



Acoustic Bat Inventory of Cuyahoga Valley National Park 2021-2022

Survey of Bat Species Ultrasonic Acoustic Monitoring

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Abstract

Bats are facing increasing pressures from disappearing habitat, urbanization, and the spread of white nose syndrome, which has caused significant declines in many species. All 10 bat species commonly found in Ohio have been state listed (Endangered, Threatened or Species of Concern), two of these species, the Indiana and Northern long-eared bat are listed as Endangered by the United States Fish and Wildlife Service (USFWS). Another Ohio bat, the Tricolored bat, has been proposed to be federally listed as and is in a review period. As an important resource for habitat preservation, Cuyahoga Valley National Park (CUVA) offers habitat for species of conservation concern, including bats, which can find important habitat to support their year-round cycle (including hibernacula and maternity roosts). A parkwide bat inventory was conducted in 2002-2003 focused on the Indiana bat. However, due to White-nose syndrome impacting bats at CUVA significant changes to bat populations have occurred since 2012. This study serves as a post-WNS inventory to document the species of bats that are present at CUVA and quantify their relative abundance. We conducted acoustic monitoring surveys in the summers of 2020 and 2021 using Wildlife Acoustic Song Meter Mini Bat Ultrasonic Recorders, deployed at 47 locations throughout the park for a total of 3,371 hours. This effort resulted in 58,660 bat recordings that were auto-identified using Kaleidoscope Pro software (version 5.4.1). Eight bat species were detected at CUVA, including the Big brown bat, Silver Haired bat, Red bat, Hoary bat, Little brown bat, Evening bat, Northern long-eared bat, and Tricolored bat. Despite the recent declines in the Northern long-eared bat remains at CUVA and this inventory identifies areas still being used and documents the importance of protecting and restoring large forest tracts.

Introduction

Ohio has historically been home to 11 native bat species, all of which are state listed, and two of which are federally listed. The federally endangered species include the Indiana bat (*Myotis sodalis*) and Northern long-eared bat (*Myotis septentrionalis*) which was upgraded from threatened to endangered in 2023. Additionally, the Tricolored Bat (*Perimyotis subflavus*) is proposed to be listed under the Endangered Species Act and is currently under at the time of writing this report. Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and Eastern small-footed myotis (*Myotis leibii*) are historical residents of Ohio but have few detections and may already be extirpated from the state (Krynak 2010; Ohio Bat Conservation Plan).

Across eastern North America, bat populations are declining, due largely to white-nose syndrome (WNS) and habitat loss. White-nose syndrome (WNS) is a non-native fungal disease caused by *Pseudogymnoascus destructans* that infects cave dwelling bats during hibernation, causing them to wake up from hibernation frequently, which depletes fat and energy reserves which often results in death. Species in the genus *Myotis* are very sensitive to WNS, as well as *Perimyotis subflavus*, or Tricolored bat. Most bats reproduce at a rate of one to two pups per year, making it difficult for populations to recover quickly when burdened with multiple threats (Barclay et al. 2004). The combination of these stressors has negatively impacted many of the bat species in Ohio. Conversely, Big brown bats (*Eptesicus fuscus*) thrive in human modified landscapes (Agosta 2002) and are seemingly resistant to WNS. A study by Frank et al. In 2014 found that Big brown bats do not develop lesions from WNS the way other species do and have seen populations growths in areas affected by WNS.

Of the 11 historical Ohio bat species, 9 have been detected within Cuyahoga Valley National Park (CUVA) including the Indiana, Little brown (*Myotis lucifugus*), Northern long-eared, Tricolored, Red (*Lasiurus borealis*), Hoary (*Lasiurus cinereus*), Silver-haired (*Lasionycteris noctivagans*), Evening (*Nycticeius humeralis*), and Big brown bat (Table 1). The rare Eastern small-footed and Rafinesque's big-eared bats have not been recorded in the region since the 1950s (Krynak 2010). *Myotis* populations regionally and within the park are susceptible to the spread of WNS and have declined significantly since 2012 when it was first detected in Summit County and surrounding counties such as Cuyahoga, Geauga, Portage (WNS Spread Mapper). Prior to the spread of WNS, the Indiana bat was already listed as endangered and found in low numbers throughout Ohio. In 2002-2003, as part of the NPS Inventories initiative, surveys targeting the federally endangered Indiana bat were conducted throughout CUVA. Only one Indiana bat was captured, confirming this species' rarity prior to WNS. The most common bat species encountered during the mist net surveys conducted in the inventory was the Northern long-eared bat (Krynak et al. 2005). The Northern-long eared bat has since declined dramatically throughout its range and was listed as federally threatened in 2015, upgraded to endangered in 2023.

Table 1: Ohio bats, their presence at CUVA, and their state and federal listing status. The presence of bats at CUVA as reported by the NPSpecies list and supported by records from Krynak are present (P), probably present (PP), unconfirmed (U), or absent (A). Abundance, as reported by the NPSpecies list, is common (C), uncommon (UnC), unknown (UnK), or rare (R) Federal Status as endangered (E) or proposed to be listed as endangered (P) is according to the US Fish and Wildlife federal listings. State statuses included endangered (E), species of concern (C), and species of interest (I) are received from the July 2022 Ohio Department of Natural Resources Ohio's Listed Species document.

Species	Common Name	Present at CUVA	Abundance	Federal Status	State Status
<i>Corynorhinus rafinesquii</i>	Rafinesque's big-eared bat	A			C
<i>Eptesicus fuscus</i>	Big brown bat	P	C		C
<i>Lasionycteris noctivagans</i>	Silver-haired bat	P	UnK		C
<i>Lasiurus borealis</i>	Red bat	P	C		C
<i>Lasiurus cinereus</i>	Hoary bat	P	UnC		C
<i>Myotis leibii</i>	Eastern small-footed bat	A			C
<i>Myotis lucifugus</i>	Little brown bat	P	R		E
<i>Myotis septentrionalis</i>	Northern long-eared bat	P	R	E	E
<i>Myotis sodalis</i>	Indiana bat	PP	R	E	E
<i>Nycticeius humeralis</i>	Evening bat	U			I
<i>Perimyotis subflavus</i>	Tricolored bat	P	UnC	P	E

New tools for inventory and monitoring have been developed in the recent years which utilize ultrasonic recorders that can be deployed for weeks at a time. By combining acoustic surveys with auto-identification computer software, non-invasive surveys to detect the species of bats can be easily conducted. In the summer of 2021, park biologists initiated an inventory and monitoring program to document bats across the park with a particular interest in locating Northern long-eared bats, which were suspected to be present at low numbers in large forest tracts of the Cuyahoga Valley. Efforts continued in the summer of 2022 to better understand the distribution and relative abundance of state and federally listed species. This baseline acoustic inventory will be used to guide the development of long-term monitoring of bats at CUVA. This information is critical to inform long-term planning for resource protection and restoration of park resources and can be used for compliance under the Endangered Species Act.

Methods

Wildlife Acoustics Song Meter Mini Bat Ultrasonic Recorders were deployed a total of 47 times between the 2021 and 2022 field seasons. 20 locations were surveyed between June 6th and July 23rd in 2021, and 27 locations were surveyed between June 17th and August 26th in 2022. Each

song meter has a microphone that records the ultrasonic vocalizations emitted from flying bats. Song meters were deployed for a period of 5 -18 nights depending on its battery life, evening rain showers, and logistics of revisitation to remove song meters. Song meters were set to begin recording 30 minutes before sunset and stop recording 30 minutes after sunrise. Recordings were done in full spectrum format with a sample rate set to 256 kHz, a minimum trigger frequency of 16 kHz, a maximum recording length of 15 seconds, and a trigger window of three seconds. Song meters were programed using the Wildlife Acoustics Song Meter Configuration App version 1.5 for Apple iOS.

