Acoustic Analysis of Nighttime Flight Calls of Migrating Passerines near Lake Erie

A thesis submitted to the
Kent State University Honors College
in partial fulfillment of the requirements
for Departmental Honors

by

Jacob Roalef

May, 2015

Thesis written by

Jacob Roalef

Approved by

____,
Advisor

____, Chair, Department of Biology

Accepted by

____, Dean, Honors College

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

Much thanks and gratitude goes out to my advisor Dr. Mark Kershner, my defense committee, Mrs. Laura Gooch, the fine folks at Cleveland Metroparks and of course my loving and supporting parents. Thank you all.

Abstract

Many neotropical birds, particularly passerines, are nocturnal migrants during spring and fall, often moving long distances during nighttime flights. However, traditional methods of assessing their population size and migratory pathways have focused strictly on diurnal data collection. In this thesis, I investigate the use of nocturnal data collection through recording nighttime passage by these birds, with subsequent acoustic analysis of the resulting call data. While little is known about seasonal variability in nighttime movement patterns and pathways in Ohio relative to Lake Erie, recording and analysis of nighttime calls is becoming increasingly used as a tool for tracking bird migration. Better call processing methods have encouraged this, particularly the use of Raven Pro, a sound analysis software package. In this study, nighttime call data from three nights during fall 2013 and three nights during spring 2014 were recorded at the Cleveland Lakefront Nature Preserve. Resulting data were processed using Raven Pro to separate bird calls from other sounds (e.g., cars, insect calls), and then sorted by major bird call types, and by species when possible. Using these data, I was able to describe patterns and trends in population frequency for bird species and call types, time of flight, and hourly recording times across both fall and spring migration for this location. Future analyses will include other nights from these same sample periods to gain a more complete understanding of migration along the Lake Erie pathway, which will be invaluable for conservation efforts focused on these avifauna.

Introduction

Most avian monitoring occurs in the form of mist-nesting and daily bird surveys (visual and call-based counts), which can be effective methods to monitor the avifauna present (Dunn 2005). These data are extremely valuable, providing several key insights to further our understanding of birds. Having accurate counts for a given species allows us to monitor its population growth or decrease over time, providing a sense of the conservation status for that species. This is key information to aid and direct avian conservation efforts in the future, given the ever-increasing threats faced by birds in today's developing world. One current threat with significant potential impacts on bird populations is the ever increasing use of wind energy. While it represents a sustainable resource, it can be a major source of mortality for migrating birds (May et al, 2014).

Tracking migration also gives us a better handle on when individual species choose to migrate and when the peaks of their movements are. With this information, bird biologists can examine if the timing of migration has changed and, if so, allow them to investigate what factors might be causing shifts in migration timing. For example, many recent studies have found that arrival dates in North America and Europe from southerly wintering grounds for many species have shifted to earlier dates. Additionally, population reports of *en route* migrants positively correlate with estimates of bird abundance on their breeding grounds (Osenkowski et al. 2012). Due to the inaccessibility of most of the breeding grounds in the north (e.g., in the boreal forests of Canada), monitoring birds along migration routes is a much easier and more efficient method of gathering data of breeding bird populations (Millikin 2005). While these methods of migration monitoring can be effective, they all occur during the day, which means they rely primarily on visual records. While reliance on diurnal sampling provides important information regarding bird populations, it has a range of biases that may limit its use in understanding bird movements and population status. It is well known that the bulk of migration for neotropical species, such as warblers and shorebirds, takes place during the night (Sanders and Mennill 2014). With cooler temperatures and fewer predators, migratory conditions are much more favorable during nocturnal periods (Able 1973). Obviously, this creates an issue for the study and research of bird movement, as monitoring methods based upon visual counts will be ineffective. The majority of migrating birds will be missed using traditional diurnal monitoring methods. Only birds that stop and rest/feed following nighttime movements in monitored areas will be counted, which is likely only a small fraction of the true population size (Dunn 2005). Further, some birds will move through completely unnoticed as they may fly straight through (without stopping) if wind patterns are optimal. Also, many birds may stopover in areas that are difficult/impossible to survey. Therefore, nocturnal avian monitoring may prove to be an important tool in supplementing diurnal methods, ultimately giving us a better sense of movement patterns and species-level abundance for migratory birds.

Attempting to monitor movement at night can be a very difficult task as one cannot look up and count/identify birds as they are flying over. Given this issue, a range of other techniques have been explored to gain insight into nocturnal migration. The use of weather surveillance radar to track large movements of birds has shown positive correlation with diurnal methods (Peckford and Taylor 2008). Migration maps resulting from radar have also been used to show the effect of weather and wind on migration (Diehl et al. 2003). The use of radar has become highly important in understanding factors affecting variability in night-to-night movement and in predicting avian movement. While this large-scale approach is useful to represent overall migration patterns, it does not provide significant insight into species-specific movement patterns. Without characterization of species or species groups, this type of data has significant limitations.

Given the lack of species-level data from radar, other methods have been investigated to provide these types of data, often associated with nighttime calling. Most birds, especially warblers and sparrows, produce a call note on the wing during migration (Ball 1952, Graber and Cochran 1959, Evans and Mellinger 1999). A night call note is typically a short burst with a high frequency that falls between 1,000 and 11,000 hertz (Farnsworth 2007), whose function is to communicate with the rest of the flock (Hamilton 1962). However it is suggested that not all bird taxa use these night calls or that some use them very infrequently. Taxa that do not typically migrate nocturnally, like the corvids (i.e., crows, jays, and ravens) and woodpeckers, will infrequently make these calls (Farnsworth 2005). It is also suggested that some neotropical bird groups that are nocturnal migrators do not make any calls while moving to temperate areas and back. These include the vireos and new world flycatchers (Farnsworth 2005).

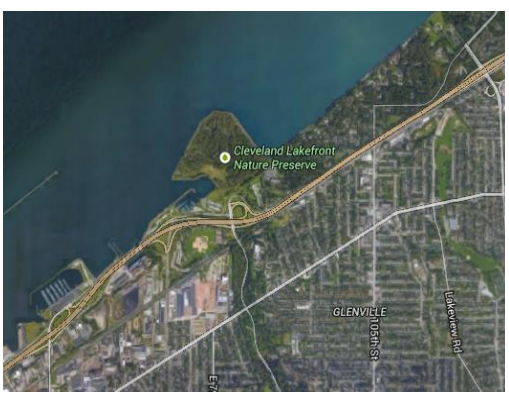
The recording of these nighttime calls as a technique to study bird migration has been underused (Sanders and Mennill 2014) but is now beginning to pick up steam as more scientists and the birding community begin to learn of and understand them, and as better technologies become available. These flight calls can be very distinctive among different taxa (Lanzone et al. 2009). However, identifying the individual calls to species continues to be an issue when working with these recordings (Lanzone et al. 2009). There is the potential for overlap among taxa as well as individual variance within a species (Evans and Rosenberg 2000), making differentiation a difficult process. One attempt to minimize the effect of this issue is to sort the calls into groups based on shape. Similar taxa appear to have a similar call type; therefore, grouping them will still produce useful data.

Given its potential uses, continued research in the area of acoustic monitoring is needed. At this time, it is an underused method that directly examines the nocturnal flights of birds in contrast with traditional diurnal methods. These data can be used to further our existing knowledge of avian migration that traditionally was gathered from diurnal sampling methods. More accurate abundance estimates are expected with this nighttime flight analysis which will provide a detailed picture of what is occurring during migration especially, when compared with other sampling methods. While the promise of these methods is great, their use can be limited by how effectively the data are processed and sorted. The calls are difficult to sort manually and it is also quite tedious. I believe that an accurate, automated process of doing this, using machine learning approaches (as the Cornell Laboratory of Ornithology is currently exploring) is possible and would make data collection and analysis much simpler and faster. With increased processing efficiency, more recording stations could be established in key areas during migration. Ultimately, acoustic monitoring will give us a better understanding of bird migration patterns and possibly even population status of certain species. Also, while there are three main migratory pathways, acoustic data may fill in the gaps between these large flyways that are not fully understood.

In this study, I attempted to further the study of acoustic recordings to track avian populations during migration events using data collected at the Cleveland Lakefront Nature Preserve. Using data from Fall 2013 and Spring 2014, I processed and identified calls by call type (i.e., species groups) and individual species. These data will begin to provide insight into bird movement patterns over this part of Ohio. It will also hopefully provide insight into how useful data collected in this way can be for determining spring and autumn movement patterns of migratory birds, particularly neotropical migrants and open the door to continued use of this methodology.

<u>Methods</u>

This study used data provided by scientists at Cleveland MetroParks. Data were collected at the Cleveland Lakefront Nature Preserve, a large area directly on the shore of Lake Erie that contains a nice mix of both woodland and grassland habitat types that host a variety of avifauna taxa (Fig. 1). A microphone and recording system purchased from "oldbird.org" has been set up on the roof of the nature center there and has recorded all nights of spring and fall migration since fall of 2013. Six nights of large movements of birds were chosen to analyze, three from Fall 2013 and three from Spring 2014. The resulting nocturnal call data were processed using Cornell's Lab of Ornithology's acoustic analysis software, Raven Pro (Fig. 1). Below, I also take a more detailed look into the protocol for processing these calls in an attempt to make things less ambiguous for future studies.



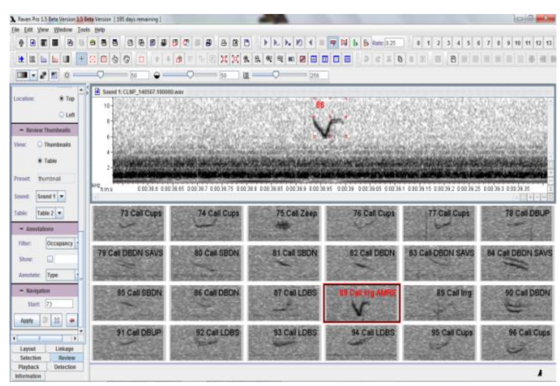


Fig. 1. A map showing the location of the site used (left) and a sample screen shot of the Raven Pro software (right).

