Chapter 4

ANALYZE AND EXPLORE SOUND

Soundscape ecologists use sound to answer a wide variety of scientific questions, and these diverse questions necessitate diverse study methods. In this chapter students will learn about the development of scientific questions and study methods, and they will design their own studies around questions of their choosing. Students will also discover that there are many ways to qualitatively and quantitatively describe sound, and they will explore sound visualization as a tool for soundscape description and analysis.

Expected Time: 60 – 120 minutes

Group Size: 2 – 3 students

Setting: Indoors

Learning Objectives:
Students will 1) define sound visualization, 2) learn to use Audacity to visualize and manipulate audio files, 3) learn to analyze and interpret oscillograms and spectrograms, and 4) explore artistic uses of sound and soundscape recordings by creating a soundscape composition.

Materials:
- 4 Audacity Audio Libraries
- Computers with Audacity installed
- Printed oscillogram and spectrograms (Sheets 11.1 and 11.2, optional)
- Headphones
- Speakers

Activity 11: Audio Visualization

Soundscapes contain a wealth of information about the world around us. If you close your eyes and listen carefully, you will probably be able to guess your location, the time of day, and some events occurring nearby: Is it quiet? What kinds of sounds do you hear? Are you near flowing water? Are you in a forest or an open prairie? Are you listening in the morning or at night? Even when you are not paying conscious attention to what you hear, your brain is analyzing the soundscape around you to provide clues about the nature and activity of your surroundings. Because it is difficult or even impossible to listen to all of the recordings collected by these automatic recorders, soundscape ecologists use visual representations of sound called oscillograms and spectrograms. In just one second, they can see an entire recording and pick out interesting features.

SOUNDSCAPES AS DATA

While the soundscapes that we hear may be memorable, humans are incapable of perfectly preserving or recalling sound without the aid of technological devices. Thankfully, microphones and audio equipment allow us to preserve and replay sounds that are nearly identical to their original forms. Microphones are much like our ears in that they detect sound using a thin, flexible membrane that is sensitive to pressure changes in its surrounding medium (like the human tympanic membrane, or eardrum).

In digital audio recording, the displacement of this membrane is recorded many times per second (44,100 for CD-quality recordings). This number is referred to as the "sampling rate," and because it is a measure of frequency, it is expressed in Hertz (Hz). When sound is recorded in a digital format, it is essentially reduced to a series of pressure measurements plotted against time—a relatively simple form of data. Digital sound data can thus be portrayed and analyzed in many different ways.

AUDIO VISUALIZATION

If soundscape ecologists had to listen to all of their data, they would never accomplish anything! Soundscape studies typically record far too many hours of audio for practical aural analysis. Luckily, there are other, more efficient ways to analyze audio data. One tool for quickly understanding the content of recorded sound is audio visualization. Audio recordings can be visualized in several different ways using a variety of software. Two primary audio visualizations are the oscillogram (waveform) and the spectrogram (Figure 11.2). An oscillogram is a two-dimensional graph with x- and y-coordinates. The x-coordinate represents time, and it is usually measured in seconds or milliseconds. To follow the change in sound over time, read an oscillogram from left to right. The y-axis represents amplitude, and it is typically measured in decibels (dB).

A spectrogram provides one more dimension of information because it is a three-dimensional representation of sound. Like an oscillogram, it notates sound's amplitude over time, but it adds an additional axis that denotes frequency, measured in Hertz (Hz). Time is still presented on the x-axis, but frequency replaces amplitude on the y-axis. To make room for amplitude without creating a visual mess, its variation is often portrayed through variation in color. Thunder's low-frequency rumblings occupy the bottom part of a spectrogram, while the higher-frequency trills of birds would occupy higher positions.

Audio visualization tools are important to soundscape ecologists, acoustic scientists, and even musicians. These tools allow them to "see" sound, and with this capability, the characteristics of recordings that are minutes, hours, or even days in length can be seen at a single glance. The occurrences of certain acoustic events can also be quickly located without skimming through hours of audio. Many programs allow for quick switching between different types of visualizations, zooming, and even custom coloring.

