al. 2006). A secondary objective was to conduct a systematic survey of the bat species present at the PEF, as this had not been previously accomplished. Although conducted at a single study area, we expect the outcome of this work to shed light on forest bat habitat features of interest and provide a baseline for future studies throughout the region.

Methods

Field Methods

We conducted this study on the 1620-ha Penobscot Experimental Forest (PEF) of central Maine, USA. The purpose of the PEF is to investigate the productivity of different silvicultural procedures, making it an ideal site for this study. The PEF supports numerous long-term silvicultural studies, which conveniently provide a range of potential habitat features to which bats may respond. The portions of the PEF used in this study were conifer dominated; dominant species were red spruce (*Picea rubens*), eastern hemlock (*Tsuga canadensis*), eastern white pine (*Pinus strobus*), and balsam fir (*Abies balsamea*), with a lesser component of northern white-cedar (*Thuja occidentalis*), red maple (*Acer rubrum*), and white birch (*Betula papyrifera*). This composition is typical of the Acadian forest in the region.

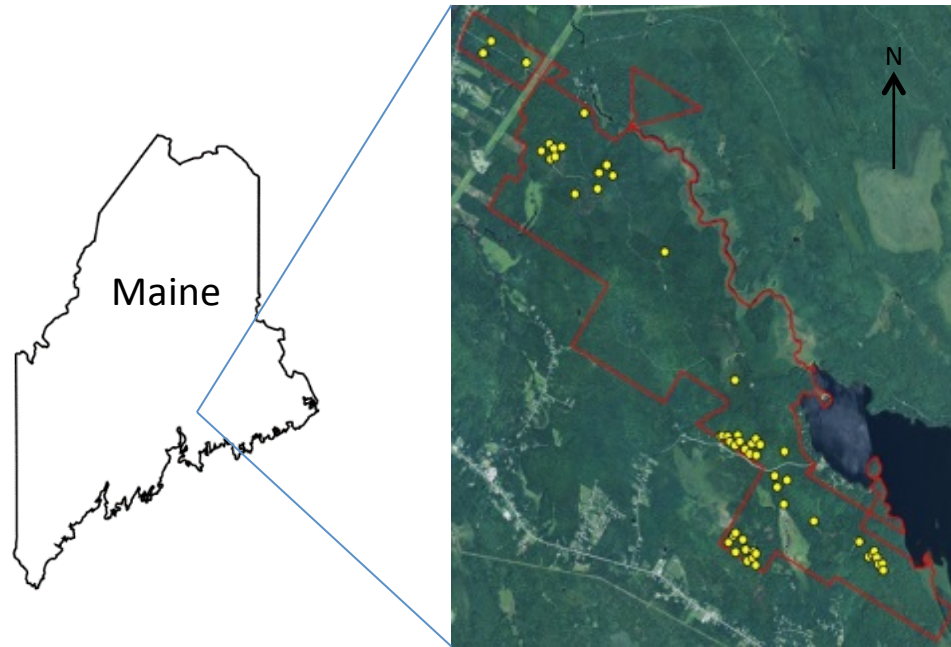


Figure 1. The Penobscot Experimental Forest of Central Maine (red border), showing the locations of acoustic detectors (yellow dots).

Within the PEF, there were several forest structure types that provided an experimental design with four treatments. Open locations, such as non-forested wetlands and forest edges bordering fields, lacked significant forest cover. Closed locations supported mature, closed canopy forest stands with no evidence of recent timber harvests. Small gaps and large gaps represent treatments within the Acadian Forest Ecosystem Research Program (AFERP), a project using silvicultural systems designed to mimic forest structure resulting from natural disturbances (Saunders et al. 2014). In these research areas (or compartments), harvests occur as expanding gaps, creating a more complex size and age structure than traditional clear-cuts. Small and large gaps refer to the two treatment sizes used in the AFERP project: small gaps have initial canopy openings of 0.1 ha and large gaps have initial openings of 0.2 ha.