Six nights were chosen for processing, three from fall 2013 and three from spring 2014, as sample dates to illustrate the type of data one is able to get from this location and setup. For each date, calls were first separated from background noise (i.e., insect calls, cars, etc…). Each of these calls was then sorted by "call type" (each call type represents a species group, see Table 1 below) and species when possible (I present data from four species below). Aggregating these data will provide insight into patterns in peak nighttime movements (in fall and spring), and frequency trends over time for species groups (particular call types) and individual species.

During processing of the call data using the Cornell Lab's sound analysis software, Raven Pro, much trial and error was required due to a lack of existing documentation. In order to correct this gap and improve the efficiency of the Raven program, there are several steps and tips to follow. In the following section, I present a step-by-step workflow/protocol that was provided by Laura Gooch (a private citizen who has been working with these types of data using a device at her house). I have also modified and clarified this protocol to reflect my own struggles during data processing. My purpose here is to have a protocol that better represents issues users will face, providing new users with a structured process for reviewing and identifying calls. At the end, there are ways to condense steps and procedures once familiarity and skill level have increased.

USING RAVEN PRO

STEP 1. The first thing that must be done in order to use the Raven program is to install certain detection presets. These presets will be used to sort the night into call detections.

Installing presets:

- Copy the **RavenPreferences.zip** compressed archive file onto your computer
- Extract the archive (Extract all files option after you double-click the archive)
- Open and read the **RavenPresetsREADME.txt** file for detailed instructions, but here are the basics:
    - Open the raven preferences file in a text editor Edit -> Preferences (should open in WordPad or something)
    - Move the cursor to the end of the file and hit return to add a blank line
    - Open RavenPreferencesKeymap.txt, select all the text, copy it
    - Move back over to the Preferences and paste these into the end of the file
    - Save the file as. **Users\username\Raven Pro 64 1.5\DefaultRavenPreferences txt**
    - Close and re-open Raven for the changes to take effect
- Copy these detector files to the **C:\Users\username\Raven Pro 64 1.5\Presets\Detectors\Band Limited Energy Detector** folder:
    - SP100.02
    - Thrush
- Copy these files (window presets) to the **C:\Users\username\Raven Pro 64 1.5\Presets\Sound Window** folder:
    - ThrushReview
    - thumbnail
    - TseepID
    - TseepReview

STEP 2. The next step is to run the night of interest through the program and presets in order to pull out all sound detections. Then, one must review each sound wave flagged as ‘detection’ and determine if it is a bird call or some other noise, sorting accordingly (described under “Tseep Review/Sorting” below). Before beginning this section of the process, it is strongly recommended that one studies what a bird call waveform looks like. The use of resources such as “oldbird.org” and Sanders and Mennill (2014) will help aid you as you learn. The more familiar one is with which waveforms are bird calls versus which waveforms are not, the easier this step becomes. If one is unfamiliar with what typical calls look like, this step is very tedious and can lead to inaccurate results.

<u>Tseep Review/Sorting:</u>

- Tseep: Load entire night (from 1/2 hour after sunset to 1/2 hour before sunrise) from OldBird microphone. Page sound at 20 second pages (in “Configure New Sound Window”). Add clock data and time data (in “Configure New Sound Window”):
    - Downloaded sunrise and sunset times for Cleveland.
    - Recordings are time stamped with their start time in the file name (CLELake.140327.180000 => CLELake.yymmdd.hhmmss). Recording is set to start at 18:00. You can also look at the "date modified" in Windows Explorer. That gives the end time of the file.
    - You add the clock and time data as follows: when you are opening a sound file in Raven, the Configure New Sound Window pops up. The rightmost tab is "Date and Time." Click the "use clock-time axis labels" box and the "file name template" button. The files are labeled with the Raven default date/time format, so that the default should result in the correct time being shown on the time axis.
    - “ll” is the "month" field.
- View using Tseep review window preset:
    - Set to **TseepReview** in the Configure New Sound Window dialog.
- Auto detect using the Cornell SP100.02 detector:
    - View -> Interactive Detectors -> Band limited energy detectors
    - Click Preset -> SP100.02
    - Add the Detector name "SP100.02" and select Add detector name annotation.
    - Hit OK

- In the Layout pane (pane selections are at lower left), click Selection Table to view the selection table:
  - Right click on the gray table header row area and select Choose Measurements.
  - Add Begin Date, Begin Clock Time, End Date, End Clock Time to the Displayed Measurements.
- Trim detections that fall before or after sunset or sunrise.
  - In the selection table, select the "hits" that are either before the time period you are interested in (select the first row you want to eliminate, find the last row, hold down shift and click that row to select all the rows). Right click and "Clear Selections" or "Clear active selection Border" (if only one row is selected; do not use "Clear Selected Cells").
- Right click on the title of the selection column and select Renumber Selections.
- Save the selection table in the Raven Selection folder with the default file name, but add the start time of the final file loaded. Example: **raven_CLNP.111018.190511-070511.SP100.02.selections.txt**. The file name gives the following information: raven_*location*.*yymmdd*.*hhmmss*-*hhmmss*.*detector*... The time in green is the time stamp on the first sound file covered by the selection table. The time in magenta is the start time of the last file covered by the selection table (if you have opened multiple sound files in Raven rather than merged them elsewhere).
- Unclick Selection Table. Now ready to begin reviewing 'detections'.
- Review detections (select Review tab) using the Raven review function:
  - In Layout pane change rows to 4 and columns to 6. This will allow reviewing of 24 sound waves in one view instead of only 1.
  - With 0.1 padding for time, view with pad, 1000 Hz padding for frequency, view with pad, full playback (Play: Full)
  - In Context Window select the Context Window: Show box
  - Select the "thumbnail" window preset (Review thumbnails, Preset: thumbnail)
  - Choose the correct selection table (Review thumbnails, Table: SP100.02).
    - For some reason I usually end up with two SP100.02 tables, and the first one is usually blank.
  - Choose "Type" in the annotate box. (Annotations Annotate: Type; You will choose "Species" when you are IDing calls, rather than screening noise.)
  - Click Apply at the bottom of the Review pane
- Page through the review panes:
  - Mark Noise with an N keystroke and Calls with a C.

    - Don't mark all Noise at this point... Just put a noise in periodically to mark progress and save the selection table periodically.
- As you page through looking at detections, select any additional unselected calls you see. For example, you may see something in the upper window that looks like a call but which the detector has missed.
    - Use the cursor to make a box around the possible call. Hit return while that box is "active" (that is, while a corner of the box is solid). If you do this correctly, the selection will get a number that will remain visible after you move on to another selection.
    - Several boxes will pop up
        - The first asks you to Replace Modify or Keep annotations. Choose Keep.
        - The next asks if you want to save this answer for future. Choose Yes.
        - The last ask you to add annotation. Annotate the type as "Call."
        - The selection will be added at the end of the selection table. You will later reorder and renumber the selection table so that the calls will be in time sequence.
    - When you are done reviewing, click the white X in the Review pane to Close all selection Review windows
- When you are through marking, look at the selection table (Choose Layout pane and select Selection table or In Review pane, under Review Thumbnails, select View: Table) and sort by type by clicking the type column heading.
- Copy the Noise annotation down the Type column by Selecting from the last marked Noise to the end of the column and using Ctrl D(own). (Ctrl U(p) copies up.)
    - You want the Type annotation to be filled in with either Noise or Call for every entry in the selection table.
- Copy the Calls from this selection table to a new selection table (Click and shift click the rows to copy, right click and Select copy selected rows).
    - In the original table, sort the entries by "Type" by clicking the title of that column.
    - Select the "Call" rows by clicking and shift clicking in the gray-shaded right-hand columns. Then right click.
    - You get an option "Copy Selection Borders to => New Table."
    - You don't need to create the table before-hand.
    - Save that as (for example) **raven.111018.190511-070511.SP100.02.hits.txt**.
- Go back to the original selection table (the one you just copied the calls from).

    - Reorder all of the selections in this table by time (by clicking the "Begin Time" column header).
    - Right click on the Selection column header and Renumber Selections.
        - See above
    - Save the table.
- Go to the new selection table.
    - Delete the "SP100.02" column (by right clicking the column header and choosing "delete column").
    - Right click in the table header and "Choose Measurements" and add "Begin Date" and "Begin Clock Time."
    - Reorder the table by time (by clicking the "Begin Time" column header) and
    - Renumber Selections.
    - Save the table again.
- At this point, you are ready to switch to the Hits selection table and go back through to further screen and ID calls.

STEP 3. The final step of the process is grouping/identifying the calls. Again, one must study and become familiar with what the calls look like for each group and/or species in order to correctly identify them. One issue that the user will face at this stage is that the acoustic signatures of nighttime calls of individual species and species groups can vary widely. Therefore, the more familiar you are with the calls, their duration, and their frequency range, the better off you will be. I cannot stress this point enough. I strongly suggest that new users start with sorting calls into species groups based upon call types, and then break them down into species. This approach can be an effective way to learn in the beginning and still get accurate results. It is simply another step to aid in narrowing down the spectrogram to individual species.

