PURDUE UNIVERSITY
Discovery Park

FNR-600-W

Your Ecosystem Listening Labs (YELLs)

The Science of Soundscape Ecology

Instructor's Guide, Grades 5-8

Center for Global Soundscapes

10th Edition, 2019.9

This project is partially supported by the National Science Foundation, grant #1323615
to Purdue University as part of the Advancing Informal STEM Learning (AISL) program.

THE CENTER FOR GLOBAL SOUNDSCAPES

ABOUT US

The Center for Global Soundscapes is home to a diverse group of researchers, scholars, and educators endeavoring to better understand nature and human-nature interactions through the lens of sound. We have training in disciplines including ecology, music, and education, and we record and analyze soundscapes in ecosystems around the world.

OUR MISSION

The world around us is full of amazing sounds that are often ignored by humans. Unfortunately, many of the sources of these sounds are actually in danger of being destroyed by human activities. Our mission is to raise awareness about soundscapes and to encourage the younger generation to open their ears and become soundscapers! More broadly, we aim to interest students in nature and science through the wonder of natural sounds.

WHERE WE GO

The activities contained in this package take students through the entire scientific method, from observations through conclusions, pairing the practice of science with the exploration of soundscape-based content.

PURDUE UNIVERSITY Discovery Park

CENTER FOR GLOBAL SOUNDSCAPES

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Maryam Ghadiri works at the intersection between ecology and education. For her PhD, she studied environmental education, and designing this curriculum was one of her primary projects. She loves nature and painting, and owls are one of her favorite animals.

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Dr. Amandine Gasc is a soundscape ecologist. She has traveled to diverse locations to record soundscapes including Alaska, Arizona, Maine, Costa Rica, France, and New Caledonia. She works to protect nature. She loves to sleep in the tropical forest listening to all the creatures singing.

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Dante Francomano has a background in music and experience in musicology, composition, and saxophone performance. For his PhD, he studied the soundscapes of Patagonia, Argentina. He has many cool recordings of penguins, cormorants, and sea lions!

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LEAD DESIGNER

Dawn Oliver is a graphic designer, and she has designed both the instructor and student guides of the YELLs. She also works on artistic projects in her free time, including bookbinding and monotype printmaking.

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Benjamin Gottesman is a talented musician and field recordist. For his PhD, he studied the effects of ecological disturbances on soundscapes. Some of his favorite recordings are from a massive crane migration through Nebraska.

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Matthew Harris is a web developer and skilled photographer. He helped to design and manage the Record the Earth app, and he took many of the photos that appear in the YELLs. He loves gadgets such as GoPro and time lapse cameras.

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PROJECT PRINCIPAL INVESTIGATOR, ACADEMIC ADVISOR

Bryan Pijanowski is the Director of Purdue's Center for Global Soundscapes. He has conducted over 40 studies globally using soundscape ecology approaches and loves camping in tents for long periods of time connecting to nature. He is trained as an ornithologist (person who studies birds) but loves other parts of the environment too such as lakes, trees, glaciers, and especially frogs.

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Daniel Shepardson is a professor of geoenvironmental science and science education. He studies students' conceptions of Earth and environmental phenomena. This work has informed the design of instructional materials and teacher professional development programs. He loves hiking and nature photography.

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Dear Educators,

I have a dream… that all people listen carefully to nature and are inspired by its special song. The research and education center that I direct at Purdue University, the Center for Global Soundscapes, is on a big mission to record the sounds of the Earth! Why? So that we may show everyone the ways that scientists use sound to study nature. This Instructor's Guide is designed to educate young minds about all areas of sound—from physics, biology, engineering, and math—using a variety of informal learning environments and pedagogical approaches.

I encourage you to visit our website (www.centerforglobalsoundscapes.org) to learn more about our work. We have collected over 1 million recordings from some very special places on Earth and many of these are online for you to experience. We hope that our website will allow you to explore the new science called soundscape ecology.

This guide is part of a larger set of curricular components, all focusing on immersive learning. I hope you'll enjoy our additional learning resources that are available to you: The *Global Soundscape — A Mission to Record the Earth* Interactive Theater Show, the *Record the Earth* citizen science app (www.recordtheearth.org) and the online [*iListen* learning portal (www.iListen.org)]. We want everyone to be a part of our effort to better understand this marvelous planet!

Funding for this project comes from the NSF Advancing Informal STEM Learning Program, Purdue Research Foundation, and the Department of Forestry and Natural Resources Wright Fund.

Listen well,

MARYAM GHADIRI
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Dear Educators,

I am a researcher at the Center for Global Soundscapes at Purdue University. My goal is to develop effective curricular materials that help youth experience the connections between all STEM fields—science, technology, engineering, and math—through the "lens" of a new field of science called soundscape ecology. I am always excited to work with young students in the field teaching them about the importance of sound in their everyday lives. Since my childhood, I've been captivated by the colorful birds, the sounds of rivers, and the wind of the desert in my native country. Soundscapes are a part of who I am as a person and as a scientist.

This curriculum was designed for students who learn in informal settings like camps, museums, and even in the classroom; we call these exercises "Your Ecosystem Listening Labs" (YELLs). The Instructor's Guide is the culmination of over two years' worth of work and is complete with inquiry-based and hands-on activities that are perfect for middle school students. You can implement these learning objectives indoors or out—an approach that can model the fieldwork of active scientists.

I am thankful to the many colleagues who assisted with formative assessments and content evaluation for the YELLs. The complementary partners included specialists from the Perkins School for the Blind, the National Audubon Society, and an interdisciplinary panel of soundscape ecology researchers from the fields of ecology, engineering, computer science, musicology, and audio engineering.

You can visit with me online [*iListen* learning portal (www.iListen.org)] to learn more about me and my colleagues.

Your fellow soundscaper,

How to Use the YELLs Instructor's Guide

Welcome to the Your Ecosystem Listening Labs (YELLs) Instructor's Guide! We hope you will find this guide full of resources to help you in teaching students about sound and soundscape ecology. The accompanying YELLs Student's Guide contains a reduced amount of background information, along with any worksheets or forms that students will need to complete.

YELLs can be conducted in any informal learning environment (e.g., summer camps, museums, and nature centers), as they are configured as games, structured learning exercises, and multi-day research projects. They can be used as singular learning exercises (<1 hour activity) or as a package of scaffolding activities (5-day summer camp). YELLs place middle school (grade 5 – 8) students in the roles of scientists and engineers who work as a team to solve problems.

This guide is composed of four chapters that focus on physics of sound, animal communication, soundscapes, and soundscape ecology. Many of the activities in Chapters 1 – 3 can stand alone, but they are certainly reinforced by the other activities. The activities in Chapter 4 are more complex and generally require knowledge that can be gained through activities in the first three chapters.

Each activity contains the following sections:

- **Core information:** This section presents the learning objectives, necessary materials, expected time, group size (how many students should be in each subgroup within the full group or class), and setting for each activity.
- **Background Information (no heading):** The scientific information relevant to each activity is presented in this section. The instructor should read this information carefully and present it to the students before, during, and/or after the activity as he or she feels is appropriate.
- **Instructor Directions:** These directions guide the instructor through implementation of the activity. Some activities contain "Pre-Activity" and "Activity" sections within the Instructor Directions. Pre-Activity sections are for instructor preparation and/or brief student introductions to the activity content.
- **Key Questions:** The instructor should ask students to discuss these questions before, during, and/or after the activity as he or she feels is appropriate, or as specified. These questions are important to engage students with the material and to encourage them to consider the broader context beyond each individual activity.
- **Possible Extensions:** This section contains suggestions to lengthen activities or to add levels of complexity.
- **Adaptations for Accessibility:** The visually impaired are especially equipped to be excellent soundscape ecologists due to their heightened reliance on their aural sense. Adaptations are suggested here to make activities more accessible for the visually impaired. Time devoted to each activity can be modified as well.
- **Worksheets:** Worksheets in which students will write are duplicated in the accompanying Student's Guide. Others may need to be printed for use in activities.

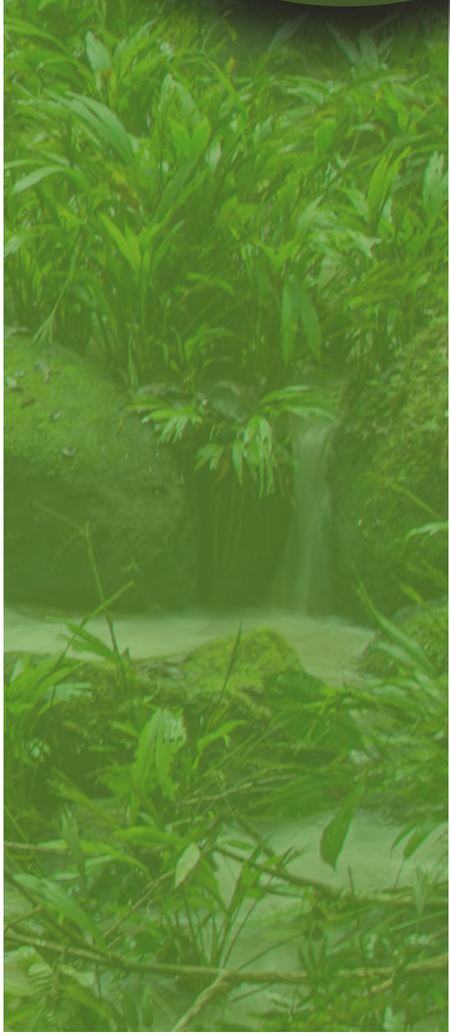
If students are viewing *Global Soundscapes — A Mission to Record the Earth*, the interactive theater show (ITS) associated with the YELLs, activities in Chapters 1 and 2 would be more appropriate to conduct before students view the show, while activities in Chapters 3 and 4 would be better for after students view the show.

Another learning resource produced by the Center for Global Soundscapes (CGS) is iListen.org, an exploratory online learning portal in which students and adults can delve into the world of soundscape ecology through various tools and activities. By completing online activities, anyone can become a citizen scientist and contribute to CGS research. The iListen portal is also aligned with Next Generation Science Standards (NGSS), so teachers can incorporate it in formal classroom settings.

There is some content that overlaps between the YELLs, the ITS, and iListen, but there is also a wealth of unique material in each media form, and each will be suitable for different learning styles. We strongly suggest using these three resources as complementary learning tools.

Automated acoustic recorders for use in Activities 10, 14, and 15 (optional for the latter two) can be purchased from Wildlife Acoustics (www.wildlifeacoustics.com) or they may be available through the CGS. Please email cgs@purdue.edu to inquire about obtaining recorders through the CGS. Manuals for Wildlife Acoustics recorders are available at https://www.wildlifeacoustics.com/support/documentation. Audacity, a free computer program required for some activities in Chapters 3 and 4, can be downloaded at http://www.audacityteam.org. Audio libraries for use in various activities can be found in the Teacher Portal of iListen.org.

We hope that you and your students enjoy exploring the world of soundscapes!



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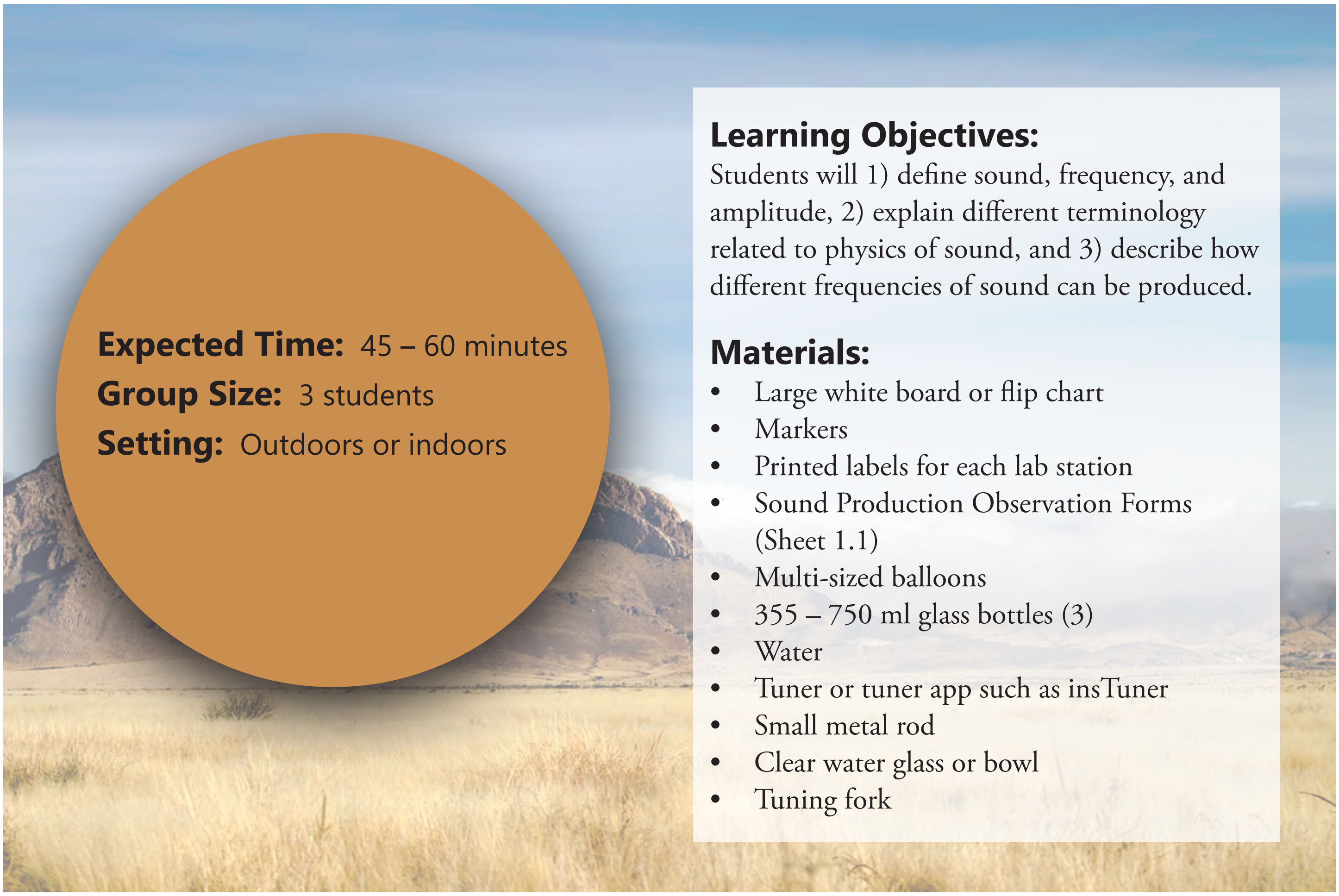
Chapter 1

PHYSICS OF SOUND

Anything that moves makes a sound. Sound sources can be biological (i.e., living organisms), geophysical (e.g., thunder, rain, wind through trees, avalanches, ice breaking, and waves breaking on a shore), or human (e.g., machine noise, church bells, and music). After sound is produced, it travels as a wave through a medium (air, water, or a solid substance such as the ground) to reach a target. Organisms (animals, plants, and even microorganisms) use audible information to survive and to understand their environments. The learning objectives of this chapter focus on understanding the physics of sound and terms such as "wavelength," "frequency," and "amplitude."



Expected Time: 45 – 60 minutes
Group Size: 3 students
Setting: Outdoors or indoors

Learning Objectives:
Students will 1) define sound, frequency, and amplitude, 2) explain different terminology related to physics of sound, and 3) describe how different frequencies of sound can be produced.

Materials:
- Large white board or flip chart
- Markers
- Printed labels for each lab station
- Sound Production Observation Forms (Sheet 1.1)
- Multi-sized balloons
- 355 – 750 ml glass bottles (3)
- Water
- Tuner or tuner app such as insTuner
- Small metal rod
- Clear water glass or bowl
- Tuning fork

Activity 1: Sound Production

Animals need to communicate, and sound is one of their primary means of communication. They use sound to coordinate collective actions and to communicate about threats and opportunities. Animals also use sound to hunt and to navigate their environments.

Various species produce unique sounds that are determined in part by the species' physiology, the physical structure of their habitats, and also by the acoustic activity in their habitats (e.g. sounds of wind, rain, and other species). Sound production requires energy—in order to maximize the value of their sound production, species produce certain types of sounds at certain times and locations that are best adapted to their needs and intentions.

A bird sings. **The vibration travels through the air.** **The receiver's eardrum vibrates, sending a signal to the brain for translation.**

WHAT IS SOUND?

Sound is vibration, and the physical aspect of acoustic communication can be conceived of as the production, propagation, and reception of that vibration. The psychological aspect of acoustic communication involves the interpretation of sound by its receiver (Figure 1.1).

The Physical Aspect of Acoustic Communication

Sound production: when an object vibrates, it produces sound. For example, when humans speak, our vocal cords vibrate.

Sound propagation: the vibrating object then transfers its energy to its surrounding medium, be that a gas such as air, a liquid like water, or even a solid like wood or metal. This medium experiences rapid changes in pressure, and those changes are passed between local groups of particles until the particles' energy dissipates. Following the previous example, our vibrating vocal cords cause the surrounding air to experience pressure changes.

Sound reception: the pressure changes reach the receiver, causing a part of the receiver's body to vibrate. For humans, pressure changes are primarily sensed through the ear when they cause the eardrum and parts of the inner ear to vibrate.

The Psychological Aspect of Acoustic Communication

The second aspect of acoustic communication concerns how the receiver understands and makes sense of the information encoded in sound. When a mother bird sings, her chicks must understand whether the sound is intended to alert them to danger, such as a nearby predator, or if it signals the location of a food source. The process by which the chicks make sense of this information is called translation.

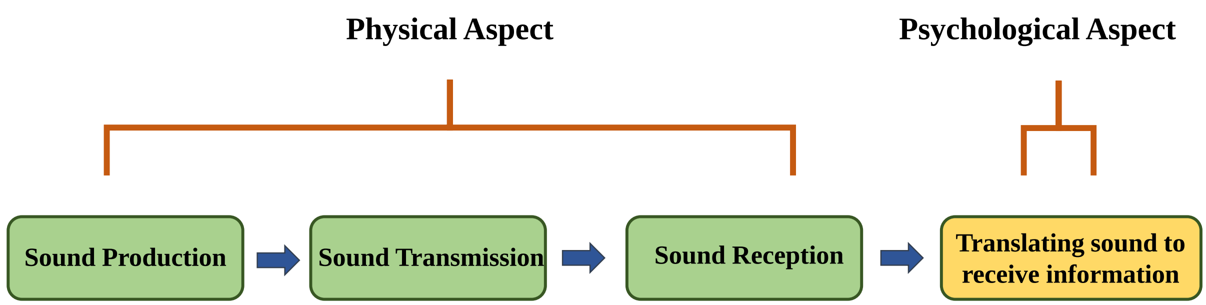
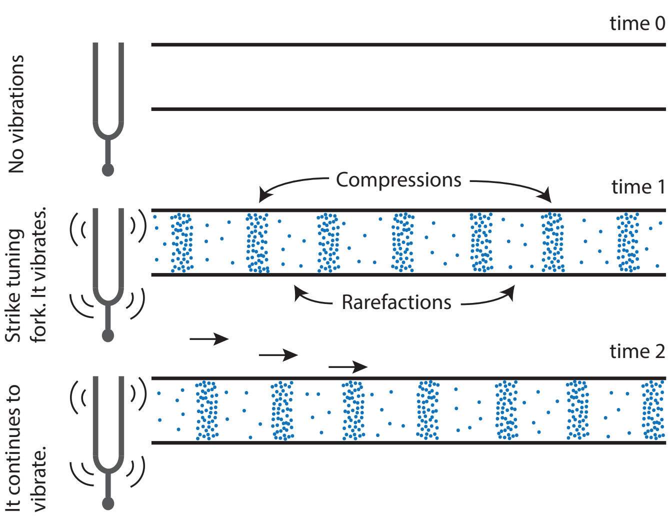


Figure 1.1. The physical and psychological aspects of acoustic communication.

NEW TERMS

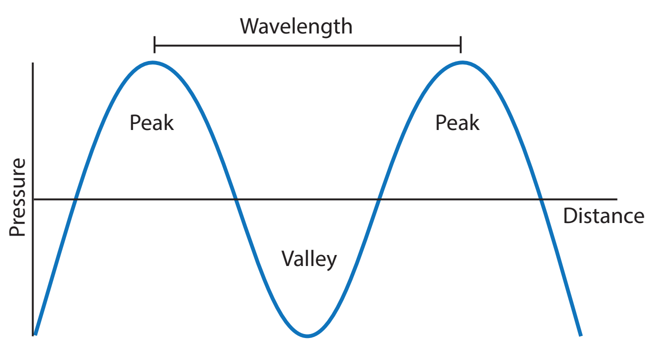
Compression and rarefaction:

"Compression" and "rarefaction" respectively refer to the areas of increased and reduced pressure that are the result of a vibration. For instance, when the tuning fork pictured below vibrates, its motion to the right compresses air molecules to the right. Then, its return motion creates an area of low pressure, and the air molecules spread out, or rarefy. This process continues until the energy in the vibrating object and surrounding medium dissipates.



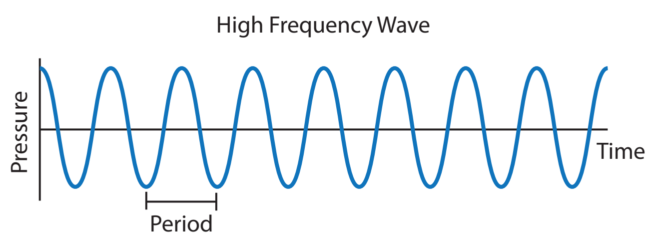
Wavelength:

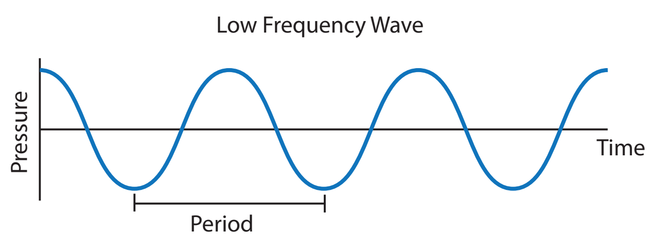
If pressure is mapped over space, pressure at any given time creates a pattern that resembles peaks and valleys, or the crests and troughs of waves. The distance between two consecutive peaks in a cycle is called a "wavelength."



Frequency (pitch):

The speed of pressure changes is expressed in terms of "frequency"— what we perceive as "pitch." Frequency is determined by the speed of vibration in the sound-producing object. High-speed vibrations produce high-frequency sounds, and low-speed vibrations produce low-frequency sounds. Frequency is measured by counting the number of full wave cycles, or "periods" per second. In simpler terms, one can also consider how many peaks or valleys occur per second. This unit of measuring frequency is called "Hertz" (Hz). Different frequencies travel varying distances. Lower-frequency sounds, such as elephant rumbles (< 400 Hz), have long wavelengths that lose energy slowly, so they can travel longer distances compared to higher-frequency sounds like cricket chirps (4,000 Hz), which have shorter wavelengths and lose energy quickly. Frequency and wavelength are inversely related. Sounds below 20 Hz are referred to as "infrasound" and sounds above 20,000 Hz are referred to as "ultrasound."

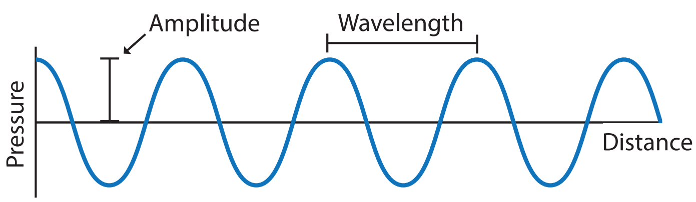




Amplitude (loudness):

"Amplitude" refers to the magnitude of pressure changes created by a sound. In the case of silence, pressure is zero—neither positive nor negative. As amplitude increases, pressure deviations from zero increase; pressure at peaks becomes greater, and pressure at valleys decreases. For example, striking a drum softly produces a low-amplitude sound, while striking it harder produces a higher-amplitude sound. Distance from the source of the sound also affects amplitude. If we are closer to the drum, it will register a higher amplitude than when we are farther away.

Amplitude is measured in decibels (dB), which represent the relationship between a sound's pressure and a given reference pressure. When talking about how loud something is, the reference pressure is typically the threshold of human hearing—the faintest sound we can detect. When making recordings, we often use decibels as negative values, where the reference pressure is the highest pressure at which a recording system can capture a sound.



INSTRUCTOR DIRECTIONS

In this activity, our main focus is on the physics of sound and the process of sound production. There are several activities or lab stations that each group will explore. Each of the first three stations start with questions that will lead students to predict what will happen at the lab station and discuss their predictions within groups. Then, after conducting the exercise, students will have a chance to revise their predictions and consider hypotheses that explain those predictions. They will need to provide evidence to defend their arguments especially if there is any counter-argument from other groups. Stations A, B, and C emphasize the vibrational nature of sound and the concept of frequency. Station D includes a knowledge check and introduces animals that produce sounds at various frequencies.

Pre-Activity

Set up lab stations. Print out observation forms from worksheet 1.1 or use those in students' guides. Explain to students how they can produce sound through their vocal chords, and ask them to touch their throats to feel the vibrations as they vocalize. Explain how hearing is only the last stage in the process of production, propagation, and reception. Present a simple example by omitting one of these three stages to see if sound is heard. For example, play a sound that students can hear, and then provide earplugs for them to block the sound from entering their ears, or ask them to cover their ears. Ask them why they cannot hear the sound. Alternatively, ask some of the students to move to another room and make sounds by jumping on the ground. The remainder of the group should listen, first while seated or standing, and then with their ears pressed against the ground. Ask them about the source of sound and the medium through which it is propagating.

Before starting the activities, make a KWL (know, wonder, and learn) chart about sound, and ask students to fill in columns K and W. The first column might address such topics as the definition of sound, different characteristics of sound, how sound can be produced, and students' previous experiences with sound.

For the second column, ask them to come up with their own questions—things they would like to learn during this activity, such as, "Through which medium can sound travel fastest?" and, "What is the difference between high- and low-frequency sounds?" The last column can be completed at the end of the activity when students will write about what they learned. Prior to visiting the lab stations, ask the group to define the meaning of "prediction" in the world of science, and share some simple examples like what students expect to see, or predict will happen, after they plant a seed. Answers will likely include that a seed will start to germinate and then produce a plant.

A definition of prediction:
"*A scientific prediction is an educated guess. It is a statement that predicts or forecasts what would happen in the future. A scientific prediction can be justified by experimenting, collecting data and providing evidence.*"

Activity

In this series of activities, students encounter various objects at different lab stations. Each station has its own "key questions," and students will be led through activities that will help them to answer those questions. Each lab station in Activity 1 will require students to record observations on an observation form before comparing their results to their predictions.

1. Distribute observation forms from worksheet 1.1 to students before beginning the activity.
2. Divide students into groups of three.
3. Send each group to a lab station.

Part 1:
Lab Station A—Balloons and Frequency

The purpose of this activity is to relate different sizes and tensions of vocal cords to frequency (pitch).

1. Provide the materials (observation form and multi-sized balloons).
2. Using the key questions, ask students if they can predict what will happen in the lab station.
3. Have students pick up a balloon and inflate it. Do not tie the opening.
4. Have them produce sound by stretching the opening of the balloon while releasing air.
5. Ask them to manipulate the size of the balloon's opening to alter the frequency of the sound.
6. Have students repeat with a different sized balloon.
7. Ask them to complete the observation form (Worksheet 1.1).

KEY QUESTIONS

How is sound produced when air is released from a balloon?
Answer: The elasticity of the balloon pushes air out through the opening. As this air passes through the opening, it causes the edges of the opening to vibrate.

How can low- and high-frequency sounds be produced with balloons?
Answer: The speed of vibration determines frequency. Larger balloons produce lower-frequency sounds than smaller balloons. Stretching the balloon opening also alters the frequency of the sound. As students stretch the balloon opening, the balloon vibrates faster, producing a higher-frequency sound.

What is the similarity between balloon sounds and animal vocalizations through vocal cords?
Answer: Both balloon openings and vocal cords vibrate to produce sound. Bigger animals have larger vocal cords that vibrate more slowly and produce lower frequencies—like larger balloons. Also, as stretching balloon openings alters frequency, animals can adjust the tension of their vocal cords to alter the frequency of their vocalizations.

Part 2:
Lab Station B—Bottles with Water

The purpose of this activity is to produce sound with specific frequencies.

1. Provide materials (observation form, 3 glass bottles (355 – 750 ml), alcohol swabs, small metal rod, tuner and water).
2. Using the key questions, ask students if they can predict what will happen in the lab station.
3. Ask students to pour different amounts of water into each bottle.
4. Have them blow across the tops of the bottles to produce sound. (If there are concerns about sanitation, wipe the mouth of the bottles with an alcohol swab before sharing. Alternatively, a metal rod can be used to tap the bottles, but this produces a far less resonant sound, and frequencies will need to be adjusted.)
5. Introduce students to a tuner and ask them to create frequencies around the musical notes, G3 (195 Hz), B3 (247 Hz), and D4 (294 Hz). These frequencies can be altered for different bottle sizes, but students should be able to produce the specified frequencies using the range of bottle sizes provided in the materials section. Play all three bottles at once to produce a major chord.
6. Have students complete the observation form (Worksheet 1.1).

