



## Recording Animal Vocalizations at the San Diego Zoo: Animal Vocalizations IV

Kathleen A. Nolan<sup>1</sup>, Katherine Wydner<sup>2</sup>, Kristy Biolsi<sup>1</sup> and Allen Burdowski<sup>1</sup>

<sup>1</sup>St. Francis College, Department of Biology, 179 Livingston St. Brooklyn, NY 11201 Address, ZIP, Country

<sup>2</sup>St. Peter's University, Department of Biology, Kennedy Blvd., Jersey City, NJ 07306 USA

### Abstract

This fourth ABLE zoo sound recording workshop took place at the San Diego Zoo where there is a wide variety of animals that vocalize. In general, at a zoo, aquarium, or farm, participants can record animals using the free downloadable Audacity or Raven Lite and convert these waveforms to spectrograms for further analysis. They can also record ambient noise and attempt to see if there are changes in the behavior of the animals under various conditions. Hypotheses can be tested about how variable vocalizations might be in different settings; in a zoo-setting this could include a variety of other surrounding animals and humans. Are vocalizations different before, during, or after a feeding? For example, a St. Francis College student noted that sea lions became unusually quiet after a feeding session at the Queens Zoo in New York City. At the San Diego Zoo, participants can record birds, sea lions, and primates under various conditions.

**Keywords:** Animal vocalization, bioacoustics, animal cognition, animal behavior

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**Correspondence to:** Kathleen Nolan, [knolan@sfc.edu](mailto:knolan@sfc.edu)

### INTRODUCTION

Animals vocalize for a wide variety of reasons, including for communication, alarm calls, mating calls, delineating territory, and to recognize members of their own species, and perhaps even their own family members. Students can participate in field trips to natural areas to record animals vocalizing, but sometimes it is difficult to get close enough to get a good recording. We have found that zoos are good places to start to learn about animal vocalizations, and students can generate and test hypotheses about the meaning of the vocalizations. (Aquaria often contain vocal sea lions, and a participant in the workshop suggested farms.) Students can also look for patterns in the vocalizations (such as duration, type, pitch, decibels) to see if they correlate with any types of behaviors. In the past, we have conducted these workshops at the Houston Zoo, the Henry Villas Zoo in Wisconsin, and the Columbus Zoo, (Nolan et al., 2017; Nolan and Callahan, 2018; Poesel et al. 2019).

The San Diego Zoo contains a number of animals that might vocalize and that could be recorded. Students could go to the San Diego Zoo website (or other location website pre-trip) and pick out an animal to record ahead of time. The students can be asked to develop a hypothesis about something they would like to test. [Wildlife | San Diego Zoo \(https://zoo.sandiegozoo.org/wildlife\)](https://zoo.sandiegozoo.org/wildlife). See also sea lions and others at the San Diego Zoo Alliance web site. [Sea Lion | San Diego Zoo Animals & Plants \(https://animals.sandiegozoo.org/animals/sea-lion\)](https://animals.sandiegozoo.org/animals/sea-lion).

Birds make excellent subjects for recording and acoustical analysis because vocalizations are essential to their communication and survival. The San Diego Zoo features birds from six continents. Their Aviary Trail features 22 individual aviary exhibits, containing roughly 40 species of birds, and it ends at the Owens Aviary, one of the largest walk-through aviaries in the world. The Owens Aviary contains approximately 200 tropical birds from around 45 species. Located nearby the Aviary Trail, the Parker Aviary houses tropical birds from Central and South America, and the Scripps Aviary contains birds of African forests.

Primates might also readily vocalize, and include: bonobos, geladas, baboons, lemurs (we heard lemurs vocalize in the June 2023 workshop), lesser spot-nosed monkeys, capuchin monkeys, colobus monkeys, northern black-crested mangabeys, orangutans, Wolf's monkeys, Red-tailed, Allen's swamp monkeys, vervet monkeys. The authors of the website mention that some of the monkeys are in mixed groups with other non-primate mammals. Hypotheses could be generated that address efficacy of vocalizations in mixed groups.

