Variations in bat species composition across disturbance gradients in the Long Island pine barrens using acoustic monitoring

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I. **Abstract:**

Pine barren ecosystems, located across the Atlantic Coastal Plain, are rare and contain extremely diverse flora and fauna. This disturbance-dependent community requires regular management to clear understory clutter and maintain the open canopy of pitch pine (*Pinus rigida*). Management in the form of mechanical treatments and prescribed fire increases necessary roosting habitat and foraging opportunities for some bat species (Order *Chiroptera*). Many bat species populations are declining from habitat loss and the deadly fungal disease, white nose syndrome (WNS; *Pseudogymnoascus destructans*). However, Atlantic coastal islands, such as Long Island may act as refugia due to a lack of the caves where WNS proliferates. As bat numbers continue to decline, particularly the endangered northern long-eared bat (NLEB; *Myotis septentrionalis*), continued surveillance is crucial to understanding conservation statuses in areas where the species are still located. To assess how different levels of disturbance in disturbance-dependent pine barrens affects bat species richness and diversity, acoustic monitors that detect echolocation were deployed across 10 different locations at Brookhaven National Laboratory. Regardless of the various forms of disturbance, at least 170+ bat calls were detected at each stand. Various forms of statistics determined that bats generally have a positive increase in presence and diversity in stands with small-scale management practices. Unfortunately, with a 90% decrease of its population, and despite being observed at BNL in the past, NLEB was not detected at any of the sites. Understanding how various forest treatments and disturbances can impact bat presence aligns with Brookhaven's and the United States Fish and Wildlife (USFWS) mission to collect data on the regional sparsity of local bat species. 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).

II. Introduction:

I. Background

Bats are the second largest order of mammals consisting of 1,400 individual species that range across world. They play important ecological roles as prey, predator, arthropod suppression, seed dispersal, nutrient distribution and pollination.[11] As most bat species only have one offspring per season, their conservation status is crucial to protect. Bat ranges were previously found all over America, however many of their species' ranges are declining due to habitat loss and white nose syndrome (WNS; *Pseudogymnoascus destructans)*. WNS usually appears as a white fungus on the nose or wings, due to altering the structure of the wings this leads to physiological problems with flying, balance and thermoregulation.[5] Ultimately, the bats are thought to die because of being awoken during hibernation leading to starvation and the loss of electrolytes and fluids across their wing membranes.[4] The fungus tends to thrive in the hibernacula of the cold and humid caves, and thus is more rapidly spread between cave-dwelling bats. Cave-dwellers tend to roost in the caves, however as they have migrated to coastal islands they will roost in the snags and exfoliating bark of trees.[2] Roosting is an essential aspect of a bat's life for protection, rest while foraging, and hibernation.[9] The NLEB has been detected during the summer months on Long Island which is when the females will form maternity colonies to raise pups while the males will typically roost singily.[17]

In New York the nine bat species consist of the: big brown bat (*Eptesicus fuscu*s; EPTFUS), eastern red bat (*Lasiurus borealis;* LASBOR), hoary bat (*Lasiurus cinereus;* LASCIN), silver-haired bat (*Lasionycteris noctivagan*s; LASNOC), eastern small-footed bat (*Myotis leibii;* MYOLEI), Indiana bat (*Myotis sodalis*; MYOSOD), northern long-eared bat (*Myotis septentrioanalis;* MYOSEP), little brown bat (*Myotis lucifugus;* MYOLUC) and the tricolored bat (*Pipistrellus subflavus;* PERSUB). LASBOR, LASCIN, and LASNOC are all forest dwellers, roosting in tree cavities and bark, and therefore tend to be less susceptible to WNS syndrome. The EPTFUS, MYOLEI, MYOSEP, MYOLUC, MYOSOD and PERSUB roost in caves, with 5 out of 6 of them being affected by WNS. Specifically, the NLEB was listed as endangered in 2023 and PERSUB, and MYOLUC are vulnerable species moving towards being endangered due to WNS.[6]