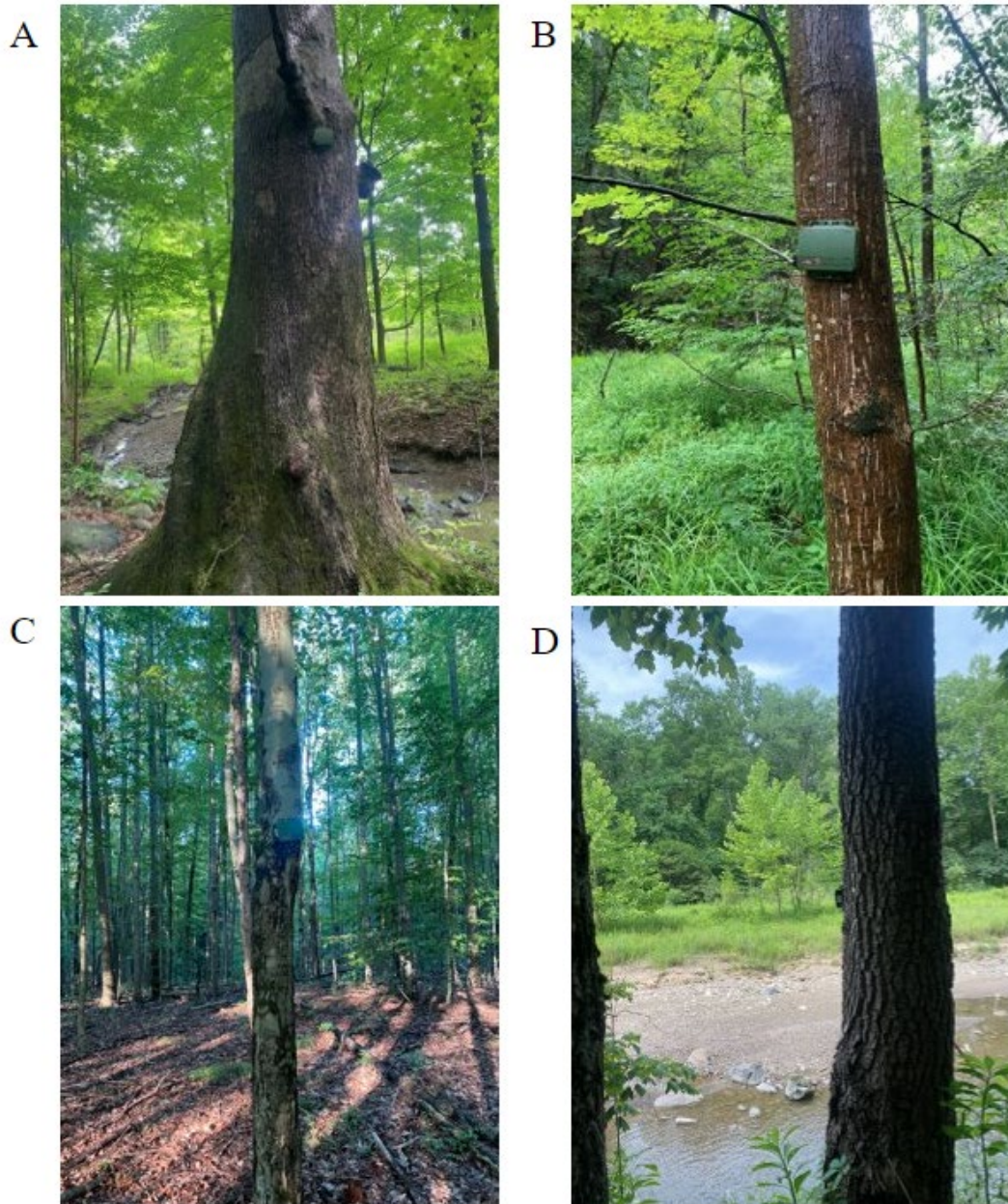


Figure 1: Deployed Song Meter Mini Bat. Acoustic monitors were deployed in a variety of habitats including stream sides (A, Oak Hill), wetlands (B, Octagon), upland forests (C, Blossom), and riverbanks (D, Furnace Run).



Song Meter Locations 2021-2022

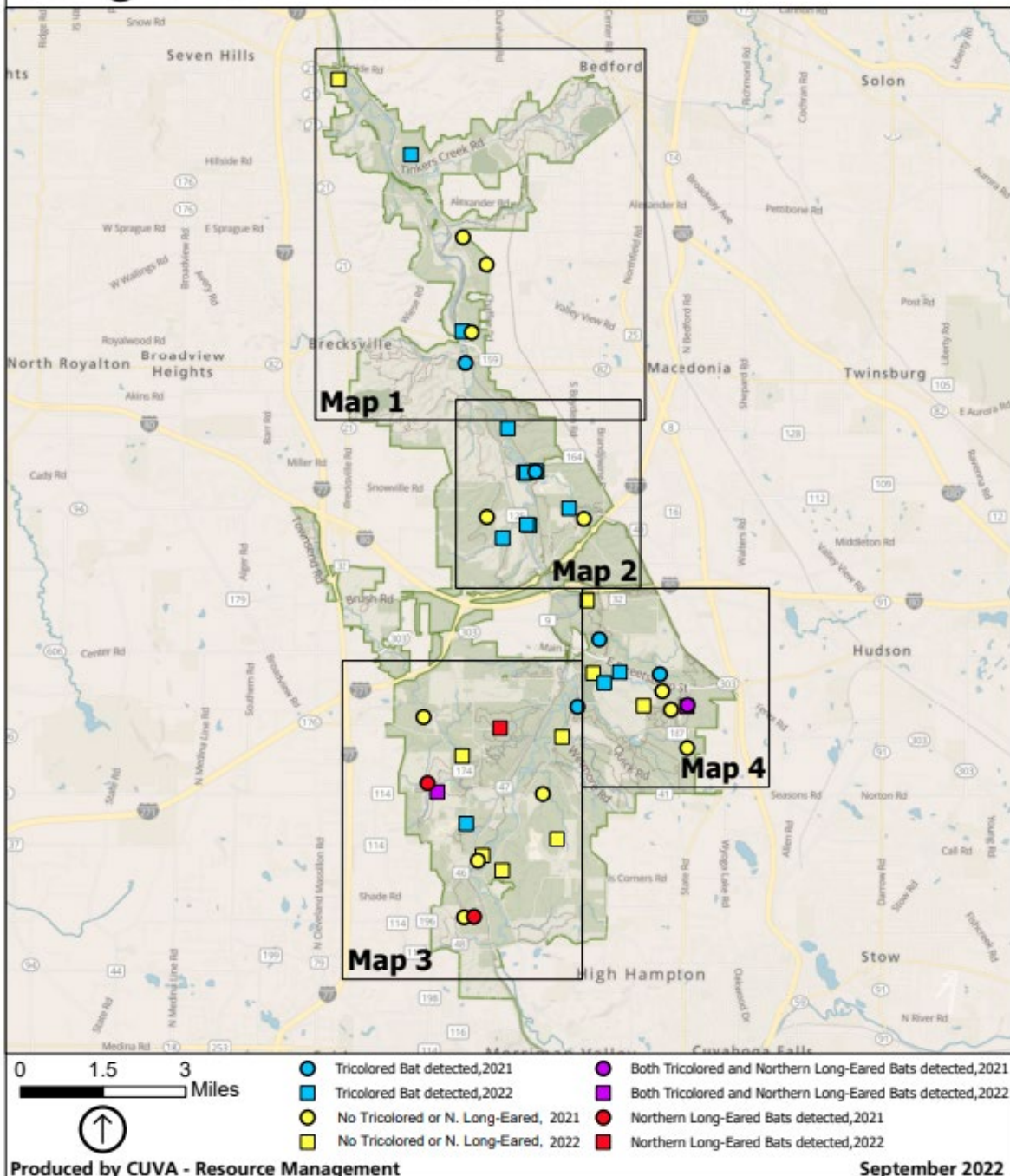


Figure 2: Map of song meter deployments within CUVA. The locations of all song meters placed in 2021 (circle) and 2022 (square) were recorded. The Northern long-eared and Tricolored bats detected with high confidence ($p < 0.05$) at each location is indicated by color-coding as described in the key on each map. Zoomed in maps (1-4) are in appendix A.

Survey areas were chosen using aerial imagery, GIS data, historic knowledge of bats at CUVA, and knowledge of bat habitat. The areas for deployment represent a variety of habitat types including the interior of large, forested areas, riversides, wetlands, rock outcrops, and generally cover the park boundaries. Deployment locations were deemed suitable if vegetation was relatively thin to ensure clear recordings and potential flight corridors from trails or streams were favored. The devices were secured to trees using two screws to minimize the risk of theft or vandalism. An attempt was made to hang song meters at least 1.5 meters above the ground to increase the probability of capturing vocal emissions from flying bats, which are unlikely to fly lower than 1.5 meters above the ground.

In 2021, 16 of the surveys were within closed canopy forests, with over half of those overlooking or in the vicinity of perennial streams. The remaining four surveys occurred in open canopy wetlands with standing dead, adjacent to large forest tracts. In 2022, 18 surveys were closed canopy forest tracts, while the nine remaining locations were open canopy wetlands, on forest edges, or in wet meadows. Survey 2022_24 resulted in only 2 high confidence ($p < 0.05$) identification, this was in an interior forest of the Blossom tract and might be explain by lack of a flight corridor. The survey was still included in analyses because it may emphasize the importance of flight corridor consideration in song meter deployments.

For this survey some deployments within and between years may represent the same site. Deployments were never in the same exact location as the song meters were moved to capture different microhabitat and topographic conditions. ‘Sites’ were classified as deployments within 123 nonlinear acres of each other, according to protocols used in Summer Range habitat surveys by US Fish and Wildlife (2022), unless a large shift in habitat type occurred between deployments (i.e., Riverside versus interior forest).