Sea lions will sometimes vocalize (we have noted that males and juveniles are the most likely to vocalize), and they are fascinating to watch. Recordings can also be made of their breathing. Do they behave and or vocalize differently when people such as children or trainers are present?

Pre-field trip, query the students as to what they think the importance of "sound" is in animal communication and/or biology. This question might elicit responses that describe uses such as: communication with each other, warnings and alarms, marking territories, and for courtship and mating. A good beginning interactive on sound can be found on the Howard Hughes Medical Institute (HHMI) Biointeractive website—"How Animals Communicate with Sound". The following text explains the entire biointeractive; however, just before embarking on a field trip, we focus solely on the bird and bat material because of time constraints. [How Animals Use Sound to Communicate \(biointeractive.org\) \(https://www.biointeractive.org/classroom-resources/how-animals-use-sound-communicate\)](https://www.biointeractive.org/classroom-resources/how-animals-use-sound-communicate).

In this interactive, students examine elephant videos, and write down as many observations as they can about a short video clip depicting a group of interacting elephants, including both visual and auditory signals. Then students make a table of general examples of the different senses that animals use to communicate, and how these senses can be advantageous or disadvantageous. (Tactile and olfactory are included in the table as well.) This interactive should then set the stage for students to do a more in-depth analysis of sound. Within the interactive there is a tutorial that defines sound, wavelength, frequency, decibels, amplitude, and velocity of sound, and gives measurements for sound in air, water and through the ground. Students are required to calculate sound wavelength if given various sound frequencies as sound travels through various media such as water or air.

The interactive then allows the student to explore bird and bat calls, (as well as additional detail on elephant bioacoustics). Commence the bird exercise by playing calls of birds titled Species "A" or "B", and then calls of nine unknown birds. Students classify the unknown birds as Species "A" or "B". (When we have done this with students and in ABLE workshops there is always quite a bit of error). Then the students are given the visual spectrograms of the two species, listen to the calls again, and are asked to re-classify the species when they can both hear the sound and see the spectrogram. The re-classification to the two species is then much more accurate. An additional exercise in which the students listen to rate-adjusted bat recordings, reveal that:1. They cannot hear the bat recordings unless the recording is slowed down (this will decrease the frequency of the bat sounds) and 2. Insects that are audible in both the normal speed and slowed down recordings sound quite different in both!

The study of sound can also be used to study soundscapes, acoustics habitats, biodiversity (how many species can one detect in an area using sound recordings?), phylogeny (can organisms be clustered into species or groups based on their acoustic signatures, usually with vocalizations?), affects of ambient noise on organisms' communication and behavior. Passive acoustic monitoring in the form of remote vehicles and balloons has increasingly been deployed to study bioacoustics. Students can obtain recordings from sound libraries---two of which we have used are the Maccaulay Sound Library and the Borror Sound Library. Additional sound libraries and their contents are listed in Table 1 in Parsons et al. (2022), as well as many additional references on sound and bioacoustics.

What is the difference between Audacity and Raven Lite? Both are free, downloadable software that allow the operator to record a vocalization in a waveform, convert a waveform to a spectrogram, adjust the rate of recording, and zoom in on the different frequencies. However, Raven Pro (\$100 for professors for a year-long license) allows automation of measurements, whereas with Audacity and Raven Lite one has to examine data and record highest and lowest frequencies by hand and make one's own tables---Raven Pro does that automatically. Raven Pro also has the capability of making tables for spectral correlations, that would be a preliminary step for making species cladograms based on vocalization spectrum analysis.