INSTRUCTOR DIRECTIONS

In this activity, students will use audio visualization software to visualize different audio files. Instructions are provided based on Audacity, but other programs could be used if desired. There are several audio libraries that relate to different parts of this activity. Each audio library has a different collection of audio files that students can use and manipulate to achieve the objectives of each activity stage.
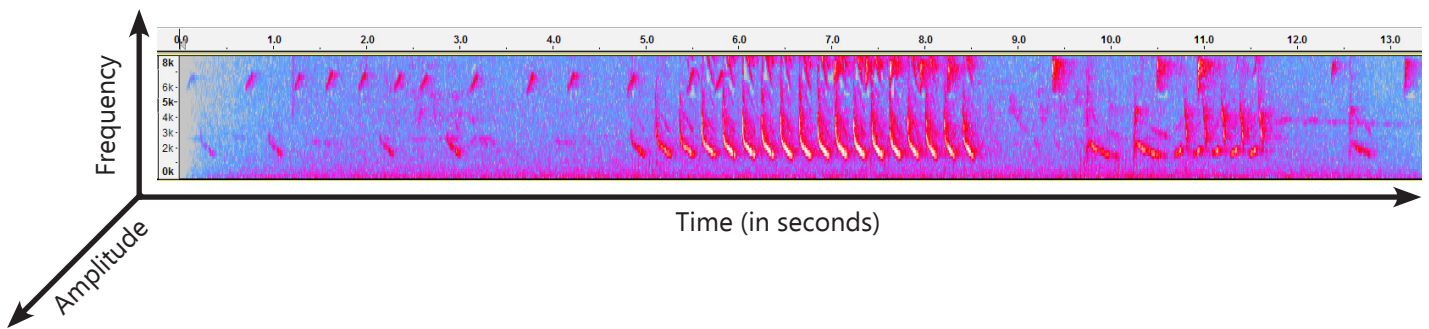
A.
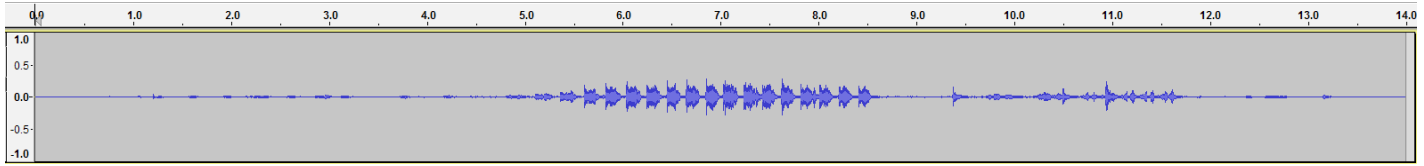
B.

Figure 11.1. Sound visualizations of a northern cardinal call in Audacity. A) An oscillogram presents the amplitude or loudness of the sound. B) A spectrogram presents 1) time, shown on the x-axis, 2) frequency, shown on the y-axis
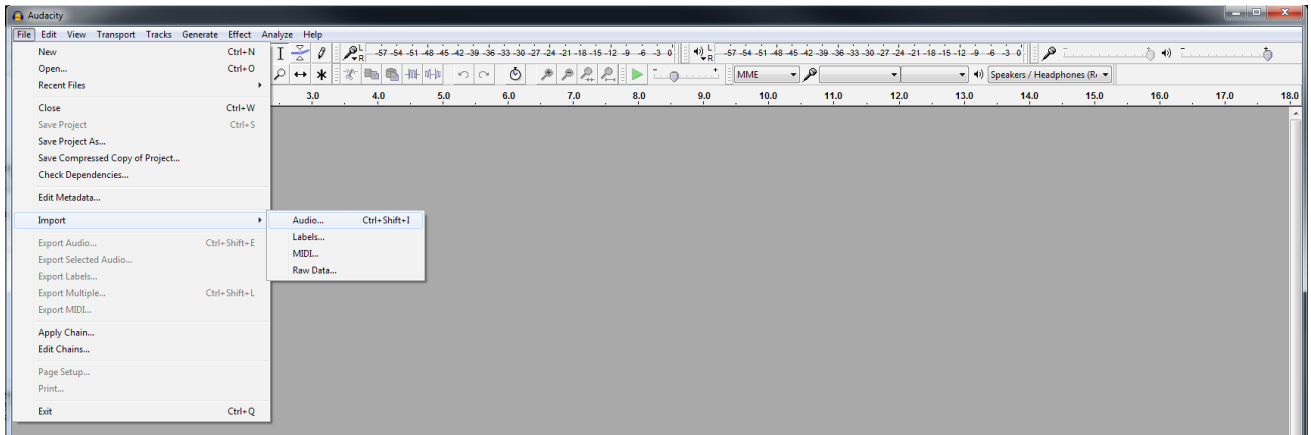
Pre-Activity

Students will need to have access to a computer with one of the audio visualization programs installed. Alternatively, printed copies of spectrograms can be provided if students do not have computer access (Sheet 11.1).

1. Start by playing a northern cardinal sound from Audacity Audio Library 1 for students, and ask them to make a creative drawing representing the sound they are hearing.
2. Show them the corresponding spectrogram, either on paper or with Audacity.
3. Notice if there are any similarities between the students' drawings and the spectrogram.
4. Give them some time to explore the spectrogram and then explain how they can read a spectrogram.
5. Play the sound file several times and show the corresponding spectrogram for students to become acquainted with the spectrogram.