Between 11 June and 18 August, 2015, we placed ten acoustic detectors (Anabat™ Model SD2) at the four location types throughout the PEF, relocating them to new locations on a weekly basis (Figure 1). Acoustic detectors allowed us to identify individual bat species based on distinct call characteristics. Bats emit ultrasonic calls as they fly to detect their surroundings. While inaudible to humans, certain types of microphones and recorders (like those in our acoustic detectors) can detect these calls. Call characteristics such as amplitude, frequency, and overall shape (distribution of acoustic signals) vary among bat species, helping us determine which species were present (Fig. 2).

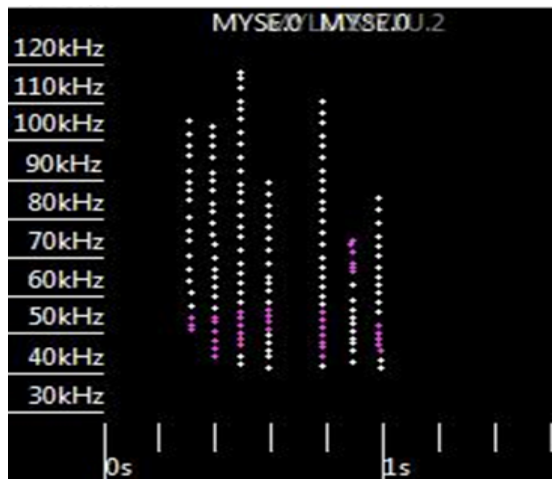


Figure 2. Northern long-eared bat acoustic signals show a nearly vertical distribution of points within clusters. Time in seconds is shown on the x-axis and frequency in kHz is shown on the y-axis.

Each week, we retrieved detectors from their previous locations, replaced the memory cards, and placed the detectors in new pre-determined locations. In most cases, detectors were rotated through two large gaps, two small gaps, one open location, and one closed location, for a total of six locations. We located more detectors in the gaps

because our main focus was features affecting bat presence among these silvicultural treatments. We moved the detectors to new compartments, or gap clusters, each week. This rotation allowed us to spread our sampling across the PEF through time. However, equipment malfunctions occasionally resulted in fewer than six detectors for a particular week. In such cases, we prioritized gaps while also considering where detectors had already been placed that week and where functioning ones had been previously placed. At the new location, detectors were strapped to trees with the microphone facing natural openings or corridors that bats would likely use for travel, increasing the likelihood of detecting bats present at that location. Geographic coordinates were recorded at each location using a handheld GPS unit (Garmin 64s GPSMap®).

Acoustic Data Processing

We analyzed the resulting acoustic files using Kaleidoscope Pro 3 software (Wildlife Acoustics, Inc.), focusing on *Myotis* and *Perimyotis* species, because WNS has significantly reduced their populations (Brooks 2011). Kaleidoscope identifies calls based on the primary bat species found in Maine: big brown, hoary (*Lasiurus cinereus*), silver-haired (*Lasionycteris noctivagans*), eastern red (*Lasiurus borealis*), little brown, northern long-eared, small-footed, and tri-colored. Calls that could not be identified as one of these species were labeled “no ID,” and all other noise was labeled as “noise”. Both “no ID” and noise files were manually vetted to confirm that none belonged to either a *Myotis* or *Perimyotis* bat. Most noise files contained no acoustic signature or acoustic signatures that did not match any known bat calls.

We checked acoustic data for errors associated with equipment malfunction. Detectors with a mean number of detections falling below the overall mean (all detectors

pooled) by >1 standard deviation were examined more closely. This procedure identified one detector of concern and, based on its distribution among location types, we determined that it was unlikely to have influenced the results (i.e., there was no bias towards certain location types).

