What Can Vocalization Tell Us about Animal Behavior? A Workshop Held at the Henry Vilas Zoo, Madison, Wisconsin

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Animal vocalizations are intimately related to their behavior. Students discussed a. what vocalizations can tell us about behavior, including territory guarding, recognition of cohorts, mating calls, warning calls and b. the kinds of vocalizations that might be recorded at a local zoo such as the Henry Vilas Zoo. Students took laptops and recorders to the Henry Vilas Zoo in Madison, Wisconsin to record animal vocalizations. Birds and orangutans are very vocal at the Henry Vilas Zoo. Upon our return to the lab, we analyzed the vocalizations with Audacity and Praat (Raven Lite was also discussed) and shared the data with the class. Students learned how to organize their data in Excel and use these data to devise and test further hypotheses. Another discussion that ensued was the value of zoos, which sparked controversial viewpoints. This workshop was similar to one conducted at the Houston Zoo in ABLE 2016.

Keywords: bioacoustics, animal vocalizations, zoos and aquaria studies

Introduction

Animals use sounds or vocalizations for a variety of reasons including courtship and mating, to establish a territory, to identify themselves to their group, to form social hierarchies, as warnings, and others. Students at St. Francis College (and through a mentoring program at the Intrepid Air and Space Museum) have been recording and analyzing animal vocalizations for the past several years. A psychology professor, Kristy Biolsi at St. Francis College, remarked during a course in Marine Mammal Cognition she was co-teaching with Kathleen Nolan, that sea lion pups can recognize their mothers' calls, and this initiated our interest in the further pursuit of animal vocalizations. Because we live in an urban environment on the east coast of the United States, without traveling, it would be virtually impossible for us to find sea lions. However, in the New York City area the Wildlife Conservation Society runs and manages five aquaria/zoos that house sea lions: New York Aquarium, Bronx Zoo, Queens Zoo, Central Park Zoo, and Prospect Park Zoo. Thus we urbanites are able to observe and record the vocalizations of quite a few sea lions (the number fluctuates because sometimes the animals are moved from location to location and there is the occasional mortality). We have been able to observe a difference in patterns among individuals, as well as a male/female difference in vocalizations (the males are usually more vocal). Each facility houses from three to seven sea lions (Chu et al., 2016, Nolan et al., 2015; 2016). There is a plethora of literature in which researchers are trying to discern the meaning of animal sounds.

Animal behavior includes the study of bioacoustics, or animal sounds, and their implications. Marques et al. (2014) have pointed out that bioacoustics is a relatively new field of study in which it has become easier to record animal sounds and vocalizations. However, they are concerned that not all of these recordings are placed in easily accessible databases, and can become lost to science. deComargo et al. (2017) point out that animal sounds can be used to study life history and behavior characteristics such as courtship or territorial calls and ecological events such as immigration or emigration of species into an area. They have used the PROTAX-Sounds to discriminate a mix of sounds to a 68% accuracy; however, that is beyond the scope of this exercise.

This particular ABLE workshop was conducted at the Henry Vilas Zoo, but it is hoped that this exercise could be conducted at any local zoo, or aquarium that might contain animals that vocalize. The mission at the Henry Vilas Zoo is: " to conserve and protect the wonders of the living natural world and to help build understanding between people and animals by promoting conservation and providing a high quality recreational and educational experience to our visitors". Their vision is the preservation of species.

The zoo was established in 1911 and was named after Henry Vilas, a young boy who died from diabetes. The Henry Villas Zoo hosts a tropical rainforest aviary, a primate house with Bornean orangutans, tigers, lions, grizzly and polar bears, harbor seals, prairie dogs, goats, red pandas and aardvarks. We were able to record a vocalization of a lemur that was reacting to a lion roaring, kookaburras and macaws, as well as birds outside of the zoo such as red-winged blackbirds.