A.
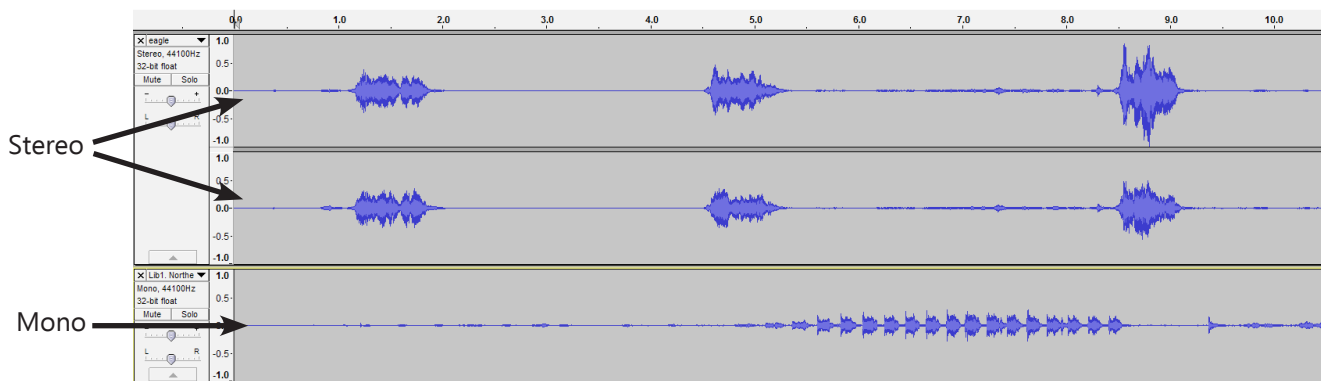

B.

Stereo

Mono

Figure 11.2. A) Importing a file; B) stereo and mono tracks.

Activity Part 1: Audio Visualization

Audacity Audio Library 1 is composed of different isolated sounds that will help students become familiar with viewing audio visualizations while listening to corresponding recordings. Students can play the different sounds and explore how time, frequency, and amplitude are represented visually.

Audacity Audio Library 1:
- Airplane and Bird
- Birds
- Coyote
- Northern Cardinal
- Thunder
- Wind

1. Instruct students to drag each sound file separately from the Audacity Audio Library 1 to the Audacity icon, or to import each file by selecting the menu option "File > Import" and selecting the file from its folder (Figure 11.3, top left). Each file will be placed in a separate "track" that starts at 0 seconds. The imported file will appear as one "channel" if it was recorded in "mono" (with one microphone) or with two channels if it was recorded in "stereo" (with two microphones) (Figure 11.3, bottom). The buttons on the control panel, in order, are pause, play, stop, skip to the beginning, skip to the end, and record (Figure 11.4).
2. Instruct students to hit the "Play" button for each sound while viewing it as an oscillogram.

3. Make sure they listen to each sound and watch the playhead move along the oscillogram (Figure 11.5). There are different visualization options in audio software. In Audacity, you can view sound as an oscillogram or as a spectrogram. Remember, a spectrogram shows three dimensions of sound.

4. Ask students to click on the arrow next to the name of the track at the left of each track. A drop-down menu will appear. They should select "Spectrum" (Figure 11.6), and notice that the one-colored oscillogram will be converted to a multi-colored spectrogram. Instruct students to view all of the sounds in Audacity Audio Library 1 as spectrograms. Show students how to listen to all of the tracks at once by pressing the "Play" button or to listen to one sound file by pressing the "Mute" button to mute tracks they do not want to hear or by pressing the "Solo" button to play the single track they want to hear (Figure 11.7).

5. Ask students about the advantages and disadvantages of oscillograms and spectrograms.

6. Remind students about the three dimensions of sound displayed in a spectrogram.
   - Time moves from left-to-right, and is represented on the x-axis.
   - Frequency is represented on the y-axis.
   - Amplitude is represented by color brightness on the z-axis.

7. Encourage students to explore the different aspects of spectrograms. If they like, they can highlight different parts by clicking and dragging with their mouse and then pressing the space bar to play that excerpt.

8. Ask them to identify sounds with high and low frequencies, high and low amplitudes, and different durations and rhythms.

As students improve their skills, they will be able to recognize how different species are located in certain frequency ranges and have certain visual patterns. They may also be able to recognize thunder, rain, or car sounds.
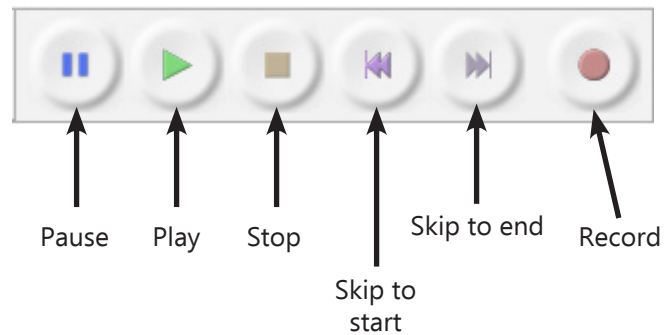

Pause   Play   Stop   Skip to start   Skip to end   Record

Figure 11.3. Control panel.

