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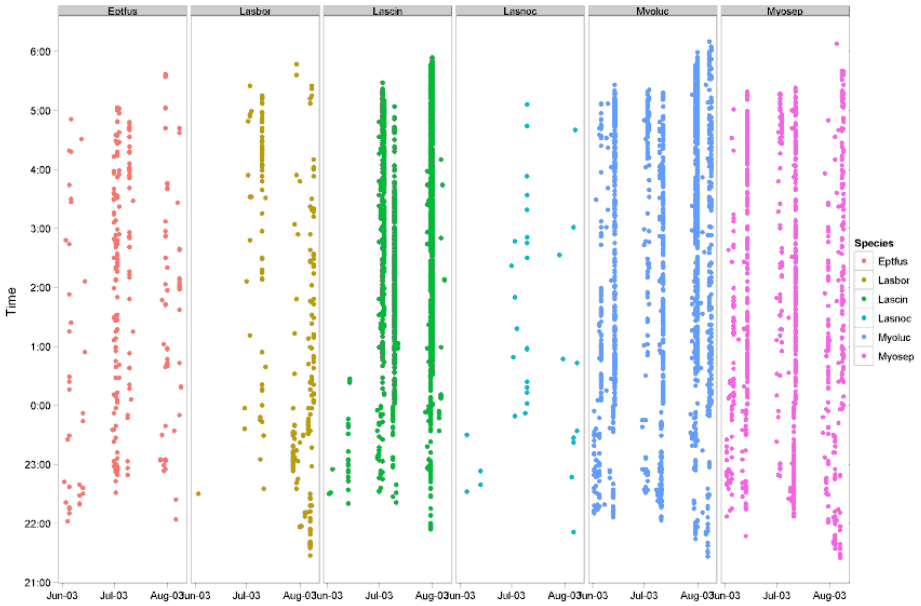
Natural Resource Program Center

Revised Relative Abundance Estimates and Temporal Activity of Bats at Three Great Lakes National Parks Based on Acoustic Data

Natural Resource Report NPS/GLKN/NRR—2010/178









ON THE COVER
Passive setup acoustic monitoring station that uses reflector tubes (from Kruger and Peterson 2008). Collected data are used to create graphs showing temporal activity between species and dates, such as the example here for Apostle Islands NL. Hoary bat and pipistrelle line drawings from Arthur's Bat Clipart (www.arthursclipart.org/bats/bats.htm).

Revised Relative Abundance Estimates and Temporal Activity of Bats at Three Great Lakes National Parks Based on Acoustic Data

Natural Resource Report NPS/GLKN/NRR—2010/178

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U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Abstract

In this study I re-analyzed acoustic bat data collected from June-August 2003 that was part of a baseline inventory of bat species in three national parks in the Lake Superior region. While the original study presented base-line data on the presence/absence of bat species in these parks, this reanalysis provides estimates of relative abundance and temporal activity of the identified species. Using a suite of recently developed acoustic analysis tools I created species specific filters. This allowed me to parse calls from non-fragmented sequences and differentiate between two species *Myotis septentrionalis* and *Myotis lucifugus* that were combined into a general *Myotis* spp. category. Using the Acoustic Activity Index (AI) it was possible to derive relative abundance estimates for each species and park. Temporal activity patterns are also presented as summaries for each species and park. An example of how spatially linked acoustic data can be useful for park management is also presented. All acoustic files were examined and the textual header data was updated with species names, locations and x, y location coordinates. An Access relational database with spatially explicit links, and relative abundance values for all species identified was also created providing a more robust archive of the data.

Acknowledgements

I thank Steve Yancho, Chief of Natural Resources, Sleeping Bear Dunes National Lakeshore for putting me in contact with the Great Lakes Inventory and Monitoring Network (GLKN). I thank Bill Route, Program Coordinator /Ecologist with the GLKN, for the opportunity to undertake this project, and Laura Kruger for invaluable help in providing coordinates, location clarification, and updates and corrections for all of the acoustic data files. Carolyn Miller proofread an earlier draft and provided useful editing comments. Editing and layout provided by Becky Brown and Ted Gostomski. This report was peer reviewed by Bill Route and Ron Moen.

Introduction

A survey of bat species was conducted in three national parks in the Lake Superior region during June, July, and August 2003 (Kruger and Peterson 2008). The three parks surveyed were: Pictured Rocks National Lakeshore (PIRO) in the Upper Peninsula of Michigan, Apostle Islands National Lakeshore (APIS) in Wisconsin, and Grand Portage National Monument (GRPO) in Minnesota. The goals for the project were to determine what bat species occurred in each of the three parks, and identify foraging areas, day roosts, maternity sites and hibernacula (Kruger and Peterson 2008). The survey sites were not randomly selected therefore the results should be viewed as only representative of areas surrounding the survey site and not the entire parks (Route pers. comm.).

Survey data on the presence/absence of temperate bat species at the sites within the three national parks was collected by: mist netting, roost searches, and acoustic sampling (Table 1). Combining multiple survey methods is the most robust means of documenting the bat fauna of a given area (Miller 2003, O'Farrell and Miller 2003). Acoustic sampling is a means of documenting the occurrence of bat species that may avoid traditional capture methods (e.g., mist nets).

Table 1. Potential occurrence of bat species in three national parks of the Great Lakes Network: Grand Portage National Monument (GRPO); Apostle Islands National Lakeshore (APIS); and Pictured Rocks National Lakeshore (PIRO). Species occurrences indicated as X (verified), L (likely), and U (unknown). Adapted from Kruger and Peterson (2008).

Common Name	Scientific Name	APIS	GRPO	PIRO
Little brown bat	*Myotis lucifugus*	X	X	X
Northern bat	*Myotis septentrionalis*	L	L	L
Eastern pipistrelle	*Perimyotis subflavus*	L	U	U
Big brown bat	*Eptesicus fuscus*	X	L	L
Silver-haired bat	*Lasionycteris noctivagans*	X	L	L
Eastern red bat	*Lasiurus borealis*	X	L	L
Hoary bat	*Lasiurus cinereus*	X	X	L

Acoustic data files also serve as archived data sets. Each file becomes a voucher record for the presence of a species at a given time and place. In addition to being useful in focal studies, these data are then available for future analysis as methods and techniques evolve. This is not unlike the value of historical museum or herbaria collections with archived voucher specimens (Reynolds et al. 1996, Yates et al. 1996). Like traditional research collections serving as functional biological libraries (Winker 1996), acoustic data have similar value. As better understandings of distinctive vocal signatures evolve and acoustic voucher call libraries are expanded, acoustic methods contribute to increasingly important and powerful data sets (Ochoa et al. 2000). Having the archived files made it possible to re-evaluate and analyze the acoustical data records from the 2003 survey.

In their discussion, Kruger and Peterson (2008) acknowledged that simply using acoustic identification as an index did not address potential skewing of the data by a single bat making

several passes at the recording site as opposed to multiple bats flying by. While it is well understood that not all acoustic recordings include diagnostic vocal signatures that allow unequivocal identification of species (Corben 2004, Miller 2004), it is possible to use an acoustic activity index (AI) to estimate relative abundance and to compare both spatial and temporal activity of bats. The AI provides a means to standardize results of acoustic surveys after adjusting by the survey times (unit effort), and provides a robust means to compare between survey sites and dates (Miller 2001).

I have examined and re-analyzed the acoustic data collected by Kruger and Peterson (2008) and employed new techniques and used new software tools that were not available during their study. The results of this re-analysis provide more detail on the relative abundance and spatial and temporal associations for the documented species at the three national parks.

Frequently, re-evaluation of archived acoustic data results in additional species identifications because our knowledge of vocal signatures has improved (Miller 2004). In order to reassess the acoustic data it was important to ascertain the potential for a given species to be present within the study areas prior to scanning the data with a broad range of species specific acoustic filters. While it is important to evaluate acoustic data for the presence of all potential species, it is not cost effective to scan data for species that are highly unlikely to occur in the areas surveyed without adequate justification.

Methods

My first task for this project was to determine what species potentially could occur in the area surveyed based upon the most recent distribution and range data available. This was necessary to make sure I scanned the acoustic data for all potential species and did not *a priori* limit the analysis of the data to only the species the initial study had identified.

This was accomplished in ArcGIS by overlaying the study site locations in the three parks on the North American species distribution ranges. The species spatial data layers used were from the IUCN-led Global Mammal Assessment (IUCN 2008). These represented the most recent range updates available for bats and were based on recent detailed expert review of taxonomists and ecologists from North and Central America and the Caribbean.

Acoustic Data File Management

I used the most recent versions of the AnalookW software re-analyze the acoustic data, add relevant header data such as location names, X-Y coordinates, and species names to the acoustic files. While an earlier version of AnalookW was available, Kruger and Peterson (2008) analyzed their data using the older DOS platform Analook (Version 4.9, January 2003).

All metadata relating to each Anabat acoustic call file is stored in the header. Header data (Figure 1) are the textual data embedded within each acoustic file and includes six descriptive fields and four relating to the spatial context of the data. A description of the textual fields follows.



Figure 1. An example of the Header portion of an Anabat file as viewed in AnalookW.

The Tape field stores the unique identification of the Compact Flash Zero-Crossing Module (CF-ZCAIM) used to record the data in the field and is an integral part of each file recorded; it is added automatically when data is recorded with the CF-ZCAIM. The Date field is used for the date the data was recorded. The Loc field is used for a unique description of the location where the recording was made. This field is critical to preserve the value as an acoustic voucher record and data must be entered manually as soon as they are downloaded from the CF memory cards.

The Species field is used to link the unique species identification codes to each file and should be entered as the identifications are made for each species in each acoustic file. The Spec field is used to automatically add information on a given set of extracted acoustic files. The Notes field is used for additional clarifications or notes that may be useful to associate with a given data set. The right hand section of the header includes the spatial data associated with each file at a unique

location and is comprised of the base-datum used for the coordinates, latitude, longitude and altitude, if known.

Managing Location Data

Once the 2003 acoustic survey data (ca. 21,460 acoustic files) was received each acoustic file was evaluated for data integrity. Adding the specific location information to acoustic data, whether actively recorded or from passive monitoring, was critical for evaluating species occurrence at each site both temporally and spatially. While partial descriptive location data had been added to some of the data during the original study, this needed to be completed for all files and standardized for each location prior to the re-analyses.

The GRPO and PIRO survey locations were based on single points or transects with identical location information for each. The APIS survey locations, however, included two or three locations, each necessitating unique descriptions and spatial coordinates. The original descriptions provided by Kruger (pers. comm.) were retained for each location and a numerical suffix was appended to each point or transect so that each location was uniquely identified. Spatial coordinates (latitude, longitude [X,Y]) and species identifications were then added to header files. The acoustic files, which were archived in separate directories for each night's survey, were linked to each unique location using the AnalookW Folder utility Unsplit. This moved all of the data files into a single folder containing all of the files recorded at each unique location.

Location descriptions were then standardized and all file headers updated with the relevant spatial coordinates provided by Kruger (pers. comm.). This was accomplished using the Anahead Positions Utility and manually adding the geographical coordinate data to each set of files. This was necessary for the files to serve not only as vouchers for the presence of a given species, but in order to spatially define each unique location for distribution mapping.

The Anabat file structure is such that the date and time of each recording is encoded into each file. This also is used as the file name during the recording and data file saving process. Therefore each acoustic record also provides a documented occurrence of a given species not only in space but in time. Given that the time and date of every recording is provided, it is possible to use the AI to develop species- and location-specific relative activity and abundance indices.