KEY QUESTIONS

How can sound be produced using glass bottles, water, and a metal rod?
Answer: Sound can be produced by tapping the bottle with a metal rod or by blowing across the mouth of the bottle. Tapping the glass and blowing across the bottle cause the bottle and the air inside it to vibrate.

What might affect the frequencies produced by the bottles?
Answer: Bottles of different sizes produce different frequencies, while for bottles of the same size, the amount of water/air in the bottle alters the frequency.

How will the addition or removal of water alter the frequency of the sounds produced?
Answer: Bottles with more water produce higher-frequency sounds, as wavelengths must be as short as the air space within the bottle.

Part 3:
Lab Station C—Tuning Fork in Water

The purpose of this activity is to discover how vibration can move water molecules.

1. Provide the materials (observation form, tuning fork, and water).
2. Using the key questions, ask students if they can predict what will happen in the lab station.
3. Have students strike the tuning fork and dip it in the container of water.
4. Ask them to complete the observation form (Worksheet 1.1).

KEY QUESTIONS

What do you expect to happen when a vibrating tuning fork is dipped in water?
Answer: The vibration of the tuning fork will be transferred to the water. This vibration should be observable on the surface of the water.
Will hard and soft strikes of the fork yield different results?
Answer: Yes, a harder strike will cause a higher-amplitude vibration in the water. The length between two waves—the wavelength—and thus the frequency of the vibration will not change. The vibration should last longer if the fork is struck harder.

Part 4:
Lab Station D—Sound Production Knowledge Check

The purpose of this activity is to understand different features of sound signals.

1. Provide the materials (Worksheet 1.2).
2. Ask students to answer the questions in Section 1.
3. According to Table 1.1, write down the names of the animals in Section 2.
4. According to Table 1.1, find the relationship between the animal's weights and the frequencies of their sounds in Section 3.
5. Play the sounds of the animals to check the answers.

POSSIBLE EXTENSIONS

Take students outdoors, and ask them to identify different sound sources. Ask them to discuss how each source is producing its sound(s), and have them qualitatively describe the frequency and amplitude of the sounds.

ADAPTATIONS FOR ACCESSIBILITY

Have an assistant for each lab station to ensure students are guided through the activity. Let students have a direct interaction with different materials and surfaces by touching different tools, using them, and capturing the vibration of sound production.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: Describe one of your favorite high- frequency sounds. What was the source of the sound? Where did you hear it?

Worksheet 1.1: Sound Production Observation Form A

Lab Station A: Balloons and Frequency	
	What did you observe at the lab station?
	What did you hear while doing the activity?
	What was the source of the vibration?
	According to your observations, how was the sound produced?
	Through what types of media (gases, liquids, or solids) was the wave traveling?
	In what direction did the wave appear to travel?
	What happened to the media as the wave traveled?

Worksheet 1.1: Sound Production Observation Form B

Lab Station B: Bottles with Water	
	What did you observe at the lab station?
	What did you hear while doing the activity?
	What was the source of the vibration?
	According to your observations, how was the sound produced?
	Through what types of media (gases, liquids, or solids) was the wave traveling?
	In what direction did the wave appear to travel?
	What happened to the media as the wave traveled?

Worksheet 1.1: Sound Production Observation Form C

Lab Station C: Tuning Fork in Water	
	What did you observe at the lab station?
	What did you hear while doing the activity?
	What was the source of the vibration?
	According to your observations, how was the sound produced?
	Through what types of media (gases, liquids, or solids) was the wave traveling?
	In what direction did the wave appear to travel?
	What happened to the media as the wave traveled?

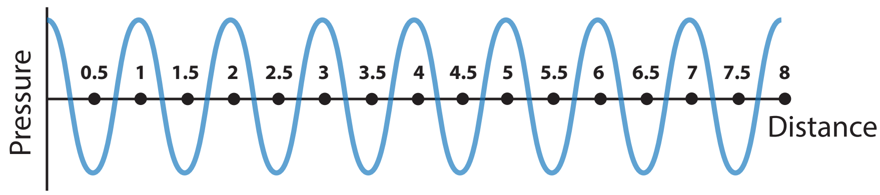
Table 1.1. Body Weights and Frequencies Produced for Various Animals

	Weight of Animal	Frequency Range
Mice	10 – 12 g (0.35 – 0.42 oz)	1,800 – 110,000 Hz
Small Birds	0.025 – 0.25 kg (0.053 – 0.5 lb)	2,200 – 2,500 Hz
Bats	1.2 – 1.4 kg (2 – 3 lb)	1200 – 16,000 Hz
Cats	2.5 – 4.5 kg (5-10 lb)	500 – 1300 Hz
Dogs	10 – 45 kg (20 – 100 lb)	300 – 800 Hz
Large Birds	22 – 45 kg (50 – 100 lb)	400 – 600 Hz
Monkeys	36 kg (79 lb)	800 – 1300 Hz
Gorillas	130 – 180 kg (300 – 400 lb)	250 – 600 Hz
Dolphins	150 – 200 kg (331.5 – 442 lb)	200 – 11000 Hz
Lions	190.5 kg (420 lb)	10 – 430 Hz
Horses	450 kg (1,000 lb)	550 – 950 Hz
Tigers	222.26 kg (490 lb)	83 – 246 Hz
Elephants	7,000 kg (15,000 lb)	30 – 70 Hz
Whales	200,000 kg (420,000 lb)	10 – 3000 Hz

Worksheet 1.2 Sound Production Knowledge Check Form

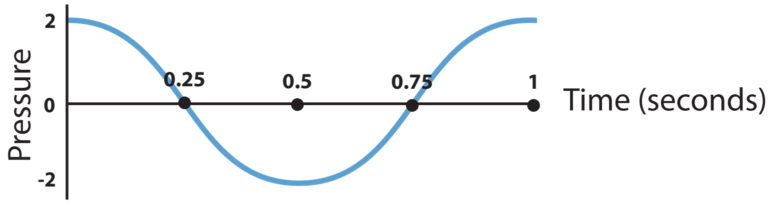
Section 1:

1. What is the wavelength of the following sound? *(Answer: 1)*

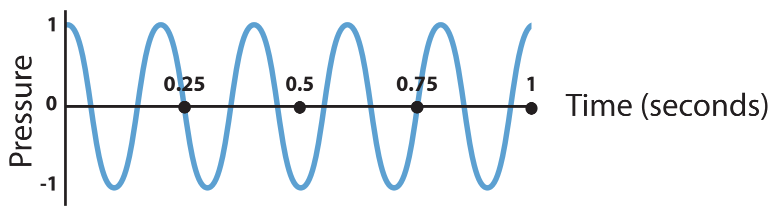


2. What is the frequency of the following waveforms? *(Answer: A=1 Hz, B=5 Hz)*

A)



B)

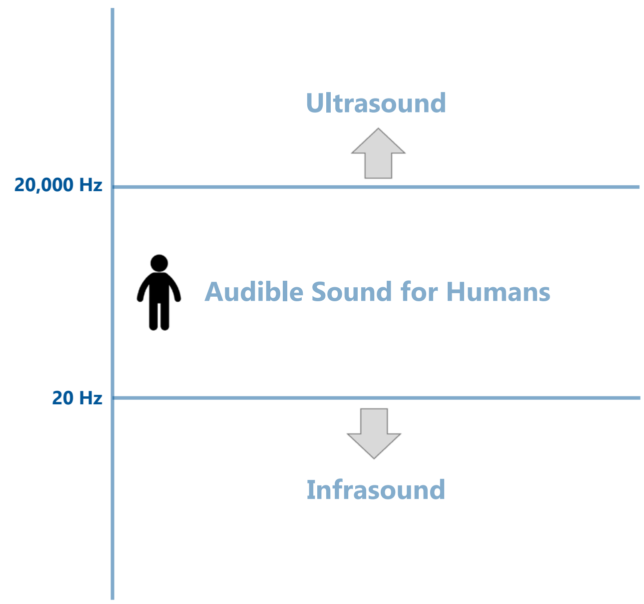


3. Which one of the previous waveforms has the higher amplitude? A or B? *(Answer: A)*

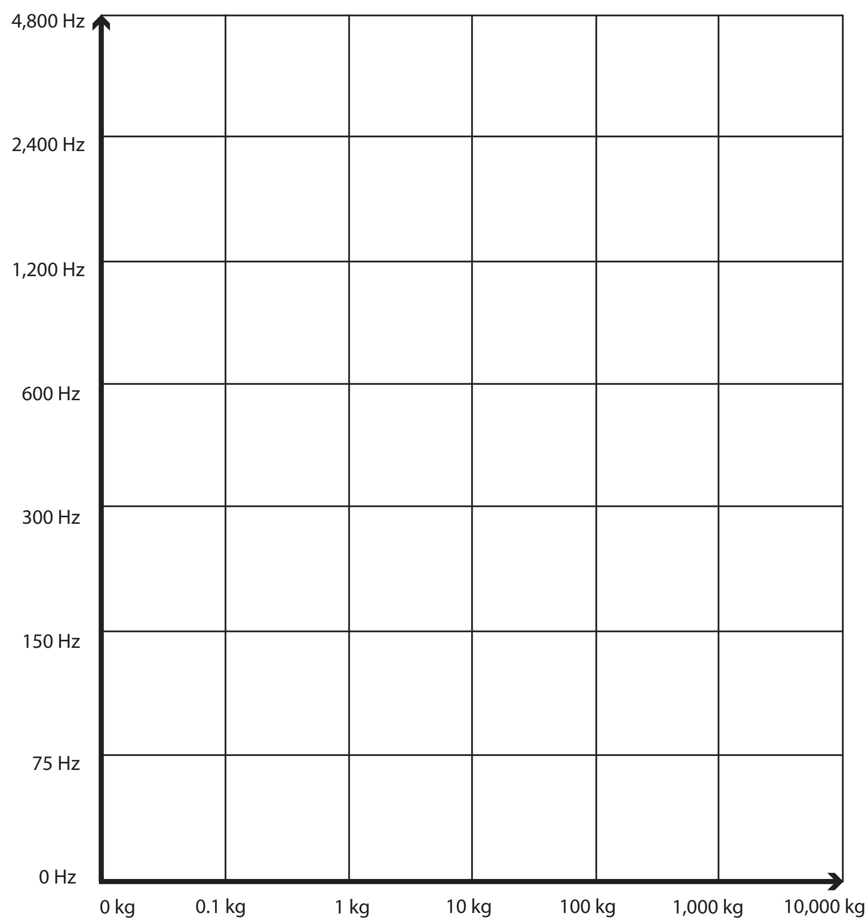
4. Look at the hearing range of a human in Table 1.1. It is between 20 Hz to 20,000 Hz. Can we hear the sounds represented on the previous waveforms? *(Answer: No. Their frequencies are below our hearing range.)*

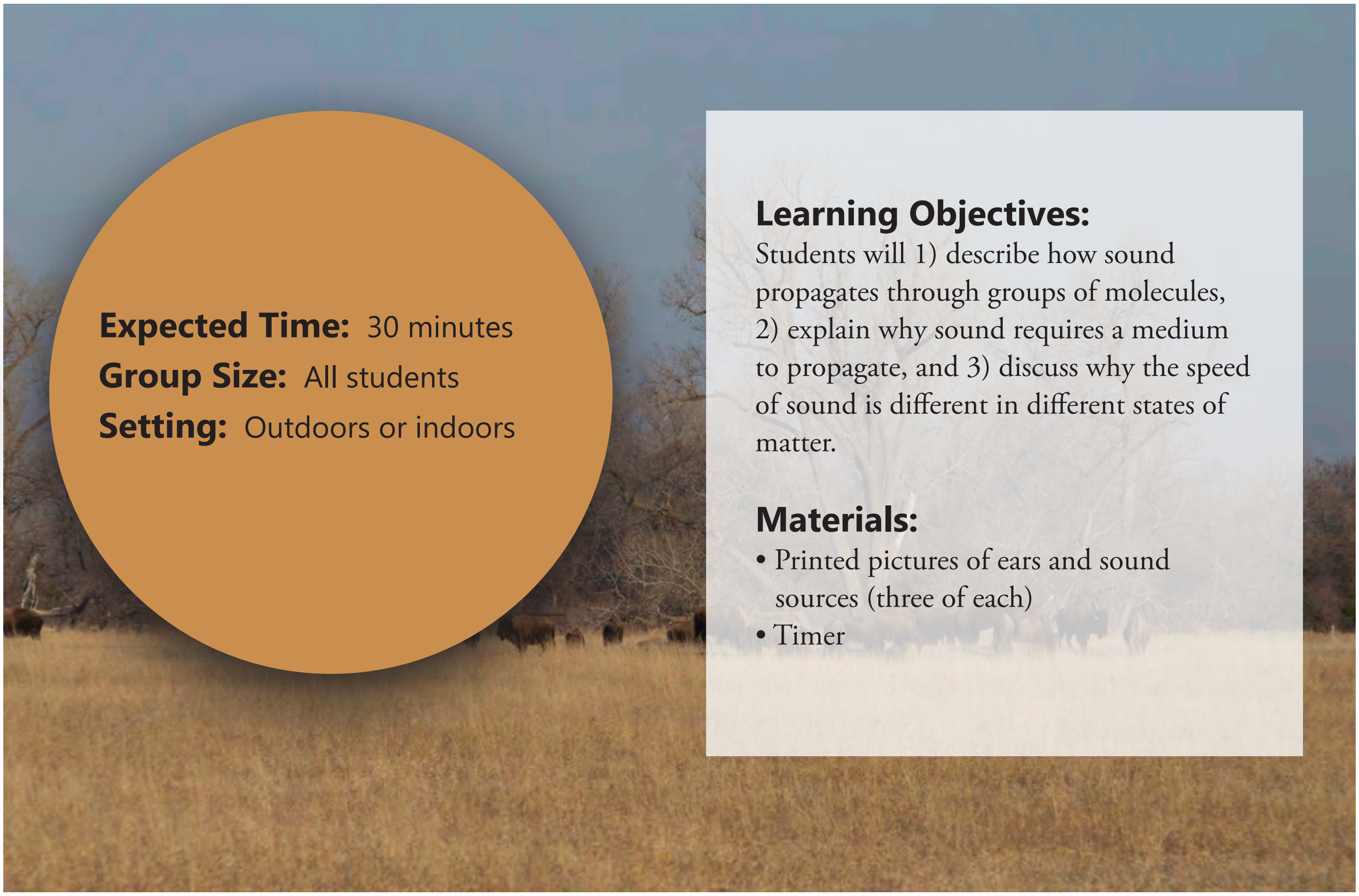
Worksheet 1.2: Sound Production Knowledge Check Form (continued)

Section 2:
Write the names of animals in the frequency ranges in which they produce sound based on the information on Table 1.1.



Section 3:
Draw animal icons on the chart based on their weights and the frequencies they produce using information in Table 1.1.





Expected Time: 30 minutes
Group Size: All students
Setting: Outdoors or indoors

Learning Objectives:

Students will 1) describe how sound propagates through groups of molecules, 2) explain why sound requires a medium to propagate, and 3) discuss why the speed of sound is different in different states of matter.

Materials:

- Printed pictures of ears and sound sources (three of each)
- Timer

Activity 2: Be a Molecule

After a signal is produced, it moves from its source through the surrounding medium, be that a gas, liquid, or solid. This process is called sound propagation (see Activity 1 for some basic information and terminology about sound production and propagation). The particles of that medium are compressed and released, transferring the energy of the vibration. The speed of sound varies depending on the density of the medium through which it is traveling. Sound travels at around 1,530 meters per second in water, a rather dense medium, and around 340 meters per second in air, a medium with much lower density.

As sound travels, it is affected by the structure of the environment through which it travels. For instance, bird song in forests is affected by tree trunks, branches, leaves, and other objects that absorb and reflect sound. In an open environment like a desert, fewer objects are likely to influence sound propagation. Low-frequency sounds can propagate farther than high-frequency sounds of equal amplitude because they compress the medium through which they are traveling less frequently. Therefore, the low-frequency sounds lose less energy that is retained in the medium.

Worksheet 2.1: Sound Source Cards

Neotropical Forest

Propagation Property
Dense tree trunks, branches, & leaves

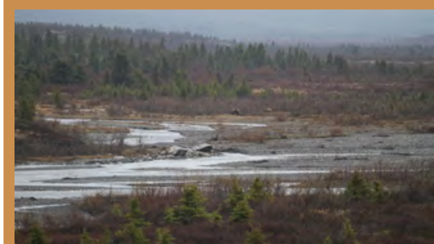
Temperate Forest

Propagation Property
Mix of trees with bushes and plants

Estuary

Propagation Property
Mix of trees with vernal ponds & ocean

Tundra



Propagation Property
Open rolling terrain with few trees

Scrubland

Propagation Property
Dry with bushes and few trees

Grassland

Propagation Property
Wide open land with grases & few trees

Chiricahua Mountains

Propagation Property
Dry mountains with bolders & plants

Desert

Propagation Property
Vast sandy environment with few plants

Dunes

Propagation Property
Wind driven ridges of sand

Temperate Wetland

Propagation Property
Vernal pools/ponds with varying plants

Polar Ice

Propagation Property
Extreme cold waters without plants

Oceans

Propagation Property
Coral Reefs with aquatic plants

Worksheet 2.1: Ear Cutouts

INSTRUCTOR DIRECTIONS

The main focus of this activity is on sound propagation. Students will learn how the speed of sound is highly dependent on the properties of the materials through which the sound is passing and how sound travels as a pressure wave. In this activity, students act as if they are molecules in different states of matter through which a sound is traveling.

Activity

If students are not familiar with the concept of molecules, introduce them to this concept. Describe typical differences in molecular density between gases, liquids, and solids.

1. Provide the materials (printed pictures of ears and sound sources—three of each—and a timer).
2. Ask students to stand in a line and explain that each one of them represents a molecule.
3. Give the leftmost person a printed picture of an animal or any object that makes sound, and give the rightmost person a printed picture of an ear.
4. Instruct the students that whenever they receive a tap or a bump from the right, they should tap on their left-hand neighbor's shoulder or "oscillate" in such a way that they bump their left-hand neighbor.
5. The leftmost person should begin the tapping or bumping, and when the last person receives the tap, they should raise the printed ear and indicate that they "heard."
6. Repeat the activity two or three times, and explain how molecules transfer the energy of acoustic vibrations. Higher energy in a sound means that the sound will have higher amplitude, and the molecules in the propagating medium will be compressed and rarefied with greater force. Then modify the activity as follows:
   a. Have the students answer the key questions.
   b. Form three lines with equal numbers of students.
   c. Ask the first group to stand two steps from each other and explain to them that they are representing a gas.
   d. Ask the second group, representing a liquid, to stand one step from each other.
   e. Ask the third group, representing a solid, to stand shoulder to shoulder.
   f. Give the last person of each group a picture of an ear.
   g. Ask them to tap their neighbor's shoulder or "oscillate" as in the previous activity. When tapped, the final person should raise the picture of ear and say "[Solid/Liquid/Gas] heard."
   h. Use a timer to time each group.

KEY QUESTIONS

Does the speed of sound change depending on the medium through which it is traveling?
Answer: Yes, the speed of sound is different in different materials. Sound is a vibration that can be transferred between molecules, and when molecules are close together, it takes less time to pass the vibration.

In what sort of medium would sound travel fastest? Why?
Answer: The density of molecules is generally highest in solids, followed by liquids and then gases. Sound travels faster in denser media, so it will usually travel fastest in a solid.

In which environment will sound travel faster—terrestrial (above ground) or marine (in water)?
Answer: Sound will travel faster in a marine environment because water has a higher density than air.

How fast would sound travel in outer space?
Answer: Sound would not propagate in outer space because there is no medium through which it could propagate.

POSSIBLE EXTENSIONS

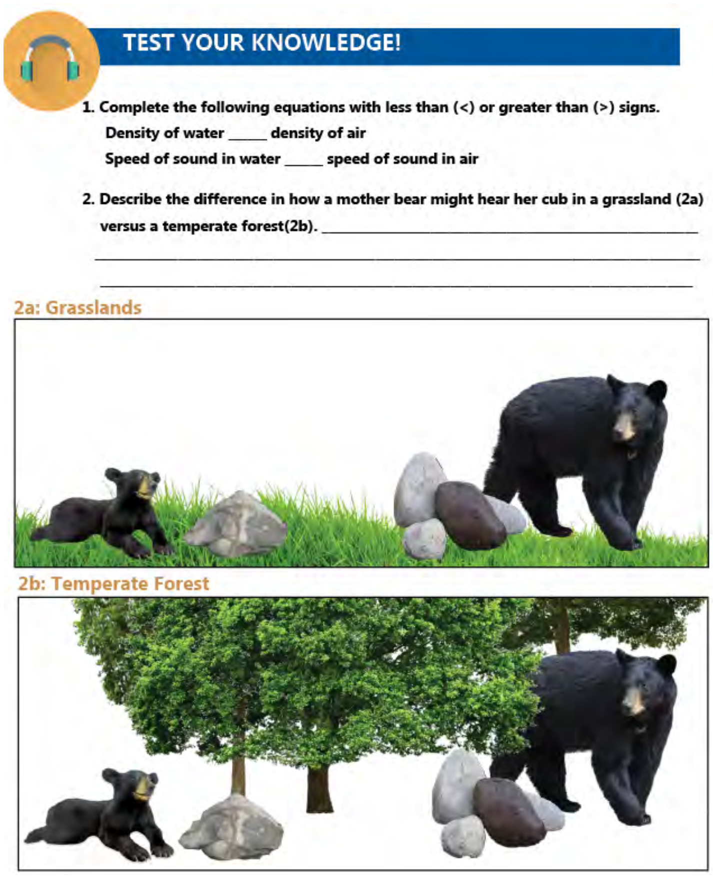
Ask students how sound might propogate differently in a gas at different pressures (and therefore densities).

ADAPTATIONS FOR ACCESSIBILITY

- An assistant may be needed to guide students to stand in different spacing and transition between states of matter (gas, liquid, and solid).
- Let students know who is located to their left and right so they have a better sense of their position. This knowledge is especially important for the students at the beginning and end of the line

TEST YOUR KNOWLEDGE

Following the completion of the hands-on activities, students should complete a worksheet about the content of this activity.



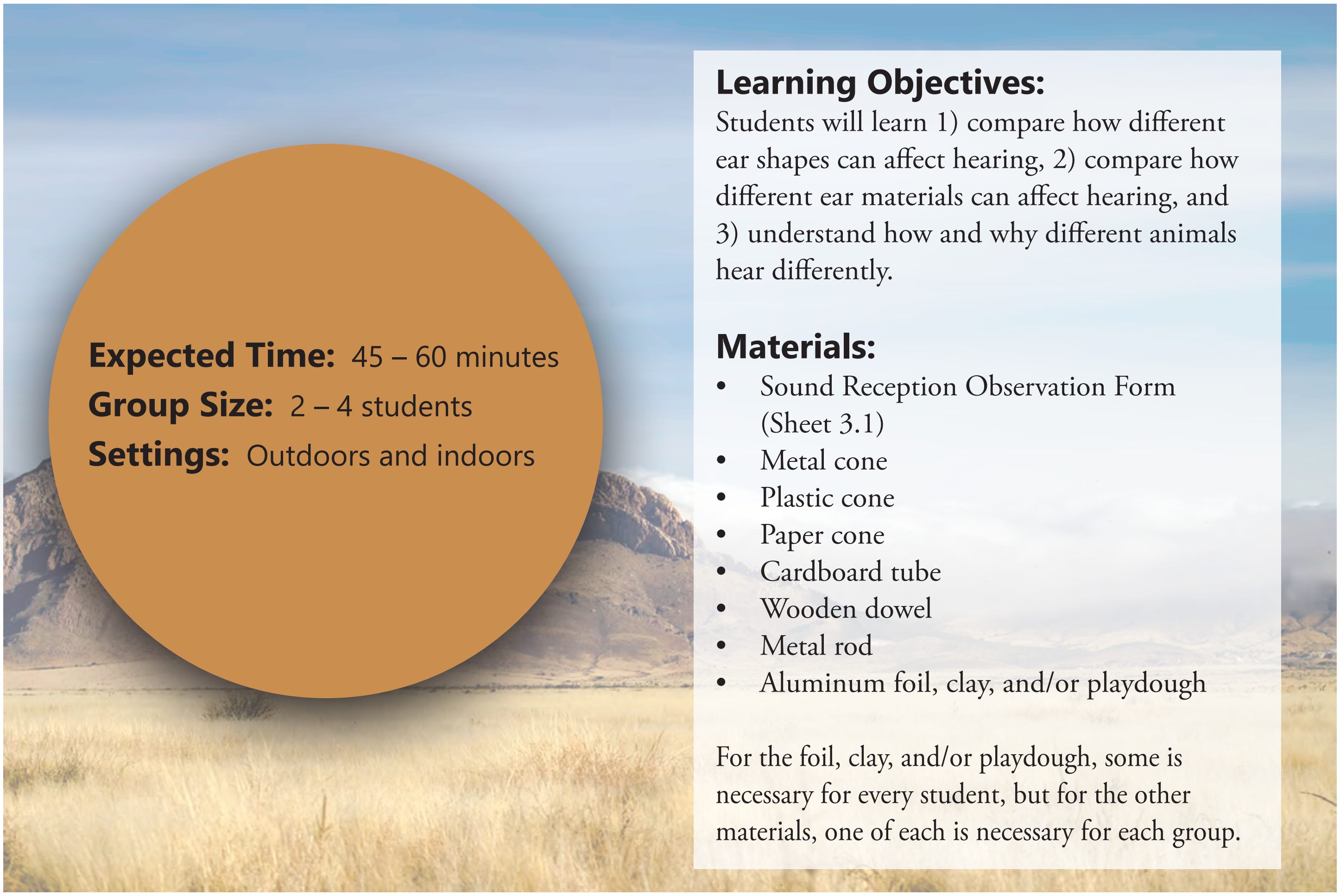
TEST YOUR KNOWLEDGE!

1. Complete the following equations with less than (<) or greater than (>) signs.
   Density of water _____ density of air
   Speed of sound in water _____ speed of sound in air

2. Describe the difference in how a mother bear might hear her cub in a grassland (2a) versus a temperate forest(2b). ____
____
____

2a: Grasslands

2b: Temperate Forest



Expected Time: 45 – 60 minutes
Group Size: 2 – 4 students
Settings: Outdoors and indoors

Learning Objectives:

Students will learn 1) compare how different ear shapes can affect hearing, 2) compare how different ear materials can affect hearing, and 3) understand how and why different animals hear differently.

Materials:

- Sound Reception Observation Form (Sheet 3.1)
- Metal cone
- Plastic cone
- Paper cone
- Cardboard tube
- Wooden dowel
- Metal rod
- Aluminum foil, clay, and/or playdough

For the foil, clay, and/or playdough, some is necessary for every student, but for the other materials, one of each is necessary for each group.

Activity 3: Using Tools to Listen

Sound is received when pressure changes in a medium are sensed by animals' organs or mechanical recording devices. In organisms, some complicated psychological processing typically follows this reception (see Activity 1 for an overview of the acoustic communication process). Certain species are sensitive to sounds of certain frequencies and amplitudes. Some animals can hear sounds that humans cannot. For example, dogs respond to dog whistles that have frequencies above the upper limits of human hearing. Human hearing ranges from 20 – 20,000 Hz. Sounds below this range are referred to as infrasound and sound above this range are referred to as ultrasound. Figure 3.1 on the next page shows the frequency hearing ranges of different animals.