We also explored possible temporal trends in bat detections by evaluating the consistency of mean number of bat calls per detector night throughout the summer. Because we only sampled each location once, a temporal trend could confound our analysis of habitat features influencing bat presence. Although no statistically significant temporal trend was found, the number of bat calls per detector night did appear to increase after the sixth week, corresponding to the volant period, that is, the time when young bats begin to become active. We simply consider this possibility as an unknown source of variability in our data set.

Finally, all acoustic identifications for *Myotis* and *Perimyotis* species were vetted to remove misidentifications. We also checked calls for the other four species to ensure that none belonged to *Myotis* or *Perimyotis*. The key characteristics used to identify *Myotis* species were call profiles that began at approximately 40 kHz or higher and had a nearly vertical slope. *Perimyotis* species were identified by their short, distinctly hook-like appearance. All such calls that fit the necessary criteria for *Myotis* or *Perimyotis* were manually identified to the appropriate species; calls that did not fit the criteria were manually placed in the appropriate non-*Myotis* taxa.

Assembling Location Predictor Variables

Our research objective required that we assemble a set of location variables that could potentially serve as predictors of cave-hibernating bat presence. To this end, we obtained GIS data layers for the PEF from U.S. Forest Service archives. From these, we determined elevation and distance to nearest wetland (as per the most recent National Wetlands Inventory), as well as the ‘gap’ treatment based on the AFERP study design for each acoustic detector location. We also used LiDAR point clouds and algorithms detailed in Ayrey et al. (in review) to derive the following metrics within a 30-m radius around each detector location: proportion canopy openness, mean tree height, basal area per ha, tree density per ha (trees ≥ 10 cm diameter), proportion of conifer cover, and canopy rugosity (a measure of canopy surface roughness). The 30-m radius was chosen to maximize the area of data extraction and minimize the amount of overlap between neighboring detector locations. These layers were converted to raster files, and data values were extracted from the overlapping buffered areas. GIS data summarizations were conducted in ArcGIS (v. 9.1, Esri, Redlands, CA, USA).

Data Analysis

Because our response variable was binary (cave-hibernating bat presence vs. non-detected), we used logistic regression to assess the importance of our predictor variables. First, for each of the ten predictors (listed above), we created a separate univariate linear model. By visually inspecting plots of probabilities of detection versus predictors, we determined that one predictor – trees per ha – may be better fit by including a quadratic term (i.e., trees per ha squared) to capture the apparent curvilinear relationship; we thus

included such a model in our set of candidate models. We also created a null model based on the intercept only.

Candidate models were compared using Akaike's corrected information criterion (AICc), allowing us to assess which models were best supported by the data (Burnham and Anderson 2002). The model with the lowest AICc score (Delta AICc value of zero) was assumed to best describe the patterns in the data. We also interpreted any models with AICc scores lower than that of the null as accounting for some variation in the data (based on the AIC weight, which is a measure of a model's relative likelihood). If the null model was found to be the lowest, this would indicate that none of our predictor variables had a significant influence on bat presence. All analyses were performed using the glm procedure in program R (version 3.0.2).

Results and Discussion

By 25 August, 2015, we had collected acoustic data from 46 locations (Table A1 in Appendix), for a total of 77 detector nights. We detected cave-hibernating bats at 43% of the locations and recorded a total number of 3761 calls.

Of the ten candidate models tested, only three accounted for significant variation in the data. Trees per hectare (quadratic form), proportion canopy open, and 'gap' (large gaps (0.2 ha), small gaps (0.1 ha), open and closed) models all accounted for the variation seen in the presence of cave-hibernating bats among sites (Table 1).

Table 1. Ten candidate models were evaluated to determine which predictors best explained bat presence. The null model is based only on the intercept. The model with the lowest AICc score was considered to be best supported by the data. All models with AICc scores lower than the null model also contributed to observed variance in bat presence. Data on bat presence were collected in the PEF over the summer of 2015.