Management and Addition of Species Data

The next phase of the data re-analysis was to independently identify the species recorded and add the species names into the header data. As noted above, acoustic files are also voucher records; files that contained calls of acoustically unknown species can be reviewed at some future time and newly recognized species added to the header data. It was necessary to examine every acoustic data file to independently determine what species were recorded prior to evaluating the relative activity and abundance.

If acoustic data is comprised of calls that are cleanly recorded, it is possible to use species-specific filters to rapidly scan data sets and to a large degree automate the addition of identifications. For example, during a long term monitoring project in Gallon Jug, Belize it was

possible to scan >800,000 acoustic files recorded at a single site (Miller, unpublished data). The data consisted of 3.5 years of nightly recordings collected from dusk until dawn. The data scan for this was completed in approximately 3 hours and resulted in a list of species and their relative abundance per unit time.

Species-specific filters used in this process are based upon a suite of call metrics that assist in identifying species that match the standard acoustic criteria (de Oliveira 1998, Korine and Kalko 2001). These acoustic criteria include a range of time and frequency values. A brief definition taken from Corben (2009a) of each of the basic parameters is provided below.

Duration (Dur) – minimum or maximum time measured in milliseconds (ms) of a pulse.
Maximum frequency (Fmax) – minimum or maximum value range for the highest measured frequency of a pulse in kHz.
Minimum frequency (Fmin) – minimum or maximum value range for the lowest measured frequency of a pulse in kHz.
Mean frequency (Fmean) – minimum or maximum value range for the mean measured frequency of a pulse in kHz.
Characteristic frequency (Fc) – minimum or maximum value range for the characteristic frequency of a pulse in kHz.
S1 is the slope at the beginning of the call, calculated over the first five dots in the call. – minimum or maximum value range for the S1 of a pulse measured in octaves per second; Note that SI can be negative.
Characteristic slope (Sc) – minimum or maximum value range for the Sc of a pulse measured in octaves per second; as with the S1 this can be negative.

A table of values for each of these acoustic criteria used to identify species in the original study was included in Kruger and Peterson (2008). The new AnalookW software uses a different filter structure, and includes a larger range of parameters that were not available in the Analook (Version 4.9, January 2003) used by Kruger and Peterson (2008). To test the efficacy of the call parameters they used to identify species, I constructed a set of the new filters based on their values. Each species specific filter was then challenged by scanning datasets comprised only of verified voucher calls of the target species to determine how well they preformed.

I created new filters based on Kruger and Peterson's (2008) parameters. However, these did not perform as well as anticipated either when discriminating between, or identifying, focal species. Most resulted in a relatively high degree of overlap. Several filters failed to identify verified voucher calls of the target species. Their parameters were derived from hand-released bats (Kruger, pers. comm.), however, such calls frequently do not provide diagnostic search phase calls (Miller 2004). Such overlap occurs when a filter is based on parameters that may be too inclusive and include call pulses that have similar components shared between a number of species.

With a high degree of parameter overlap, filters will flag all files that contain any fragments of call pulses of all species that are within the filters range for the given parameters. For example if a filter has a broad range of parameters for a Fc given as 38 kHz but with a range between 28 kHz to 50 kHz all files that have a Fc within this 22 kHz range would be flagged as a match.

A new set of filters specific to species expected to occur within the study areas were then created based on voucher files of search phase calls from reliable sources. Each species specific filter is constructed to use a range of the call parameters that reduces potential species specific overlap. The definition of a "bat call" used by Kruger and Peterson (2008) appears to more closely match the definition of a pulse rather than a call as I have used it for this analysis. They used sequences consisting of five or more calls (pulses) when they identified species. Filter parameters also include the number of pulses required per unit time in order to be recognized as a call sequence. While for some species this may be a minimum of five consecutive pulses within 15 seconds, for other species 10 pulses within 10 seconds is often used (e.g., some *Myotis* spp.). Definitions of each filter parameter with comparisons of the values used by Kruger and Peterson (2008) and new values for each species are presented in the appendix. Scanning the data using the updated criteria and with the new filters resulted in differences in identified species. As a result the relative abundance and seasonal composition of species for each location may differ from that reported by Kruger and Peterson (2008).

Assigning Species Identifications

It is difficult if not impossible to identify most species of bats from incomplete call sequences (O'Farrell 1997, O'Farrell and Miller 1997, Ochoa et al. 2000, Miller 2003). For this re-analysis of the acoustic data I used only complete call sequences for most species. In a few cases (e.g., species in the genus *Lasiurus*), a few pulses can be diagnostic for identification as the two species occurring in the study area have widely separated characteristic frequencies.

Given the high percentage of acoustic data from the Kruger and Peterson (2008) study that were fragmented or incomplete call sequences (Table 2), direct scanning of the data set to derive species composition and relative abundance was not an option. An example of call fragments compared to clean identifiable files can be seen in Figure 2.

Table 2. Percentage of identifiable call sequences versus unidentified call fragments at each of the three parks.

Park	No. of Identified Species	Fragments
APIS	36.2	63.8
GRPO	43.3	56.7
PIRO	54.6	45.4

In this re-analysis only search phase calls were used for the species identifications. Even when well recorded, not all echolocation calls are useful for species identifications (Fenton and Bell 1981; O'Farrell et al. 1999; Corben 2004; Corben 2004; Miller, unpublished data). For example it is not unusual to record social calls, approach phase, feeding buzzes and commuting calls but they have not yet proven to be diagnostic for species identifications.

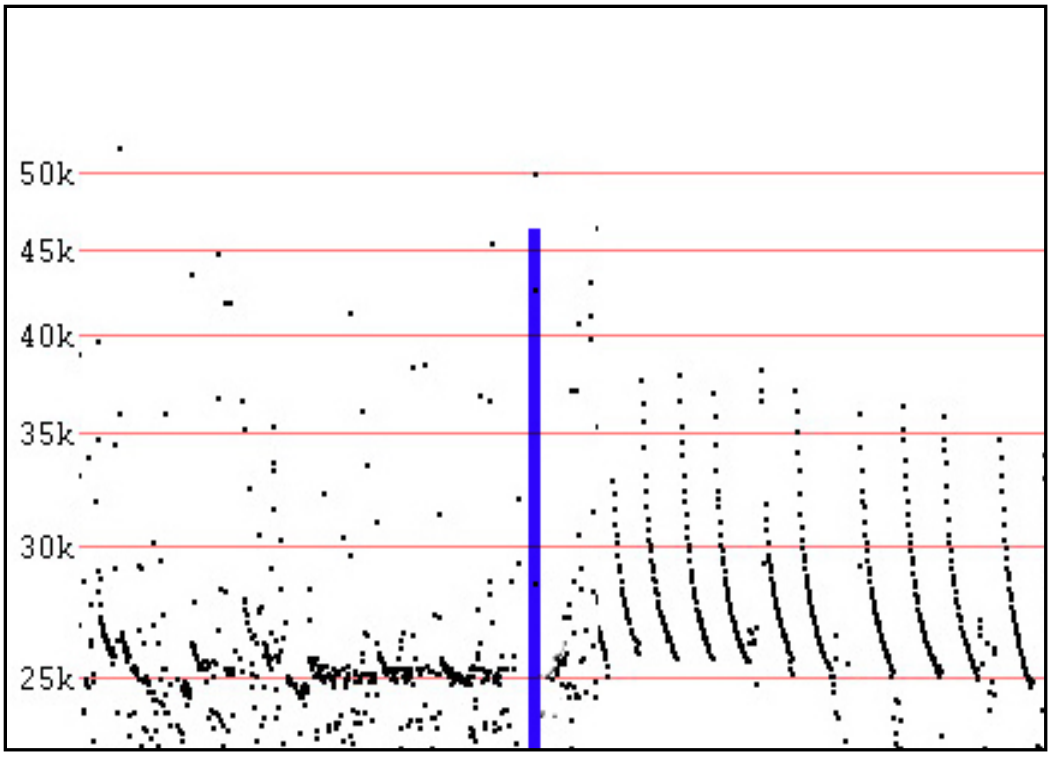


Figure 2. Example of unidentifiable call fragments (left) compared to an identifiable call sequence (right).

Using the new filters the data sets for GRPO, APIS and PIRO were scanned and the results used to create an Analist file (ANL). The ANL files enables the user to view all the acoustic files which pass a species specific filter, even though they may be dispersed in multiple directories and scattered on the hard disk. When the ANL file created using the suite of filters is opened in the AnalookW program, the user selects the species they wish to view. The advantage of using the ANL file is that one can then review only those files that matched parameters selected by the species specific filter.

In order to determine the relative abundance of species for each location it was important to verify that calls were as accurately identified as possible. I used the ANL file utility to review the results of each species filter throughout the entire 2003 acoustic data set.

Using the ANL utility facilitated a review of each file identified be the species-specific filter, and subjectively matching calls to verified vouchers (Erickson and West 1995, O'Farrell 1997, O'Farrell et al. 1999). This eliminated errors in identification based on pulses from incomplete calls that may have been incorrectly selected by a specific filter.

Questionable calls were visually compared with verified voucher calls and key acoustic parameters were measured at the same scales using the side-by-side feature in the AnalookW program. When in doubt, or calls could equivocally be assigned to one or more species, they were conservatively listed as unidentified fragments. Once confident that the identification was

correct, the species codes were added to the header of each file using the species tool bar in AnalookW (Figure 3).

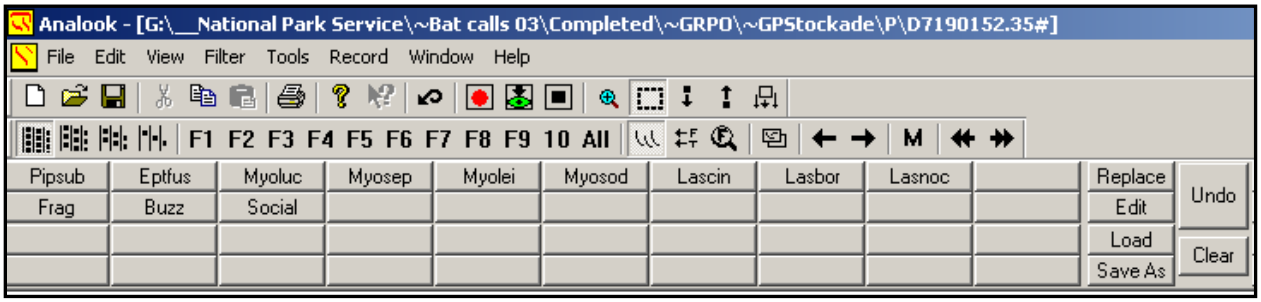


Figure 3. Species identification buttons in AnalookW.

It was not uncommon to have multiple species recorded in a single call file, resulting in several species codes being entered in the header of the same file and separated by a comma. Additional information was also noted such as feeding buzzes, social calls, incompletely recorded calls or unknown fragments. The majority of the latter appeared to be fragmented or incompletely recorded calls of either *Myotis lucifugus* or *Myotis septentrionalis*. These were identified as "Frag" and are included as such in the results as an overall indication of *Myotis* spp. activity. Files that contained hand released bats, insects, and other "noise," or only 40 kHz calibration tones were marked and deleted from the datasets prior to analysis.