Grouping/Identifying Calls:

- Begin with the Hits selection table that you created as you were reviewing the night's detections and the reviewing Raven window. The small review panes should be filled with items you've picked out as potential hits.
- Click in the upper window to select view. Then go to the menu View: Window Preset and chose the TseepID preset. This changes the scale of the upper window to zoom in and adds grid lines to help show the frequency and duration of the detected calls.
- Review the selections just like before with the review pane. All the settings are the same but change Type to "Species". Now 24 'hits' will be shown on the screen for reviewing and IDing. This step also allows for revision of calls vs. noise. If a 'detection' that was orginially labeled as a 'call' is now thought to be a 'noise' it can be changed and sorted out of the call table.
- Click on any of the small review panes to show that call zoomed in the upper pane.
- You can add an ID to any of the detected calls in one of two ways: 1) In the Review control panel, click the Table button to switch from the thumbnails to the table and manually add your ID; 2) Use a single key stroke that has been defined in the Raven Preferences file. In general, it is much fast to do the latter, but there will be some IDs that are not defined in the preference table that will need to be entered by hand.
- To add the ID with a predefined key, simply click in the small review pane that shows the call and hit the appropriate key. The annotation information will appear in the review window and in the selection table.
- Key presets can be customized by editing the Raven Preferences file. Currently defined keys are:

  raven.annotation.keyMap.useUnmappedKeys=true
  raven.annotation.keyMap.1=n,Type:Noise
  raven.annotation.keyMap.2=c,Type:Call
  raven.annotation.keyMap.3=z,Type:Call,Group:zeep,Species:ZEEP
  raven.annotation.keyMap.4=e,Type:Call,Group:Sparrow,Species:Sparrow sp
  raven.annotation.keyMap.5=d,Type:Call,Group:Warbler,Species:Warbler sp
  raven.annotation.keyMap.6=t,Type:Call,Group:double up,Species:NAWA
  raven.annotation.keyMap.7=v,Type:Call,Group:Sparrow,Species:SAVS
  raven.annotation.keyMap.8=u,Type:Call,Group:single up

raven.annotation.keyMap.9=w,Type:Call,Group:Long double sparrows,Species:WTSP
raven.annotation.keyMap.10=q,Type:Call,Species:UNID
raven.annotation.keyMap.11=m,Type:Call,Group:Sparrows,Species:SOSP
raven.annotation.keyMap.12=l,Type:Call,Group:Sparrows,Species:WCSP
raven.annotation.keyMap.13=g,Type:Call,Group:Sparrows,Species:SWSP
raven.annotation.keyMap.14=p,Type:Call,Group:Sparrows,Species:CHSP
raven.annotation.keyMap.15=a,Type:Call,Group:Sparrows,Species:ATSP
raven.annotation.keyMap.16=r,Type:Call,Group:Warblers,Species:AMRE
raven.annotation.keyMap.17=f,Type:Call,Group:Sparrows,Species:FISP
raven.annotation.keyMap.18=j,Type:Call,Group:Sparrows,Species:DEJU
raven.annotation.keyMap.19=o,Type:Call,Group:Warblers,Species:OVEN
raven.annotation.keyMap.20=h,Type:Call,Group:Warblers,Species:CSW
A
raven.annotation.keyMap.21=y,Type:Call,Group:Warblers,Species:COYE
raven.annotation.keyMap.22=k,Type:Call,Group:Other,Species:GCKI

- At this time it is best to add key strokes that will work well with an individual's personal preference. Adding a key stroke for each group/species one would like to examine is the easiest method to sort out the hits.
- There were 11 groups used to sort the calls for this research as well as 4 species, each with a unique key stroke to create simple and quick separation.
    - Example: raven.annotation.keyMap.23=i,Type:Call,Group:Irrg
    - With a simple press of the i key, that call gets placed into the group of Irregular type calls.
- Save the table periodically and once data is sorted. The table can be exported into other systems like Microsoft excel for further use and manipulation.

Once a reviewer has become extremely familiar with bird spectrogram waves, he/she can begin to skip and condense steps making the process quicker and less tedious. With enough skill, all three steps can be condensed into a single reviewing process. Instead of sorting into noise and calls, one would be able to immediately ID calls into species or groups. However, combining steps would eliminate the "double check" of the data and should only be used by highly skilled individuals that have many hours of experience and practice sorting calls in this program.

For my research project, I followed the preceding protocol/workflow. First, all acoustic signals from each night were determined to be either a call or noise and sorted into these groups accordingly. The number of detections (including both calls and other noise) for each night ranged from 8,000 all the way up to 28,000 with an average of around 14,200 detections to sort per night. Once all the nights were sorted into calls and noise, the acoustic signals designated as noise were deleted from the data table, leaving only selections labeled as 'call'. The next step was to review the 'calls' and sort them into call types/species groups based on their shape. These groups pertain to certain species and can be analyzed to get a better sense of species movements. Also, most of the groups have some degree of relatedness (similar species, some cover an entire genus). Table 1 lists the call types and the bird species that fall into each species group.

Finally, I chose a few species that I believed to be relatively easy to identify by call. The four species chosen were White-Throated Sparrow (Fig. 2), Savanah Sparrow (Fig. 3), Black-and-White Warbler (Fig. 4), and American Redstart (Fig. 5). The data was then imported into excel files for further manipulation. Finally, I examined average nighttime wind data from Cleveland Hopkins Airport on those nights to get some idea of the role of wind in determining bird movements,

Table 1

The ten groups that calls were sorted into (left-hand column; with acronyms used to refer to the call types in the text) and the list of species that fall within each group (right-hand column).

Group	Species
	• Blue-winged Warbler

Single-banded Upsweep (SBUP)	• Golden-winged Warbler
Double-banded Upsweep (DBUP)	• Tennessee Warbler • Yellow-rumped Warbler • Orange-crowned Warbler • Mourning Warbler • Nashville Warbler • Black-throated Green Warbler • White-crowned Sparrow • Vesper Sparrow
Single-banded Downsweep (SBDN)	• Pine Warbler • Northern Parula • Prairie Warbler • Yellow-throated Warbler • Field Sparrow
Double-banded Downsweep (DBDN)	• Savanah Sparrow • Le Conte's Sparrow • Nelson's Sparrow
Zeep Warblers (ZEEP)	• Cerulean Warbler • Blackburnian Warbler • Magnolia Warbler • Blackpoll Warbler • Worm-eating Warbler • Yellow Warbler • Bay-breasted Warbler • Connecticut Warbler • Louisiana Waterthrush • Indigo Bunting
Buzzy Warblers (BUZZ)	• Hooded Warbler • Common Yellowthroat • Chestnut-sided Warbler
Long Double-banded Sparrows (LDBS)	• Fox Sparrow • Song Sparrow • White-throated Sparrow
Cup-shaped (CUPS)	• Chipping Sparrow • American Tree Sparrow
Short-buzzy Sparrows (SBSP)	• Lincoln's Sparrow • Swamp Sparrow
Irregular Type (IRRG)	• Henslow's Sparrow • Black-throated Blue Warbler • Palm Warbler • Black-and-white Warbler

	• American Redstart • Ovenbird • Canada Warbler • Wilson's Warbler • Northern Waterthrush • Cape May Warbler

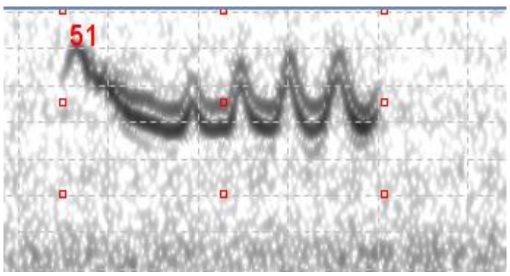


Fig. 2. WTSP spectrogram

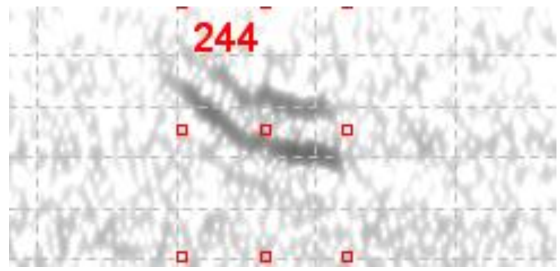


Fig. 3. SAVS spectrogram

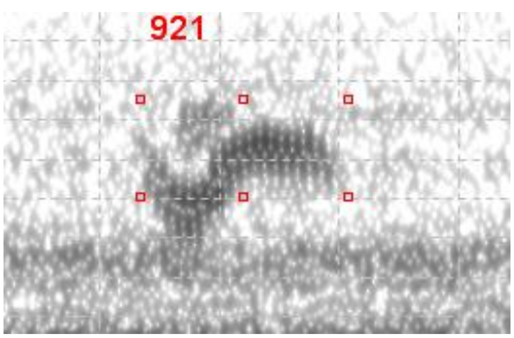


Fig. 4. BAWW spectrogram

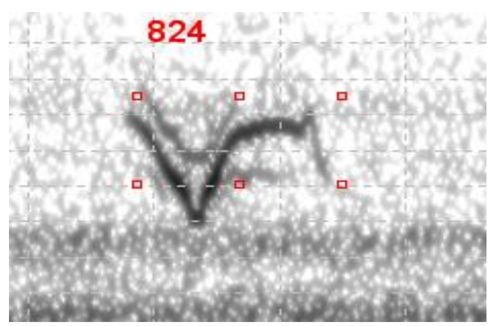


Fig. 5. AMRE spectrogram

Results

At Cleveland Lakefront Nature Preserve, the microphone on the recording device is set up to turn on at dusk and shut off at dawn during spring and fall migration. Each night from the six analyzed nights were approximately 13 hours in length and for each individual night the times before sunset and after sunrise were eliminated. These nights were sorted into various groups of bird call types by shape. The 12,134 calls detected across these nights were first analyzed in an aggregate fashion (i.e., the total number of calls recorded across the night) and then sorted into ten call types. Of those detections determined to be calls, 257 (2.12%) were not able to be accurately sorted into groups.

Time of Flight

In order to examine the time of birds arrival and migration as a whole, graphs were created using the total number of bird calls detected vs. what time they were detected by hourly intervals. During the fall nights, the number of total birds recorded peaked during the early morning hours from 3:00-5:00 AM (Fig. 6). The general shapes for bird movements on each fall night are similar. During spring nights, some peaks are in the same time interval as the fall nights (Fig. 7). However, there are several other peaks on some nights and these dates tend to be more variable overall.