Model	k	AICc	Delta AIC	AICcWt	Cum. Wt
Trees per hectare (quadratic)	3	63.29	0	0.21	0.21
Proportion open canopy	2	63.9	0.61	0.15	0.36
Gap	4	64.58	1.29	0.11	0.59
<i>NULL</i>	1	65.08	1.78	0.08	0.67
Mean height	2	65.65	2.36	0.06	0.73
Rugosity	2	65.93	2.64	0.05	0.79
Trees per hectare (quadratic)	2	66.35	3.06	0.04	0.83
Basal area per hectare	2	66.49	3.2	0.04	0.87
Proportion softwood	2	66.93	3.64	0.03	0.91
Distance to wetland	2	67.12	3.83	0.03	0.97
Elevation	2	67.17	3.88	0.03	1

The quadratic model of trees per hectare revealed a high probability of presence at low tree densities, a low probability at intermediate tree densities, and returning to a high probability at high tree densities (Figure 2). We note that these probabilities represent four species that may exhibit different preferences for foraging habitat. We combined the four species for analysis because of small sample sizes of northern long-eared and eastern small-footed bats, which will be discussed below. Little brown bats often forage over open water, which could account for the increase in probability of presence in areas of lower tree density (Fenton and Barclay 1980). Other *Myotis* species, like the northern long-eared bat, are more forest dependent (Pauli et al. 2015). Thus the pooling of these species, and their associated foraging preferences, likely explains the U-shaped pattern of probabilities shown in Figure 2.

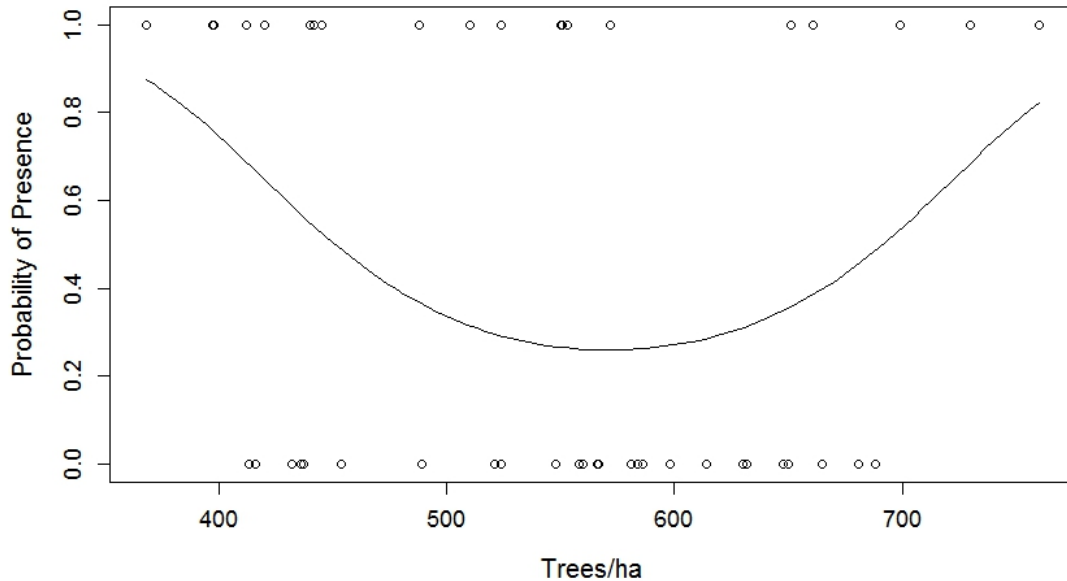


Figure 3. The probability of presence of cave-hibernating bats at any given location in the PEF during summer 2015 based on stand density (trees / ha) was best represented with a quadratic model.

