Fire effects on bat species diversity present at Brookhaven National Labs

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I. Abstract

Many bat species are under threat from habitat loss, climate change, and white-nose syndrome (*Pseudogymnoascus destructans*) (Frick, et al., 2019), and it's important to know what species are present in order to manage them properly. The study looked at bat species diversity across sites at Brookhaven National Laboratory, which is located in the heart of the Long Island Central Pine Barrens region. Pine barrens are a fire-adapted ecosystem and thus prescribed fire is an important tool in managing the forest, helping to reduce wildfire risk and promoting biodiversity and resiliency (BNL, 2021). To determine if this affects habitat use by various bat species, species diversity for individual sites will be compared looking at disturbance type (e.g., prescribed fire, mechanical treatment, wildfire, or no treatment). Ultrasonic detectors were put up at locations of special interest, and recordings were processed to identify the bat species. Models were run to obtain occupancy and detectability estimates, stratifying occupancy probability, detection probability, or both by forest type, and model fit was assessed with a Goodness of Fit test. None of the models detected any meaningful differences in occupancy or detectability between intact or disturbed forest. This could mean bats aren't affected by small-scale prescribed fires, which has interesting management applications for endangered species.

II. Selected Acronyms

BNL	Brookhaven National Laboratory
EPTFUS	Big Brown Bat
LASBOR	Eastern Red Bat
LASCIN	Hoary Bat
LASNOC	Silver-Haired Bat
MYOLEI	Eastern Small-Footed Bat
MYOLUC	Little Brown Bat
MYOSEP	Northern Long-Eared Bat
PERSUB	Tricolored Bat

III. Introduction

A. Background

Bats (Chiroptera) are a large order consisting of over 1,400 species, making up about a quarter of all mammals, and are the only mammals known to have evolved powered flight (Anderson & Ruxton, 2020). They play a large role in the environment, and provide many ecosystem services such as arthropod suppression, seed dispersal, and pollination (Kunz et al., 2011). Insectivorous bats in particular have been found to suppress many species of agricultural and forest pests. It's estimated that a colony of 150 big brown bats (*Eptesicus fuscus*) in the midwestern United States can consume 600,000 cucumber beetles, 194,000 June beetles, 158,000 leafhoppers, and 335,000 stinkbugs annually. Northern long-eared bats (*Myotis septentrionalis*) have also been found to suppress mosquito populations, showing a significant reduction in egg-laying activity correlated with bat predation (Reiskind & Wund, 2009). Many bat species are under threat from habitat loss and degradation, climate change, and particularly white-nose syndrome (*Pseudogymnoascus destructans*) in North America (Frick, et al., 2019), and it's important to know what species are present in order to manage them.

There are eight species of bats currently found on Long Island, NY, all in the Vespertilionidae family- the big brown bat, the eastern red bat (*Lasiurus borealis*), the hoary bat (*Aeorestes cinereus*), the silver-haired bat (*Lasionycteris noctivagans*), the eastern small-footed bat (*Myotis leibii*), the little brown bat (*M. lucifugus*), the northern-long-eared bat, and the tricolored bat (*Perimyotis subflavus*) (Harvey, et al., 2013). The silver-haired, eastern red, hoary, eastern small-footed, and little brown bat are all classified as species of greatest conservation need in the state, while the northern long-eared is federally threatened and is currently under review to be reclassified as endangered under the Endangered Species Act by the United States

Fish and Wildlife Service (BNL, 2021). The little brown bat is listed as endangered under the IUCN Red List of Threatened Species (Solari, 2018). Many bat species migrate between summer and winter use areas and so their ecology differs among seasons, including where they roost (Perry, 2012). Roosts are a vital resource for bats, as they spend much of their time in them being sheltered from both the weather and predators. Roosting sites are diverse and vary with species but can include foliage, tree cavities, underneath tree bark, caves, mines, and other structures. The eastern red bat and hoary bat are both forest-dwelling bats and roost in trees and foliage most of the time. The big brown bat, eastern small-footed bat, little brown bat, northern long-eared bat, and tricolored bat are all cave-dwelling bats, who mainly roost in caves, mines, or other structures, sometimes roosting in the forest in the summer.