Additional websites listed below provide more ideas about animal vocalizations to explore with your students. The Bird Song Hero game was developed to help students identify birds by adding a song recording and its spectrogram to a visual image. Students play the song, and try to match it with one of three birds (<https://academy.allaboutbirds.org/features/bird-song-hero/bird-song-hero-tutorial#%2Fbird-song-hero-tutorial>). This game could be used as a stand alone exercise as a group or at-home online game, or in addition to a spectrogram analysis lesson plan with Bird song hero game [Ed-BlandingBirdSpectrograms.pdf \(virginia.edu\)](https://blanding.virginia.edu/sites/blanding.virginia.edu/files/Ed-BlandingBirdSpectrograms.pdf) (<https://blanding.virginia.edu/sites/blanding.virginia.edu/files/Ed-BlandingBirdSpectrograms.pdf>).

The apps Merlin and BirdNET can be downloaded (at no cost) onto a phone. Both aid in identifying birds through their songs. Merlin also asks questions about the color and shape of the bird; BirdNET asks the user to select part of a recorded spectrogram, and then provides their best-guess as to the bird species. [Merlin Identification, All About Birds, Cornell Lab of Ornithology](https://www.allaboutbirds.org/guide/merlin/) (<https://www.allaboutbirds.org/guide/merlin/>)

and [BirdNET Sound ID – The easiest way to identify birds by sound. \(cornell.edu\)](https://birdnet.cornell.edu/) (<https://birdnet.cornell.edu/>).

Additional references with compelling ideas about animal vocalizations and bioacoustics include: Aide et al., 2013; Lingle and Riede, 2014; Ravnani et al., 2019; Sainberg et al., 2022 and Snyder et al., 2022.

## STUDENT OUTLINE

### Objectives

- Learn how to observe animals in the wild or in captivity by adding sound to the senses' repertoire.
- Learn about the physics behind sound
- Learn how to use Audacity and Raven Lite to record vocalizations
- Learn how to analyze data that can be obtained from spectrograms
- Describe and attempt to interpret patterns noted in animal vocalizations

### Introduction

How is sound used in animal communication? List several examples.

You will be given a short tutorial on sound in the lab before you go to the zoo or out into the field. The instructor, in the interest of time, will also have you guess which nine unknown bird calls can be assigned to each of two species by call alone, and then by call and seeing the spectrogram of the call. The instructor may ask you to complete the student worksheet for homework.

[How Animals Use Sound to Communicate \(biointeractive.org\)](http://biointeractive.org)

Next, you will see how spectrograms can help you learn how to identify birds using the Bird Hero Game

[Bird Song Hero \(allaboutbirds.org\)](http://allaboutbirds.org)

Your instructor might have you include Spectrogram analysis lesson plan with Bird song hero game for homework or as part of your lab report.

[Ed-BlandyBirdSpectrograms.pdf \(virginia.edu\)](http://virginia.edu)

### Directions for Downloading Raven Lite and/or Audacity:

1. To download Raven Lite, go to this link: <https://ravensoundsoftware.com/raven-lite-downloads/> You will then be prompted to register and use the free license code emailed to you.
2. To download Audacity, go to this link: <https://www.audacityteam.org/download/>
3. Your instructor will show you how to record your own voice with Audacity/Raven Lite which will appear as a spectrogram, which spans decibels of various frequencies of sound. You will convert your waveform to a spectrogram, and locate the minimum and the maximum frequency in hertz of your voice. You will learn how to slow the playback rate, which can be useful in playing back sounds of high frequencies.
4. Once you are familiar with the software, your instructor will take you to a zoo or other area to record animals.
5. Find an animal that you would like to record (a vocalizing bird is a good beginning).
6. Make a hypothesis as to why the animal is vocalizing the way it is, or, if you anticipate that a situation might change (you note the presence of several children approaching, you note different assemblages of animals, you take a note of the weather. Aim for a time of at least 20 minutes.
7. When you come back to the lab, you will generate a table in Excel that lists: a. species b. number of vocalizations, average duration of vocalization, delta time in between each vocalization, the highest and lowest frequency of each vocalization. Note any unusual pattern you see in the spectrograms.
8. This information will comprise your results sections of your lab report. (Of course, you will also write an introduction along with any hypotheses you were testing, materials and methods, location, names of animals and conditions. Write a short discussion of what you learned about the animals from this exercise, including their behavior as related to the vocalizations, and any other observations pertinent to the topic at hand. What more would you like to learn about these animals?)