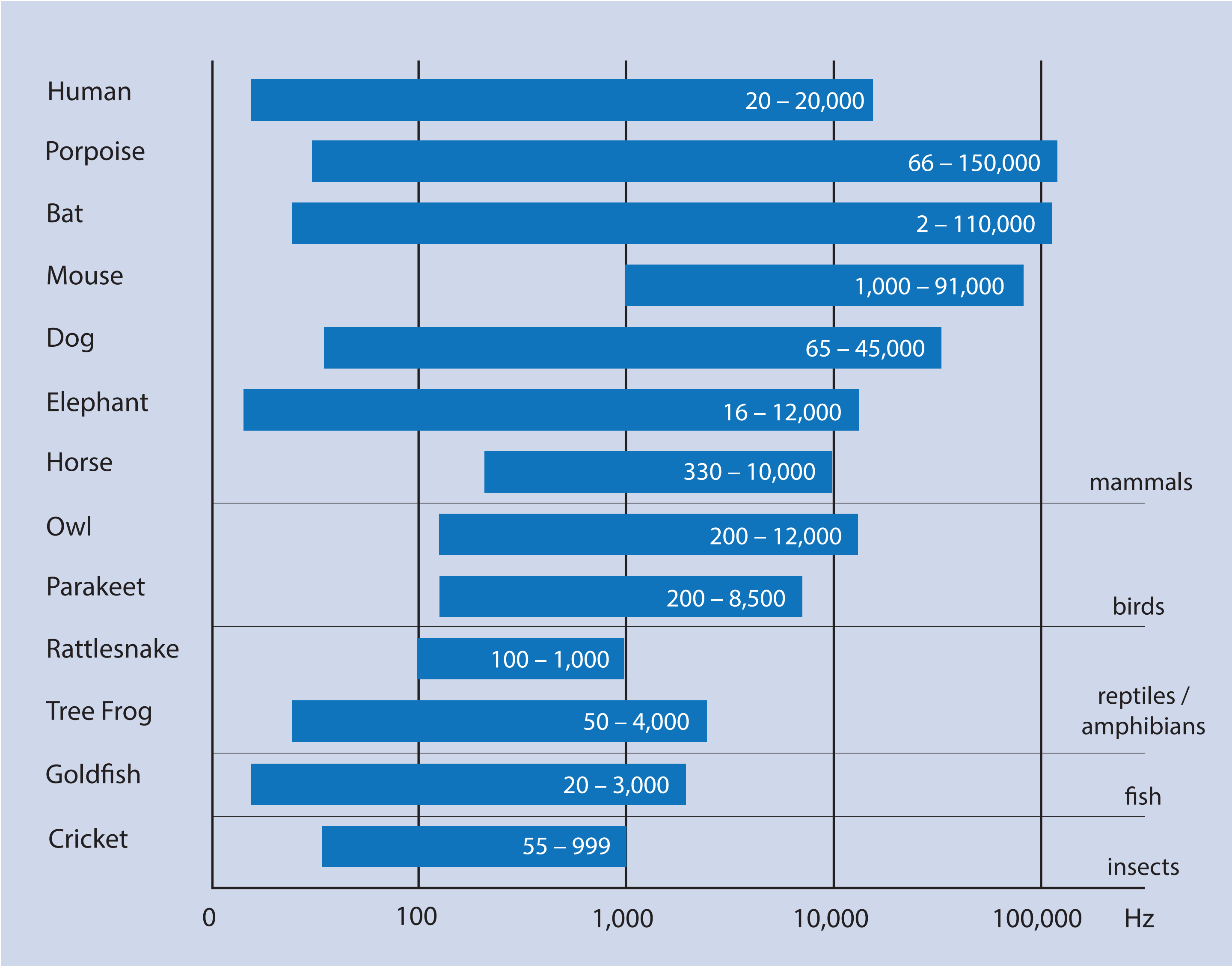


Figure 3.1. The range of frequencies commonly heard by different animals.

An animal's ability to hear a given sound depends on two conditions. The first condition is the size of any passage through which a sound must travel before reaching the reception organ. Sounds with wavelengths greater than the width of the passage (low frequencies) cannot reach the receiving organ, so they are not detected. The second condition is the size and tautness of the receiving organ. The frequencies at which that organ can vibrate are physically limited by those two parameters, filtering out frequencies above and below the range within which the organ can vibrate. In humans, a key part of the receiving organ is the tympanic membrane, or eardrum — a thin membrane stretched tightly across the ear canal. The tympanum vibrates when struck by pressure waves propagating through air or water.

Animals with two ears can often determine the directionality of a sound based on different sound arrival times at each ear, different amplitudes at each ear, different frequency properties at each ear, and/or changes in pressure based on head position. External organs that direct sound towards the receiving organ and filter frequencies are called pinnae. Different animals exhibit vast differences in the shape of their pinnae, and some animals can move their pinnae, while others cannot. African elephants even use their giant pinnae to keep cool. They direct bloodflow to their pinnae to dissipate heat through their large surface area, and they flap them to generate a local breeze.

INSTRUCTOR DIRECTIONS

The main purpose of this activity is to make students familiar with sound reception and to show them how they can listen to their surrounding soundscapes differently. They have access to several easily made listening devices with which they will explore their surroundings. In this activity there will be a lab station at which each group can listen to the sounds around them (or the sounds they produced in Activity 1) using different listening devices.

1. Provide the materials (metal cone, plastic cone, paper cone, cardboard tube, wooden dowel and metal rod) for each group.
2. Ask students to use these tools to change the way they hear. Provide an observation form for them to complete (Worksheet 3.1).
3. Instruct them to listen through a cone and see how it affects hearing.
4. Have students check whether paper, plastic, and metal cones alter sound differently.
5. Have them use the dowels and rods by pointing one end toward the sound source while the other is held close to the ear.
6. Lead them to some of the different lab stations from Activity 1, and have them listen to those diverse sounds through this activity's tools.
7. Provide aluminum foil, clay or playdough and ask participants to design their own model of an outer ear (pinna).
8. Ask them, "How might different ear shapes affect animals' hearing?" Answer: The outer ear, or pinna, funnels sound into the inner ear. Head and pinna structure affect the amplitude of certain frequencies; therefore, animals with differently shaped ears will hear sounds differently. Some animals can move their ears (like cats) but others (like most humans) have fixed ears. Some animals hear binaurally—they have two ears located in a manner that allows them to better localize (find) a sound source. Certain animals like rabbits and many rodents also have large pinna that help them detect very low-amplitude sounds in their surroundings.
9. Take students outside and let them listen to the sounds around them through different tools and their custom ears. Ask each student to try their group mates' custom ears.

KEY QUESTIONS

Listen with and without tools. How does your hearing change when you use the tools?
Answer: Answers will vary, as different tools provide different listening experiences, and individuals will use them in different manners. Cones typically increase amplitude by funneling more acoustic energy toward the ear.

How do different tool materials affect how you hear?
Answer: Different materials absorb and reflect sound differently based on their physical properties. Denser materials like metal will reflect more sound than less dense materials like paper.

Do any tools make it harder or easier to identify sounds?
Answers will vary.

POSSIBLE EXTENSIONS

Play a predator and prey game. Divide students into two groups—predators and prey. Predators must be blindfolded and must remain stationary, but they can use a hearing device of their choice (from this activity) to try to find the non-blindfolded prey. The prey try to move from one side of a defined area to another without a predator pointing at them. If a prey student is pointed out three times, they are eliminated from the game.

ADAPTATION FOR ACCESSIBILITY

An assistant is needed to read the observation form and guide the outdoor excursion.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: How did the different listening tools affect your hearing experience? Were there any tools that you did or did not like?

Worksheet 3.1: Listening Tools Observation Sheet

1. Visit each lab station and listen to the sound with and without a tool. Complete the table.

Lab Station Tool	**Sound**	**Observation with Tool**	**Observation without Tool**
metal cone			
plastic cone			
paper cone			
cardboard tube			
wooden dowel			
metal rod			
other:			

1A: How does your hearing change when you use the tools?

1B: How do different tool materials affect how you hear?

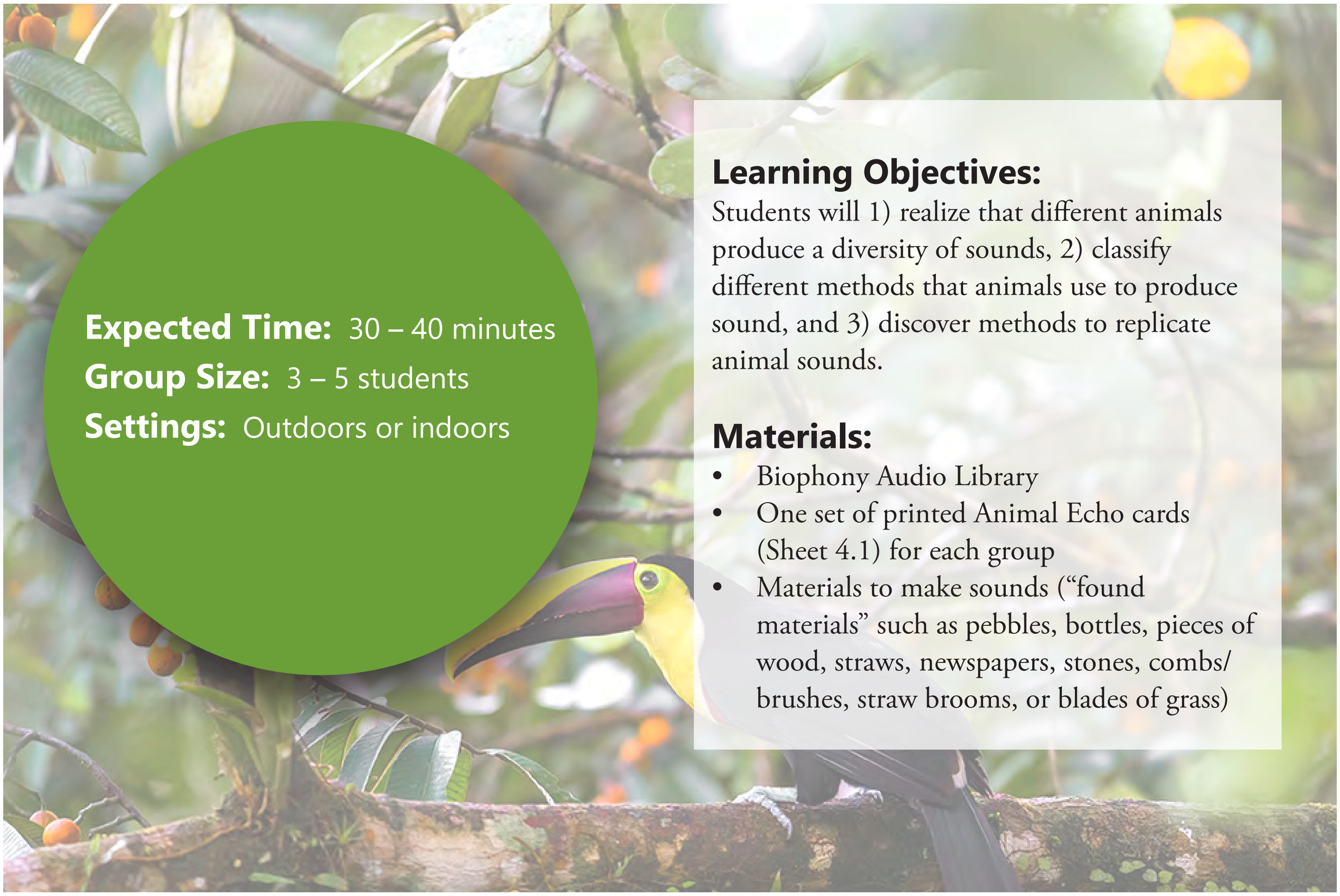
1C: Do any tools make it harder or easier to identify sounds?

2. Shape alumunium foil, clay, playdough into a model of the outer ear. How might different ear shapes affect animals' hearing?

Chapter 2

ANIMAL COMMUNICATION

Animals use sounds, odors, visuals, and other signals to communicate. Sound is a common method of communication, and it is especially useful in places with limited visibility like the rainforest of Costa Rica. Animal sounds serve various communicative functions, including finding mates, warning of predators, and informing about locations of food sources. Some animals produce complex sounds that have subtle differences in meaning. For example, vervet monkeys produce different sounds to specify when a predator is approaching from the ground or from the air. Activities in this chapter focus on teaching students about how animals communicate using sound.



Expected Time: 30 – 40 minutes
Group Size: 3 – 5 students
Settings: Outdoors or indoors

Learning Objectives:
Students will 1) realize that different animals produce a diversity of sounds, 2) classify different methods that animals use to produce sound, and 3) discover methods to replicate animal sounds.

Materials:
- Biophony Audio Library
- One set of printed Animal Echo cards (Sheet 4.1) for each group
- Materials to make sounds ("found materials" such as pebbles, bottles, pieces of wood, straws, newspapers, stones, combs/brushes, straw brooms, or blades of grass)

Activity 4: Animal Echo

Animals use sound as one means of transmitting information. Sound can be a particularly useful method for communication in habitats like dense forests or deep water, where complex environmental structure or lack of light limit visibility.

Animal sounds are very diverse—some are melodic with many frequency variations, like bird songs, while others are more repetitive, such as cricket chirps. These diverse sounds are influenced by a number of factors including habitat, body size, and the medium in which sound is produced.

Animals produce sounds for many reasons. Some primary communicative reasons include finding mates, defending territory, or warning of predators. Some animals, such as bats and dolphins, use sound for echolocation—they produce clicking sounds that allow them to detect prey and identify the structure of their surroundings.

Sound Production Methods

Animals produce sound in different ways, and some animals have more than one way to produce sound. Different sound production techniques include:

1. Body movement
2. Body movement through a medium
3. Vocalization

Body Movement

Percussion refers to sounds that are produced by striking two objects together. Here are some examples of percussive animals:

1. Woodpeckers strike trees with their beaks, producing repetitive, marimba-like sounds
2. Beavers slap the surface of water with their tails
3. Gorillas beat their chests with their hands—these thumping sounds are pitched based on the gorilla's body size.

Stridulation is the sound produced by rubbing two body parts against one another. Examples include cricket and grasshopper chirps and the hissing sound produced by some snakes when they rub their scales against one another.

Tremulation, or shaking, is performed by such animals as cicadas, spiders, and katydids. These animals typically tremulate near plants or under the soil, and they sometimes produce sounds that are above or below the range of human hearing.

Body Movement through a Medium

Some species produce sound when a body part interacts with a medium like air or water. In the case of insects, like mosquitoes and bees, rapid wing movement through the air produces a buzzing sound. Snapping shrimp rapidly close a claw to produce an underwater bubble that produces sound when it bursts due to water pressure. Snapping shrimp are one of the loudest animals in the world despite their small size. Their sounds can be heard in the water, and in some cases, even above the surface.

Vocalization

The respiratory system in terrestrial and marine animals is used for vocalization. Terrestrial animals like birds, mammals (including humans), and frogs vocalize using air flow and a vocal box such as the larynx or syrinx. Frogs have a vocal sac that inflates after the air flow passes through their vocal cords, making the inflated sac visible after the frog croaks.

Another type of vocalization is echolocation, which is used by some animals that fly in the dark, like bats, or by marine mammals that need to navigate and forage in large, often dark and murky bodies of water. Bats emit echolocation sounds through their mouth or nose. The sound then bounces off objects, allowing the bats to create a mental map of their surroundings based on the reflection of their calls. Bats can determine very specific information from these reflections, such as the size, shape, texture, and distance of a small insect. Marine animals like sperm whales and dolphins need echolocation as they have limited vision to navigate their vast habitats. They use echolocation to navigate, communicate and find food.

Body Size and Sound Frequency

The frequencies produced by animals tend to be related to body size (Figure 4.1). Bigger animals typically produce lower frequency sounds, and vice versa.

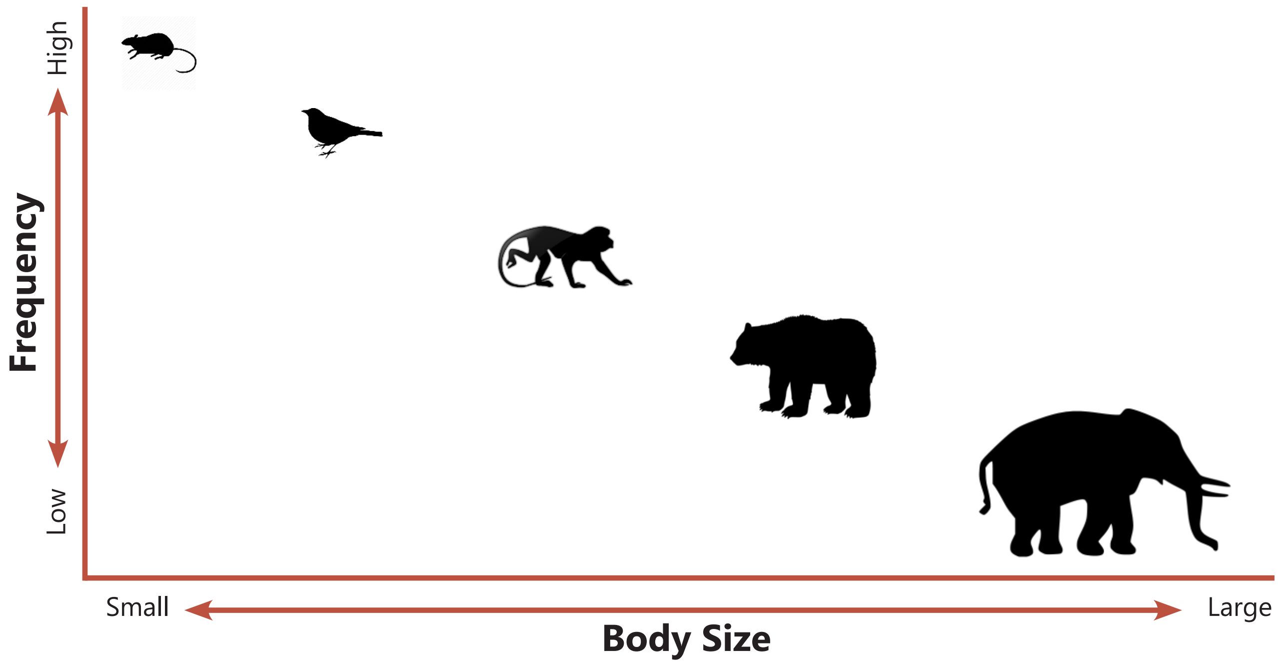


Figure 4.1. The inverse relationship between sound frequency and body size.

INSTRUCTOR DIRECTIONS

In this activity, students will learn how different animals produce sounds. They will listen to several recordings of animals' sounds and discuss how those sounds have been produced. Finally, they will practice animals' sound production strategies by attempting to imitate them.

Part 1: Meet the Animals

Print Animal Echo Cards (Worksheet 4.1) and laminate them for better preservation. Each card has the name of an animal and the way that animal produces sound. "Found materials"—local natural or recycled items—can help students replicate animal sounds.

The Biophony Audio Library is a collection of recordings of the animals on the Animal Echo cards, labeled as the following: birds (black capped chickadee, goose, barred owl, whooping crane, pileated woodpecker, white stork, and mallard duck), mammals (beaver, deer, howler monkey, humpback whale, coyote, sheep, gorilla, and bat), insects (cricket, cicada, and jumping spider), and reptiles and amphibians (rattlesnake, bullfrog, and spring peeper). Introduce the sounds to all students by playing the sound files.

1. Ask students to guess how a certain animal produces sound.
2. Refer to the background information to explain different ways in which animals produce sounds.
3. Give examples for each method and encourage students to produce each sound while you discuss a given animal's sound production techniques.
4. Ask students to provide other examples. Using specialized terminology is optional; however, students can be encouraged to learn and repeat the new terms.

Part 2: Echo the Animals

1. Divide students into groups of three.
2. Each group will have the same stack of up to 24 animal cards. The student who is making animal sounds cannot speak words except to answer a "yes/no" question posed by a group member.

3. Select space for each group near a table, but separated from other groups. Have students place their "found sound materials" on the table for easy access during the game. Each group plays independently.
4. Each group will shuffle the cards and place the stack of cards facedown in the center of the table.
5. The first member of the group picks the first card. They will look at the animal on the card and announce the habitat to which it belongs without revealing the name of the species. Then, they will make the sound of the animal by mimicking the sound-production method of that animal and using found materials, body parts, and/or vocalization. Students can use any of the materials on the table to help produce the sounds. Some examples using found materials include rubbing sticks together to mimic cricket sounds or shaking small pebbles in a container to mimic cicada sounds.
6. The other group members guess what animal is on the card based on the sound they hear. If the answer is correct, the second member of the group picks up the next card and repeats Step 5. If the members cannot determine the animal based on the sound, the members can ask "yes/no" questions about the habitat, food, temporal activity patterns, or distribution of the species such as: "Does this animal live in a forest?" or "Is it a common animal that we have seen before?"
7. Continue this process until the groups have finished the provided deck.
8. At the end of this activity, encourage students to have a group discussion about which animal they liked and then ask all of them to create a soundscape by making the sounds of their favorite species at the same time.

KEY QUESTIONS

Why might animals produce such diverse sounds?
Answer: Animals must often communicate complex information about their identity and behavior, and they must do so in the context of many other environmental sounds. Other animals use sound to hunt or navigate, and these sounds must have certain properties.

Why do animals use diverse methods to produce sounds?
Answer: Animals differ widely in the methods by which they produce sounds because of their evolutionary histories, physical characteristics, and the environments in which they produce sounds.

How hard was it to reproduce the sounds?
Answers will vary.

Why is echolocation important?
Answer: Animals like bats and dolphins use echolocation in to locate food and identify habitat structure in environments where visibility is limited.

What environmental factors could affect animal sound production?
Answer: Habitat structure, weather (temperature and wind), the medium in which animals produce sound (underwater vs. terrestrial), and noise from other sound sources can affect animal sound production.

POSSIBLE EXTENSIONS

Take students outdoors, and ask them to identify different animals producing sounds. Discuss how each animal is producing sound.

ADAPTATIONS FOR ACCESSIBILITY

Use braille cards or tactile images of animals.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: Why might animals use such diverse methods to produce sounds?

Worksheet 4.1: Animal Echo Cards

Lion


Vocalization
Habitat: grasslands, open woodlands

Bottlenose Dolphin


Vocalization
Habitat: bays, estuaries, river mouths

Rattlesnake


Percussion
Habitat: prairies, marshes, deserts

Mallard Duck


Vocalization
Habitat: wetlands, ponds, lakes

Spring Peeper


Vocalization
Habitat: ponds, swamps

Cricket

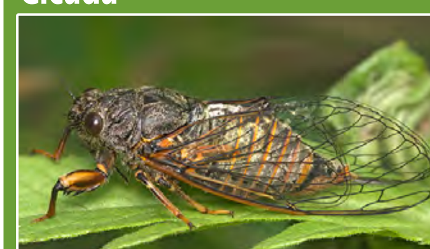

Stridulation
Habitat: grass, mulch piles, logs

Howler Monkey

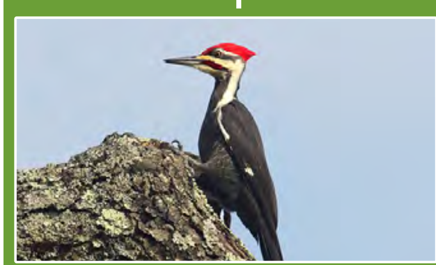

Vocalization
Habitat: rainforests

Ring Tailed Lemur

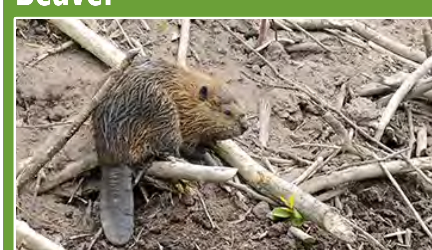

Vocalization
Habitat: forests, various

Cicada


Tremulation
Habitat: open forests, woodlands

Pileated Woodpecker


Percussion
Habitat: forests

Beaver


Percussion
Habitat: small lakes, ponds, marshes

White Stork


Percussion, Vocalization
Habitat: marshes, swamps, riverbanks

Worksheet 4.1: Animal Echo Cards (continued)

Black Capped Chickadee

Vocalization
Habitat: forests

Elk

Vocalization
Habitat: meadows, woodlands

Canada Goose

Vocalization
Habitat: ponds, marshes

Bullfrog

Vocalization
Habitat: rivers, streams, ponds

Barred Owl

Vocalization
Habitat: coniferous forest

Whooping Crane

Vocalization
Habitat: wetlands, salt marshes

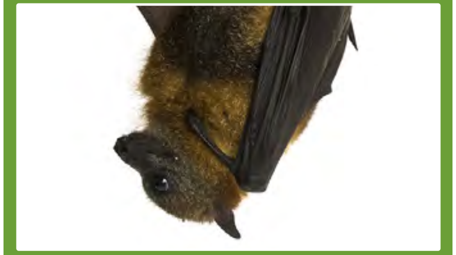
Humpback Whale

Percussion, Vocalization
Habitat: oceans

Coyote

Vocalization
Habitat: grasslands, desert scrublands

Bat



Vocalization
Habitat: caves, forests, various

Sheep

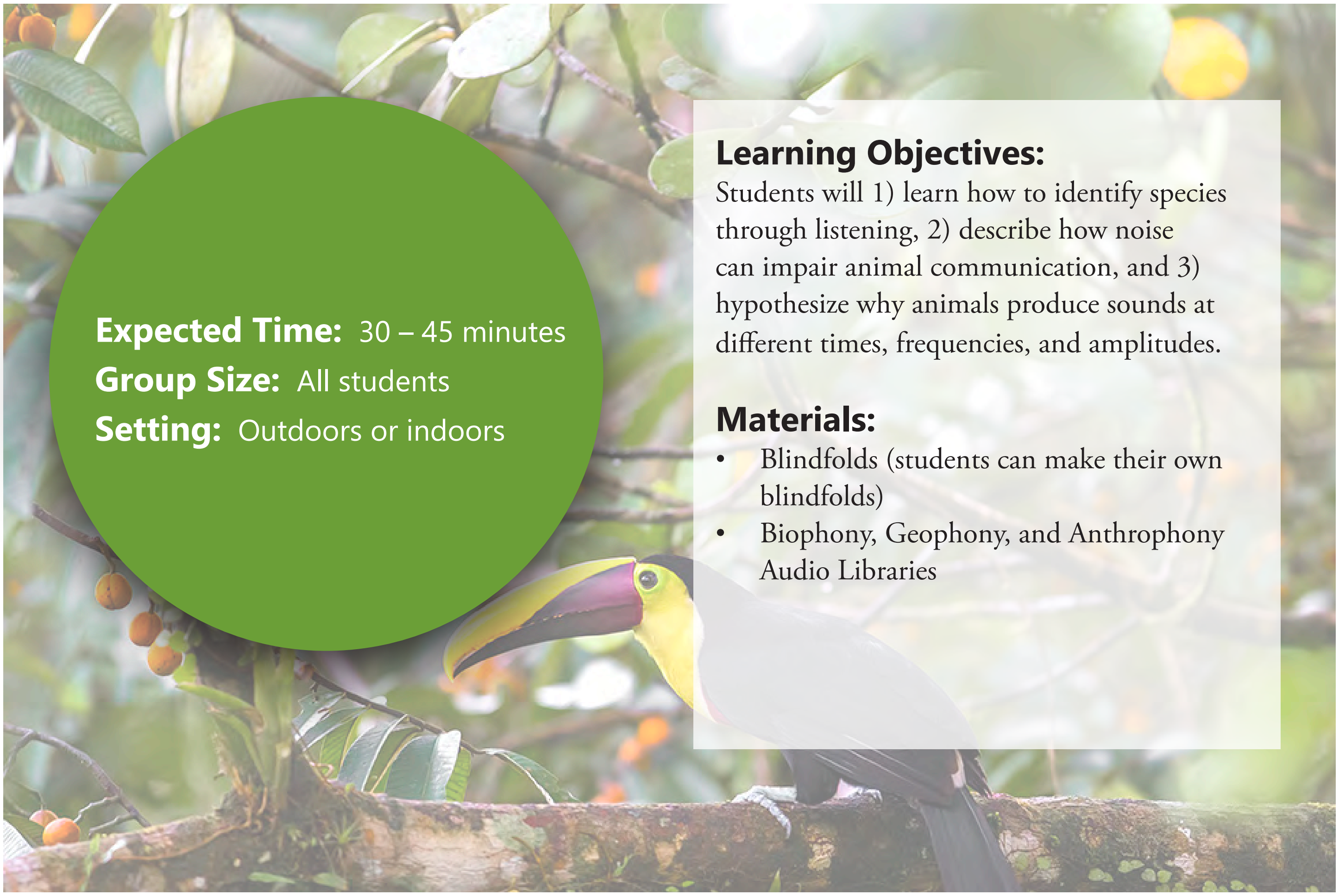
Percussion, Vocalization
Habitat: mountains, deserts, grasslands

Gorilla

Percussion, Vocalization
Habitat: tropical forests

Jumping Spider

Percussion
Habitat: forests, deserts, various



Expected Time: 30 – 45 minutes
Group Size: All students
Setting: Outdoors or indoors

Learning Objectives:
Students will 1) learn how to identify species through listening, 2) describe how noise can impair animal communication, and 3) hypothesize why animals produce sounds at different times, frequencies, and amplitudes.

Materials:
- Blindfolds (students can make their own blindfolds)
- Biophony, Geophony, and Anthrophony Audio Libraries

Activity 5: Find Your Pair

Sound is one of several methods of animal communication mentioned in the introduction to this chapter, and animals make different sounds to communicate different messages. For instance, one type of sound might attract a mate, while another might warn of a nearby predator. Over time, evolutionary forces have altered the sounds that animals produce, and they have shaped the ways that animals monitor their acoustic surroundings. Habitats, temporal activity periods, and body sizes also directly influence how animals produce sounds.

Acoustic communication is not always easy. Both the sender and receiver spend costly time and energy to produce and receive sound. Animals may even endanger themselves by revealing their locations to predators through sound. Animals can often be heard, even in environments where they cannot be seen, such as in a dense forest or during times of darkness. For humans interested in natural sounds, listening is easy and does not require any fancy equipment. Bird watchers, naturalists, bioacousticians, and soundscape experts can identify species and find out what animals are doing, just by listening to their sounds.

Why Do Animals Produce Sound?