II. Disturbances and Bats

Brookhaven National Laboratory, where this study takes place, is located in the Long Island Central Pine Barrens, a highly fire-dependent community. While the fire is beneficial to the ecosystem, unfortunately it impacts bats through smoke inhalation and heat as well as physical damage to the bat where they don't have hair covering their bodies.[13] Torpor is a less intensive state of hibernation in order to save a bats energy for foraging.[13] Non-reproductive female and male bats enter a shallow torpor during the summer, but since it is not as intense as winter hibernation, it allows for an easy escape from the fire.[16] The only bats that may not be able to truly escape fire are the non-volant young.[13] Regardless, studies have shown that fire (wildfire or prescribed) creates or improves habitat for many bat species by providing roost locations through creation of snags, reducing clutter in the understory, and increasing insect abundance. [7,13] The NLEB is a small bat that can easily maneuver through clutter and prefers to forage in the mid-story, too much or too little understory vegetation can vastly impact the areas in which they choose to roost and forage.[2] Overall, the NLEB tends to select for trees that are taller, larger in diameter, decayed and with greater solar exposure due to the large canopy gaps that pine barrens provide.[9,18] It is important to note that wetland presence can affect where a bat species forages as well, as proximity to water increases foraging habitat.[2]

The southern pine beetle (*Dendroctonus frontalis;* SPB) is also a disturbance at Brookhaven National Laboratory. SPB has been deemed as one of the most destructive pests of pine forests increases in stands that have high pitch pine basal area and sandy soil texture.[10] While there isn't a lot of existing literature on how SPB affects bat roosting sites, the beetle accelerates the succession of the fire-dependent pitch-pine barrens (*Pinus rigida*) to species like oaks (*genus Quercus*), red maple (*Acer rubrum*), and white pine (*Pinus strobus*).[10] Dead trees could increase roosting habitat, consequentially, the amount of understory vegetation and insect abundance is altered and therefore could affect the composition and diversity of bats depending on where the individual species forages.

III. Purpose of Project

This project aims to understand how bat species diversity is affected by different disturbances across the site. Acoustic monitoring is a way to accurately obtain species information without the actual capturing of the animal. While there is no current research on the effect of SPB damage to bat presence, as more pitch pine forests are affected by the beetle it is important to know how that could affect the species. In addition to this, scale, disturbance type and frequency difference could affect how different bats respond to disturbance. Time since fire will alter forest structure and its suitability for foraging. In addition to this, as the NLEB populations continue to decline, it is important to continue monitoring for it across the Lab site, as it has been previously found here.

III. **Methods:**

Survey Sites:

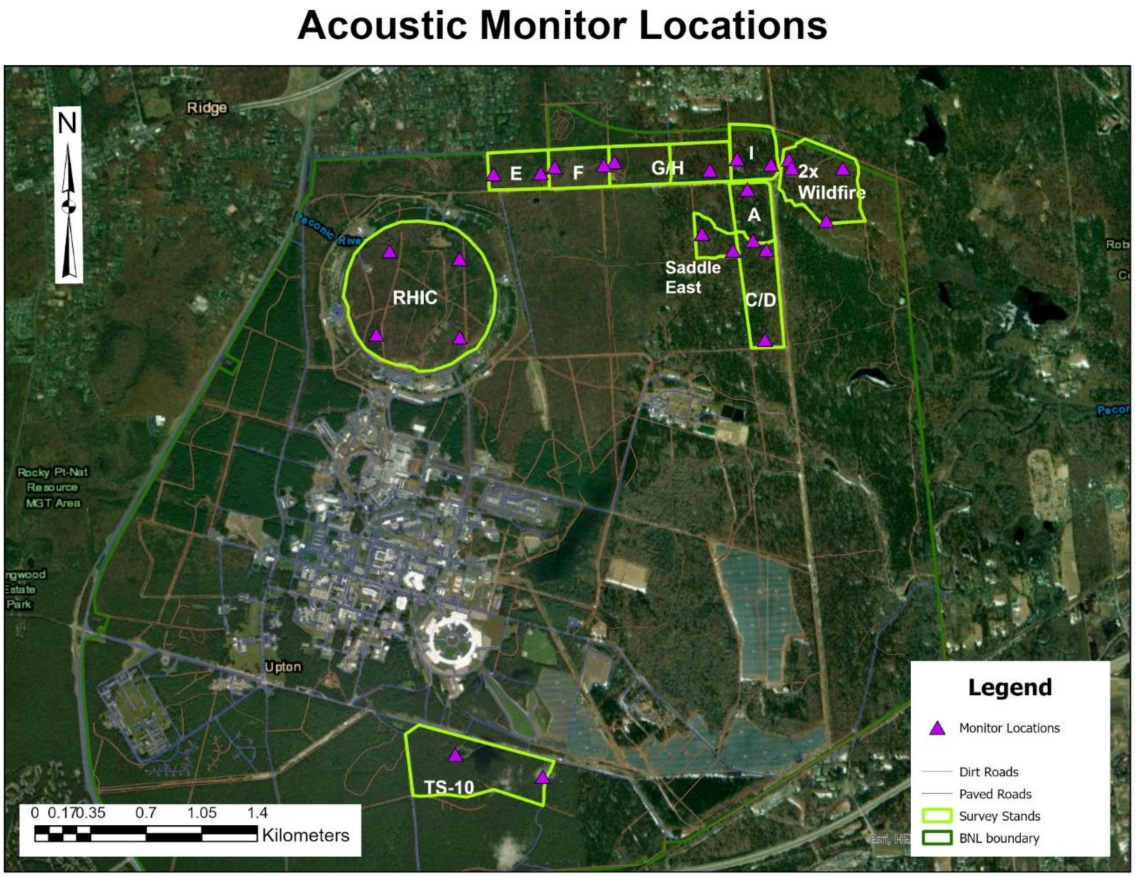

Figure 1. Map of Brookhaven National Laboratory with bat monitor locations

Brookhaven National Laboratory is located in Suffolk County and has approximately 1394.1 hectares (3,445-acres) of undeveloped of pitch pine barrens woodlands and forest dominated by pitch pine and oak species (*Quercus spp.*) in the overstory and an understory consisting primarily of heath species like blueberry (*Vaccinium* spp.) and huckleberry (*Gaylussacia* spp,), and scrub oak (*Quercus ilicifolia*).[15] To maintain the pitch pine barren ecosystem and prevent the shift to an oak-dominated woodland certain management techniques like prescribed burning and mechanical treatment are required.[15] Regardless of the benefits, fire suppression and the loss of native American fire culture these forests can shift in succession to more hard-wood oak trees that aren't supportive to the unique flora and fauna.[5] Across

Brookhaven, there are only certain areas that have been maintained through prescribed fires however many forests are unmanaged or have had high intensity wildfires. Certain areas also have intense SPB damage which kills the different pitch pine trees by disrupting the tree nutrient flow and ultimately leads to a dead forest. By considering the disturbance type and the presence of wetlands, ten different study sites were chosen to deploy ultrasonic acoustic monitors. The areas surveyed included an unmanaged control unit, areas with extensive SPB mortality, stands containing wetlands, and areas that have experienced some kind of disturbance or combination thereof including wildfire, prescribed fire, and mechanical treatments. See Table 1 for treatment or disturbance type in each survey area.

The most recent United States Fish and Wildlife (USFWS) Range-Wide Indiana Bat & Northern Long-Eared Bat Survey Guidelines (May 2024) were used to develop a survey plan. Per the Survey Guidelines, fourteen detector nights are required per 49.7 ha of area surveyed. Survey sites ranged from ~5.6 ha to ~52.6 ha and the number of detector nights ranged from six to sixteen (Table 1). Some areas were oversampled to account for weather conditions.

Table 1.

Unit	Hectares	# Detector Nights	Treatment/Disturbance Type
E	9.3 ha	16 nights in 2024 24 nights in 2022	Unmanaged control
F	9.3 ha	16 nights in 2024 in 2022 24 nights in 2024	Prescribed burn 2022, SPB damage
G+H	18.61 ha	10 nights in 2024 16 nights in 2022	Crescent Bow Fire 2012, Mechanical treatment 2022+ 2023
I	9.3 ha	16 nights in 2024 in 2022	Crescent Bow Fire 2012, Mechanical treatment 2021, Prescribed burn 2023 Wildfire and Mechanical treatment by 2022 survey
A	8.5 ha	16 nights in 2024 No 2022 data	Crescent Bow Fire 2012
Saddle East	5.6 ha	10 nights in 2024 10 nights in 2022	Prescribed fire 2023 Nothing done in 2022 survey
C+D	15.4 ha	18 nights in 2024	Prescribed fires 2017/2018

RHIC	52.6 ha	16 nights in 2024 20 nights in 2024	Wetlands, SPB presence
2x Wildfire	10.1 ha	8 nights in 2024 8 nights in 2022	Crescent Bow Wildfire 2012, Paumanok Wildfire 2020
TS-10	30.35 ha	20 nights in 2024 No 2022 data	Man made pond