Fires can affect bats indirectly by changing the habitat characteristics such as insect abundance and physical clutter (Loeb, 2007; Swengel, 2001), and directly through exposure to smoke, heat, and carbon monoxide leading to displacement and death (Dickinson, 2009). In a review of 52 studies, bats tended to show either positive or neutral responses to prescribed fire, and more negative responses to wildfire, as they're often larger and more severe (Loeb & Blakey, 2021). These responses are complex and rely on a number of factors such as fire severity, fire frequency, time since last burn, season of burn, and ecological factors of both the forest and the bats themselves. Northern long-eared bats in particular have been observed to shift locations after prescribed burn to follow insect availability and roost microsites, which suggests they might be tolerant of prescribed fire (Lacki, et al., 2009).

Here we look at bat species diversity across different types of forest disturbances (e.g., prescribed fire, mechanical treatment, wildfire, or no treatment) at Brookhaven National Laboratory, located in the Long Island Central Pine Barrens region. Pine barrens ecosystems have evolved over thousands of years in the presence of frequent fire, so much of the flora and fauna have developed adaptations to survive and even benefit from fire (BNL, 2021). For example, pitch pine (*Pinus rigida*) has thick bark to help insulate them from fire, as well as seeds that germinate best in the conditions created when the fire burns off surrounding leaf litter and vegetation; mineral soil in full sunlight. Fires used to occur in the Long Island pine barrens in 10-40-year intervals, but fire in the Long Island Pine Barrens has been aggressively suppressed for at least the last 75 years. In the absence of forest disturbances such as frequent fire, frost damage, insect herbivory, or cutting, fire-intolerant species invade and the normally open canopy barrens convert to closed-canopy forests (Jordan, et al., 2003; Kurczewski & Boyle, 2000; Motzkin & Foster, 2002). Atlantic coastal pine barrens are a globally rare ecosystem and support many other rare flora and fauna that depend on them (BNL, 2021, Jordan, et al., 2003). Likewise, many barrens depend on active management to restore and preserve them, which includes prescribed fire and ecologically sensitive wildfire control. BNL began conducting prescribed fires in 2004 to work towards this. These fires get rid of the buildup of vegetation and debris that would act as fuel and so reduce the risk of more uncontrollable wildfires, as well as promote a healthier forest by reducing competition (BNL, 2021). Of the eight species of bats present on Long Island, big brown bats, northern long-eared bats, and eastern red bats have been confirmed to be on site in the past through mist netting. Acoustic detectors will be deployed to survey for bat calls across different disturbance types on site to see if these factors affect habitat use for different species.