Animals use sound for a number of different purposes. Many animals produce sound to attract mates. Such is the case with the singing of male frogs in the early spring and with the honking of male hammer-headed bats. Gibbons are rather special because as part of their mating process, males and females vocalize together in an elaborate duet pattern. Gibbons also use sound to defend their territories. Some animals make sounds when they find food, a strategy used to attract a mate by advertising the individual's ability to find food. Roosters and rhesus macaques (a type of monkey) produce this type of food call. Penguins live in large colonies and tend to retain mates for several consecutive years. The only way penguin couples can find each other in a large crowd of visually similar individuals is through sound.

Many animals make sounds to intimidate other animals and to display strength. Big cats' roars, gorillas' growls and chest beating, wolves' howling, and hyenas' "laughter" are some examples of this practice.

Animals also produce sounds to warn other members of their own species about the presence of a predator. Monkeys such as Diana monkeys and Campbell monkeys produce varied vocalizations according to the type of predator that is present. For example, their call changes if they are threatened from the air by an animal like an eagle or from the ground by an animal like a leopard.

Other animals use sound to find food. Bats use echolocation, a high-frequency vocalization that bounces off objects in their surroundings and reflects back to the bat, revealing information about the surrounding environment. Using echolocation, bats can detect food and environmental structures like trees.

Acoustic Niche Hypothesis

Ecologists define the "niche" of an organism, a population, or a species as a certain ecological space or role that entity occupies (Figure 5.1). Niches are considered in relation to two factors: 1) the necessary conditions for survival (i.e. resource availability and climate) and 2) the competition for these conditions. When species coexist in the same niche, they use adaptation strategies to share resources, and they are said to be practicing "niche partitioning." The same theory may be applicable to acoustic "space."

Acoustic space is a dimension of the environment that is partitioned between species that use sound to communicate. There are unique symphonies of sound in all ecosystems due to the presence of different

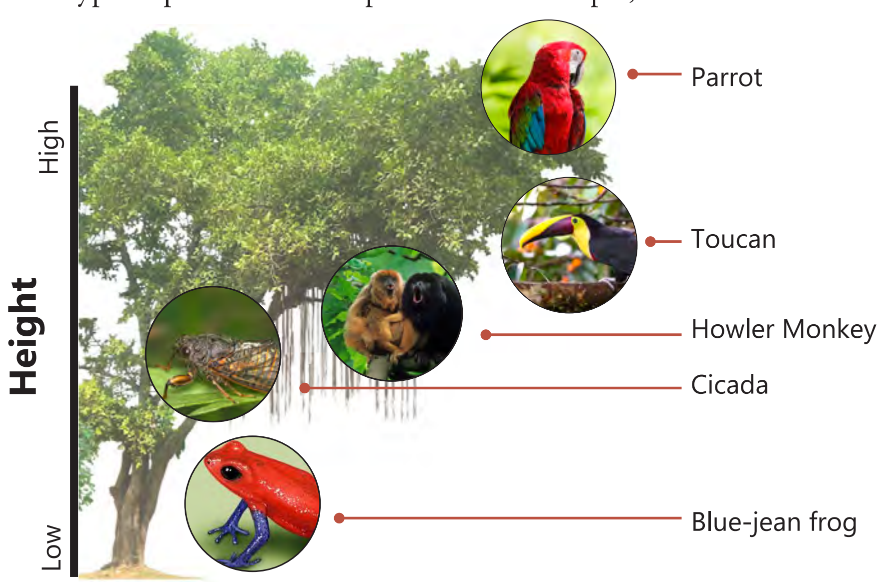


Figure 5.1. Niche partitioning.

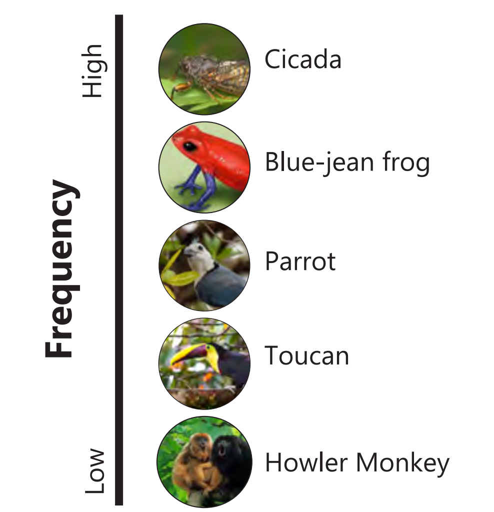


Figure 5.2 Acoustic niche partitioning.

animals and sounds generated by geological and climatic factors. The rainforest in Costa Rica is rich in acoustic communication for two main reasons: 1) the undisturbed forest hosts a large number of species, and 2) the dense habitat limits visual communication. In the rainforest, many different animals like toucans, monkeys, and cicadas have to communicate with each other acoustically (Figure 5.2). Besides intense biologic competition, other environmental conditions can also impair acoustic communication. Such factors include sound absorption by the dense environment, sound from geophysical activity like rain, wind, and river flow, and human sounds like noise from roads and airplanes.

How do all these animals manage to communicate in this cacophony? According to bioacoustician and soundscape recordist Bernie Krause, "Each creature appears to have its own acoustic niche (channel, or space) in the frequency spectrum and/or time slot occupied by no other at that particular moment." Species avoid masking each other and try to find "niches" in which they can hear and be heard. These acoustic niches can be frequency niches—frequency ranges in which certain species communicate—or they can be specific times of the day or season during which certain species communicate.

The Effect of Noise

Noise is sound that blocks a receiver's detection or recognition of a signal. "Noise masking" can occur in any ecosystem. The frequency and amplitude of noise can affect the degree to which it interferes with communication. In the case of low-frequency noise, like that from many human-built machines, receivers can often detect the signal, but signal recognition is difficult because only the higher-frequency components of the signal are discernible to the receiver.

The marmoset monkey increases the length of its call when it is noisy.

Cope's gray tree frog increases the speed of its call repetition when it is noisy.

Nightingales sing louder when it is noisy.

Red winged blackbirds change their calls when their environments are noisy.

European robins wait to sing until it is quieter.

Habitat change can alter the presence and influence of noise as well. Forested areas generally serve as buffers to noise transmission because the forest structure (trunks, branches, and leaves) degrades the sound. If those forests are removed, noise can propagate farther.

Temporal patterns of noise are significant as well. Continuous noise presents a greater problem than intermittent noise because it has a greater potential to mask the temporal acoustic niche on which a species depends for communication.

In urban areas traffic noise is mostly composed of low frequency sounds, and studies indicate that this noise may impair vocal communication of urban species. Species that live in noisy environments may adapt to noise in several ways. Time scales over which such adaptations occur may vary, as some species may adapt more easily than others.

INSTRUCTOR DIRECTIONS

In this activity, students will learn why animals produce sounds and how different natural and human made sounds can affect animal sound production strategies. Students will form pairs, put on blindfolds, and play the role of a particular species; they will then try to find their partners amidst a mix of natural and human sounds.

Part 1: Communication

1. Have students brainstorm a list of all the different ways in which human beings communicate with each other. Discuss how many of those methods involve sound, smell, body motion, and color.
2. Start the game by asking some questions about the role of sound in animals' lives:
   - How do animals produce sound?
   - Why do animals need to produce sound, and what is the role of sound in an animal's life?
   - What kind of sounds do animals hear from their surroundings?
   - Do animals hear the same things as humans?
   - Play sounds from the Biophony Audio Library.
   - Place students in pairs.
   - Student pairs will select one animal from the Biophony Audio Library.
   - All students will congregate in a large space.
   - Once in position, students will put on blindfolds to cover their eyes.
   - Mix students so that individuals in pairs are far apart.
   - Give a starting cue.
   - Students will listen for their partner's sound and move to find their partner. If holding this activity outdoors, mark a boundary for the game space, and watch to keep students within the boundary.
   - The game is over when all students have found their partners.
3. Ask the key questions that follow.

KEY QUESTIONS

Was it easy to find your partner? Why or why not?
Answers will vary.
How did other sounds affect your search?
Answers will vary.
How might an animal make sounds so that it does not mask the sounds of other animals?
Answer: Animal sounds will not overlap if they are produced in different ranges of frequency, time, and space.
Why might animals produce sounds at different times of day?
Answer: Some animals may produce sound at dawn and dusk when wind and human noise are less likely to hinder their communication. Others may simply be active at different times of day for other biological reasons that are not related to sound.

Part 2: Noise

Ask students about the impacts of noise, and ask what are the sources of noise in an environment that may mask animal communication.

1. Ask students to wear their blindfolds and put them in position.
2. Ask them to find each other again but this time, play some natural sounds, like wind, waves or rain (Geophony Audio Library). The sounds can be added gradually so students understand the change.
3. Repeat the same activity, but this time play some human-made sounds like traffic, machinery, or an airplane (Anthrophony Audio Library).

KEY QUESTIONS

Was it more difficult to find your pair in a noisy environment?
Answers will vary.
What did you do to find each other through the natural noise?
Answers will vary.
How might a noisy environment affect an animal?
Answers will vary.
What can animals do to overcome the effects of noise?
Answer: There are several strategies to adapt to a noisy environment such as increasing the sound length, amplitude, or repetition speed and waiting to produce sound until a quieter time.

POSSIBLE EXTENSIONS

Take students outdoors and ask them to listen to the soundscape and its dynamics. Ask them what animals exist there, how they are communicating, and how they are sharing their acoustic environment. Ask them to find any sources of noise and to explain how the noise might affect animal communication.

ADAPTATIONS FOR ACCESSIBILITY

Using an unobstructed area is preferable for this activity and having extra assistants can ensure student safety from accidental collisions.

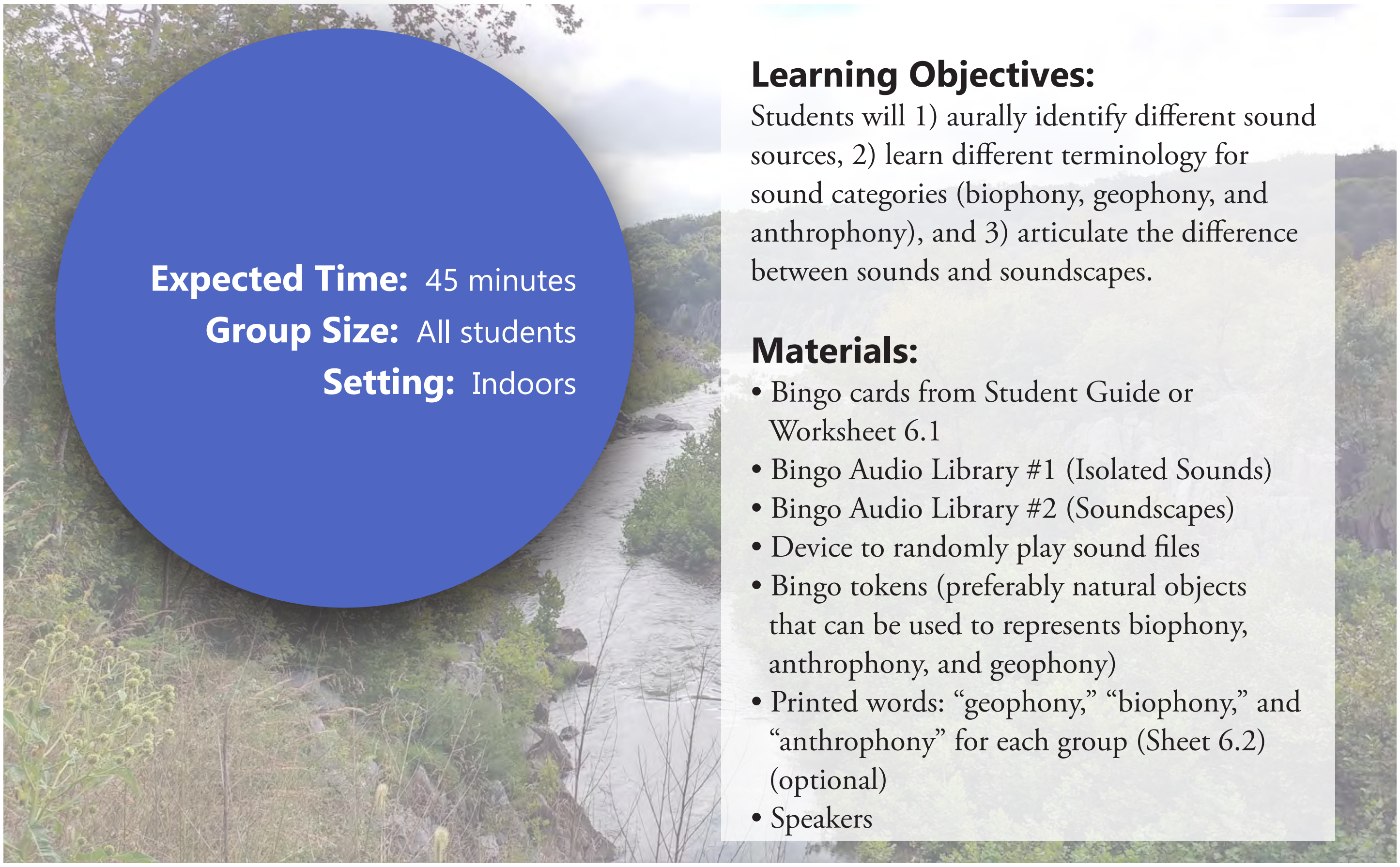
BRAIN DUMP

Following the completion of the hands-on activities, students should complete a “brain dump” reflection.
Reflection: What does noise mean to you, and how do you feel about it? Is there any noise that you enjoy?

Chapter 3

SOUNDSCAPES AROUND US

Everywhere we go, we are surrounded by diverse sounds. Some sounds are dominant, such as the sound of wind in deserts and the sounds of traffic and people talking in large cities. Some sounds are linked to specific places or times (e.g., morning birdsong in forests and spring evening croaking of spring peepers near wetlands). The combination of all sounds in a specific location and at a specific time period is called a soundscape. Soundscapes change over space and time, as they are unique to different ecosystems and times of day or year. Activities contained here focus on getting students to improve observational skills in several experiential settings.



Expected Time: 45 minutes
Group Size: All students
Setting: Indoors

Learning Objectives:

Students will 1) aurally identify different sound sources, 2) learn different terminology for sound categories (biophony, geophony, and anthrophony), and 3) articulate the difference between sounds and soundscapes.

Materials:

- Bingo cards from Student Guide or Worksheet 6.1
- Bingo Audio Library #1 (Isolated Sounds)
- Bingo Audio Library #2 (Soundscapes)
- Device to randomly play sound files
- Bingo tokens (preferably natural objects that can be used to represents biophony, anthrophony, and geophony)
- Printed words: “geophony,” “biophony,” and “anthrophony” for each group (Sheet 6.2) (optional)
- Speakers

Activity 6: Audio Bingo

Forests, oceans, wetlands, deserts, and other ecosystems host particular species adapted to these particular environments. The biodiversity of a given ecosystem can include both native and exotic species that contribute to the unique soundscapes of that ecosystem. A soundscape is the collection of all sounds in a particular place over a certain time period.

We can say that soundscapes on Earth are composed of three broad categories of sounds:

- Geophony—the sounds created by non-biological natural elements like wind, running water, and seismic events.
- Biophony—the sounds produced by animals like frogs, wolves, geese, and crickets.
- Anthrophony—the sounds produced by humans (e.g., talking and laughter) as well as those produced by human-built machines like cars, musical instruments, and construction equipment.

Within each of these three categories, sounds can be quite diverse due to varying methods of sound production and differing environmental conditions that affect sound propagation.

A soundscape” is the combination of all the sounds happening at a given place over a given period of time. Earth is home to a wide variety of soundscapes! For example, city soundscapes are composed of honking cars, laughing humans, and peeping sparrows. Desert soundscapes consist of howling wind, chirping crickets, and rumbling thunder. Natural and human-made sounds both contribute to soundscapes. One can think of any soundscape as a mix of anthrophony (human-produced sounds), biophony (non-human animal-produced sounds), and geophony (atmospheric and geophysical sounds) (Figure 11.1).

INSTRUCTOR DIRECTIONS

This activity is composed of two parts. There are two audio libraries—one that contains isolated sounds and another that contains soundscapes. The first part encourages students to listen to recordings and identify sound sources. In the second part of this activity, students categorize sources of sounds within soundscapes.

Pre-Activity

Load all sounds to a playback device. Connect to speakers, and test functionality. If students do not have Student Guides, print bingo cards. Optionally, ask students to go outside to collect different natural items like pebbles, small sticks, or acorns to use as tokens.

Activity Part 1: Bingo!

1. Print bingo cards if students do not have Student Guides. (Worksheet 6.1).
2. Instruct students to be silent and attentive to all the sounds around them during the game.
3. Have students fill out one bingo card using the list of sounds given in Table 6.1.
4. Load Audio Library 1 on a computer or MP3 player that is connected to speakers.
5. Using the shuffle feature on the playback device, play the sounds.
6. Note which sounds have been played to keep track of correct answers. This list will be used validate a winner's list at the end of the game.
7. Students will place a token on each space that matches a sound they heard.
8. The objective of the game is to place a token on every space.
9. When a student completes their bingo card, they should shout "AUDIO BINGO!" The winner(s) will then read sounds on their card to verify their win. If they would like, they can also recreate the sounds.
10. Repeat the game, but use Bingo Audio Library 2, and have students create their bingo cards using sounds in Table 6.2. In this version, there may be multiple sounds in each sound file, and students can mark as many sounds as they can distinguish.

KEY QUESTIONS

What is the difference between a sound and a soundscape?
If students have difficulty explaining the difference, play one sound followed by one soundscape (from Audio Library 2), and ask students how they would differentiate between the two.
Answer: A sound has one source while a soundscape is composed of different sources.

TEST YOUR KNOWLEDGE

Following the completion of the hands-on activities, students should complete a worksheet about the content of this activity.

Table 6.1. Sounds in Bingo Audio Library 1

Geophony	Biophony	Anthrophony
Avalanche	Bees	Airplane
Breaking ice	Cicadas	Applause
Bubbles	Crows	Breaking plate
Falling tree	Dogs	Clock
Hail	Dolphins	Creaking door
Lightning	Horse	Eating carrot
River	Lemurs	Evil laughter
Splashing water	Lions	Fireworks
Thunder	Parrots	Footsteps
Wildfire	Rattlesnakes	Guitar
Waterfall	Red squirrel	Laughing baby
Wind	Roosters	Opening soda bottle
	Snapping Shrimp	Piano
	Starlings	Traffic
		Train
		Typing
		Vibrating phone
		Yawning

Activity Part 2: Categorize Sound

1. Without defining the terms "biophony," "geophony," and "anthrophony," ask students to categorize the sound sources on their bingo cards. Students might follow the divisions of biophony, geophony, and anthrophony, or they might invent their own classification systems.
2. The instructor can provide more hints if students are confused. One can ask students about natural and human-made sounds or about the difference between birdsong and rain, as both are natural.
3. Before giving students the new terms, ask them to explain the reasons behind their own classifications. Possible invented classifications might include:
   - Sounds I like vs. sounds I don't like
   - Loud sounds vs. soft sounds
   - Sounds I have heard vs. sounds I have never heard
   - Natural sounds (both biophony and geophony) vs. human-made sounds (anthrophony)
4. Pass out the three term cards, "biophony," "geophony," and "anthrophony," (Worksheet 6.2), or write these terms on a whiteboard or flipchart without defining the terms (Appendix B). Explain to students that scientists use these three categories to discuss components of soundscapes and ask students to discuss which sounds from the bingo cards they might place in which category. In this way, students can discuss the terms and draw connections between past knowledge of concepts like "biology" and "geology" with the new terms, "biophony" and "geophony." Encourage students to share their ideas with their group members.
5. Check their answers and explain the meaning of each category. Ask students to provide examples of sounds within each category.
6. Ask students to compare this classification system with their own systems and to consider how this system might be superior or inferior to their own systems.
7. Ask if this system presents any problems.
8. Play some of the soundscapes from Bingo Audio Library 2 and ask them to dissect the soundscape and categorize the sources of sound using scientific terminology.

KEY QUESTION

How might biophony, geophony, and anthrophony differ between ecosystems?
Answer: Different landscapes and structures within ecosystems provide habitats for various species which produce varying levels of biophony, and climate strongly affects geophony. Some ecosystems like temperate forests are more accessible to humans, so they are full of anthrophony while other ecosystems like tundra are less accessible and less affected by human sounds.

POSSIBLE EXTENSIONS

- Ask students to mimic one of the soundscapes from Sound Library 2. Each student can choose to produce one of the sounds within the soundscape, and together they can produce the soundscape. Record their sounds, play back the recreated soundscape, and compare it with the original.
- Take students outdoors to experience the sounds in their surroundings. Ask them to categorize sounds as biophony, anthrophony, or geophony.
- Create customized sound bingo cards for your local area. Distribute cards to students with clipboards or weights, and bring students outdoors with the custom cards. Play bingo counting any sound when it is heard in the live outdoor soundscape.

ADAPTATIONS FOR ACCESSIBILITY

Use braille cards.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: List some of the common sounds around you. Are they biophony, geophony, or anthrophony?

Worksheet 6.1: Bingo Cards

B	I	N	G	O

B	I	N	G	O

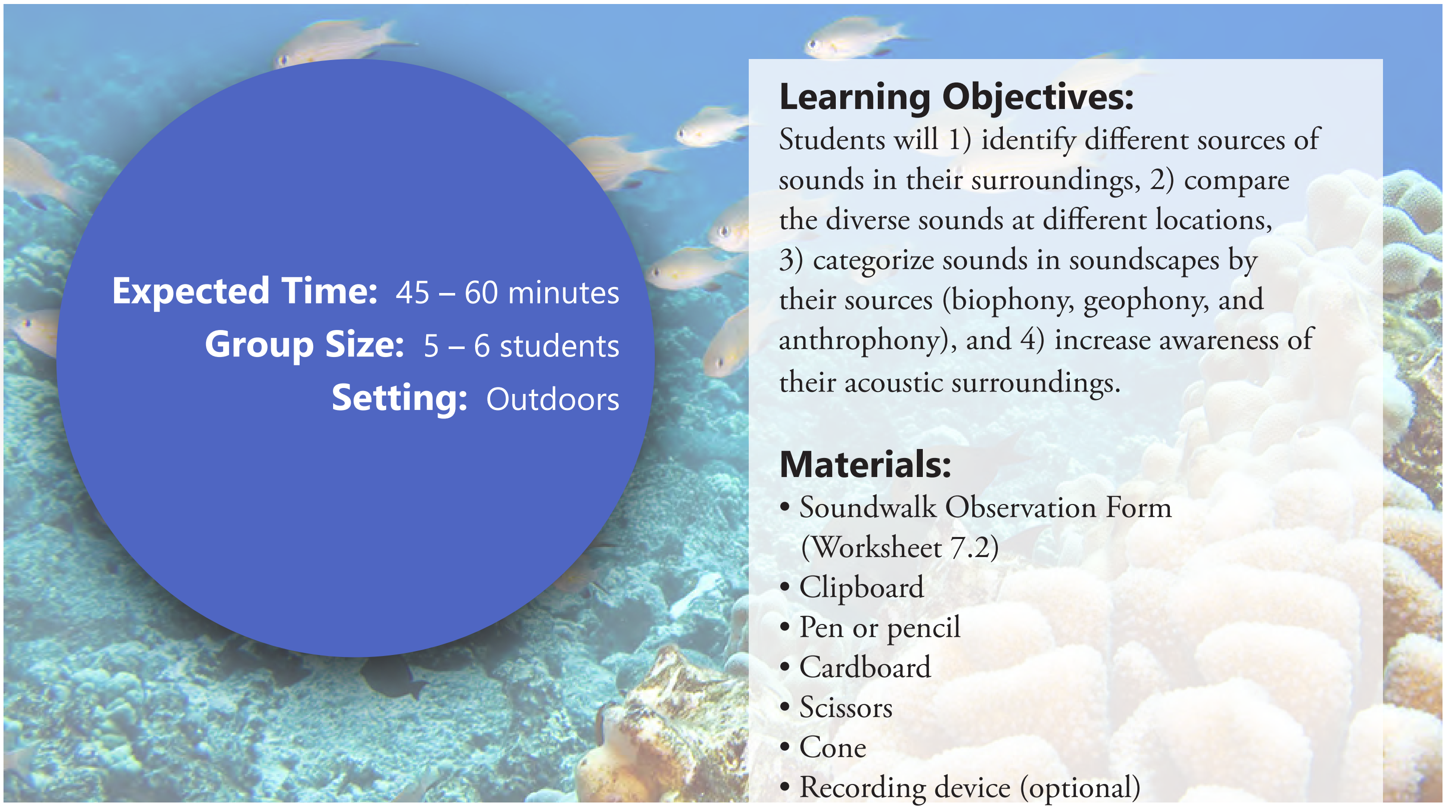
Worksheet 6.2: Sound Categories

Worksheet 6.2: Sound Categories (continued)

Biophony

Worksheet 6.2: Sound Categories (continued)

Anthrophony



Expected Time: 45 – 60 minutes
Group Size: 5 – 6 students
Setting: Outdoors

Learning Objectives:

Students will 1) identify different sources of sounds in their surroundings, 2) compare the diverse sounds at different locations, 3) categorize sounds in soundscapes by their sources (biophony, geophony, and anthrophony), and 4) increase awareness of their acoustic surroundings.

Materials:

- Soundwalk Observation Form (Worksheet 7.2)
- Clipboard
- Pen or pencil
- Cardboard
- Scissors
- Cone
- Recording device (optional)

Activity 7: Sound Walk

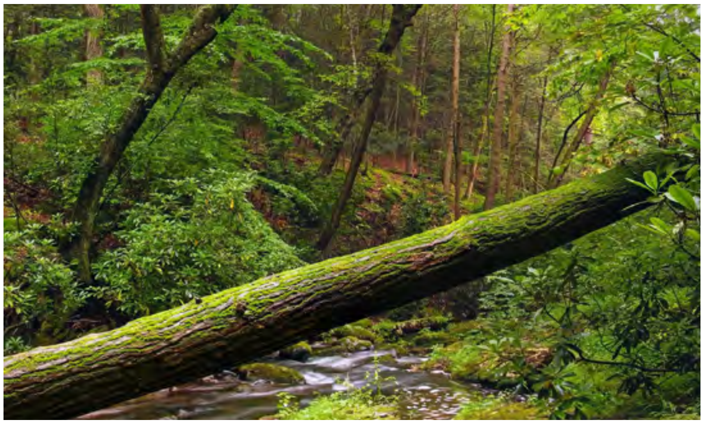
Sound walks were originally conceived by teachers of music and the visual arts. The main purpose of an ecological sound walk is to actively listen while walking in a natural setting. Have you ever noticed how the sound of a river changes after a rainy day? What about the chorus of birds at sunrise? Why does the environment sound quieter after it snows?

Soundscapes reflect the identity of landscapes. The acoustic identity of each ecosystem reflects and affects the quality of the area for both wildlife and people. Through intentional listening, people can develop a sense of place and greater attachment to nature and certain locations. Sound walks allow for such intentional listening.

A sound walk is also a good method to introduce students to the fieldwork methods of soundscape ecology. Many soundscape ecologists spend hours listening to the soundscapes of a place. During the sound walk, encourage your students to listen to local sound sources. This experience will not only enhance their connection to nature, but also develop their awareness of spatial variation in soundscapes and their geographical orientation in a certain place.

Sound walks can take place anytime and anywhere—during the day or night, in a park, in a forest, or even in a street! Every environment has its own unique soundscape, be it a rich, biologically diverse soundscape in a rain forest or a busy, human-dominated soundscape in an urban area. Sound walks can be part of an everyday routine. They are spatial activities that combine visual and aural perception of landscapes, and they can help students to better appreciate natural spaces.






INSTRUCTOR DIRECTIONS

This is a field activity that encourages students to open their ears and listen to their surrounding soundscapes. They will learn how to make observations by trusting their sense of hearing.

Pre-Activity

Choose several locations that will serve as places to stop and listen during the sound walk. It is highly recommended that these sites be located in places associated with different soundscapes (e.g., close to a pond, in the middle of a forest, or close to a road) so that students are exposed to different soundscapes. Ask students to make the "viewfinder" and "sound finder" before the sound walk, and explain how they can be used for focused listening (Worksheet 7.1).

Activity

During the sound walk, students should not talk, though they can communicate by quietly mimicking sounds they hear or by pantomiming. Each group can choose a signature call (preferably a local biophonic or geophonic sound so that they can easily find their group members without disturbing the natural soundscape).

Before leaving, provide materials for students to build their viewfinder and sound finder (Worksheet 7.1). "Warm up" students' ears with the following exercises:

1. Have students cover their ears with their hands for 20 seconds, and then ask them to remove their hands. This action helps them to calibrate and focus on their sense of hearing.
2. Ask them to listen to the sound that is nearest to them and then to the sound that is farthest from them.
3. Ask them to focus on the sounds they hear with their left ear and then with their right ear.
4. Ask them to listen to sounds behind them.