Wildlife Acoustic’s Kaleidoscope Pro (version 5.4.1) software was used for analysis of ultrasonic recordings. This software compares ultrasonic pulses and sequences to known vocalization patterns of North American bat species to generate an Auto-ID for each recording captured by the deployed song meters. The rare Eastern small-footed myotis was included in Kaleidoscope analysis but was not detected in any recordings. Rafinesque’s big-eared bat was not included in analyses. Kaleidoscope Pro provides a p-value indication of the confidence of the presence of a particular species from all recordings from one deployment event, not the confidence of the accuracy of one single recording. Detections were considered ‘true’ when $p < 0.05$. There is some inherent uncertainty of Kaleidoscope’s IDs for certain species, with *Myotis* species being the most confused. Specifically, the calls of the Little brown bat (*Myotis lucifugus*) can be misidentified as Indiana or Northern long-eared bats. The match ratios, sonograms, and time sequence of all auto-identified Indiana and Northern long-eared bat ultrasonic emissions were further investigated by park Biologist Ryan Trimbath with guidance from local and regional experts. Some identifications of Indiana and Northern long-eared bat remain suspect and require confirmation by NPS or USFWS bat specialist. Recordings classified as ‘noise’ or ‘no ID’ were deleted from the dataset.

Results

The surveys conducted in 2021 resulted in 1,400 hours of recording and 24,065 ultrasonic emissions auto identified to species. The 2022 season resulted in 1,971 hours of survey with 34,595 individual recordings auto identified to species. There were nine bat species recorded in Cuyahoga Valley National Park during the 2021 and 2022 field seasons. In general, the recordings from both 2021 and 2022 reported the same bat species with similar relative abundances CUVA (Figure 3).

	Big brown	Red	Hoary	Silver-haired	Little brown	N. long-eared	Evening	Tricolored	
2021_1	84	-	104	-	3	-	-	3	194
2021_2	164	60	162	-	113	-	-	22	521
2021_3	329	16	318	-	-	-	-	-	663
2021_4	1217	353	-	-	166	-	-	-	1736
2021_5	119	9	30	-	-	2	12	7	179
2021_6	55	-	38	-	3	-	-	-	96
2021_7	537	2	118	-	-	-	-	-	657
2021_8	2084	15	520	-	-	-	-	-	2619
2021_9	-	5	160	-	8	-	-	-	173
2021_10	104	-	77	-	-	-	-	-	181
2021_11	1051	38	687	-	17	-	-	17	1810
2021_12	503	57	616	-	27	-	99	-	1302
2021_13	338	9	175	-	14	-	-	20	556
2021_14	73	-	-	-	16	-	-	-	89
2021_15	464	22	993	-	34	-	77	-	1590
2021_16	1711	11	493	-	10	-	-	-	2225
2021_17	1413	-	-	-	2	3	-	-	1418
2021_18	1493	6	-	-	-	26	-	-	1525
2021_19	4661	17	278	-	13	-	-	-	4969
2021_20	174	-	22	65	4	-	-	3	268
2022_1	979	51	1522	622	299	-	-	90	3563
2022_2	3199	-	607	-	11	-	8	45	3870
2022_3	242	81	154	-	43	-	-	-	520
2022_4	499	120	667	-	52	-	-	91	1429
2022_5	1436	14	348	-	14	-	16	8	1836
2022_6	644	36	423	219	-	-	31	15	1368
2022_7	198	43	172	-	15	-	-	34	462
2022_8	769	12	112	-	-	-	17	-	910
2022_9	1160	-	77	-	13	10	74	15	1349
2022_10	2622	31	-	-	175	-	-	14	2842
2022_11	164	-	16	-	2	2	-	-	184
2022_12	486	23	-	-	20	14	44	17	604
2022_13	711	98	207	-	-	-	73	-	1089
2022_14	1251	15	2149	973	-	-	-	-	4388
2022_15	38	18	85	-	39	-	-	107	287
2022_16	141	-	23	-	2	-	-	-	166
2022_17	1657	711	-	-	-	-	-	-	2368
2022_18	808	49	82	652	-	-	-	1050	2641
2022_19	115	17	-	-	-	-	-	-	132
2022_20	289	-	46	74	95	-	-	58	562
2022_21	302	28	64	-	50	-	-	126	570
2022_22	317	4	106	132	7	-	-	10	576
2022_23	29	-	6	14	6	-	-	6	61
2022_24	-	-	-	-	2	-	-	-	2
2022_25	136	16	61	-	25	-	-	-	238
2022_26	69	8	-	-	-	-	-	6	83
2022_27	491	-	43	-	13	-	11	6	564
Species Total	35326	1995	11761	2751	1313	57	462	1770	55435
Percent of Detections	63.7	3.6	21.2	5.0	2.4	0.1	0.8	3.2	

Figure 3: Detections and Recordings of Bat Species at CUVA. The number of recordings identified as a species from song meter deployments in 2021 and 2022 as reported by kaleidoscope. A p-value<0.05 indicates a high confidence in species detection. All detections with p-value>0.05 were not considered as true detections and excluded from further analysis. Detections of Evening bats are asterisked because they are commonly misidentified by Kaleidoscope Pro and require further evaluation by a bat professional to determine if detections are true.

The Big brown bat was the most detected species representing 63.7% of all detections from 2021 and 2022. There was a higher proportional abundance of detections of Big brown bats in 2021 (72.8%) than in 2022 (57.6%). The Big brown bat was detected with high confidence ($p < 0.05$) at all but one deployment in each survey seasons (Blossom and Shultz Barn) (Figure 4). The next most common species at CUVA was the Hoary bat, which was detected at 37 of 47 deployments and represents 19.9% of all 2021 and 20.1% of all 2022 recordings. The Silver-haired bat was

the third most common detection in 2022 and represented 7.8% of all recordings but only represented 0.3% of recordings in 2021. Similarly, the Silver-haired bat was detected in high confidence at only one deployment in 2021 but was detected with high confidence at 7 deployments in 2022. The remaining six species were uncommon and include the R bat (3.4%), the Little brown bat (2.3%), the Evening bat (1.9%), the Tricolored bat (3.4%), and the Northern long-eared bat (<1%). Some recordings (<1%) were identified as the Indiana bat, however it was not detected with high confidence at any of the deployments and were not included in the above analyses. It is of note that while some species did not represent a large portion of total recordings, they had high confidence ($p < 0.05$) at a large proportion of deployments. This includes the Red bat and the Little brown bat, both of which were present with high confidence ($p < 0.05$) at 33 deployments.

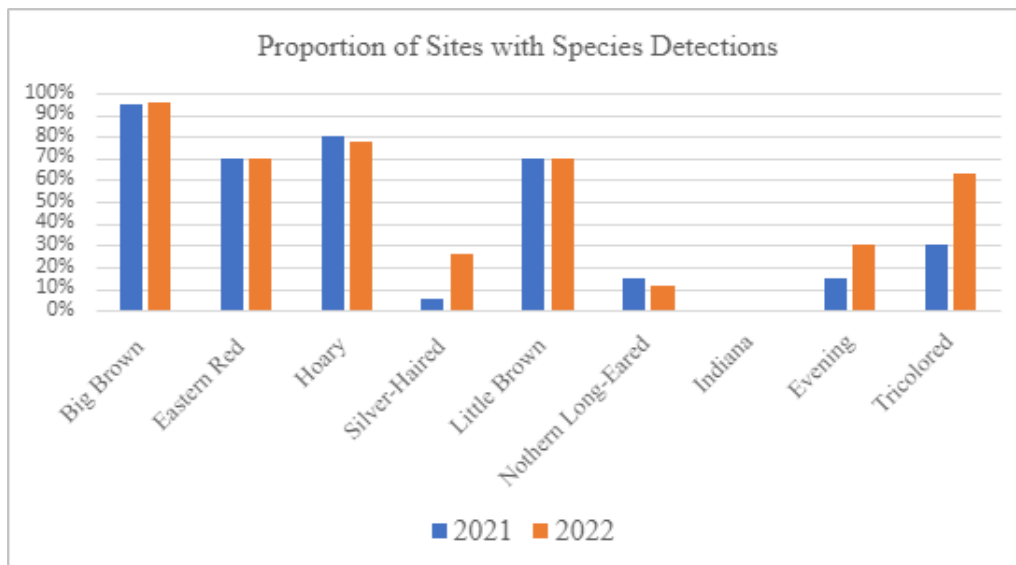


Figure 4: Changes in the proportion of deployments with species detections from 2021 to 2022. The percent of each deployment surveys in 2021 (blue) and 2022 (orange) that had each detection from each species were calculated. Species detections with high confidence ($p < 0.05$) were included.