Additional variance could also be attributed to the proportion of open canopy and gap type because their AICc values were lower than those of the null model (Table 2). Specifically, the probability of presence for cave-hibernating species (when pooled) increased with increasing canopy openness (Fig. 4). We further explored this trend by analyzing site-level probabilities of presence (multiple pair-wise comparisons). While not statistically significant based on a confidence interval test, perhaps given the low statistical power resulting from our small sample size, the results suggest that the proportions of open canopy and large gap locations predicted to be occupied may be greater than those of closed canopy and small gap locations. Previous work has found that some *Myotis* species prefer foraging in more open environments, such as forest edges (Grindal and Brigham 1999, Patriquin and Barclay 2003). In one study, bat foraging activity was greatest in environments with less spatial clutter, like forest edges and cutblocks (areas designated for harvesting; Grindal and Brigham 1999). Authors suggest that these environments provide a better energy balance between prey availability and

energy expenditure in maneuvering. They also suggest that although *Myotis* bats have characteristics suited to foraging in forests, they may attain greater net energy gains by foraging in less complex environments. One exception to this general trend is the northern long-eared bat, which feeds gleaning its prey from vegetation (Faure et al. 1993). Because of this feeding strategy, northern long-eared bats frequently forage in more densely forested stands (Patriquin and Barclay 2003).

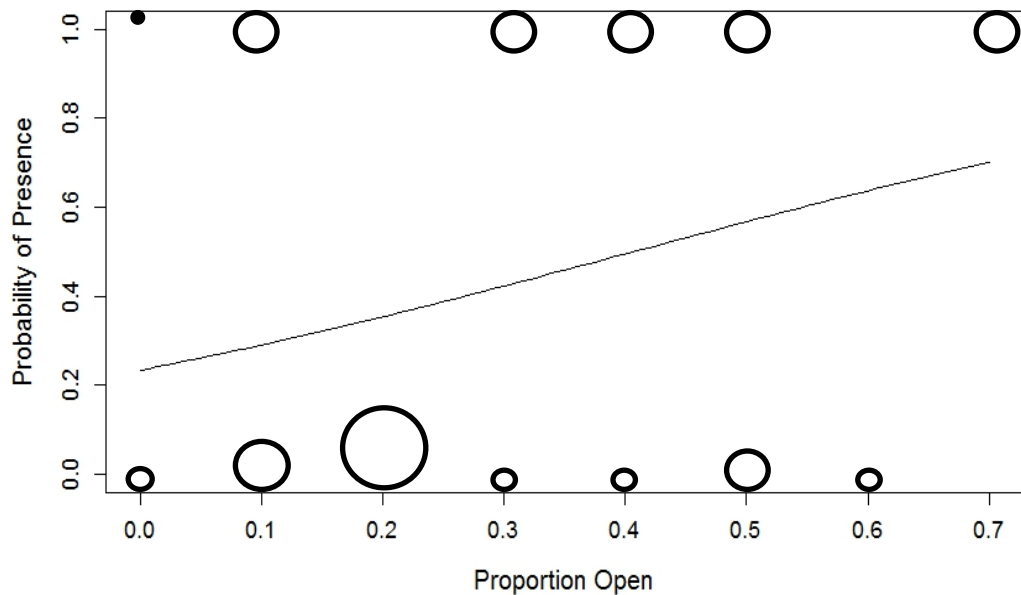


Figure 4. Probability of cave-hibernating bat presence increased with increasing canopy openness. The size of the circles represents the number of locations, with the largest circle representing ten locations and the smallest representing one location.

Although increased stand density has been shown to decrease foraging activity in some *Myotis* species, such as little brown bats (Grindal and Brigham 1999, Patriquin and Barclay 2003), our results appear to contradict this. While trees per hectare is a measure of stand density, we note that this only accounts for trees greater than 10 cm in diameter. It is possible that locations with greater tree density have a sparser understory than locations of intermediate density. This could explain the lowest probability of presence

occurring at intermediate stand densities, not at the highest. In general, these densities are typical of Maine forests.

