Michigan Bat Monitoring Program—2016 Acoustic Report

A Report Submitted to the
Michigan Department of Natural Resources

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Summary

- The Organization for Bat Conservation (OBC) and the Michigan Department of Natural Resources (MDNR) partnered together to create objectives and goals for the Michigan Bat Monitoring Program.
- This was the inaugural year of the Michigan Bat Monitoring Program—a citizen-science based effort to monitor the state's bats via bioacoustics.
- There were nine survey routes conducted on 16 nights, in conjunction with seven regional partner organizations and 27 volunteers. Six surveys occurred in late July, seven throughout August, and one survey was conducted in early September.
- We recorded a total 761 bat passes, 668 of which were attributable to specific species or species groups. These included calls of 541 (81.0%) big brown/silver-haired bats, 108 (16.2%) eastern red bats, 14 (2.1%) hoary bats, 3 (0.4%) evening bats, and 2 (0.3%) little brown bats. The remaining calls were categorized as unidentified.
- This information is the beginning of a baseline against which future surveys can examine the impacts of new and ongoing threats, including climate change, invasive pathogens, and alternative energy development, as well as more traditional forms of habitat loss.

Introduction

Bats in Michigan

Bats are unique and important animals—they are the only mammals in the world that can fly, and they provide ecological and economic benefits to humans. All bats in the Midwestern United States eat insects. A single bat can eat thousands of insects each night. Many of these pests include crop-damaging pests that harm forests and farms. Nine species of bat occur in Michigan (Kurta, 2008). These include the big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), red bat (*Lasiurus borealis*), hoary bat (*Lasiurus* or *Aeorestes cinereus*; Baird et al., 2015), Indiana bat (*Myotis sodalis*), little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), evening bat (*Nycticeius humeralis*), and tri-colored bat (*Perimyotis subflavus*).

Populations of bats are vulnerable to decline because of low reproductive rates, and many species assemble at a limited number of locations due to a variety of threats that cause habitat loss. The Indiana bat is the only mammal in Michigan listed as an endangered species by the U.S. Fish and Wildlife Service (USFWS, 2007). However, since 2014, a destructive disease called white-nose syndrome (WNS), has caused drastic declines of additional species of bats in Michigan, highlighting the importance of immediate monitoring efforts (U.S. Fish and Wildlife Service, 2011). Consequently, the USFWS recently (2015) listed the northern long-eared bat as a threatened species, and will be making a listing recommendation regarding the eastern subspecies of the little brown bat (*M. l. lucifugus*) in Fiscal Year 2023. Both of these actions result from the effects of WNS on bats elsewhere in the eastern U.S. (Warnecke et al., 2012), where the disease has been impacting some populations since 2006. In addition to the species with actual or proposed federal status, the evening bat is currently classified as threatened at the state level, and the tri-colored bat is listed as a species of "special concern" by the Michigan Department of Natural Resources (MDNR; 2013a, 2013b). Wind power projects in Michigan and other states may also have a negative impact on populations, primarily long-distance migratory species that do not hibernate in caves and thus are not affected by WNS. High numbers of silver-haired bats, eastern red bats, and hoary bats have been found dead at wind farms (Arnett et al., 2008; Kunz et al., 2007a, 2007b), and these species were previously included as "species of greatest conservation need" in the state's Wildlife Action Plan. Thus, eight of the nine species of bat in Michigan are a cause for concern by conservationists and natural resource managers. Finally, climate change presents an increasingly looming threat, which may cause shifts in populations and community composition of bats over time.

To better understand the effects of these impacts on bat populations, it is imperative to gather baseline population, community composition, and distribution information regarding Michigan's bats, allowing us to evaluate spatial and temporal trends. Lack of such basic data is one of the greatest limitations to conservation managers. The Michigan Bat Monitoring Program was created to monitor the statewide distribution and relative abundance of bats in their summer range using bioacoustics. Bats maneuver through their environment and detect prey using echolocation, a process in which they emit high-frequency, ultrasonic sound waves typically above the range of human hearing. If the waves strike an object, a reflected wave is created that returns the sound to the bat. Advances in technology have led to equipment that can record species-specific echolocation calls. Specialized equipment is used to record bat echolocation calls, allowing citizen scientists to both hear and see these calls.

Objectives

- Foster awareness and appreciation of Michigan's bats by increasing the visibility of these difficult-to-observe animals to the public.
- Increase our knowledge of Michigan's bats by documenting population levels, relative abundance of species within communities, and distributions of species within the state.

Principle investigators

Giorgia Auteri, Citizen Science Coordinator for OBC, is a bat biologist, author, and educator. She has over five years of experience working with bats, including various acoustic and live-capture methods. Giorgia conducted research for her master's thesis regarding bat behavior and ecology at Eastern Michigan University, and is currently a doctoral student at the University of Michigan, where she is pursuing research on evolutionary ecology of bats.

Giorgia is active in the North American Society for Bat Research, American Institute of Biological Sciences, American Society of Mammalogists, Citizen Science Association, National Speleological Society, and Michigan Academy of Sciences. Her experience working with bats spans the private and public sectors, including work for state, tribal, academic, non-profit, and environmental consulting organizations.

Rob Mies, Executive Director and co-founder of OBC, is a bat ecologist, author, and conservation spokesperson. Over the past 25 years, Rob has appeared on many television shows promoting awareness of bat conservation. These shows include The Doctors, The Tonight Show, The Ellen DeGeneres Show, The Today Show, Live with Regis and Kelly, Late Night with Conan O'Brien, Fox & Friends, CBS Early Show, and Martha Stewart. Rob is the Chairman of the Michigan Bat Working Group, President of the Midwest Bat Working Group, and Coordinator of the North American Bat Conservation Alliance. He is an advisor and member of the American Zoological Association Bat Taxon Advisory Group, North American Society of Bat Researchers, Association of Nature Center Administrators, Michigan Wind and Wildlife Advisory Group, and the white-nose syndrome Communications Working Group.

Methods

Volunteer coordination

To facilitate selection of safe, effective routes for driving acoustic surveys, OBC relied on coordinators at Regional Partner Organizations (RPOs). Due to a shifted project timeline which made it difficult to complete surveys before the end of July, OBC reached out to reliable organizations with which a previous working relationship existed. These regional leaders were able to identify transects which could safely be driven at reduced speeds, and were also adeptly suited to coordinate community volunteer efforts.

After partners were identified, OBC provided RPO colleagues with training on equipment use and survey protocols, and provided guidance on route development. Instructional materials included documents providing an equipment overview (Fig. 1), safety suggestions for volunteers (Fig. 2), a list of survey steps (Fig. 3), and datasheets to be filled out with each survey (Fig. 4). OBC also developed and shared an online video tutorial (http://go.savebats.org/2abRJG8; Fig. 5). The video showed all steps involved in starting a survey—from first removing equipment from the box, to attaching equipment to a vehicle, to operation of associated software. Point-people at RPOs were then free to conduct surveys themselves, or pass training material on to other local volunteers.

After completing surveys, RPOs were provided with shipping labels to return monitoring equipment and datasheets to OBC. Poor retention of volunteers is too often a plague of citizen-science projects. It is our hope that these RPOs will help facilitate continuity of routes for years to come, and provide a source of institutional memory and expertise.

Route selection and protocol

To begin developing a baseline of acoustic data in the state, emphasis was placed on obtaining wide-ranging geographic coverage. Ultimately, survey locations at a broad scale were dictated by the availability of volunteers. Routes in a variety of land cover/use categories were selected, in an effort to sample a variety of habitat types, levels of urbanization, and regions of the state. We did not specifically target areas of presumably high quality habitat.

Route paths at the local scale were determined by colleagues at RPOs, who were asked to develop a route 20–30 miles in length and which could be driven safely at a maximum speed of 20 miles per hour. Volunteers were asked to start their surveys roughly 30 minutes after sunset, as well as to avoid surveying if rain, strong winds, fog, or temperatures below 50° F (Fig. 3). These weather parameters, in addition to an estimate of percent cloud cover, were recorded at the start and end of each survey (Fig. 4).

Acoustic monitoring

The OBC was provided with all hardware by the MDNR, and in turn provided guidance on equipment operation and survey protocol to RPOs. Each set of survey gear consisted of a detector to be attached to the roof of a vehicle, and which was connected to a recording/display device inside the vehicle via a cord running through the passenger window. Specifically, provided equipment consisted of:

- Echo Meter Touch (EMT; Wildlife Acoustics, Inc., Maynard, MA)
- IPad Mini 2 (Apple Inc., Cupertino, CA) with Echo Meter Touch Bat Detector App (Wildlife Acoustics, Inc., Maynard, MA)
- Protective case for IPad (Griffin Technology, Nashville, TN)
- Six-foot extension cable (to connect EMT recorder to IPad; CableJive, Malden, MA)
- Garmin Glo external GPS unit (Garmin International, Inc., Olathe, KS)
- Gaffer's tape for attaching EMT unit to roof of car, while also preventing damage to vehicles
- Styrofoam to place between EMT unit and roof of car (assists with reduction of noise from vibration)

EMT units are often used by hobbyist bat enthusiasts because the detectors are cost-effective, compact, and provide an attractive visual display of calls. However, there is no means to standardize the units via calibration. In lieu of being able to formally tune recorders, OBC staff performed simultaneous testing of units prior to sending out equipment (Fig. 6). Ten EMT units at a time were attached to the vehicle roof and an abbreviated version of a survey was performed. The calls recorded were compared among units to detect whether there were differences in detection ability of various units, and allow biologists to quantify those potential differences. Call files were stored internally on the IPad Mini 2.

Volunteers conducted surveys in a similar manner to our testing efforts, except using only a single unit at a time. The microphone of the detector was placed on a piece of Styrofoam before being mounted on the vehicle roof (Fig. 5), which helped to both reduce noise from vibrations of the vehicle, and minimize the recording of reflected echolocation pulses from the roof of the vehicle. Gaffer’s tape was used to affix the microphone, Styrofoam, and the extension cable to the vehicle roof. The extension cable ran through the open passenger window of the vehicle, to the IPad Mini 2 inside the vehicle. The IPad allowed non-driving volunteers to view echolocation calls of bats and monitor equipment. The Garmin Glo

GPS unit was paired with the rest of the equipment, and allowed each recorded call to be tagged with its corresponding coordinates.

Acoustic analyses

Echolocation calls of bats are often distinctive and species-specific, like birdsongs, and can be used to identify members of individual species or species groups that are flying past in the dark (O'Farrell et al., 1999). Number of acoustic recordings is often used as an index for level of activity (e.g., Tibbels and Kurta, 2003). However, acoustic recordings cannot be used to reliably estimate population size in a specific area—there is no way to determine whether a single individual, or five different bats made the calls that were recorded. Sounds may also be recorded which are not issued from bats at all, for example ultrasonic sounds of rustling leaves or wind. To counter this, downloaded files from each unit were first subjected to a simple, automated noise filter. This filter separates files containing structured bat calls from those that contain only unorganized ultrasonic sounds.

Even after filtering out interfering sounds, species identification of bats via recorded calls is more prone to error than classifications based on direct observations. To help mitigate this, we developed a conservative approach to identification which required agreement of multiple methods before a final species designation was given. Three separate identification methods were used, and a final identification was assigned only if at least two agreed. Two of these methods were quantitative and relied exclusively on automated identifications, the third was qualitative and consisted of the primary author, who has five years of experience working with calls of bats, visually inspecting each call using AnalookW (Titley Electronics, New Ballina Australia). Both quantitative software programs are currently approved by the USFWS: Kaleidoscope (Wildlife Acoustics, Inc., Version 4.0.0) and Echoclass (Eric Britzke, ERDC, Version 3.1). These methods use parameters such as pulse duration, minimum frequency, interpulse interval, and shape of the frequency-versus-time curve to characterize calls (Tibbels and Kurta, 2003; O'Farrell et al., 1999).

We attempted to assign a species-specific identification in almost all cases. However, calls of the silver-haired bat and big brown bat are quite alike (Betts, 1998), and no effort was made to separate these species acoustically. Similarly, files often contain sounds made by bats that are not suitable for identification. As opposed to search-phase calls, these files consist of only feeding buzzes, social calls, and calls that are fragmented or otherwise not clearly recorded. These poor quality recordings can be due to distance of the bat from the detector, the animal's orientation to the unit, or increased Doppler Effect, which is associated with recordings obtained from driving surveys. These files, nevertheless, are useful in quantifying overall levels of bat activity, so we cataloged such calls as "unidentified."

We quantified species richness, evenness, and diversity for each site using the total number of calls attributed to each species. We calculated Simpson's Index of Diversity, $1 - [\frac{\sum n(n-1)}{N(N-1)}]$, where n represents the species-specific total for each route, and N is the total number of calls attributed to all species. This index, which takes into account species abundance and evenness, ranges from 0–1, with 1 representing the greatest possible diversity. Evenness also ranges from 0–1, and was calculated as the ratio of observed diversity to maximum possible diversity (Brower and Zar, 1984).

To examine mean calls per unit of survey effort, we tallied calls of each species by ten-minute intervals. To help account for variability in reporting of survey start times, and allow us to examine data where volunteers did not explicitly report a start time, we used the times of first-recorded call as the start for our ten-minute bins for each survey. While this method may slightly inflate mean number of calls, its effect will likely be minimal and will allow us to include data from additional survey routes.

Results

Volunteer coordination

OBC received equipment from the MDNR in early July, reached out to potential RPOs in mid-July, and was able to provide training materials and equipment to RPOs in late July. These seven RPOs included Blandford Nature Center, Crosswinds Marsh, the Dahlem Conservancy, Grand Traverse Regional Land Conservancy, Huron County Nature Center, Little Traverse Conservancy, and Saginaw Valley State University. Two OBC staff members also volunteered their time and each conducted a survey route. Volunteers were asked to attempt a survey route in the few remaining days of July, but also invited to conduct surveys through August and early September in an attempt to document activity of bats during periods of swarming and migration. Equipment containing recordings of calls, datasheets, and information on routes were all returned to OBC by mid-September. While most recording units were returned with data on them, two units did not have data (presumably due to either equipment or user error). Several solutions to this error rate are presented in the Discussion.

Survey routes

Nine survey routes were sampled. These were located throughout the southern and central Lower Michigan, with the exception of one route in the Eastern Upper Peninsula (Map 1). Survey paths transected a variety of ecosystem types, which we determined by looking at U.S. Environmental Protection Agency (EPA) Level IV Ecoregions (Omernik and Gallant, 1988; last evaluated for our study area in 2011; Map 2). These included three routes in the Interlobate Dead Ice Moraines, and one route each in the Battle Creek/Elkart Outwash, Lake Michigan Moraines, Saginaw Lake Plain, Tawas Lake Plain, Rudyard Clay Plain, and Manistee-Leelanau Shore (Table 1). We also examined route locations in relation to urban areas, and found that for five routes at least a moderate portion fell inside a designated urban boundary (Map 3). Similarly, many of the routes were not in heavily forested regions of the state (U.S. Forest Service Forest Inventory Analysis and Forest Health Monitoring Programs; data derived from 2002 and 2003 growing seasons; Map 4). According to remote sensory data, forest types along our survey paths included Aspen, Hard Maple/Basswood, Northern White-cedar, Red Pine, and White Oak/Red Oak/Hickory forests.