Data Analyses

Due to the high percentage of incompletely recorded or fragmented calls it was not possible to use recently developed advanced methods to scan the data and add species identifications that would yield robust results. Therefore an estimated 70 hours was spent carefully reviewing each of the 21,460 files. I used the ANL utility to group files by each unique species filter. During this time species identifications or other descriptors (e.g., feeding buzz) were added to the headers of each acoustic data file. Once the identification phase was completed, the header data was extracted from the files and grouped based on each unique location. Each of these header file compilations was subsequently imported into a proprietary acoustic data management and analysis system (Miller, in review).

As noted above, it is not uncommon to have multiple species recorded in one Anabat file. To accurately analyze such files, all species and additional information recorded were parsed into separate species records into three relationally linked database tables when imported into the system. These records are stored in a master header data table, a separate table of AI values and a location table with relevant spatial data including a description of the location and X, Y coordinates. The AI table was automatically updated so that values were adjusted to reflect the survey unit effort (hours of survey time) for each location or transect provided by Kruger (pers. comm.). The AI values per survey hour were also automatically standardized to 10 survey hours to allow comparison between sites and or survey dates. Using the standardized AI allows

comparison of the relative abundance of species between dates and sites and is used in the results section below.

Using a suite of queries in the data management system, relevant data was extracted for each location and species and is presented in the results. In addition to the Anabat data files, with the completed header data, an MS Access database containing the three base tables is available as a supplement to this final report.

Results

A large percentage of the acoustic files were comprised of call fragments that could not be identified to species. These ranged from a low of 30.4% at Miner's Castle to a high of 85.2% at Chaple (Table 3). I attribute the high percent of unidentifiable species to the passive recording setup used, and possibly having the gain set too high during several transects, resulting in distorted signals. Technology has changed since the early days of passive monitoring and so has our understanding of the impact that weather-proofing the Anabat microphone has on the recorded data. When Kruger and Peterson (2008) conducted their surveys, the use of curved PVC tubes (O'Farrell 1998) was being adapted by many researchers in the region (e.g. Nordquist 2006) as a means of weather-proofing the Anabat system.

Table 3. Percentage of recorded calls that were unidentifiable fragments at each survey site.

Location	Percent fragments
APIS	
Devil's Island	80.4
Little Sand Bay	67.7
Outer Island	44.1
Stockton Island	58.2
PIRO	
Beaver Lakes	78.4
Chapel	85.2
Grand Sable	51.6
Kingston Lake	31.4
Miner's Castle	30.4
Sand Point	46.3
GRPO	
Fort Charlotte	55.4
GP Stockade	48.9
Poplar Creek	78.9

Some setups that used reflector tubes were considerably better than others. For example the passive set up illustrated by Nordquist (2006) shows a poorly placed detector microphone cocked at what appears to be a 45° angle and not aligned with the tube (Figure 4). With this set up, incoming sound signals may bounce around the tube and secondary echoes may be generated within the weather-proof enclosure, further confounding the ability to identify clean signals. Kruger and Peterson (2008) show the microphone properly aligned to maximize signal reception with the use of the reflector tube (Figure 4).



Figure 4. Passive setups of acoustic monitoring stations showing use of reflector tubes. From Nordquist (2006), left, and Kruger and Peterson (2008), right.

In a study to evaluate the impacts of weather-proofing and possible loss of bat calls, Livengood et al. (2003) demonstrated that curved PVC tubes had a greater impact on frequencies at 25 kHz and 80 kHz with a diminished reception distance. The curved tube reduced the length of the primary lobe of sound detection. Bats that echolocated within those frequencies could not be detected from as far away as they could with the unprotected microphone or with the use of a reflector plate (Livengood et al. 2003). This resulted in a signal loss when using reflector tubes reducing the received sounds to a narrower sound signal, as opposed to open reflector plates that are generally used today that record a wider range of bat calls (Livengood et al. 2003).

There were few problems in identifying the calls attributed to the two species of *Lasiurus*, given the distinctive alternating up and down frequency of the Fc that is characteristic for the genus. The remainder of the complete and identifiable sequences were used to summarize the standardized AI comparison for species and sites.

Spatial and Temporal Comparison of Species

Using the AI standardized to 10 hours of survey time, it was possible to compare the relative abundance of bats between the three parks and look at seasonal differences during the months June, July, and August (Figure 5). *Lasiurus cinereus* was present in all parks from June and throughout the survey period. In June, *L. borealis* was only present in very low numbers with more individuals arriving later in July and remaining in August at both at APIS and PIRO and to a lesser extent at GRPO. All other species were present at all three parks during all three months surveyed, albeit in considerably different numbers. The large number of calls that were unidentified fragments were not included in the figures as this would obscure the relative abundance and activity of the identifiable calls. It is likely these incomplete call sequences were comprised mainly of the two species: *Myotis septentrionalis* and *M. lucifugus*. If combined with calls that were identifiable it is not unreasonable to assume that these are the two dominant species at all sites.

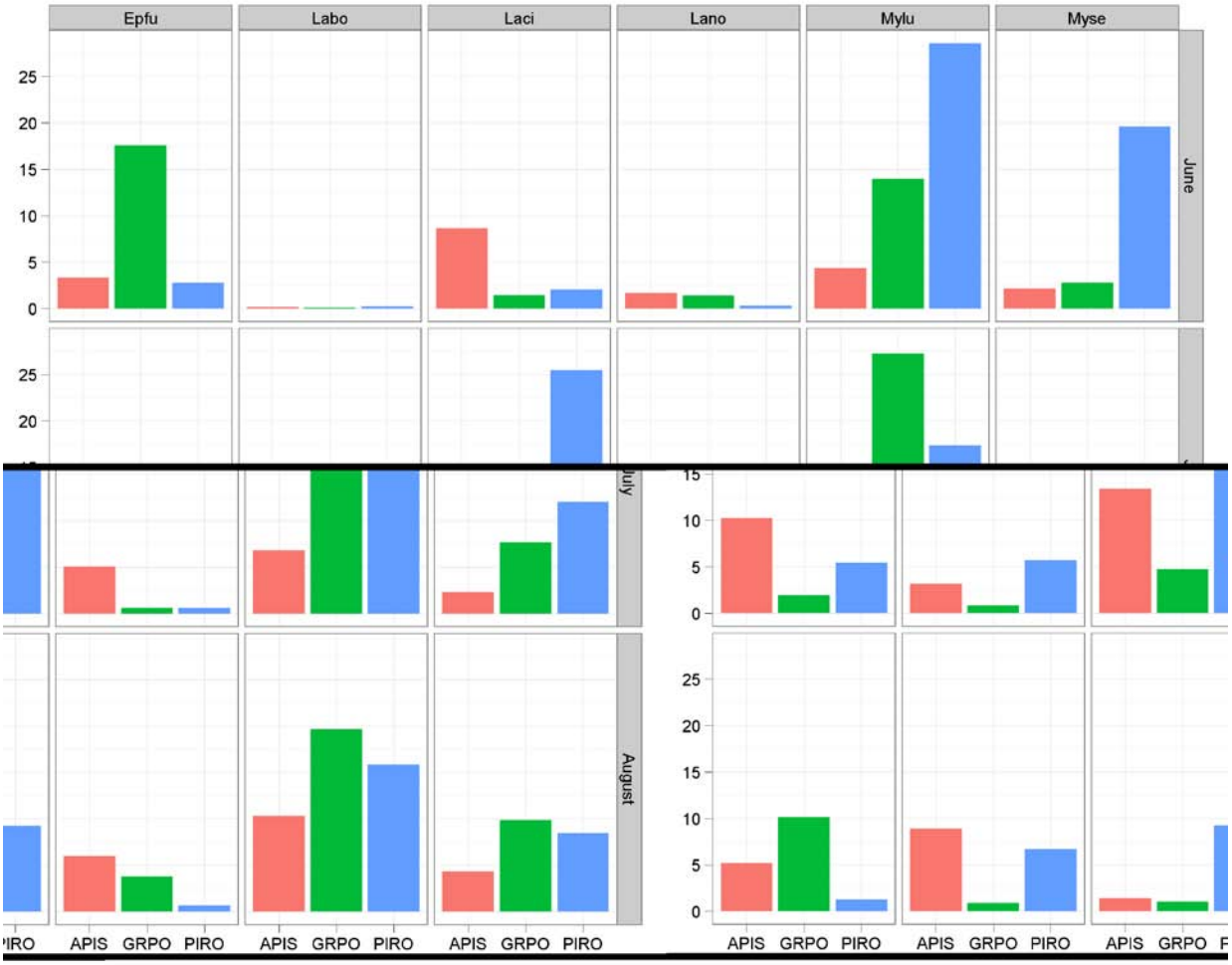


Figure 5. Comparison of relative abundance of species by month June-August 2003. The Y axis is the AI value standardized per 10 hours of survey time. Species codes: Epfu = *Eptesicus fuscus*, Labo = *Lasiurus borealis*, Laci= *Lasiurus cinereus*, Lano= *Lasionycteris noctivagans*, Mylu= *Myotis lucifugus*, Myse= *Myotis septentrionalis*.

Relative Abundance and Temporal Activity of Species at Each Park

By combining the standardized AI data, it was possible to examine the relative abundance and temporal activity of species at each of the three parks during the three month survey period (Figure 6).

Of the six species identified during the survey *Lasiurus cinereus* and *Myotis lucifugus* were the most abundant at the Apostle Islands National Lakeshore followed by *Eptesicus fuscus*. The remaining three species, *Lasiurus borealis*, *Lasionycteris noctivagans* and *Myotis septentrionalis* were approximately equally abundant (Figure 6).

