Final report for WM-0321: Acoustic Monitoring of Bats in North Carolina

May 2017 – October 2019

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October 2019

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- hoary bat (*Lasiurus cinereus*, LACI) – 3
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- gray bat (*Myotis grisescens*, MYGR) – 1, 2, 3

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- evening bat (*Nycticeius humeralis*, NYHU)
- tricolored bat (*Perimyotis subflavus*, PESU) – 2, 3
- Mexican free-tailed bat (*Tadarida brasiliensis*, TABR)

*Due to the methodology limitations Seminole bat (*Lasiurus seminolus*) monitoring was not included in this project. It was not possible to differentiate the Seminole bat and the eastern red bat using acoustic methods (Li et al., 2019)*

Number(s) following each species indicate based on 2015 NC wildlife action plan (https://www.ncwildlife.org/plan):

1. Federally listed endangered or threatened species
2. Species of Greatest Conservation Need (SGCN)
3. Knowledge gap species

Additionally, all bat species listed above are on the management priority list according to the 2015 NC wildlife action plan.

Summary

Ten of the 17 bat species found in North Carolina are species of greatest conservation need. To better understand the current distribution of bats in North Carolina, we were tasked by the North Carolina Wildlife Resources Commission (WRC) to implement the North American Bat Monitoring Program (NABat) for the summer and to set up a winter monitoring network to gain information on winter bat activity patterns and distributions. Furthermore, to better understand the trends of bat activity, we were tasked to analyze the North Carolina Bat Acoustic Monitoring Program (NCBAMP) data collected in the mountain region of NC since the summer of 2011.

Between May 2017 and August 2019, we conducted three seasons of NABat summer acoustic surveys. The stationary point survey effort was 43 cells in 2017, 44 cells in 2018, 39 cells in 2019. In 2017 and 2018, the NABat mobile transect survey was conducted by UNCG bat biologists and collaborators. We completed 33 transects in 2017 and 34 in 2018. Since the fall of 2018, an effort to merge NABat and NCBAMP has been initiated. The summer of 2019 was the first pilot season to run a statewide citizen scientist program for the mobile transect survey. A total of 30 transects were driven by citizen scientists, including 9 transects from NCBAMP. Additionally, collaborators from previous summers continued surveying 7 NABat transects. We completed two winter seasons of bat acoustic monitoring. We set 14 site across NC in the winter of 2017 – 2018 and 11 sites in the winter of 2018 – 2019 to monitoring bat activity nightly in December, January, and February.

The winter bat monitoring suggested that three SGCN species, the southeastern myotis, the little brown bat, and the northern long-eared bat were active throughout the winter season across the entire coastal plain of NC, even though the latitudinal winter climate gradient along the coast is evident. The tri-colored bat was detected throughout the state during the winter and its probability of presence would be higher in warmer parts of the state. In the mountain region,

several SGCN species were found active during the winter, including the gray, little brown, and northern long-eared bats.

We complied the mobile transect survey data from 2015 to 2018 and generated a publication on *BMC Ecology* (Li, Parker, and Kalcounis-Rueppell, 2019*)*. The publication examined factors that might affect bat regional distributions. The key finding is that the association between bat activity and land cover was species specific, suggesting the needs to conserve diverse land covers to better conserve the total diversity of bats. The publication also examined the trend of bat activity across years. Significant fluctuations between years were found but there was no clear directional trend. In contrast, we also analyzed the NCBAMP data from 2011 to 2018 in the mountain region and identified a significant decline of the tricolored bat activity and significant increases for several species, including the big brown bat, which is suspectable to the white-nose syndrome (WNS). We also compared the overall community composition by examining NCBAMP and WRC mountain region mist-netting data. We identified similar bat community compositional changes, including the loss of tricolored bats and increase of big brown bats. However, each dataset also indicated changes of some species that the other dataset was not able to target (for example NCBAMP detected the increase of Mexican free-tailed bats whereas the mist-netting data detected the increase of small-footed bats). This suggests these methods complement each other and are both important for monitoring SGCN.

The NABat stationary point survey generated estimations of occupancy probability for three SCGN species, the tricolored bat, the little brown bat, and the northern long-eared bats. Among them, the northern long-eared bat had the lowest overall occupancy probability (less than 0.4). Occupancy estimation maps can guide local survey efforts to identify roosts or specific habitats that are particularly important to these species. We also used the stationary point survey data to identify SGCN hotspots. A total of ten areas were identified and recommended for long-term monitoring. We also encourage a small monitoring effort between SGCN hotspots to better understand the distribution boundaries and potentially identify barriers.

Another effort we have initiated is to integrating data at multiple scales. We are actively unloading NABat data to the national NABat database hosted by USGS. Meanwhile, we are developing two websites, one hosted by UNCG, one hosted by WRC Outer Banks Center for Wildlife Education, to improve data sharing and communication. Currently our project has over 20 diverse collaborators and involves over 50 individual citizen science volunteers. The WRC website will be tailored towards citizen scientists to provide survey outcomes and bat scientific knowledge to volunteers. It will also allow direct volunteer interactions. The website hosted by UNCG is designed for professional bat biologists to share bat monitoring data and extract information from acoustic surveys to guide any local survey efforts.

The key next steps are: 1. Continue merging NCBAMP and NABat to ensure each education region have enough transects for different future scenarios; 2 improve the data integration effort. The stationary survey will continue to improve the knowledge of SCGN species that cannot be well detected by the mobile transect survey. Additionally, findings based on NCBAMP 2011-2018 data are being summarized into a manuscript by the collaboration between Dr. Han Li and WRC biologists. The goal is to publish these findings to inform more bat biologists at a broader scale.

Winter bat acoustic monitoring

The winter bat acoustic monitoring started as a master student thesis by K. Parker at UNCG in 2016-2017 with a goal to better understand the winter ecology of bats in NC . Previously winter activities have been documented in the coastal plain and the Piedmont of NC for several bat species, including several SGCN species, such as the northern long-eared bat and the tricolored bat (Grider et al. 2016). In the winter of 2016-2017, our preliminary monitoring confirmed the previous result for the coastal plain and the piedmont. Additionally, we documented winter bat activity in the mountains, including recordings of SGCN species, such as the gray bat. Therefore, we proposed to the WRC to include a winter bat monitoring component in the current grant.

Field sampling

In each winter, we conducted bat monitoring from December to next year February. We used AnaBat SD2 (Titley Scientific Inc., Australia) to record bat activity from sunset to sunrise nightly for three consecutive months. The detail sampling method can be found in Parker et al (under review). It is important to highlight that solar panels were used at certain sites as the power source of the detector for both year. A total of 17 sites were sampled, including two sites on private properties (Figure 1). Among these sites, 8 were sampled in both years, 6 in 2017-2018 only, and 3 in 2018 – 2019 only. Most sites were selected for sampling because of the presence of SGCN or species with other conservation interests. Sites that were on public lands have the site coordinates listed in Table 1.

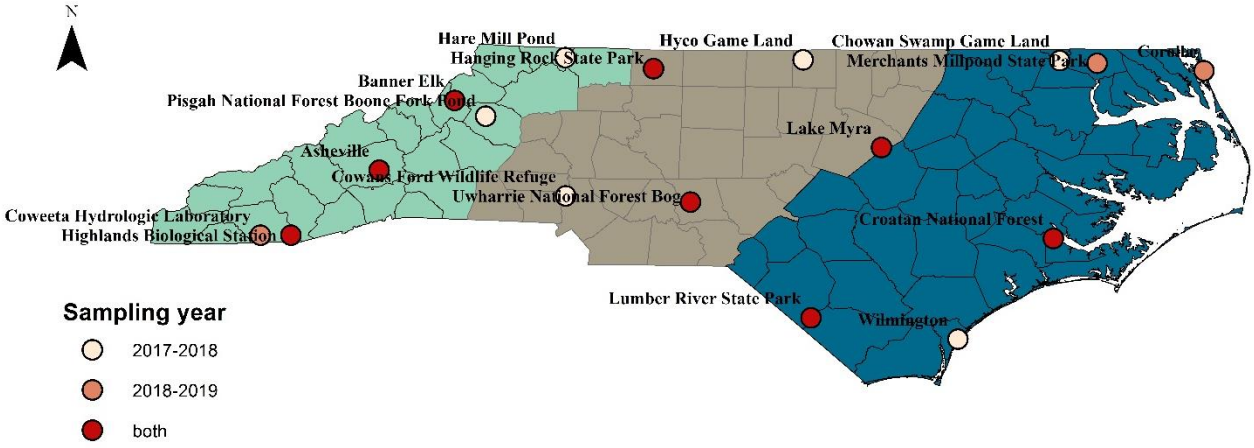

Figure 1 2017-2019 winter bat monitoring sites in NC

Key results

In 2017-2018 winter, we collected 148,486 recording files from 14 sites. In 2018-2019 winter, we collected 102,535 recording files from 11 sites. We used Kaleidoscope (Version 4.3.2, Wildlife Acoustics, Inc, Maynard, MA, USA) as the tool for filtering recordings that contained only noises and for automatic species identification. We used the match ratio larger than 50% as the criterion for common species identification. All myotis species were further

vetted manually by Dr. Han Li. After filtering noise files, we collected 24,839 bat recording files that included at least 3 bat calls in 2017-2018, and 15,061 bat files in 2018-2019.