Table 1. Encapsulation of units surveyed with associated disturbance

Deployment:

In accordance with USFWS survey protocols, the bioacoustics detectors (Song Meter Mini Bat, Wildlife Acoustics Inc., Maynard, Massachusetts, USA) monitors were deployed approximately 2 meters off the ground, and at least 200 meters apart from one another and tied to a tree. These monitors record bat vocalizations using echolocation during hours when the bats are most present, beginning 30 minutes before sunset and ending 30 minutes after sunrise. Each monitor was deployed on a tree facing towards the area of interest with the ultrasonic microphone facing upwards. Per USFWS protocols, on nights where it rained after sunset the data was not included in the analysis.

Figure 2. Photo of a deployed bioacoustics mini bat song meter

Analysis:

Using Kaleidoscope Pro® (v. 5.4.8, Wildlife Acoustics, Inc., Maynard, Massachusetts, USA) each site was individually batch-processed for cluster analysis and auto-identification of the bats. In Kaleidoscope, the default bat-analysis mode was used and was set for "Bats of North America 5.4.0" in the region set to "New York." Kaleidoscope analyzes each audio file to determine the species bat presence and provides a presence-p value to indicate the accuracy of the identification. If the p-value was $<.05$ the species was considered present and if the value was $>.05$ the species was considered absent. Using the significant p-values, a comparison analysis was done between each unit to determine if bat presence was dependent on disturbance type, and time since disturbance. In order to increase sample size of each area and discuss differences in species richness and density acoustic survey data from 2022 done in the same areas were used. The only areas that differed were Unit T-S 10 and the area of the 2x wildfire. Areas that were sampled twice in 2022 survey areas (E, I, F and C/D) were also sampled twice to increase comparison results between the two areas. Other areas of interest were still analyzed, but with smaller data sets.

IV. Results:

Across Brookhaven National Laboratory over 30,000 possible bat identifications were significant. The bat species at the lab is primarily made up of EPTFUS, LASBOR, LASCIN and LASNOC.

Table 2.

Total Bat Species Found	EPTF US	LASB OR	LASC IN	LASN OC	MYO LEI	MYO LUC	MYO SEP	MYOS OD	PERS UB
Unit G/H	982	126	398	311	0	9	0	1	2
2x Wildfire	51	23	77	26	0	5	0	0	1
RHIC	5852	191	1545	1658	0	20	3	4	6
Saddle East	282	218	134	28	0	17	0	0	16

Unit E	2935	157	836	462	0	31	6	0	14
Unit F	2234	104	853	377	0	25	3	1	36
Unit C/D	1843	385	912	270	0	79	0	1	28
Unit I	2652	406	963	563	0	11	0	0	12
Unit A	989	194	376	143	0	15	1	0	35
T-S 10	525	471	597	512	0	18	0	0	7
Total	18345	2275	6691	4350	0	230	13	7	157