5. Ask students if there are any continuous sounds around them.
6. Ask if there are any sounds that are periodic (occur in a pattern) or random.
7. Ask students to close their eyes, and ask if they hear anything differently with their eyes closed.
8. Ask them to limit their field of vision with their hands or a viewfinder, and ask if this changes what they hear.
9. Ask them to use the sound finder, and ask if it affects their hearing. Listening devices from Activity 3 can also be reintroduced if desired.
10. Take students to each site, and stay for several minutes (at least two minutes per site) of focused listening. Students can arrange themselves in a circle; they can face inward to communicate or outward if the group has problems focusing.
11. At each site, students should categorize the sounds they hear on their observation form (Worksheet 7.2).
12. On the way back to the starting location, ask some follow-up questions:
    - Which categories of sound (geophony, biophony, and anthrophony) did you hear and note on your observation form?
    - Which category was most prominent? Which was rarest?
    - At which site did you hear your favorite soundscape? Why?
    - Which soundscape was your least favorite? Why?
    - Were there any sounds that you could not identify?
    - How did your silence shape your experience?
    - Compare the soundscapes of the different sites you visited. What might explain any similarities or differences you noticed?

KEY QUESTIONS

If you could alter one of the soundscapes you heard, what sounds might you add or remove? Why?
Answers will vary.
Did you make any sounds like footsteps or rustling of clothes that contributed to the soundscape?
Answers will vary.
If you were an animal such as bird or frog, in which place that we visited would you choose to live? Why?
Answers will vary.
How might the loss of biodiversity alter the soundscape?
Answer: Disturbances like human development, climate change, and invasive species affect biodiversity negatively. If biodiversity declines, biophony will decline as well.
What might this area have sounded like before human development?
Answers will vary.

POSSIBLE EXTENSION

Sound walks can be modified in a number of ways. Here are a few possibilities:

- Record different sounds during the walk.
- Go to different locations to explore new sounds.
- Use the same locations at different times of day to see how some sounds change over time.
- Have students change their physical positions while at a site (in a circle, line, lying down, etc.).
- Have students describe the differences between sounds at different locations.
- Have students write in a journal about the soundscape in greater detail.
- Have students write poems about soundscapes.

ADAPTATIONS FOR ACCESSIBILITY

- Choose accessible sites, and/or allow students input to guide site selection.
- Clarify the route of the sound walk before starting.
- One assistant per group may be needed to complete the students' observation forms.

BRAIN DUMP

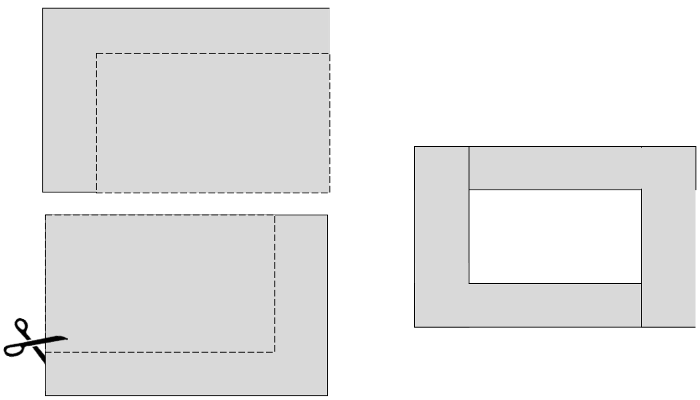
Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: What is your favorite location? Describe it's soundscape.

Worksheet 7.1: How to Make and Use a Viewfinder and a Soundfinder

Materials: Scissors, 2 pieces of rigid card stock, pencil, ruler, paper clip

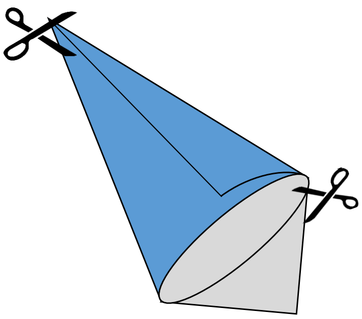
How to Make the Viewfinder

- With a ruler, draw two L-shapes on the card.
- Cut out the two L-shapes with scissors and put the Ls on top of each other to make a window.
- Use a paper clip to hold the pieces together.



How to Make the Sound Finder

- Cut and fold an 18" x 24" sheet of paper to make a cone, as shown below.
- Use a paper clip to hold the cone together.



How to Use the Viewfinder

- Hold your viewfinder in your hand or make a frame with your hands.
- Look through its window at the landscape, pan around the landscape, and adjust the size and shape of the viewing window.
- Look at different views, until you find a view that you like.
- Hold the viewfinder or your hands steady and focus your ears to hear the sounds that are coming from the area you can see.
- Reset your viewfinder and focus on how the sounds you hear change as you change the content in your viewing window.

Worksheet 7.2: Soundwalk Observation Form

Name:

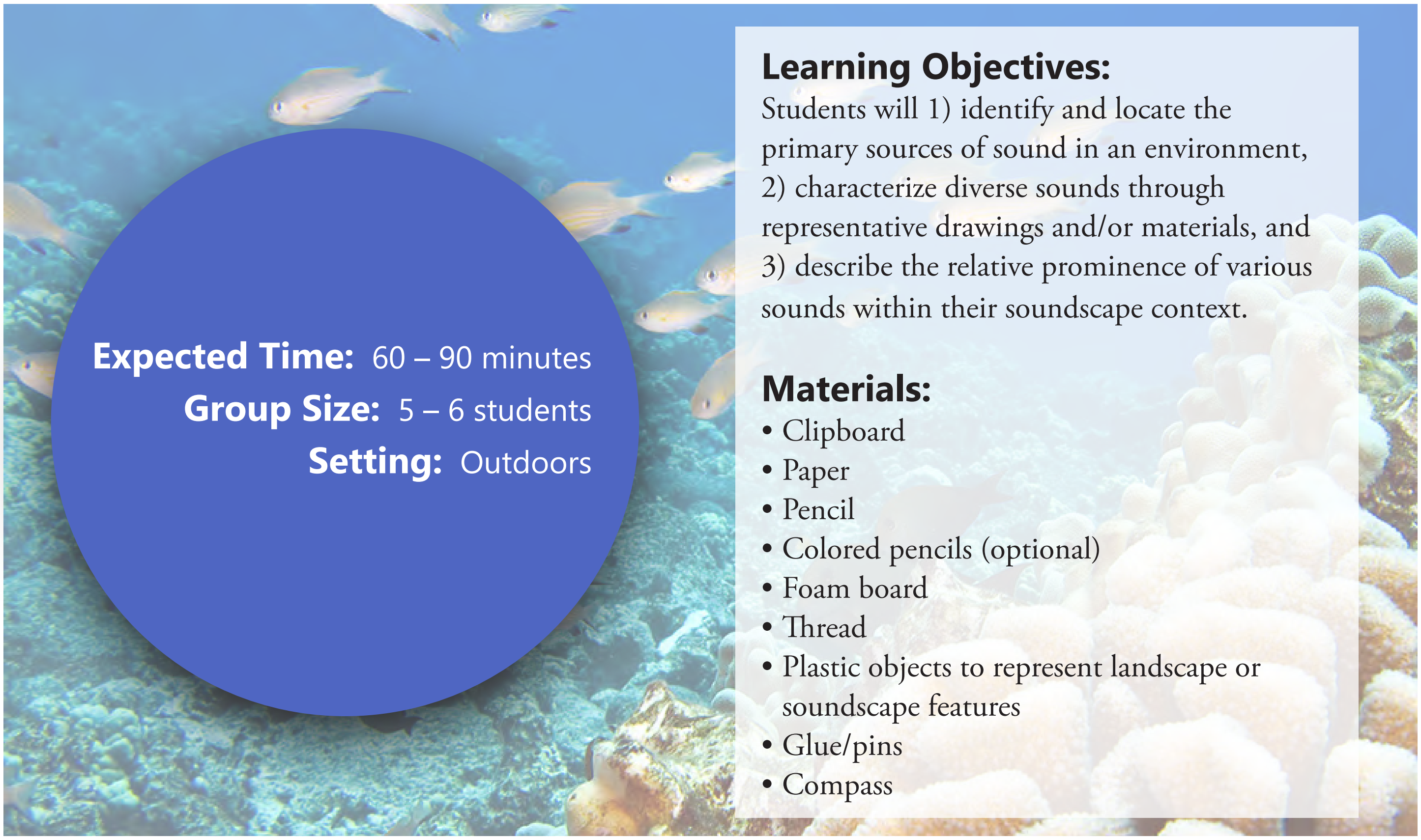
Date:

Time:

At each site, list all of the sounds in your surroundings and put them in one of the categories below.

Keep a tally of every kind of sound you hear on your walk. Which sound did you hear the most?

	Natural Sounds				**Human-made Sounds**	
	Biophony	Tally	Geophony	Tally	Anthrophony	Tally
Site Name	e.g., bird sounds 		e.g., rain sounds 		e.g., car sounds 	



Expected Time: 60 – 90 minutes
Group Size: 5 – 6 students
Setting: Outdoors

Learning Objectives:

Students will 1) identify and locate the primary sources of sound in an environment, 2) characterize diverse sounds through representative drawings and/or materials, and 3) describe the relative prominence of various sounds within their soundscape context.

Materials:

- Clipboard
- Paper
- Pencil
- Colored pencils (optional)
- Foam board
- Thread
- Plastic objects to represent landscape or soundscape features
- Glue/pins
- Compass

Activity 8: Sound Map

It might seem difficult to imagine the soundscape of a place, let alone visualize that soundscape. However, just as we can map landscapes, we can also map soundscapes. Sound maps can take many forms, but at their base, they are acoustic representations of a location. Mapping the soundscape of a location allows us to gain a better sense of that place's acoustic identity, and it helps us to better understand how sound relates to other features of the landscape. Sound maps can be made for any environment such as forests, mountains, or even train stations in large cities. Sound mapping, the process of going out and making a sound map, is similar to a sound walk. Both activities require active listening and contemplation of the connection between the soundscape and the environment.

Let's say you are walking on a trail in a neighborhood park. You hear sounds coming from various directions. There is a fast-flowing river gurgling to your left, and to the right, three rowdy crows caw atop a maple tree that is shaking in the wind. Overhead you hear the dull roar of an airplane, and right in front of you there is a Chihuahua barking at a St. Bernard.

You can map all of these sound sources and the areas over which they propagate. An airplane or rainstorm will cover a large area within a landscape, while the sounds of sparrow chicks chirping in their nests will not travel very far. You can show the coverage, direction, intensity, and duration of sounds by using different colors, shapes, and/or patterns. There are different ways to make a sound map. Maps can be two- or three-dimensional. They can be simple if they only map sound sources and their coverage, or they can be more complex if they include features like sounds' duration, loudness, pitch, timbre, or pleasantness (Figures 8.1 and 8.2). Maps should also include the main physical elements of the landscape, such as trees, roads, or buildings.

INSTRUCTOR DIRECTIONS

In this activity, students will learn how to make 2D or 3D maps of their surrounding soundscapes. In a 2D map, students can draw different sound sources by using symbols such as wavy lines for wind, leaves for rustling leaves, and even question marks for unidentified sounds. In a 3D map, students can either find or make objects that symbolize the various sound sources. Students should also make legends for the symbols on their maps. Instructors should pick out several sites in advance that students can explore in order to make sound maps. A new map can be made for each listening site, or students can contextualize multiple sites on a single map Students will map out the distribution and direction of key sounds in a given area. Sound maps can be part of the sound walk activity (see Activity 7), but instead of writing, students can produce maps of sound sources.

1. Divide students into groups of two to three, and bring each group to a predetermined site.
2. Begin by having students note the location, date, and time at the top of their maps, and use a compass to record the cardinal directions. A compass rose will help keep the maps accurate and well-oriented once students start moving between sites and adding map features.
3. Have students create a base map by noting several key landmarks such as buildings or roads. If creating 3D maps, provide materials such as small manipulatives like buttons, string, and small pieces of wood (Figure 8.2).
4. Make sure students are comfortable and ready to listen and draw.
5. Have students note each listening location in relation to the landmarks on their maps.
6. Brief students with the following instructions before beginning at each site:
    a. Close your eyes and listen intently for two minutes.
    b. When asked to open your eyes, begin marking the sounds that you heard during the two-minute listening period.
    c. Choose different colors, symbols, or objects to signify different sound sources. The characteristics of these symbols can relate to characteristics of the sounds (e.g., larger symbols representing higher amplitude, lighter colors representing higher frequencies, different shapes representing different timbres). Include a legend.
    d. Remain quiet during this process.
    e. When marking sounds' locations on the map, consider direction, coverage, and distance of the sound source.
6. After completion of the first map, take students to the next site and ask them to make a more comprehensive map or add to the existing map.
7. After a sufficient period of time when students feel they have completed their maps, allow them to share their maps with others and to discuss what they have heard and mapped.

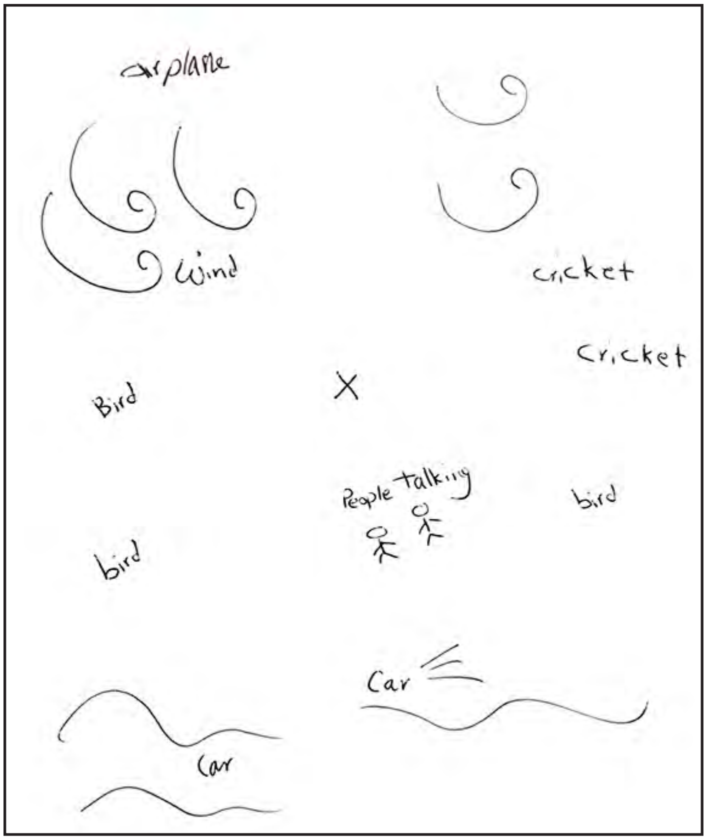


Figure 8.1. Sample 2D sound map.

KEY QUESTIONS

How many different sounds did you hear?
Answers will vary.
What continuous, periodic, or random sounds did you hear?
Answers will vary.
Could you identify all the sounds you heard?
Answers will vary.
Did you notice any sounds overlapping in time? What might be the consequence of such overlap?
Answers will vary.
How might your map be different if you were to sit somewhere else?
Answers will vary.
How might your map be different at another time of day or during another season?
Answers will vary.
How might a loss of biodiversity change the sounds you heard?
Answer: Disturbances like human development, climate change, and invasive species affect biodiversity negatively. If biodiversity declines, biophony will decline as well.
How might climate change alter the sounds you heard?
Answer: Climate change alters weather, landscapes, and the timing of biological processes. Changes in weather and landscapes would affect geophony and the community of species that might inhabit a certain area. Changes in the timing of biological processes would mean that sound production events associated with mating, foraging, and migration might occur at different times.
What might this area have sounded like before human development?
Answers will vary.

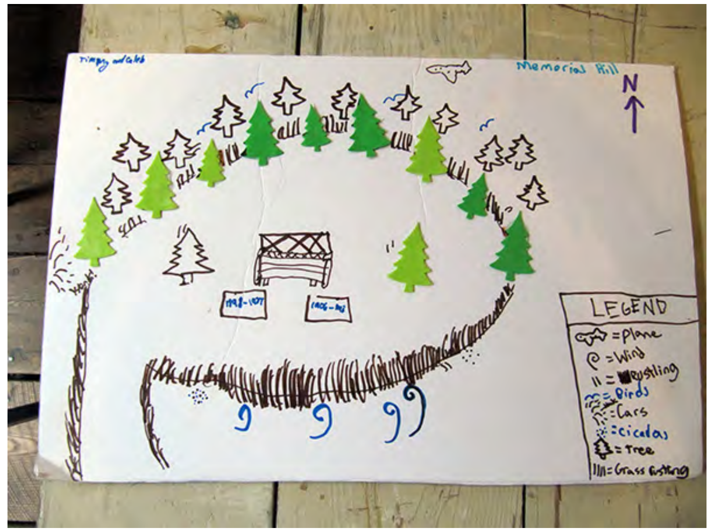


Figure 8.2. Sample 3D sound map.

POSSIBLE EXTENSIONS

- Students can make and compare sound maps for different sites or for the same site, but different times of the day or days of the week.
- Students can join several sound maps of limited spatial coverage to create a detailed map of the broader area.

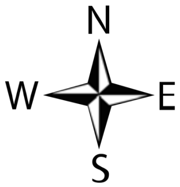
ADAPTATIONS FOR ACCESSIBILITY

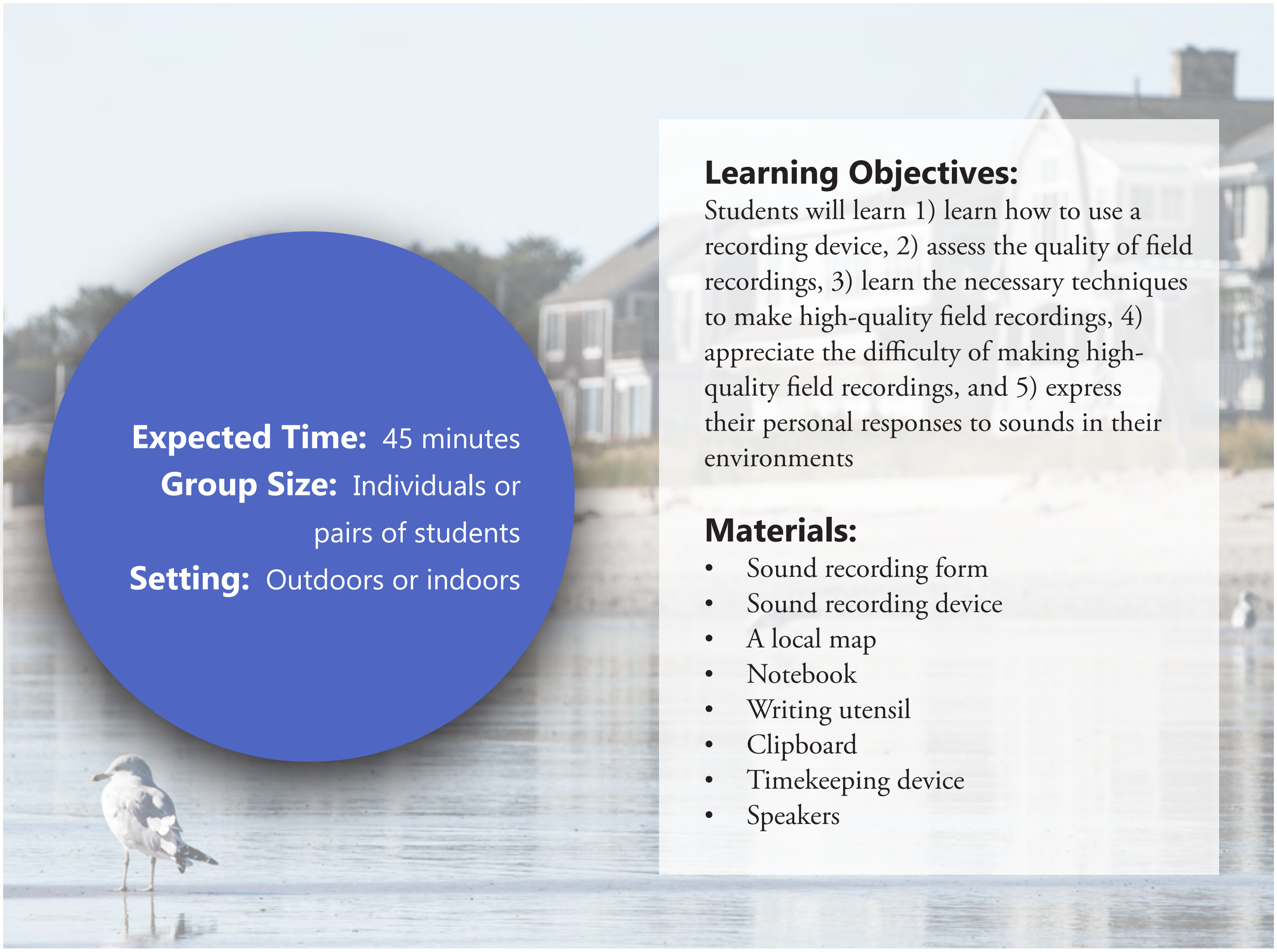
- One assistant per group may be needed for walking to different sites.
- Provide either Picture Maker or the Tactile Drawing tool for each student to customize his/her own map.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: Draw a sound map of a place you visit regularly (like your classroom or home). Then, listen and see if your sound map matches the location.

Worksheet 8.1: Blank Sound Map





Expected Time: 45 minutes
Group Size: Individuals or pairs of students
Setting: Outdoors or indoors

Learning Objectives:

Students will learn 1) learn how to use a recording device, 2) assess the quality of field recordings, 3) learn the necessary techniques to make high-quality field recordings, 4) appreciate the difficulty of making high-quality field recordings, and 5) express their personal responses to sounds in their environments

Materials:

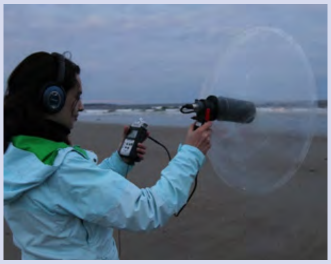
- Sound recording form
- Sound recording device
- A local map
- Notebook
- Writing utensil
- Clipboard
- Timekeeping device
- Speakers

Activity 9: Sound Scavenger Hunt

A good recording is necessary for soundscape ecology research. While small hand-held recorders and cellphones can sometimes provide satisfactory recordings, soundscape ecologists typically use programmable recorders that can be left out in nature for months at a time (Figure 9.1). These units record automatically, making it possible for soundscape ecologists to collect data over long periods of time. This enables researchers to investigate phenomena such as climate change or invasive species, which can be best understood through long-term monitoring.

ZOOM H1
HANDY RECORDER
This unit records in stereo (two microphones, two channels) and is easy to carry.

SURROUND-SOUND
MICROPHONE ARRAY
Surround sound records from four or more different directions to create very immersive recordings.



ZOOM H4
WITH PARABOLIC DISH
This special-shaped dish focuses sound onto the microphone. The dish collects sounds from the direction in which it is pointed.

SONG METER 2
This recorder is used for long-term acoustic monitoring. It has a customizable schedule and can record in stereo.

Figure 9.1. Different types of recorders used by soundscape ecologists.

Soundscape studies depend on high-quality soundscape recordings. Data quality can usually be controlled through the choice of recording equipment and techniques. Some of soundscape ecology's founders were experts in field recording—that is, the art of recording sounds outside of the controlled environment of a recording studio.

Field recording is an outdoor challenge that requires patience, thoughtfulness, and a sense of adventure. It also raises a number of questions: What do you want to record? Where can you find those sounds? When is the best time to record them? What kind of equipment should you use?

If you are a novice field recordist, try recording in a nearby park or favorite place. Then, back at home, listen to what you recorded. Evaluate how you might be able to improve your recordings.

Become familiar with when different animals are acoustically active. In the morning, especially in the spring, many birds sing during the dawn chorus. At night, you can record owls, bats, and many types of insects. Frogs are most vocal during spring and summer. Geophony also changes throughout the year. During the summer you might be able to record loud thunderstorms, and during the winter you can record the sounds of icicles dripping or the soft sounds of snowfall.

There are many different recording formats that each have pros and cons. Higher-quality recordings will generally take up more space on your computer or memory card. If you want to save your files with the highest quality, use a lossless file format. ".wav" and ".aiff" are the best options. Compression reduces the size of the file, but it also reduces the quality of the recording. ".mp3" is the most common compressed format for audio recordings.

HOW TO IMPROVE RECORDINGS OF NATURAL SOUNDS

1. Check, double-check, and recheck the double-check

Before you head into the field (any outdoor recording site), make sure that you have everything you’ll need for the day: a charged recorder, microphones, batteries, cables, headphones, available file storage space (internal or SD cards), recorder mounting equipment, a notebook, pen, and any other tools that you might need. If you are going to an unfamiliar location, bring a map and compass or a GPS. Don’t forget to check the weather forecast, dress properly for the weather, and bring water and snacks if you will be out for an extended period of time!

2. Be quiet!

In the field, try to be quiet so as not to spook any of the animals that you are trying to record. Be patient when you are recording! Plan to spend thirty minutes to a few hours during each recording session. Some sounds will repeat many times, so you will have ample time to capture them; other sounds are very rare. It takes patience, skill, and luck to record a rare or mysterious sound or soundscape!

3. Hear with your ears, not your eyes!

Your microphone doesn’t care about what you see! Think about what it is that you want to record, and then use your ears to find the place that sounds best. Practice: let’s say you’re on the beach and want to record the ocean. Do you want to record the distant thundering of the waves, or the trickle of the white-foam as it bubbles over the sand? Trust your ears. Listen through headphones connected to your recorder to make sure that you are recording what you want.

4. Set your gain levels right!

You need to adjust some settings on your recording unit before you press the record button. One of the most important settings is gain, which controls the strength of the signals that are recorded. Find the buttons that control the gain setting on your recorder. The gain level you set should depend on the loudness of the soundscape. If the soundscape is loud, lower your gain levels. Loud sounds have the potential to overload the microphone/recorder and cause clipping. Clipping means that a part of your sound isn’t recorded, and it can ruin your recording. At the same time, setting gain levels too low reduces the quality of the whole recording. It takes practice to get the right gain level. Ideally, you can visually monitor the sound levels on your recorder. You generally want the loudest sounds to register between -20 dB and -6 dB.

5. Hands off. Step away from the microphone!

Once you’ve found your recording site and the place for your recorder, decide how you can stabilize your recorder. Some scientists use a tripod, and others use wire to secure the device to a tree, while some just place the recorder somewhere secure. Hand-noise will ruin a good recording. Move quietly from the recorder—the farther away the better—but only if you’re sure that the recorder is safe. Even if you can’t get a few hundred feet away, just setting the recorder down will make a world of difference.

6. Make voice-notes

Record a voice-note at the beginning of each recording. Tell your future self when, where, and what you are recording. Then while recording, write down notes of any interesting sounds that occur, and mark the approximate time of occurrence. Also, make sure the time and date on your recorder are correct before you start recording!

7. Listening makes perfect

After a few minutes, listen to what you've recorded while you're still in the field. Check if the gain settings were too low, or if a low-flying plane rumbled past and ruined the best part of your recording. Perhaps you forgot to press record. It happens to all of us. Listening to your recordings and experimenting with different microphone locations based on what you hear is how you become a field-recording master. Trust your ears.

INSTRUCTOR DIRECTIONS

In this activity individuals or pairs of students will explore their surroundings to "collect" different sounds and soundscapes. This activity is designed to employ sound recording tools, such as specialized microphones or cellphones/tablets; however, in case a recorder is not available or not working properly, students can participate in the listening part of the activity by using Sheet 9.1.

1. Provide each student or group with a sound recording form (Worksheet 9.1), recording device, and timekeeping device.
2. If necessary, instruct students on how to use the recording and timekeeping devices.
3. If using tablets or smart phones as a recording device, download the Center for Global Soundscapes' app, "Record the Earth," (or another recording app), and use it to make your recordings. If students have access to different types of microphones, let them explore recording with different tools.
4. Allot a certain amount of time, establish spatial boundaries, and send students off to record sounds.
5. The students should use the sound recording form as a scavenger hunt list—they should try to record as many sounds on the list as they can. Points are assigned to each sound. If they record a different sound that is not on the list, students can add the sound to the list.
6. The goal is to get as many points as possible, but students cannot count the same sound more than once. The student or group that has the most points is the winner.
7. Points are awarded based on the quality of the recordings, as low-quality recordings are difficult to analyze scientifically. The target sound should be easily identifiable. The recording should also have little to no handling noise or student sounds. The instructor should score each recording from 0 to 10 in the "Sound Quality Multiplier" column. The "Weighted Points" are the product of each sound's point value and the sound quality multiplier score for that recording. Remind students to check the quality of their recordings.
8. Students should also note their feelings about each sound and how easy it was to capture. They should also record voice-notes to describe the sounds they are capturing.
9. After participants have finished recording and filling out Worksheet 9.1 of the scavenger hunt, ask them to complete Worksheet 9.2. Give them the option of recording any other sounds from the environment or producing the sound and recording it.
10. Instructors can use Worksheet 9.3 to create custom sound lists.