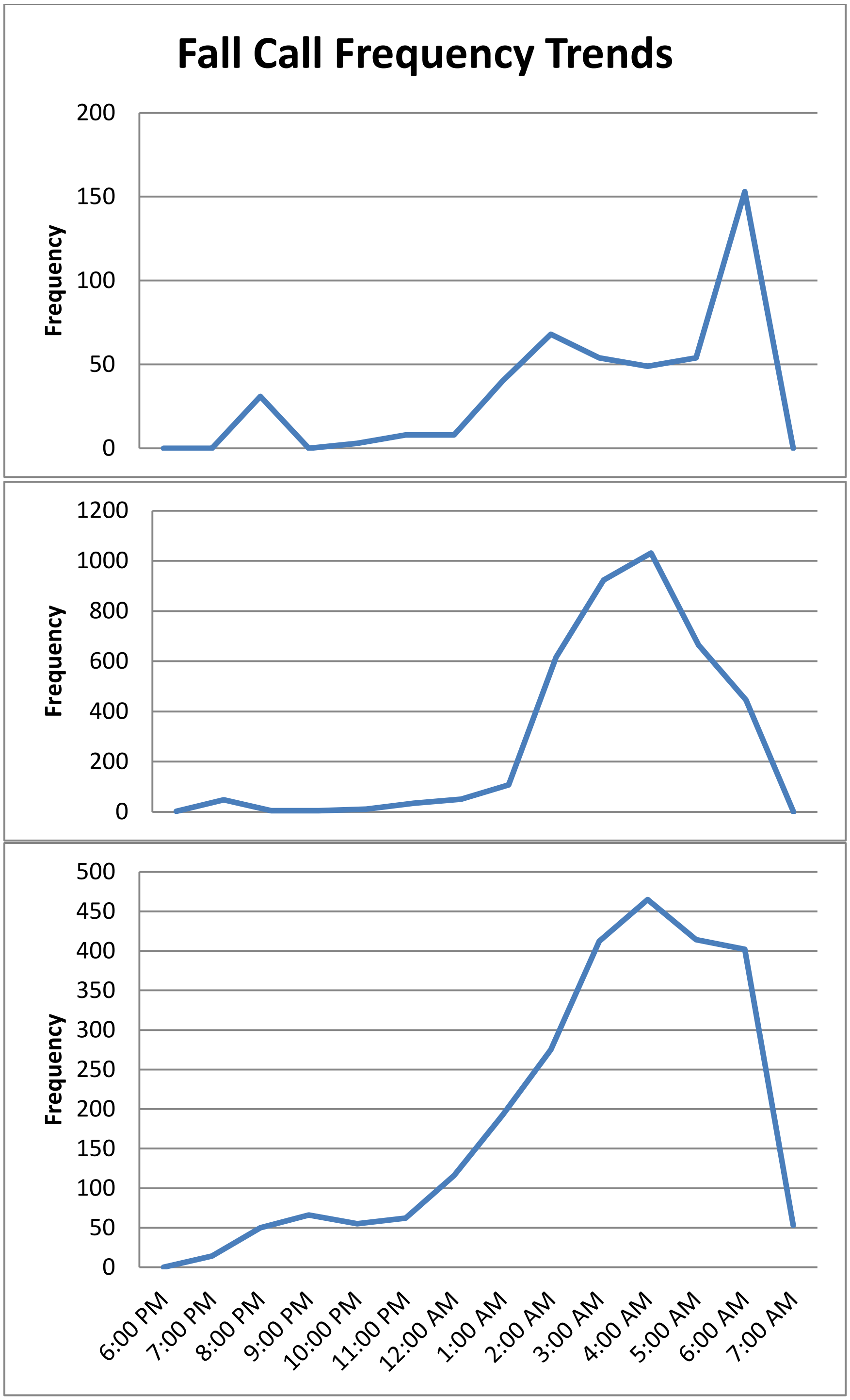


Fig. 6. Trends in nighttime call frequency of all bird calls recorded across hourly segments (6:00PM until 7:00AM) for three fall nights, 8/28/13 (top panel), 9/22/13 (middle panel), and 10/8/13 (bottom panel) at Cleveland Lakefront Nature Preserve.

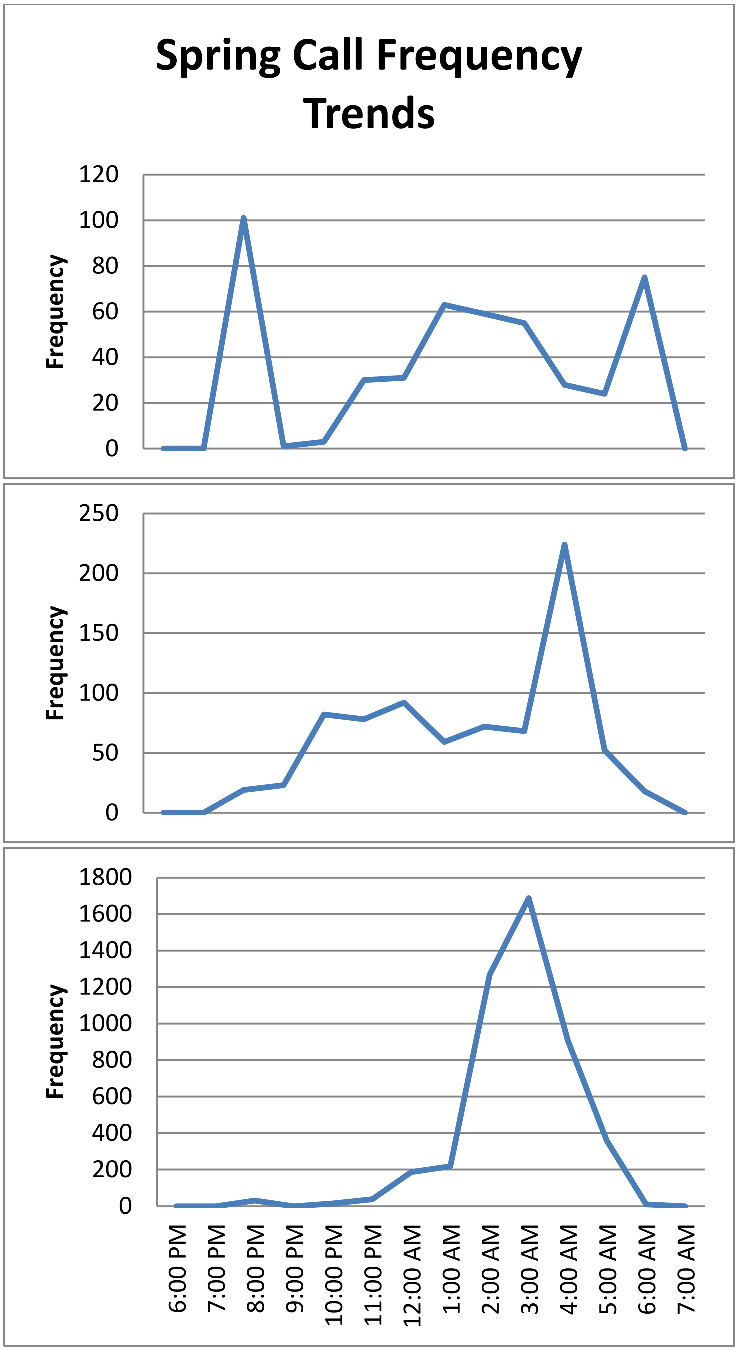


Fig. 7. Trends in nighttime call frequency of all bird calls recorded across hourly segments (6:00PM until 7:00AM) for three spring nights, 4/12/14 (top panel), 5/2/14 (middle panel), and 5/7/14 (bottom panel) at Cleveland Lakefront Nature Preserve.

Call Type/Species Group Frequency

To see trends in nighttime migration by species groups and individual species over time, total frequency graphs were created. For the spring dates, 5/7/14 dominates in almost every group of birds in numbers (Fig. 8). Most groups show a gradual increase in frequency over these three dates with exceptions being SBDN, ZEEP, SBUP, and BUZZ (Fig. 9; acronyms defined in Table 1). For the fall nights, it is clear that some groups (e.g., DBUP, LDBS) dominate on certain dates while other groups dominate at a different date. 8/28/13 stays at relatively low frequency across all groups (Fig. 9).