A few examples of what researchers learned from studying animals similar to those in the Henry Vilas Zoo are summarized here. Bolt (2013) studied male ring-tailed lemur calls and found that they were used in the presence of another group of lemurs, not as intergroup calls as originally thought. Baker (2004) studied kookaburras (laughing birds) in Australia and was able to distinguish 24 of the 25 groups studied based on their calls. It is hypothesized that the birds use their calls to establish territories and group identification. Spillmann et al. (2017) recorded Bornean orangutans' long calls (calls used to communicate over a long distance) in an attempt to identify individuals for conservation purposes. They noted a 93.3% correct identification rate with high-quality recordings, and 72.23% with recordings stemming from an acoustic localization system with variable microphone-caller distances (20–420 m). Cramer and Price (2007) found that male Red-winged Blackbirds could distinguish different qualities of songs when they were played back to them as recordings and reacted differently to these sounds.

Student Outline

- The goal of this exercise is to learn more about animal behavior through vocalizations. A second goal is to look for patterns in the vocalizations and to see if you can discern within-species as well as among-species variation. What are some of the reasons that animals might vocalize? While you are conducting this exercise, you are participating in the field of bioacoustics.

- Recording animal vocalizations is pretty straightforward: you just open up your computer and place it so the microphones are as close to the animal as possible.

  Next, open up either Audacity or Raven Lite and press "record". The URL's for these sites are: http://www.audacityteam.org and http://www.birds.cornell.edu/brp/raven/RavenOverview.html.

- The longest we have recorded sea lion vocalizations has been twenty minutes. If you would like to record more than one animal, you may shorten the recording time. Raven Lite (or the full version) automatically places the spectrogram below the waveform while recording.

- An alternative to "opening your laptop and pressing "record" is to use a recorder with a microphone and a memory card. The card can then be inserted into the computer and you can import recordings into Audacity.

- When you get back to the lab, you will analyze some of the waveforms you recorded. A waveform is the collection of all the frequencies that pass through the air during a certain time period. The program measures sound in six-second intervals on your screen. When you save your file, you should have a master file, and a series of MP3 files that are each 6 seconds long. These can be a bit difficult to keep track of, so segments with vocalizations can be renamed by their patterns, or another naming system of your choosing.

- Watch these two videos: https://www.youtube.com/watch?v=7WYw3qoTdU4 Exploring Audacity's spectrogram view by Matt Thibault, and

- https://www.youtube.com/watch?v=Gg4IHbiITd0 Tutorial on Praat analysis of spectrograms by Charles J. Pindziak

- The first video asks you to listen to six seconds of sounds and then to analyze them. Then Matt Thibault, the author of the video, converts the waveforms to spectrograms by clicking on the black arrow on the left of the screen. You can change the frequency range on "spectrogram settings", and you can zoom in on selections to see more detail. (You can also "zoom" by clicking on the Y-axis—but sometimes one can zoom too much. If you do this, it is sometimes irreversible, and you have to start over—so, be careful what you zoom for.)

- The Praat video shows you how to determine the exact frequencies of your formants, although you can eyeball them in Audacity. Import your .wav file into Praat, convert to spectrogram, and click on "formants". This reveals a series of wavy red dots, but if you click on an actual formant, you will see a horizontal red-dotted line that gives an exact frequency.