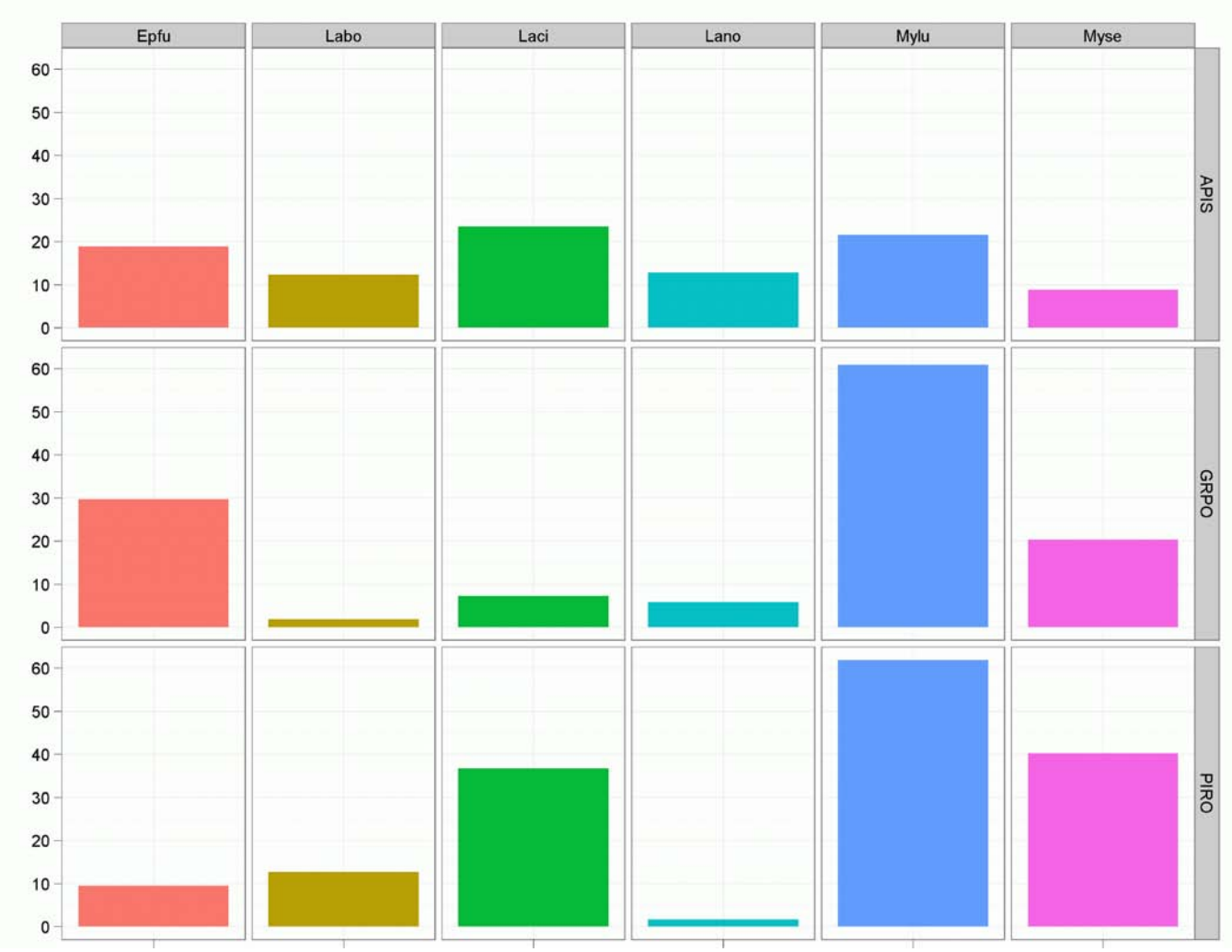


Figure 6. Comparison of relative abundance of species between three parks combining the standardized AI values from June-August 2003. The Y axis is the AI value standardized per 10 hours of survey time. Species codes: Epfu = *Eptesicus fuscus*, Labo = *Lasiurus borealis*, Laci= *Lasiurus cinereus*, Lano= *Lasionycteris noctivagans*, Mylu= *Myotis lucifugus*, Myse= *Myotis septentrionalis*.

Myotis lucifugus was the most abundant species at GRPO, followed by *Eptesicus fuscus* (Figure 6). It is probable that some of the files labeled as "unidentified fragments" included *Myotis septentrionalis* as many of the fragments were in that species frequency range. There were considerably fewer unidentified call fragments in this range at APIS and PIRO. Therefore this species may have been considerably more abundant than the confirmed identifications would suggest. Both species of *Lasiurus* and *Lasionycteris noctivagans* were less abundant at GRPO during this survey (Figure 6).

Myotis lucifugus was also the most abundant species at PIRO. *Lasiurus cinereus* and *Myotis septentrionalis* were nearly equal in abundance. *Lasionycteris noctivagans* was rare and *Eptesicus fuscus* had the next lowest abundance (Figure 6).

Temporal Activity

The Anabat data and file structure is ideally suited to deriving temporal activity since the date and time is encoded into each file during recording. This also is used as the file name during the recording and data file saving process. The file name format stems from the legacy days when computer file names were constrained by the 8.3 convention under the DOS operating system. Each Anabat file name is comprised of seven parts that encodes both the date and the time (Figure 7).

Y	M	D	HH	MM	SS	Ext
D	8	20	21	14	28	#

Figure 7. Anabat file structure. Y=year, M=month, D=day, HH=hour, MM=minute, SS=seconds, and # the Anabat file extension.

For the months January through September (months 1-9) a single digit space works well. For the remaining three months – October through December, using the months 10-12 – or years beyond 1999, a single digital character would not suffice. Therefore a modified version of hexadecimal numbering is used where numerals 0-9 only used as single digit and from 10 onwards a single letter is used to denote the number. For example the Anabat file name **D8202114.28#** translates to August (month 8) 20 (date) 2003 (D) recorded at 21:14:28.

In order to evaluate temporal activity it is assumed that the user has correctly set the time in the storage detectors and made certain to adjust for daylight savings shifts and or time zone shifts when moving about the landscape. There are utilities included in the AnalookW program to correct such time adjustment oversights or errors if discovered at a later date. It is also important for storage detectors to have the correct time set to allow the programmable Compact Flash (CF) memory cards that both store recorded data and include programming instructions to turn the monitoring equipment on and off at the desired times. There were several acoustic data sets for several nights and locations that had times incorrect by an hour and these were corrected prior to analyzing the data.

Using a suite of acoustic data management and analytical tools I am developing as a new acoustic data management and analysis service, it was possible to compare temporal activity between the species, parks, and dates. In addition to linking spatial data to the acoustic files, the acoustic data analysis system (Miller 2009) includes program code for R, an integrated suite of software facilities for data manipulation, calculations and graphical displays (http://www.r-project.org/), and the GGPLOT2 graphics plotting package (http://www.had.co.nz/ggplot/). This was used for analyzing and plotting the temporal activity data.

Species Temporal Activity Patterns

A summary of the temporal activity for the six species in the three parks suggests that most species were active throughout the night during the surveys (Figure 8). Looking at the temporal activity by park and date provides considerable insight into bat activity patterns.

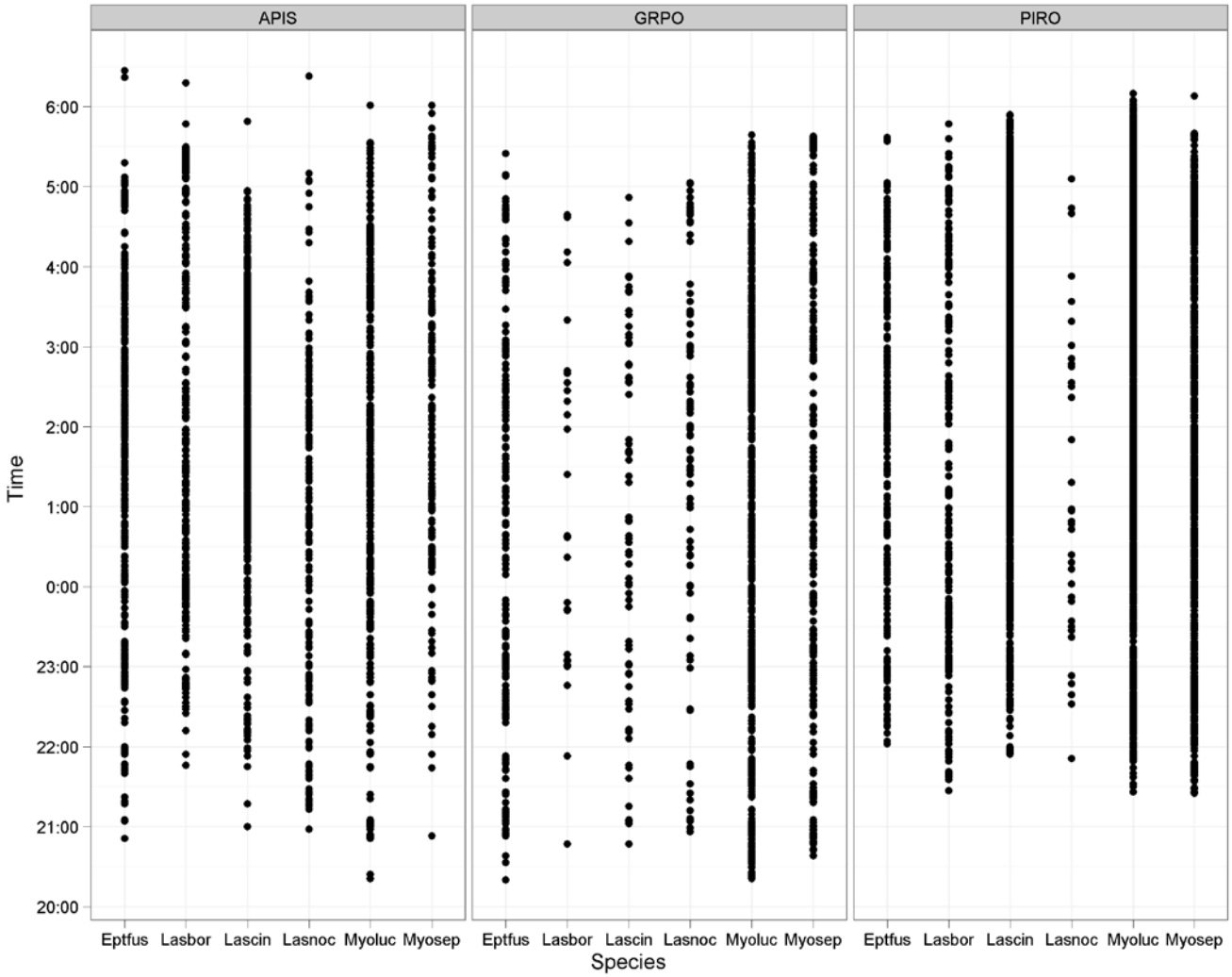


Figure 8. Summary of temporal activity for the three parks during the entire survey period.

Apostle Islands National Lakeshore

There was scant activity throughout the night during the month of June for most species (Figure 9). There was an increase in activity in July and for most species August. *Lasionycteris noctivagans* was active throughout the night in July only.

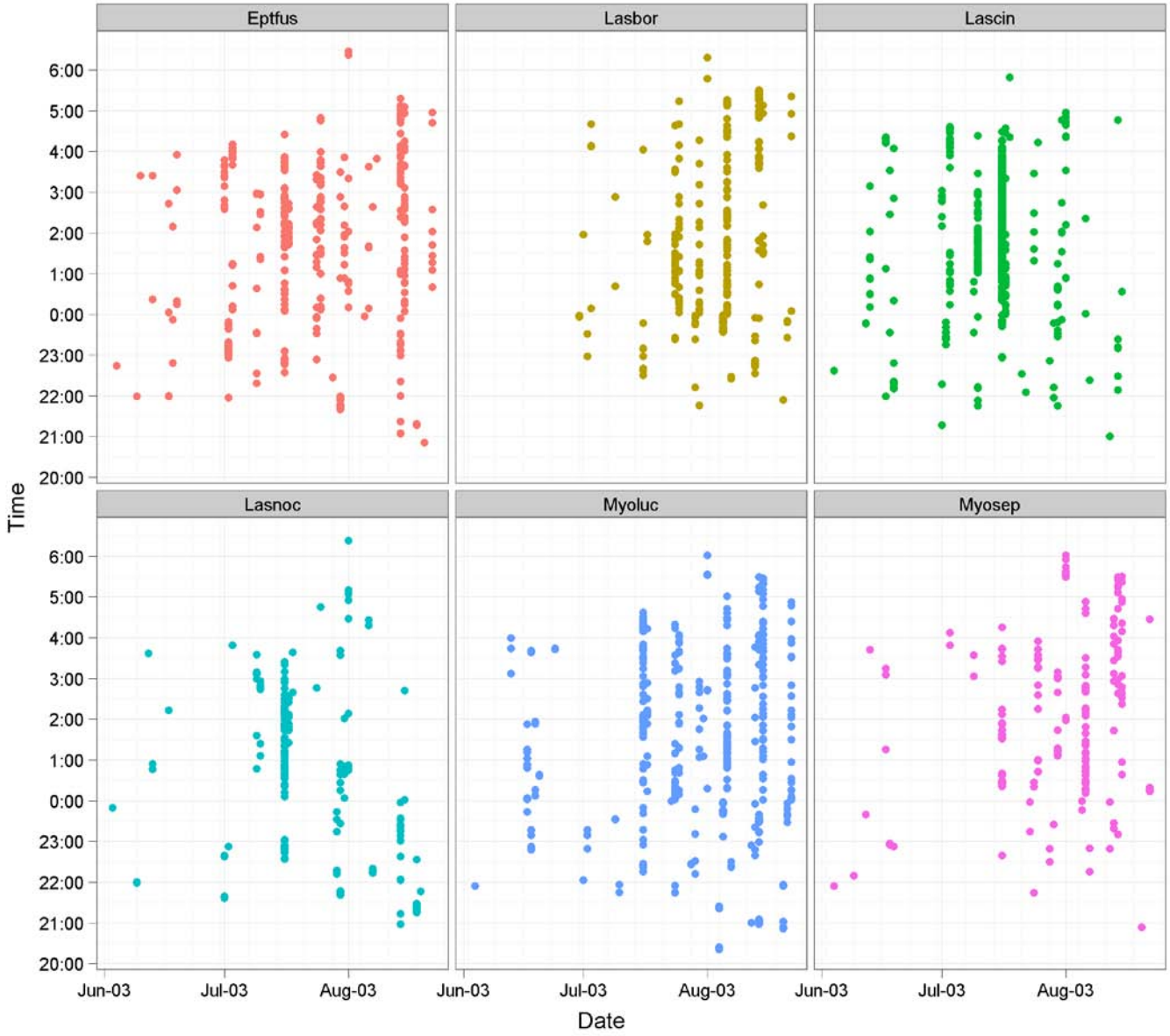


Figure 9. Comparison of temporal activity patterns for the six species of bats at APIS.