Table 1 2017-2019 winter bat monitoring site coordinates and ownership

Site	Lat	long	landowner	2017_2018	2018_2019
Asheville	35.5764	-82.4791	public	yes	yes
Chowan Swamp Game Land	36.4581	-76.9954	public	yes	no
Corolla	36.3755	-75.8332	public	no	yes
Cowans Ford Wildlife Refuge	35.3694	-80.9769	public	yes	no
Coweeta Hydrologic Laboratory	35.0534	-83.4355	public	no	yes
Croatan National Forest	35.0275	-77.0464	public	yes	yes
Hanging Rock State Park	36.3928	-80.2685	public	yes	yes
Hare Mill Pond	36.4811	-80.9794	public	yes	no
Highlands Biological Station	35.0536	-83.1899	public	yes	yes
Hyco Game Land	36.4637	-79.0634	public	yes	no
Lake Myra	35.7590	-78.4314	public	yes	yes
Lumber River State Park	34.3897	-79.0000	public	yes	yes
Merchants Millpond State Park	36.4357	-76.6935	public	no	yes
Pisgah National Forest Boone Fork Pond	36.0108	-81.6213	public	yes	no
Uwharrie National Forest Bog	35.3200	-79.9700	public	yes	yes

The numbers of recordings for common species with high automatic identification confidence (big brown, red, hoary, silver-haired, evening, tricolored, and Mexican free-tailed bats) for each winter season are listed in Table 2 and Table 3. For both winter seasons, silver-haired bats were the most recorded species. This is consistent with the current knowledge of silver-haired bats being cold weather adapted species (Dunbar 2007). The number of bat files at a site over a winter season reflects both the winter climate and the habitat condition.

Table 2 Numbers of bat call files recorded during 2018-2019 winter by species

Site	EPFU	LABO	LACI	LANO	NYHU	PESU	TABR
Asheville	6	3	24	39	12	4	1
Banner Elk	90	29	17	69	4	5	5
Corolla	2	3	10	36	1	1	0
Coweeta Hydrology Laboratory	6	0	82	33	0	1	37
Highland Biological Station	22	5	720	143	395	15	2
Lake Myra	191	195	23	311	235	280	162
Lumber River State Park	8	136	52	2	360	725	63
Merchants Mill Pond	117	119	784	1086	164	918	147
Uwharrie National Forest	169	889	53	351	364	446	56
Croatan National Forest	25	44	37	8	43	32	25
Hanging Rock State Park	365	27	264	526	36	54	369
Total bat files	1001	1450	2066	2604	1614	2481	867

Table 3 Numbers of bat call files recorded during 2017-2018 winter by species

Site	EPFU	LABO	LACI	LANO	NYHU	PESU	TABR
Asheville	3	1	23	46	0	1	14
Banner Elk	31	2	1	4	1	3	1
Boone Fork Pond	115	35	305	743	48	55	504
Chowan Swamp Game Land	19	109	52	149	98	60	18
Cowans Ford Wildlife Refuge	40	90	55	96	102	149	50
Croatan National Forest	185	164	92	36	231	97	83
Hanging Rock State Park	256	38	199	975	50	35	349
Hare Mill Pond	9	0	3	46	1	0	2
Highland Biological Station	46	28	451	559	119	10	18
Hyco Game Land	5	447	7	620	200	80	33
Lake Myra	221	130	360	1567	59	203	3377
Lumber River State Park	4	104	12	4	205	957	8
Uwharrie National Forest	91	598	94	413	298	312	28
Wilmington	43	784	517	66	764	74	254
Total bat files	1068	2530	2171	5324	2176	2036	4739

Due to the special conservation concerns over myotis species, we manually vetted recordings that have been automatically identified as species in this genus. We reported them species by species below.

- Southeastern myotis:
    - Lumber River State Park – present every month Dec. to Feb. in both winter seasons; 110 bat files in 2017-2018, 256 bat files in 2018-2019
    - Croatan National Forest - present every month Dec. to Feb. in both winter seasons; 20 bat files in 2017-2018, 25 bat files in 2018-2019
    - Lake Myra - present every month Dec. to Feb. in both winter seasons; 26 bat files in 2017-2018, 21 bat files in 2018-2019
    - Chowan Swamp Game Land - present every month Dec. to Feb. in 2017-2018 winter; 93 bat files collected
    - Merchants Millpond State Park - present every month Dec. to Feb. in 2018-2019 winter; 36 bat files collected
    - Corolla – recorded on Feb 2th and 19th 2019.
- Gray bat:
    - Boone Fork Pond – present every month Dec. to Feb. in 2017-2018 winter; near nightly presence after Feb 12th, 2018 until the end of Feb.
    - Hanging Rock State Park – present every month Dec. to Feb. in both winter seasons; near nightly presence after Feb 19th, 2018/Feb 13th, 2019 until the end of Feb.
- Little brown bat:
    - Boone Fork Pond – present every month Dec. to Feb. in 2017-2018 winter; 79 bat files recorded.
    - Highland Biological Station - present every month Dec. to Feb. in both winter seasons; 31 bat files in 2017-2018, 29 bat files in 2018-2019
    - Chowan Swamp Game Land - present every month Dec. to Feb. in 2017-2018 winter; 259 bat files collected

    - Merchants Millpond State Park - present every month Dec. to Feb. in 2018-2019 winter; 150 bat files collected
    - Hanging Rock State Park – present every month Dec. to Feb. in both winter seasons; near nightly presence after Feb 22nd, 2018/Feb 16th, 2019 until the end of Feb.
    - Hyco Game Land - present every month Dec. to Feb. in 2017-2018 winter; 65 bat files collected
    - Uwharrie National Forest - present every month Dec. to Feb. in both winter seasons; 43 bat files in 2017-2018, 36 bat files in 2018-2019
    - Lumber River State Park – present every month Dec. to Feb. in both winter seasons; 91 bat files in 2017-2018, 135 bat files in 2018-2019
- Northern long-eared bat:
    - Highland Biological Station – recorded on Feb. 11th, 2018 and Feb. 21st, 2019
    - Lumber River State Park – present every month Dec. to Feb. in both winter seasons; 37 bat files in 2017-2018, 89 bat files in 2018-2019
    - Croatan National Forest - present every month Dec. to Feb. in both winter seasons (no recording between mid-Dec. to mid Jan, though); 22 bat files in 2017-2018, 19 bat files in 2018-2019
    - Lake Myra – recorded on Jan 9th, 2018
    - Chowan Swamp Game Land - present every month Dec. to Feb. in 2017-2018 winter (no recording between mid-Dec. to late Jan, though); 21 bat files collected
    - Merchants Millpond State Park – recorded on Jan 1st, Feb 5th, 8th, 18th, 2019,
    - Corolla – recorded Dec.3rd 2018, Feb. 8th, 21st, 2019.

Management recommendations for winter monitoring

Two years of winter monitoring suggested that the presence of SGCN species, southeastern myotis, little brown, and northern long-eared bats, was prevalent throughout the coastal plain. These species were not restricted to the southern part of the coastal plain, even though the latitudinal winter climate gradient along the coast line is evident in NC. This finding emphasizes the importance of maintaining suitable habitats in the northern part of the coastal plain during the winter.

One particularly interesting result was the detection of northern long-eared bats in Corolla, outer banks, NC. It is not clear if those bats were roosting in the outer banks or flying over from the mainland, where North River Game Land, a known northern long eared bat habitat, is approximately 5 miles across the Currituck Sound. Similar incidences in New York and Massachusetts have been found during the winter in coastal islands, suggesting northern long-eared bats might use empty summer houses to overwinter (M. Fisher, personal communication). Continuous monitoring over future winter seasons might help understanding how this species use coastal habitats.

The financial cost of winter monitoring is relatively low as most equipment involved should be part of the summer NABat program. With the use of solar panels as the power source, winter sites will only require minimal maintenance if a site is excluded from public access. We recommend using existing NABat network and inviting collaborators to participate as a format of long-term monitoring for local inventory purposes. Currently, the Corolla site, in collaboration with the WRC Outer Banks Center for Wildlife Education, the Highland site, in collaboration with the Highland Biological Station may continue with no cost. Several state parks may also be

potential long-term sites that require no to minimal cost to continue. This effort will also increase the efficiency of the bat detecting equipment purchased for this project and better maintain the functioning of equipment.

NCBAMP and NABat mobile transect surveys

Since the arrival of WNS in NC in 2011, WRC has been monitoring bats in the mountains with a mobile transect survey protocol named NCBAMP. Between 2011 and 2018, NCBAMP replied on both professional biologists and volunteers to survey 32 transects. Each year NCBAMP reached out to approximately 20 volunteers, showing a strong potential for public science education. In 2015, NABat was initiated in NC at a statewide scale. Part of the NABat effort is a mobile transect survey protocol similar to NCBAMP. There are 44 NABat transect across NC. Several NABat transects overlapped with NCBAMP transects. After the initial 4 years of NABat mobile transect survey implementation, both WRC and bat biologists at UNCG agreed that two survey protocols can be merged into one statewide citizen science monitoring program.

Analysis of NCBAMP data

One main task for this project is to analyze NCBAMP data and understand the species specific population trend in the mountains since the arrival of WNS. Due to the methodology limitations, mobile transects require publicly accessible roads with certain length and width. The road condition might exclude some bat species that prefer intact forest vegetation. Some myotis species might not be adequately detected. Thus, we decided to quantitatively analyze these following bats: EPFU, LABO, LACI, LANO, NYHU, PESU,TABR. The rest species were qualitatively described. All bat species recorded via any form of mobile transect surveys were manually vetted.

For the seven species mentioned above, we analyzed year as a continuous independent variable to test how species specific bat activity change over time. We used a covariate, Julian date (how many days into the summer field season, count May 15th each year as day 1) to incorporate the increase of temperature during a summer. Species specific results are below:

- The big brown bat showed a significant trend of increasing (Figure 2), contradictory to this species being negatively impacted by WNS.