KEY QUESTIONS

- Answers to the following questions will vary:
- How many different sounds did you hear?
- Could you identify all of the sounds that you recorded?
- How could you improve the quality of your recordings to ensure that all sounds in your recordings are identifiable?
- Which sounds were common or rare?
- Which sounds were easy or difficult to capture? Why?
- How did microphone placement influence the sounds you recorded?
- Did you use any unexpected or experimental recording techniques that improved the quality of your recordings or generated interesting recordings?
- What was your favorite recording? What was your favorite sound? Are they the same?
- How might the loss of biodiversity change the sounds you recorded?
- How might climate change alter the sounds you recorded?
- What might this area have sounded like before human development?

POSSIBLE EXTENSIONS

- Adapt this activity to a particular location by customizing the sounds and/or point values on the list (Worksheet 9.3).
- Ask students to collect rare sounds or soundscapes to make the activity more challenging.
- Ask students to find different combinations of sound types (e.g., a combination of biophony and anthrophony or a combination of anthrophony and geophony).
- Ask students to invent a novel way to use the recording device.

ADAPTATIONS FOR ACCESSIBILITY

- Show the recorder to each individual student, and teach each individual how to operate the recorder.
- One assistant per group may be needed for walking to different sites, helping students make recordings, and helping to complete the observation forms.

BRAIN DUMP

Following the completion of the hands-on activities, students should complete a "brain dump" reflection.
Reflection: What was one of your challenges in recording the sounds?

Worksheet 9.1: Sound Recording Form

Sound Recording Form						Instructor	
Sound	**Points**	**Check Mark**	**Like It or Not**	**Easy or Hard**	**Where You Heard It**	**Sound Quality Multiplier (0 – 10)**	**Weighted Points**
Bird	20	☐	👍 👎	☺ ☹			
Thunder	20	☐	👍 👎	☺ ☹			
Squirrel	20	☐	👍 👎	☺ ☹			
Cicadas	20	☐	👍 👎	☺ ☹			
Cricket	20	☐	👍 👎	☺ ☹			
Water	15	☐	👍 👎	☺ ☹			
Leaves rustling	15	☐	👍 👎	☺ ☹			
Wind	15	☐	👍 👎	☺ ☹			
Rain	15	☐	👍 👎	☺ ☹			
Electronic device	10	☐	👍 👎	☺ ☹			
Dog	10	☐	👍 👎	☺ ☹			
Cat	10	☐	👍 👎	☺ ☹			
People talking	10	☐	👍 👎	☺ ☹			
People walking	10	☐	👍 👎	☺ ☹			
Someone laughing	10	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			
....	5	☐	👍 👎	☺ ☹			

Worksheet 9.2: Record What You Feel

Sound Recording Form							Instructor	
Record a sound or soundscape that makes you:	**Name of Sound**	**Points**	**Check Mark**	**Like It or Not**	**Easy or Hard**	**Where You Heard It**	**Sound Quality Multiplier (0 – 10)**	**Weighted Points**
Happy		10	☐	👍 👎	☺ ☹			
Excited		10	☐	👍 👎	☺ ☹			
Curious		10	☐	👍 👎	☺ ☹			
Frightened		10	☐	👍 👎	☺ ☹			
Laugh		10	☐	👍 👎	☺ ☹			
Think		10	☐	👍 👎	☺ ☹			
Run		10	☐	👍 👎	☺ ☹			
Explore		10	☐	👍 👎	☺ ☹			
				👍 👎	☺ ☹			
				👍 👎	☺ ☹			
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Worksheet 9.3: Custom Sound Recording Form

Sound Recording Form						Instructor	
Sound	Points	Check Mark	Like It or Not	Easy or Hard	Where You Heard It	Sound Quality Multiplier (0 – 10)	Weighted Points
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
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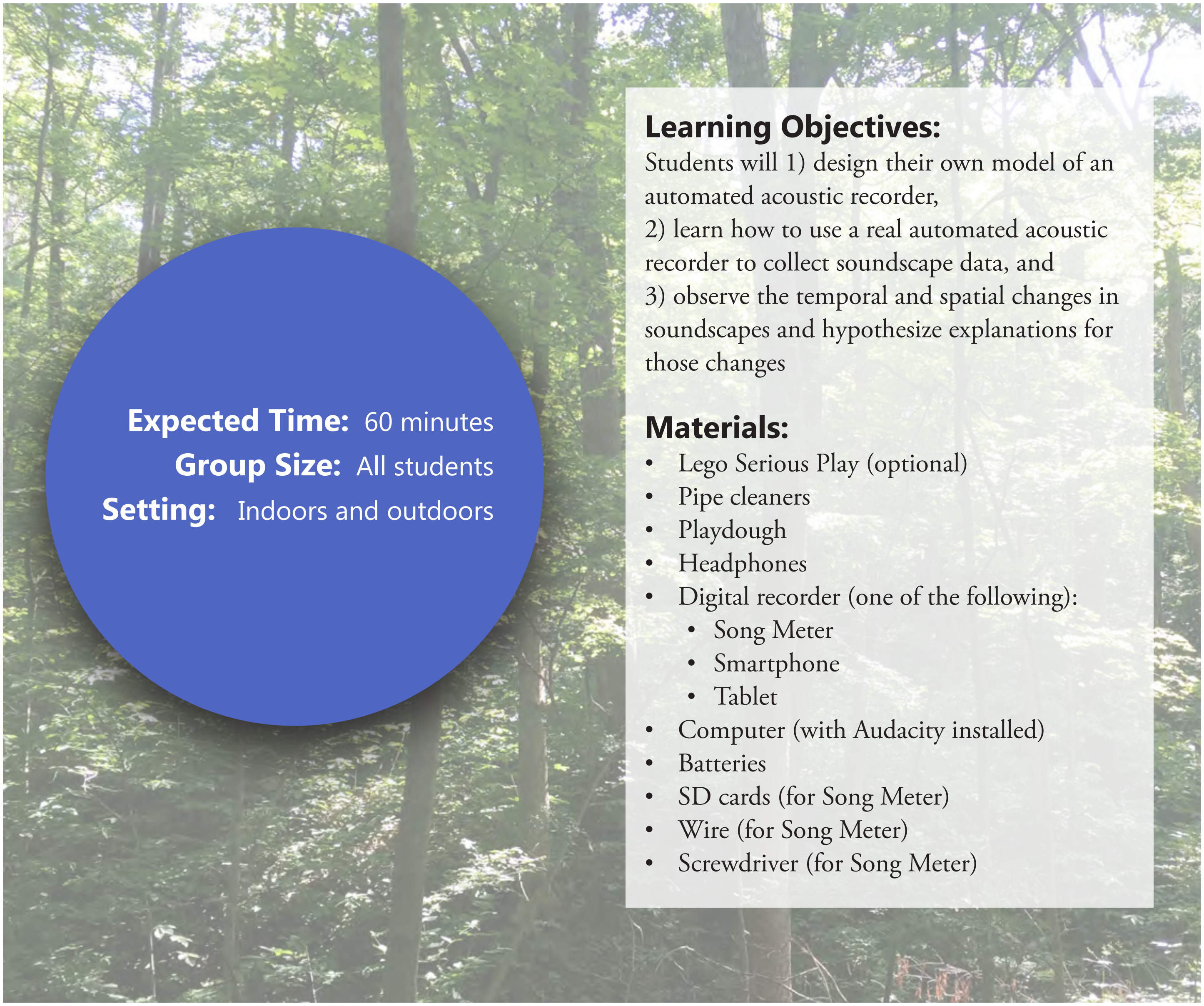


Expected Time: 60 minutes
Group Size: All students
Setting: Indoors and outdoors

Learning Objectives:

Students will 1) design their own model of an automated acoustic recorder,
2) learn how to use a real automated acoustic recorder to collect soundscape data, and
3) observe the temporal and spatial changes in soundscapes and hypothesize explanations for those changes

Materials:

- Lego Serious Play (optional)
- Pipe cleaners
- Playdough
- Headphones
- Digital recorder (one of the following):
    - Song Meter
    - Smartphone
    - Tablet
- Computer (with Audacity installed)
- Batteries
- SD cards (for Song Meter)
- Wire (for Song Meter)
- Screwdriver (for Song Meter)

Activity 10: Soundscape Data Collection

Almost all scientists use some forms of technology to collect their data. Microbiologists use microscopes to view tiny bacteria and ecologists use GPS to navigate in the field. Soundscape ecologists use technology to record soundscapes. Soundscape recording equipment essentially consists of two parts: a microphone and a recorder. Microphones convert sound to an analog electrical signal. Then, it is transmitted to the recorder where it is converted to a digital format and stored on SD cards.

Soundscape ecologists travel to diverse ecosystems—from deserts to rainforests—so their recorders need to be adapted to work in a wide range of climates. Most recorders used by soundscape ecologists for data collection are durable and weatherproof, can be programmed with custom duty cycles (recording schedules), and are designed with low power requirements. These features enable scientists to monitor wildlife in places that are otherwise very hard to access. For example, researchers studying the impact of human noise on whales use hydrophones—microphones that work underwater—to record whale sounds and boat noise for long periods of time hundreds of meters deep in the ocean.

A common device used by soundscape ecologists is an automatic acoustic sensor (Figure 10.1), "Song Meter" also referred to as an autonomous recording unit(ARU). Instructions for using a sensor is provided in Activity Instructions Part 2: Using a Recorder.

INSTRUCTOR DIRECTIONS

This activity can be one day or a part of multiple days. A recorder can be deployed in different locations each day as a way for students to participate in the collection of scientific data. This relocation provides an opportunity for participants to record at a diversity of sites. They can switch memory cards each morning in order to listen to the previous day's recordings. They can also participate in choosing recording locations.

While conducting this activity with a Song Meter or another automated field recorder is preferable, it is not necessary. If you do not have such a device, a non-automated, non-weatherproof recorder, a smartphone, or a tablet can be used instead. If using such an alternative, adapt the activity so that the recorder is not left outdoors in inclement weather or for longer than it can actually record based on storage, battery, and software limitations.

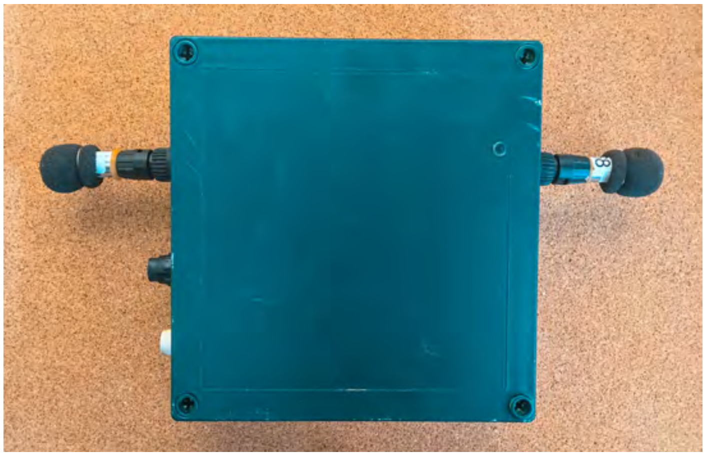


Figure 10.1. A Song Meter is an automatic acoustic sensor.

Part 1: Design a Recorder

1. Start the activity by asking the following questions:
   - How do scientists record soundscapes?
   - How would you design a tool that would help scientists to record soundscapes?
2. Provide paper and pencils for students to design their models.
3. Give them some prompts to promote them to work on their models by asking how scientists can record for long periods of time, in harsh weather conditions, in many locations at the same time, and even underwater.
4. Provide more materials (such as Lego Serious Play, pipe cleaners, and/or playdough) that can help them to make their models.
5. Ask them to consider the following questions and to share their models with their peers. When they finish, ask them to answer these questions:
   - How does the recorder work?
   - What is its energy source?
   - How long can it work?
   - How can you deploy it in nature?
6. Allow students some time to modify their models and then provide some time for them to compare their designs.
7. Write down or highlight the main criteria that they considered in their designs.

Part 2: Using a Recorder(see information sheet 10)

1. Show a Song Meter or photos of a Song Meter to the students
2. Explain that it is an automated acoustic recorder and what that means. If you do not have access to a Song Meter, skip to Step 9.
3. Let them know that there are different kinds of recording units but that the one they will use is called a "Song Meter."
4. Open the Song Meter and let them guess the functions of the different parts and controls inside the box.
5. Name and explain the main parts of the Song Meter.
6. Turn the Song Meter on and demonstrate some basic functions:
    - Set the date and time
    - Set the duty cycle
    - Check the microphones' sensitivity
7. Ask them how they think scientists would use this tool. *(Answer: Scientists deploy several Song Meters in their study sites. They set the duty cycle according to their research questions. For example, if scientists are studying bird diversity, they might set the Song Meter to record only during spring mornings. If they are studying coyotes, they might set a duty cycle that calls for evening and night recording when coyotes are active. For long-term deployments, scientists return to their study sites to install fresh batteries and SD cards. All the recordings on SD cards are considered as one form of data in the study.)*
8. Attach headphones to the Song Meter, and begin recording by simultaneously pushing the "UP" and "DOWN" buttons. Then push SELECT to activate the headphone port, and let participants listen to the live sound being captured by the Song Meter's microphones. If possible, use a headphone splitter to attach several sets of headphones to the Song Meter.
9. Give them some time to explore their recorder.
10. Ask them to choose a good place to deploy the recorder for the day.
11. Go to the location, and have students deploy the recorder.

12. Have them report some basic information about the location in Worksheet 10.2. Also, ask students to take a picture of the site and draw a map showing sensor locations. If you can, record the GPS coordinates in the field with a GPS or smartphone. If not, you could use Google Earth later to have students identify the sensor locations and record their coordinates. When the location is identified, center the screen by double clicking on the location. Click "Add Placemark" (the yellow pushpin at the left of the toolbar). Latitude and longitude coordinates for the site will be displayed in the window that pops up.
13. The next day, go back to the deployment site and collect the recorder (or replace its memory card(s)).
14. On the way back from the site, ask participants what they think might have been captured in the recordings.
15. Download the recordings to a computer, and show the students how each file is named (their naming conventions).
16. Use Audacity to show oscillograms and spectograms of some recordings (see Activity 12 for more information).
17. Then play a sampling of the recordings as requested by students.
18. Compare some of the recordings to introduce the concept of temporal change.

Information Sheet 10, Part 2: Song Meter Mini Manual

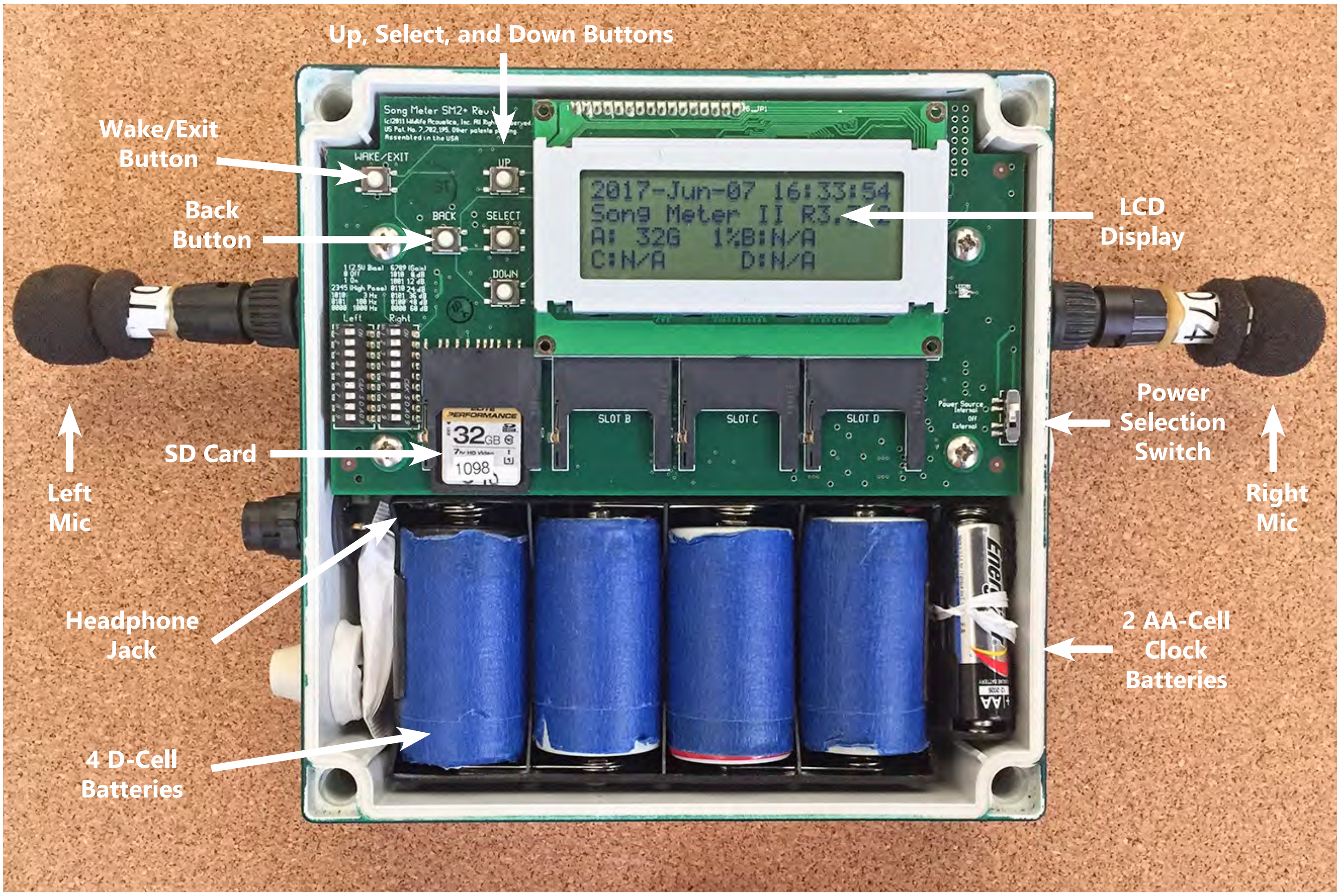


Figure 10.2. Parts of a Song Meter.

Step 1: Opening the Song Meter

To open the Song Meter's casing, unscrew the four plastic screws on the corners with a large Phillips head screwdriver. These screws will not come out, so they should just be loosened until they protrude no farther. The Song Meter's features include an LCD display, a power selection switch, five navigation buttons, and nine settings switches for each microphone port. Figure 10.2 shows these features in an SM2.

Step 2: Turning it on

Insert four D-cell batteries according to the images at the base of the battery pack, and do the same with the two AA-cell batteries in the compartment at the bottom right. Insert one or more SD cards, beginning with slot A and proceeding to the right. Move the small power selection switch on the bottom right of the circuit board up to the "Internal" position, and the Song Meter will turn on.

Step 3: Adjusting the settings

SM2 units can be programmed to record automatically using the navigation buttons or programmed through a computer-based configuration utility and then loaded onto the recorder through an SD card. To set the date and time, press the button marked "SELECT." This will bring you to the main menu. Using the buttons marked "UP" and "DOWN," scroll through the menu to "Settings," and press SELECT to enter the settings menu (Figure 10.4). If you ever wish to return to a

Information Sheet 10, Part 2: Song Meter Mini Manual (continued)

Figure 10.3. Turn the Song Meter on by moving the small power selection switch to the internal position.

Figure 10.5. Select "Time and date" by pressing "SELECT."

Figure 10.4. The SM2's main menu.

Figure 10.6. The display shows that the left (L) and right (R) microphones are working.

higher-level menu, press the button marked "BACK." In "Settings," select "Time and date." With the cursor on the first line, press SELECT again, and the cursor will jump to the last digit of the year. Pressing UP or DOWN will then change the year. Pressing SELECT again will move the cursor progressively right, to the month, date, hour, minute, and second. Each can be altered using the UP and DOWN buttons. Set the date to the most accurate timekeeping device available, and if using multiple Song Meters, try to synchronize the times (Figure 10.5).

Step 4: Checking the microphones and listening to live sounds

Plug standard 3.5 mm headphones into the headphone jack on the bottom left underside of the circuit board. Press UP and DOWN at the same time and then press SELECT to activate the headphone port. The recording levels can be monitored visually by watching the asterisks and by looking at the dB values at the right of the screen (Figure 10.6). To stop recording, press BACK. To erase this test recording, (and to clear the memory cards) navigate back to the main menu. Select "Utilities" and then select "Erase all cards."

Step 5: Setting a recording schedule

To set a recording schedule, navigate to "Schedule" in the main menu, and press SELECT. The cursor will jump to the right over "(daily)" or "(advanced)." If you choose "(daily)," you will arrive at a screen that prompts you to "Add a new entry." Press SELECT, and you should see "@ 00:00 for 00:00." This first time is the time (in 24 hour time) at which a recording will start. The second time is the duration of that recording (Figure 10.7). Navigate and change values as you did for the date using the SELECT, UP, and DOWN buttons. When finished, if you have set a recording duration other than 00:00, a new "Add a new entry" line will appear. If you wish to program a second recording, follow the same process for this line. Be careful not to

Information Sheet 10, Part 2: Song Meter Mini Manual (continued)

Figure 10.7. Check the recording schedule. Each line shows the time and duration for a single recording.

overlap recording times, or you will receive an error that says, "OVERLAP! TRY AGAIN." To delete a line, set its recording duration to 00:00.

Step 6: Starting to record

To launch a programmed duty cycle, press the "WAKE/EXIT" button while on the home screen that shows the date, firmware version, and memory card capacities. If the Song Meter is programmed to record at a certain time, it will say "Going to sleep until [the date and time it is supposed to record]." If you wish to simply record for one hour starting immediately, press BACK until you arrive at the home screen. Press UP and DOWN simultaneously to begin recording. If you choose the "(advanced)" option under "Schedule" (press UP or DOWN if your cursor is over "(daily)"), you have some more complex options that you can explore in the Song Meter User Manual.

Step 7: Mounting the Song Meter

The easiest way to mount a Song Meter outdoors is to attach it to a small tree or post with sturdy wire. Choose a small tree so that the back side of the microphones are not obstructed. To mount the Song Meter, cut one piece of wire long enough to wrap all the way around the Song Meter and tree/post held next to each other. Cut the wire in half. With the Song Meter's cover removed, pass the wire halfway through one of the top screw holes. Take the end of the wire that is sticking out on the screen side, and bend it so that it catches firmly on the back end of the screw hole and will not pull through. Do the same with the other piece of wire. Have one person hold the Song Meter up to its desired mounting location while a second goes to the opposite side of the tree/post and twists the two loose ends of wire together, first by hand and then with a pair of pliers. Be careful not to twist too hard, or the wire may break. Once the Song Meter is secure, press WAKE/EXIT to launch a programmed duty cycle or press UP and DOWN to begin recording immediately. If all is well, replace the cover, tightening the plastic screws firmly, but not too hard.

Step 8: Data collection

To collect data, ensure that the Song Meter is not currently recording. If it is, press BACK to stop that recording. Then switch the power switch on the bottom right of the circuit board to "Off," and remove the SD card(s).

Each card will contain a folder, "Data," that contains recordings and a .txt text file with some data about the device's operation, which is only useful for advanced diagnostics.

KEY QUESTIONS

What can scientists learn from recording soundscapes? What sorts of research questions can they answer?
Answer: The world around us is filled with diverse sounds of animals and the environments they inhabit. Soundscape patterns within each ecosystem reveal information about animal behavior and populations, ecosystem characteristics, and human activity. Scientists can simply describe soundscapes, but they can also compare soundscapes between different times and places and correlate measures of soundscapes with other ecological variables to investigate how they are related.
What did you notice about recordings from different times of day?
Answers will vary.
What did you notice about recordings from different sites?
Answers will vary.
Why might soundscapes differ at different sites and times of day?
Answer: Different animals are active at different times of the day and also some human activity may change during the day. For example, traffic sounds are more intense during morning and evening commutes.
What were some of the challenges of making soundscape recordings?
Answers will vary.

POSSIBLE EXTENSIONS

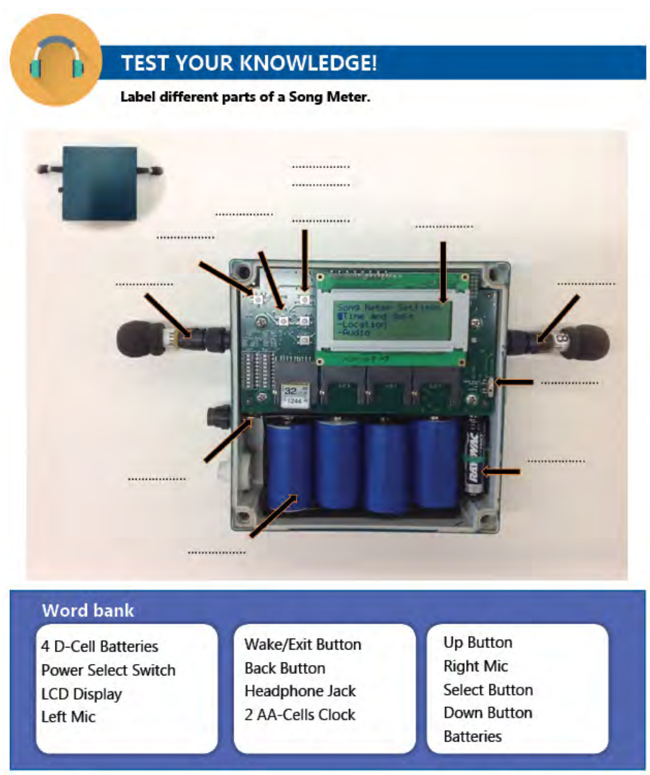
- Take students outdoors with recorders, and ask them to record some sounds or soundscapes. Students can record sounds freely, or you can ask them to record sounds with specific characteristics such as high or low-frequency sounds, sounds with varying frequency, continuous sounds, rhythmic sounds, or different categories of sound (biophony, geophony, and anthrophony).
- When students return, have then to work with Audacity to visualize the recordings.

ADAPTATIONS FOR ACCESSIBILITY

- Show the recorder to each individual student.
- Assist students with starting and programming the Song Meter.
- One assistant per group may be needed to walk to a site and deploy the recorder.

TEST YOUR KNOWLEDGE

Following the completion of the hands-on activities, students should complete a worksheet about the content of this activity.



Worksheet 10.1: Design a Recorder

How do scientists record soundscapes? **How would you design a tool that would help scientists to record soundscapes?**
Soundscape Recording Device Model In your design, consider its energy source, how long does it work, and if it is durable outdoors.

Worksheet 10.2: Site Information Form

Date: **Time:** **GPS coordinates:** **Song Meter serial number:** **Mic numbers (optional):**
Quick Drawing/Picture of the Landscape/Landmarks

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 how to think like an ecologist by understanding the differences between four major global biomes and there soundscapes. Then, students are introduced to techniques to visualize and analyze these soundscapes on a computer.

Expected Time: 30 minutes
Group Size: 3 – 4 student
Setting: Indoors

Learning Objectives:

Students will 1) define biomes and the features that distinguish them, 2) identify the locations of different biomes, and 3) explain the relationship between biomes and their soundscapes.

Materials:

- World Biomes Audio Library
- Speakers to play soundscape recordings
- Biome Fact Sheet (Worksheet 11.1)
- Place the Biomes (Worksheet 11.2)
- Global Soundscapes Observation Form (Worksheet 11.4)
- Colored pencils

Activity 11: Global Soundscapes

Biogeographers and ecologists study the distribution of living organisms throughout the world. Certain types of plant and animal communities have evolved together over time in a way that creates similar living conditions in different places around the world, even on different continents. These distinct communities of plants and animals are called biomes.

Biomes are ecological regions shaped by the topography and climatic conditions of an area, such as temperature and precipitation. According to Campbell (1996), biomes are, “the world’s major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment.”
Figure 11.1 shows the distribution of the major biomes on Earth. Note that biomes are usually distributed in latitudinal bands around the earth. For example, tropical rainforest can be found across Asia, Africa, and South America near the equator.

Four Major Biomes

There are categories and sub-categories of biomes. For this activity, we will focus on four major categories: tropical rainforest, temperate forest, desert, and tundra (Figure 11.1).

Tropical Rainforest

Earth's tropical rainforests are located near the equator and are characterized by a hot, humid climate and dense vegetation. Scientists estimate that more than half of all the world's plant and animal species live in tropical rainforests and that tropical rainforests produce up to 40% of Earth's oxygen.

Temperate Forest

Temperate forests are located near the mid-latitudes of the northern (United States, Europe, China, and Russia) and southern hemispheres (Argentina, Chile, Australia, New Zealand, and South Africa). Temperate forests have four seasons—winter, spring, summer, and fall.

Desert

Deserts have very little rain, and most are very hot. Earth's deserts are located near latitudes 30° north and 30° south on six of the seven continents. Their locations are due to global atmospheric circulation patterns.

Tundra

Tundra is located between latitudes 55° and 70° north. It is characterized by permafrost (permanently frozen soil below a depth of 25 to 100 cm) and a very short growing season, creating an environment in which few trees can grow.

The Difference between Biomes and Ecosystems

An ecosystem is a place in which animals and plants live and interact with elements of the physical environment such as climate and soil. Different natural processes or ecological systems such as the nutrient cycle ensure functional relationships between living and non-living entities. An ecosystem may be very small, as in a pond or even a puddle, or it may be quite large, as in the earth's oceans. Biomes are much larger on a spatial scale, as they refer to vast geographic regions with specific environmental conditions like climate and geology.