B. Site Overview

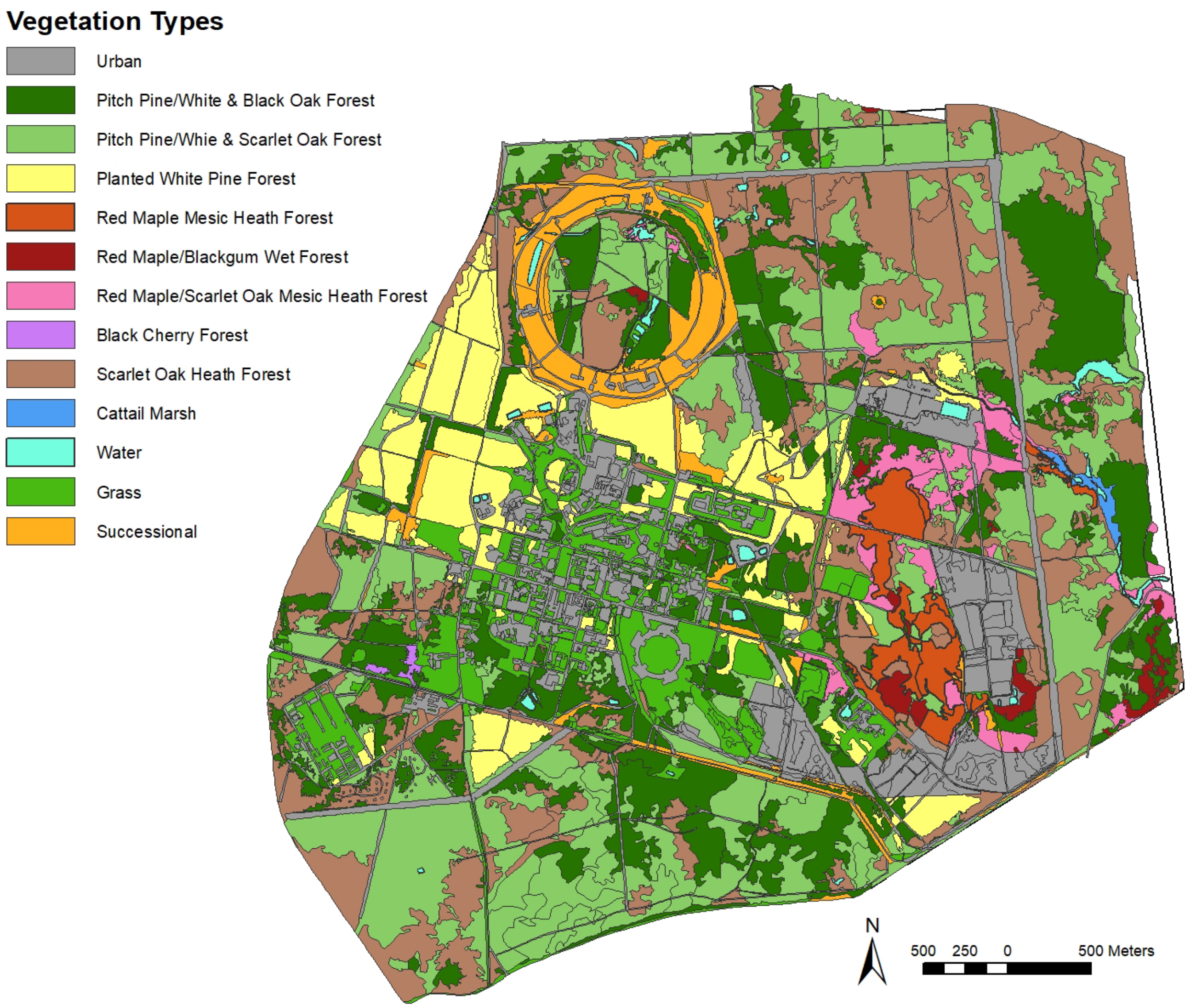

Figure 1. Map of the vegetation types present at Brookhaven National Labs

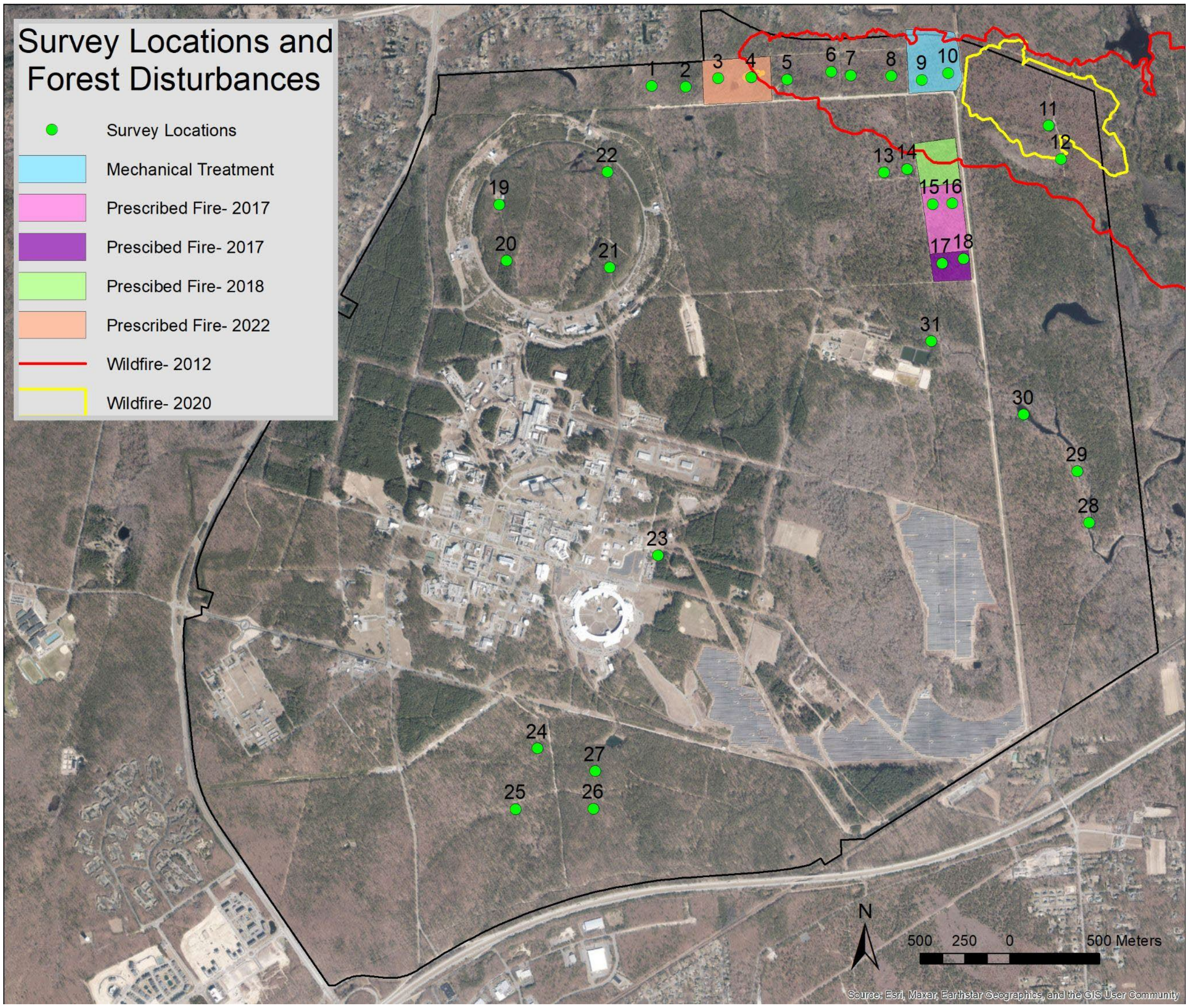

Figure 2. Map showing survey locations and where they occur in relation to the forest disturbances

Brookhaven National Laboratory is a federal facility spanning 2,130 hectares in the Long Island Central Pine Barrens, with about 1,394 hectares of undeveloped forest primarily consisting of communities of pitch pine and oak species (*Quercus coccinea, Q. rubra, Q. alba, Q. velutina*) with a varied understory of shrubs and herbaceous plants (BNL, 2021). The forests are mostly unmanaged and so contain large amounts of surface litter and downed woody debris. There were two wildfires on site in recent decades- survey locations 5, 6, 7, 8, 9, 10, 11, and 12 are all in the Crescent Bow wildfire of 2012, which covered almost 400 hectares (115 on site) and ranged from low to high severity with locations 6, 7, 8, 9, and 10 in the higher severity areas (all locations shown on figure 2). Locations 11 and 12 reburned in the Paumanok wildfire of 2020, which covered 38 hectares. There were also three prescribed fires on site, all low-to moderate-severity. Survey locations 3 and 4 are in the 1.5 hectares of the 2022 prescribed fire area. Locations 15, 16, 17, 18 are in the 2017 prescribed fire areas and covered 11.5 hectares. Locations 9 and 10 are in the 9.5 hectares that had been mechanically treated in 2022 to prepare it for burning and resulted in decluttering the midstory and understory. All other survey locations had not undergone any fire in at least 20 years. The vegetation map used aerial data collected from 2001, though the vegetation types have remained largely unchanged since then.

IV. Methods

A. Field Surveys

Bioacoustic song meters (song meter mini bat, Wildlife Acoustics Inc., Maynard, Massachusetts, USA) were used to passively detect ultrasonic bat vocalizations, set up over the course of 10 weeks from June through August. There were 12 surveyed plots- one mechanically treated site, three sites that had experienced wildfire, three sites that had undergone prescribed fires, and five sites that had not been burned or cleared. At least two detectors were set up in each plot, a minimum of 50 meters apart, for a total of 31 survey locations. Detectors were set-up in each plot at a height of approximately 1.5 meters, secured with paracord, and left to record for a minimum of three nights, set to start 30 minutes before sunset to 30 minutes after sunrise subject to triggering.