KEY QUESTIONS

What is the length of each sound in Audacity Audio Library 1? Describe the length using a standard timecode format of hours, minutes, and seconds (00:00:00).
Answer: See the description of Audacity Audio Library 1 in Activity Part 1.

What is the frequency of each sound? (Hint: Look at the y-axis. The numbers you see are frequency values. A sound might occupy a range of frequencies.)
Answer: See the description of Audacity Audio Library 1 in Activity Part 1.

What is the difference between the recordings within this audio library and those in other libraries?
Answer: This library contains multi-source soundscapes while the other sound libraries included distinct sounds from single sources.

What are the sound sources in each recordings?
Answer: Alaska_20140810_133000: birds and frog; Borneo_015116_20140209_183000_000: birds, cicadas, and breaking tree branches; Costa Rica_20150422_054500: Cicadas, birds, and howler monkey; Nebraska_20150321_172200: cranes and songbirds; Indiana_20120501_063000: geese and songbirds.

Are these sounds examples of geophony, biophony, or anthrophony?
Answer: All of them are biophony, except for the breaking tree branches that are geophony.
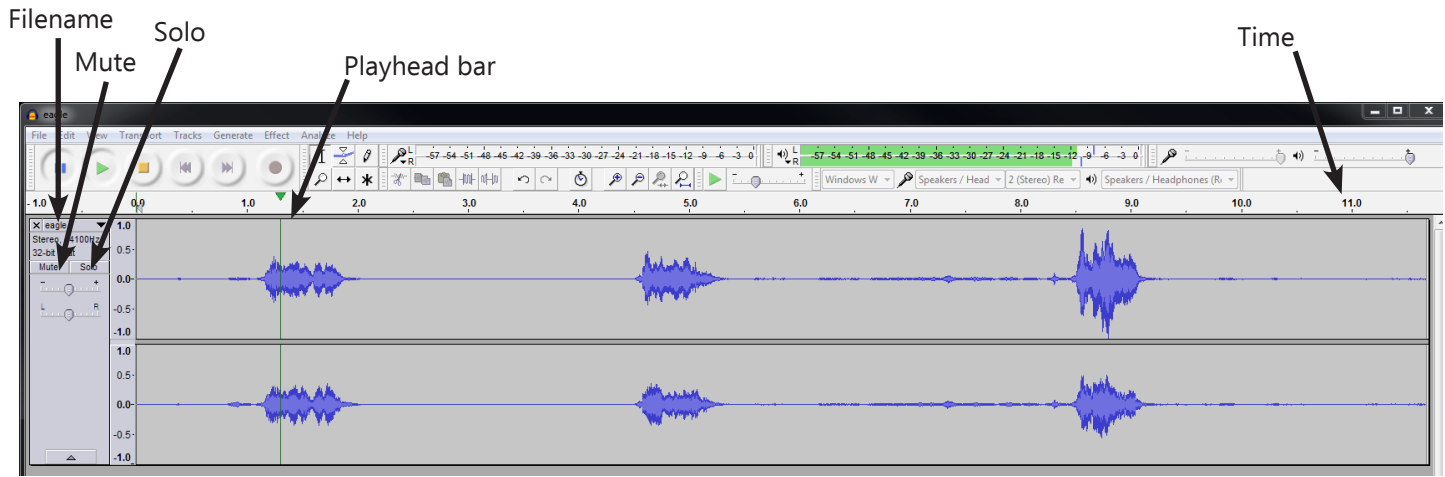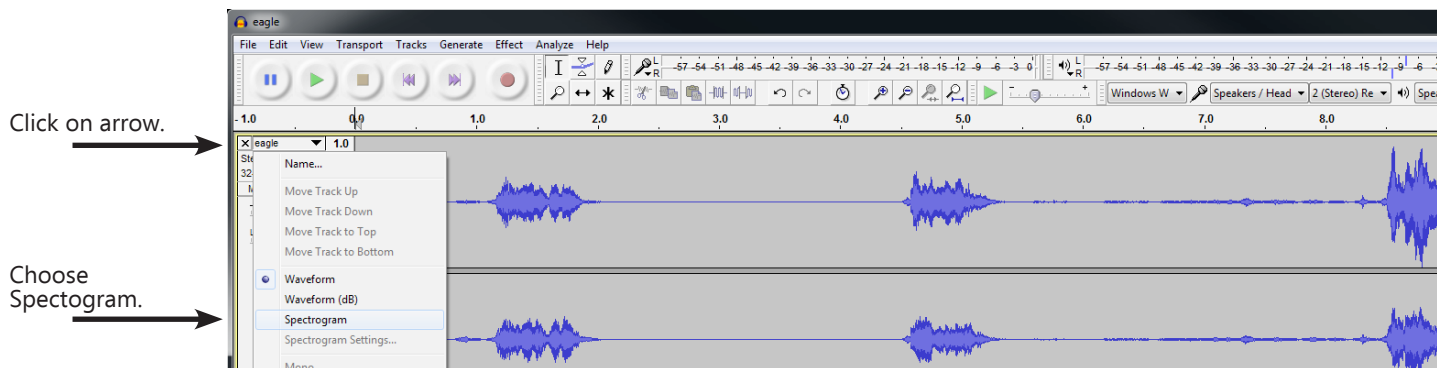
Figure 11.4. Oscillogram of a bald eagle call.