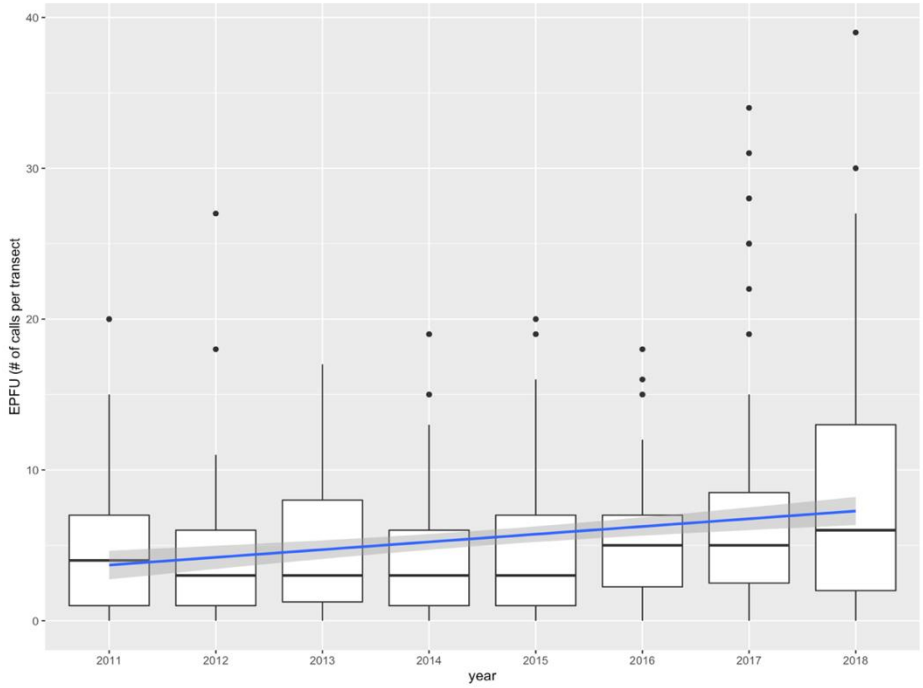

Figure 2 Big brown bat acoustic activity trend (increasing) from 2011-2018

- The red bat showed a general trend of increasing (Figure 3).

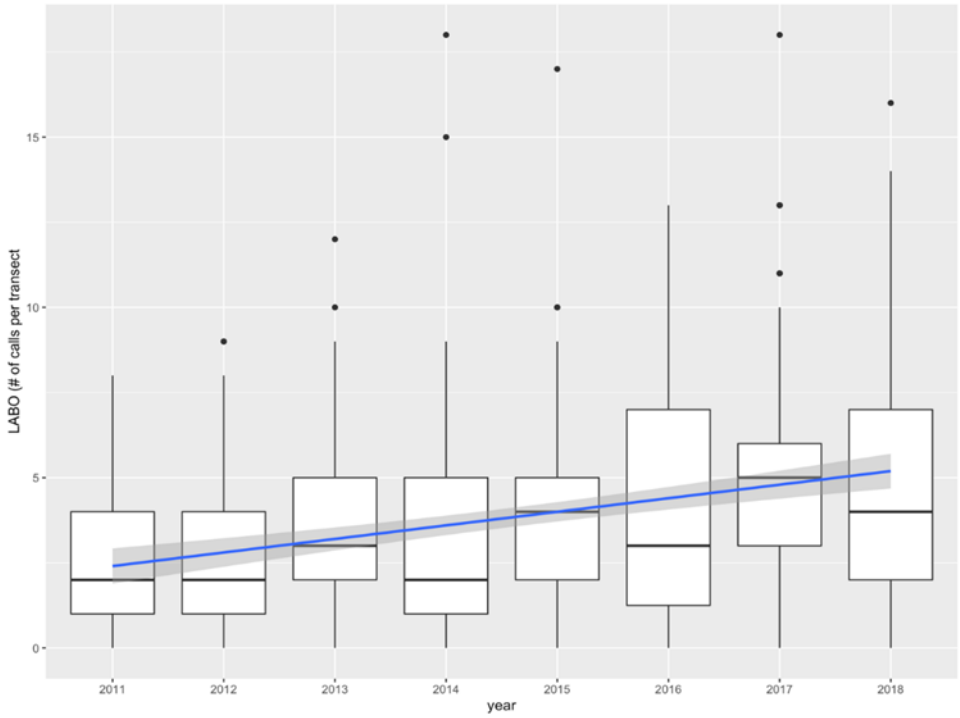

Figure 3 Eastern red bat acoustic activity trend (increasing) from 2011-2018

- No significant trend was found for the hoary bat (Figure 4).

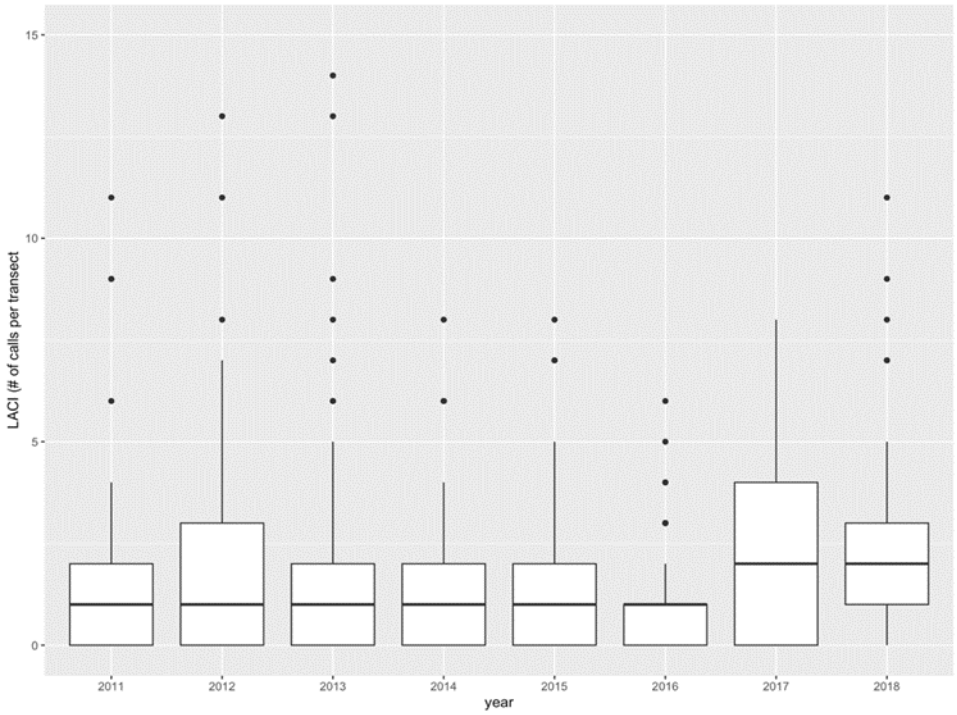

Figure 4 Hoary bat acoustic activity trend (no significant result) from 2011-2018

- The silver haired bat showed a general trend of increasing (Figure 5).

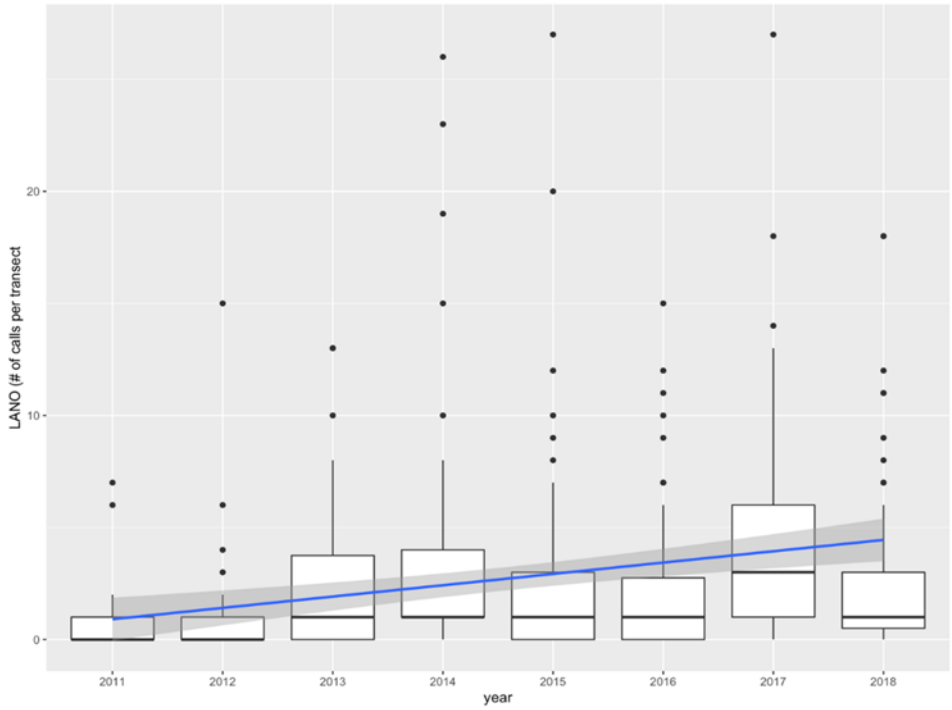

Figure 5 Silver haired bat acoustic activity trend (increasing) from 2011-2018

- No significant trend was found for the evening bat (Figure 6).

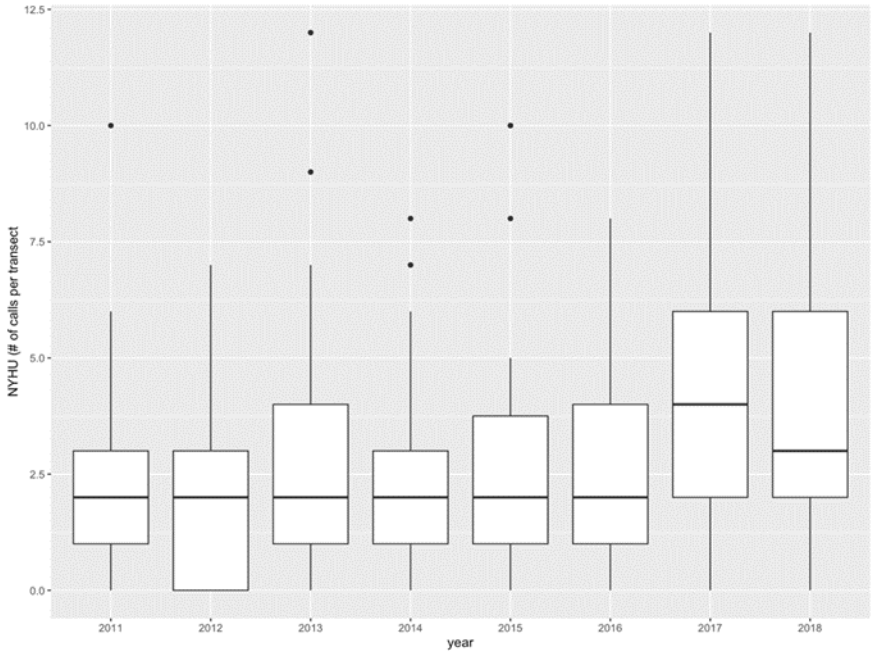

Figure 6 Evening bat acoustic activity trend (increasing) from 2011-2018

- The tricolored bat showed a significant trend of declining (Figure 7).