The Tricolored bat and Northern long-eared bat were found at CUVA. In 2021, the Tricolored bat represented <1% of recordings and was detected in high confidence ($p < 0.05$) at 6 of 20. In 2022, however, Tricolored bats represented 5.3% of all recordings and was detected in high confidence ($p < 0.05$) at 17 of 27 deployments. As can be seen in the map showing the placement of song meters throughout the park and the detections of Northern long-eared and Tricolored bats (Figure 2), the Tricolored bat was seen in both southern and northern ends of the park. Of all the deployments that had Tricolored bat detections, 69% were stream or riverside (16/23) and 78% were closed canopy (18/23) (Table 2). The Northern long-eared bat, which was detected at 6 deployments between 2021 and 2022, these were restricted to the southern end of CUVA and only closed canopy areas. In 2021, one deployment had a potential Indiana bat detection ($p = 0.08$), however the recording should be analyzed by a professional to determine whether the identification is accurate. No Indiana bat detections were observed in 2022.

Table 2: Habitat types at deployments that had Tricolored bat detections

ID	Habitat Type	River/stream	Closed Canopy
2021_1	Forested Stream Slope	X	X
2021_11	Wetland		
2021_13	Upland Forest		X
2021_2	Upland Forest		X
2021_20	Forested Stream Slope	X	X
2021_5	Forested Area Near Cave		X
2022_1	Forested Riverbank	X	X
2022_10	Upland Forest	X	X
2022_12	Upland Forest		X
2022_15	Forest Stream Slope	X	X
2022_18	Wetland	X	
2022_2	Forested Riverbank	X	X
2022_20	Forested Riverbank	X	X
2022_21	Forested Riverbank	X	X
2022_22	Forested Riverbank	X	X
2022_23	Wetland	X	
2022_26	Upland Forest		X
2022_27	Upland Forest	X	X
2022_4	Forested Stream Slope	X	X
2022_5	Forested Steam Slope	X	
2022_6	Wetland	X	
2022_7	Interior Forest Stream	X	X
2022_9	Forested Area Near Cave		X

Table 3: Habitat types at deployments that had Northern long-eared bat detections

ID	Habitat Type	River/stream	Closed Canopy
2022_9	Forested Area Near Cave		X
2022_11	Interior Forest Stream	X	X
2022_12	Upland Forest Slope		X
2021_5	Forested Area Near Cave	X	X
2021_17	Upland Forest		X
2021_18	Upland Forest		X

Discussion

Bat populations have declined dramatically across eastern North America in recent decades, coinciding with the spread of WNS. The significance of this decline is emphasized with the

recent reclassification of Northern long-eared bat from threatened to endangered in 2022, and the proposed listing of the Tricolored bat. Additionally, the Little brown bat was listed as endangered in Ohio as of 2020. There has not been a systematic effort to monitor changes in bat populations at CUVA since the appearance of WNS in 2012. This is partially due to a moratorium on mist netting combined with the lack of expertise in CUVA staff to conduct surveys. Recent advances in technology has allowed for general application of acoustic monitoring and USFWS has committed to use of this technology and the community of scientists and resource managers have made this tool more accessible. There is no reason to believe that bat populations at CUVA have not been impacted by WNS. The most important information to CUVA resource managers is confirming presence of and locations where federal and state T&E species are still present.

The Northern long-eared bat was the most common species detected during the 2002-2003 field surveys using mist-nets to capture bats. The species was found at 29 out of the 35 sites across all habitat types sampled in 2002-2003. A 2015 re-survey showed significant decline with NLE bats present at only 3/13 sites. In 2021-2022 Northern long-eared bats were only detected in 6 out of 47 song meter deployments and represent less than 1% of all detections. We can conservatively say that Northern long-eared bats were present at 4 out of 36 sites (appendix d) in 2021-2022 surveys, all of which could generically be classified as interior forest habitats. This suggests a significant decline in overall abundance and a change in overall habitat use. The Northern long-eared bat was detected at the Everett Road area in both 2021 and 2022 (map 3), which indicates favorable locations for the species: 40 of 55 detections occurred by Everett Road with 26 detections North of the road in 2021 and 14 detections south of the road in 2022. Detections occurred on 5 of the 7 nights deployed near Everett road in both 2021 and 2022. The species was also found at the Virginia Kendal Ledges area in proximity to the Sharon conglomerate ledges and the Ice Box cave where the species has been known to hibernate. The species is likely present in other locations but assumed to be at low numbers due to the overall rareness of Northern long-eared bats and lack of detection in other locations. Continued survey efforts in interior forest habitats will likely result in additional detections, areas to target include the Carriage Trail, Wetmore, and Blossom woods.

There has been one record of Indiana bat at CUVA, a male bat from Krynak, during each of the 2002-3 surveys. The record is from mist net surveys within CUVA congressional boundaries but within property owned and managed by the Cleveland Metroparks near Sharon conglomerate outcroppings, which provide crevices and small caves that are good for roosting and hibernating. The Indiana bat was not detected at CUVA in 2021-2022. While Kaleidoscope analysis did identify this species at 8 deployments these were all with low confidence ($p > 0.05$) and overall few observations (see Appendix C). These identifications were further investigated and we consultation with regional bat experts to conclude these were in fact miss-identifications. It is possible that the bat is present at CUVA but in low numbers or in locations that were not surveyed. It is also possible that the species has been extirpated from the area, but further surveys should be conducted with the intent to target habitat areas favorable to the Indiana bat, including targeting outcroppings of Sharon conglomerate.

Tricolored bat was uncommon during 2021 while it was detected during 4 out of 20 deployments there were relatively few detections with <1% total detections ranging 3-22 detections per deployment. In 2022, Tricolored bat detections were more common, present on 17 out of 27 deployments representing 5% of total observations and ranging from 6-1,040 (Figure 4). There may be a true increase in Tricolored bat populations at CUVA, but this was unexpected due to the sensitivity of the species to WNS, as populations numbers have fallen and stayed low regionally and elsewhere (Perea et al. 2022; Loeb and Winters, 2022). One other explanation for the increased number of detections are the survey locations chosen, if deployments in 2022 happened to be in areas already occupied by Tricolored bats 2021 but were not surveyed. It was considered that Kaleidoscope Pro may have mis-identified the Tricolored bat vocalizations, however recent literature exploring the accuracy of kaleidoscope found that the Tricolored bat vocalization was one of the most accurately identified ultrasonic emissions, which supports the validity of Tricolored bats found throughout CUVA (Tabak et al. 2022; Loeb et al. 2019). Similarly, the Northern long-eared bat can be accurately identified by kaleidoscope and detections are likely true.

The Red and Evening bats are commonly misidentified as each other by programs use to auto identify bat calls (Licht 2017; Tabak et al. 2022; Lemen et al. 2015). Kaleidoscope Pro is one software that over-identifies the detections of Evening bats. With the uncertainty of acoustic identification and no physical record of an Evening bat collected at CUVA, further work is required to determine if the species is present in the park. The evening bat roosts in tree cavities, particularly those in beaver ponds and old growth forests, which are present at CUVA, and the park is in the known range of the Evening bat (Menzel et al. 2001; Bokman et al. 2016). The species still relatively rare in the state.

It is not surprising that the resistant Big brown bat would fill the population gaps caused by population declines of the more sensitive myotis species including the Little brown bat, Northern long-eared bat, and Tricolored bat after the spread of WNS (Pettit and O'Keefe 2017; Perea et al. 2022). Our studies reflect this shift in population dynamics with Big brown Bats being detected at all but two deployments between 2021 and 2022, while the myotis species were less frequently detected (Figure 4). With this being said, the number of detections from an acoustic recorder does not necessarily reflect the true abundance of a species. For example, one bat flying past a device repeatedly over the course of a recording session would likely result in more 'detections' than a dozen bats flying past the device once. Assessing the actual abundance of species with acoustic recording requires information regarding call frequencies and pass frequencies, however, some studies suggest that general trends of abundance may be able to be drawn from acoustic recordings (Newson and Pearce 2022; Cruncheon 2022). Our results may reflect the relative abundance of species in the areas of the park that were surveyed, but the limited range of acoustic devices (up to 28 meters for Tricolored bats) should be considered when drawing conclusions for the entire park (Wildlife Acoustics).

Conclusions

CUVA is an important resource for bats by providing habitat components including flight corridors for feeding activities, caves and barns for maternal roosts and hibernacula, old growth forests, which are preferred by bats when compared to younger forests that make flight more difficult (Carter, 2008). Future surveys to identify important habitat within the park should be conducted to ensure long-term protection and recovery of the remaining populations. The park biologist will work to develop a monitoring program to track long-term trends following the North American Bat Monitoring Program (NABat). Historically, the park has participated in monitoring programs with the Ohio Department of Natural Resources (i.e., acoustic monitoring on roads and roost monitoring), and as of 2021, the state has also moved to the NABat program and protocols. Additionally, it is important for the park to review SOPs and projects to ensure compliance with ESA and to protect state listed species as bat populations statuses have changed significantly over the past decade.