Figure 11.5. Changing oscillogram to spectrogram.

Activity Part 2: Match up the Sounds

Audacity Audio Library 2 has six samples of animal sounds that are typical in six different biomes. These animal sounds are paired with pure tones that match the animal sounds' frequencies.

Audacity Audio Library 2:
*   Bald eagle, Alaska, Tundra (1,900 Hz)
*   Bird, Arizona, Desert (8000 Hz)
*   Coyote, Indiana, Temperate forest (620 Hz)
*   Bullfrog, Maine, Estuary (200 Hz)
*   Siamong monkey, Borneo, Rainforest (3,126 Hz)

1. Ask students to drag an animal sound and a pure tone to the window (you will have two tracks in the same window).
2. Play the animal sound. Then, play the pure tone. Then play both sounds simultaneously.
3. Ask the students to match all of the animal sounds with the correct pure tones and to write down the dominant frequency for each species.

Frequency			Animal
1,900 Hz	⬡	◀	Coyote
8,000 Hz	⬤	◆	Siamang Monkey
200 Hz	◼	⬤	Arizona bird
700 Hz	◆	⬡	Bald Eagle
620 Hz	◀	◼	Bullfrog

Table 11.1. Animal sounds matched with their frequencies.

Activity Part 3: Complex Soundscapes

Audacity Audio Library 3 has more complex soundscapes, with multiple sound sources making sounds at various frequencies and temporal patterns. Scientists use various naming conventions to help them identify files. The convention generated by Song Meters is [Song Meter Serial Number]_[YearMonthDay]_[HourMinuteSecond]. For instance, 015116_20110416_150000 means:

    Song Meter Serial Number: 015116
    Date: 2011/04/16 (Year/Month/Day)
    Time: 15:00:00 (3:00:00 p.m.)

The serial number has been replaced with a location for the files in this library.

Audacity Audio Library 3:
*   Alaska_20140810
*   Borneo 015116_20140209
*   Costa Rica 20150422
*   Indiana_20120501
*   Nebraska 20150321

1. Explain to students the differences between sound, noise, and soundscapes. Sound has one source, like a single animal. A soundscape is the product of a combination of different sound sources, like a bird, cricket, and running water. Noise can be any sound that masks a signal. For instance, birdsong can be masked by the noise of traffic or rain.
2. Ask students to drag and drop each soundscape from Audacity Audio Library 3 into separate windows of Audacity. Students should repeat the steps outlined in Part 1.
3. Then ask the following key questions.

Activity Part 4: Match the Soundscape with the Spectrogram

For this activity, students are given 5 printed spectrograms (Sheet 11.2). Then, by accessing Audacity Audio Library 4, they will match the printed spectrograms with the corresponding soundscape recordings.

Audacity Audio Library 4:
- Alarmers tropical cops 20140218
- Isolated trumpeter 20140314
- Natures rowingmachine20130208
- Onecrazybird 20140210
- Shrieking me out 20140117

1. Play each recording in a random order without showing their spectrograms. Students can work in groups and should try to describe why they chose each specific spectrogram for each soundscape.
2. Next, ask students to identify where the soundscape might have been recorded. Location clues might include types of animal sounds, presence and types of water sounds, and presence of wind. Students have access to information about several ecosystems. Have students use these resources to match the soundscapes to their corresponding ecosystems.

KEY QUESTIONS

**How did you match the spectrograms to the recorded soundscapes?**
Answers will vary.

To which category do the sounds in each recording belong (geophony, biophony, and anthrophony)?
Answer: Biophony