Table 2. Distribution of bat species per stand at Brookhaven National Laboratory

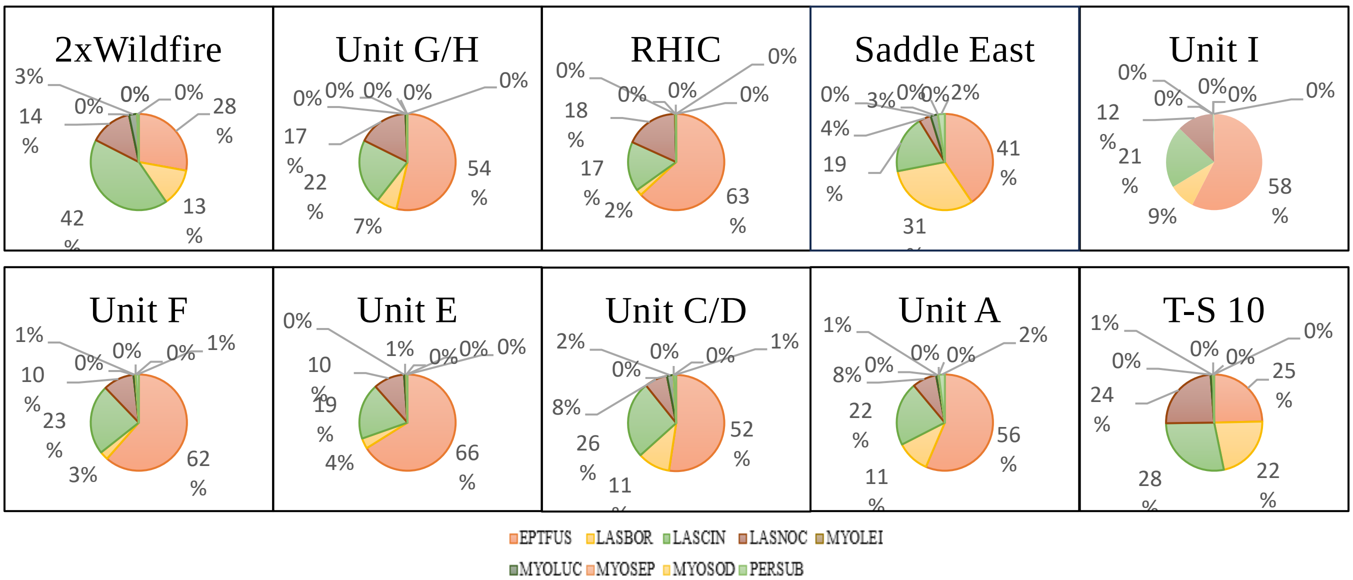

Figure 3-12. Pie charts of species distribution across units surveyed

All bat species except for MYOLEI showed up as possible identifications with EPTFUS being the most prominent. However, it is important to note that p-values of the identification show how accurate the identification is, which can also be defective at times. Species such as MYOSOD, MYOSEP, and MYOLUC were determined as false positive identifications when vetted by an expert. It is also important to note that this doesn't show the true abundance of bats across BNL, but rather if they are present or absent.

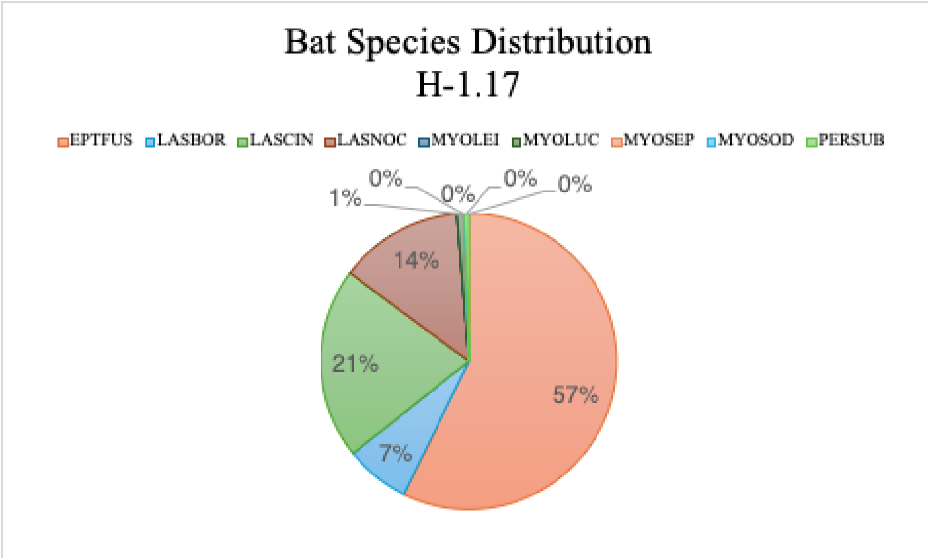

Figure 13. Pie chart of bat species distribution across entire BNL

Bats were present in all the stands across Lab, and while there were different amounts of bat calls found in each area, a Shannon diversity index analysis was then done to determine how diverse the presence of bats was at each stand. The Lab has the species its intended to, but overall H is a small number of 1.17 due to the small abundance of some of the species.

Table 3.