Surprisingly, distance to wetland was not a useful predictor of cave-hibernating bat presence. Previous work indicates that little brown bats show preference towards foraging over water (Broders et al. 2006, Barclay 1991). We suspect that this parameter's lack of influence in our study is due to the abundance of wetlands throughout much of the PEF, which greatly limited the range of distances that we could evaluate. No detector location ever exceeded a distance of 360 m from the nearest wetland, and the distances were skewed towards being shorter. Our results also suggest that differences in forest characteristics (i.e. basal area, proportion softwood, rugosity, and mean height) did not significantly affect the presence of cave-hibernating bats. This is likely due to detectors being placed in gaps or on edges of gaps, which created variability of within-buffer stand characteristics. Elevation was the least significant variable of those evaluated here, perhaps because elevation, like distance to wetland, did not vary greatly among the detector locations.

Other studies have found that bats use trails and other linear features as travel corridors, making distance to trail a possible predictor of bat roosting presence (Zimmerman and Glanz 2000). However, we did not investigate the influence of roads in this study, primarily because of the absence of primary (i.e., paved) roads and the abundance of various secondary roads, harvesting skid trails, and other forest trails.

Although our primary objective was to determine the habitat and environmental features influencing cave-hibernating bat presence, our secondary objective was to

produce a list of all bat species encountered at the PEF. We detected eight species of bats, which represents all bat species known for Maine (Table 2). Number of passes refers to the number of times we detected a bat. Unfortunately, we cannot tell from this how many bats were present because of the inability to distinguish between one bat passing multiple times and multiple bats passing once.

Table 2. Bat species detected in the Penobscot Experimental Forest from early June to mid-August 2015. *Myotis* and *Perimyotis* species were of particular interest due to the effect of WNS on their populations. At some locations, species were detected multiple times. Number of passes refers to the numbers of total detections recorded across all locations.

Common Name	Scientific Name	No. of passes
Silver-haired bat	<i>Lasiurus noctivagans</i>	1818
Big brown bat	<i>Eptesicus fuscus</i>	1514
Hoary bat	<i>Lasiurus cinereus</i>	187
Eastern red bat	<i>Lasiurus borealis</i>	123
Little brown bat	<i>Myotis lucifugus</i>	79
Tri-colored bat	<i>Perimyotis subflavus</i>	32
Northern long-eared bat	<i>Myotis septentrionalis</i>	5
Small-footed bat	<i>Myotis leibii</i>	3

We detected U.S. federally threatened northern long-eared bats in at least three locations (Table A2 in Appendix), all of which were either closed canopy or small gap. Although our sample size was small, likely due to severe population declines that have made this species uncommon in the region, these results reflect the findings in other studies. Northern long-eared bats are known to specialize in the forest interior (Broders et al. 2006). They catch insects by gleaning and thus often forage in forested areas where they can pluck insects from the vegetation (Faure et al. 1993). Another study comparing northern long-eared bat presence among multiple location types (clearcut, 20% thinned, 50% thinned, and intact; Patriquin and Barclay 2003) speculated that intact forests and thinned locations provide more opportunity for gleaning than do clearcuts.

Eastern small-footed and little brown bats are listed as threatened by the state of Maine (MDIF&W 2015). We detected eastern small-footed bats at three locations (Table A2 in Appendix). In contrast to the northern long-eared bats we detected, all eastern small-footed bat detections occurred in either open areas or large gaps. We detected little brown bats at a total of 19 locations (Table A2 in Appendix), including all locations at which we detected northern long-eared and eastern small-footed bats. Sites with closed canopies had the smallest number of little brown bat detections (5% of all locations). Detections were evenly split between the remaining three gap types (32% for small, large, and open locations each).

Our study includes four limitations worth discussing. First, we had a limited number of detectors: only six detectors were available for our use. Occasionally, malfunctions occurred, preventing us from utilizing all six, which restricted the number of locations we could sample in a given week. While we were able to collect data from a majority of the gap locations, we were unable to sample all of them. More detectors would have allowed us to sample a greater number, and possibly greater diversity, of locations within the PEF.