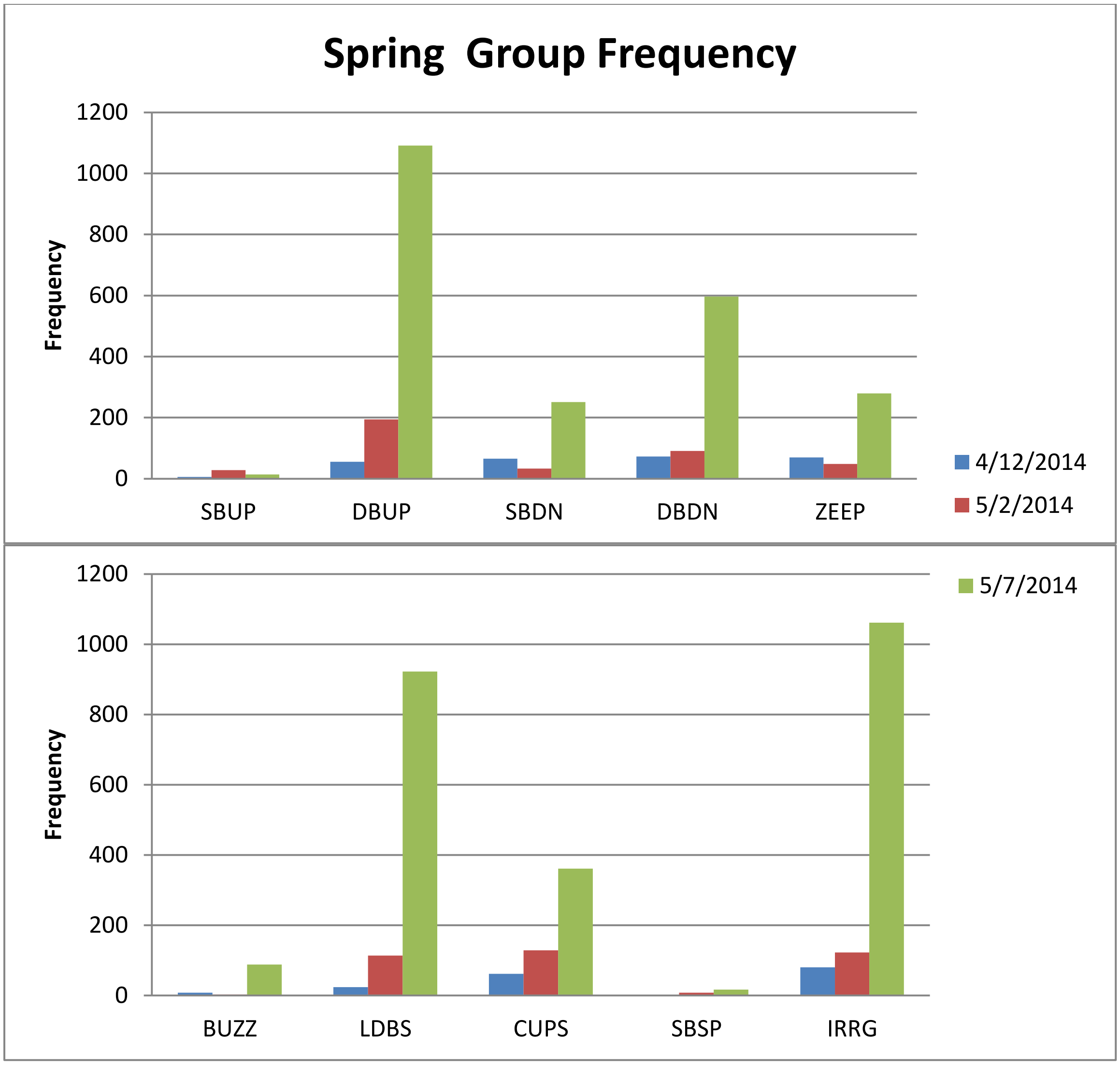


Fig. 8. Nighttime call frequency of ten call types, Single-Banded Upsweep (SBUP), Double-Banded Upsweep (DBUP), Single-Banded Downsweep (SBDN), Double-Banded Downsweep (DBDN), and Zeep (ZEEP) (top panel), Buzz (BUZZ), Long Double-Banded Sparrow (LDBS), Cups (CUPS), Short Buzzy Sparrow (SBSP) and Irregular (IRRG) (bottom panel) at Cleveland Lakefront Nature Preserve on three spring dates (4/12/14, 5/2/14, 5/7/14).

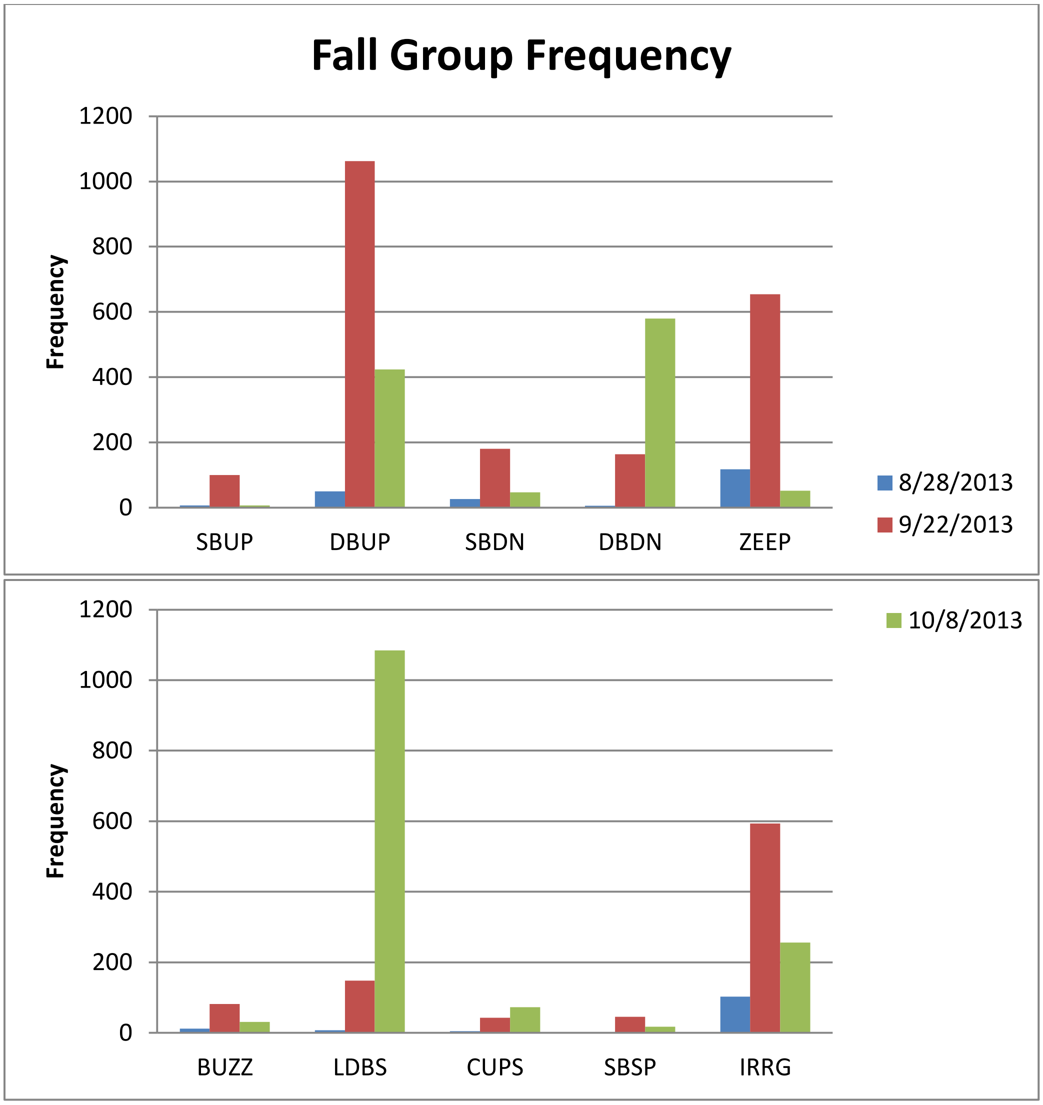


Fig. 9. Nighttime call frequency of ten call types, Single-Banded Upsweep (SBUP), Double-Banded Upsweep (DBUP), Single-Banded Downsweep (SBDN), Double-Banded Downsweep (DBDN), and Zeep (ZEEP) (top panel), Buzz (BUZZ), Long Double-Banded Sparrow (LDBS), Cups (CUPS), Short Buzzy Sparrow (SBSP) and Irregular (IRRG) (bottom panel) at Cleveland Lakefront Nature Preserve on three fall dates (8/28/13, 9/22/13, 10/8/13).

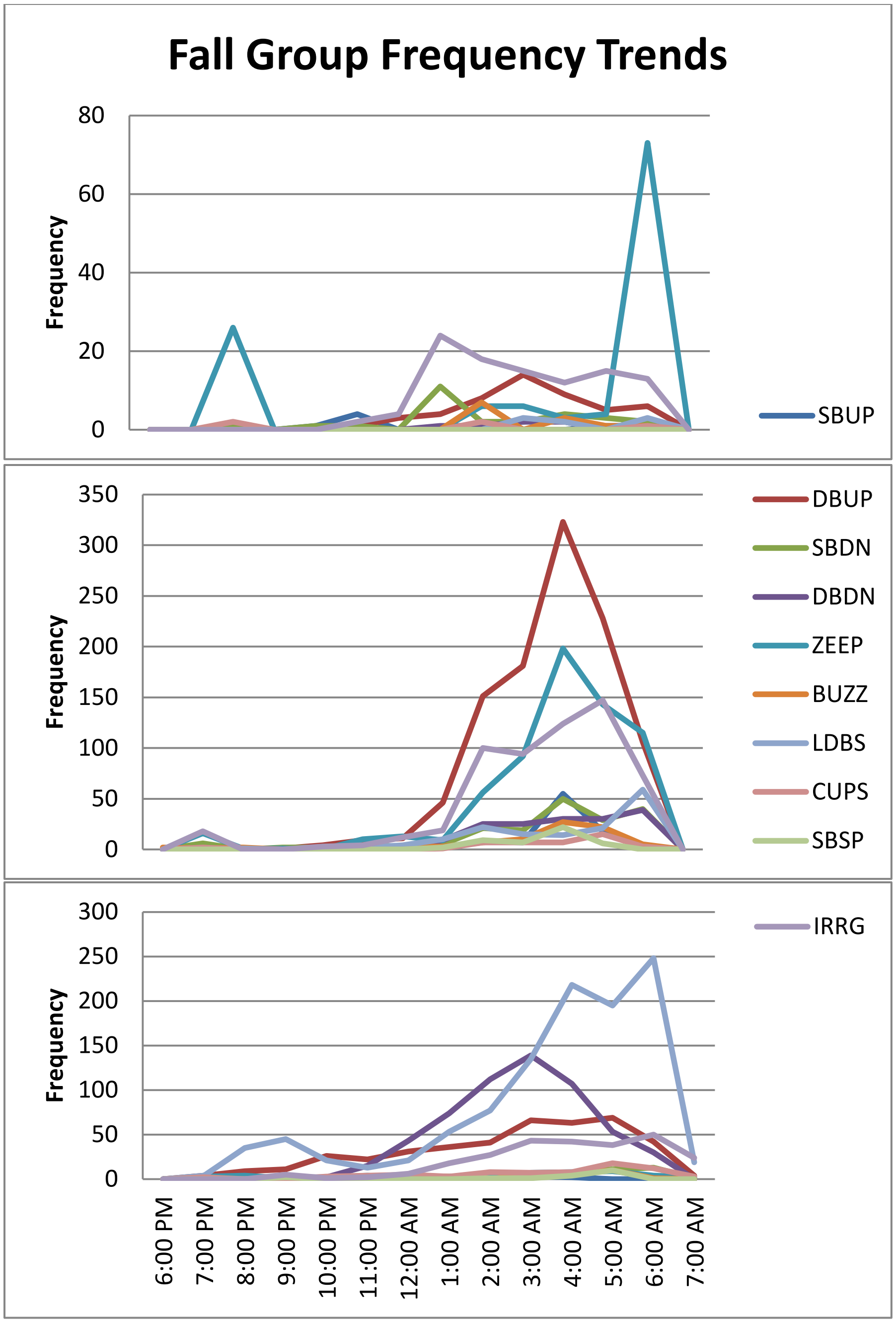


Fig. 10. Trends in nighttime call frequency of ten distinct group types, Single-Banded Upsweep (SBUP), Double-Banded Upsweep (DBUP), Single-Banded Downsweep (SBDN), Double-Banded Downsweep (DBDN), Zeep (ZEEP), Buzz (BUZZ), Long Double-Banded Sparrow (LDBS), Cups (CUPS), Short Buzzy Sparrow (SBSP) and Irregular (IRRG) recorded across hourly segments (6:00PM until 7:00AM) at Cleveland Lakefront Nature Preserve on three fall dates 8/28/13 (top panel), 9/22/13 (middle panel), 10/8/13 (bottom panel).