- Figure 1 depicts a waveform of a single frequency. Note that it oscillates like waves---sound travels rather like a slinky through the air. Since the total number of waves in Figure 1 is 20 per 0.1 sec, this can be transformed via a spectrogram to frequency on the Y-axis and seconds on the X-axis. Since sound is usually made up of more than one frequency, your spectrograms should reveal a series of frequencies, or resonances, called "formants' (See Figure 2 for a picture of formants in sea lion barks). Save a section of your vocalization with .wav after its name.
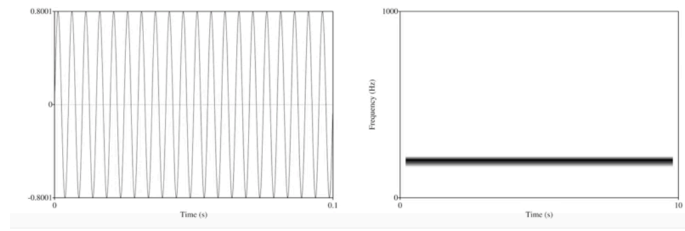
Figure 1. Screenshot captured on Praat tutorial on sound. https://www.youtube.com/watch?v=Gg4IHbiITd0
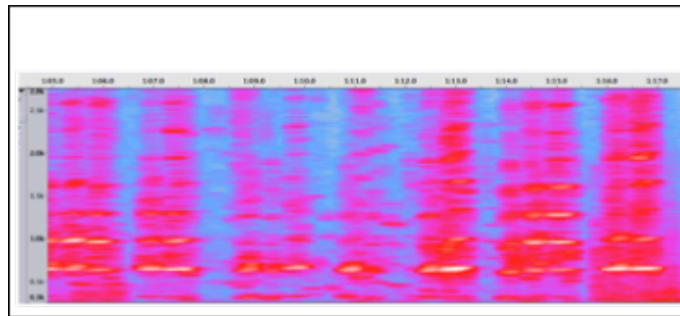
Figure 2. Formants of sea lion barks at the Bronx Zoo (1/3/16) on an Audacity spectrogram (approximately 8 per bark)

- Now open Praat (http://www.fon.hum.uva.nl/praat/) and import your file of interest that was saved with .wav at the end of its title.

Find the spectrogram of your file in Praat, and click on "formants". Red lines will appear and will indicate the frequency of each formant, which is more accurate than "eye-balling" it. Click on the actual formant on the screen and you will get a straight horizontal dotted line that gives you the exact frequency of that formant.

Making Excel Spreadsheets of Your Vocalizations

Open up Excel and make a spreadsheet of your data. For each column, put a different heading: number of vocalizations, duration of vocalization, number of "sub" vocalizations---i.e., if there are trills---the number of trills per vocalization. Add any other data that you think might be pertinent. For each column, determine the average or mean, and the standard deviation. Write down some questions that will define comparisons that you want to make. For example, "do male sea lions vocalize more than female sea lions?" You can answer your questions quantitatively by making inferential statistical comparisons, when you have a sufficient number of replicated values for each group (e.g. males vs. females). For you data analysis, note:

a. Total number of vocalizations per unit of time
b. Type of vocalization---was it a bark? growl? chirp? chichichi sound? Try to be as descriptive as you can be
c. If it was a bark, how many barks were in a series? (I once counted 13 woodpecker "pecks" in just one second!)
d. Think about how vocalizations may function as adaptations in an evolutionary sense. How would these vocalizations help the animal survive and/or reproduce?
e. What do you think the function of the zoo is? Has this zoo fulfilled its mission?

Materials

- Laptops loaded with the free programs Audacity, Praat and Raven Lite (these programs do NOT work on an IPad). http://www.audacityteam.org

- http://www.fon.hum.uva.nl/praat/ and

- http://www.birds.cornell.edu/brp/raven/RavenOverview.html

- Students may record the sounds on their phones, and then play the sounds back in the lab.

- There are also recorders such as Zoom H4n in which you can insert an SD memory card and a USB. The recordings can then be saved directly on your computer back at the lab.

- Microsoft Excel; optional statistical software

Notes for the Instructor

This is a fun exercise in which students can actually acquire data from a zoo setting. Call the zoo first to give them a heads-up---both the Houston and Henry Vilas Zoo did not require any special permits (I did have to fill out a form stating my intentions for "research' before I visited the Mystic Aquarium.)

Have the students watch the two videos listed in the Student Outline after they come back from the zoo but before they begin their analysis of the sounds.

If the students have time, you might want them to learn how to record and analyze animal vocalizations from a sound library; a list is enclosed. The Macaulay Sound Library of Cornell University is the most extensive. The Borror Laboratory of Bioacoustics works best if you input the Latin species name. It is very easy to work with the two windows open. In these sound libraries, you can open up Audacity or Raven Lite, and press "record" and then press "record on your sound library window. The Macaulay and Borror Sound Library now have the Raven spectrograms that are displayed upon opening up the recording.