Diversity Over Time	2022	2024	Together
Unit G/H	H=1.21	H=1.19059	H=1.18
2x Wildfire	H=.97001	H=1.29	H=1.3
RHIC	H=.805	H=1.05	H=1.0
Saddle East	H=1.2	H=1.18	H=1.35
Unit E	H=-.556	H=1.18	H=1.0
Unit F	H=.67	H=1.32	H=1.068
Unit C/D	H=.81	H=1.22	H=1.25
Unit I	H=1.06	H=1.16	H=1.14
Unit A	N/A	H=1.22	N/A
T-S 10	N/A	H=1.43	N/A

Table 3. Diversity differences across the years at the lab

Done individually for each stand, there was a comparison analysis done between 2022 and 2024, and then an overall richness was determined at each stand. Unit G/H was burned by the Crescent Bow Wildfire in 2012, G was mechanically treated in 2022, and H was then mechanically treated in 2023. Since 2022 bat acoustic surveys, the diversity index has decreased from 1.21 to 1.19, but there were overall more bat presence calls identified. Unit G/H was mechanically treated in 2022 after the bat acoustics were completed, it was then again mechanically treated in 2023. The area with the 2x wildfire (Crescent Bow Wildfire and Paumanok Wildfire) has become more diverse with H being .97 in 2022 and now 1.29 in 2022, however there was more bat identification in 2022. This is likely because it's been four years since the fire instead of two, which can create more suitable roosting and foraging habitat for some bat species. The RHIC unit has had more SPB damage since 2022, however since 2022 where H was .805 it has become more diverse, now being 1.05 also has an increased bat presence. Unit Saddle East was just burned in 2023, the bat presence has decreased, and diversity decreased insignificantly from 1.2 to 1.18 since 2022. Unit E, the control unit overall has gotten more diverse from .556 to 1.18 and has an increased amount of bat presence, even though no management has been done. Unit F was prescribed burned in 2022, since then there has been more bat presence and diversity increased from .67 to 1.32. Unit C/D was burned in 2017/2018, since 2022 the area has become more diverse jumping from .81 to 1.22 and has had a higher bat presence. Unit I was burned in the 2012 Crescent Bow Wildfire, was then mechanically treated in 2022 and just prescribed burned in 2023, Since being burned in 2023, it has now had a diversity of 1.16, whereas in 2022 it was 1.06 it increased bat call identification. Because there was no past data on Unit A and T-S 10, the diversity was only looked at for 2024. Across the lab, there was the most bat presence in the RHIC unit, and the most diverse area was T-S 10. While some diversity changes may not be significant between the years, this is important conservation knowledge for following years of acoustic monitoring.

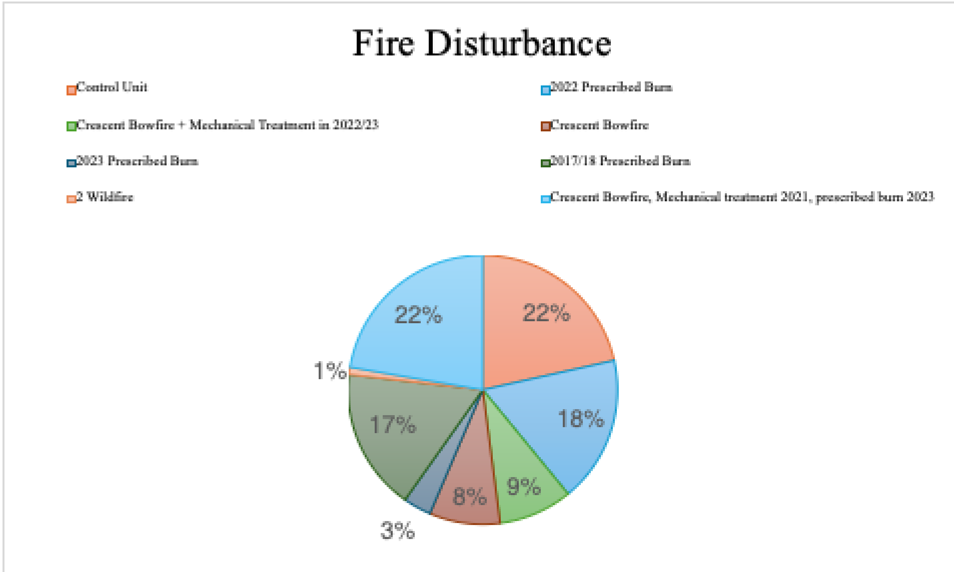

Figure 14. Amount of bat presence in relation to fire disturbance gradients

When looking at fire disturbance, Unit E (control unit) and Unit I (Crescent Bow Fire, mechanical treatment and prescribed fire) had the most bat presence. Other areas such as Unit F (prescribed burn in 2022) and Unit C/D (prescribed burns in 2017/18) also had significant bat presence.