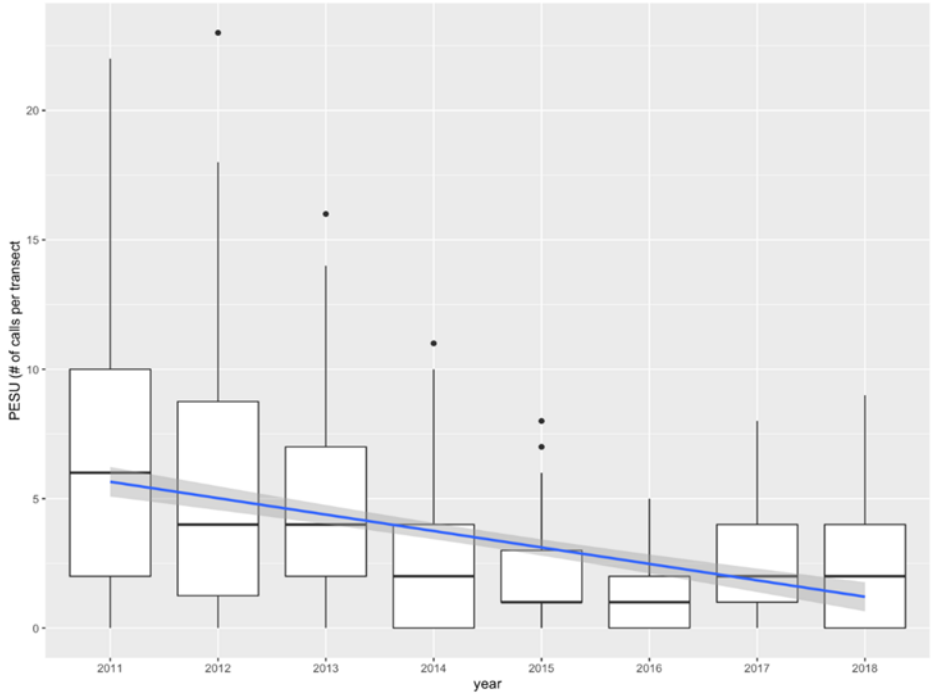

Figure 7 Tricolored bat acoustic activity trend (decreasing) from 2011-2018

- The Mexican free-tailed bat showed a significant trend of increasing (Figure 8), consistent with published research reporting this species' range expansion (McCracken et al. 2018).

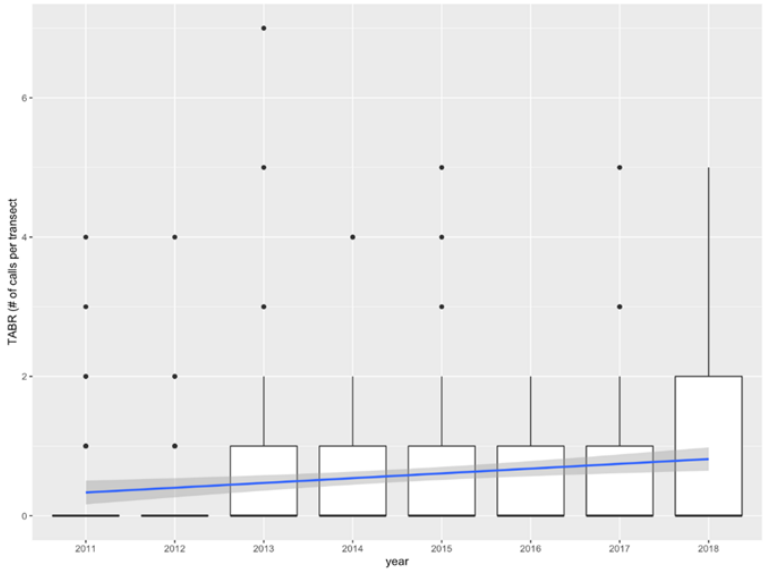

Figure 8 Mexican free-tailed bat acoustic activity trend (increasing) from 2011-2018

Two myotis species, the gray bat and the little brown bat were evaluated for trend qualitatively as both species have unique acoustic characteristics for identification. The gray bat was recorded on scattered transects. In contrast, the little brown bat showed a trend of decline. In 2011, 19 transects recorded little brown bats with a total over 100 call files. Whereas in 2018, 8 transects recorded this species with about 40 call files. The spatial extent of the little brown bat in 2011 was wide (blue transects in Figure 9) . In 2018, it shrank to mainly southwest of Asheville in the Nantahala national forest (red transects in Figure 9).

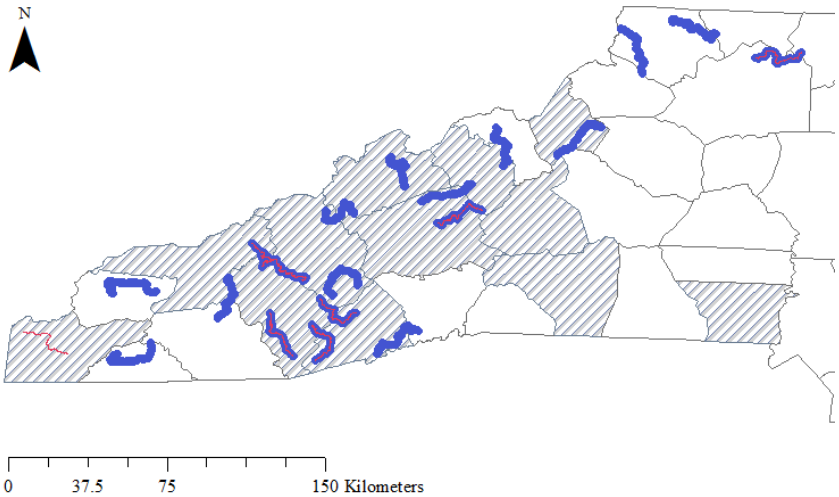

Figure 9 NCBAMP transects that recorded little brown bats in 2011 (blue line) and in 2018 (red line)

Overall a community compositional change was observed. We conducted non-metric multidimensional scaling (NMDS), to plot each transect in the multiple dimensional space. Each dimension represented a bat specie. Each transect was plotted based on the number of bat call files recorded. Then we reduced the dimension of the plot based on statistical similarity. A final plot included three dimensions. The loss of tricolored bats significantly re-shaped the community (Figure 10).

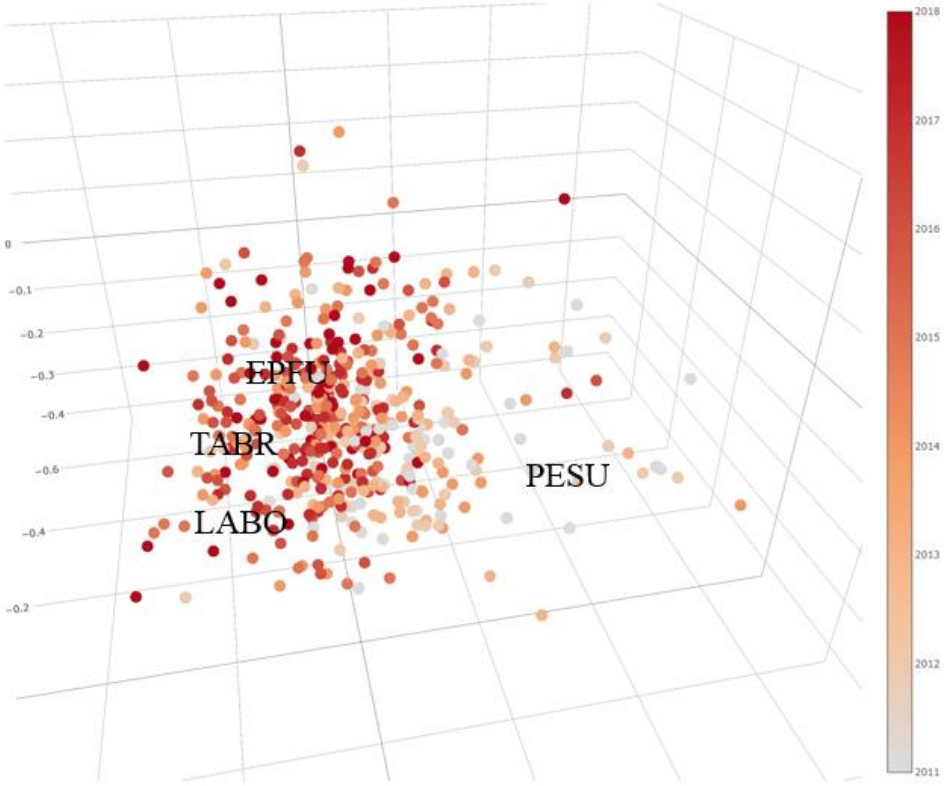

Figure 10 NMDS plotting showing community composition change between 2011 and 2018 using NCBAMP data

To better understand the community compositional changes and if there might be an overall loss of ecosystem services provided by bats, we also analyzed the mist-netting survey data collected by WRC. The mist-netting effort in the mountains dated before the arrival of WNS. Thus, we were able to examine the community composition before and after the arrival of WNS. Using the same non-metric multidimensional scaling (NMDS) technique, we plotted each mist-netting site in the multiple dimensional space. Each mist-netting site was plotted based on the number of capture. Then we reduced the plot into a two-dimensional graph (Figure 11). NMDS results showed that after the arrival of WNS, MYSE, MYLU, PESU were replaced by EPFU, LABO, MYLE, whereas species LACI remained the same. Interestingly two survey methods showed similarities when indicating the decline of MYLE and PESU and the increase of EPFU and LABO. However, the increase of MYLE indicated by the mist-netting and the increase of TABR indicated by the transect survey were not shown by the other method. This suggests each survey method has its own limitation and complement each other.