There are some truly fascinating vocalizations and sounds such as walrus clicking and "bell" noises, the droning of the Weddell seal, clicking of the sonar of whales, and the "beating" of drum fish (Tajibaev et al. 2017)! You could even have a contest with students to try to come up with the most interesting or unusual recording! You can assign animals for students to "record" and make presentations about. These sound libraries have provided our students with a wealth of information and enjoyment.

Sound libraries

http://macaulaylibrary.org

Yellowstone National Park---Sand bill cranes, elks bugling https://www.nps.gov/yell/learn/photosmultimedia/soundlibrary.htm

Sea world---an example is the beluga whale https://seaworld.org/en/Animal-Info/Animal-Sounds

Borror Laboratory of Bioacoustics of The Ohio State University---over 40,000 recordings (look up Latin names of species for better results). http://blb.osu.edu/

The Ocean Conservation Research website has many audio recordings of fish and whales. Especially fascinating to us are the drum fish.
    http://www.ocr.org

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http://www.audacityteam.org

http://www.birds.cornell.edu/brp/raven/RavenOverview.html

http://www.fon.hum.uva.nl/praat/

http://www.hhmi.org/biointeractive/how-animals-use-sound-communicate

https://www.youtube.com/watch?v=7WYw3qoTdU4

https://www.youtube.com/watch?v=Gg4IHbiITd0

https://www.zooniverse.org/

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Acknowledgments

About the Authors

Kathleen A. Nolan, Ph.D. is a professor of biology and Chair of the Biology and Health Sciences Department at St. Francis College. She has been a long- time ABLE member and has presented numerous major and mini-workshops at ABLE conferences. She is interested in a wide variety of topics, including fish population genetics, animal vocalizations, and biology laboratory education.

Jill E. Callahan is an Associate professor of biology and Chair of the Biology Department at St. Peter's University. She teaches and coordinates the Honors General Biology lecture and lab, Microbiology lecture and lab, Anatomy and Physiology, and Research Methods. She obtained a BA in Biology from St. Anselm College and a Ph.D. from Virginia Commonwealth University. She is very interested in infectious disease, including bacterial biofilms and parasites, and bioacoustics.

Appendix A
# Howard Hughes Medical Institute Biointeractive Website

Another exercise about animal sounds is provided by the Howard Hughes Medical Institute Biointeractive website http://www.hhmi.org/biointeractive/how-animals-use-sound-communicate. This website contains a tutorial on sound and requests that the student watch videos of animal behavior and/or spectrograms of animal sounds. The three cases presented are: 1) Long-distance, low-frequency communication by elephants; (2) Species-specific courtship songs in closely-related finch species; (3) Use of ultrasound by echolocating bats and their prey. The finch case presents audio clips and asks the students to group the finches into species based on vocalizations. After the student does this, the spectrograms along with specific patterns belonging to each group are revealed. The bat case study is fascinating, because the bat's sounds (sonar) are only revealed when the student "slows" down the frequencies.

Selected Results from the Wisconsin Zoo

We were not able to open all the Audacity files that were e-mailed to me, but we were able to open the kookaburra MP3 file. We opened Audacity, pressed "record" and then played the kookaburra file that was downloaded into ITunes.
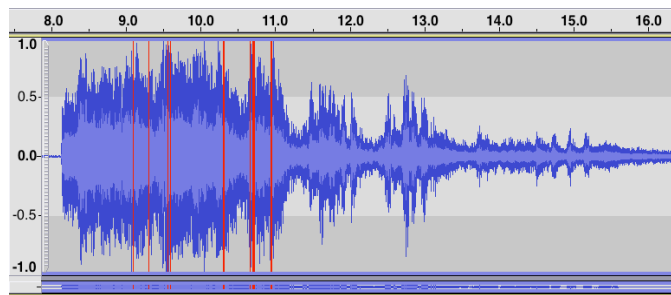