B. Data Analysis

Field recordings were analyzed using Kaleidoscope Pro® (v. 5.4.8, Wildlife Acoustics, Inc., Maynard, Massachusetts, USA) to batch process the recordings. Default signal parameters were used; 8-120 kHz frequency range, 2-500 milliseconds length of detected pulses, 500 milliseconds maximum inter-syllable gap, and 2 minimum number of pulses. Recordings were filtered to automatically discard noise files. The Auto ID for Bats feature was used to identify the species, using Bats of North America 5.4.0 New York region. If that species had a presence p-value of <0.05, then it was determined that that species was present. If that species had a presence p-value of >0.05, then it was determined that there was insufficient evidence to prove that species was present. ArcMap® (v. 10.8.1, ESRI, Inc., Redlands, California, USA), a geographic information system (GIS), was used to map the survey points alongside the burn units and other treatments. Program Presence (v. 2.13.39, USGS, Renton, Virginia, USA) was used to see if any of the disturbance types had affected habitat use by the bats in intact and disturbed forests. Models were run for the big brown bat, eastern red bat, hoary bat, and silver-haired bat, as the other species had insufficient data, stratifying occupancy probability, detection probability, or both by forest type Model fit was assessed with a Goodness of Fit test. For each location, a 1 (detected) was recorded if the bat species had at least 5 calls that night, or 0 (non-detection) if not.

V. Results

Almost 80,000 audio files were recorded, with approximately 16,000 possible bat identifications.