When and in what season were the recordings made? (Hint: check the file names.)
Answer: Alarmers tropical cops 20140218_0630: 6:30am on February 2014; Isolated trumpeter 20140314_1800: 6:00 pm on March 2014; Natures rowingmachine20130508_1200: 12:00 pm on Mary 2013; Onecrazybird 20140210_0500: 5:00 am on February 2014; Shrieking me out 20140117_1800: 6:00 pm on January 2014
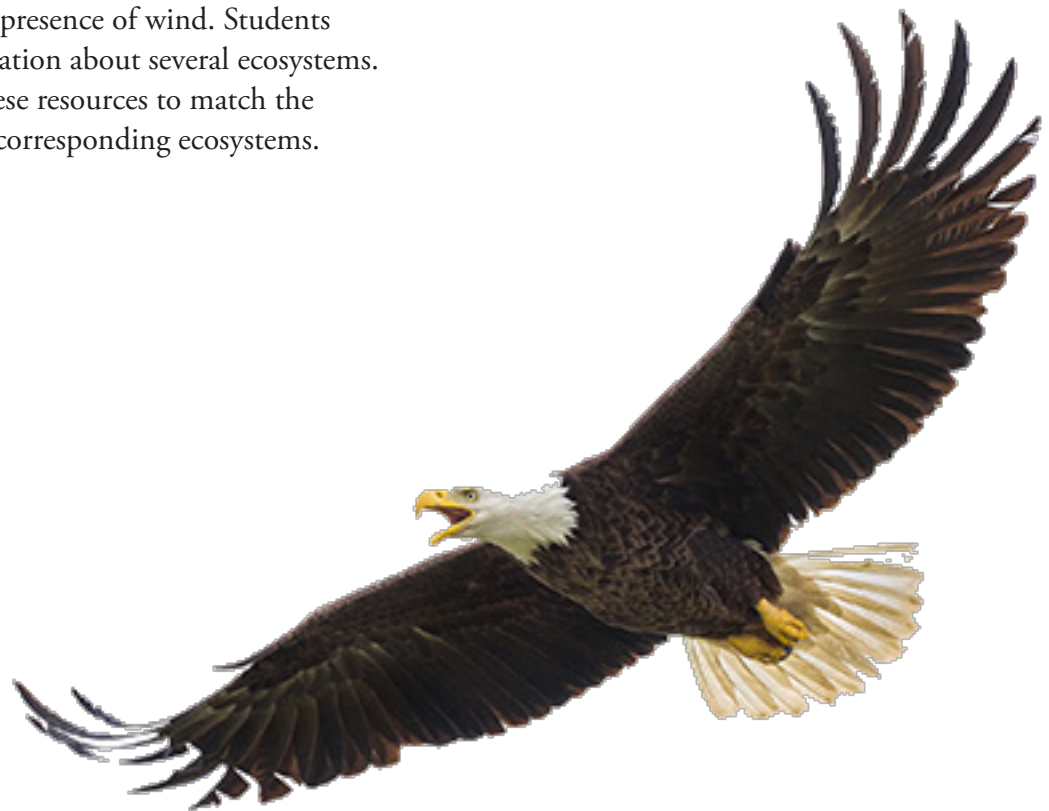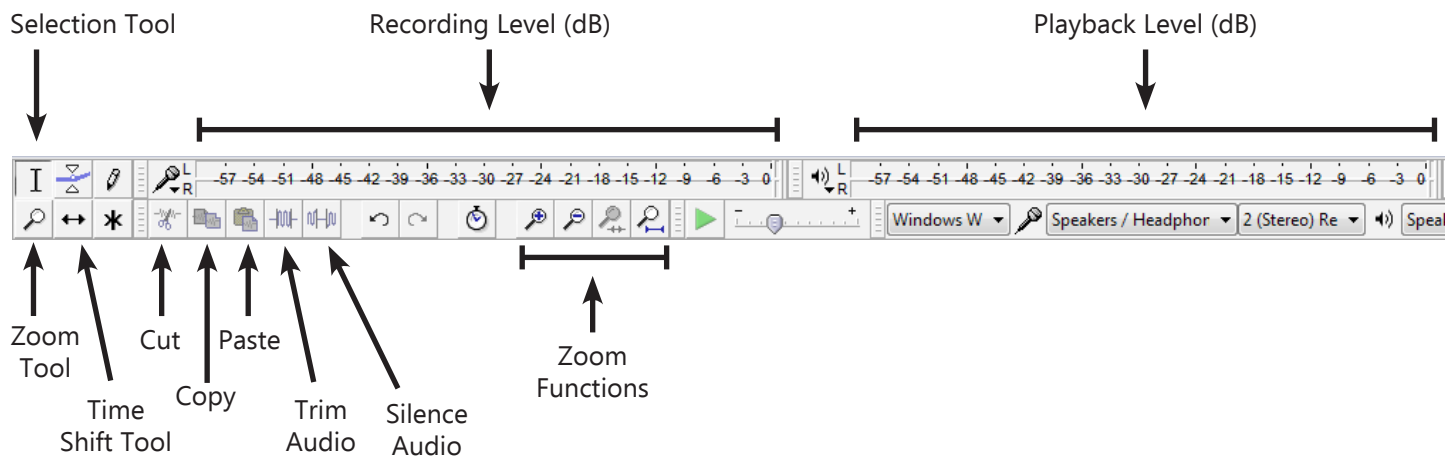
Figure 11.6. Audacity toolbar.