These nine routes were sampled, collectively, on 16 total nights. Total hours surveyed were 22.6, and ranged from 0.3 to 2.3 hours with a mean survey length of 1.6 hours. Surveys occurred between July 21st and September 2nd of 2016, with routes driven one to three times. Six surveys occurred in July, seven in August, and one in September. While two units were returned without data, a total of nine survey routes were still achieved because one RPO did routes in two geographically disparate locations, and data from OBC trial efforts were included as a ninth route. The latter explains the unusual nature of Route 09, which was by far the briefest survey (roughly 20 minutes). Without this route, total length of accumulated surveys was 22.3 hours (mean 1.7 hours ± SD 0.32), and ranged from 1.14 to 2.3 hours. Dates and durations of each survey are displayed in Table 2. Maps 5–12 depict survey routes, although displayed route paths are sometimes estimates to accommodate variation in routes that were driven multiple times and some uncertainties associated with route reporting.

Starting temperature ranged between 69–80 °F (mean 72.7 $\pm$ SD 3.5 °F), and ending temperature ranged between 63–77 °F (mean 69.3 $\pm$ SD 4.2 °F). No rain, fog, or wind greater than a gentle breeze was reported during any of the surveys. Cloud cover ranged from 99–0% (mean 37.6 $\pm$ SD 31.8).

Acoustic recordings

During equipment testing, some differences in strength (or "loudness") of call recording were observed, but there were no differences in number of calls attributed to each species per EMT unit. This is after the exclusion of two units that appeared to be frequently freezing and functioning abnormally. Additional troubleshooting on these units will determine if they can be sent to citizen scientists during the next survey period.

A total of 2,815 files (74%) contained only noise, whereas 991 (26%) contained sounds possibly made by bats. This is a somewhat higher ratio of "noisy" calls than what is typical for an acoustic survey, but may be partially attributed to vehicle noise. Our three identification methods—Kaleidoscope, Echoclass, and manual vetting—yielded differing results (Table 3). Kaleidoscope was the least conservative of these methods, assigning 100% of filtered files to a species-specific group. Echoclass identified 62% (616 files), and visual identification identified a select 49% of calls (485 files), marking the rest of files as either "unidentified" or additional "noise." A final call identification was assigned only if at least two methods agreed (after grouping calls of big brown and silver-haired bats). There was no agreement between any two of the methods for 229 files (23%). After removing these calls, we were left with 761 calls attributable to bats. Of these, Kaleidoscope and Echoclass agreed 60% of the time, Kaleidoscope and manual vetting agreed 62% of the time, and Echoclass and manual vetting agreed 40% of the time. In relation to agreement with the final call identification, contributions of each identification method were 87% agreement by

Kaleidoscope, 70% from manual vetting, and 60% from Echoclass. Table 3 shows calls attributed to each species via the different identification methods. There was consensus that 93 calls (12%) were issued by bats but were not identifiable to species ("unidentified"), and we excluded these from future analyses.

Of the 668 passes identified to species or species group, 541 (81.0%) were assigned to big brown/silver-haired bats, which were ubiquitous and recorded at all surveys (Fig. 7). They were followed by eastern red bats (108 calls, 16.2%) and hoary bats (14 calls, 2.1%), which were recorded at eight and six different sites, respectively. Evening bats (3 calls, 0.4%) and little brown bats (2 calls, 0.3%) were each detected at single, disparate sites. Images of calls attributed to little brown bats (recorded along Route 07 on July 28th; Fig. 8) and evening bats (recorded along Route 01 on July 31st; Fig. 9) are shown. Consequently, these two sites had the highest species richness (four). No fewer than two species were recorded at any site (for three sites). Evenness ranged from 0.26–0.73, and Simpson's Index of Diversity ranged from 0.18–0.50 (Table 4). Route 01 had the highest diversity, closely followed by Route 07.

Mean calls per ten-minute interval (± standard deviation) are included for each species for surveys in July and August (Table 2; Fig. 10; Fig. 11). By far the most active site was Route 02, with the highest absolute number final species identifications (229) and highest activity per unit effort (mean 1.6 ± SD 3.9 calls per ten-minute interval). This was due primarily to the preponderance of big brown/silver-haired calls recorded at the site in July (10.4 ± SD 4.7.) The most active site in August was Route 06 (1.3 ± SD 3.4 calls/ten-minute interval). While it is difficult to tell from our limited data, relative abundances at different sites appears to shift in August compared to July.

Discussion

Michigan's citizen-scientists

Despite delays in project timeline—and even uncertainty about whether equipment would arrive in time for summer surveys to be conducted in 2016—OBC was able to quickly coordinate volunteer efforts. Most RPOs were associated with nature centers, parks, biology departments at universities, and other organizations which were ecologically inclined and willing to quickly jump into a citizen-science project. We credit the successful completion of the 2016 survey season to the eager participation of these volunteers.

Most volunteers were able to effectively collect data, although two units were returned without data despite being taken out on survey efforts. Improvements to address this issue will include 1) altered guidance on equipment use, 2) increased connectivity/overlap among volunteers, and 3) modifications to survey reporting to help better pinpoint instances of missing data. Regarding the first point, a protocol step will be added prompting volunteers to occasionally check the EMT's recording log. This will empower volunteers to spot malfunctions in the field. If no files are being stored, this likely means they have not hit the "record" button. Additionally, next survey season we will be able to ship equipment to volunteers further in advance, allowing staff at RPOs more time to become familiar with the equipment, and for OBC staff to schedule in-person visits or remote video-conference calls to review survey protocols. These additional steps will likely be immensely useful, not just for avoiding errors, but also for obtaining higher quality and more uniform data.

To increase volunteer overlap, and therefore reduce user-errors, OBC will prioritize collaborations with previous RPOs and increase volunteer connectivity. Continued participation by preceding RPOs will both increase consistency of routes among years, decrease risk of usage errors as people become more familiar with the equipment over multiple years. Another goal is to increase connectivity of spatially disparate volunteer groups by creating a social media group for volunteers to communicate with each other. This will provide a sense of community, expose surveyors to questions they may not have thought to ask, and could be a useful way to poll volunteers regarding issues and concerns.

Finally, for the third point, OBC will make modifications to datasheets to help with internal identification of equipment issues. This will include sections asking volunteers to describe the bat activity they observed, to report starting and ending mileage, and a space to record whether there were any known temporal gaps in the survey period. This last item will also allow for routes to be developed which have "breaks" in them—e.g. for volunteers to briefly get on a highway or major road.

In the future we would like to reach out to a more diverse group of potential stakeholders, including local farm and 4H communities; groups in urban areas involved with renewal, reclamation, and urban gardening; and township groups, particularly in areas affected by WNS and wind development.

Michigan's bats

There is an inherent amount of uncertainty in identifying bats based solely on acoustic recordings. While agreement of multiple methods was a condition for assigning a final species identification to a call, our results should not be used to quantitatively compare different identification methods to each other. For example, due to differences in customizability, Echoclass evaluated calls based on a broader pool of species than was found in the area (e.g. we could not tell the software to not consider the gray bat). Additionally, automated programs may be subject to similar biases, and thus be more likely to validate each other or make similar errors.

Most of our surveys occurred in the central and southern Lower Peninsula, with the exception of one route in the eastern Upper Peninsula (Map 1). Not surprisingly, the community of bats we detected is similar to that in central and southern Lower Michigan as a whole—big brown bats represent 81% of captures in the entire region (Winhold and Kurta, 2008) and were 81% of the acoustic recordings which we identified as belonging to either the ubiquitous big brown bat or silver-haired bat, which is rarely captured during summer in the region. The big brown bat is a generalist species (Kurta and Baker, 1990) whose members often use manmade structures for rearing pups and hibernation. These bats are capable of foraging in a range of habitats, including woodlands, agricultural fields, and rivers and lakes. Beetles are a favorite food item of this species, and big brown bats may provide important pest-control services in Michigan's agricultural areas.

Eastern red bats were, not surprisingly, the second most commonly recorded species (16%). This matches expectations based on more historic observations in the region (12%) by Winhold and Kurta (2008) who provided evidence for a decrease in the abundance of red bats over the last few decades. However, other anecdotal accounts from the eastern U.S.

suggest increases in populations of this species. The hoary bat, a species similar to the red bat in roosting habits, is generally uncommon in southern Lower Michigan (0.7% of captures—Winhold and Kurta, 2008), so their infrequent documentation in our survey (2%) was expected. Both species are killed in high numbers at wind energy facilities, and widespread, consistent monitoring during both residency and migration will help monitor trends in these species.

Increasingly, members of the genus *Myotis* are of concern due to the detrimental effects of WNS on these species. Of the three members of this genus in the state, only one, the little brown bat, was detected during our survey efforts in 2016. Two calls of this species were recorded along Route 07 (Map 10). This route was in the central Lower Peninsula, within several miles of the coastline of Lake Michigan, in an area with moderate coverage of Aspen, Northern White-cedar, and Red Pine forests. We suspect the absence of calls attributed to this species along other survey routes is an artifact of distances to potential hibernacula, and is not necessarily indicative of declines due to WNS. Most routes were near the maximum distance these migratory animals would travel from suitable hibernation sites. Route 07, in contrast, is just northwest of Tippy Dam, a hibernacula for little brown, northern long-eared, and even, occasionally, Indiana bats. These results highlight the importance of increased survey efforts in the Upper Peninsula, northern Lower Peninsula, and southern edge of the state.

Evening bats, which are listed as threatened by the MDNR and only have a single documented breeding colony in the state (Munzer, 2008), were documented along Route 01 (Map 5), in Berrien County. Calls were recorded near the St. Joseph River near Buchanan, MI—a partially urban area in a matrix of Hard Maple/Basswood and White Oak / Red Oak / Hickory forest. One evening bat was previously documented in the county in 1969 (Kurta, 1982) along with a handful of other observed locations within the state (Map 13). These include an individual was captured via mist-net this past summer (2016) in the adjacent Cass County—directly east of Berrien County (unpublished report submitted to USFWS by Environmental Solutions and Innovations, Inc.). In recent years, there have been a handful of observations which indicate this species may be becoming more common, or expanding, at the northern edge of its range (e.g. Auteri and Kurta, 2015; Minnesota DNR, 2016;

Wisconsin DNR, 2016). Increased monitoring along the evening bat's range in Michigan could help biologists and natural resource managers better understand whether this species is shifting its range due to climate change, and identify potential impacts of this new addition on local communities of bats. A goal for the 2017 summer survey season is to add a route along the Huron River in Washtenaw County, where evidence suggests there may be an unidentified maternity colony of the species, which would represent the most northern breeding colony in the continent (Auteri and Kurta, 2015).

The tri-colored bat is an uncommon species in the state, which is considered of "special concern" by the MDNR (2013b). While no distinctive calls of this species were recorded during the 2016 survey period, circumstantial evidence suggests they are expanding in the state (Kurta et al., 2007). There have been occasional summer records (Map 14), and small hibernating populations are documented in Alpena, Berrien, and Manistee counties (Kurta et al., 2007; Slider and Kurta, 2011). Recently, a rabid individual was captured in August in Washtenaw County (Map 14; Brown and Kurta, 2013). Continued survey efforts could help quantify shifts in abundance of this species in in the Lower Peninsula. This species also starts foraging earlier in the night compared to other species, closer to sunset, and starting some survey efforts earlier may be one method to target this species.

Identifying regional trends

Routes were conducted over a relatively large extent of the state given the number of surveys that occurred. However, the limited nature of the data precludes our ability to formally analyze trends based on habitat parameters. We suspect that distance to hibernacula and latitudinal gradients may be important factors driving regional species diversity in the state, as suggested by the high diversity at routes 01 and 07. Future survey efforts may be able to quantify this effect. At the local scale, diversity may be influenced by distance to water, percent and type of forest cover, degree of urbanization or agricultural use, and ecotype, among other factors.

Moving forward, we would like to increase the geographic span of surveys in the state, as well as focus on adding routes that are in under-sampled ecoregions, are farther from urban areas, include more forested areas, and are closer to suitable hibernacula. Many of these goals would be met by adding routes in the western and central Upper Peninsula, as well as northern Lower Peninsula and Michigan's "thumb." We also suggest continued extension of survey efforts throughout August, as we did in 2016. It is important to understand activity of bats during the period of summer residency, but activity levels during fall mating/swarming and migration may be important for assessing impacts of WNS and wind-energy development.

It is our hope that future survey efforts will allow us to identify changes in overall bat activity in the state in response to WNS, climate change, and development of wind energy. We have developed tentative hypotheses and predictions specific to each of these threats:

- WNS has already measurably reduced population levels in many of Michigan's hibernacula from when it was first detected in the winter of 2013/14. As WNS continues to affect the state's bats, we expect that these declines will also become evident during periods of summer residency and autumn swarming, as evidenced by fewer absolute detections per unit of survey effort. If this disease is the strongest agent of population declines in the state, we predict declines in relative abundance of affected species (mainly, the little brown bat, northern long-eared bat, and big brown bat) in coming years. We also predict observable range contractions within the state of members of the genus *Myotis*, which do not hibernate in manmade structures, as these weakened individuals have less energy to invest in regional migrations away from their winter hibernation sites.
- Climate change is expected to disproportionately affect some forest types and ecoregions in Michigan more than others (Handler et al., 2013), as well as to generally push the upper bounds of species ranges farther north. To this effect, we predict that over future years, community composition of bats will shift relatively more in sensitive forest communities and ecoregions. We further predict that the range of the evening bat, which is currently limited to the southern two rows of counties in the state, will expand farther northward, and that individuals of this species will more frequently be encountered in the

state. Finally, the eastern small-footed bat (*Myotis leibii*), which has never been documented in Michigan, may eventually expand into the state either via the eastern Upper Peninsula or southeastern Lower Michigan.

- Wind energy facilities kill many more bats compared to birds. Among bats, long-distance migratory species (the eastern red bat, hoary bat, and silver-haired bat) are disproportionately affected. We would expect to see declines in observations of these species per unit of sampling effort, perhaps inversely related to the degree of wind energy development in the state, and which may be more evident during fall migration, when most individuals are killed.

Interplay of these multiple, simultaneous threats will likely confound our observations. Careful thought will have to be put into how concurrent threats would impact discernable activity levels of bats, as well as to how persistent, background levels of habitat loss would be manifested in the data. One thing is certain—now, more than ever, Michigan's citizen scientists are needed help us understand how to protect these amazing animals.