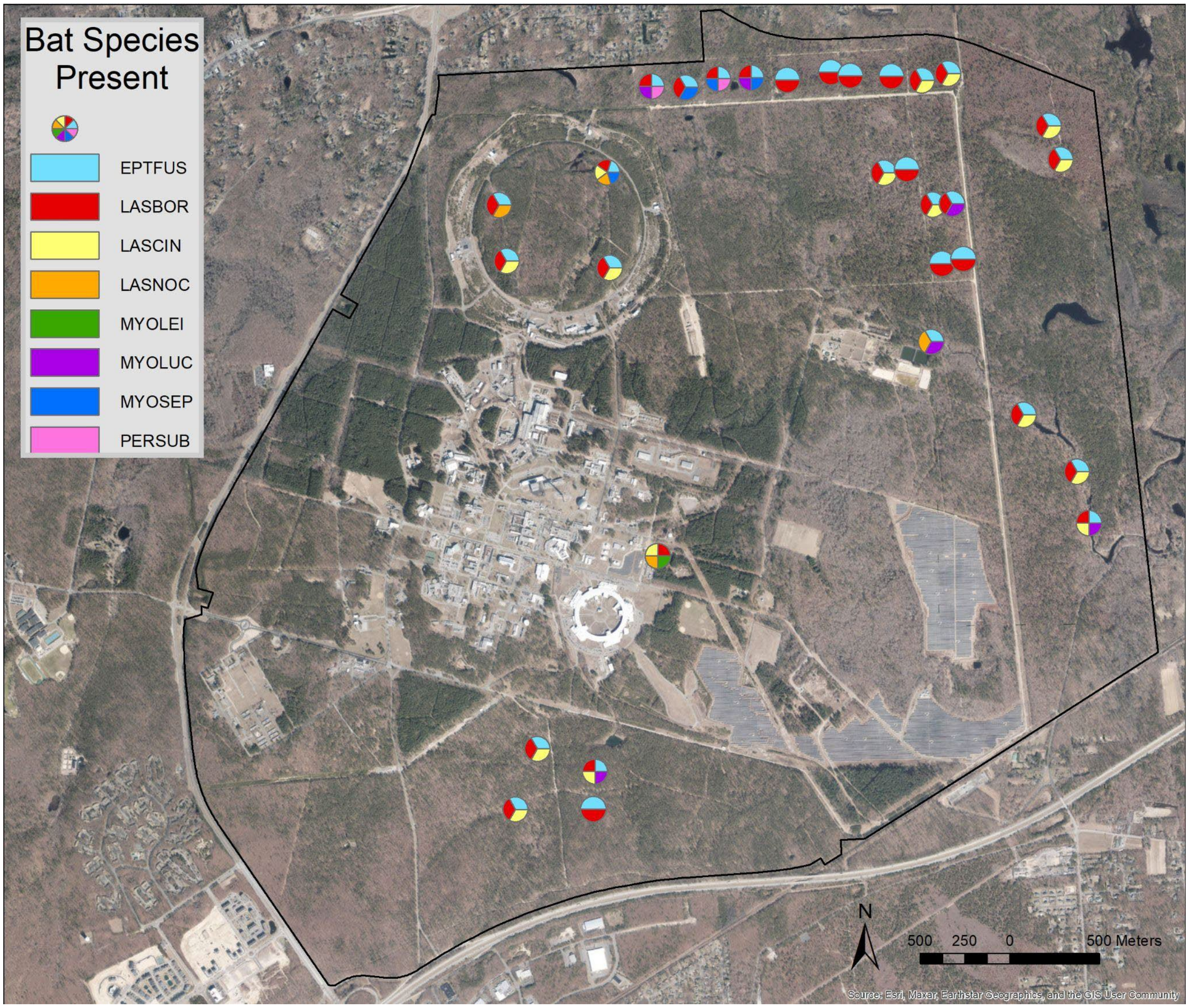

Figure 2. Bat species present across the laboratory

All eight species of bats present on Long Island showed up as possible identifications. It is important to note that this map does not show abundance of bats, it merely indicates presence or absence at each site.

Table 1. Bat species presence (1) or absence (0) across the different disturbance types.

Survey Location	Disturbance Type	Year	EPTFUS	LASBOR	LASCIN	LASNOC	MYOLEI	MYOLUC	MYOSEP	PERSUB
1	None		1	1	0	0	0	1	0	1
2	None		1	1	0	0	0	0	1	0
3	Prescibed	2022	1	1	0	0	0	0	1	1
4	Prescibed	2022	1	1	0	0	0	1	1	0
5	Wildfire	2012	1	1	0	0	0	0	0	0
6	Wildfire	2012	1	1	0	0	0	0	0	0
7	Wildfire	2012	1	1	0	0	0	0	0	0
8	Wildfire	2012	1	1	0	0	0	0	0	0
9	Mechanical	2022	1	1	1	0	0	0	0	0
10	Mechanical	2022	1	1	1	0	0	0	0	0
11	Prescibed	2020	1	1	1	0	0	0	0	0
12	Prescibed	2020	1	1	1	0	0	0	0	0
13	None		1	1	1	0	0	0	0	0
14	None		1	1	0	0	0	0	0	0
15	Prescibed	2017	1	1	1	0	0	0	0	0
16	Prescibed	2017	1	1	0	0	0	1	0	0
17	Prescibed	2017	1	1	0	0	0	0	0	0
18	Prescibed	2017	1	1	0	0	1	0	0	0
19	None		1	1	0	1	0	0	0	0
20	None		1	1	1	0	0	0	0	0
21	None		1	1	1	0	0	0	0	0
22	None		1	1	1	1	0	0	1	0
23	None		0	1	1	1	0	0	0	0
24	None		1	1	1	0	0	0	0	0
25	None		1	1	1	0	0	0	0	0
26	None		1	1	0	0	0	0	0	0
27	None		1	1	1	0	0	1	0	0
28	None		1	1	1	0	0	1	0	0
29	None		1	1	1	0	0	0	0	0
30	None		1	1	1	0	0	0	0	0
31	None		1	0	0	1	0	1	0	0

For the big brown bat, the null model, with no effect of forest type, had the highest support with an estimated probability of test statistic = 81.19% (alternative models with ΔAIC ≥ 0.77). The model showed high detectability ($\hat{p}$ = 0.92, 0.02 SE), with 97% of their range occupied (ψ= 0.97, 0.03 SE).

For the eastern red bat, the null model, with no effect of forest type, had the highest support with an estimated probability of test statistic = 93.07% (alternative models with ΔAIC ≥

0.1.28). The model showed low detectability ($\hat{p}$ = 0.38, 0.04 SE), with 77% of their range occupied (ψ= 0.77, 0.10 SE).

For the hoary bat, the null model, with no effect of forest type, had the highest support with an estimated probability of test statistic = 63.37 (alternative models with ΔAIC ≥ 2.00). The model had a moderate detectability ($\hat{p}$ = 0.71, 0.05 SE), with 83% of their range occupied (ψ= 0.77, 0.09 SE).

For the silver-haired bat, the null model, with no effect of forest type, had the highest support with an estimated probability of test statistic = 89.1% (alternative models with ΔAIC ≥ 2.00). The model had a moderate detectability ($\hat{p}$ = 0.72, 0.06 SE), with 54% of their range occupied (ψ= 0.54, 0.10 SE).