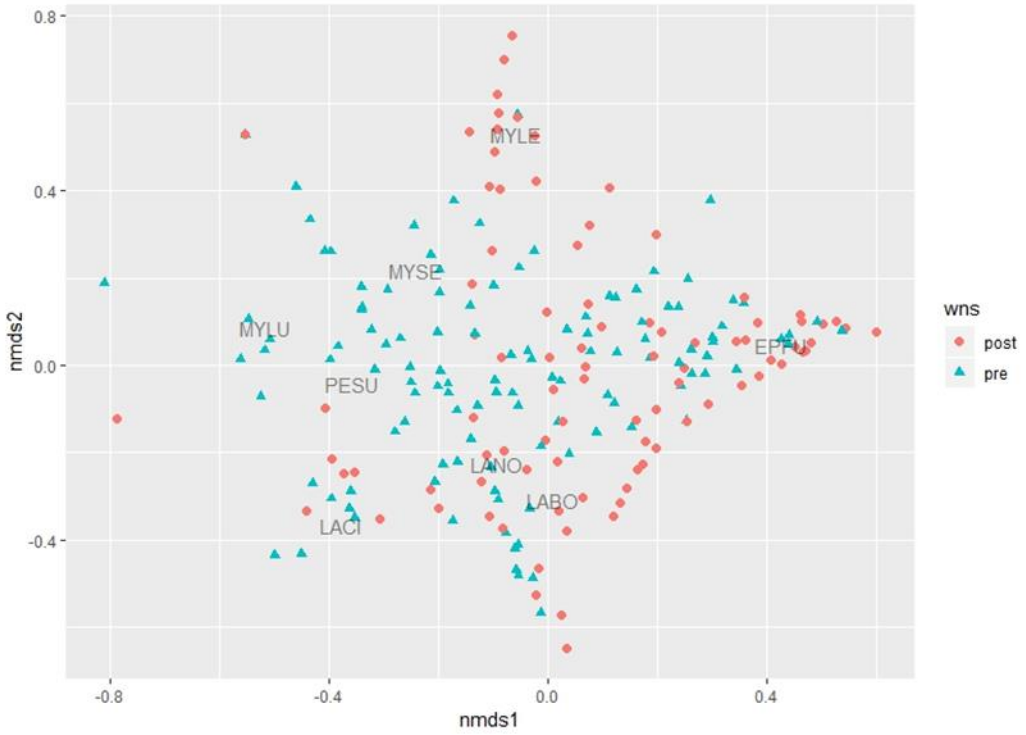

Figure 11 NMDS plotting showing community composition change before and after the arrival of WNS in NC mountain region using mist-netting data

NABat survey 2015 – 2018 and the comparison to NCBAMP

The NABat mobile transect survey was initiated in 2015 with a statewide sample design. The sampling sites/transects were selected by the NABat grid cell framework (Loeb et al., 2015). A total of 44 NABat transects have been mapped. One transect near Lake James State Park was purposefully designed for an on-going bat monitoring project administrated by Duke Energy and has been treated separately. For the rest of 43 transects, between 2015 and 2018, approximately 50% transects were driven by bat biologists at UNCG. The rest were sampled by collaborators, generally with a career in wildlife conservation or environmental science.

Data collected between 2015 to 2018 have been analyzed and summarized into two publications Li and Kalcounis-Rueppell (2018) and Li, Parker, and Kalcounis-Rueppell (2019). The statewide distributions of these following species: EPFU, LABO, LACI, LANO, NYHU, PESU,TABR have been analyzed with various environmental variables. Some key points include:

- Urbanization might have facilitated the range expansion and the local abundance increase for EPFU, LANO, and TABR.
- Water eutrophication might benefit PESU by providing prey but might be potentially harmful to several other species.
- Woody wetland is an important habitat for PESU whereas emerging herbaceous wetlands might not benefit most species.
- Deciduous and evergreen forests would be beneficial to different species.

Additionally, in Li, Parker, and Kalcounis-Rueppell (2019), we also reported the annual variation of species specific bat acitivty (Figure 12, Parker, and Kalcounis-Rueppell, 2019). At the state scale, 4 years of data indicated fluctuations between years. However, no clear increasing or decreasing trend was identified. The relative abundance indicated by bat activity is comparable between NCBAMP in the mountains and NABat statewide. There were more big brown bat and hoary bat activities recorded by NCBAMP in the mountains than the whole state. Whereas red, evening, tricolored, and Mexican free-tailed bats had lower activities in the mountains than in the entire state. The level of silver haired bats was relatively the same. This compariosn is particularly important for tricolored bats, suggesting the decline of tricolored bats might be limited to WNS postive areas.

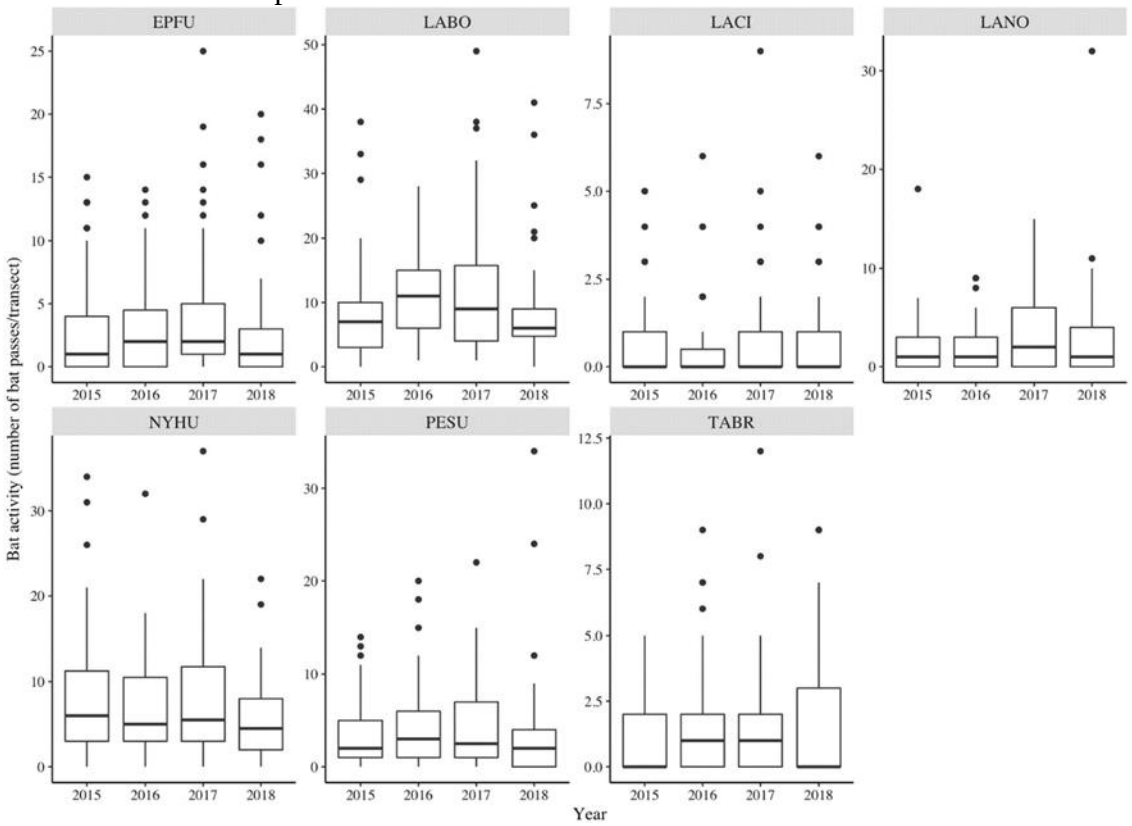

Figure 12 NABat species specific bat activity varying by years across NC between 2015 and 2018

Merging NABat and NCBAMP

Due to the similarity between NCBAMP and NABat, espcially the overlapping transects from both protocols in the mountains, we initiated the effort to combine two programs. The mobile transect survey in general requires less professional knowledge and can be completed on public roads without typical safety concerns related to fieldworks. This is one reason that NCBAMP had a success incoprating a citizen science approach into the data collection. For the long term success of a wildlife monitoring program, the public outreach and support are enssential. Therefore, we decided to continue the ciziten science approach when merging two programs.

In the fall of 2018, Dr. Han Li started working with various groups within WRC to merge two programs. The summer of 2019 marked the first successful season in which at least half of

the NCBAMP transects were merged into NABat grid cells and most transects were driven by volunteers. The following key events have occurred in the process of merging two programs.