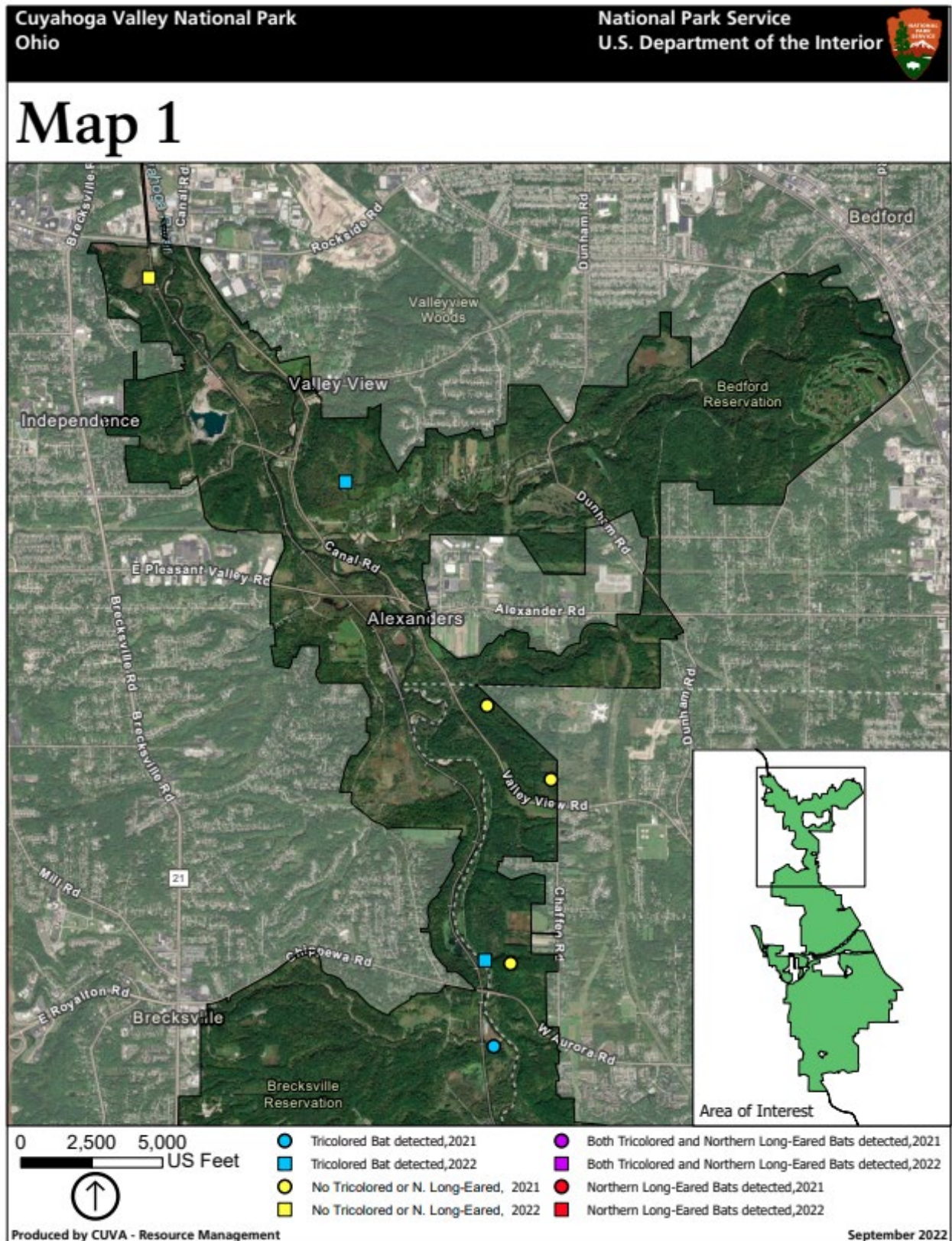
The decline of bat populations since the spread of WNS has been alarming, and the species populations at CUVA have faced major challenges. With the recent listing of the Northern long-eared bat as endangered and the proposed listing of the Tricolored bat, conservation efforts directed towards protecting the populations present at CUVA are crucial. These efforts should include habitat protections such as emergence surveys of structures and trees that are planned to be removed and the protection of old growth forests. A big potential impact to bats at CUVA is visitor use, especially around the Virginia Kendall Ledges area which is a known hibernacula site. Ice Box Cave is a well-known overwintering site for bats including the endangered Northern long-eared bats, however the area is also one of the most popular visiting locations in the park. A gate was installed at the entrance of Ice Box Cave to keep visitors out and slow the spread of WNS. The ledges have many other cracks and crevices that may provide sanctuary to bats that are not protected from visitors. Identifying other areas that bats emerge from the ledges and implementing further protections as necessary may be a next step in bat conservation at CUVA.

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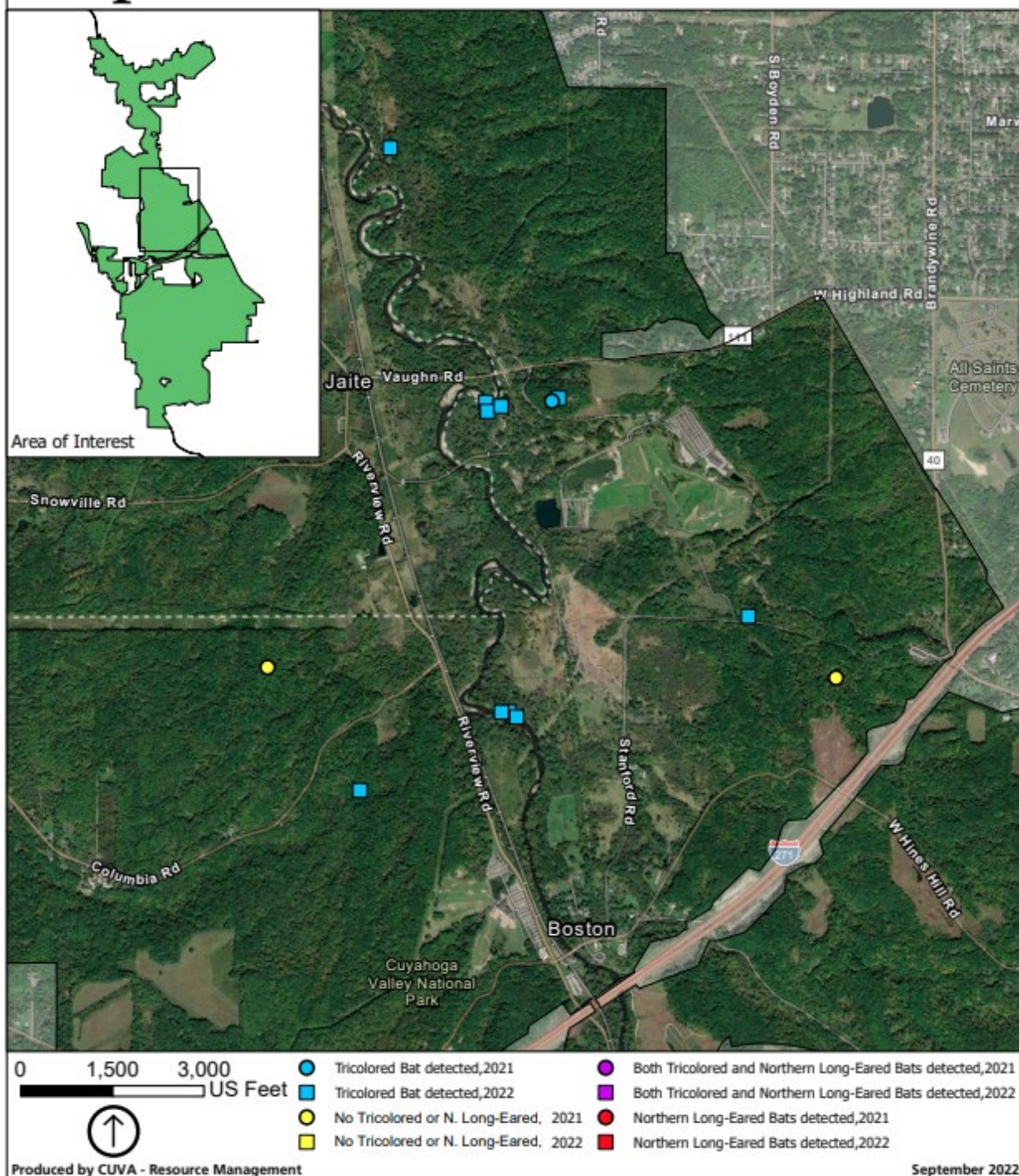
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Appendix A. Maps