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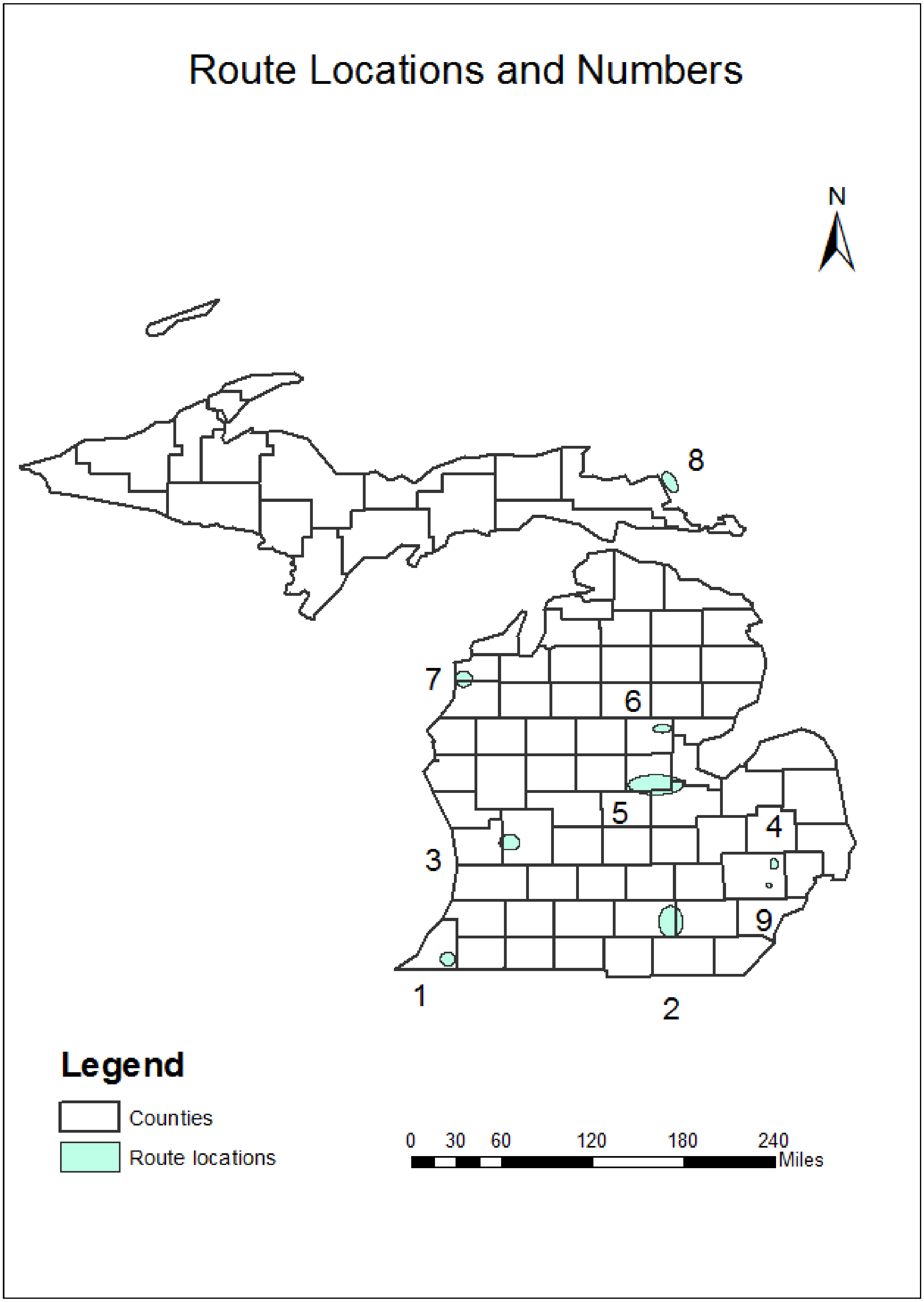
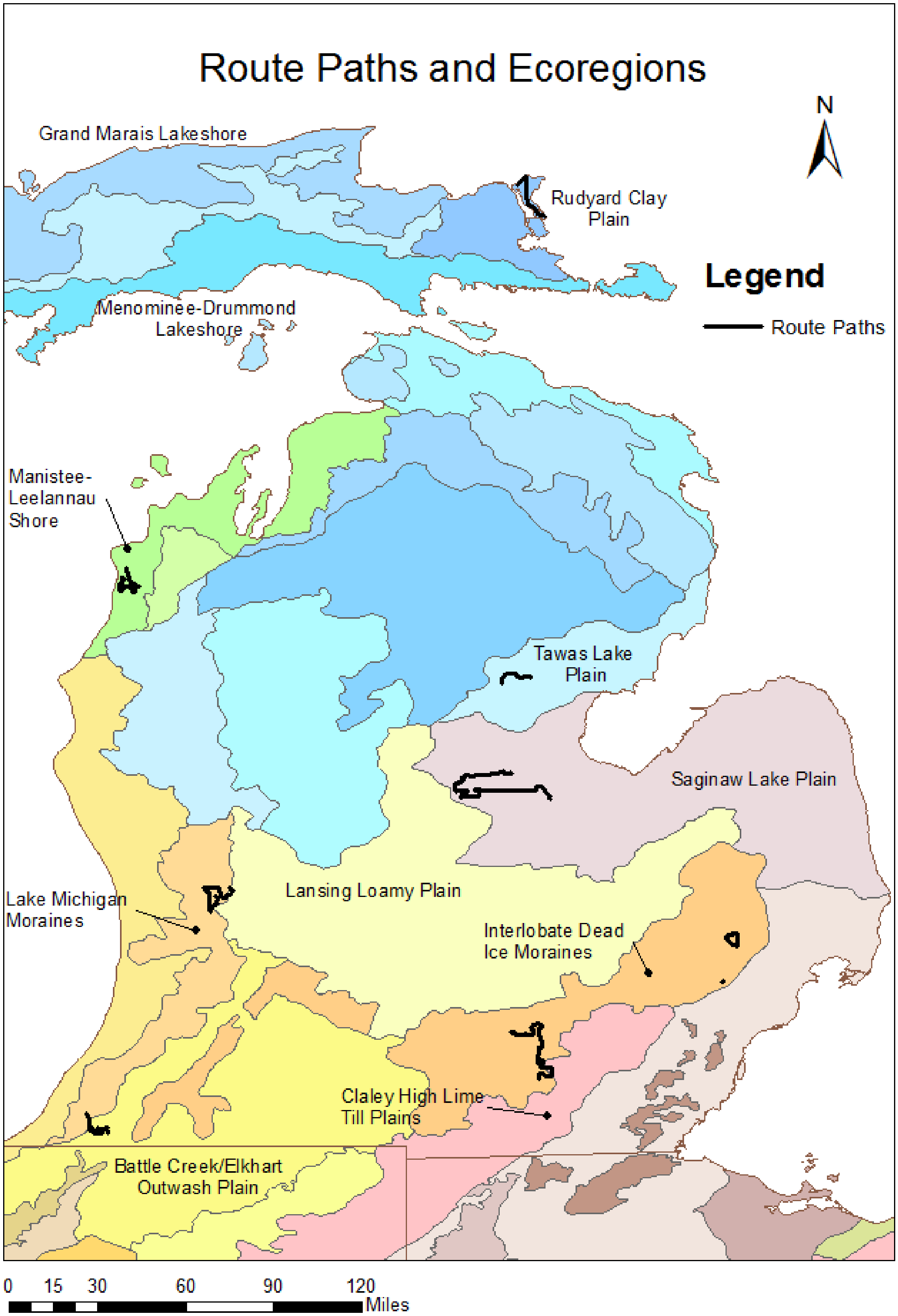
Maps

Survey locations, routes, and distributions of select species.

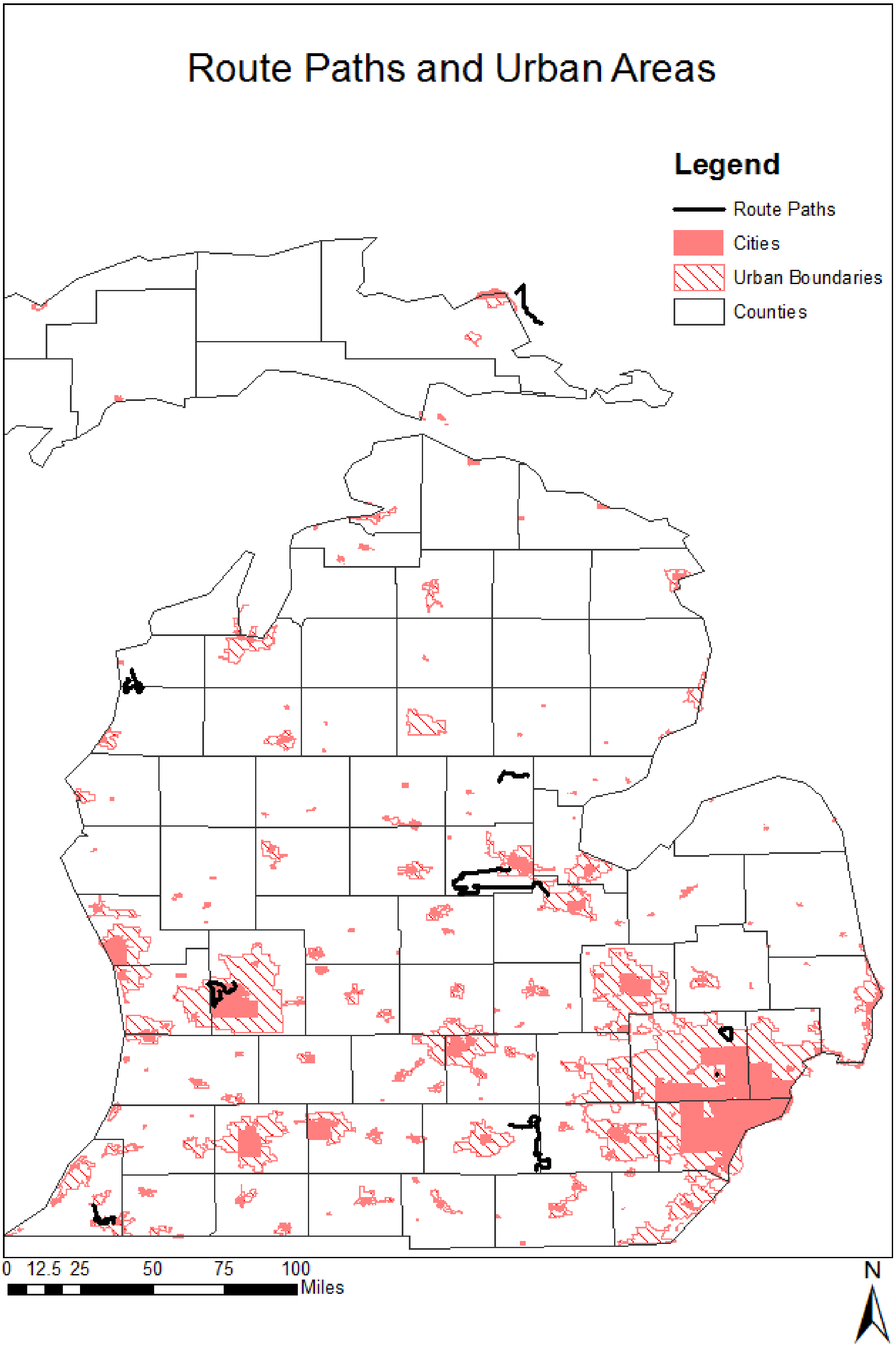
Map 1. General location of acoustic driving routes (1–9) in Michigan. Sizes of ellipses roughly correlates with survey distance.



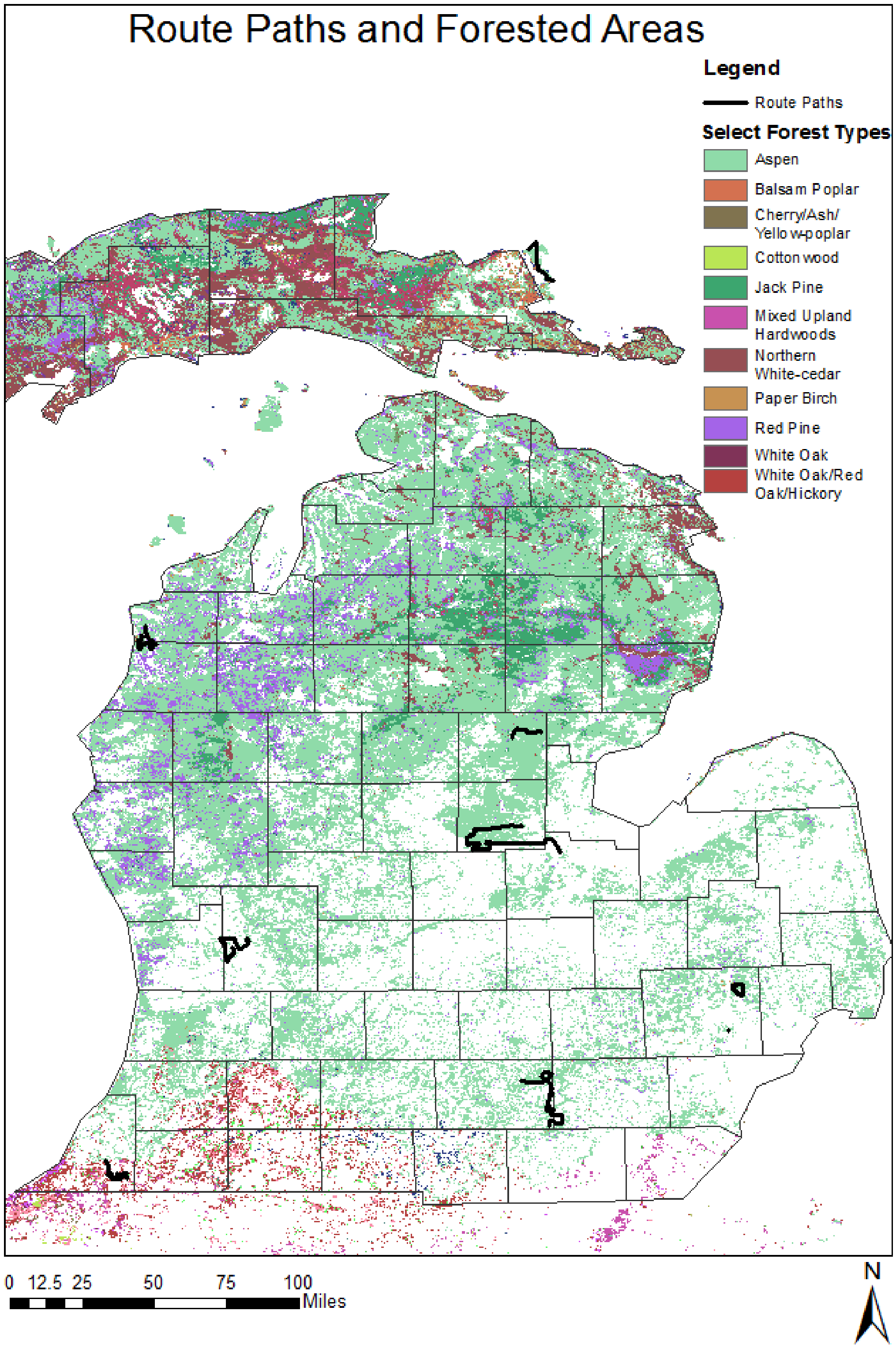
Map 2. Route paths in relation to select U.S. EPA Level IV Ecoregions (2011).