Time of Migration by Group:

Call frequency (by call type) over time (hourly scale) was examined to see if species groups had earlier/later movements relative to each other across an individual night (Figs. 10, 11). For both fall and spring nights, the overall trend of movement matches well with overall movement patterns from those nights (Figs. 6,7). However, some species groups had more variable flight times with earlier peaks for some groups (e.g., CUPS on 5/2/14) and later peaks for others (e.g., SBUP on 4/12/14).

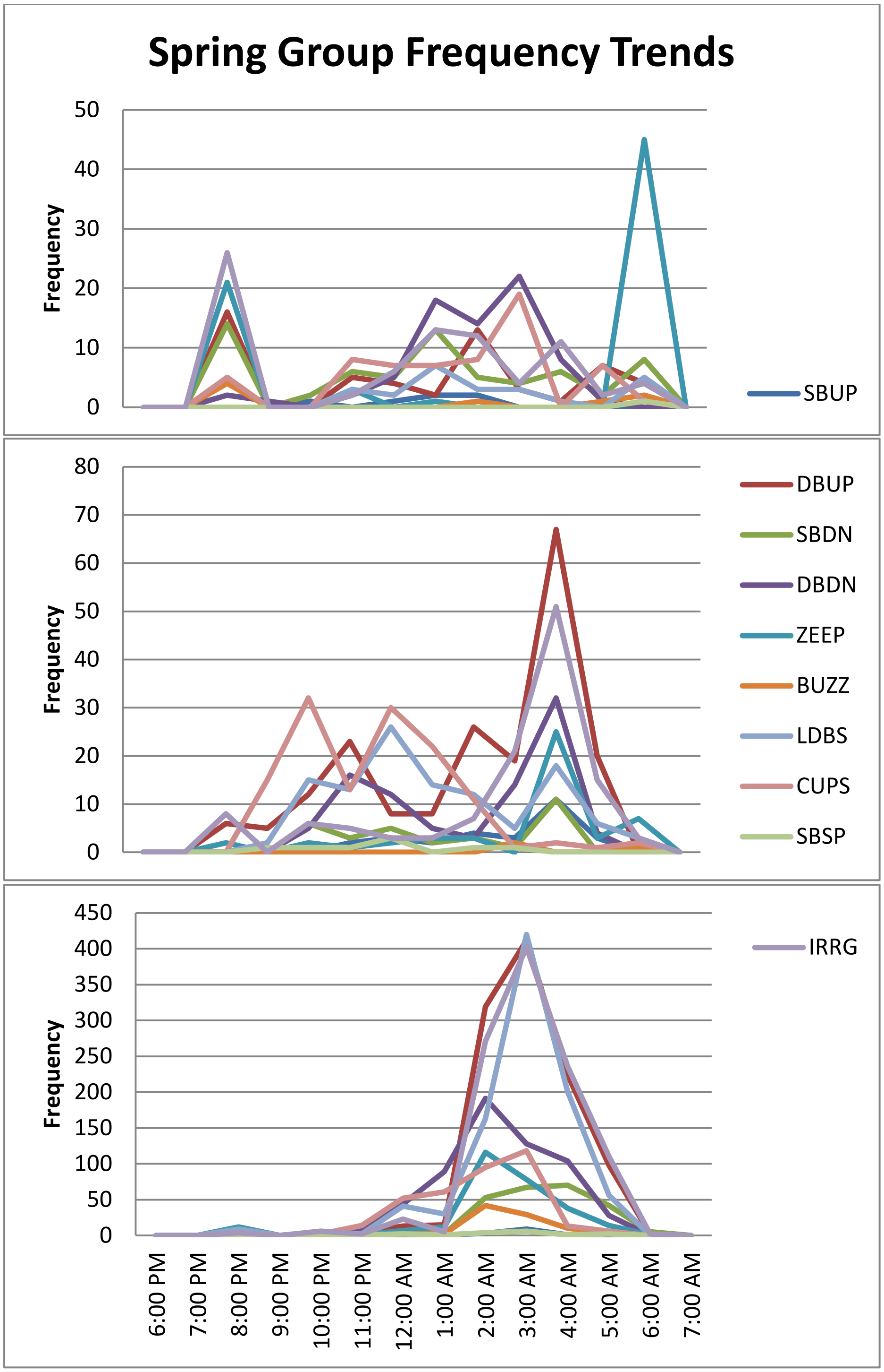


Fig. 11. Trends in nighttime call frequency of ten distinct group types, Single-Banded Upsweep (SBUP), Double-Banded Upsweep (DBUP), Single-Banded Downsweep (SBDN), Double-Banded Downsweep (DBDN), Zeep (ZEEP), Buzz (BUZZ), Long Double-Banded Sparrow (LDBS), Cups (CUPS), Short

Buzzy Sparrow (SBSP) and Irregular (IRRG) recorded across hourly segments (6:00PM until 7:00AM) at Cleveland Lakefront Nature Preserve on three spring dates 4/12/14 (top panel), 5/2/14 (middle panel), 5/7/14 (bottom panel).

One interesting trend in the call type data was the presence of multiple peaks in call detection during the night, in fall and spring nights (Figs. 10,11). For example, on 4/12/14, call detection peaked for multiple species groups around 8:00 PM, with other peaks later at night (Fig. 11). Early peaks are likely associated with birds that were resting nearby during the daylight hours. These birds then continued their migration early in the evening, while later peaks were birds starting in Canada (during fall) or further south in the United States (during spring).

Species Frequency

Migratory timing for four species with distinctive calls was also examined. The sparrow species peaked later in the fall (10/8/13), while the warbler species peaked on an earlier date (9/22/13), with a significant dropoff in migration later (Fig. 12). During spring, all four species showed a peak that was much larger at the later spring date (5/7/14) (Fig. 13).

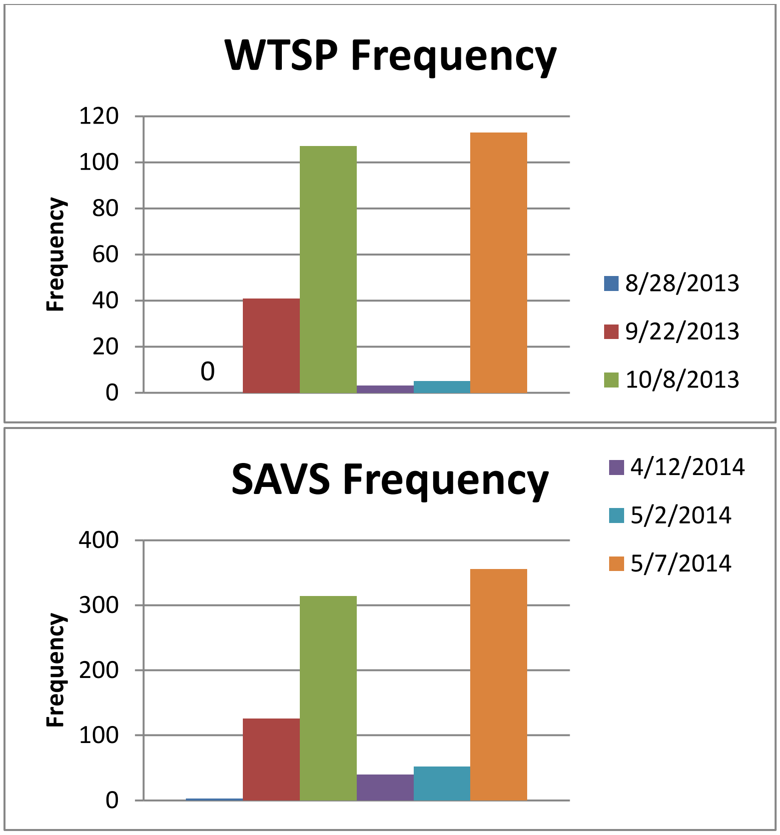


Fig. 12. Trends in nighttime call frequency of White-Throated Sparrow (top panel) and Savanah Sparrow (bottom panel) at Cleveland Lakefront Nature Preserve on three fall dates (8/28/13, 9/22/13, 10/8/13) and three spring dates (4/12/14, 5/2/14, 5/7/14).

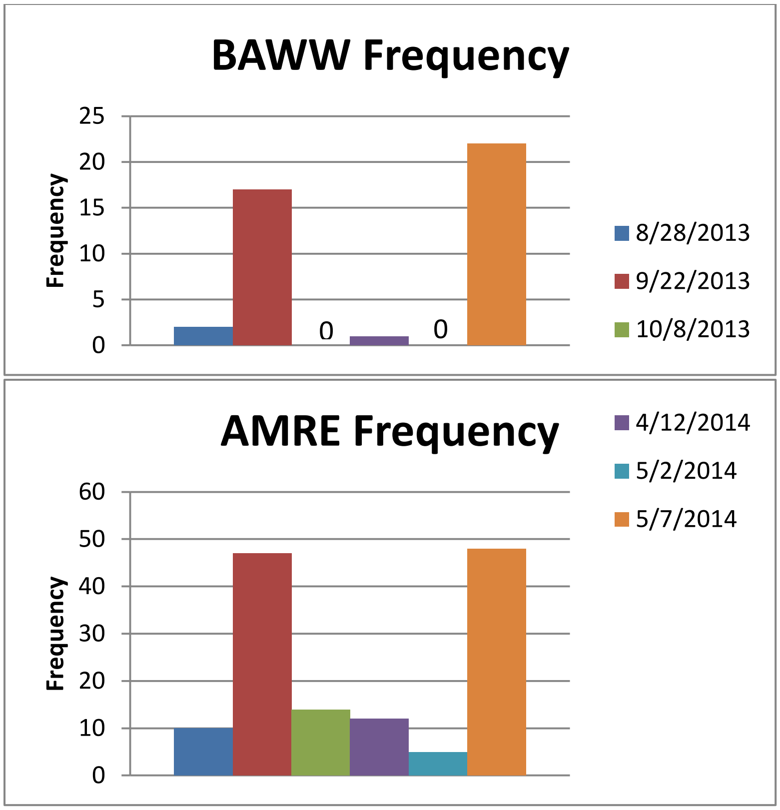


Fig. 13. Trends in nighttime call frequency of Black-and-White Warbler (top panel) and American Redstart (bottom panel) at Cleveland Lakefront Nature Preserve on three fall dates (8/28/13, 9/22/13, 10/8/13) and three spring dates (4/12/14, 5/2/14, 5/7/14).