Grand Portage National Monument

There was scant activity for *Lasiurus borealis* at GRPO throughout sampling period, while *Lasiurus cinereus* was most active in July (Figure 10). *Lasionycteris noctivagans* activity was minimal in June and July but increased considerably in August. With the exception of *Lasiurus cinereus*, nightly activity was greatest in August.

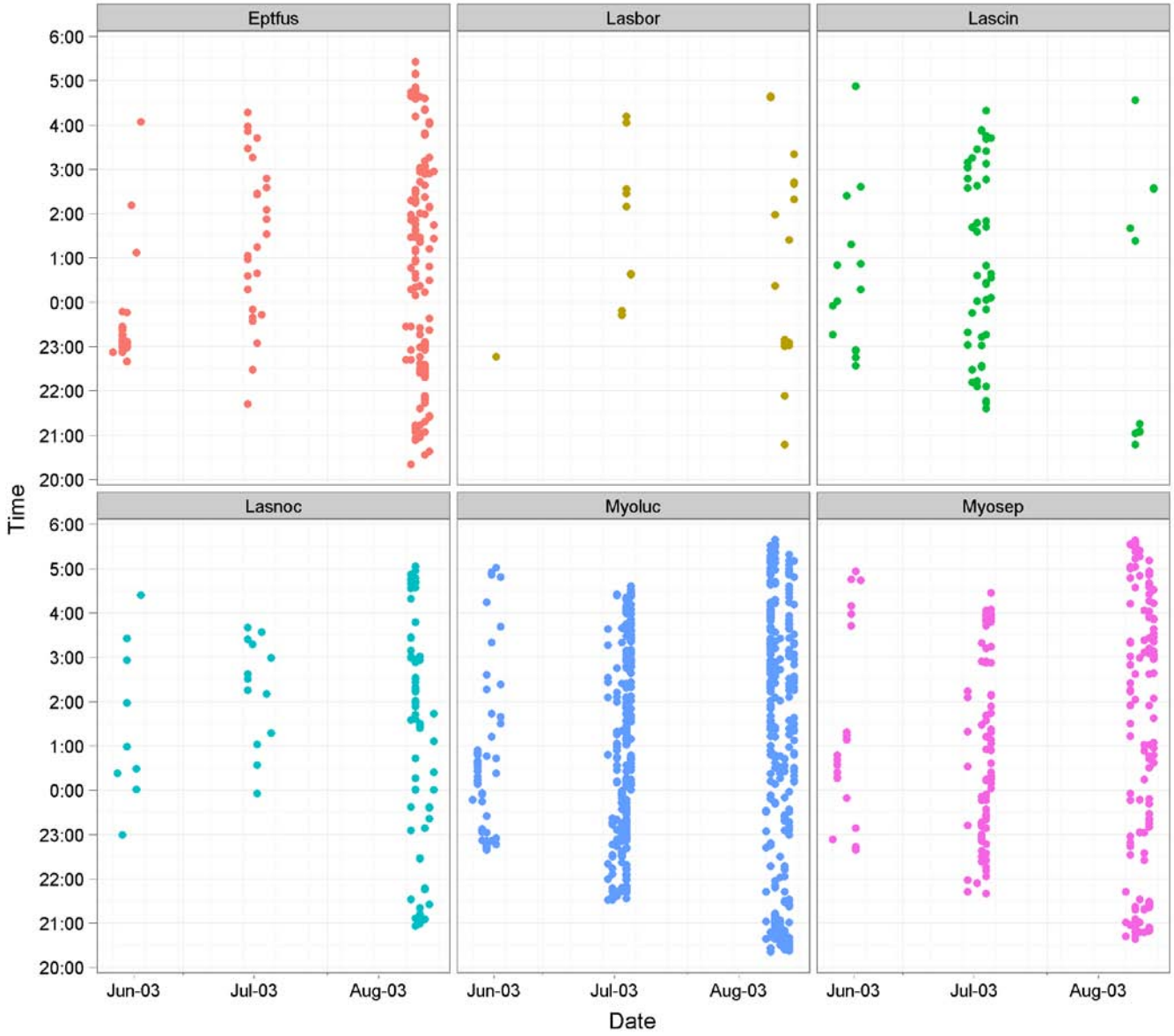


Figure 10. Comparison of temporal activity patterns for the six species of bats at GRPO.

Pictured Rocks National Park

Lasiurus borealis and *Lasionycteris noctivagans* were absent or only marginally active in June, respectively (Figure 11). Nightly activity was fairly constant for all other species at PIRO during the sampling period.

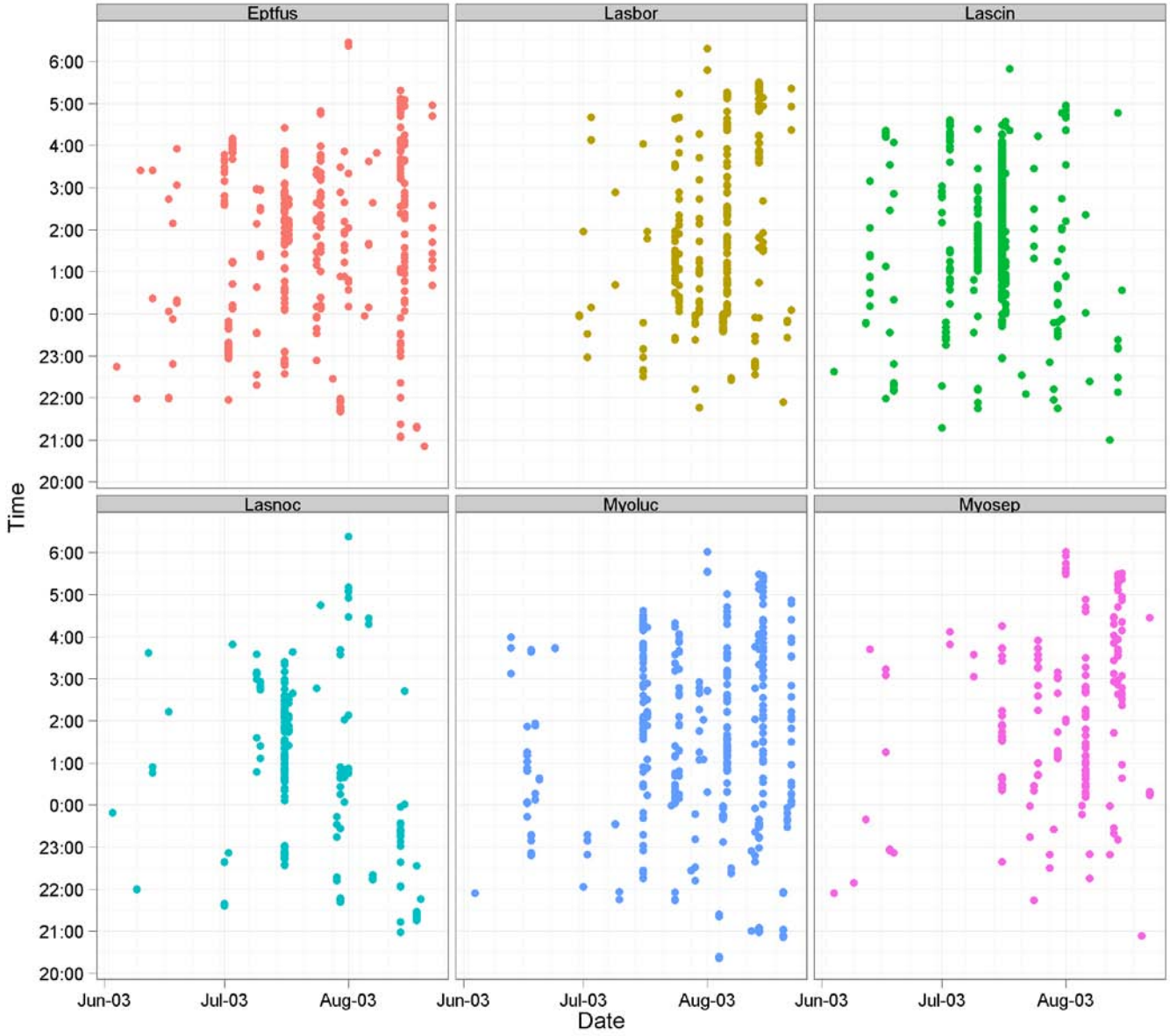


Figure 11. Comparison of temporal activity patterns for the six species of bats at PIRO.

Discussion

Kruger and Peterson's (2008) study sites were not randomly chosen, thus all conclusions are for the sites only. While it is possible to infer relative abundance and activity for the parks the results may not be representative (Route pers. comm.). Kruger and Peterson (2008) concluded that six of the seven species thought to occur in the three parks were present during a three month survey period in 2003. A review of the species distribution maps (IUCN 2008) suggest that possibly the seventh species, eastern pipistrelle (*Perimyotis subflavus*) might occur in the area. It was neither captured nor detected acoustically at any of the park survey locations (Kruger and Peterson 2008). My re-analysis supports the Kruger and Peterson (2008) conclusions that there were six verified species. Moreover, during this re-analysis, all acoustic files were subsequently scanned with new robust filters and they performed well when challenged with focal species voucher files. I found no acoustic files flagged as matches to the *P. subflavus* vocal signature parameters, corroborating the conclusion that the *P. subflavus* was not present during the survey period. It remains possible that the species was present in very small numbers and was not detected acoustically or if present it was using areas that were not surveyed.

Kruger and Peterson (2008) assumed that it was not possible to determine relative abundance from their acoustic data since calls could have been produced by a few individuals or by many individuals. Kruger and Peterson (2008) also assumed that it was not possible to use the acoustic data to directly evaluate temporal variation in bat activity between parks or between sites within the parks. While they were constrained by limitations of equipment and could not sample all sites simultaneously, it was possible to generate relative temporal activity for each species at each park. Variation in bat species temporal activity at a given site may reflect responses to varied environmental conditions. These include seasonal shifts in localized prey availability, transient climatic factors (i.e. wind, rain), or lunar phase.