VI. Discussion

A. Impacts of results

Big brown bats and eastern red bats were the most prevalent across sites, both showing up in 30 out of 31 of the survey locations. None of the models detected any meaningful differences in occupancy between the two habitat types. The prescribed fires conducted at the survey locations were all small-scale (<10 hectares), and the more severe Crescent Bow fire was 10 years old, with the Paumanok fire being 2 years old at this point, which could be a reason for this result. Some of the negative responses bats have to wildfire are short-lived or local, often recovering within a couple years, so this corresponds with existing research that bats might be resilient to the effects of fire (Loeb & Blakey, 2021). With northern long-eared bats likely being reclassified as endangered in the state soon, more forest management restrictions will come into being. However, if small-scale fires don't have any significant impact on their habitat use, then that is important to note for management and policy applications. Prescribed fires are incredibly important for forest management, so all of their impacts must be understood in order to make sure one species isn't protected at the expense and detriment of others. More sample sites over a longer period of time are recommended in future studies for a more precise estimate.

B. Factors affecting study design

Recent advances in technology in the last couple decades have allowed researchers to use ultrasonic detectors to study bats, as opposed to capture methods. As multiple ultrasonic detectors can be set up and left to record automatically for long periods of time, it's increased survey efficiency and allowed scientists to discover more about bat ecology than was previously possible (Britzke, 2013). And as bat populations plummet with the rise of white-nose syndrome and habitat loss, capturing them becomes even less cost-effective. Song meter mini bat recorders were chosen as they were easily transportable, equipped with a weatherproof housing to allow for deployment without extra protection, readily available, and has comparable recording quality to the industry standard Song Meter SM4BAT.

There are many considerations to be taken when using ultrasonic detectors to survey for bat species. As bat activity can vary substantially among nights, it's important to sample multiple nights to get as accurate a result as possible (Hayes, 1997). Bat home ranges are incredibly variable by factors such as species, time of year, and sex, ranging for northern long-eared bats between 18.6-172 hectares (Frafjord, 2013; Lacki, et al., 2009). Even taking that into account, detectors placed even more than just 50-m away from each other show significant variation (Fischer et al. 2009), and within a vegetation stand paired sampling with two detectors were needed to get an accurate estimate of bat activity (Hayes 1997). Structural clutter such as foliage and branches are known to impact bat calls, as bats in more cluttered environments produce echolocation calls that differ from those produced in other habitats (Broders, et al., 2004; Schnitzler et al. 2003). This can affect the accuracy of the species identification, if the calls it's being compared to were made in a different environment. The nature of the study had calls being sampled from sites ranging from highly cluttered to highly uncluttered, and all were analyzed using the same call library, which added to the level of uncertainty concerning correct identification.

Species specific differences in flight location, echolocation intensity, speed, and foraging mode can also contribute to their detectability. This makes surveying for multiple species, as done in this study, difficult, as bats that fly high up in the canopy, or even above the canopy as the hoary bat and eastern red bat do (Wunder & Carey, 1996), might be missed since the survey was conducted under the canopy closer to the ground. Failure to account for any of these temporal or spatial variables could result in biased estimates. Ideally, mist netting and roost surveys would also be done to get a fuller picture of the bat communities present, as only doing one is not as effective (Flaquer, et al., 2007), but could not happen due to time and cost restraints. There is still a lack of studies on many of fire's effects on bats, including bat mortality from fire events, the effects of fire on roosting habitat, and the effects that climate change may have on them (Loeb & Blakey, 2021).

VII. Conclusion

Although some people have negative preconceived notions about bats, they are an integral part of the ecosystem and provide many benefits. Many species of bats are under threat from all directions- climate change, habitat loss and degradation, disease, etc. and we need to know more about these amazing creatures to be able to help conserve and manage them. It's been proven that fire affects bats in many ways, both positive and negative, and there is still so much to learn. While there were no significant differences detected over the different treatment types here, due to the small study area of study and short time frame these may not be indicative of the actual relationship between bats and fire in this habitat and more research is required.

VIII. Acknowledgments

I would like to thank my mentors at Brookhaven, Timothy Green and Kathy Schwager, for their guidance and support throughout this project. I would also like to thank the DOE and BNL for the opportunity to conduct research with them. This project was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internships Program (SULI).

IX. Appendixes

Participants:

Name	Institution	Role
Timothy Green	Brookhaven National Laboratory	Mentor, provided leadership, advice, and field assistance
Kathy Schwager	Brookhaven National Laboratory	Mentor, provided leadership, advice, and reviewed deliverables

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