Changes in Biomes

Plants and animals are adapted to their biome's climate, but biomes can change through either natural processes or human activities. The human population is growing, and it occupies over 20% of the earth's terrestrial area. In addition to land, humans use natural resources such as trees, underground minerals and oil, and water, and we pollute air, water, and soil. These activities change the physical aspects of biomes, which may drive animals and plants to adapt to their altered environments.

Weather and Climate

Weather and climate are defined differently. Weather occurs over short periods of time in certain locations, and it has characteristics such as temperature, precipitation, wind speed, and humidity. On the other hand, climate occurs over longer periods of at least several decades. Its characteristics include averages and typical variation in temperature, precipitation, wind speed, and humidity.

Soundscapes and Biomes

Each biome has its own environmental features like sandy dunes in deserts or dense trees in tropical forests. The soundscapes of a biome depend on the sounds that are produced within those biomes and how those sounds propagate. The interplay of elements within each biome such as topography, climate, present species, and present vegetation all shape the soundscapes of that biome. For example, in the temperate forest, many animals produce sounds (especially birds), and the forest structure affects sound propagation by absorbing or reflecting that biophony.

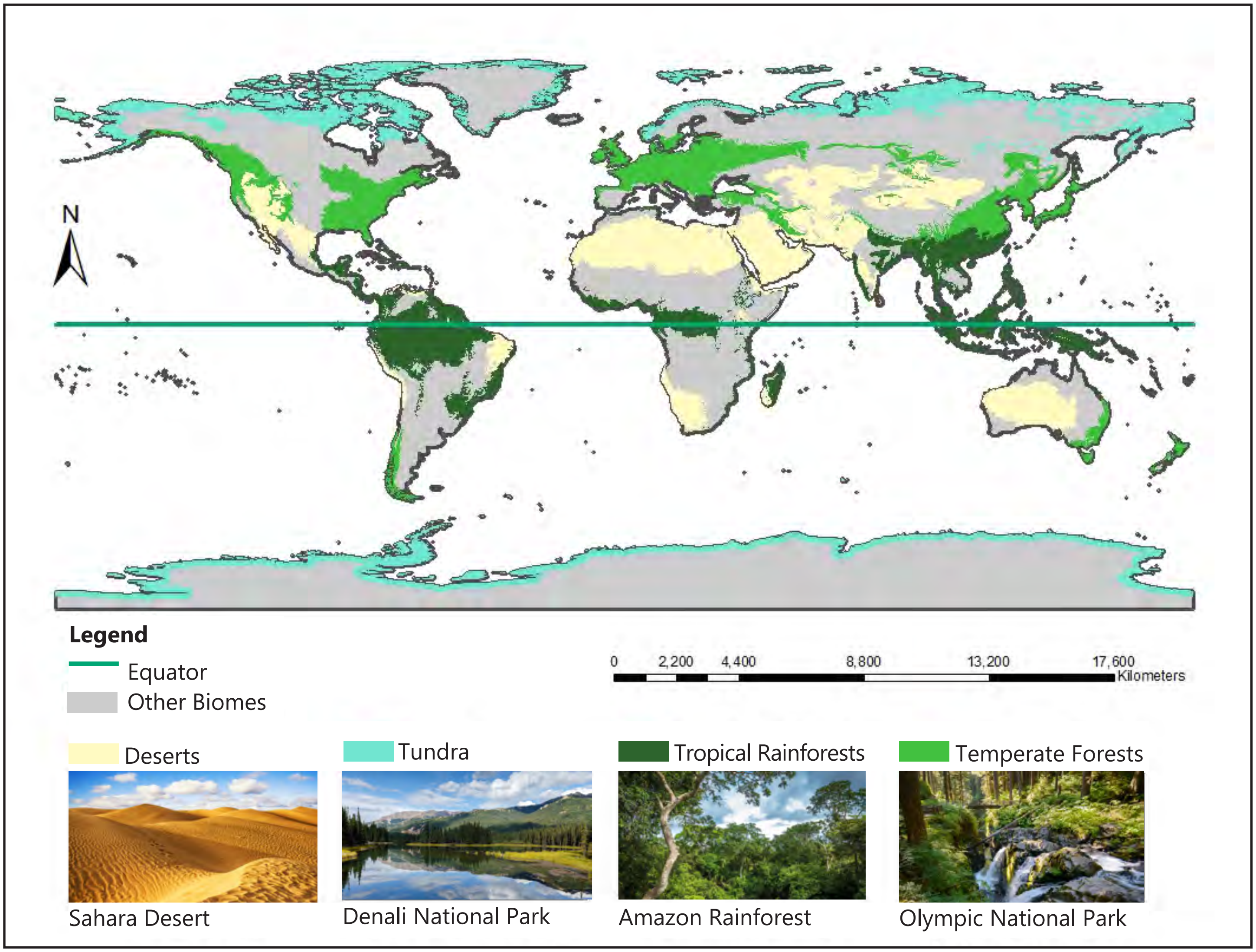


Figure 11.1: Map of four major world biomes.

Changes in biomes can affect the biomes' soundscapes because of the impact of biomes' structure and biological composition on soundscapes. For example, global climate change has caused some forms of biophony like frog and bird vocalizations to occur earlier in the spring in temperate forests.

INSTRUCTOR DIRECTIONS

In this activity, students learn about the location of biomes on Earth and the impact of climate, precipitation, and temperature in shaping them. Then, they investigate the characteristics of major biomes' soundscapes by listening to those soundscapes.

Pre-Activity

If students do not have Student Guides, print the Worksheet 11.1 set for each student. A general description of each biome helps students link biomes to climate and other information. Students will complete Worksheet 11.1 using the information provided in the biome's description.

Part 1: Describe the Biomes

1. Present the map of the world (Worksheet 11.2).
2. Present the different biomes on the map, and ask students why different biomes exist in different locations.
3. Inform them about the role of environmental and climate conditions in differentiating between biomes.
4. Ask them to assign one precipitation symbol to each biome according to the description of the biomes.
5. Ask them to color the temperature layer in the map background according to the description of the biomes.
6. Ask them to look at their map and Worksheet 11.1 to answer questions on Worksheet 11.4.

Part 2: Biome Listening Lab

1. Provide the World Biomes Audio Library (which features soundscapes from each biome) to each group.
2. Ask them to listen to the soundscapes of different biomes.
3. Have students listen and answer the questions on Test Your Knowledge Worksheet within their groups.

KEY QUESTION

What are the reasons for differences between biomes?

Answer: Climate and the biological communities that can exist in certain climates are the primary factors that differentiate biomes. Different biomes have different climates as a result of varying topography, proximity to large bodies of water, and reception of solar radiation due to latitude.

POSSIBLE EXTENSIONS

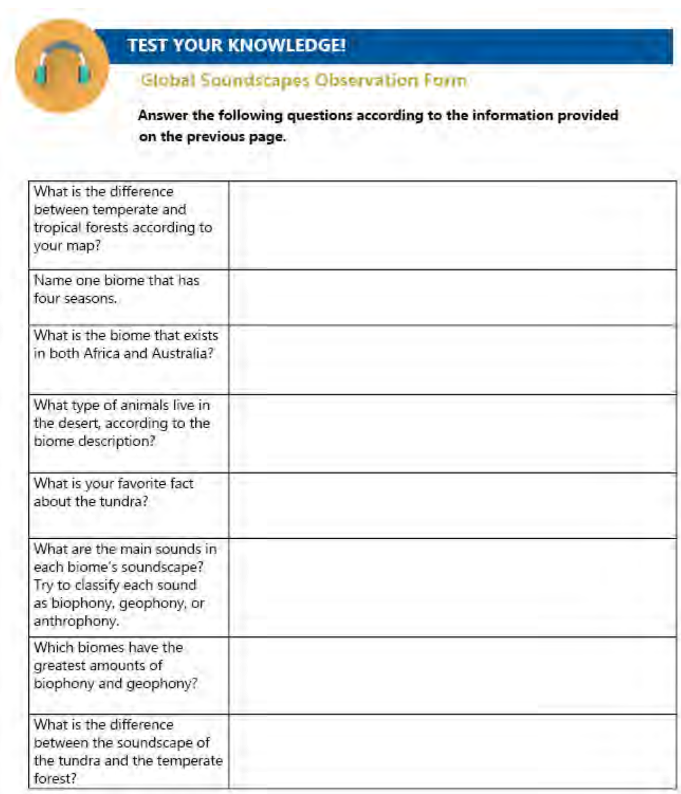
Take students outdoors to observe and describe the environmental features in their biome. Encourage them to listen to the soundscape. Ask them to record the soundscape and compare their recordings with those from the other biomes presented in this activity.

ADAPTATIONS FOR ACCESSIBILITY

- Provide a tactile map for students.
- If students are not familiar with the different biomes, play the sound of each biome and explain its environmental structure.

TEST YOUR KNOWLEDGE

Following the completion of the hands-on activities, students should complete a worksheet about the content of this activity.



TEST YOUR KNOWLEDGE!

Global Soundscapes Observation Form

Answer the following questions according to the information provided on the previous page.

What is the difference between temperate and tropical forests according to your map?	
Name one biome that has four seasons.	
What is the biome that exists in both Africa and Australia?	
What type of animals live in the desert, according to the biome description?	
What is your favorite fact about the tundra?	
What are the main sounds in each biome's soundscape? Try to classify each sound as biophony, geophony, or anthrophony.	
Which biomes have the greatest amounts of biophony and geophony?	
What is the difference between the soundscape of the tundra and the temperate forest?	

Worksheet 11.1: Describe the Biomes

Tropical Rainforest

Temperature: 20 to 25 °C (68 to 77 °F)

Precipitation: 2,000 to 10,000 mm (79 to 394 inches) of rain per year

Plants: Orchids, bromeliads, vines, strangler figs, giant tree ferns

Animals: Howler monkeys, toucans, anacondas, scarlet macaws, poison-dart frogs, blue morpho butterflies, army ants, katydids

Facts:

1. Tropical rainforest is one of the oldest biomes on Earth, and some rainforests have existed since the time of the dinosaurs.
2. Rainforests have rain in all seasons.
3. Rainforests are extremely important for global water and oxygen production.
4. Rainforests have dense forest canopies, and they can have giant trees that can grow up to 75 meters (250 feet) in height.
5. Rainforest vines climb trees to access sunlight.

Temperate Forest

Temperature: -30 to 30 °C (-22 to 86 °F)

Precipitation: 750 to 1,500 mm (30 to 59 inches) of rain per year

Plants: American beech, carpet moss, ponderosa pine, white oak, common primrose, lady fern

Animals: Black bear, bullfrogs, northern cardinals, raccoons, white-tailed deer, pileated woodpeckers, starlings, spring peepers, gray squirrels

Facts:

1. This biome experiences four seasons.
2. The soil is fertile because the deciduous trees' fallen leaves decompose on the forest floor.
3. Animals adapt to changing seasons by hibernating or migrating in winter.

Desert

Temperature: -4 to 38 °C (25 to 100 °F)

Precipitation: 250 mm (10 inches) of rain per year

Plants: Prickly pear cacti, saguaro cacti, ocotillos, elephant trees, desert sage, palm trees

Animals: Cactus wrens, desert tortoises, bearded dragons, Arizona hairy scorpions, roadrunners, ostriches, sidewinder rattlesnakes, coyotes

Facts:

1. 20% of Earth's land surface is covered by deserts.
2. The largest desert is the Sahara Desert in North Africa.
3. Deserts only get 10% of the rain that rainforests receive.
4. The temperature changes drastically from day to night in a desert because there is very little surface or atmospheric water to stabilize temperature.
5. Many animals have adapted to the heat of the desert by becoming nocturnal. They are active at night and sleep during the day when it is very hot.

Tundra

Temperature: -40 to 18 °C (-40 to 64 °F)

Precipitation: 150 to 250 mm (6 to 10 inches) of rain per year

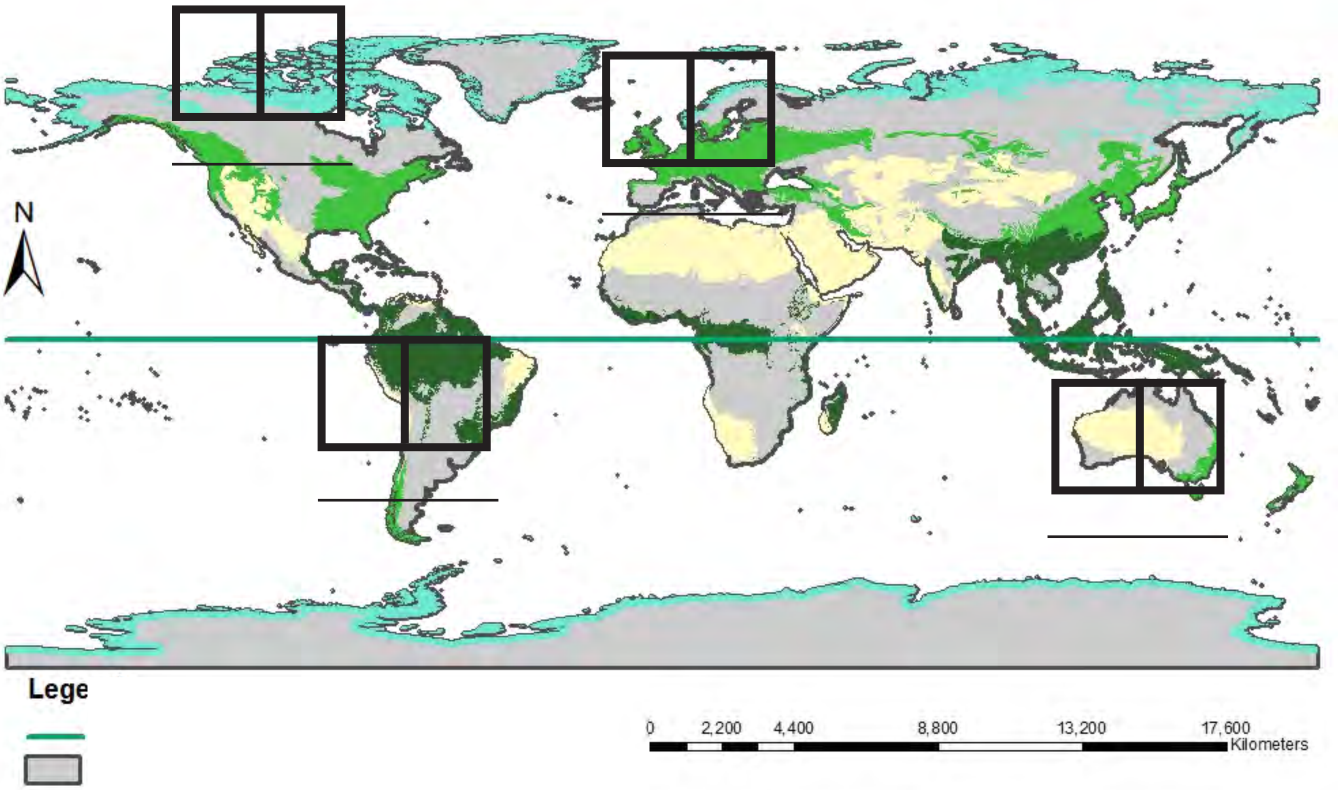
Plants: Evergreens, mosses, lichens

Animals: Gray wolves, bald eagles, long-eared owls, red foxes, wolverines, snowshoe hares, moose, snow geese, Canada geese, Arctic foxes

Facts:

1. 20% of Earth's land surface is covered by tundra.
2. Animals have adapted to the extreme cold of the tundra by hibernating during the cold season or by migrating to warmer locations.
3. Due to its harsh conditions, much of the tundra is not frequently visited by humans.

Worksheet 11.1: Describe the Biomes

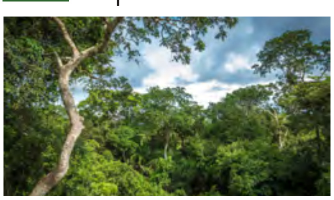


Legend

Equator

Other Biomes

Tropical Rainforests



Amazon Rainforest

Deserts

Sahara Desert

Temperate Forests

Olympic National Park

Tundra

Denali National Park

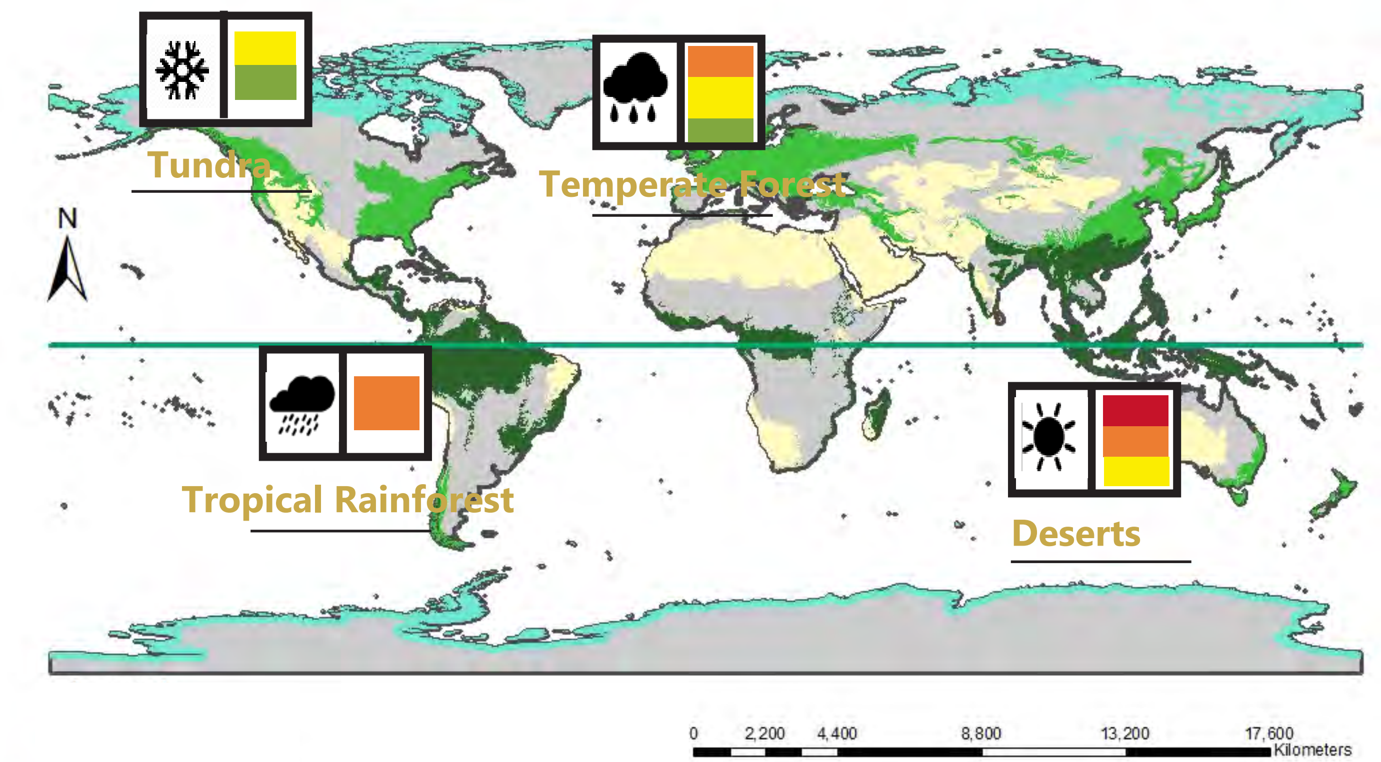
Precipitation

Temperature

Instructions

1. Label the biome.
2. Color the box the average temperature of the biome.
3. Draw a precipitation symbol for the biome.

Worksheet 11.1: Describe the Biomes



Precipitation

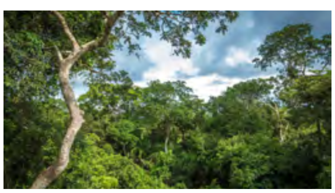
Temperature

Legend

Equator

Other Biomes

Tropical Rainforests



Amazon Rainforest

Deserts

Sahara Desert

Temperate Forests

Olympic National Park

Tundra

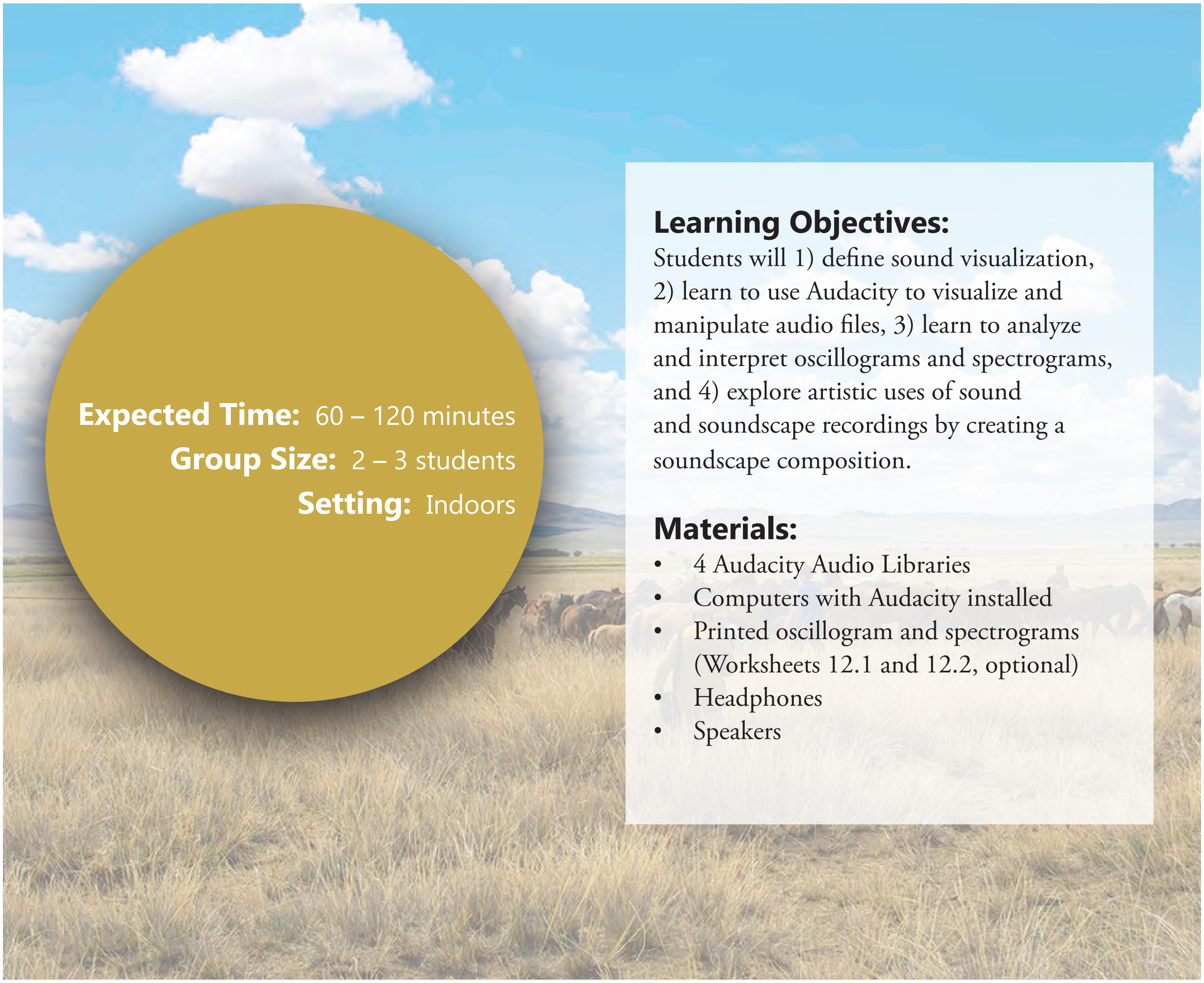
Denali National Park

Instructions

1. Label the biome
2. Color the box the average temperature of the biome
3. Draw a precipitation symbol for the biome

Test your Knowledge Answer Key

What is the difference between temperate and tropical forests according to your map?	**Answer:** Temperate forests have lower temperature and precipitation, and they occur at higher latitudes.
Cite one biome that has four seasons.	**Answer:** Temperate forest
What is the biome that exists in both Africa and Australia?	**Answer:** Desert
What type of animals live in the desert, according to the biome description?	**Answer:** Cactus wrens, desert tortoises, bearded dragons, Arizona hairy scorpions, roadrunners, ostriches, sidewinder rattlesnakes, coyotes.
What is your favorite fact about the tundra?	**Answers will vary.**
What are the main sounds in each biome's soundscape? Try to classify each sound as biophony, geophony, or anthrophony.	**Answer:** Tropical forest: Biophony (frogs, howler monkeys, birds, katydids). Temperate forest: Biophony (lots of birds) and anthrophony (plane). Tundra: Biophony (bird) and geophony (wind). Desert: Biophony (bird) and geophony (thunder).
Which biomes have the greatest amounts of biophony and geophony?	**Answer:** The tropical forest sound file has the highest number of biological sounds, while the desert sound file has the greatest number of geophysical sounds.
What is the difference between the soundscape of the tundra and the temperate forest?	**Answer:** In the sound files within the sound library, there are birds in both ecosystems, but the number of birds is lower in the tundra sound file.



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 (Worksheets 12.1 and 12.2, optional)
- Headphones
- Speakers

Activity 12: 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 12.2). An oscillogram is a two-dimensional graph with x- and y-coordinates. The x-axis represents time—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 software to visualize audio files. Instructions are provided for software package, 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.

PRE-ACTIVITY

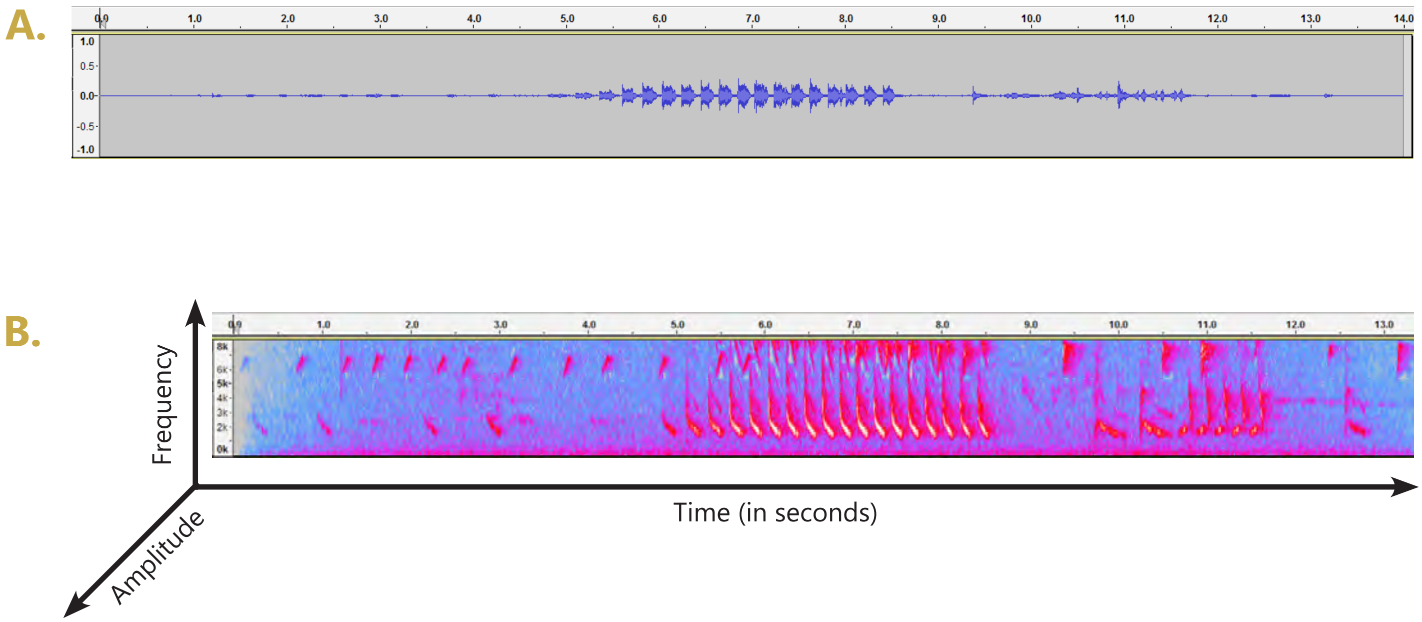


Figure 12.1. Sound visualizations of a Northern Cardinal call in Audacity. A) An oscillogram presents the amplitude or loudness of the sound. B) A spectrogram presents 1) time, shown on the x-axis, 2) frequency, shown on the y-axis, and 3) amplitude, shown in color.

Pre-Activity

Students will need to have access to a computer with an audio visualization programs installed. Alternatively, printed copies of spectrograms can be provided if students do not have computer access (Worksheet 12).

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.

ACTIVITY

A.

B.