<u>Unidentifiable Calls</u>

While most calls could be sorted into distinct call types, some calls were not identifiable beyond “bird calls”. On 28 August 2013, 28.2% of calls were unidentifiable to group on 8/28/13, while the next highest percentage of unidentifiable calls was on 4/12/14 (5.5%) (Fig. 14).

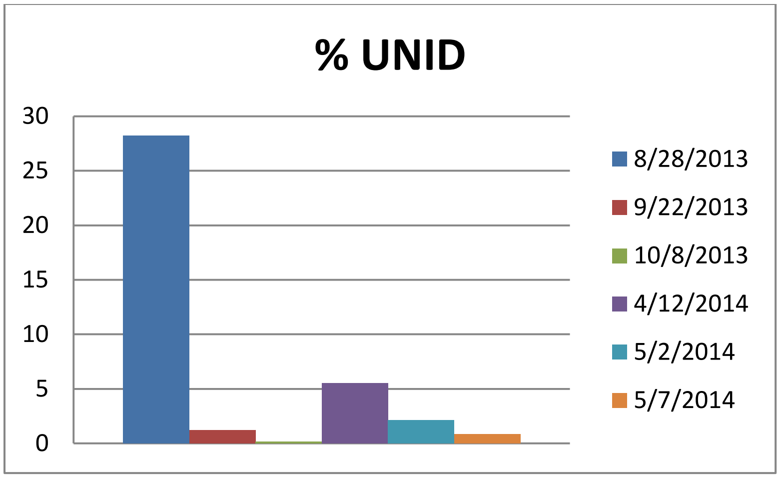


Fig. 14. The percentage of calls that were could not be sorted into one of the ten distinct groups and therefore, were unidentifiable for three fall (8/28/13, 9/22/13, 10/8/13) and three spring (4/12/14, 5/2/14, 5/7/14) dates.

Wind Speed and Direction and Bird Movement

Winds are the most important factor to consider when determining bird migration during spring and fall. During fall, birds will be looking to migrate with winds coming from the North and during spring they will have strong movements with winds coming from the South. Fig. 15 shows the average wind direction for each night and a relative magnitude. Overall, there were good bird movements on the dates examined (Figs. 6,7). Not surprisingly, during the fall, winds were blowing from the North with an average speed of 4-9 mph, while during the spring, the winds were coming from the South with an average speed of 7-10 mph.

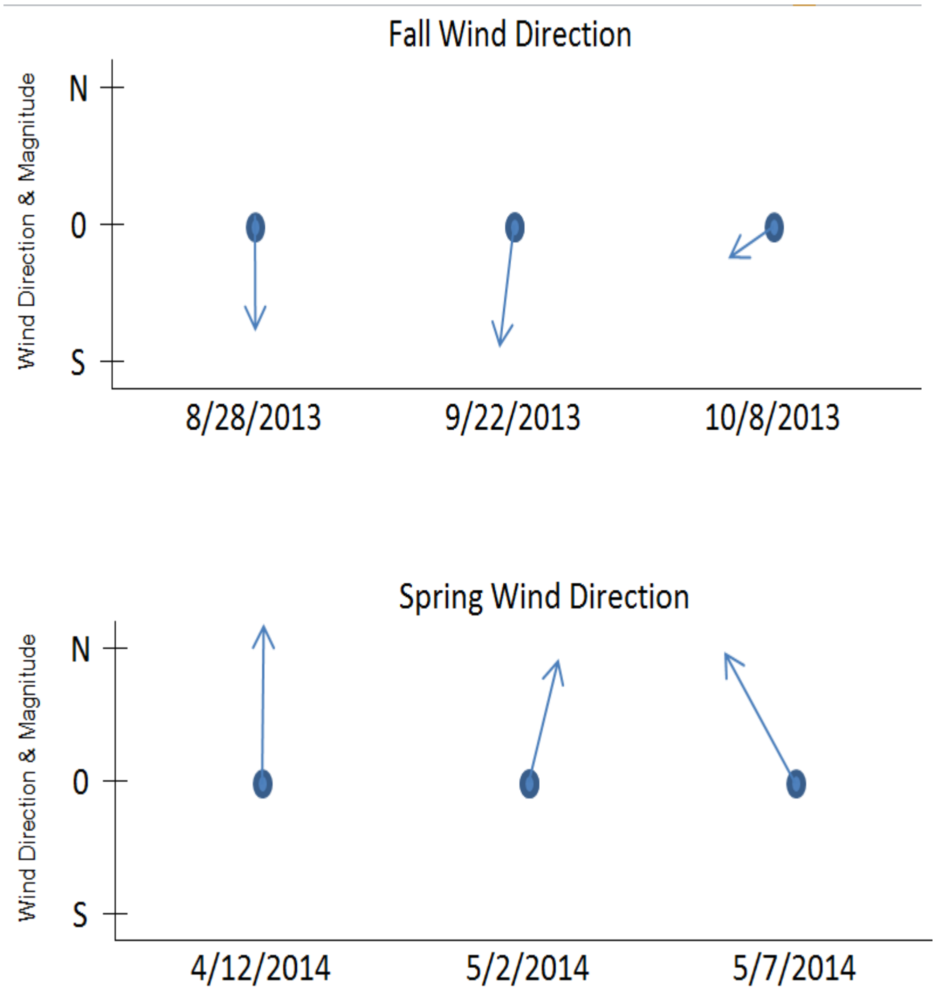


Fig. 15. The average wind speed and direction over the course of the night for three fall dates, 8/28/13, 9/22/13, 10/8/13 (top panel) and three spring dates, 4/12/14, 5/2/14, 5/7/14 (bottom panel).

Discussion

Widespread use of acoustic monitoring of nighttime flight calls has the potential to provide a better understanding of when and where large numbers of birds are moving across North America. In my study, call numbers were quite high, making it clear that birds are staging either in the Cleveland area during spring or directly across the lake in Canada during fall before making the long trip across the central basin of Lake Erie.

Nocturnal call data allows us to get a sense of peak movement patterns and when the bulk of the birds are arriving at a particular location. For example, in the fall, birds will be staging on the Canadian side of the lake and then migrate south in early evening. Therefore, we would expect there to be a peak in recorded calls in the early morning hours of fall nights in the Cleveland area, which was observed for all three fall nights (Fig. 6). For spring dates, the opposite pattern was expected, with larger peaks in the early evening when birds are preparing to leave for their northerly journey across the lake. This trend was best represented on 12 April 2014 (Fig. 7), with other dates having multiple peaks during the early morning hours. Clearly, spring flight times and bird arrival at Lake Erie are unpredictable, as birds are making their way through the southern portion of North America. These data also suggest that birds may fly separately, arriving at the lakefront at different times, where they then proceed to stage for their movement across the lake in a large group within the next few nights. To provide more evidence for this idea, one could use a similar microphone set-up in Canada across from Cleveland. It would likely show that migration patterns from Cleveland during the spring would be similar to the fall patterns along the Canadian coast.

One major disadvantage of monitoring nocturnal migrants using acoustic tools is that several species of birds are next to impossible to differentiate with any level of confidence due to their similar shape, frequency, and individual variance. One way to resolve this issue to a certain degree is to group species based upon call types (Table 1). For example, species such as Pine Warbler and Northern Parula are very closely related with strong potential for overlap (Fig. 16), and were both placed into the single-banded downsweep group. While not giving species-level resolution, it does help us get a better picture of the migration and bird movements.

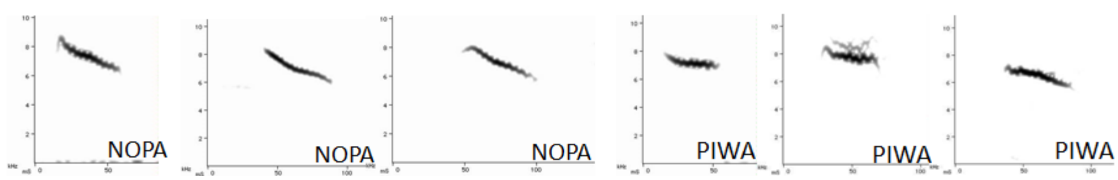


Fig.16. Samples of both NOPA (Northern Parula) and PIWA (Pine Warbler) spectrograms.

Another issue that makes call identification to the species level difficult is the overall quality of the actual call recordings. In some instances, only a vague shape can be made out and it can only be sorted by call type. At other times, the spectrogram quality is so poor that a group cannot be established and that is when the call is placed into the UNID group. There are several potential causes for the quality issue: some sort of interference with the recording device, background noise, and strength of the call which could be a reflection of the altitude at which the bird is flying and how loudly it calls. That said, some species are unique and distinctive enough to be picked out with a high level of confidence regardless of spectrogram quality. For my project, I chose four species that were always identifiable to the species level (Figs. 12, 13). Future species-level analysis could also include Indigo Bunting and Ovenbird (Fig. 17), among others as a function of their distinctive call patterns.

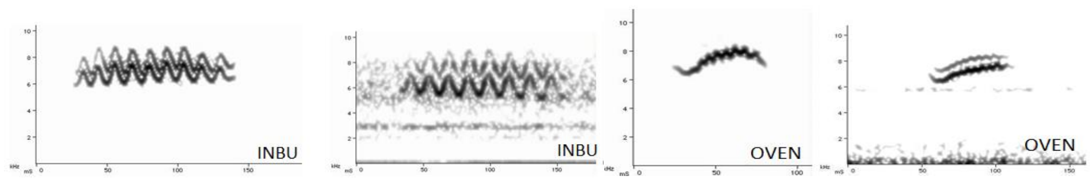


Fig. 17. Examples of the distinct spectrograms of INBU (Indigo Bunting) and OVEN (Ovenbird).