How To Record At The Zoo (Or in the Field) With a Smartphone (if you would rather record with your phone and play the recordings back in the lab with your laptop with microphones available):

Your iPhone or Android Smartphone will need a recording App. There are many options that will make suitable recordings. We recommend that you follow the guidelines below and make sure the recording system is working on your phone before the workshop. Here is a brief outline of what you need to do to get started.

1. Select a recording App for your phone and operating system. Free Apps should work just as well as the ones you pay for - they may have fewer options but should record animal vocalizations and provide appropriate sound files. Some examples of suitable Apps for the iPhone include VoiceMemo, iTalk, Audio, and RecorderApp. Two examples for Android include Sound Recorder Plus: Voice Rec and Sound Memo Voice Recorder.

Note: The Merlin Bird ID App by Cornell Lab is available for iPhone and Android, and has a sound feature that records in wav format, displays a “live” spectrogram of the sound while recording, and offers identifications for “expected” birds in the area where it is used. Although designed for birds, it will record any sounds, and although it is free, there are absolutely no ads!

2. Record using the highest quality settings available in your App (wav file format, 16-bit or higher, 44.1kHz if these settings are available). Get as close to the animal vocalization as appropriate without disturbing the animal. For example, in the case of a bird singing, begin recording immediately, and then proceed to get closer for better recordings. Orient the microphone of the Smartphone towards the vocalizing animal.
3. Whenever possible, save the sounds files in AIFF or wav file formats. These preserve the original sound quality (are “lossless”) and are the easiest to process.
4. Make sure that you know where the audio files are stored on your phone so you will know where to access them. In advance, locate the files and check that the files can be played back.
5. Have a plan for moving these audio files to your laptop computer for analysis. Some Apps may let you e-mail the sound files directly from within the App. If you have an iPhone, you may be able to connect your iPhone to your computer’s USB port and use iTunes to transfer file directly to the computer. From an Android phone, you should be able to transfer files by attaching them to emails or – if they are very large – transfer them to your Google Drive and then upload them to your computer from there.

## Cited References

[Bird Song Hero \(allaboutbirds.org\)](http://allaboutbirds.org)

[Ed-BlandyBirdSpectrograms.pdf \(virginia.edu\)](http://virginia.edu)

[How Animals Use Sound to Communicate \(biointeractive.org\)](http://biointeractive.org)

<https://ravensoundsoftware.com/raven-lite-downloads/>

<https://www.audacityteam.org/download/>

### MATERIALS

A computer with Internet access and smart phones (if available).

### NOTES FOR THE INSTRUCTOR

Depending on timing, the introduction to sound and the How Animals Use Sound to Communicate can be done just prior to a field trip to “collect” animal vocalizations, or in a prior class period. For our previous zoo trips, we spend approximately 45 minutes discussing sound and going through the Biointeractive tutorial. The Bird Song Hero exercise can then be used for homework, and to supplement their lab reports. Students should download Audacity and/or Raven onto their computers before embarking on the field trip. Even though we have also recorded animals with smart phones, we have found that the best results are obtained by opening the laptops and directly recording the animals as they are vocalizing. In this way, the students can see the waveforms and/or spectrograms in real time.

### Additional materials

This is a great tutorial on differentiating among bird vocalizations by augmenting listening with spectrogram analysis. [Start Using Spectrograms to 'Read' Bird Songs and Calls | Audubon](https://www.audubon.org/news/start-using-spectrograms-read-bird-songs-and-calls) (<https://www.audubon.org/news/start-using-spectrograms-read-bird-songs-and-calls>).

Another exercise in which students can examine spectrograms in more detail is explained by the Eavesdropping on Elephants—Elephant Listening project.

[Eavesdropping on Elephants – Elephant Listening Project](https://www.elephantlisteningproject.org/infrasound/) (<https://www.elephantlisteningproject.org/infrasound/>).