1. Re-mapping NCBAMP transects into NABat grid cells. The transect design for NCBAMP is different from NABat in term of the spatial layout. NABat uses a 10 km by 10 km grid cell design for each transect, whereas a NCBAMP transect usually overlaps with two to three NABat grid cells. Therefore, if a NCBAMP transect generally overlaps with an existing NABat transect, only the NABat transect is kept. Among 32 original NCBAMP transects, 5 were removed because of the overlapping between two programs. Before the summer of 2019, 9 NCBAMP transects were trimmed and rearranged to fit into a NABat grid cell.
2. Re-distribute sampling efforts. Previously several local/tribal agencies (such as Eastern Band of Cherokee Indians, Blue Ridge Parkway, several NC state parks) used NCBAMP transects for local inventory purposes. For these agencies, the original NCBAMP transects have been kept for the 2019 summer season. The conversion of those NCBAMP transects will be accomplished in a case by case manner in the next grant between 2019 and 2021, depending on each agency's needs.
3. Working with WRC education specialists to recruit and train volunteers. Between the fall of 2018 and the 2019 summer season, Dr. Han Li had 5 meetings with WRC education specialists to develop plans to recruit volunteers statewide for the 2019 summer season. The overarching plan is to use WRC education regions (Northern Mountain, Southern Mountain, Northern Piedmont, Southern Piedmont, Northern Coast, Southern Coast) to divide equipment and management efforts. Each region has a set of transects, its own equipment, and a leader/WRC education specialist for volunteer recruitment and training.
4. Solving equipment challenges. Previously AnaBat SD2 has been used as the detector for both programs. The detector itself is expensive and requires some specific knowledge to operate. Additionally, the detector only provides real time audio feedbacks to surveyors and is hard for education purposes. To solve these challenges, Wildlife Acoustics EchoMeter Touch 2 has been selected as the new detector for the mobile survey. New training materials have been developed for this change.

The merging of NABat and NCBAMP mobile transect programs will continue for the next two summer seasons. It will be a complete citizen science program, reaching out to near 100 individuals each summer. The next steps will focus on building in flexibilities (including transect, equipment, training, etc.) for each education specialist at WRC. Products generated for this effort are stored at https://sites.google.com/view/nabat/home.

Management recommendations for mobile transect surveys

Before merging NABat and NCBAMP, about 50% NABat mobile transects were conducted by UNCG bat biologists. All NCBAMP volunteer recruitment and training were conducted by WRC biologists. Even though both programs had success, the large potential of public engagement and education was not reached. By collaborating with WRC education specialists, in the next two years a new citizen science program will be fully developed. In the pilot season of 2019 summer, we saw an increase of volunteers involved. Over 50 volunteers expressed interests in the program and attended the corresponding education sessions. A total of 30 transects across the state were surveyed by volunteers. For the future implementation, we recommend that professional bat biologists should still be responsible for managing and

analyzing acoustic data and presenting scientific knowledge to volunteers. The bat detectors should be calibrated by professionals before each summer season.

NABat stationary surveys

One main effort within NABat, which complements the mobile transect survey is the stationary point survey. Between 2015 and 2018, we selected 57 NABat grid cells within North Carolina based on accessibility and other logistic constraints for the stationary point survey (Figure 13). Totally we developed 161 sites to select from. Among these sites, 36 sites are in counties (16 counties total) where WNS has been found/suspected. Each summer season we maintained the sampling effort between 80 – 120 sites, 35 – 45 grid cells. The stationary point survey require specific knowledge to set up a detector. Each season a site must be re-evaluated for suitability for acoustic monitoring. Therefore, this monitoring effort has been mainly accomplished by bat biologists at UNCG. About 10% stationary point surveys have been conducted by professionally trained biologists.

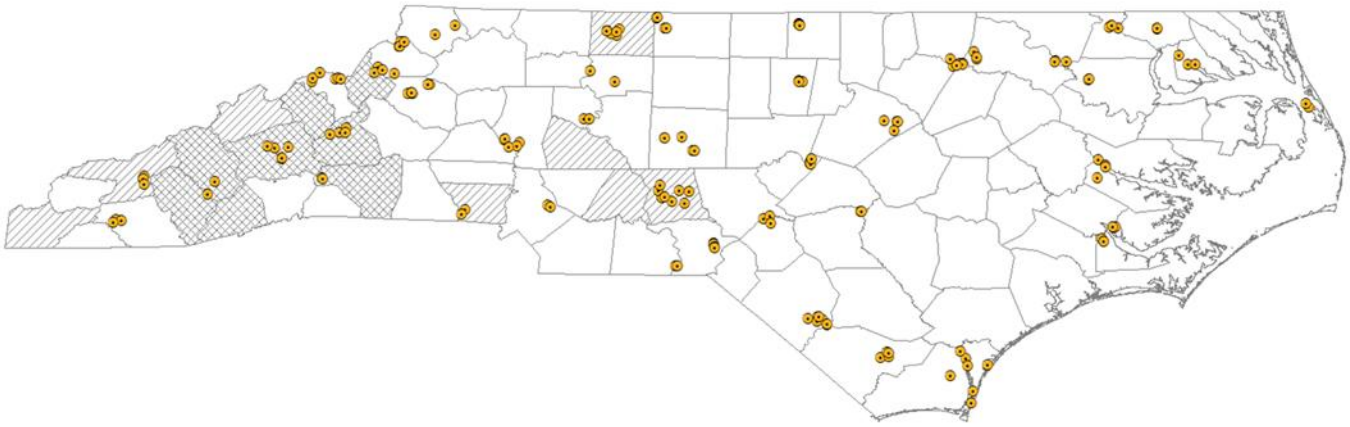

Figure 13 NABat stationary survey sites in NC, shading indicates counties with WNS

The stationary point survey, when conducted at appropriate sites, has the capacity to detect all species in NC, except for the seminal bat, which cannot be distinguished acoustically from the red bat. Therefore, the stationary point survey has been used strategically to monitor unique habitats for rare SGCN species. The data generated from the stationary point survey are suitable to estimate species specific occupancy. We have focused on three species, little brown, northern long-eared, and tricolored bats that have been heavily impacted by WNS. With 2015-2017 data, it is estimated that statewide the occupancy probabilities for NABat grid cells were on average 0.833, 0.696, and 0.315 for PESU, MYLU, and MYSE respectively. The PESU occupancy is relatively the same across three regions in NC (Figure 14), except for areas that have been developed for human settlements. In contrast, both MYLU (Figure 15) and MYSE (Figure 16) occupancies showed disconnect patterns with significantly low occupancy in the Piedmont.

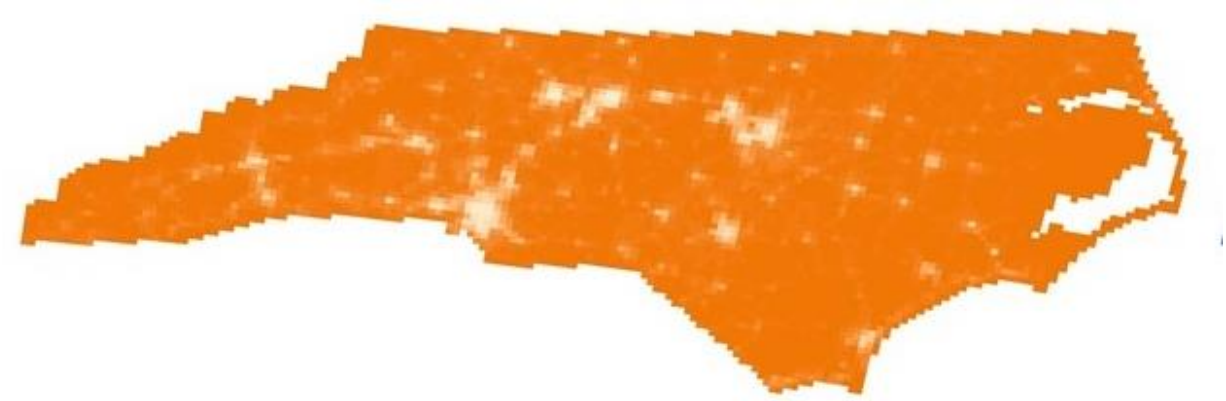

Figure 14 PESU occupancy estimated by 2015-2018 NABat stationary point surveys

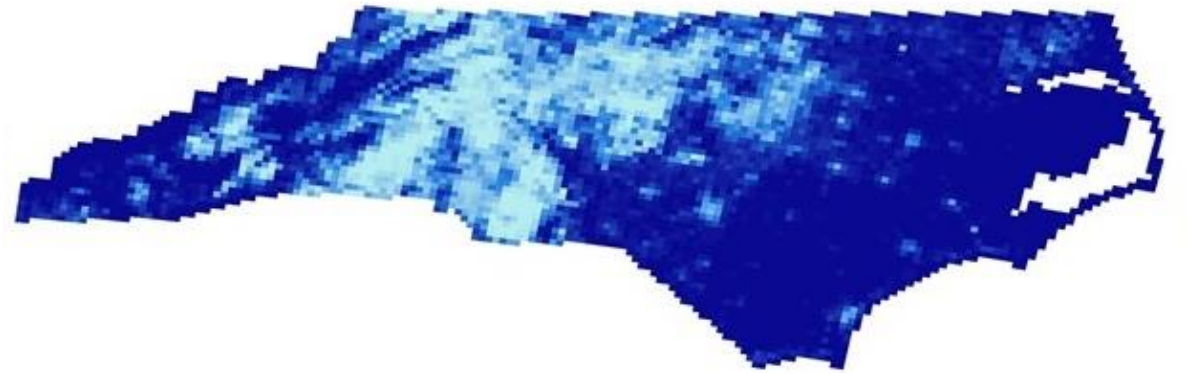

Figure 15 MYLU occupancy estimated by 2015-2018 NABat stationary point surveys

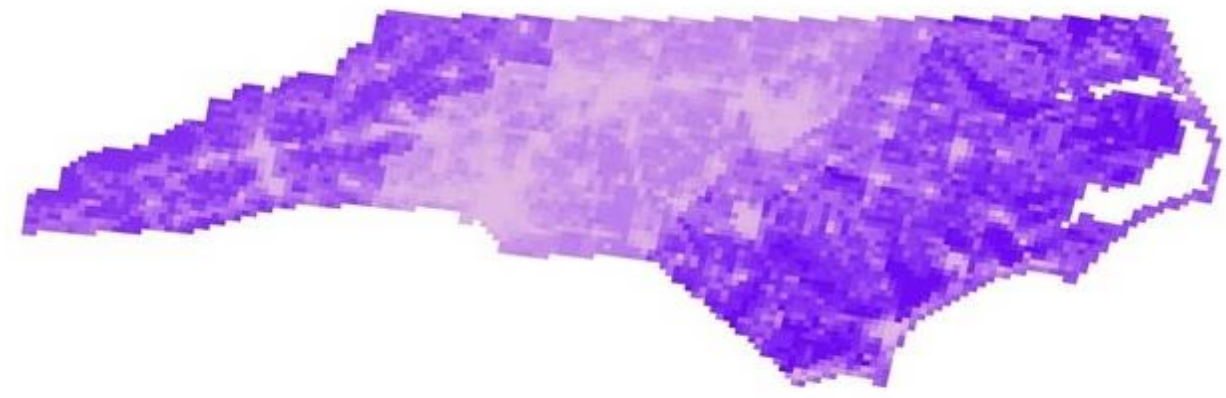

Figure 16 MYSE occupancy estimated by 2015-2018 NABat stationary point surveys

The stationary survey also indicated important local sites for species with limited distributions in NC. By overlaying sites with rare species detections and publicly owned properties, we identified the following species hotspots (Figure 17).