V. Discussion:

Overall, Brookhaven National Laboratory is primarily composed of four bat species: EPTFUS, LASNOC, LASCIN and LASBOR. The relatively large abundance of these species could be drawn back to physiology, foraging and roosting type. EPTFUS usually roosts in large groups of up to 100 bats, and only changes roosting sites every 3-10 days.[12] However, the NLEB often will roost singly or in a small maternity group but change roost site every 1-2 days.[12,16] When the monitors are out for approximately 5 nights at a time, it is very easy to miss a solitary NLEB in comparison to 100 EPTFUS in one area. EPTFUS isn't affected as drastically affected by WNS because they are highly resistant to the fungus, even when they are affected with WNS their population doesn't seem to decline.[8,14] This allows for their population to be more stable than other species such as the *Myotis*. LASBOR, the other common species at BNL, hasn't been documented to be affected by WNS at all and shows no population declines from the pathogen, also remaining at a stable population.[14] Furthermore, the protocols used for this study were meant to maximize detection for NLEB, so it is possible that some bat species weren't identified but it doesn't mean that the species are not present.

While all nine species of bats are insectivorous, they forage in different ways. Many of the bats (EPTFUS, LASNOC, LASCIN and LASBOR) detected forage higher up in the canopy, where it is less cluttered and therefore easier to detect.[3] Most bats will emit short-duration echolocation calls while foraging, however, those calls are only suited to locating prey in uncluttered areas which could lead to issues within the data where they survey was done in a more cluttered area.[1,17]

NLEB was not detected with significance at any sites, with 90% if the NLEB species being gone, and it not being detected or mist-netted in years, it is possible that the NLEB is no longer at BNL. Additionally, detections through acoustic analysis software of the *Myotis* genus are commonly inaccurate for these small bats.[1] *Myotis* bats typically forage using a gleaning strategy, which allows them to forage in cluttered areas, consequentially, echolocation calls that are suited to being accurately identified on acoustics are those that are in areas that are uncluttered.[1] While acoustic analysis can be a useful non-invasive strategy, it should be used with caution as it is unlikely to accurately identify less-known species.[11]

When assessing how bats respond to disturbance gradients of fire, there were no significant negative effects on the bat species composition or diversity. Regardless of fire type, or year since fire, there was bat presence detected on the acoustic monitors. The beneficial impacts of fire such as creating possible habitat to bats provides far more benefit than the negative impacts from the actual burning.[7] It was shown that diversity does increase when there have been more years since the disturbance which could simply be because of an increase in the abundance of insects and will eventually level off as vegetation regrows.[7] Fire also creates canopy gaps, which allow species such as EPTFUS, LASBOR and other species to be able to forage more effectively.[7] Areas such as Unit I where it has only been a year since it was last burned, had not only a drastic increase in bat presence since 2022 but also an increase in diversity, but it is important to remember that some species may not always use burned areas right away, such as the NLEB because newly creates snags may not be useable yet.[7] While this is a short survey time, it is significantly shown that some bat species benefit from the fire-adapted ecosystem and the frequent management of the forest.

Proximity to water has been studied as an important consideration for foraging, while my results indicate that there was no significant correlation, an increased sample size would be needed to validate these results.[3] While water may be a good area to forage, and drink water for the bats, it's possible that there are no good roosting sites nearby leading to a smaller number of bat presence calls because of the energetic costs.[3] It is also possible that the because the forests surrounding the wetlands have been unmanaged, causing a closed canopy and therefore an unsuitable foraging habitat.[7] It is possible that since these beetles kill trees in the surrounding area that these could act as roosting habitats and possible increase arthropod abundance by speeding up succession, but more research is needed to accurately provide that conclusion.[10] Overall, due to the small sample size and the inaccuracies in acoustic analysis, many of the conclusions drawn from this are unknown and require a more in-depth study.

VI. Conclusion:

While acoustic surveillance of echolocation calls isn't always accurate in determining species, it is still an important non-invasive management tool for understanding species composition, especially for threatened and endangered species. Brookhaven National Laboratory, regardless of being fire-dependent remains home to many bats' species, possibly even to those that are threatened (MYOLUC and PERSUB). Bats, like fire have negative connotations, however both are important factors of the environment and deserve to be correctly understood.

VII. Acknowledgements:

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