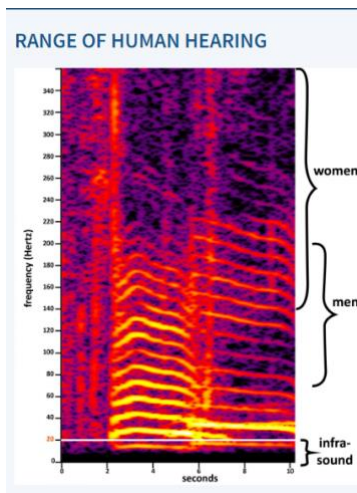


Figure 1. Elephant rumbles (<https://www.elephantlisteningproject.org/infrasound/>).

Information gleaned from looking at Figure 1 and studying the information provided in the website includes:

- There are two elephant rumbles (stacks of parallel lines).
- The white line is the upper boundary of 'infrasound' – humans cannot hear frequencies below this.
- The bracketed areas show speaking frequencies for men (70-200 Hz) and women (140-400 Hz).
- The stacks of lines above the white line are harmonics of the fundamental frequency. In these calls the fundamental frequency is infrasonic.

### **Advanced research projects**

For more advanced research projects, students can generate correlation tables, and even cluster analysis.

Bird songs can be very complex, with both similarity and diversity of songs within a population of the same species, and sometimes even within one individual. A bird's song generally consists of a series of notes and syllables separated by time gaps, and can be repeated many times in succession. Raven Pro offers a method to quantify song similarities through the use of an energy detector and batch correlations followed by the use of statistical software to create cluster diagrams in the form of tree diagrams, aka dendrograms. Results depicted in a dendrogram of song similarity are similar to those that display a phylogeny of related species on the tree of life.

Cornell Bioacoustics Research has created a video (<https://vimeo.com/220340190>) that provides an overview of one way that Raven can quantify song similarity for birds, but this same method can be used to quantify the songs of other vocalizing animals, including insects and frogs. As shown in their video, an example of a research question that can be answered using in this manner, is “Is a bird improvising different versions of a song as it goes along or is it drawing from some limited repertoire of a song type that it knows?”.

This method for quantifying similarities among the songs of a bird begins with a recording that is several minutes long. For this approach to work best, one should begin with a recording that has minimal background noise and interference from the singing of non-target species. One then needs to use a tool found in Raven Pro known as Raven’s Band Limited Energy Detector to detect all the individual sounds on a recording. Raven’s online User Manual Chapter 9, page 286 ff (<https://ravensoundsoftware.com/raven-lite-downloads/>)

provides information on how to configure/adjust the energy detector parameters. Essentially, the Band Limited Energy Detector finds sections of signal that exceed a user-specified signal-to-noise ratio threshold within a range of time and frequencies that the user specifies. The energy detector runs on a spectrogram view. Visually comparing the shapes of song notes and other elements on a spectrogram display to evaluate degrees of similarity or dissimilarity would be very tedious and time-consuming, but Raven’s Energy Detector combined with its Batch Correlator feature (described below) can quantify a two-minute recording containing over 90 individual songs within only a couple of minutes! A tutorial using the Black-capped Vireo is given here (Figure 2 depicts an example of a spectrogram display generated using Band Limited Energy Detector on a 20 second recording of a Black-capped Vireo (BCV).