1. North River Game Land, Merchant Millpond State Park, Chowan Swamp Game Land – CORA, MYAU, MYSE, MYLU
2. Croatan National Forest, Neuse River Game Land – MYAU, MYSE, MYLU
3. Lake Waccamaw State Park, Columbus County Game Land, Lumber River State Park – CORA, MYAU, MYSE, MYLU
4. Wake County properties – MYAU, MYLU, MYSE
5. Uwharrie National Forest, Sandhills Game Land, Pee Dee River Game Land – MYLU
6. Hanging Rock State Park – MYGR, MYLU
7. New River State Park, Beech Mountain State Natural Area, Bear Paw State Natural Area, Elk Knob State Park, Elk Knob Game Land, Pisgah Game Land, Pisgah National Forest, Buffalo Cove Game Land – COTO, MYLU, MYLE, MYSE, MYGR,
8. Pisgah Game Land, Pisgah National Forest – MYLU, MYLE, MYSE, MYSO
9. Asheville, Blue Ridge Parkway, Chimney Rock State Park – MYLU, MYGR, MYSE
10. Nantahala national forest, Cold Mountain Game Land, Cherokee Nation – CORA, MYLU, MYGR, MYSE

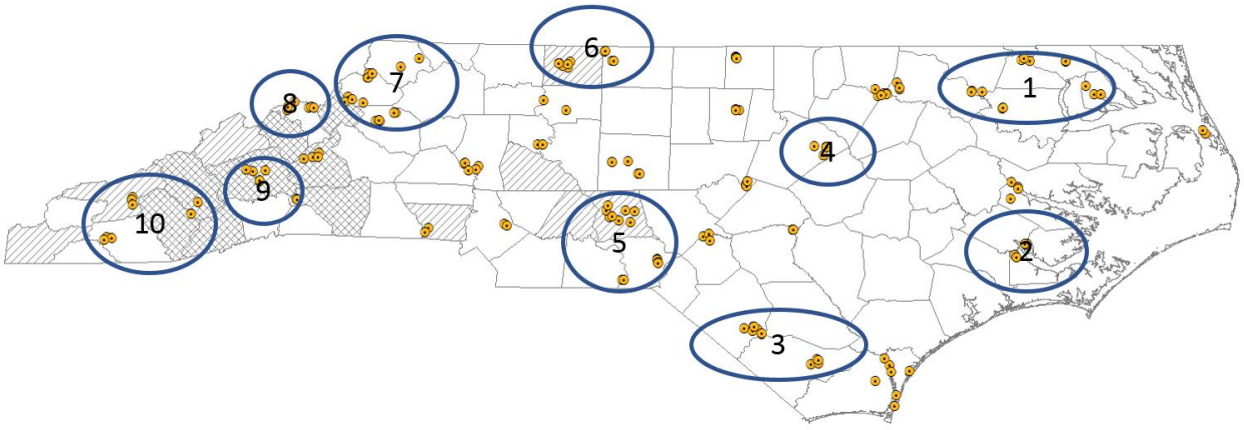

Figure 17 SGCN hotspots generated by 2015-2018 NABat stationary point surveys.

While it is important to maintain monitoring efforts at SGCN hotspots, it is also necessary to improve the understanding on if there are barriers that have caused species distribution gaps. For example, between hotspot 3 and 5, there is the loss of southeastern myotis and northern long-eared bats. Similarly, the distribution of Rafinesque's big-eared bats is disconnected. This map should also guide surveys between hotspots to clearly define the distribution edge of SGCN species.

Management recommendations for NABat stationary point surveys

By decoupling NABat stationary point surveys and mobile transect surveys, the fieldwork for each component becomes more logistically flexible. We recommend choosing 5 – 10 sites

within each SGCN hotspots to survey each summer with a total effort near 80 sites. Additionally, selectively choosing sites (both existing or new) between hotspots to better understand the species distribution boundary. A centrally located team is essential for making field season traveling feasible.

It is not recommended to involve citizen scientists/volunteers in the stationary point survey or add sites on privately owned properties. This is because the setup of a stationary point survey site is crucial to ensure the detection of SGCN species. Each site should be carefully examined by experienced bat biologists each season before the deployment of the bat detector. To ensure the consistency of a long-term monitoring effort, privately owned properties should be a low priority to survey unless there is a guaranteed access for at least 4 -5 years. Additionally, all bat detectors should be calibrated together before each summer season. All equipment should be planned for refurbishment every 5-7 years.

Integrating data at multiple scales

In the past five years, NABat and other acoustic monitoring efforts in NC have accumulated a large amount of data. With the development of the national NABat data base and involvements of citizen scientists, it is important to create a platform for communicating survey results and sharing data. Therefore, we started the process to integrate three databases, the NABat national database (hosted by USGS, Figure 18), the NABat NC volunteer website (Figure 19), and the NC bat database (hosted by UNCG, Figure 20).

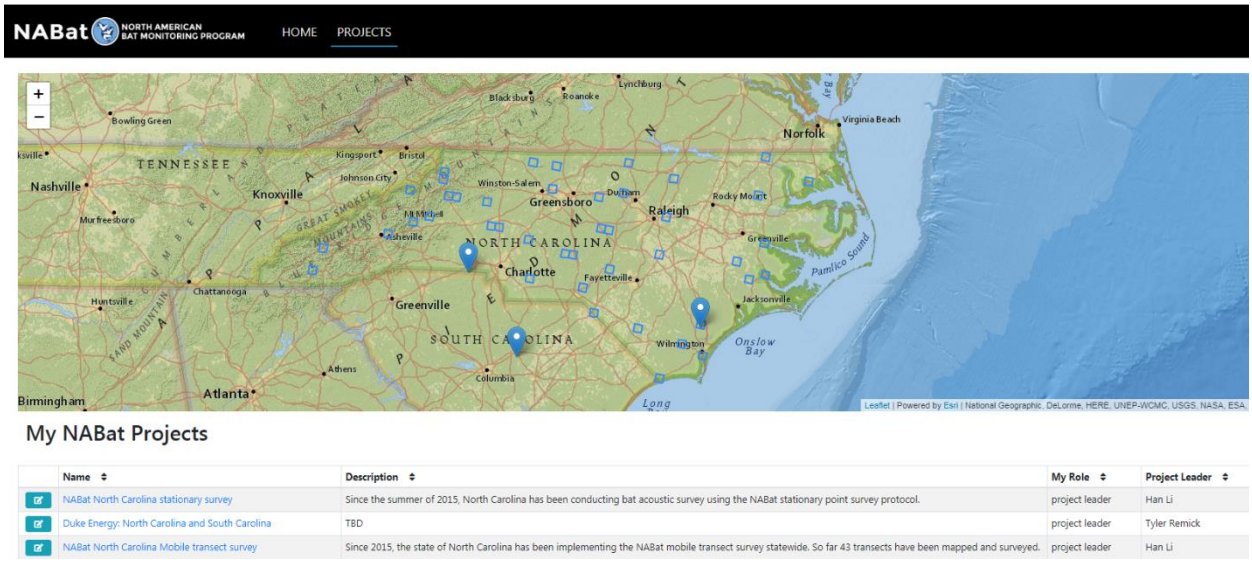

Figure 18 NABat national database showing NABat projects in NC

One goal of this effort is to improve NABat data storage. All NABat data have been stored in three copied on external hard drives. One copy is provided to WRC for storage. We are also actively uploading data to the national NABat database. By integrating these websites, volunteers in the citizen science program will be acknowledged for the contribution and impact they have made at a much broader scale. It will also provide feedbacks to the survey effort volunteers have accomplished. The UNCG website designed for professional bat biologists to share bat monitoring data and extract information from acoustic surveys to guide any local survey efforts.