Activity Part 5: Create a Soundscape Composition

In this part students can combine different sounds from any of the audio libraries to make their own innovative soundscape compositions. Soundscapes can serve as inspiration or models for imitation. Encourage them to get creative! One way to do this is by using some effects in Audacity.

Useful Audacity tips:

1. Click and drag to highlight sections of audio (like in a text document). Press the space bar to play and pause any sound excerpt.
2. Select an entire track by clicking the gray area to the left of the oscillogram, where the track name is listed.
3. In a multi-track session where you have more than one sound file imported into the same window, mix the sound by adjusting the track levels.

Experiment with Audacity's easy-to-use effects by exploring the "Effects" menu located on the top menu bar. "Reverse," "Equalization," "Change Pitch," "Change Speed," "Change Tempo," "Fade In," and "Fade Out," can be applied to an entire track or to highlighted sections of a track.

Reverse: plays the sound in reverse
Equalization: amplifies or reduces certain frequencies in the sound

Change Pitch: raises or lowers the pitch
Change Speed: raises or lowers the speed (pitch will be altered as well)
Change Tempo: raises or lowers the speed without affecting the pitch
Fade In: makes the beginning of a highlighted section inaudible, while creating a gradual increase in amplitude to the end of the highlighted section, which is kept at the original amplitude
Fade Out: opposite of "Fade In"

Students can also manipulate sounds by using different options in the toolbar (Figure 11.8).

1. Introduce students to some of these tools in Audacity.
2. Let them explore the audio libraries, import files, and creatively combine and edit to craft their own unique soundscape compositions.
3. After students finish creating their own soundscape, they should click on "File" > "Export...," choose a file name, and save the file in a "WAV (Microsoft) signed 16 bit PCM" format. Then, they can share their new creations. They can also click on "File >"Save Project As..." to save their Audacity projects to continue experimenting with soundscape music outside of the classroom.

KEY QUESTIONS

What is the length of each sound in Audacity Audio Library 1? Describe the length using a standard timecode format of hours, minutes, and seconds (00:00:00).
Answer: See the description of Audacity Audio Library 1 in Activity Part 1.

What is the frequency of each sound? (Hint: Look at the y-axis. The numbers you see are frequency values. A sound might occupy a range of frequencies.)
Answer: See the description of Audacity Audio Library 1 in Activity Part 1.

What is the difference between the recordings within this audio library and those in other libraries?
Answer: This library contains multi-source soundscapes while the other sound libraries included distinct sounds from single sources.

What are the sound sources in each recordings?
Answer: Alaska_20140810_133000: birds and frog; Borneo_015116_20140209_183000_000: birds, cicadas, and breaking tree branches; Costa Rica_20150422_054500: Cicadas, birds, and howler monkey; Nebraska_20150321_172200: cranes and songbirds; Indiana_20120501_063000: geese and songbirds.

Are these sounds examples of geophony, biophony, or anthrophony?
Answer: All of them are biophony, except for the breaking tree branches that are geophony.

POSSIBLE EXTENSIONS

Revisit recordings from previous activities, and visualize and describe those sounds using Audacity.