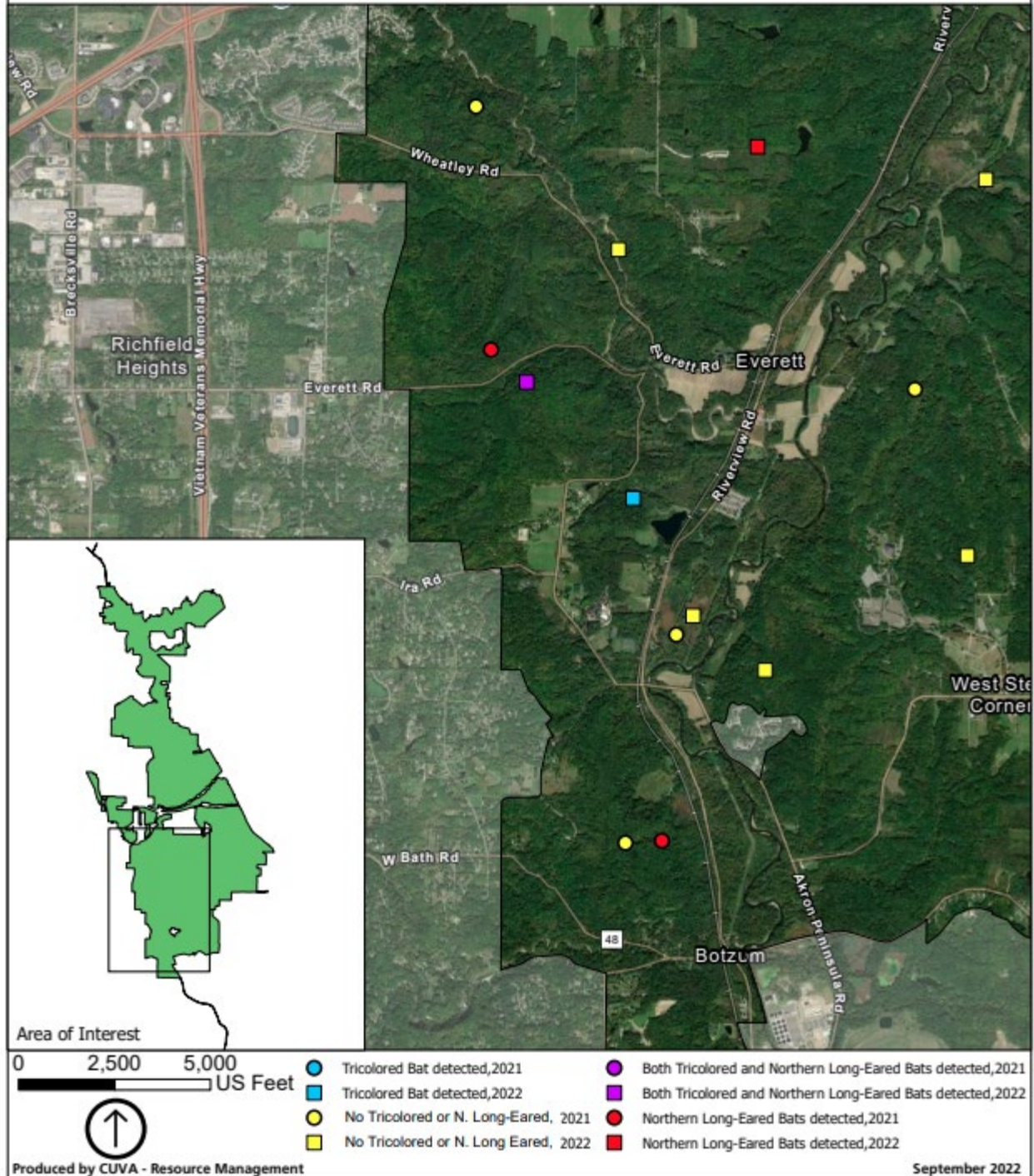


Map 2



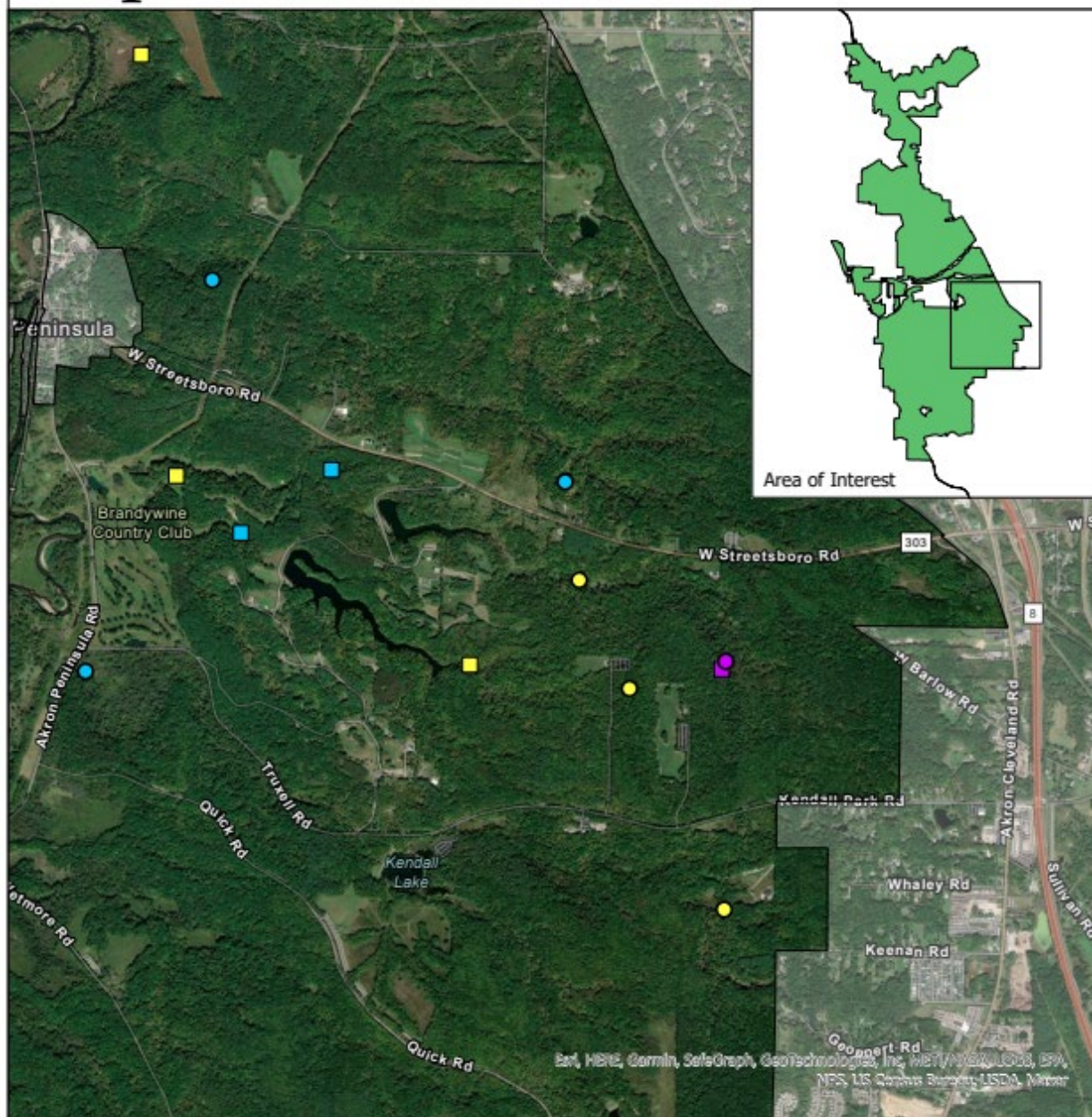


Map 3





Map 4



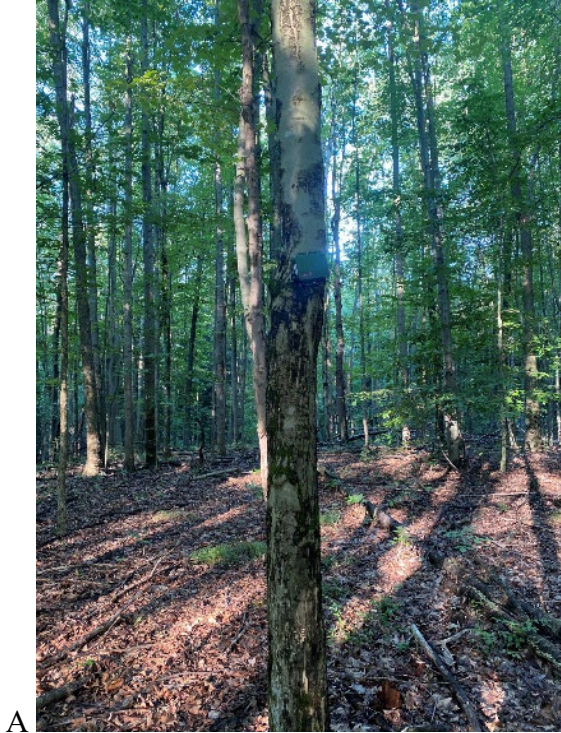
0 1,500 3,000
US Feet



- | | |
|---|---|
| ● Tricolored Bat detected, 2021 | ● Both Tricolored and Northern Long-Eared Bats detected, 2021 |
| ■ Tricolored Bat detected, 2022 | ■ Both Tricolored and Northern Long-Eared Bats detected, 2022 |
| ● No Tricolored or N. Long-Eared, 2021 | ● Northern Long-Eared Bats detected, 2021 |
| ■ No Tricolored or N. Long-Eared, 2022 | ■ Northern Long-Eared Bats detected, 2022 |