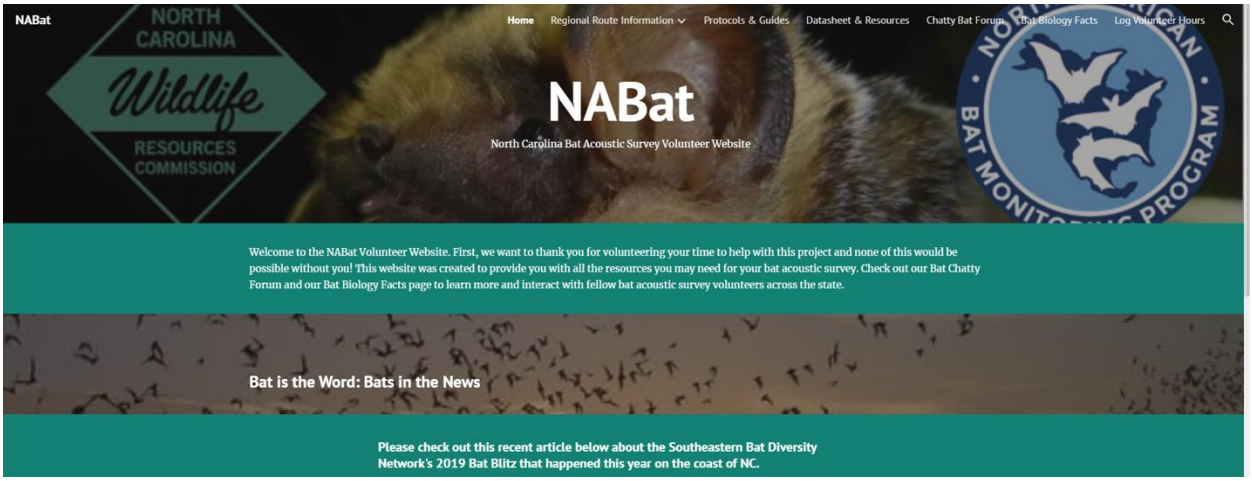

Figure 19 NABat NC citizen science program ***volunteer resource database***

Figure 20 Dr. Han Li's website hosted by UNCG serving at the intermediate database for professional bat biologists in NC

Next steps

The key next steps are: 1. Continue merging NCBAMP and NABat to ensure each education region have enough transects for different future scenarios; 2 improve the data

integration effort. The stationary survey will continue to improve the knowledge of SCGN species that cannot be well detected by the mobile transect survey. Additionally, findings based on NCBAMP 2011-2018 data are being summarized into a manuscript by the collaboration between Dr. Han Li and WRC biologists. The goal is to publish these findings to inform more bat biologists at a broader scale.

Major project equipment

A list of major equipment purchased is below:

Table 4 Equipment purchased for project

Item	Amount
AnaBat SD2 Bat Detector with Stainless Microphone	12
AnaBat Car mount with suction cup and 3m detachable cable	4
Additional stainless Microphone	4
Mouse GPS powered through USB port with an included AA battery pack	4
Water proof setup including: 1400 Pelican case configured for detector and 12 volt battery, internal cabling, 1 battery connector lead, 3m microphone extension cable, weather proof weather head with stainless microphone	12
AnaBat Equalizer - Chirper II, Jig, and Equalizer Software which electronically controls the detector and sets the sensitivity of the detectors	1
Battery Maintenance Kit with connectors that match those used in AnaBat Weather Proof Setups including: 12 volt 1.25 amp battery charger, volt meter (to measure and health), and 3 Y-connectors (to enable up to battery voltage 4 batteries at once)	3
12 Volt 7.5 Amp Sealed Lead Acid Battery	24
Battery Connector to Power Lead	8
Tripod Mount	4
T- Post Mounting Bracket	2
Belt and Ratchet Mounting Bracket	5
Dual Angle Weather Head Mount to attach to poles: 1 inch	5
Python Lock by Master Lock	16
Solid brass padlock	12

Oral presentations given between 2017-2019 based on this project

*Bold highlighted presenters

1. H. Li, K. A. Parker, and **M. C. Kalcounis-Rueppell**. The luxury effect beyond cities: bats respond to socioeconomic variation across landscapes. North American Society for Bat Research (NASBR) annual conference, Kalamazoo, MI, 2019
2. **H. Li**, K. A. Parker, and M. C. Kalcounis-Rueppell. The luxury effect beyond cities: bats respond to socioeconomic variation across landscapes. International urban wildlife conference, Portland, OR, 2019
3. **H. Li**, K. A. Parker, and M. C. Kalcounis-Rueppell. Urbanization exacerbates the decline of white-nose syndrome affected bat species. International urban wildlife conference, Portland, OR, 2019
4. **H. Li**, K. A. Parker, and M. C. Kalcounis-Rueppell. The luxury effect beyond cities: bats respond to socioeconomic variation across landscapes. The 24th annual meeting of the southeastern bat diversity network and the 29th annual colloquium on the conservation of mammals in the southeastern US, Jacksonville, Florida, 2019
5. H. Li, K. A. Parker, and **M. C. Kalcounis-Rueppell**. Acoustic monitoring of federal endangered or threatened bat species in North Carolina. The Wildlife Society North Carolina Chapter career workshop, Southern Pine, North Carolina, 2018
6. H. Li, K. A. Parker, and **M. C. Kalcounis-Rueppell**. Conservation actions are needed for both acute and chronic threats to North American bats. North American Society for Bat Research (NASBR) annual conference, Puerto Vallarta, Mexico, 2018
7. **H. Li**, K. A. Parker, and M. C. Kalcounis-Rueppell. White-nose syndrome management and protection of critical habitats are both important for bat conservation. The 25th annual The Wildlife Society (TWS) conference, Cleveland, Ohio, 2018 (video available to TWS members at: https://tws.sclivelearningcenter.com/MVSite/MVVideo.aspx?SessionID=239171&presentationID=123173)
8. **K. A. Parker**, H. Li, and M. C. Kalcounis-Rueppell. Species-specific low-temperature thresholds for bat activity in North Carolina. The North Carolina chapter of The Wildlife Society annual meeting. Haw River, North Carolina, 2018
9. **K. A. Parker**, H. Li, and M. C. Kalcounis-Rueppell. Species-specific low-temperature thresholds for bat activity in North Carolina. Joint bat working group meeting, Roanoke, Virginia, 2018
10. **H. Li** and M. C. Kalcounis-Rueppell. Threshold patterns in the effect of residential urbanization on bat diversity. North American Society for Bat Research (NASBR) annual conference, Knoxville, Tennessee, 2017
11. **K. A. Parker**, H. Li, and M. C. Kalcounis-Rueppell. Species-specific probability of winter activity across a temperature gradient in bats. North American Society for Bat Research (NASBR) annual conference, Knoxville, Tennessee, 2017
12. **K. Caldwell**, H. Li, K. Parker, G. Graeter, K.k Weeks, and M. C. Kalcounis-Rueppell.

Community compositional changes observed in bat field surveys since white-nose syndrome arrived in North Carolina. North American Society for Bat Research (NASBR) annual conference, Knoxville, Tennessee, 2017

13. H. Li and **M. C. Kalcounis-Rueppell**. Separating the effects of water quality and urbanization on temperate insectivorous bats at the landscape scale. North American Society for Bat Research (NASBR) annual conference, Knoxville, Tennessee, 2017
14. **K. A. Parker**, H. Li, and M. C. Kalcounis-Rueppell. Examining the effectiveness of the North American Bat Monitoring Program (NABat) acoustic survey protocols. The 24th annual The Wildlife Society (TWS) conference, Albuquerque, New Mexico, 2017
15. **H. Li** and M. C. Kalcounis-Rueppell. Threshold patterns in urbanization's effects on bat soundscape. International urban wildlife conference, San Diego, California, 2017

Publications based on this project

- Li H. and M. C. Kalcounis-Rueppell. 2018. Separating the effects of water quality and urbanization on temperate insectivorous bats at the landscape scale. *Ecology and Evolution*, 2018(8):667–678. DOI:10.1002/ece3.3693
- Li H., K. A. Parker, and M. C. Kalcounis-Rueppell. 2019. The luxury effect beyond cities: bats respond to socioeconomic variation across landscapes. *BMC Ecology* 19, 46 (2019) doi:10.1186/s12898-019-0262-8
- Parker K. A., H. Li, and M. C. Kalcounis-Rueppell. Species-specific probability of winter activity across a temperature gradient in bats and its conservation implication. *Journal of Mammalogy* (accepted with major revision)
- Li H., K. A. Parker, and M. C. Kalcounis-Rueppell. Land cover change exacerbates the decline of white-nose syndrome affected bat species. *Remote Sensing in Ecology and Conservation* (in preparation)

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Acknowledgements

We sincerely thank the following organizations and indiciduals for the support and help for this project: National Park Service: Bob Cherry; US Army: Eric Britzke, Janice Patten; US Forest Service: Sheryl Bryan, Hugo Cobos, Susan Loeb, Deb Walker; US Fish and Wildlife Service: Susan Cameron, Laura Fogo, Michael Morse; US Geological Survey: Brian Reichert; Eastern Band of Cherokee Indians: Dallas Bradley, Caleb Hickman, Michael LaVoie, Josh Paris; NC Division of Parks and Recreation: Doug Blatny, Ed Corey; NC Wildlife Resources Commisson: David Allen, Allen Boynton, Katherine Caldwell, John Carpenter, Kacy Cook, Maria Dunn, Isaac Harrold, Allison Melford, William Ridgeway, Kendrick Weeks; Mecklenburg County: Catherine Luckenbaugh and fellow biologists; Wake County: Deborah Fowler; Salem College: Traci Porter; University of North Carolina Greensboro: Paul Hidalgo, Ashley Matteson, James Nelson, Omar Raya, Sadie Scott, Aaron Wagner; Highlands Biological Station/Western Carolina University: Chan Chandler, James Costa, Mike McMahan; Greensboro Science Center: Lindsey Zarecky; NC Aquarium: Peggy Sloan, Joanna Zazzali; NC Coastal Land Trust: Janice Allen, Jesica Blake; NC Museum of Natural Sciences: Stephanie Schuttler; NC Zoological Park: Nell Allen, Corinne Kendall, Melissa Vindigni; Duke Energy: Will Ricks; Titley Scientific: Kim Livengood, Chris Corben; Michelle Amato; Kory Armstrong; Barbara and Keith Bollman; Bob Bryden; Karen Curry; Laura Ellison; David and Cathy Fields; Ed and Liz Harris; Fritz and Renee McPhail; Bailey Morgan; Julia Nawrocki; Kevin and Gretchen Parker; Scott Perry; Lloyd Raleigh; Bryan and Cynthia Redd; Bradley Saul; Brandon Sherrill; Shane Staples; Emilie Travis; Garcy and Allison Ward; Stacey Weddle; Michael Whitby; Jim Willis; Tom and Mary Vann

Appendices

Appendix 1 – Abstracts (when applicable) of oral presentations given between 2017-2019 based on this project

Appendix 2 – Publications based on this project