ADAPTATIONS FOR ACCESSIBILITY

- Walk students through each step.
- Provide a thermally-printed copy of spectrograms and oscillograms for each student
- Play each audio recording several times and guide the students through interpretation of the oscillogram and spectrogram.
- Ask students to rotate the paper ninety degrees, as it is easier to follow the stereo recording by touching the left and right channels with the left and right hand, separately.
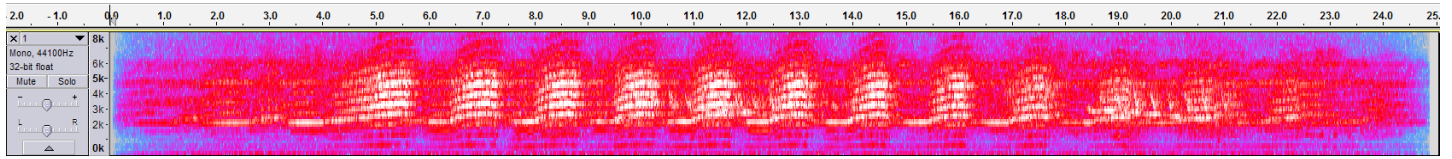
Sheet 11.1: Spectrogram and Oscillogram of a Northern Cardinal's Song
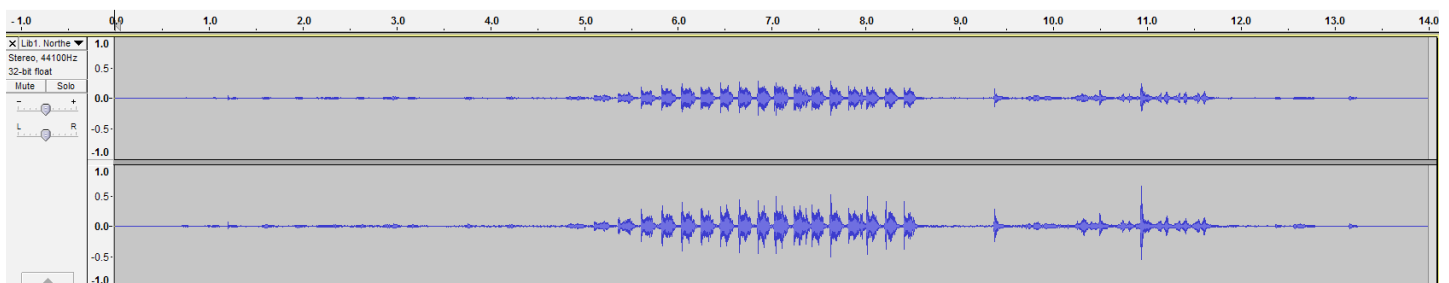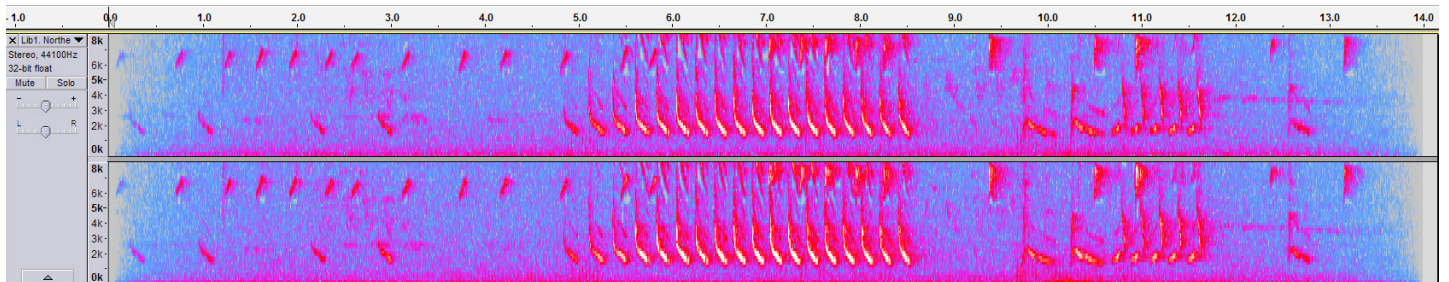
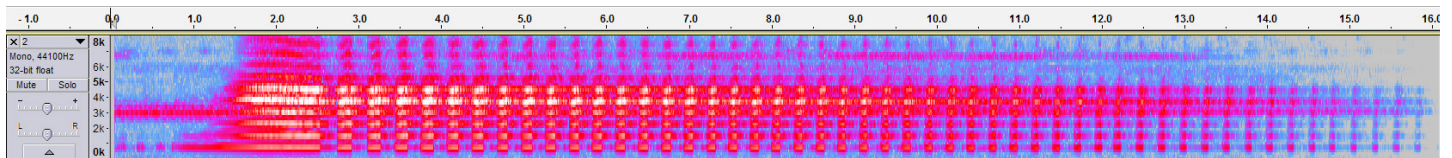# Sheet 11.2: Spectrograms of Different Soundscapes

A.

B.

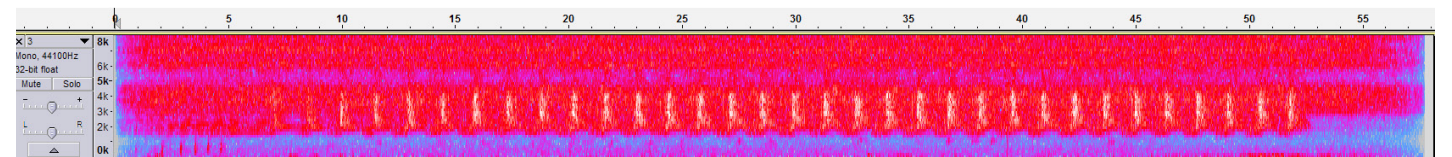
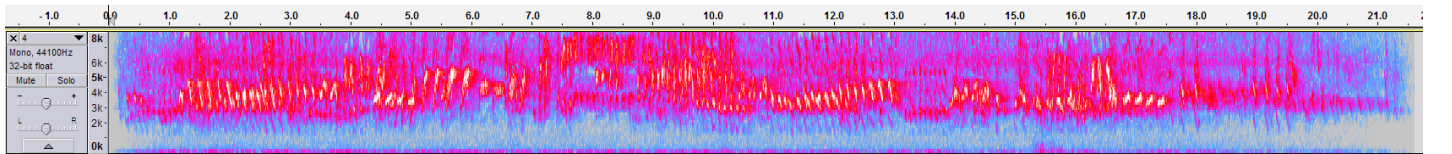
C.

D.

E.