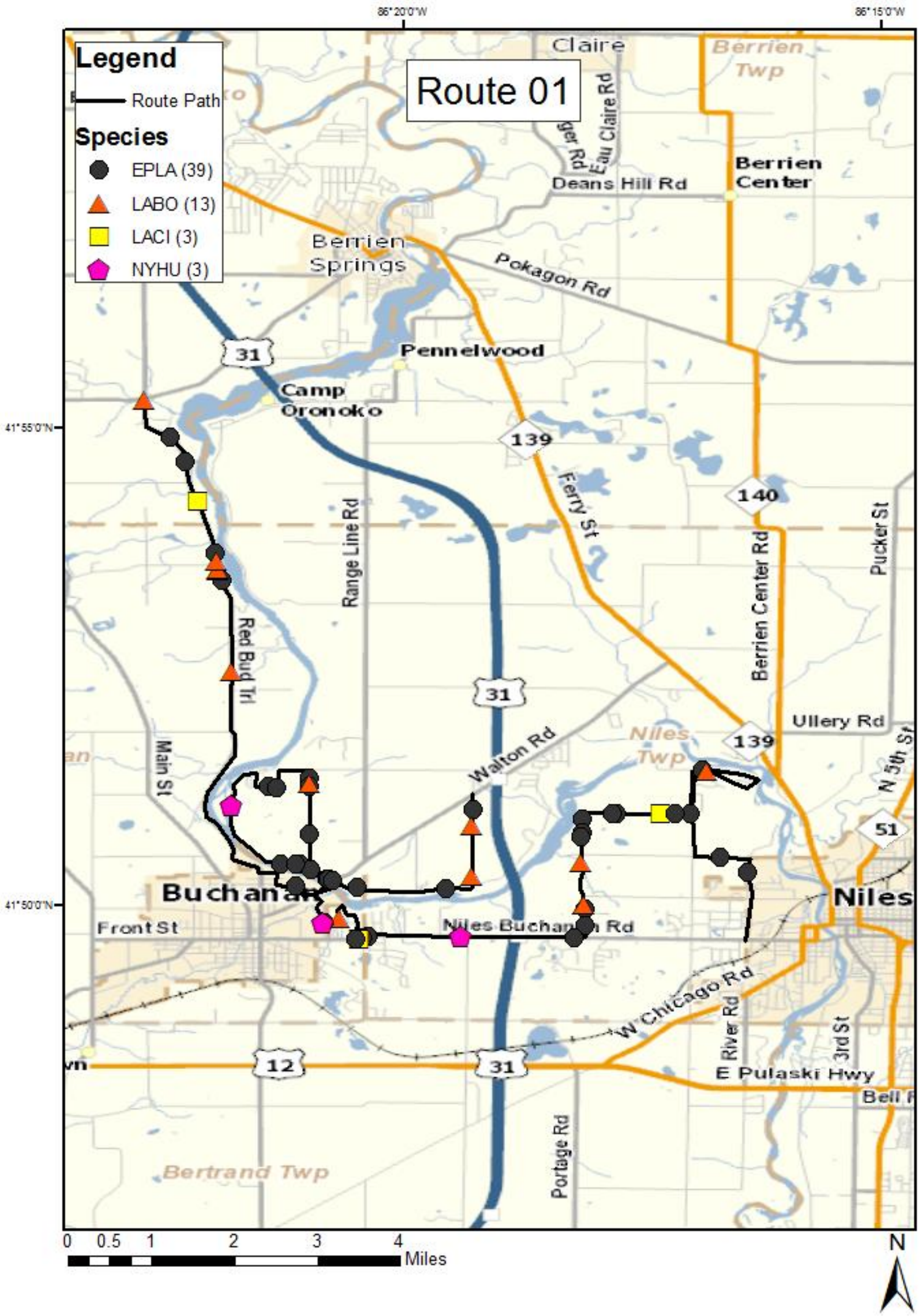
Map 3. The nine survey route paths in relation to cities and urban boundaries. Five routes fell at least partially within a designated urban boundary.



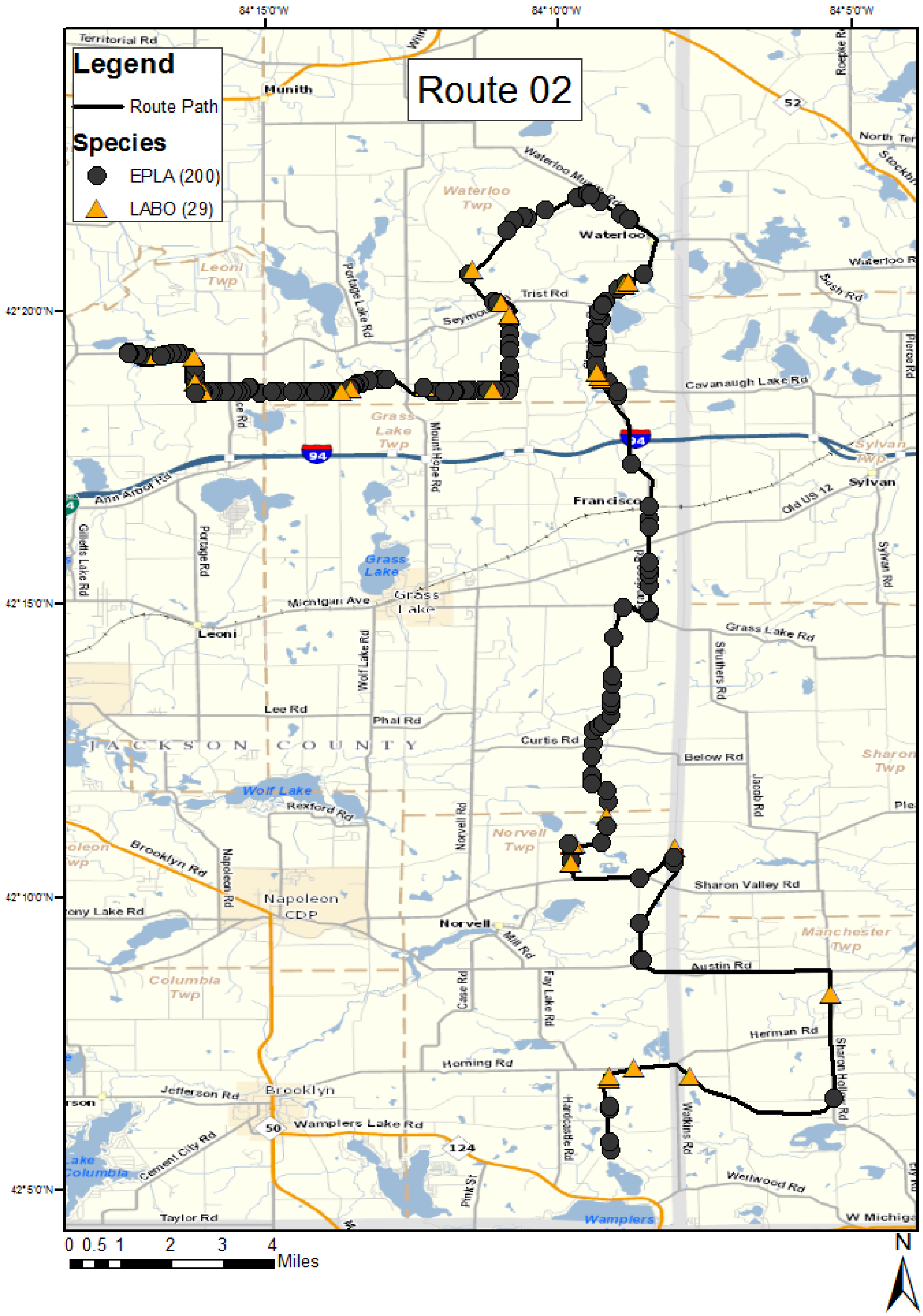
Map 4. Survey route paths in relation to cities select USDA forest types. Survey routes included areas of Aspen, Hard Maple/Basswood, Northern White-cedar, Red Pine, and White Oak/Red Oak/Hickory forests.



Map 5. Route 01 path and final species designations with counts. The survey was conducted on 31 July 2016. Species recorded were the big brown/silver-haired bat (EPLA), eastern red bat (LABO), hoary bat (LACI), and evening bat (NYHU).

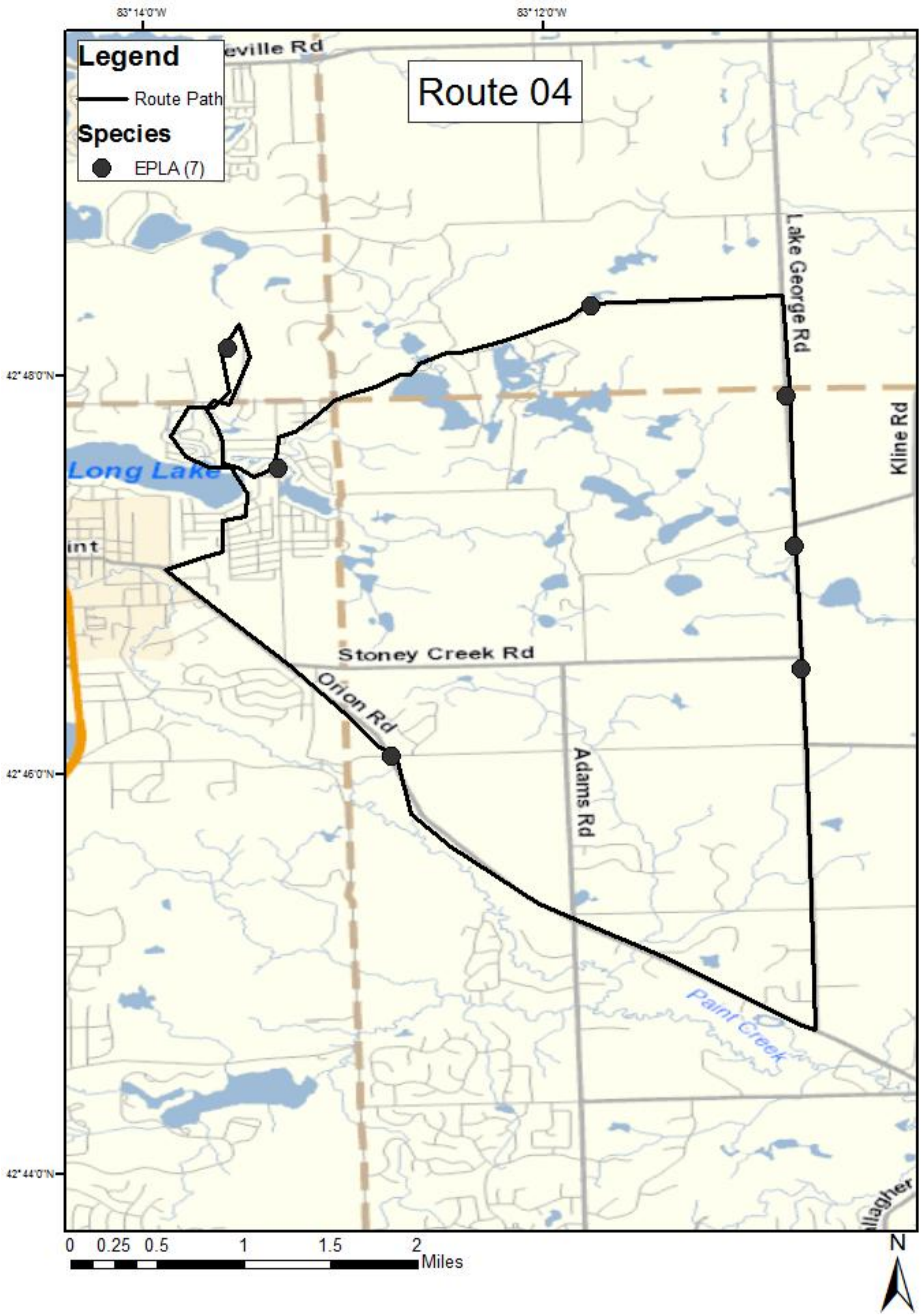


Map 6. Route 02 path and final species designations with counts. Surveys occurred on 29 July, 31 July, and 14 August 2016. Species recorded were the big brown/silver-haired bat (EPLA) eastern red bat (LABO).



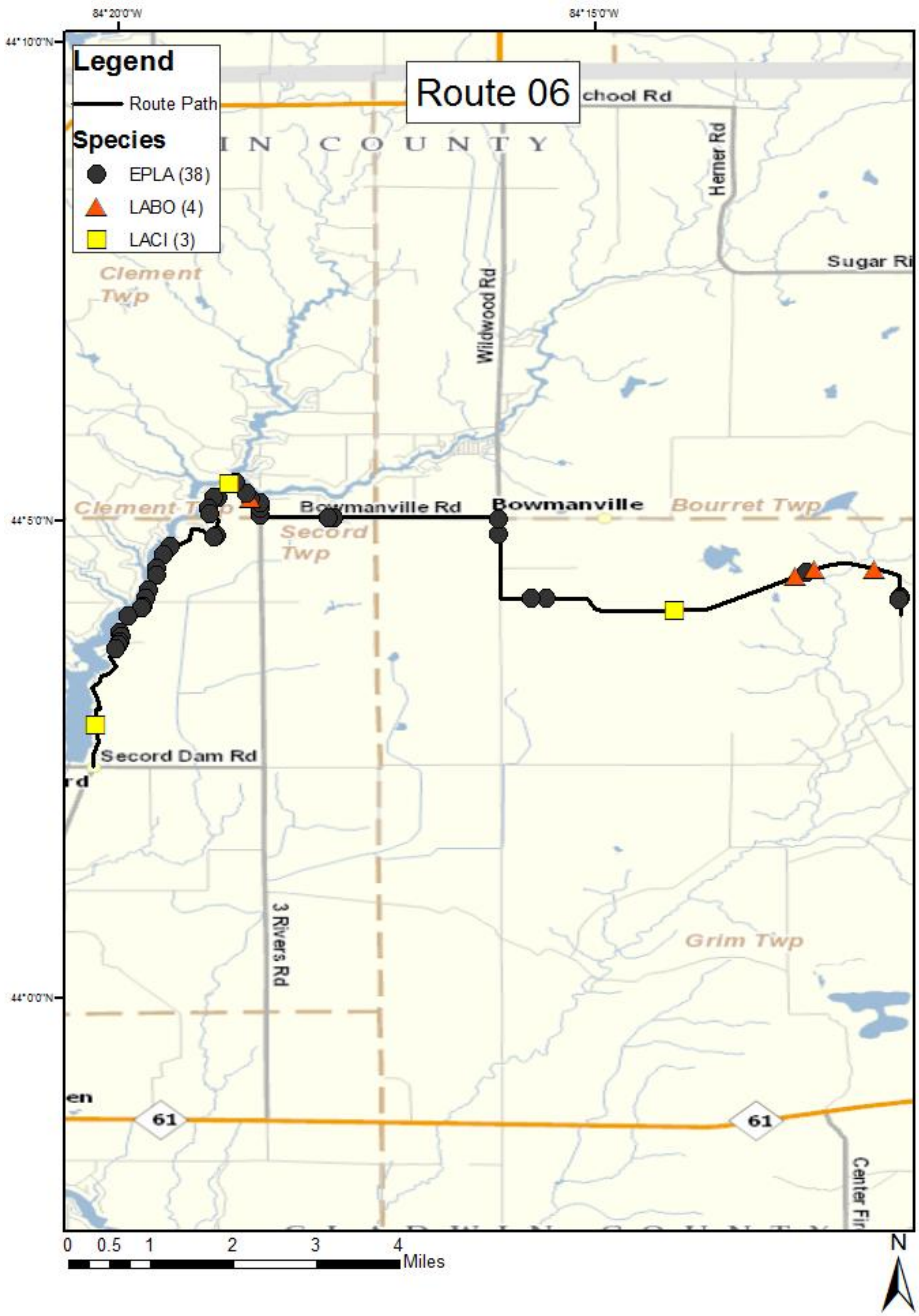
Map 7. Route 03 path and final species designations with counts. Surveys were conducted on July 31 and 30 August, 2016. Species recorded were the big brown/silver-haired bat (EPLA) and eastern red bat (LABO).