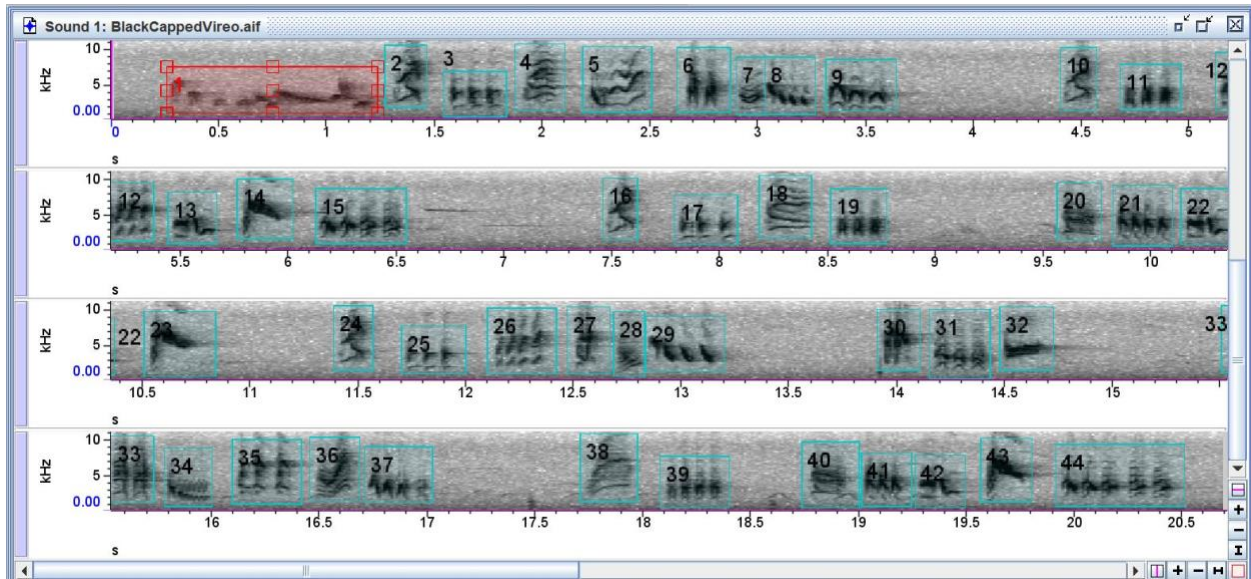


Figure 2. Spectrogram display generated using Band Limited Energy Detector on a 20 second recording of a Black-capped Vireo (BCV) by Katherine Wydner

Using the example shown in Figure 1, the next step in this process is to ask Raven to calculate numerical values for how similar each song selection is to the other 43 individual songs. The result is a Batch Spectrogram Correlation Table, which is a square table of numbers called spectrogram correlations. Each number in the table represents a comparison between two of the 44 songs. Chapter 9 of the Raven

User Manual walks one through the steps to save selections to a folder named after a selected recording (e.g. BCV) and to run a batch correlation of all the files in the folder against each other. To perform this step, choose Tools > Batch Correlator in the Raven menu, which will display the appropriate dialog box; for both input files, choose Browse ... and select the new folder you created, BCV, and use the BCV folder as both input 1 and input 2. After following Raven’s guidance, select OK to begin the correlation (which will take less than a few minutes). Figure 2 reveals the resulting Batch Correlation Table. Values range from 1 to 0, and can be color coded; identical values are shown in red and the most dissimilar values for songs are dark blue.