Secondly, we were limited because the populations of cave-hibernating bats have experienced significant population declines in recent years (Francl 2012, Langwig et al. 2012, Moosman 2013). Between 2004-06 and 2010, some *Myotis* populations declined by 72% (Brooks 2011). Lower abundance in bat populations translates to fewer detections. The resulting low numbers required that we pool species, thereby confounding our analyses, and possibly producing the non-linear pattern indicating that probability of presence is highest in low and high density stands. Clearer patterns may have appeared

had the numbers of individuals per species been sufficient to warrant separate analyses. In future studies, it is suggested that detectors be placed in the same location multiple times or placed in more locations during the same week. This could potentially increase the number of detections and subsequently the sample size.

Thirdly, our analysis was limited by the margin of uncertainty associated with call identification. The non-linear trend observed in Fig. 3 could be attributed to the strong presence of little brown bats at all sites where cave-hibernating bats were detected. Misidentification of bat species could have occurred, despite our best efforts to avoid it through hand vetting of all cave-hibernating bat calls. For example, some calls identified as little brown bats could have been produced by northern long-eared bats. Because northern long-eared bat calls can reach very high frequencies that are occasionally missed by the detector, their calls can be mis-attributed to little brown bats.

Lastly, out of necessity, our study was limited to one study area. Although the PEF conveniently provided a range of forest structures resulting from long-term silvicultural studies, it did not provide the full range of regional forest types, elevations, distances to wetlands, and perhaps other features to which bats may respond. For example, previous work based on the preferences of male little brown bats indicated that flight activity is lower in overmature forests with a high proportion of softwood (Krusic et al. 1996). Conditions at our study locations could have belonged to a forest type less desirable to bats as locations within foraging range of the PEF.

The findings from this study were intended to provide baseline data for future research conducted in this region. The northern long-eared bat is already federally listed

as threatened, and is also listed with the little brown and eastern small-footed bats as threatened in Maine (USFWS 2015; MDIF&W 2015). Research indicates that several *Myotis* species could continue to decline over the coming years (Brooks 2011). Their consumption of insects makes these bats important to ecosystem health as well as the human economy (Boyles et al. 2011). Bats can also potentially benefit the forest industry through predation on pest insects (Boyles et al. 2011). Because of their ecological importance and the challenges they currently face, it is necessary to understand the habitat features that influence their presence to properly implement forest management strategies that minimize harm.

Recommendations for Future Research

Future research should evaluate characteristics that make individual trees ideal for *Myotis* bat summer roosting in Maine. This can be done by placing radio transmitters on bats and tracking their locations. Similar work has mostly focused in the southern Appalachians and mid-west U.S. Little brown bats are known to roost in both human-made structures and natural spaces (Fenton and Barclay 1980). Northern long-eared bats will occasionally roost in human-made structures, but are more commonly found roosting in trees that vary in stages of decay (Caceres and Barclay 2000). Forested regions with a moderate proportion of edge habitat were found to have a positive relationship with roost occupancy for northern-long eared bats in Indiana (Pauli et al. 2015). In the future, it will be necessary to understand whether similar conditions affect roost selection for *Myotis* species in Maine.

Another avenue for future studies is investigating winter hibernacula in Maine. Maine has few hibernacula (MDIF&W 2011), and for northern long-eared bats, only three hibernacula are known in Maine (USFWS 2015). In the coming years, it will be important to continue monitoring these hibernacula, as they will provide insights into how vulnerable bat populations are responding to WNS.

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Appendix

Table A1. Description of the 46 locations where acoustic detectors were placed in the PEF from early June to mid-August, 2015. Geographic coordinates are listed in UTM, Zone 19T; Basal area is given as m².