Tracking peaks in the migration of species groups and individual species allows us to track the migratory patterns across different seasons, giving us a better sense of seasonal variability in abundance and migratory pathways as well. Spring analyses show a significant increase for each species group and all four species as time moves forward during spring migration. This would suggest that as the spring season moves along, the number of migratory birds skyrockets quickly. The five-day difference between 5/2/14 and 5/7/14 shows a significant increase in the bird populations. Adding more Spring dates would be needed to give a more accurate sense of group and species movement across the spring season. During the Fall season, species groups containing warbler species peaked on 9/22/13, with a rapid decline in detection by 10/8/13. However, call types primarily associated with sparrow species had their highest peaks at the later date. This trend in timing differences was also reflected in the species-specific data for the two sparrow and two warbler species. Overall, these results suggest that warbler species move earlier during fall migration, while sparrow species migrate later in the season. With more dates, it would also be possible to get a sense of whether or not individual species/species groups have very brief (a few weeks) or prolonged (a few months) periods of migration. Ultimately, the trends from the limited data set I worked with suggest that data collected using these recording devices will be very useful in reconstructing seasonal migration patterns for bird species that use nocturnal calling.

Call data from these recording devices may also provide insight into nightly movement periods and raise the following questions. For example, do some groups tend to move earlier in the night relative to other groups or do all groups/species move together as sort of a large flock? While the trends from my analysis are not completely clear, it appears that fall birds tend to move as a large unit rather than as individual species/species groups. This may not be surprising in that they share a large obstacle (Lake Erie) to cross as they return to their wintering grounds. Spring appears to be more variable with some groups showing earlier peaks during the night than others. It is possible that during spring, individual species may take different routes and move at different times. However, there is also evidence that they may stage along the lake before making larger movements across the lake as a large flock. More data is needed before coming to a definite conclusion on this topic.

Timing is not the only factor that effects avian migration. Wind direction and strength play a very important role in bird movements and affect the number of birds moving on a certain spring/fall day. A day with strong headwinds is generally correlated with a great decrease in bird movement when compared with a day with more favorable wind direction (tailwinds). If a bird encounters unfavorable conditions, it will generally stay put in one area and feed while it waits for wind/weather conditions to improve. In my analysis, all three spring dates showed favorable winds (from the south) and the three fall dates also showed favorable winds (from the north). Therefore, it is not surprising that there were good bird movements on these nights. With processing of more fall and spring dates, we should have nights with unfavorable wind conditions that will provide a good comparison for determining the role of wind conditions in migration across Lake Erie. Ultimately, in order to more fully understand bird migration, wind and time of year need to be looked at together. Day-to-day movements will likely be better predicted based upon the combined impact of these two factors. However, overall movement across the full migration seasons should not be affected by the wind of individual days. Eventually, birds will get a day of favorable conditions and move in large numbers to where they need to be, either wintering or breeding grounds. Wind and weather will prove very useful in making daily migration predictions but may be less relevant to understanding the seasonal aspect to when particular species/species groups are moving. For example, one might predict that May 7th is a typical peak movement date for American Redstarts (based upon historical data). However, movement on a particular day during that time period will be dependent upon a night of favorable winds for a good movement of these birds.

One of the main goals of my thesis project was to establish a useful, logical protocol/work flow for processing call data. Once that was done, I wanted to show what can be done with the type of data collected by these recording devices. A few interesting trends came out of these analyses, and with the addition of more nights and entire migration seasons, statistical analyses could be used to provide better insight into the significance of various trends and relationships. Further, it would be very useful in future studies of this type of data (particularly from this location) to make direct comparisons with multiple other approaches for tracking bird migrations, including weather radar data, mist-netting stations, and citizen science efforts like eBird.

eBird is a website run by the Cornell Laboratory of Ornithology that allows users to document their bird observations from the field in geospatially referenced database. Anyone is able to create an account and begin to submit records of birds that they saw (or heard), how many of those birds there were, and where and when they made the observations. Many people actively bird and record their findings to eBird from parks in the Cleveland area, including Cleveland Lakefront Nature Preserve. The data represented by eBird entries would be incredibly valuable to compare with the nighttime bird calls recorded. For example, if nocturnal call data shows a large number of American Redstarts being recorded on a given night, one could look at the eBird database for visual records of American Redstarts in the same geographical area to provide confirmation of conclusions drawn from nocturnal data (e.g., Fig. 18). Also, eBird data can be analyzied to create charts of daily changes in species abundances that are comparable to those made for the call data in this project. Graphs with data collected using these two different methods can then be compared to see if there is any correlation between these data collection techniques, one of which relies on nocturnal patterns and the other of which relies on diurnal data collection.

In addition to eBird data, doppler radar maps typically used to track weather patterns can be used to supplement nighttime flight data. These radar maps are just like the ones for weather but in addition to showing storms the radar shows ‘clouds’ of bird populaitons (Fig. 18). These “bird clouds” are such large masses of birds that they get picked up by the radar. These maps allow us to see where large populations of birds are dropping down for a given night. These ‘clouds’ can then be compared with the nighttime recordings to see if there is any correlation between the two data collection techniques. For example, on nights where radar detects a ‘cloud’ of birds over the Cleveland area, we would expect very high levels of call detections on the recordings.

Mistnetting at nearby locations or at Cleveland Lakefront Nature Preserve may provide yet another source of data to supplement call recordings. A mist net is simply a net set up between two poles to capture birds for research and banding purposes. Having mist net data from a nearby station allows for a direct comparison of the species recorded between it and the nightly recorded call data. A future study may consider setting up one of these stations at CLNP as another source to help support the night recordings and track migration in this area.

Fig. 18. Left: eBird submission screen where an observer is recording 5 American Redstarts. Right: Example of Doppler Radar output where the blue circles are 'clouds' of birds. Storms can also be seen in green and yellow.

Finally, continued call monitoring and research at this site (and others) may lead to major contributions to future projects and our understanding avian migration along this pathway. These data can also help track species population fluxes through time to determine which ones are increasing or decreasing. It will also help to monitor time of migration for a species over the course of many years to determine if some other factor is affecting their migration tendencies, such as climate change or light pollution. Further research along the Great Lakes, and particularly Lake Erie will also provide helpful insight into the current issue of wind turbine development offshore in Lake Erie. Getting a sense of the magnitude of birds moving across the lake during Spring and Fall will help others make informed decisions when choosing if and where to build wind turbines.

Clearly, further research in nocturnal call analysis will provide a valuable resource for data regarding many aspects of bird migration biology. There are so many insights they may shine a light on for the future of various bird species. While call analysis can be extremely tedious, improvements in available software may make the data more amenable to rapid processing. In a perfect world, the program and associated devices would be able to record bird calls at night and then sort into species as the microphone is recording. While we are probably quite distant from the ‘perfect setup’, recent efforts using machine learning techniques (automated detection based upon pattern recognition algorithms) may provide up to 95% accuracy in species identification when working through previously recorded data. With continued software development, microphones could be set up in many different migration corridors and rapidly sorted, quickly giving mounds of strong data. Research with acoustic recordings for birds is just starting to develop, and my project helps show the types of questions it can be used to effectively address.

Works Cited

Able, K. P. (1973). The role of weather variables and flight direction in determining the magnitude of nocturnal bird migration. Ecology 54:1031–1041.

"Birding by Radar--Archive of US Composite Radar Maps." *Birding by Radar--Archive of US Composite Radar Maps*. N.p., n.d. Web. 2014.

Diehl, R. H., R. P. Larkin, and J. E. Black (2003). Radar observations of bird migration over the Great Lakes. The Auk 120:278–290.

Dunn, E. H. (2005). Counting migrants to monitor bird populations: State of the art. In USDA Forest Service General Technical Report PSW-GTR-191. pp. 712–717

Evans, W. R., and D. K. Mellinger (1999). Monitoring grassland birds in nocturnal migration. Studies in Avian Biology 19:219–229.

Evans, W. R., and K. V. Rosenberg (2000). Acoustic monitoring of night-migrating birds: A progress report. In Strategies for Bird Conservation: The Partners in Flight Planning Process. Proceedings of the Third Partners in Flight Workshop (R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, Editors). USDA Forest Service, Rocky Mountain Research Station, Ogden, UT, USA. pp. 51–159.

Farnsworth, A. (2005). Flight calls and their value for future ornithological studies and conservation research. The Auk 122:733–746.

Farnsworth, A. (2007). Flight calls of wood-warblers are not exclusively associated with migratory behaviors. Wilson Journal of Ornithology 119:334–341.

Graber, R. R., and W. W. Cochran (1960). Evaluation of an aural record of nocturnal migration. Wilson Bulletin 72:253–273.

Hamilton, W. J. III (1962). Evidence concerning the function of nocturnal call notes of migratory birds. The Condor 64:390–401.

Lanzone, M., E. Deleon, L. Grove, and A. Farnsworth (2009). Revealing undocumented or poorly known flight calls of warblers (Parulidae) using a novel method of recording birds in captivity. The Auk 126:511–519.

May, R., O. Reitan, K. Bevanger, S.-H. Lorentsen, and T. Nygård. "Mitigating Wind-turbine Induced Avian Mortality: Sensory, Aerodynamic and Cognitive Constraints and Options." *Renewable and Sustainable Energy Reviews* 42 (2015): 170-81. Web.

Millikin, R. L. (2005). Migration monitoring with automated technology. In USDA Forest Service General Technical Report PSW-GTR-191. pp. 860–870.

"Old Bird, Inc." *Old Bird, Inc.* N.p., n.d. Web. 2014.

Osenkowski, J. E., P. W. C. Paton, and D. Kraus (2012). Using longterm constant-effort banding data to monitor population trends of migratory birds: A 33-year assessment of adjacent coastal stations. The Condor 114:470–481.

Peckford, M. L., and P. D. Taylor (2008). Within night correlations between radar and ground counts of migrating songbirds. Journal of Field Ornithology 79:207–214.

Sanders, Claire E., and Daniel J. Mennill. 'Acoustic Monitoring Of Nocturnally Migrating Birds Accurately Assesses The Timing And Magnitude Of Migration Through The Great Lakes'. *The Condor* 116.3 (2014): 371-383. Web.