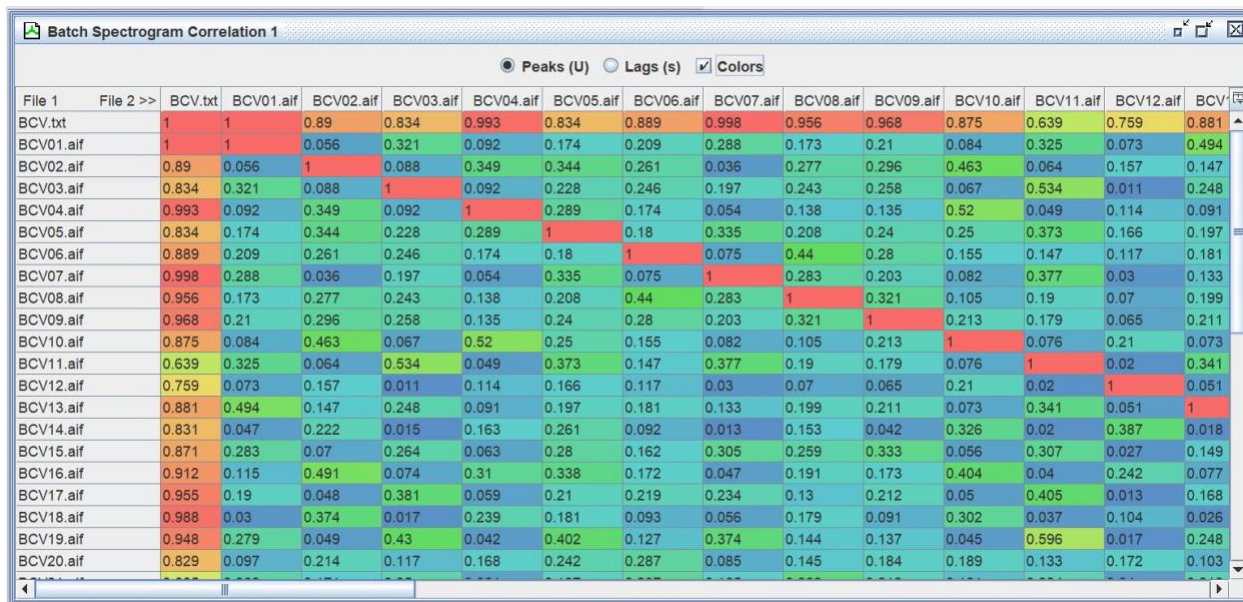


Figure 3. Batch Correlation Table generated by Katherine Wydner

Using a statistical analysis program, cluster analysis can now be performed. This cannot be done directly in Raven, but a variety of statistical packages will work, including using R and RStudio software (R Core Team, 2022; RStudio Team, 2021). The Batch Correlation tool writes a file called BatchCorrOutput.txt to Raven’s User Data Folder, which you can find by selecting Open User Data Folder from the Help menu. BatchCorrOutput.txt can be opened in any text editor, but it is recommended to open and work with it in Excel or another spreadsheet application. The format is tab-delimited text file, but the file extension can be changed to comma-separated values (csv) for working in packages like R.

Cluster analysis enables the visual similarities among song types to be viewed in a display known as a tree diagram or dendrogram. An example of the type of diagram that can be generated is shown in Figure 3 (<https://vimeo.com/220340190>). The labels at the bottom of the dendrogram represent the individual songs arranged so that the most similar songs are next to each other. Color coding helps with visualization of songs that are different enough from each other to be considered distinct songs. From the Figure 4 tree diagram, which is derived from a two-minute recording of a Black-capped Vireo with 91 song selections, cluster analysis reveals that there are 25 distinct song types. In answer to the research question that was posed earlier, one can conclude that this bird is creating its songs from a fixed



Nolan et al.

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### About the Authors

Kathleen A. Nolan, Ph.D., Professor of Biology Emerita has been a long-time ABLE attendee and workshop and poster presenter and author. She has also served on the board of ABLE. She was retired from St. Francis College, but is now serving as Interim Chair of Biology.

Katherine S. Wydner is an Associate Professor in the Biology Department at Saint Peter's University where she has been teaching a variety of courses since 1996: general biology, astrobiology, ornithology, genetics, microbiology, and natural ecosystems of New Jersey. A graduate of Princeton University (AB, Biology) and Rutgers University (PhD, Cell and Developmental Biology), she has participated in Project FeederWatch since 2013 and eBird since 2014. Since 2018, she has been engaging students in bioacoustics research on bird vocalizations, especially with respect to the effects of anthropogenic noise on birdsong.

Kristy Biolsi, Ph.D., Professor of Psychology and the Chair of the Psychology Dept. at St. Francis College, has been studying animal behavior and cognition for decades. She was the initial inspiration for the Animal Vocalization workshops with her study of pinniped cognition.

Allen Burdowski, Ph.D., Professor of Biology, and the Dean of Health Science, Sciences and Nursing at St. Francis College, was the first to suggest employing Audacity, a very user-friendly program, in our Animal Vocalization studies.

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