Using the standardized AI during this data re-analysis, I estimated relative abundance for each species at each park by month. Given the nature of the Anabat acoustic file structure that automatically captures the date and time of each recording it was also possible to evaluate temporal activity.

Kruger and Peterson (2008) reported that two species – *E. fuscus* and *Lasiurus cinereus* – were only verified by acoustic methods. Moreover, this re-analysis shows Lasiurus *borealis* is probably very rare during June.

Kruger and Peterson (2008) did not distinguish between the two species of *M. septentrionalis* and *M. lucifugus* and combined these into a *Myotis* spp. category. With a larger library of verified reference calls it was possible during the re-analysis to identify these two species from the complete call sequences included in the *Myotis spp.* category. They also had a number of sequences they could not identify and placed these into an "unidentifiable" category. The majority of these calls were comprised of incomplete call sequences with frequencies were not specifically diagnostic search phase calls and with the overlap could match either species of *Myotis*.

It is possible they were not aware of the frequency shift that occurs when multiple individual conspecifics are present and recorded at the same time. This may have confounded their ability to differentiate diagnostic calls of these two species. This occurs when individual bats shift their characteristic frequency up or down when another conspecific arrives in the same area (Miller 2004). These frequency shifts range from 2-3 kHz. In addition to confusing identifications, researchers who are unaware of such frequency shifts could over-estimate the variation in the basic search phase calls of an individual or species.

This re-analysis of the Kruger and Peterson (2008) data added species identifications and spatial attributes to the data set that were not previously included thereby enhancing the archival value. Additionally, using the AI (Miller 2001) it was possible to provide reasonable estimates of relative abundance for all species occurring during the study that would not have been possible using the metric of files per hour (Britzke 1999). The results of this re-analysis also provided temporal activity patterns for each species as summarized for each park.

Recommendations

Additional acoustic data files are available for the three parks (L. Kruger, pers. comm.). If Kruger's 2004 survey acoustic data set is also re-analyzed and combined with the re-analyzed 2003 data set, a better understanding of the temporal and spatial species distributions within each park may be possible. Further, if spatial data that includes habitat information is available for each sample location, it may also be possible to derive habitat preferences and evaluate niche overlap for the species at each of the three parks. This would provide information useful to manage the parks for each species in a more proactive and robust manner and further identify critical habitat.

Bats are increasingly recognized as excellent taxa for monitoring habitats (Miller 2003; Rainey et al. 2006, 2009; Jones et al. 2009). Acoustic sampling is both a powerful and cost effective means to monitor bat populations. Future bat surveys in any of the national parks should employ reflector plates for the monitoring stations instead of the curved PVC tubes. This will result in a higher percentage of identifiable calls, fewer fragmented calls, and more complete vocal signatures for species recorded. All future acoustic transects should also employ current technology using the Anapocket software and the Anabat SD1 storage detector linked to a PDA so that the person(s) conducting the surveys can examine the calls as they are produced during transects. This allows immediate adjustment of the microphone sensitivity and gain to eliminate overdriving the microphone and resulting distortion of signals. With the addition of a GPS CF card receiver linked to a PDA, potential microhabitat associations may be discovered during subsequent analysis of the data as the X-Y-Z data is added automatically to each file recorded.

Using acoustic monitoring is a very cost effective means of monitoring bats once the initial investment of equipment is made. A number of Anabat acoustic monitoring stations have been operating in Yosemite for several years unattended dusk until dawn (W.E. Rainey, pers. comm.). Aside from data recovery field time, no costly human resources are necessary for data collection during the monitoring periods. Preliminary analysis of this data suggest that even with snow on the ground bats may become active during sunny periods, which has management implications applicable to winter months. Similar bat monitoring efforts within the GLKN would also be a cost effective means of gathering a large amount of data over landscape level and time scale monitoring efforts. With the investment of monitoring station equipment and a modest investment for training field technicians a program could be implemented that would yield robust data for proactive management decisions.

There was no habitat data available for the three parks during this re-analysis. If spatial habitat data could be made available for all sites, it would be possible to evaluate the relative abundance on a habitat basis to determine habitat preferences and provide better information for on-the-ground management of these protected areas.

While bats have been a relatively low priority monitoring target they are now very much in the forefront of conservation concerns given the spread of white-nose syndrome (Blehert et al., 2009, Reichard et al., 2008, Veilleux, 2008). If priorities within the GLKN shift due to the rapid spreading and anticipation of white-nose syndrome arrival in Michigan within the next year or so (Kurta pers. comm.) it may be desirable to begin a monitoring program. The existing 2004

acoustic data when reanalyzed and combined with the results of this project could serve as a starting point for such a monitoring program.

Often, what has been referred to as “monitoring” is actually surveillance, or tracking the change over time. Monitoring differs from surveillance as the goal is to track progress over time towards a target or objective (Figure 12). If there is no clear idea of what this objective is, then there is nothing to monitor. Setting explicit targets lies at the core of effective monitoring. Monitoring towards a target provides data verifying whether management efforts are successful, whereas surveillance alone will not provide that information (Wilke 2005).

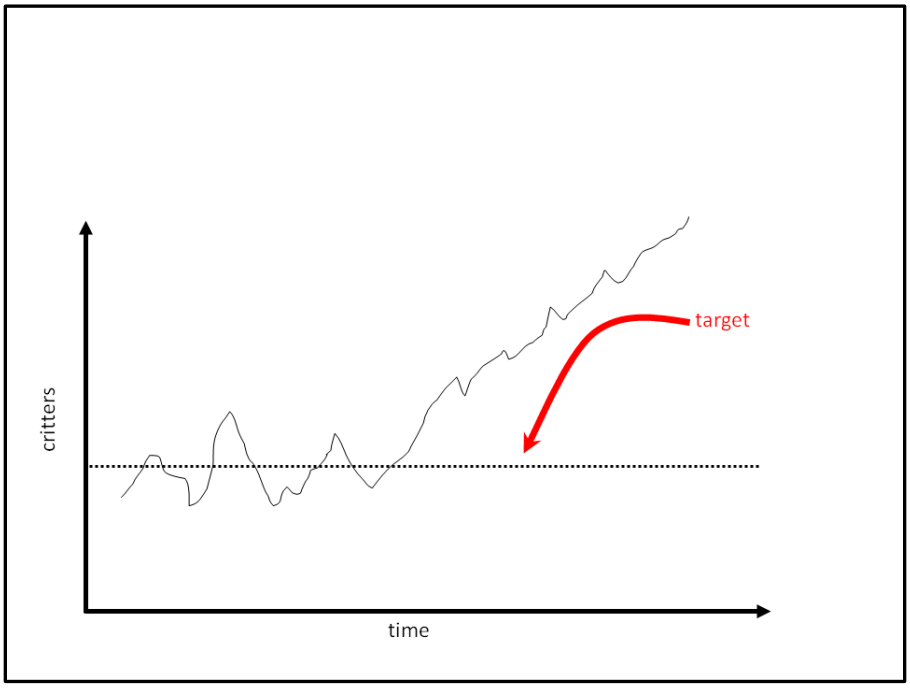


Figure 12. A target is necessary for monitoring, otherwise it is simply surveillance.

I suggest that the monitoring targets initially be equal to or greater than the baseline numbers of the conservation targets. The combined results of the 2003 and 2004 acoustic surveys might serve as a starting point. If the relative abundance of a bat species of conservation concern drops below the established targets, then management intervention may be required. Effective bat conservation relies on gathering sufficient information to identify changes in populations that are of conservation concern and to measure the population response to management (Walsh et al. 2006).

The number of acoustic stations required for the simultaneous collection of data will depend on the area of the landscape to be monitored. I suggest that a statistical power analysis (Aughney and Roche 2006; Barclay et al., 2004; Gerrodette 1987) be used to estimate the optimum number of monitoring stations for each site in order to statistically detect trends. This is useful since the results will determine whether the number of stations (sample size) is too high or too low. If the

number of stations used is too low, the data may lack the precision to reliably detect trends that are being monitored. Conversely if too many are used, time and resources may be wasted, often for only minimal gain.

Establishing the locations for each monitoring station will generally be determined by the initial baseline sampling period or data on hand. Experience has shown that for baseline data collection, a minimum of 3 nights is required for documenting common species, although 5-10 nights is considerably better for detecting rare species. Rare species are often those that are of conservation concern and may be focal monitoring targets. This is corroborated by using rarefaction species accumulation curves (Gotelli and Colwell 2001).

Example of Use of Spatial Data From Acoustic Data Sets

The following examples using data from this re-analysis are illustrative of how acoustic data can be linked to spatial analyses and visually provide new and useful information for park management. Anecdotal evidence suggests that the north shore of Lake Superior is important for migrating bats; however no studies have documented the travel pattern (Nordquist 2006). Three species *Lasionycteris noctivagans*, *Lasiurus borealis* and *Lasiurus cinereus* migrate out of the state during the winter and return in the spring (Nordquist 2006). The acoustic data linked explicitly to spatial survey points suggests that arrival of one of these known migrants (*L. cinereus*) may begin in June with a peak in August in the three parks surveyed (Figures 13-15). The increase in relative abundance from the western to the eastern portion of PIRO may be coincidental or linked to an important seasonal habitat change.

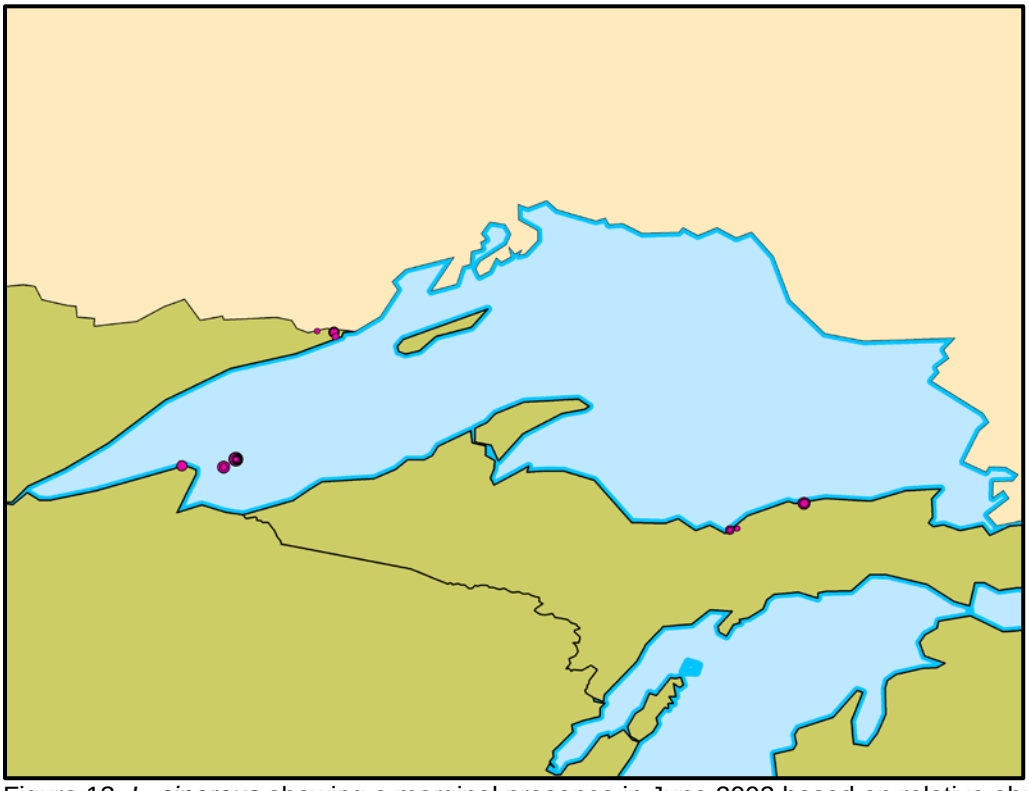


Figure 13. *L. cinereus* showing a marginal presence in June 2003 based on relative abundance.