Map 8. Route 04 path and final species designations with counts. The survey was conducted on 02 September, 2016. Only calls of the big brown/silver-haired bat (EPLA) were recorded.

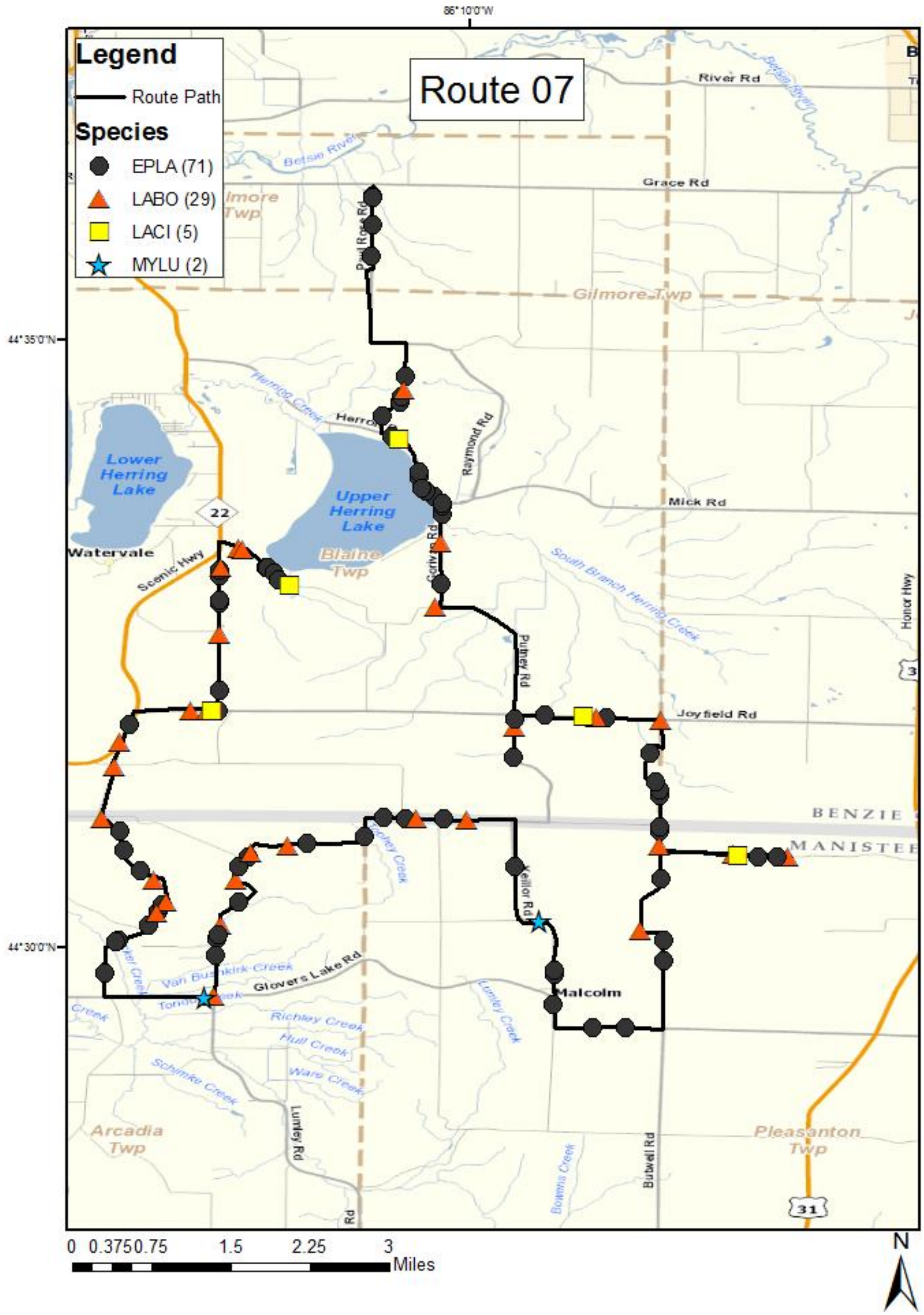


Map 9. Route 05 path and final species designations with counts. Survey was conducted on 01 and 22 August, 2016. Calls of the big brown/silver-haired bat (EPLA), eastern red bat (LABO), and hoary bat (LACI) were recorded.

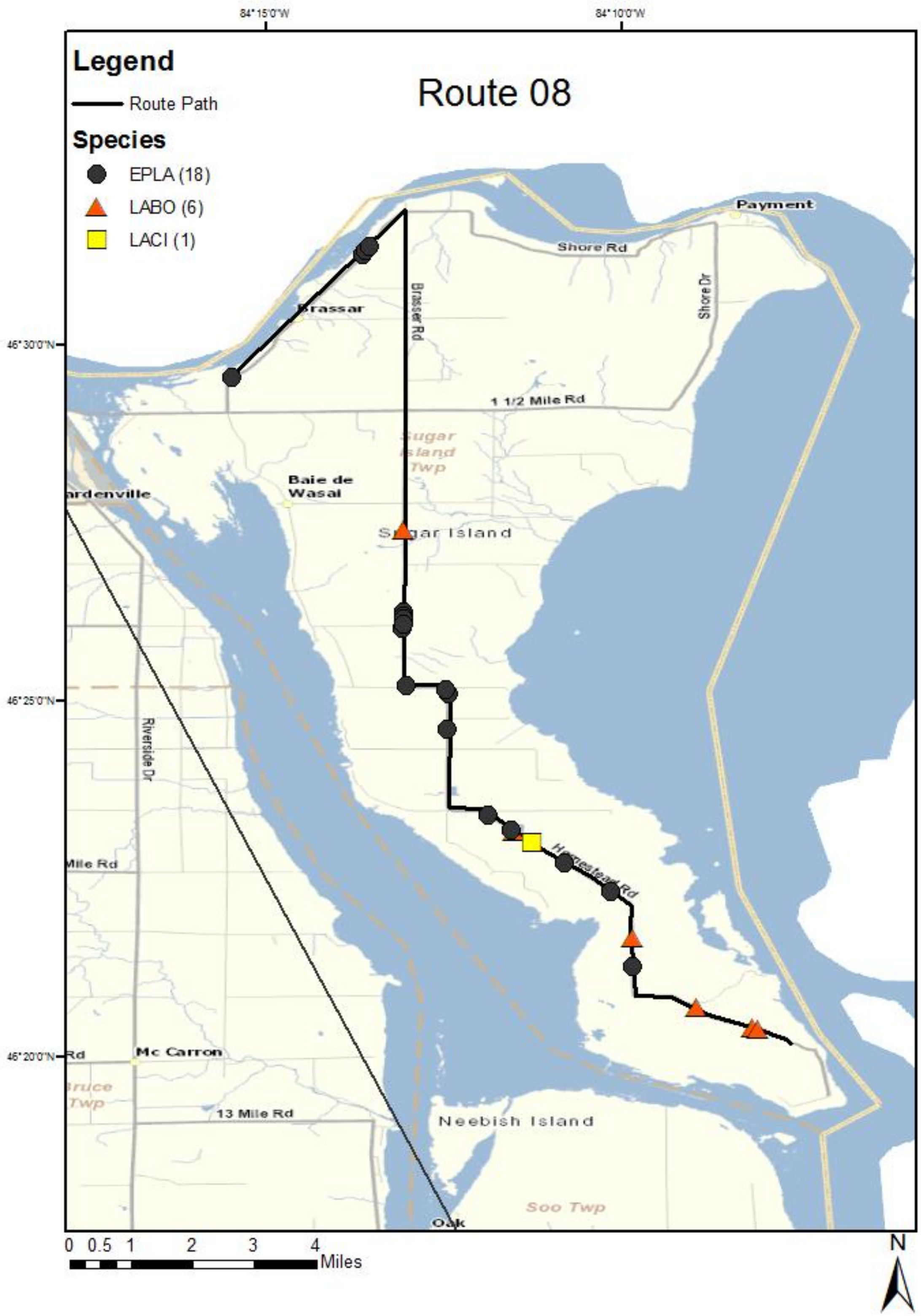
Map 10. Route 06 path and final species designations with counts. The survey was conducted on 20 August, 2016. Species recorded were the big brown/silver-haired bat (EPLA), eastern red bat (LABO), and hoary bat (LACI).



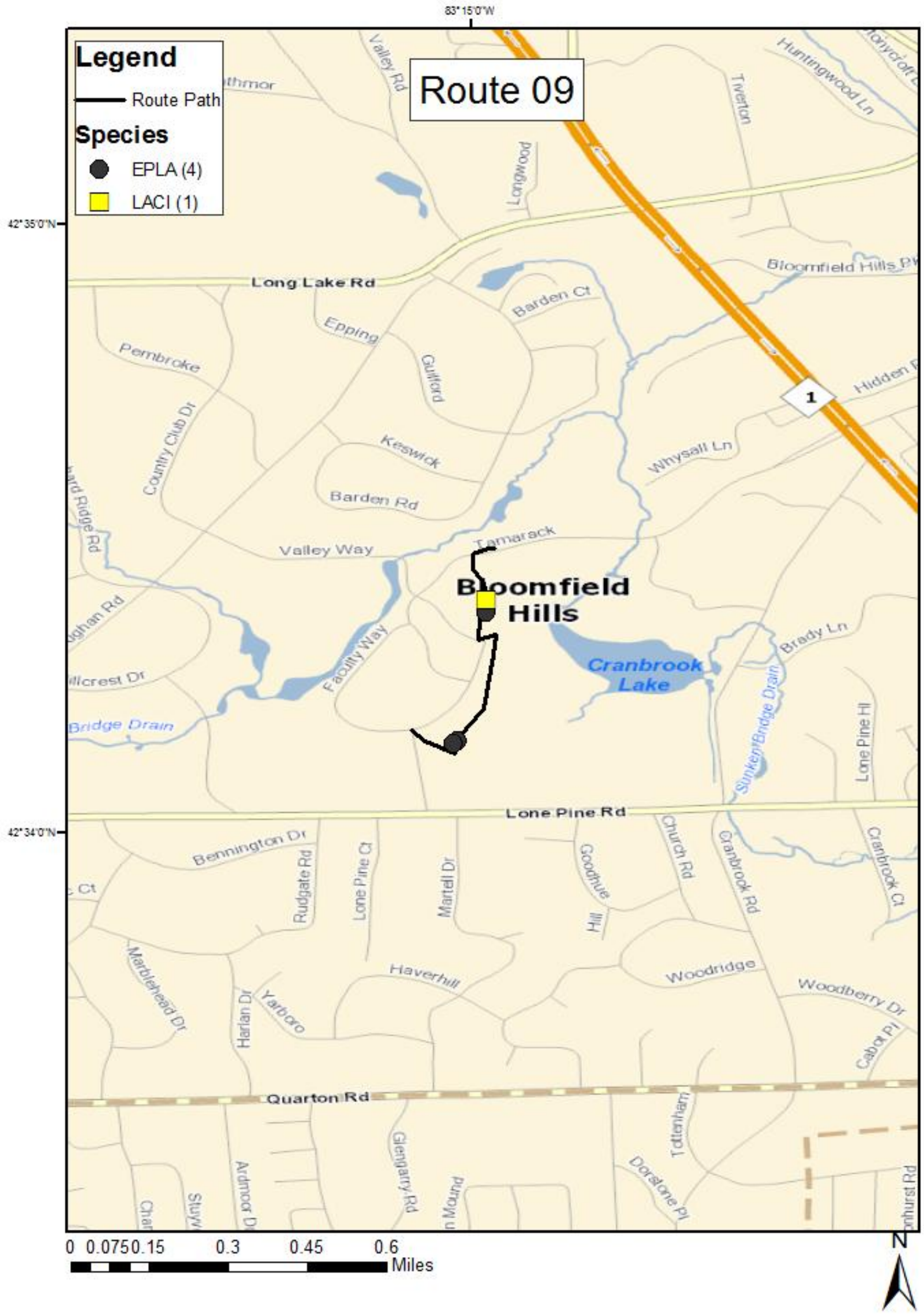
Map 10. Route 07 path and final species designations with counts. Surveys occurred on 28 July and 25 August, 2016. Species recorded were the big brown/silver-haired bat (EPLA), eastern red bat (LABO), hoary bat (LACI), and little brown bat (MYLU).