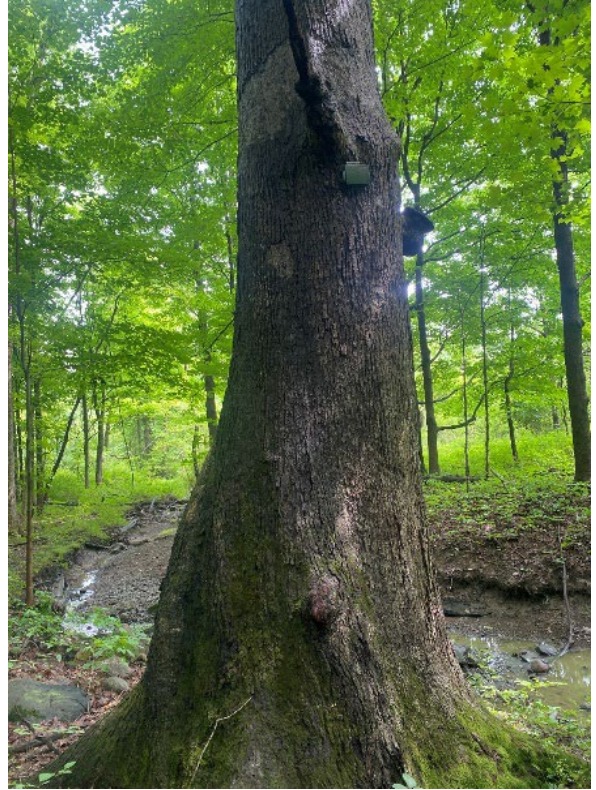
Appendix B. - Photos

Photos were taken of deployments at (A) Blossom, (B) Beaver Marsh, (C) Indigo Lake, (D) Furnace Run hilltop, (E) Furnace Run bank, (F) Oak Hill, (G) Octagon, (H) the ledges trail, (I) Columbia Run, (J) Stanford run confluence - Boston North Project, (K) Redlock, and (L) Mudcatcher





E



F



G



H



I



J



K



L

Appendix C. - Deployment dates, locations, coordinates, nights, and hours of all surveys in 2021 and 2022.

Coordinates were determined with points set on Avenza at each deployment. Hours were approximated by the hours of recording multiplied by the total number of nights the recorders were left out.

Date Deployed	Survey ID	Date Retrieved	General Location	y	x	Survey Nights	hours (approx)
6/17/2022	2022_1	7/5/2022	Stanford run confluence - Boston North Project	41.273635	- 81.564008	18	162
6/17/2022	2022_2	7/5/2022	Jaite paper mill/Brandywine - Boston North Project	41.287521	-81.5655	18	162
6/21/2022	2022_3	7/5/2022	At Brandywine golf course on ridge between haskell and ritchie run	41.234674	- 81.540995	14	126
6/21/2022	2022_4	7/5/2022	At brandywine golf course on haskell run	41.234986	- 81.531708	14	126
7/6/2022	2022_5	7/15/2022	Mudcatcher	41.324382	- 81.587424	9	81
7/6/2022	2022_6	7/15/2022	Brandywine golfcourse, Ritchie	41.232105	- 81.537111	9	81
7/6/2022	2022_7	7/15/2022	Red Lock near HOBO Logger site 45	41.298909	- 81.571292	9	81
7/18/2022	2022_8	7/25/2022	Octagon	41.226187	- 81.523334	7	63
7/18/2022	2022_9	7/25/2022	Ledges Trail	41.226047	- 81.508238	7	63
7/18/2022	2022_10	7/25/2022	Indigo Lake	41.194881	- 81.584889	7	63
7/18/2022	2022_11	7/25/2022	Oak Hill	41.220092	- 81.573322	7	63
7/26/2022	2022_12	8/3/2022	Everett Rd (closed) south on hill	41.203145	- 81.595048	8	72
7/26/2022	2022_13	8/3/2022	Furnace Run River Side	41.212674	-81.58644	8	72
7/26/2022	2022_14	8/3/2022	Stumpy Basin	41.25375	- 81.543259	8	72
7/26/2022	2022_15	8/3/2022	Columbia Run	41.270061	- 81.572841	8	72

8/4/2022	2022_16	8/9/2022	Beaver Marsh	41.186514	- 81.579137	5	45
8/4/2022	2022_17	8/9/2022	Brown Bender	41.182657	- 81.572283	5	45
8/4/2022	2022_18	8/9/2022	Terra Vista	41.370745	- 81.605806	5	45
8/4/2022	2022_19	8/9/2022	Rockside	41.39043	-81.63131	5	45
8/10/2022	2022_20	8/19/2022	Stanford run confluence - Boston North Project	41.2734	- 81.563542	9	81
8/10/2022	2022_21	8/19/2022	Stanford run confluence - Boston North Project	41.273618	- 81.564449	9	81
8/10/2022	2022_22	8/19/2022	Jaite paper mill/brandywine - Boston North Project	41.287111	- 81.565397	9	81
8/10/2022	2022_23	8/18/2022	Jaite paper mill/brandywine - Boston North Project	41.287344	- 81.564592	8	72
8/19/2022	2022_24	8/26/2022	Blossom	41.190945	- 81.553198	7	63
8/18/2022	2022_25	8/26/2022	Dickerson Run	41.217859	- 81.551681	8	72
8/18/2022	2022_26	8/26/2022	Stanford/Brandywine (Helltown)	41.277989	- 81.549799	8	72
8/18/2022	2022_27	8/26/2022	Across from Redlock	41.287732	- 81.561157	8	72
6/11/2021	2021_1	6/22/2021	Station Rd overlook S of parking lot	41.316037	-81.58623	10	90
6/11/2021	2021_2	6/22/2021	Behind Marsh Barn	41.234133	- 81.517691	10	90
6/11/2021	2021_3	6/23/2021	Near PWA trillium plots	41.202813	- 81.558272	11	99
6/11/2021	2021_4	6/22/2021	Chaffee and Sagamore Creek	41.341976	- 81.579105	10	90
6/24/2021	2021_5	6/29/2021	Ledges, downstream of Ice Box	41.22641	- 81.508001	5	45
6/24/2021	2021_6	6/29/2021	Oniel Woods	41.170237	- 81.585403	5	45
6/23/2021	2021_7	6/29/2021	Near Sagamore trillium plot, near stream	41.349111	- 81.587391	5	45

6/23/2021	2021_8	6/29/2021	In Beaver Marsh, on SW edge	41.185151	- 81.580721	5	45
6/30/2021	2021_9	7/8/2021	Shultz Barn	41.215162	- 81.508013	8	72
6/30/2021	2021_10	7/8/2021	Octagon	41.225151	- 81.513762	8	72
6/30/2021	2021_11	7/8/2021	Truxell and AP wetland	41.225785	- 81.546366	8	72
6/30/2021	2021_12	7/9/2021	Behind Jyurovat near old dam pool	41.230054	- 81.516814	9	81
7/8/2021	2021_13	7/14/2021	Top of Brandywine ski ridge near deer enclosure	41.287587	- 81.561569	6	54
7/8/2021	2021_14	7/13/2021	North side of stanford run stream, upstream of trillium plot	41.27525	- 81.544551	7	63
7/9/2021	2021_15	7/14/2021	On ridge above mudcather plot, S side	41.324097	- 81.584142	5	45
7/12/2021	2021_16	7/19/2021	On Coonrad ridge W of buckeye trail, near deer enclosure	41.275558	- 81.578384	7	63
7/14/2021	2021_17	7/26/2021	O'neil woods, off of buckeye trail	41.170404	-81.58195	12	108
7/16/2021	2021_18	7/26/2021	Riding Run, NPS property north of closed section of Everett	41.205446	- 81.598447	10	90
7/16/2021	2021_19	7/28/2021	Furnace Run, open flyway north of Wheatley near top of slope	41.222832	- 81.600027	12	108
7/23/2021	2021_20	7/29/2021	Pine Lane, deployed by Ryan	41.243554	- 81.538914	6	54

Appendix C. Species detection counts and P values of all recordings from deployments in 2021 and 2022.