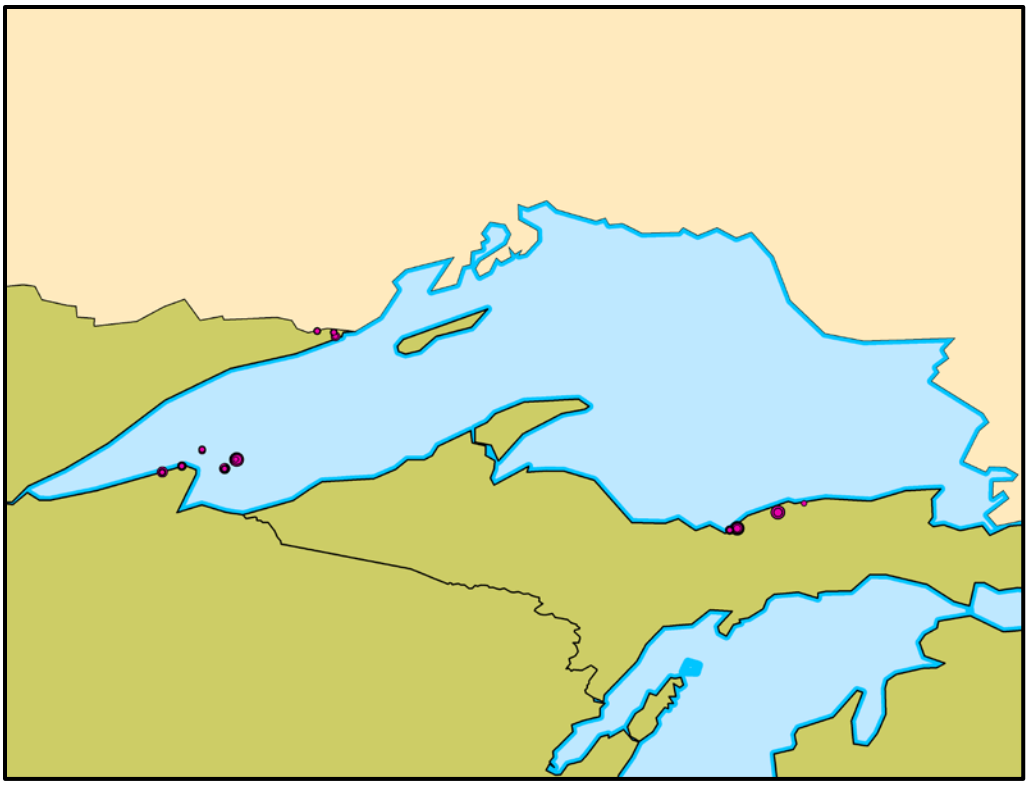


Figure 14. *L. cinereus* showing an increase in numbers during July 2003.

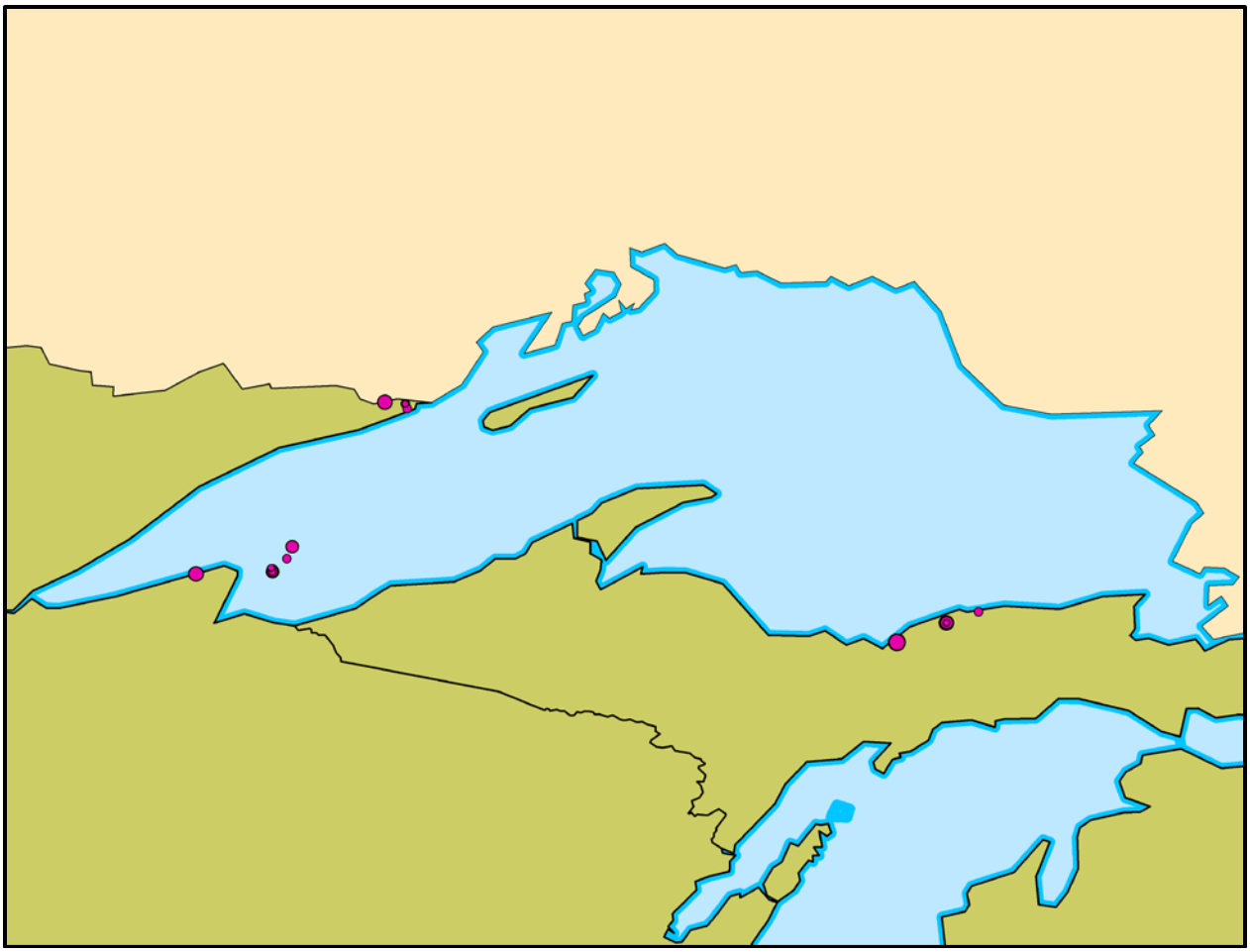


Figure 15. *L. cinereus* showing the increased numbers and spatial distribution of relative abundance in August 2003.

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Appendix A. A Review of Filters and Filter Parameters Used in AnalookW.

As the use of filters appears to be a point of uncertainty with users of the AnalookW software, a review of the basic filter parameters (O'Farrell and Corben 2001) is presented with additional notes on the new filter formats are provided below. This is followed by a species by species comparison of the filters constructed using the Kruger and Peterson (2008) call parameters and those created specifically for this re-analysis based on a robust set of species specific voucher calls. The later set of filters was used for identification of species to scan the entire acoustic data set and create the Analist files and verify species identifications.

Filter Parameters

The filter parameters and descriptions (Corben 2009b) are included here as a resource for those who may not be familiar with the use of filters and the variables used to use them.

smooth

This process recognizes groups of dots that are smoothly connected to each other and therefore might be bat calls. These groups of dots are treated as bat calls, and are then examined by subsequent filter operations. Thus, the selection of an appropriate smoothness parameter is the first step in defining a filter. The lower the value, the more stringent the filtering process (i.e., the higher the quality a call must have before it can be recognized as a call). Typical values to choose would lie between 20 and 100. The default value of 9999 has virtually no effect. As a rough guide, when this parameter is set to 100, it allows about a 10% deviation of each point from the mean frequency of the points either side of it.

maxposchg

This parameter defines the maximum positive change in frequency that a call can contain. As a rough guide, a value of 200 allows one point to be about 10% higher in frequency than the previous point.

maxnegchg

This parameter defines the maximum negative change in frequency that a call can contain. As a rough guide, a value of 200 allows one point to be about 10% lower in frequency than the previous point.

bodyover

The bodyover is the number of transitions in the original bat call over which certain other parameters are calculated. The number of transitions is divided by the current DivRatio to determine the number of dots over which the body is calculated. Using transitions rather than dot intervals frees the effect of this value from any dependence on the DivRatio. For example, if the bodyover is chosen as 80 when the DivRatio is 16, this gives a value of 5 for the number of dots included in the body. Any bat call is then scanned for groups of 5 dots (covering 4 inter-dot intervals) until the group of 5 dots is found that has the lowest overall slope. This call fragment is treated as the right-hand end of the body of the call and is used to estimate the characteristic frequency (Fc) and characteristic slope (Sc). Larger values for the bodyover parameter will make the measurement of these parameters more reliable because they will be less affected by small

variations within the call. However, if the body length becomes a large proportion of a non-linear call, it will effectively form a chord across the curve and give an inaccurate result. We recommend a value of 160 for long duration calls with long, linear segments but a reduced value of 80 for short duration calls.

highstart
When set to 1, this parameter constrains a call to begin at the point of highest frequency. Thus, any dots prior to that point will be excluded from the call. The default (0) has no effect.

lowstart
When set to 1, this parameter constrains a call to begin at the point of lowest frequency. Thus, any dots prior to that point will be excluded from the call. The default (0) has no effect.

alldrop
When set to 1, this parameter constrains a call to consistently decrease in frequency from one dot to the next. Thus, positive changes in frequency will be excluded from the call. The default (0) has no effect.

minNtrans
This parameter determines the minimum number of dots a call must have before it can be accepted. The number of dots is equal to minNtrans/DivRatio. Normally, this parameter can be left at 0, which will have no effect and the call can be constrained using the minDUR parameter.

minDur
This feature sets the minimum length (ms) a call must have before it is accepted. Shorter calls will be rejected.

maxDur
This feature sets the maximum length (ms) a call must have before it is accepted. Longer calls will be rejected.

minFmax
Any call whose maximum frequency is less than this value is rejected.

maxFmax
Any call whose maximum frequency is more than this value is rejected.

minFmin
Any call whose minimum frequency is less than this value is rejected.

maxFmin
Any call whose minimum frequency is more than this value is rejected.

minFmean
The Mean Frequency (kHz) is the area under a bat call divided by the duration. Any call whose mean frequency is less than minFmean is rejected.

maxFmean
Any call whose mean frequency is more than this value is rejected.

minSweep
Any call in which the difference between the highest and lowest frequencies is less than this value will be rejected.

maxSweep
Any call in which the difference between the highest and lowest frequencies is more than this value will be rejected.

minFc
The characteristic frequency (Fc) is measured as the frequency at the right-hand end of the body (see above). Any call in which Fc is less than minFc will be rejected.

maxFc
Any call in which Fc is greater than maxFc will be rejected.

minS1
S1 is the slope at the beginning of the call, calculated over the first five dots in the call. Any call with SI less than minS1 will be rejected. Note that SI can be negative.

maxS1
Any call with SI greater than maxS1 will be rejected.

minSc
Sc is the slope of the body of the call. Any call with Sc less than minSc will be rejected. Note that Sc can be negative.

maxSc
Any call with Sc greater than maxSc will be rejected.

minNcalls and Tforcalls
MinNcalls (number of calls) that must be detected within Tforcalls (seconds) in order for any calls to be accepted. For example, if these parameters are set to 5 and 0.5, respectively, then 5 calls must occur within a half second interval or all calls in the file will be rejected.