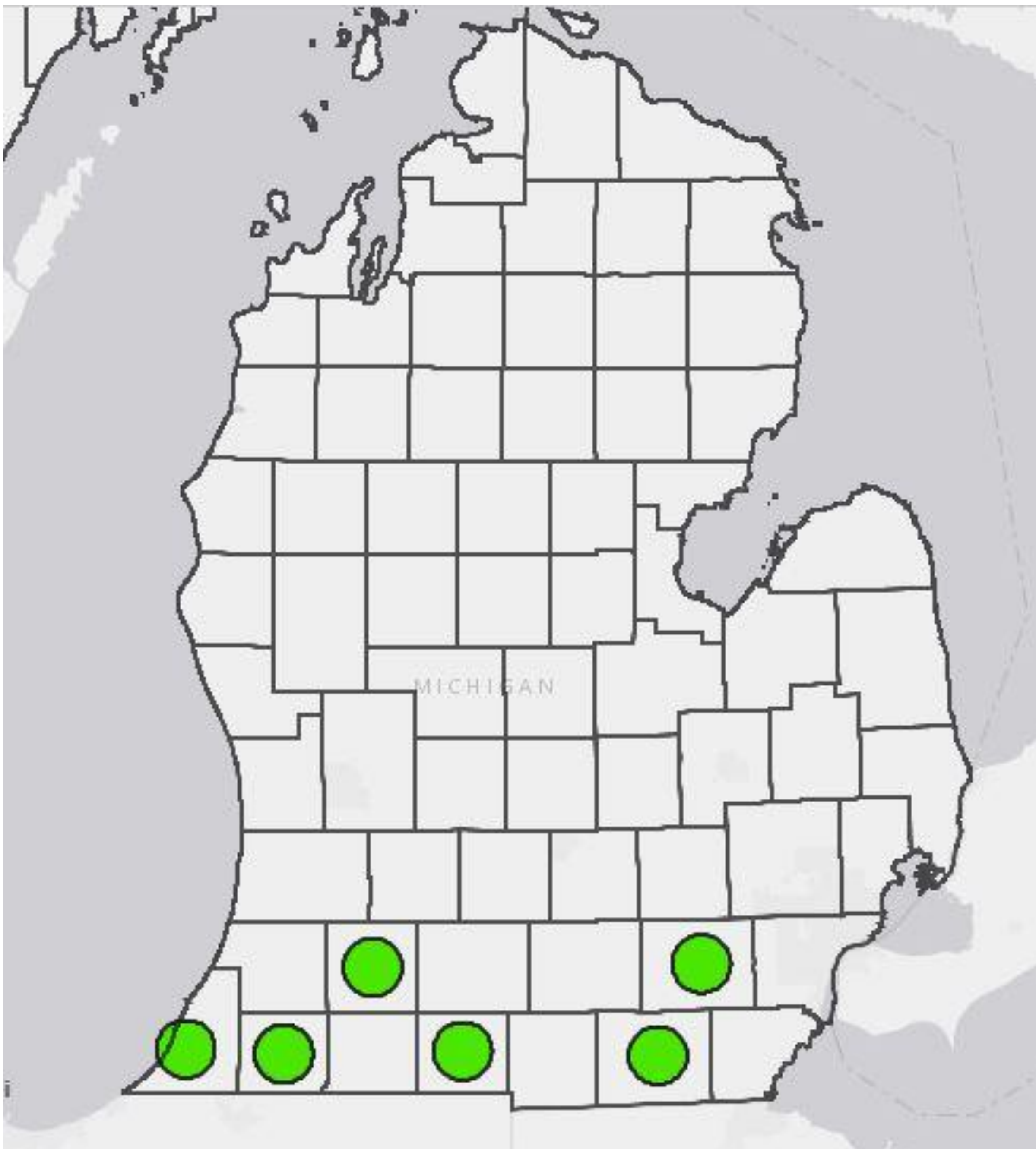
Map 11. Route 08 path and final species designations. The survey was conducted on 10 August, 2016. Species recorded were the big brown/silver-haired bat (EPLA), eastern red bat (LABO), and hoary bat (LACI).



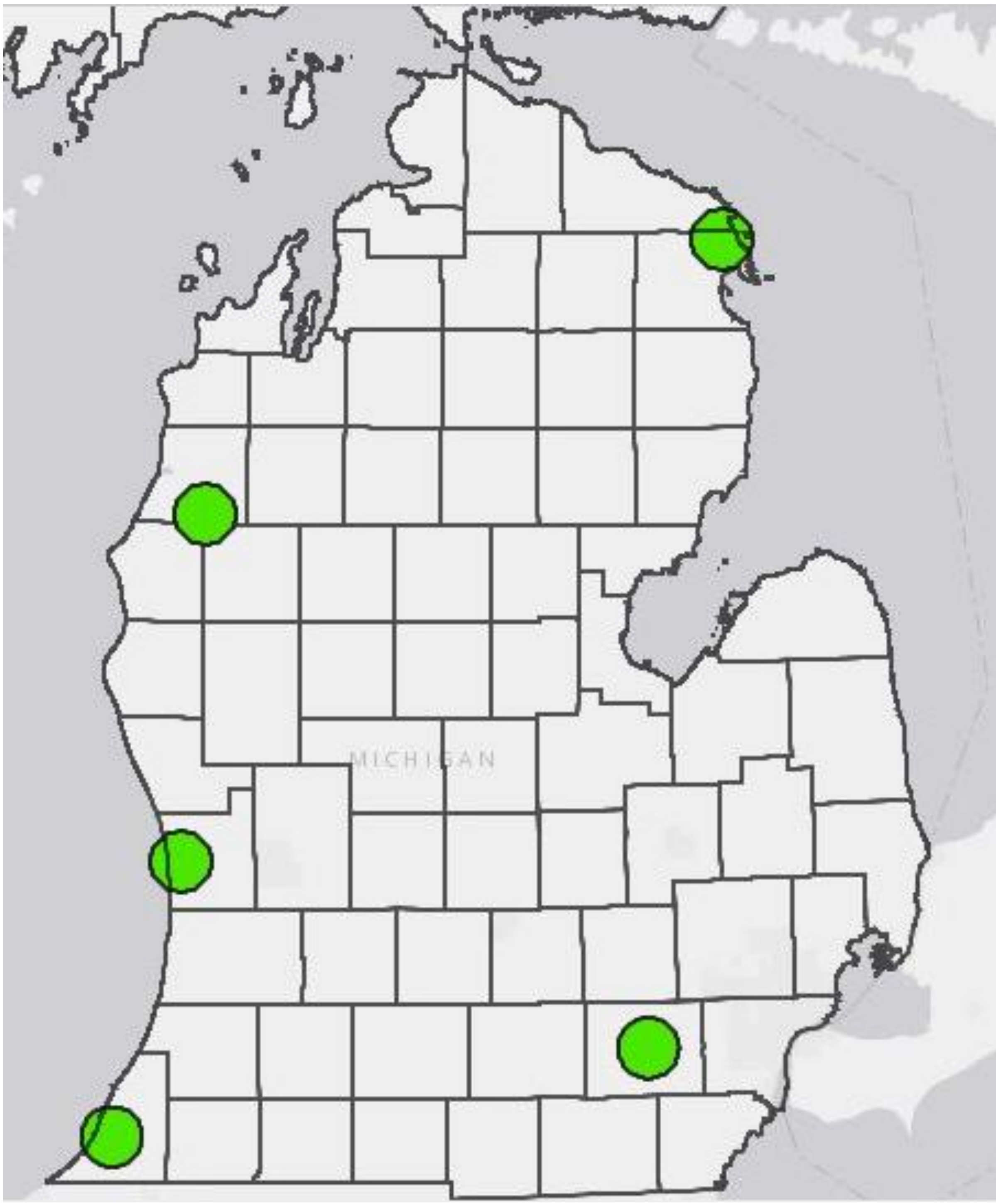
Map 12. Route 09 path and final species designations with counts. The survey was conducted on 21 July, 2016. Species recorded were the big brown/silver-haired bat (EPLA) and hoary bat (LACI).



Map 13. All previously-documented capture locations of the evening bat in Michigan. Circles represent (from left to right) captures in Harbert, Cass County, Climax, Sherwood, Palmyra, and Ann Arbor. There are two additional records of unknown origin within Washtenaw County (which contains Ann Arbor). Our survey attributed three calls of this species to Berrien County, which contains the Harbert record.



Map 14. All previously-documented capture locations of tri-colored bats from the Lower Peninsula, where only a handful of individuals have been encountered. These captures were at (from top to bottom) Rockport, Tippy Dam, Grand Haven, Ann Arbor (rabid), and Bear Cave. However, the species can also be found in the western Upper Peninsula. Our survey efforts attributed no calls to this distinctive-sounding species.



Figures

Survey documents, photos, and graphs.

Figure 1. Equipment provided to RPOs, and subsequently individual volunteers, by OBC.

Citizen Bat League
Inventory Checklist

- ☐ Ipad with protective case
- ☐ Ipad lightning charging cable with wall mount
- ☐ Wildlife Acoustics Echo Meter Touch (EMT) unit
- ☐ Gaffer's tape
- ☐ Cube of Styrofoam (for mounting to car)
- ☐ Garmin GPS unit (with car charging cable)

Figure 2. Safety guidelines provided to RPOs. Ultimately, safety is the volunteer's responsibility.

Citizen Bat League
Safety Suggestions

- You will be working at night, wear bright colors in case you need to exit the vehicle.
- You will likely be driving slower than the normal flow of traffic, turn on hazard lights to alert other drivers.
- As the driver, do not become distracted by monitoring equipment—rely on passenger for all navigation and monitoring of equipment.

Figure 3. Stepwise instructions for conducting driving acoustic surveys which was provided to Regional Partner Organizations.

Citizen Bat League

Survey Steps

Prior to survey

- Receive equipment and route from coordinating partner organization. Review route plan and equipment use. Make sure Garmin GPS unit and Ipad are charged.
- Chose a night to conduct the survey. You will want temperate weather (above 50 F, no rain or fog, no wind strong enough to move branches on trees). Plan to start the survey about 30 minutes after sunset, with a drive time of about 1.5 hours.

Night of the survey

- Attach microphone to top of car
    - Plug the Wildlife Acoustic Echo Meter Touch (EMT) unit to the 6-foot extender cable
    - Using Gaffer's tape, tape the square of foam to the roof of the car, with Styrofoam between the recording unit and car, and metal-tipped corner of unit facing forward.

- Connect Garmin GPS to Ipad via Bluetooth
    - Turn on the Garmin GPS unit by holding the power button (you should see the green and blue lights on the unit blinking)
    - Turn on the ipad (Hit the rectangular button on the top edge of the Ipad)
    - On the IPad, click the gray settings icon, then "Bluetooth" on the left. Make sure the slider to the right is green (for on), and select the Garmin device to connect. Ignore any alerts to install additional apps for the Garmin to work.
    - It should say "connected" to the right of the Garmin on the IPad, and the Garmin unit itself should have a solid blue light (no longer flashing).

- Connect to the microphone and start the Echo Meter app
    - Plug the other end of the lightning cable into the Ipad (this MUST be plugged in AFTER plugging into the EMT unit)
    - Swipe right on the IPad screen to unlock. If necessary, enter the passcode "bats," and hit "done."
    - If prompted if you would like to allow Echo Meter to communicate with the Wildlife Acoustic unit, click "allow"
    - The app should immediately open to a black screen with a green start circle, if not select the EchoMeter app from the menu screen (if you do not see the app you may need to swipe to the side for more apps).
    - Click the green start button
    - When prompted if you would like to allow Echo Meter to access your location when you are not using the app, select "allow"

Figure 4. Datasheet for volunteers to record information during driving acoustic surveys.

Citizen Bat League

Data Collection Sheet

Surveyor Info

Surveyor 1 Name:	Email:	Phone:
Surveyor 2 Name:	Email:	Phone:
Additional volunteers:		

Route Info

Route location: County: Starting location (crossroads): Partner organization:

Equipment

Ipad number:

Survey Info **Date (dd-mm-yy):**________________________

Start	**End**
Time:	Time:
Temp (°F):	Temp:
Wind (calm or breezy):	Wind:
Rain or fog (y/n)?	Rain or fog?
Cloud cover (%):	Cloud cover:

! Do not drive faster than 20 mph with equipment on car !

! Do not survey if below 50°F !

! Do not survey if branches on trees are moving !

! Do not survey if rain or fog are present !

Additional comments (e.g. damaged equipment, error messages, etc.):

Contact Giorgia Auteri for questions at (312) 972-2339, or gauteri@batconservation.org

Figure 5. Three screenshots from an instructional video created to assist RPOs and volunteers, showing (top) how to attach the microphone to the top of the vehicle, (middle) operation of the software, and (bottom) the final setup on a vehicle.

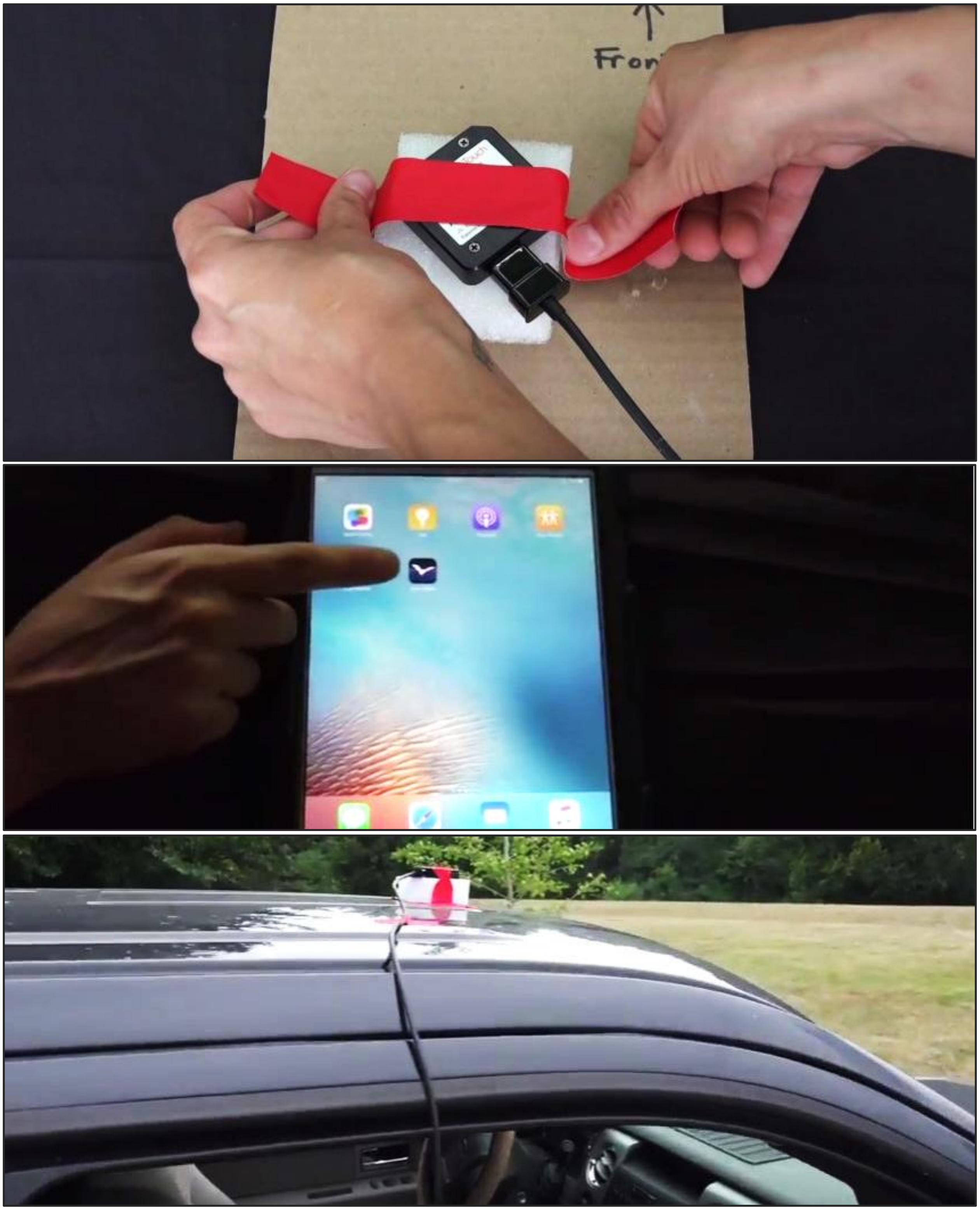


Figure 6. Equipment-testing efforts: (top) ten microphones attached to the roof of a vehicle and (bottom) corresponding output (full-spectrum bat calls) on units inside the vehicle.