As reported by auto identification of northeastern bats by Kaleidoscope Pro.

2022	Big brown		Red		Hoary		Silver-haired		Little brown		Northern long-eared		Indiana		Evening		Tricolored		Total
ID	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	
2022_1	0	979	0	51	0	1522	0	622	0	299	1		1	8	1	8	0	90	3579
2022_2	0	3199	0.74	2	0	607	1	214	0	11	1		1		<0.01	8	0	45	4086
2022_3	0	242	0	81	0	154	1	17	0	43	1	1	1	2	1	3	1	4	547
2022_4	0	499	0	120	0	667	1	173	0	52	1		1	1	1	6	0	91	1609
2022_5	0	1436	0	14	0	348	1	237	<0.01	14	1		1		0.02	16	0.03	8	2073
2022_6	0	644	0	36	0	423	0.01	219	0.99	6	1		1		0.01	31	0.01	15	1374
2022_7	0	198	0	43	0	172	1	42	0.02	15	1		1		1	15	0	34	519
2022_8	0	769	<0.01	12	0	112	1	75	1	2	1		1		<0.01	17	1	2	989
2022_9	0	1160	0.16	10	0.03	77	1	41	<0.01	13	0	10	1		0	74	<0.01	15	1400
2022_10	0	2622	0	31	1	21	1		0	175	1		1	1	1	10	<0.01	14	2874
2022_11	0	164	0.25	1	0.05	16	1	3	0.04	2	0.01	2	1		1		1		188
2022_12	0	486	0	23	1	14	1	14	<0.01	20	0	14	1		0	44	<0.01	17	632
2022_13	0	711	0	98	0	207	0.54	155	1	7	1		1		<0.01	73	0.98	15	1266
2022_14	0	1251	0	15	0	2149	0	973	1	1	1		1		1	6	1	1	4396
2022_15	0	38	0	18	0	85	0.29	31	0	39	1		1		1	2	0	107	320
2022_16	0	141	1		<0.01	23	0.09	37	<0.01	2	1		1		1		1		203
2022_17	0	1657	0	711	1	24	1	44	1	15	1		1		0.59	282	0.42	103	2836
2022_18	0	808	0	49	<0.01	82	0	652	1	11	1		1		1	45	0	1050	2697
2022_19	0	115	0	17	1	3	1	5	1	1	1		1		0.75	9	0.16	6	156
2022_20	0	289	1	3	0	46	0.01	74	0	95	1		1		0.54	6	0	58	571
2022_21	0	302	0	28	0	64	0.16	71	0	50	1		1		0.21	25	0	126	666
2022_22	0	317	0.01	4	0	106	0	132	<0.01	7	1		1		0.58	4	<0.01	10	580

2022_23	0	29	1		0.05	6	0.02	14	<0.01	6	1		1		1		<0.01	6	61
2022_24	0.24	1	1		0.18	1	1		<0.01	2	1		1		1		1		4
2022_25	0	136	0	16	0	61	0.31	41	0	25	0.95	1	1		1	1	0.99	2	283
2022_26	0	69	<0.01	8	0.10	8	0.98	12	0.18	4	1		1		1	3	0.01	6	110
2022_27	0	491	0.32	3	<0.01	43	1	9	0	13	1		1		<0.01	11	<0.01	6	576
Total		18753		1394		7041		3907		930		28		12		699		1831	34595
Proportion of Detections		54.21		4.03		20.35		11.29		2.69		0.08		0.03		2.02		5.29	

2021	Big brown		Red		Hoary		Silver-haired		Little brown		Northern long-eared		Indiana		Evening		Tricolored		Total
ID	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	P-Value	Count	
2021_1	0	84	0.09	2	0	104	0.99	33	0.05	3	1	-	1	-	0.72	2	0.04	3	231
2021_2	0	164	0	60	0	162	1	33	0	113	1	-	1	6	1	16	<0.01	22	576
2021_3	0	329	0	16	0	318	1	88	0.87	3	1	-	1	-	1	4	0.1	6	764
2021_4	0	1217	0	353	1	30	1	10	0	166	1	-	1	2	0.09	170	1	21	1969
2021_5	0	119	<0.01	9	0	30	1	8	0.57	3	0.03	2	0.18	2	0.03	12	0.01	7	192
2021_6	0	55	1	-	0	38	1	12	<0.01	3	0.24	1	1	-	1	-	1	-	109
2021_7	0	537	<0.01	2	0	118	1	87	0.53	1	1	-	1	-	1	-	1	-	745
2021_8	0	2084	0	15	0	520	1	84	0.89	3	1	-	1	-	0.42	10	0.37	5	2721
2021_9	1	9	<0.01	5	0	160	1	7	<0.01	8	1	-	0.085	1	1	-	0.86	1	191
2021_10	0	104	0.09	1	0	77	1	10	1	-	1	-	1	-	1	-	1	-	192
2021_11	0	1051	0	38	0	687	1	200	<0.01	17	1	-	1	-	0.59	21	<0.01	17	2031
2021_12	0	503	0	57	0	616	0.7	207	<0.01	27	1	-	1	-	0	99	0.76	14	1523
2021_13	0	338	<0.01	9	0	175	1	68	<0.01	14	1	-	1	-	0.1	11	0	20	635
2021_14	0	73	1	-	0.27	7	1	6	0	16	1	-	1	-	0.52	1	0.34	1	104
2021_15	0	464	<0.01	22	0	993	1	20	0	34	1	-	1	-	0	77	0.58	9	1619
2021_16	0	1711	0	11	0	493	1	16	<0.01	10	1	1	1	-	1	-	1	1	2243

2021_17	0	1413	1	-	1	16	1	12	<0.01	2	<0.01	3	1	-	1	-	1	-	1446
2021_18	0	1493	<0.01	6	1	9	1	2	0.15	3	0	26	1	-	1	1	0.6	2	1542
2021_19	0	4661	0	17	<0.01	278	1	1	<0.01	13	1	-	1	-	1	-	1	-	4970
2021_20	0	174	1	-	<0.01	22	<0.01	65	<0.01	4	1	-	1	-	1	-	<0.01	3	268
Total		16583		623		4853		969		443		33		11		424		132	24071
Proportion of Detection		68.89202775		2.588176644		20.16118981		4.02559096		1.84038885		0.137094429		0.045698143		1.761455694		0.548377716	

2022_4	Brandywine Golf Course Haskell Run	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	0	1	0
2022_6	Brandywine Golf Course Ritchie Run	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	1	0	1
2022_3	Brandywine Golf Course Ridge	1	-	-	-	-	-	-	-	-	-	1	0	0	1	1	1	0	1	0
2021_20	Pine Lane	1	1	0	1	1	0	1	1	1	0	-	-	-	-	-	-	-	-	-
2022_14	Stumpy Basin	1	-	-	-	-	-	-	-	-	-	1	0	0	1	1	1	1	0	0
2021_14	North Side of Stanford Run	1	1	0	0	1	0	0	0	1	0	-	-	-	-	-	-	-	-	-
2022_1, 2022_20, 2022_21	Stanford Run Confluence	3	-	-	-	-	-	-	-	-	-	3	0	3	3	2	3	2	3	0
2022_15	Columbia Run	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	0	1	0
2021_16	Coonrad Ridge	1	1	0	0	1	1	1	0	1	0	-	-	-	-	-	-	-	-	-
2022_26	Helitown	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	0	0	0	0
2022_27, 2021_13	Brandywine Ski Ridge	2	1	0	1	1	1	1	0	1	0	1	0	1	1	0	1	0	1	1
2022_3, 2022_22, 2022_23	Brandywine Confluence	3	-	-	-	-	-	-	-	-	-	3	0	3	3	2	3	2	3	0
2022_7	HOB0 Logger site 45	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	0	1	1
2021_1	Station Road	1	1	0	1	1	0	1	0	1	0	-	-	-	-	-	-	-	-	-
2021_15	Mudcatcher Ridge	1	1	0	0	1	1	1	0	1	1	-	-	-	-	-	-	-	-	-
2022_5	Mudcatcher Edge	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	0	1	1
2021_17, 2021_4	Sagamore	2	2	0	0	2	1	0	0	1	0	-	-	-	-	-	-	-	-	-
2022_18	Terra Vista	1	-	-	-	-	-	-	-	-	-	1	0	1	1	1	1	1	0	0
2022_19	Rockside	1	-	-	-	-	-	-	-	-	-	1	0	0	1	1	0	0	0	0