Location	Gap	Easting	Northing	Trees per hectare	Basal area per hectare	Proportion softwood
C1	Closed	531587	4963447	651	48.7	0.697
C2	Closed	528991	4967753	632	39.3	0.760
C4	Closed	532786	4962696	630	34.1	0.638
C5	Closed	529197	4967714	581	25.5	0.739
C8	Closed	531555	4963603	681	40.5	0.708
C9	Closed	529106	4967861	521	31.1	0.822
CX	Closed	529955	4966669	688	35.8	0.803
CY	Closed	528780	4968574	650	40.7	0.649
O1	Open	530974	4964910	730	36.0	0.748
O2	Open	532124	4962983	368	8.0	0.561
O3	Open	528971	4967537	548	14.3	0.741
O4	Open	531688	4963216	661	28.1	0.762
O5	Open	527933	4969261	420	9.8	0.763
O6	Open	528644	4967462	488	22.3	0.779
RA1E2G2	Large	531120	4963968	445	20.0	0.753
RA1G5	Large	531187	4963903	558	29.2	0.761
RA1H6	Large	531286	4963885	566	28.5	0.776
RA1J4J5	Large	531340	4964033	437	22.1	0.681
RA2E10	Small	530762	4964141	584	25.7	0.646
RA2E11	Small	530974	4964022	560	29.1	0.805
RA2E15	Small	531044	4964073	567	32.5	0.765
RA2E4	Small	531016	4964157	760	28.2	0.717
RA2E6	Small	530900	4964068	699	40.6	0.787
RA2E9	Small	530870	4964141	550	26.5	0.761
RA5C2	Small	531280	4962376	665	42.6	0.731
RA5E1	Small	531155	4962437	489	26.1	0.705
RA5E4	Small	531282	4962538	614	34.8	0.676
RA5E5	Small	531253	4962569	572	42.2	0.727
RA6A3B4	Large	531128	4962591	416	16.3	0.807
RA6C6	Large	531087	4962727	553	31.1	0.735
RA6E2	Large	530882	4962689	510	21.6	0.748
RA6E4	Large	530954	4962782	412	21.8	0.753
RA7E1	Small	533003	4962572	598	31.4	0.689
RA7E10	Small	533039	4962483	551	26.3	0.736
RA7E18	Small	533127	4962399	397	22.7	0.701
RA7E19	Small	533066	4962388	648	30.9	0.754
RA7E2	Small	532919	4962496	524	22.9	0.713

RA7E3	Small	532974	4962531	586	33.0	0.575
RA9E1	Large	528449	4968107	440	19.7	0.722
RA9E3	Large	528336	4968086	442	22.3	0.759
RA9E5	Large	528355	4967977	436	25.0	0.725
RA9E6	Large	528285	4967941	454	21.9	0.780
RA9E7	Large	528156	4968051	432	16.2	0.741
RA9E8	Large	528271	4968149	398	17.5	0.717
WaYS1	Open	527422	4969553	524	27.1	0.768
WaYS2	Open	527304	4969395	413	8.90	0.672

Table A2. Locations of species of conservation concern.

Species	Gap	Location
Little brown; northern long-eared	Closed	C1
	Small	RA2E4
	small	RA7E18
Little brown; eastern small footed	Open	O2
	Large	RA6E2
	Large	RA6E4
Little brown	Open	O1
	Open	O4
	Open	O5
	Open	O6
	Small	RA2E6
	Small	RA2E9
	Small	RA5E5
	Large	RA6C6
	small	RA7E10
	Large	RA9E2
	Large	RA9E3
	Large	RA9E8
	Open	WaYS1

Biography

Emily Anderson was born on April 10th, 1994. She grew up in Middlebury, Vermont and graduated from Middlebury Union High School in 2012. She majored in ecology and environmental sciences. She is a member of the National Society of Collegiate Scholars.

After graduation, she will spend ten weeks working as an intern at the Smithsonian Environmental Research Center. When the internship is finished, she will continue to pursue paths that interest her, whatever they may be.