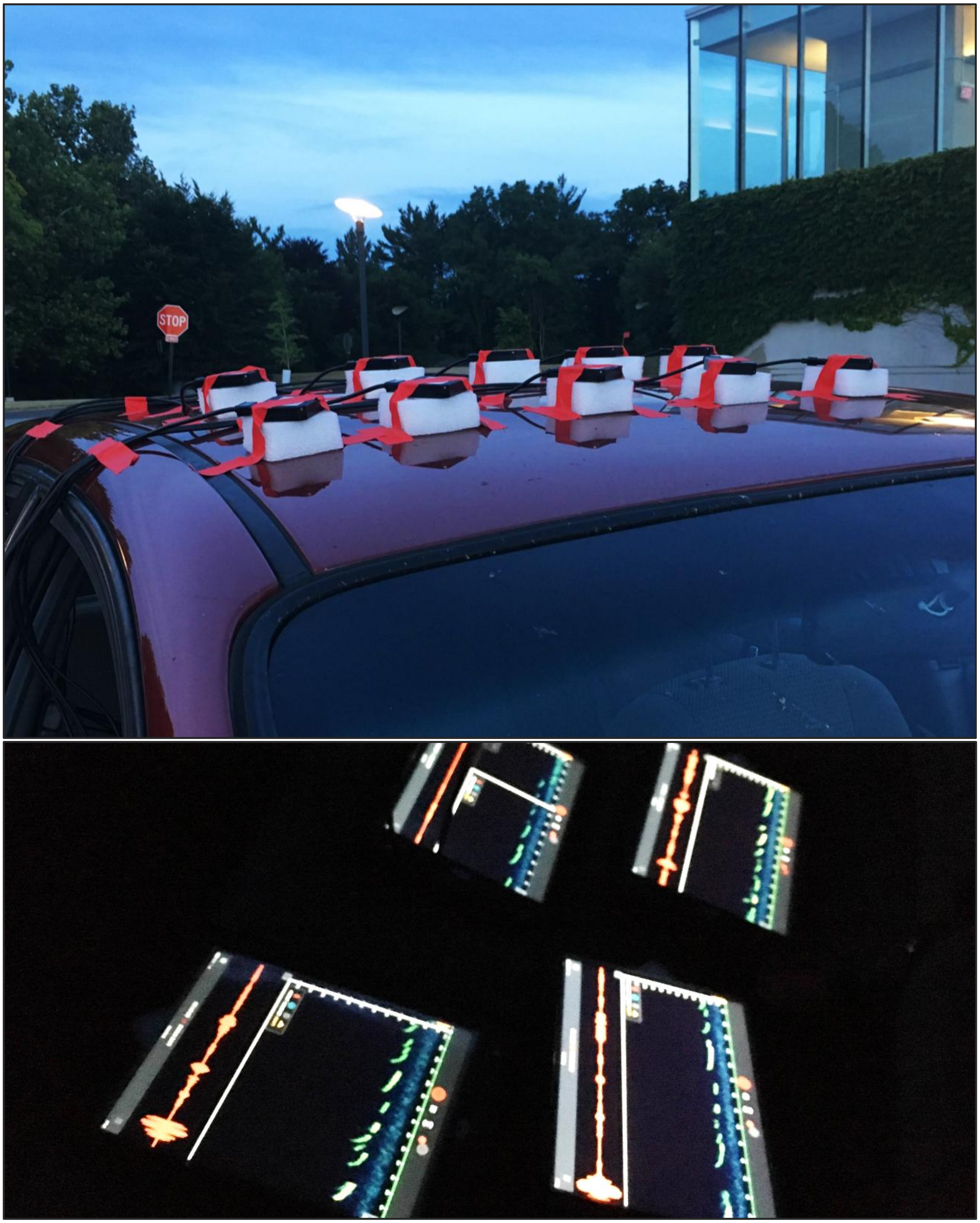


Figure 7. Proportions of calls attributed to different species at each route. Routes 01 and 07 had the highest species diversity (four species), and Route 01 had the highest evenness. Evening bats were only recorded at Route 01, and little brown bats were recorded at Route 07. Species designations are big brown/silver-haired bat (EPLA), eastern red bat (LABO), hoary bat (LACI), little brown bat (MYLU), and evening bat (NYHU).

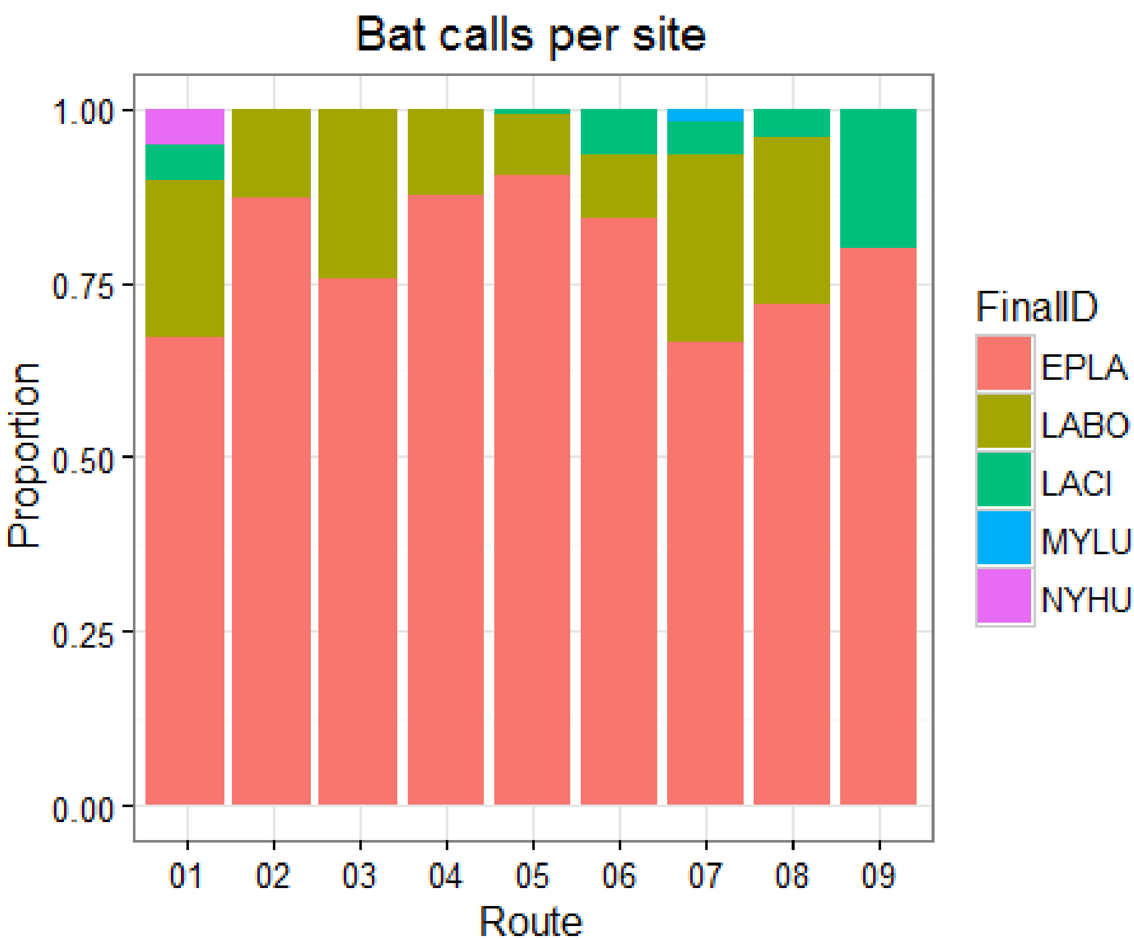


Figure 8. The two calls (top and bottom) attributed to little brown bats, displayed in zero-crossing. Frequency (kilohertz) is on the y-axis and time (seconds) is on the x-axis. Time between call pulses is compressed for easier viewing. Each call is displayed in two ways: (left) frequency by time and (right) slope of frequency by time. Date and coordinates are displayed under the x-axis of each call. Kaleidoscope, Echoclass, and manual vetting all agreed on the species identifications for these calls, which were recorded along Route 07.

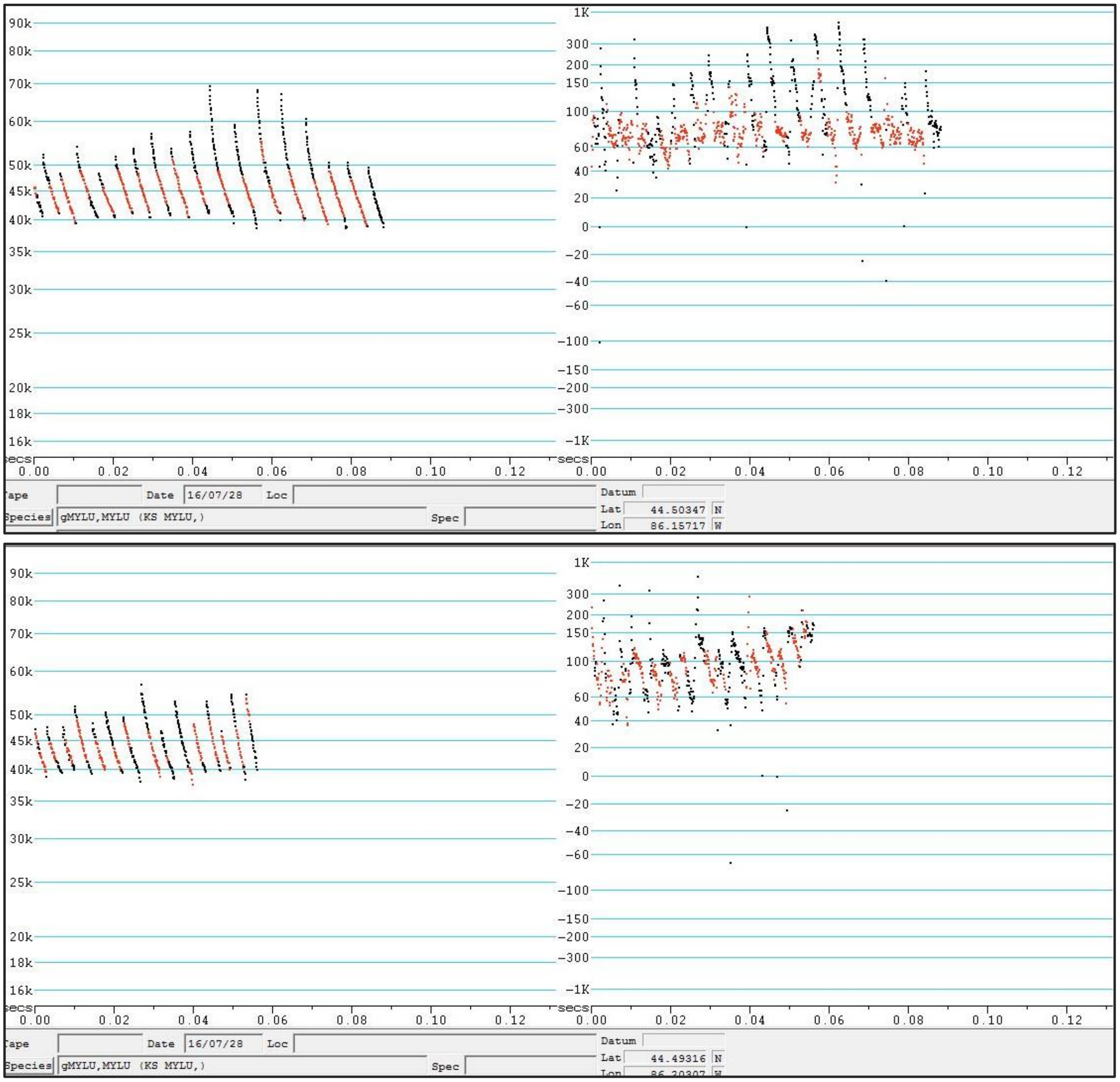


Figure 9. Three calls (top, middle, and bottom) attributed to evening bats, displayed in zero-crossing. Frequency (kilohertz) is on the y-axis and time (seconds) is on the x-axis. Time between call pulses is compressed to ease viewing. Each call is displayed in (left) frequency by time and (right) slope of frequency by time. Date and coordinates are displayed under the x-axis. Kaleidoscope and manual vetting determined identification of the top call, while Kaleidoscope and Echoclass agreed on identifications of the others. All calls were recorded along Route 01.