Appendix B. Comparison of Filter Parameters Used for This Analysis.

Values used to construct the filters used for this re-evaluation of the data are presented below. The filters (KP filters) were based on the Kruger and Peterson (2008), call parameters (see Table 3). To provide a clear understanding of the parameters used for the identification of species during this reanalysis a comparison of the KP filters and those based on a robust set of species specific voucher calls is provided below (Tables B1-B7). The new AnalookW filter format includes several new parameters that were not included in the older Analook formats. For filters based solely on the KP parameters no values were available for these new parameters. Therefore the default filter values were used for these parameters and had no effect.

The new filters include 80 parameters that encompass a full range to include distinctive separation of species of multiple families and call types. Not all of these are applicable to the Vespertilionid species under consideration in this study. Therefore parameters such as harmonic content which were not applicable or used in either filter set, are not included here. For other parameters that did not prove useful in species discrimination the default filter values were used and had no effect.

Table B1. Average acoustic parameters with ranges from Kruger and Peterson (2008) used to construct filters. Species codes Eptfus = *Eptesicus fuscus*, Lascin = *Lasiurus cinereus*, Lasbor = *Lasiurus borealis*, Myluc = *Myotis lucifugus*, Myosep = *Myotis septentrionalis*, Persub = *Perimyotis subflavus*. Parameter values: Dur = msec, Fmax = kHz, Fmin = kHz, Fmean= kHz, Tk = msec, Fk = kHz, Tc = msec, Fc= kHz, S1= octaves per second, Sc = octaves per second.

Species	Dur	Fmax	Fmin	Fmean	Tk	Fk	Tc	Fc	S1	Sc
Eptfus	10.12 ± 0.16	33.81 ± 0.34	24.61 ± 0.09	27.17 ± 0.12	2.97 ± 0.07	27.56 ± 0.09	9.67 ± 0.15	24.83 ± 0.09	151.8 ± 6.11	28.66 ± 1.26
Lascin	6.75 ± 0.09	26.06 ± 0.27	20.23 ± 0.09	21.64 ± 0.13	2.22 ± 0.05	21.85 ± 0.11	6.34 ± 0.09	20.31 ± 0.10	153.7 ± 4.89	30.96 ± 0.80
Lasbor	6.41 ± 0.09	58.33 ± 0.57	38.3 ± 0.15	42.44 ± 0.20	2.83 ± 0.05	41.07 ± 0.16	5.98 ± 0.08	38.51 ± 0.15	301.2 ± 8.33	33.47 ± 1.18
Lasnoc	9.98 ± 0.14	37.36 ± 0.26	26.46 ± 0.04	28.81 ± 0.06	3.5 ± 0.06	28.78 ± 0.05	9.33 ± 0.13	26.62 ± 0.04	221.6 ± 5.58	24.64 ± 1.00
Myoluc	3.78 ± 0.05	62.35 ± 0.41	40.28 ± 0.10	47.14 ± 0.15	1.9 ± 0.03	46.04 ± 0.13	3.53 ± 0.05	41.42 ± 0.13	325.9 ± 6.20	118.7 ± 1.78
Myospe	2.5 ± 0.03	70.62 ± 0.45	41.54 ± 0.10	51.19 ± 0.19	1.39 ± 0.03	50.38 ± 0.19	1.87 ± 0.03	46.61 ± 0.16	445.8 ± 4.07	283.3 ± 3.60
Persub	7.01 ± 0.07	48.51 ± 0.22	41.28 ± 0.06	42.86 ± 0.07	1.71 ± 0.04	43.4 ± 0.07	6.63 ± 0.07	41.54 ± 0.06	166.5 ± 5.53	14.77 ± 0.46

Table B2. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Eptesicus fuscus*.

Filter section	Parameter	Miller	KP
Calls	smooth	20	20
Times	mindur ms	2000	9960
Times	maxdur ms	20000	10280
Freq.	minFmax kHz	25170000	33470000
Freq.	maxFmax kHz	55000000	34150000
Freq.	minFmin kHz	23500000	24520000
Freq.	maxFmin kHz	39120000	24700000
Freq.	minFmean kHz	23990000	27050000
Freq.	maxFmean kHz	35000000	27290000
Body	bodyover ms	80	80
Body	minFc kHz	23700000	24740000
Body	maxFc kHz	50000000	24920000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	1000	9520
Body	maxTc ms	20750	9820
Body	minFk kHz	24000000	27470000
Body	maxFk kHz	50000000	27650000
Body	minTk ms	1000	2900
Body	maxTk ms	13900	3040
Slopes	minS1 OPS	-4295000	145.68
Slopes	maxS1 OPS	1925000	157.9
Body	minSc OPS	-1991000	27.4
Body	maxSc OPS	2033000	29.92
Sequence	minNcalls pulses	5	5
Sequence	Tforcalls seconds	10	15

Table B3. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Lasiurus borealis*.

Filter section	Parameter	Miller	KP
Calls	smooth	15	15
Times	mindur ms	1000	6320
Times	maxdur ms	16200	6500
Freq.	minFmax kHz	31000000	57760000
Freq.	maxFmax kHz	85000000	58900000
Freq.	minFmin kHz	29000000	38150000
Freq.	maxFmin kHz	55000000	38450000
Freq.	minFmean kHz	30000000	42240000
Freq.	maxFmean kHz	55000000	42640000
Body	bodyover ms	80	80
Body	minFc kHz	29700000	38360000
Body	maxFc kHz	62100000	38660000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	280	5900
Body	maxTc ms	14100	6060
Body	minFk kHz	30000000	40910000
Body	maxFk kHz	66700000	41230000
Body	minTk ms	100	2780
Body	maxTk ms	3000	2880
Slopes	minS1 OPS	-14080000	292.85
Slopes	maxS1 OPS	2775000	309.51
Body	minSc OPS	-985000	32.29
Body	maxSc OPS	1880000	34.65
Sequence	minNcalls pulses	8	5
Sequence	Tforcalls seconds	15	15

Table B4. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Lasiurus cinereus*.

Filter section	Parameter	Miller	KP
Calls	smooth	20	20
Times	mindur ms	1000	6660
Times	maxdur ms	16800	6840
Freq.	minFmax kHz	23000000	25790000
Freq.	maxFmax kHz	53000000	26330000
Freq.	minFmin kHz	18000000	20140000
Freq.	maxFmin kHz	29000000	20320000
Freq.	minFmean kHz	20000000	21510000
Freq.	maxFmean kHz	38000000	21770000
Body	bodyover ms	40	40
Body	minFc kHz	16000000	20210000
Body	maxFc kHz	40000000	20410000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	3000	6250
Body	maxTc ms	30000	6430
Body	minFk kHz	20000000	21740000
Body	maxFk kHz	30000000	21960000
Body	minTk ms	1000	2170
Body	maxTk ms	15000	2270
Slopes	minS1 OPS	-5723000	148.82
Slopes	maxS1 OPS	1254000	158.6
Body	minSc OPS	-490000	30.16
Body	maxSc OPS	951000	31.76
Sequence	minNcalls pulses	5	5
Sequence	Tforcalls seconds	15	15

Table B5. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Lasionycteris noctivagans*.

Filter section	Parameter	Miller	KP
Calls	smooth	20	20
Times	mindur ms	400	9840
Times	maxdur ms	30000	10120
Freq.	minFmax kHz	25100000	37100000
Freq.	maxFmax kHz	62700000	37620000
Freq.	minFmin kHz	20000000	26420000
Freq.	maxFmin kHz	36600000	26500000
Freq.	minFmean kHz	23900000	28750000
Freq.	maxFmean kHz	51200000	28870000
Body	bodyover ms	80	80
Body	minFc kHz	24000000	26580000
Body	maxFc kHz	35000000	26660000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	0	9200
Body	maxTc ms	999000	9460
Body	minFk kHz	24100000	28730000
Body	maxFk kHz	57900000	28830000
Body	minTk ms	0	3440
Body	maxTk ms	999000	3560
Slopes	minS1 OPS	-4294000	215.98
Slopes	maxS1 OPS	1864000	227.14
Body	minSc OPS	-1990000	23.64
Body	maxSc OPS	2032000	25.64
Sequence	minNcalls pulses	8	5
Sequence	Tforcalls seconds	15	15

Table B6. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Myotis lucifugus*.

Filter section	Parameter	Miller	KP
Calls	smooth	80	80
Times	mindur ms	3500	3730
Times	maxdur ms	15000	3830
Freq.	minFmax kHz	41000000	61940000
Freq.	maxFmax kHz	67800000	62760000
Freq.	minFmin kHz	28000000	40180000
Freq.	maxFmin kHz	60000000	40380000
Freq.	minFmean kHz	29000000	46990000
Freq.	maxFmean kHz	45000000	47290000
Body	bodyover ms	80	80
Body	minFc kHz	30640000	41290000
Body	maxFc kHz	41750000	41550000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	2000	3480
Body	maxTc ms	10000	3580
Body	minFk kHz	34500000	45910000
Body	maxFk kHz	49600000	46170000
Body	minTk ms	600	1870
Body	maxTk ms	5600	1930
Slopes	minS1 OPS	-9999000	-9999000
Slopes	maxS1 OPS	9999000	9999000
Body	minSc OPS	-13600	116.92
Body	maxSc OPS	167000	120.48
Sequence	minNcalls pulses	5	5
Sequence	Tforcalls seconds	10	15

Table B7. Comparison of filter parameters used for this study (Miller) and those used by Kruger and Peterson (2008) (KP) for *Myotis septentrionalis*.

Filter section	Parameter	Miller	KP
Calls	smooth	80	80
Times	mindur ms	2000	2470
Times	maxdur ms	6000	2530
Freq.	minFmax kHz	45000000	70170000
Freq.	maxFmax kHz	98000000	71070000
Freq.	minFmin kHz	40500000	41440000
Freq.	maxFmin kHz	50000000	41640000
Freq.	minFmean kHz	46000000	51000000
Freq.	maxFmean kHz	56000000	51380000
Body	bodyover ms	80	80
Body	minFc kHz	41000000	46450000
Body	maxFc kHz	50000000	46770000
Body	minDc ms	0	0
Body	maxDc ms	999000	999000
Body	minTc ms	0	1840
Body	maxTc ms	999000	1900
Body	minFk kHz	4000000	50190000
Body	maxFk kHz	300000000	50570000
Body	minTk ms	0	1360
Body	maxTk ms	999000	1420
Slopes	minS1 OPS	-9999000	441.71
Slopes	maxS1 OPS	9999000	449.85
Body	minSc OPS	-9999000	279.68
Body	maxSc OPS	9999000	286.88
Sequence	minNcalls pulses	5	5
Sequence	Tforcalls seconds	10	15

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