Figure 3. Waveform for the laughing kookaburra recorded at the Henry Vilas Zoo, downloaded into ITunes as an MP3 file, provided by Marcus Banks. There was more than one kookaburra; the red lines indicate the loudest decibels.
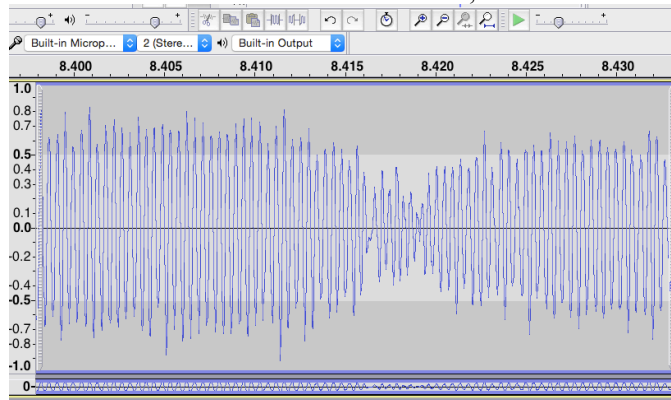
Figure 4. Zoomed waveform of laughing kookaburras—Henry Vilas Zoo. Zooming in on the waveform reveals individual sound waves in hundredths of seconds!
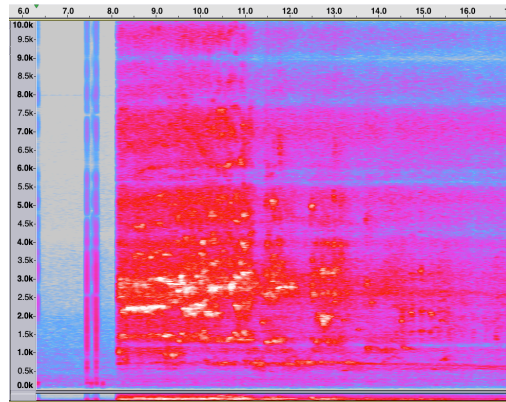
Figure 5. Audacity spectrogram of kookaburras at Henry Vilas Zoo. Note the cacophony of different sound frequencies!
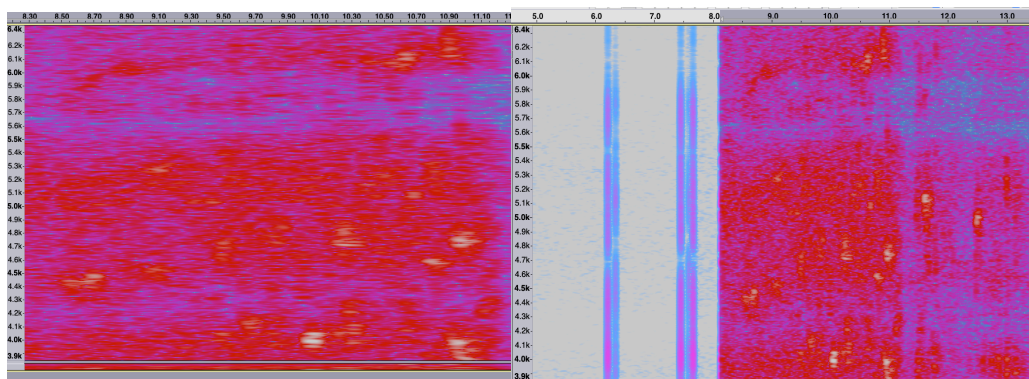
Figures 6 and 7. Kookaburra sounds zoomed into specific frequencies in kilohertz. The majority of sounds are between 1000 and 6000 hertz (1-6 kilohertz).

Figure 8. Laughing Kookaburra - *Dacelo novaeguineae* Macaulay Sound Library by Gregory Budney (ML55739611). This recording was taken in the Freycinet National Park, Tasmania, Australia. The spectrogram reveals a periodicity in the vocalization of 24 vocalizations per second. It sounds almost like a purring noise on the recording.

Zooniverse

An ABLE member who took this workshop (Kathy Winnett-Murray) made me aware of what looks to be a wonderful opportunity for students and faculty to participate as citizen scientists to utilize and draw conclusions from a wealth of data. One such site invites citizen scientists to listen to and comment about bat vocalizations and additional future projects will focus on analysis of animal vocalizations: https://www.batdetective.org/?_ga=2.160418813.1548262979.1518131987-1693801566.1517507001#!/home.

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