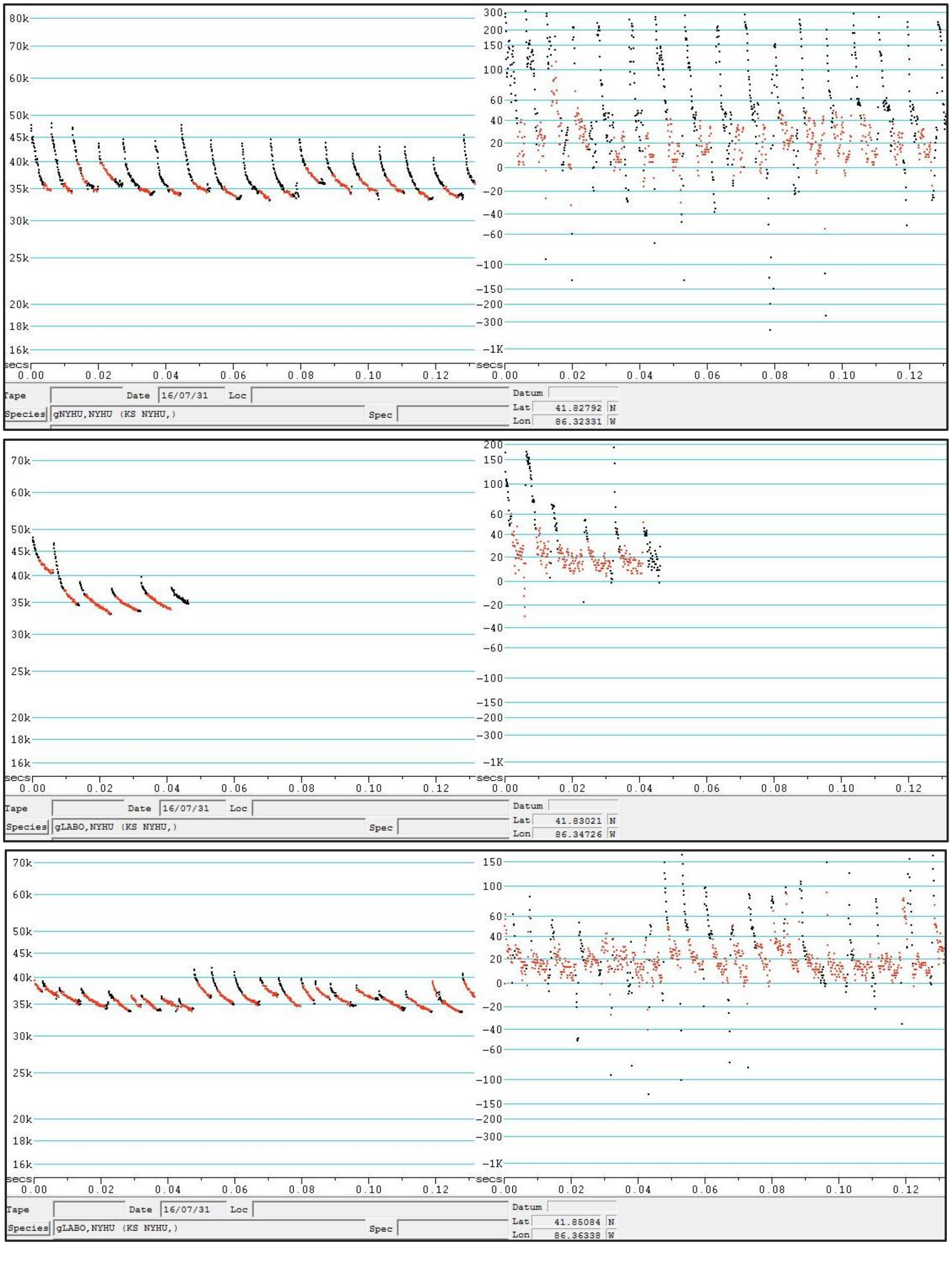


Figure 10. Mean number of calls (top) and kernel probability density (bottom) of calls recorded per ten-minutes in July. Evening bats and little brown bats are not show due to small sample size. Species codes are big brown/silver-haired bats (EPLA), eastern red bats (LABO), and hoary bats (LACI).

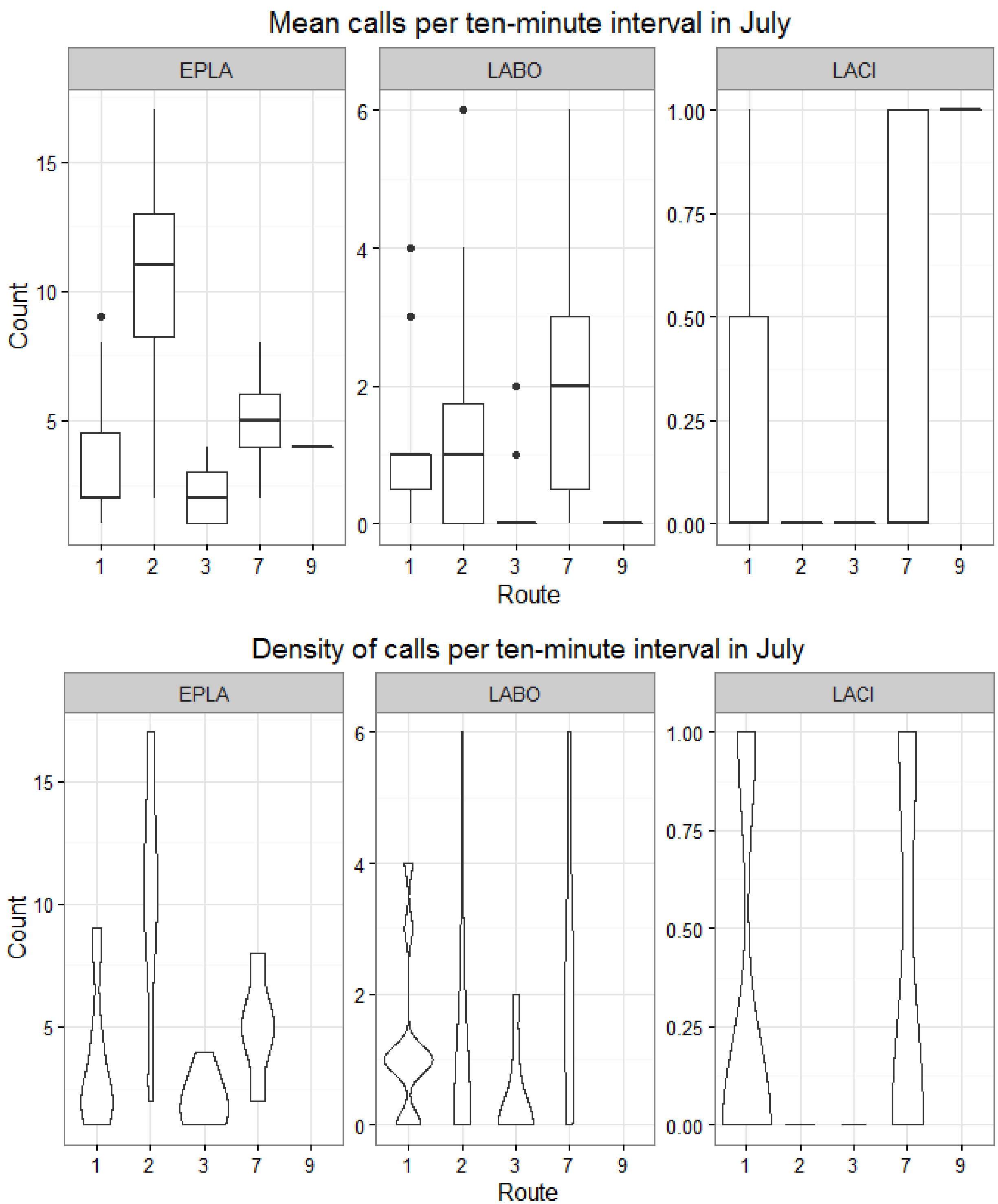
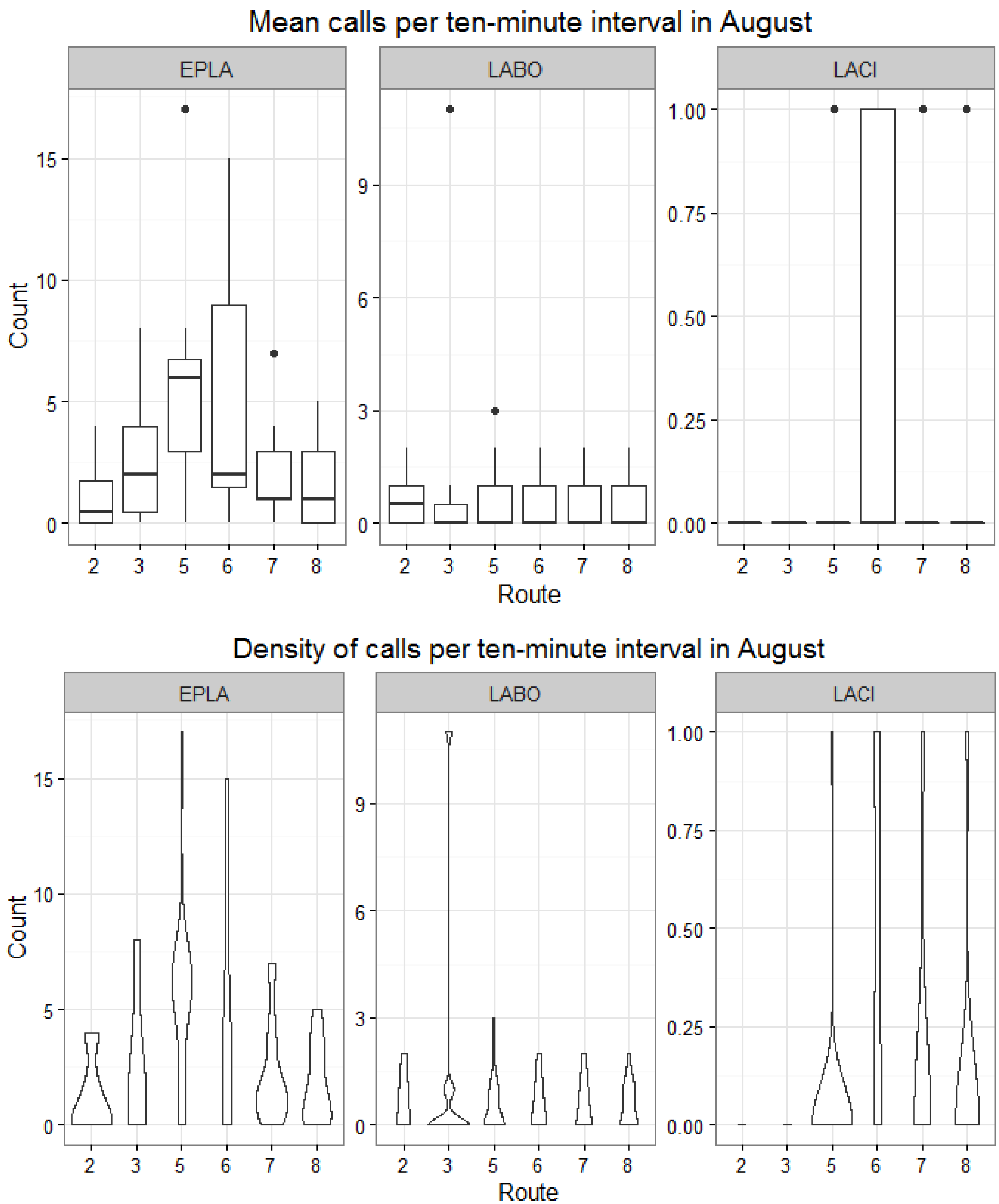


Figure 11. Mean number of calls (top) and kernel probability density (bottom) of calls recorded per ten-minutes in August. Species codes are big brown/silver-haired bats (EPLA), eastern red bats (LABO), and hoary bats (LACI).



Tables

Summary information for routes and recordings.

Table 1. Description of survey routes in Michigan, including number of times each route was driven approximate locations (degrees minutes seconds), primary ecoregion, and whether the route was in Michigan's Upper (UP) or Lower (LP) Peninsula.

Route	***# of Surveys***	***Approximate Location***	***Primary Ecoregion***	***LP/UP***
01	1	41°52‘0’`N 86°19‘0’`W	Battle Creek/Elkhart Outwash	LP
02	3	42°15‘0’`N 84°10‘0’`W	Interlobate Dead Ice Moraines	LP
03	2	43°0‘0’`N 85°44‘0’`W	Lake Michigan Moraines	LP
04	1	42°47‘0’`N 83°12‘0’`W	Interlobate Dead Ice Moraines	LP
05	2	43°33‘0’`N 84°20‘0’`W	Saginaw Lake Plain	LP
06	1	44°4‘0’`N 84°17‘0’`W	Tawas Lake Plain	LP
07	3	44°‘33’`N 86°12‘0’`W	Manistee-Leelannau Shore	LP
08	1	46°25‘0’`N 84°11‘0’`W	Rudyard Clay Plain	UP
09	1	42°34‘0’`N 83°15‘0’`W	Interlobate Dead Ice Moraines	LP

Table 2. Information specific to each run of a route, including survey date(s), duration(s), and means and standard deviations (SD) of calls attributed to each species per ten-minute interval. Species codes are as follows: big brown/silver-haired (EPLA), eastern red bat (LABO), hoary bat (LACI), little brown bat (MYLU), evening bat (NYHU), and unidentified (UNID).

Route	***Date***	***Duration***	***EPLA***	***LABO***	***LACI***	***NYHU***	***MYLU***
		(H:mm)	*(# calls* ± SD)				
01	31 July	1:57	3.5 ± 2.7	1.2 ± 1.2	0.3 ± 0.5	0.3 ± 0.5	—
02	29 & 31 July	1:50 & 1:46	10.4 ± 4.7	1.1 ± 1.2	—	—	—
	14 Aug	1:45	1.2 ± 1.6	0.7 ± 0.8	—	—	—
03	31 July	1:24	2.1 ± 1.1	0.3 ± 0.7	—	—	—
	30 Aug	1:50	2.8 ± 3.2	1.1 ± 3.2	—	—	—
04	02 Sep	1:08	1.0 ± 0.0	—	—	—	—
05	01 & 22 Aug	1:47 & 2:06	5.2 ± 3.7	0.5 ± 0.8	0.05 ± 0.2	—	—
06	20 Aug	2:17	5.4 ± 6.3	0.6 ± 0.8	0.4 ± 0.5	—	—
07	28 July	1:41	5.0 ± 2.0	5.0 0± 2.0	0.4 ± 0.5	—	0.1 ± 0.3
	25 Aug	1:09	2.3 ± 2.4	0.6 ± 0.8	0.1 ± 0.4	—	—
08	10 Aug	1:32	1.6 ± 1.8	0.5 ± 0.7	0.1 ± 0.3	—	—
09	21 July	0:20	4.0 ± 0.0	0.1 ± 0.4	—	—	—

Table 3. Total calls attributed to each species via each of the three identification methods—Kaleidoscope, Echoclass, and manual vetting—followed by final designations based on agreement between paired identification methods. Species codes are as follows: big brown/silver-haired (EPLA), eastern red bat (LABO), hoary bat (LACI), gray bat (MYGR), small-footed bat (MYLE), little brown bat (MYLU), northern long-eared bat (MYSE), evening bat (NYHU), tri-colored bat (PESU), and unidentified (UNID). Dashes indicate identifications that were excluded as options for some methods. Discrepancies in totals among methods are indicate differences in number of calls attributed as "noise."

Species	***Kaleidoscope***	***Echoclass***	***Human***	***Final***
EPLA	742	342	405	**541**
LABO	160	194	71	**108**
LACI	58	61	5	**14**
MYGR	—	8	—	**—**
MYLE	0	1	0	**0**
MYLU	18	0	3	**2**
MYSE	0	1	0	**0**
NYHU	16	8	1	**3**
PESU	3	2	0	**0**
UNID	0	368	347	**93**
Total	997	985	832	**761**

Table 4. Species richness, evenness, and diversity for each route. Richness simply indicates the number of species recorded at a site. Evenness is a measure of how similar the relative abundances of those species are. Diversity was calculated using Simpson's Index of Diversity. For both diversity and evenness, 0 denotes no diversity/evenness and 1 representing the maximum possible diversity/evenness.

Route	***Richness***	***Evenness***	***Diversity***
01	4	0.66	0.50
02	2	0.44	0.22
03	2	0.73	0.37
04	2	0.44	0.25
05	3	0.26	0.18
06	3	0.41	0.28
07	4	0.64	0.49
08	3	0.63	0.44
09	3	0.64	0.40