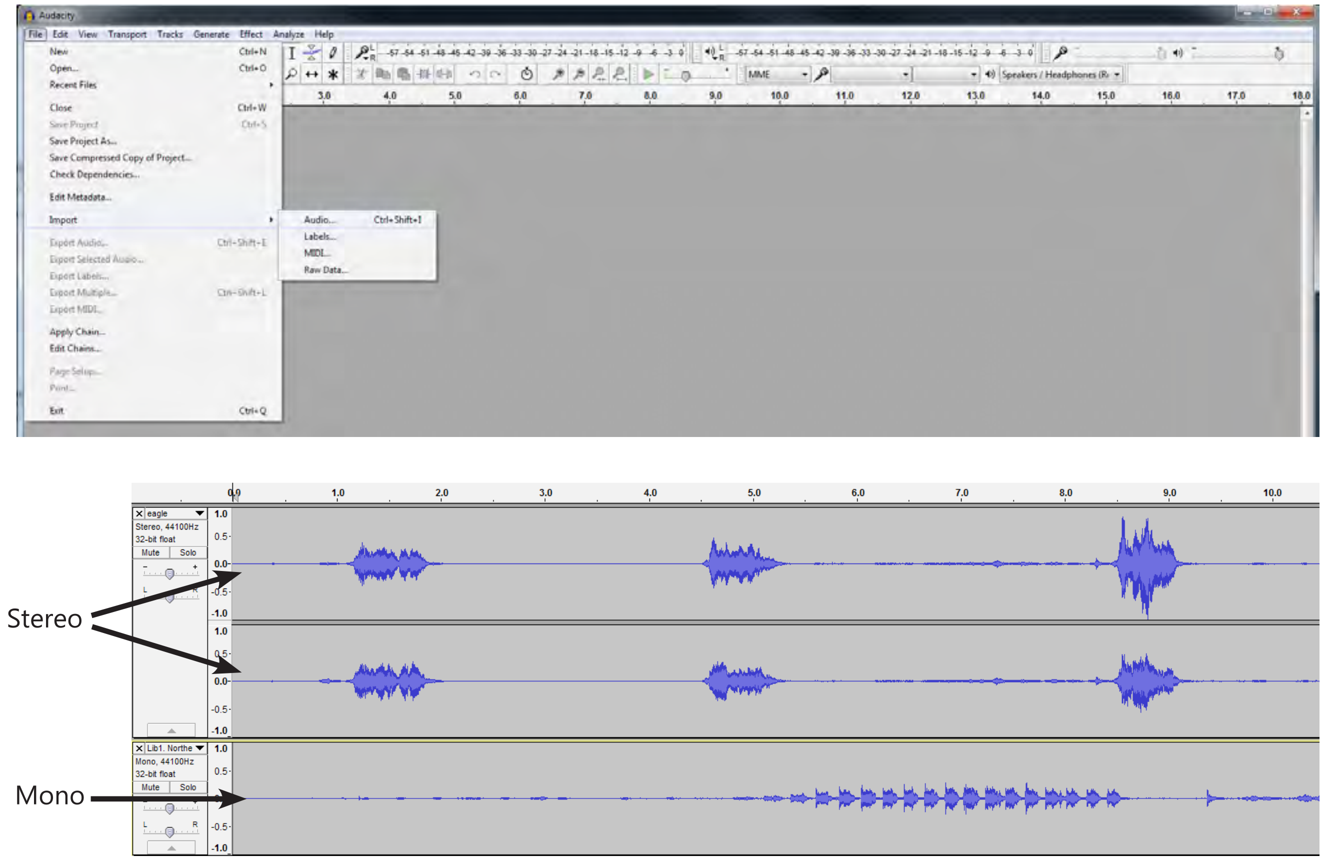


Figure 12.2. A) Importing a file; B) stereo and mono tracks.

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 12.2 A). 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 12.2 B). The buttons on the control panel, in order, are ["Pause," "Play," "Stop," "Skip to the beginning," "Skip to the end," and "Record"] (Figure 12.3).
2. Instruct students to hit the "Play" button for each sound while viewing it as an oscillogram.

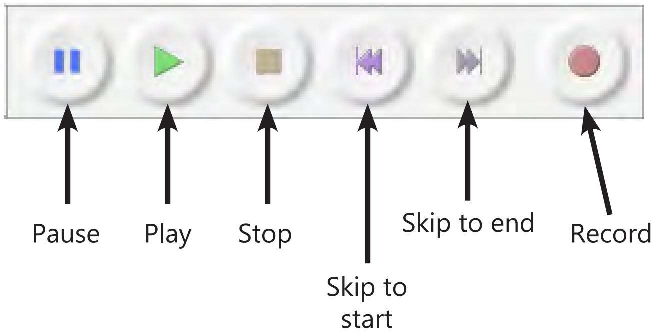


Figure 12.3. Control panel.

3. Make sure they listen to each sound and watch the playhead move along the oscillogram (Figure 12.4). 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 "Spectrogram" (Figure 12.5), 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 12.4).
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.
7. Time moves from left to right, and is represented on the x-axis.
8. Frequency is represented on the y-axis.
9. Amplitude is represented by color on the z-axis.
10. 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.
11. Ask them to identify sounds with high and low frequencies, high and low amplitudes, and different durations and rhythms.
12. 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.

KEY QUESTION

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.

Frequency	Animal
1,900 Hz	Coyote
8,000 Hz	Siamang Monkey
200 Hz	Arizona bird
700 Hz	Bald Eagle
620 Hz	Bullfrog

Part 2 Answer Key. Animal sounds matched with their pure tone frequency.

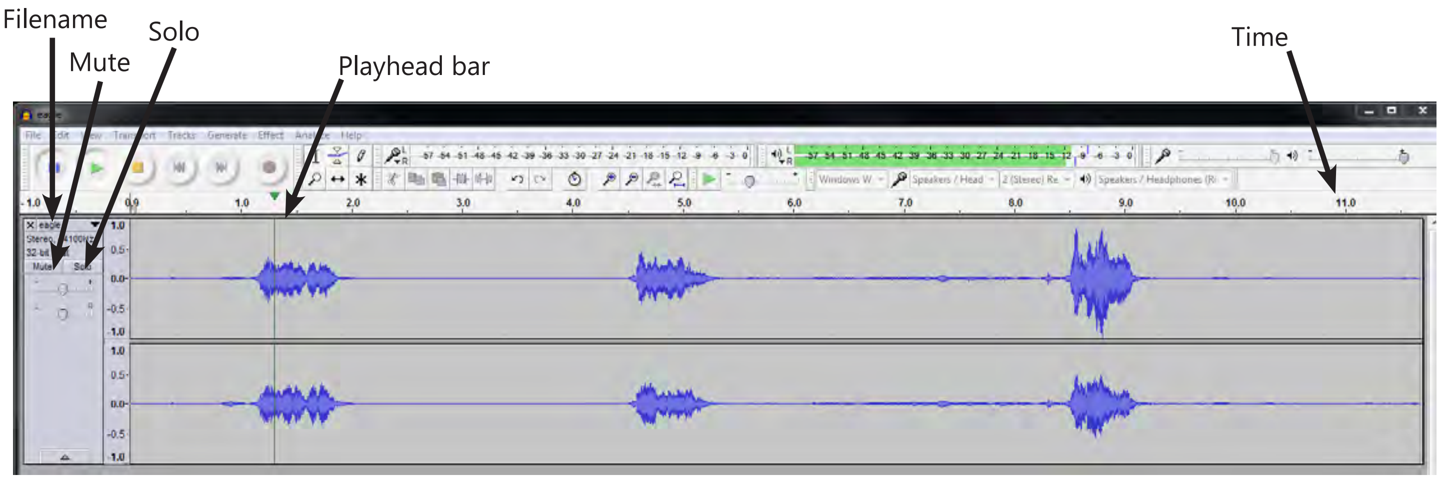


Figure 12.4. Oscillogram of a bald eagle call.

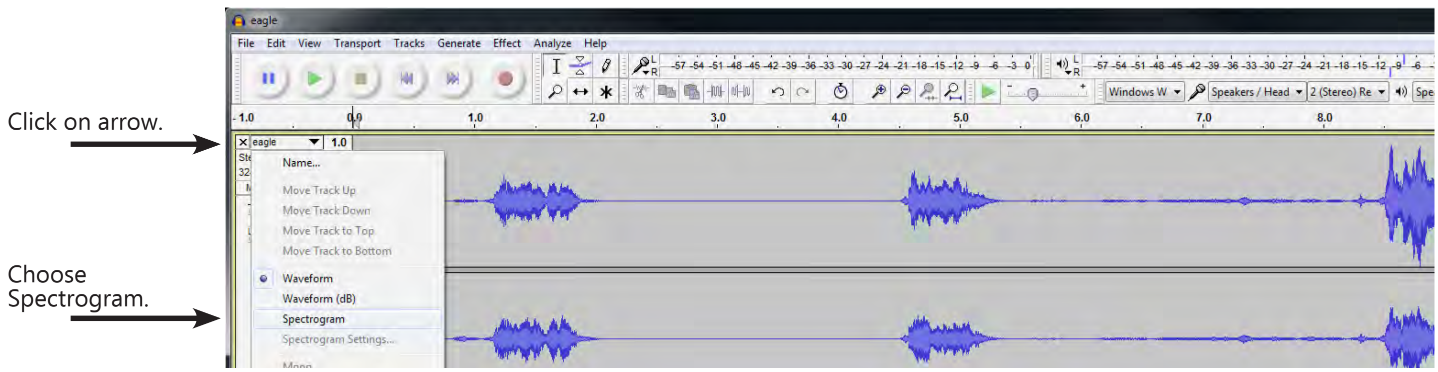


Figure 12.5. Changing oscillogram to spectrogram.

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:

- BaldEagle_Alaska_Tundra_1900Hz
- Bird_Arizona_Desert_8000Hz
- Coyote_Indiana_TemperateForest_620Hz
- Bullfrog_Maine_Estuary_200Hz
- SiamangMonkey_Borneo_Rainforest_3126Hz

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 the animal sound with the correct pure tones and to write down the dominant frequency for each species.

KEY QUESTION

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 2.

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_133000
- Borneo_015116_20140209_183000
- CostaRica_20150422_050000
- Indiana_20120501_060000
- Nebraska_20150321_170000

1. Explain to students the differences between sound, noise, and soundscapes. Sound has one source, like a single animal. A soundscape is 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.

KEY QUESTIONS

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.

Part 4: Match the Soundscape with the Spectrogram

For this activity, students are given five printed spectrograms (Worksheet 12.1). Then, by accessing Audacity Audio Library 4, they will match the printed spectrograms with the corresponding soundscape recordings.

Audacity Audio Library 4 (Labels A-E match image on Worksheet 12.1)**:**

A. AlarmersTropicalCops_20140218_063000
B. IsolatedTrumpeter_20140314_180000
C. NaturesRowingMachine_20130208_120000
D. OneCrazyBird20140210_103000
E. ShriekingMeOut_20140117_180000

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 biomes in Activity 11. 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: See the description of Audacity Audio Library 4.

Part 5: Create a Soundscape Composition

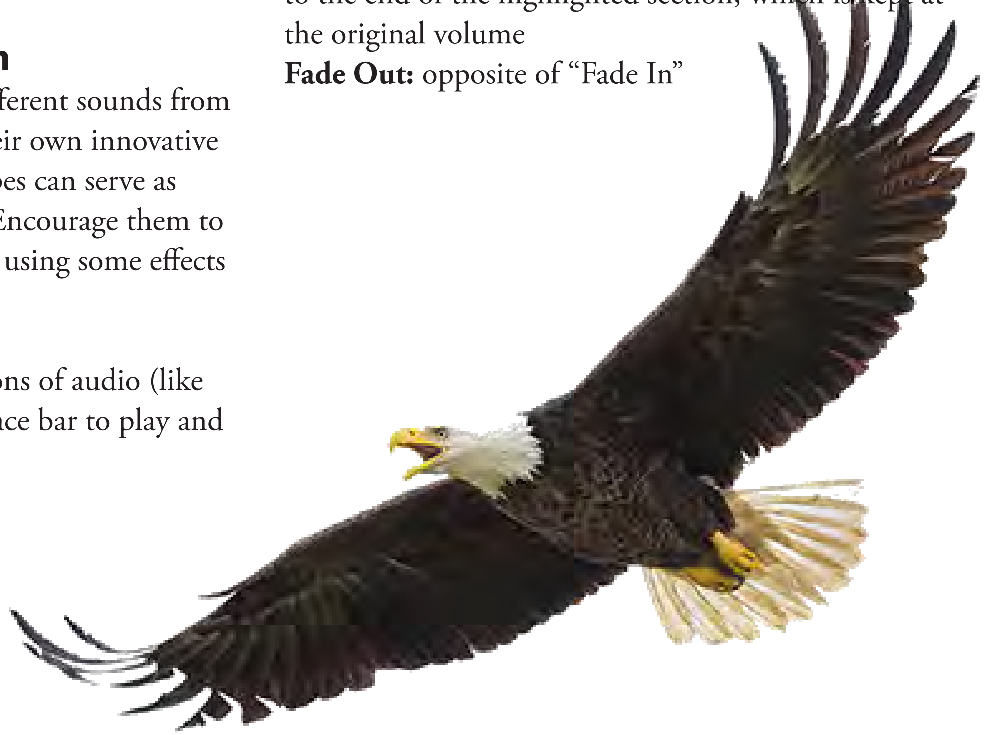
In this part students can combine different sounds from any of the audio libraries to make their own innovative soundscape compositions. Soundscapes can serve as inspiration or models for imitation. Encourage them to get creative! One way to do this is by using some effects in Audacity.

Useful Audacity tips:

- Click and drag to highlight sections of audio (like in a text document). Press the space bar to play and pause any sound excerpt.
- Select an entire track by clicking the gray area to the left of the oscillogram, where the track name is listed.
- 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 volume to the end of the highlighted section, which is kept at the original volume
Fade Out: opposite of "Fade In"



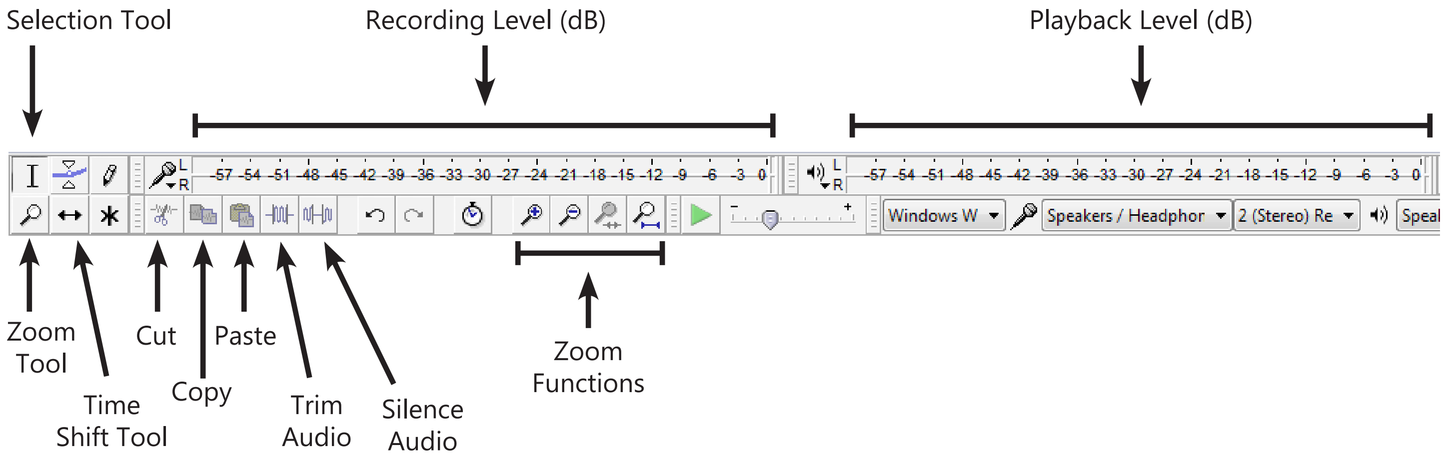


Figure 12.6. Audacity toolbar.

Students can also manipulate sounds by using different options in the toolbar (Figure 12.6).

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 Audio**, type a file name. In the format menu at the bottom of the screen 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.

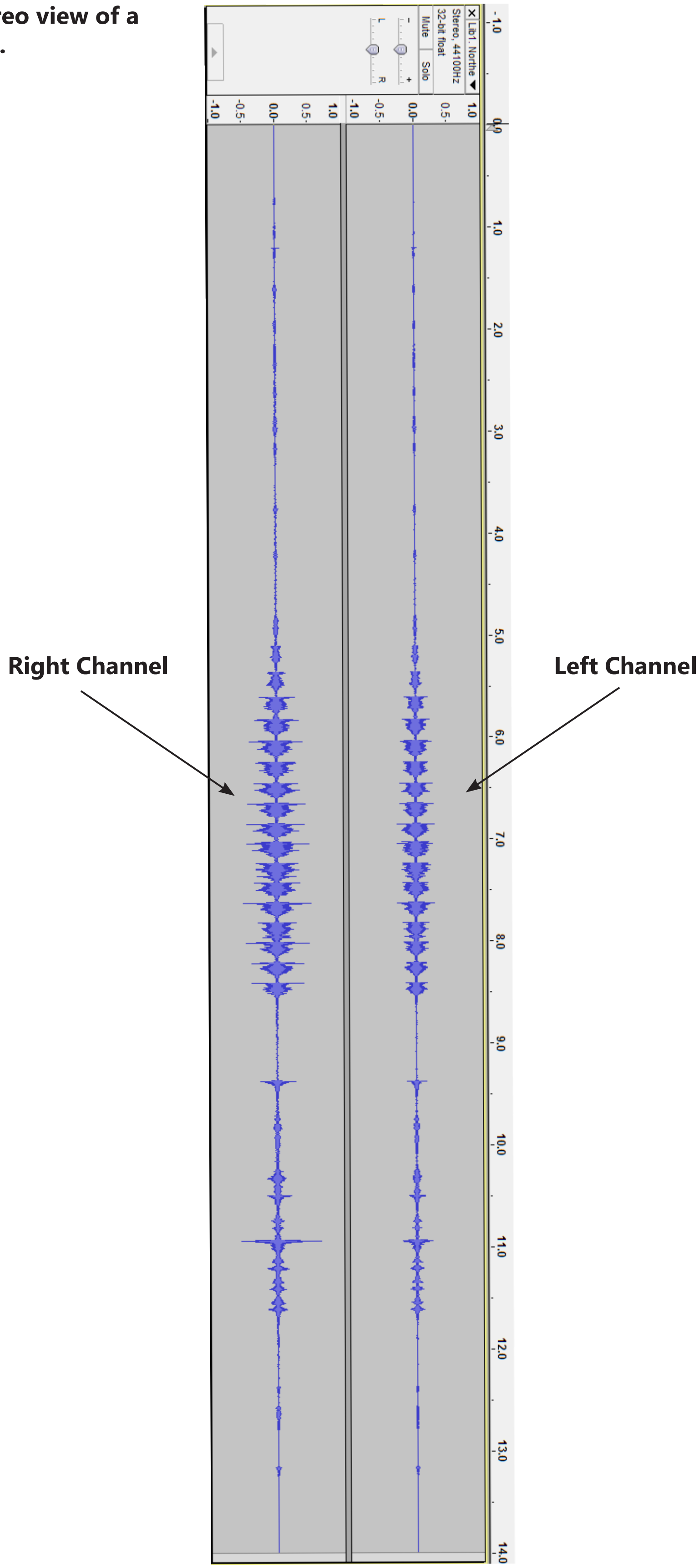
POSSIBLE EXTENSIONS

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

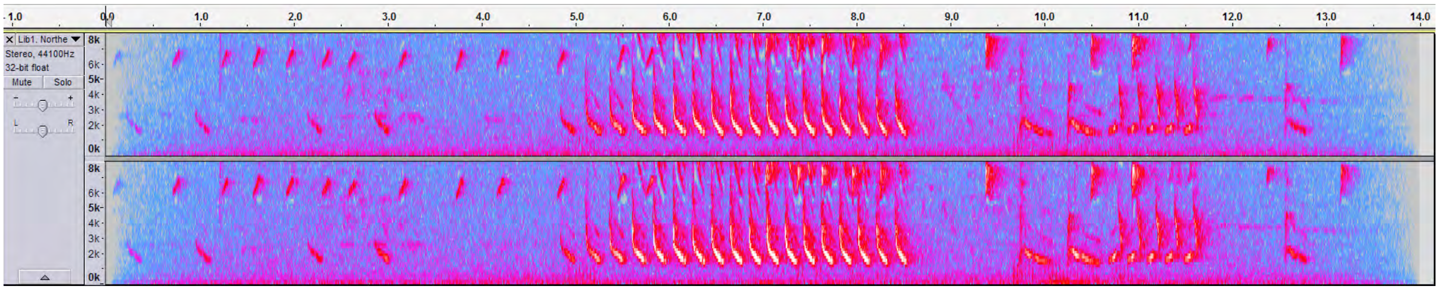
ADAPTATIONS FOR ACCESSIBILITY

- 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 stereo figure (Figure 12.7) ninety degrees, as it is easier to follow the stereo recording by touching the left and right channels with the left and right hands, separately.

Figure 12.7. Audacity stereo view of a Northern Cardinal's Song.

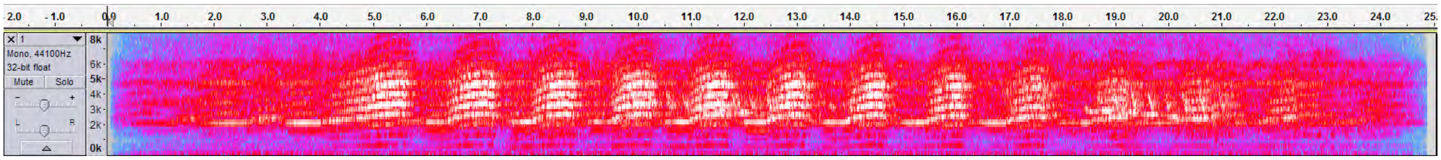


Worksheet 12: Pre-Activity, Spectrogram of a Northern Cardinal's Song

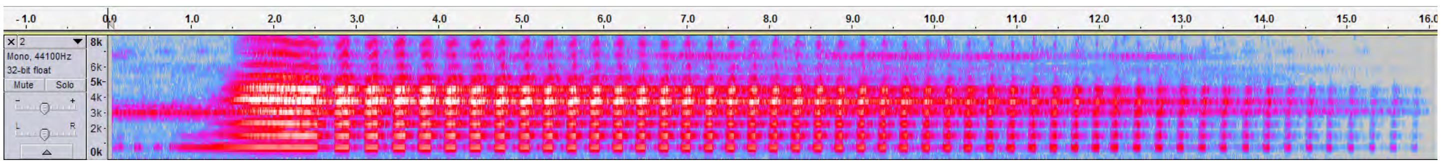


Worksheet 12.1: Part 4, Spectrograms of Different Soundscapes

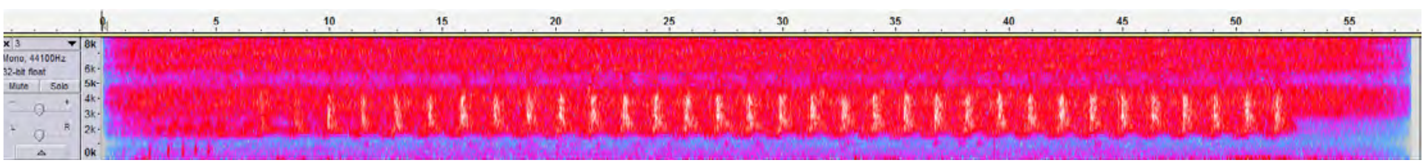
A.



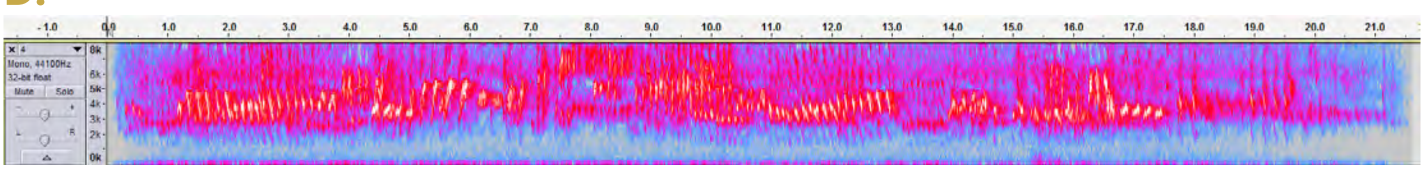
B.



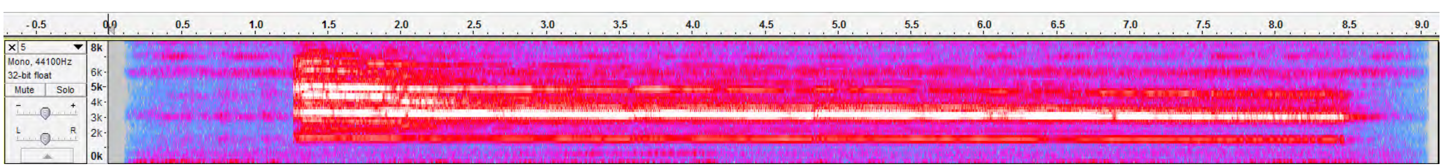
C.

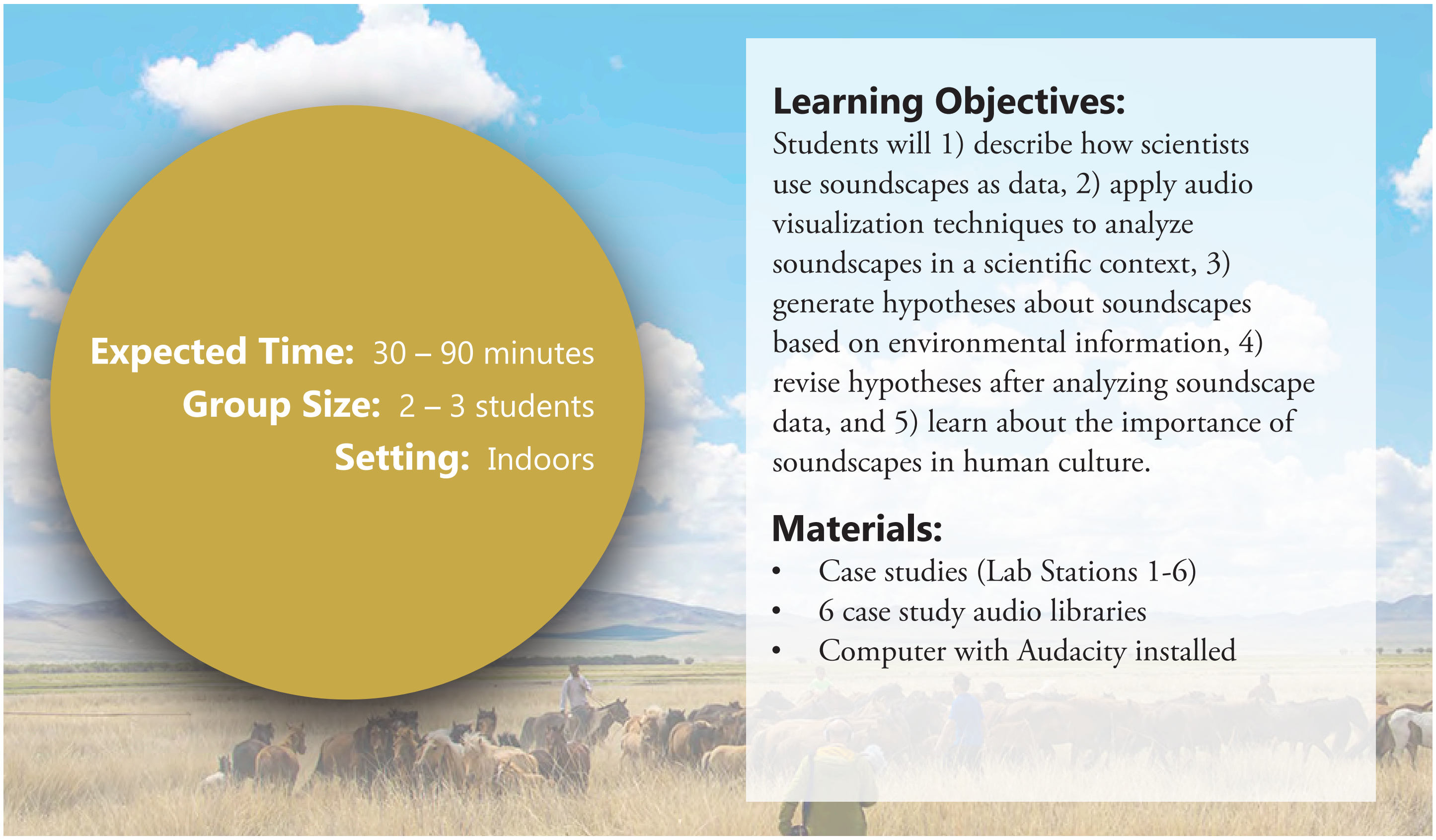


D.



E.





Expected Time: 30 – 90 minutes
Group Size: 2 – 3 students
Setting: Indoors

Learning Objectives:
Students will 1) describe how scientists use soundscapes as data, 2) apply audio visualization techniques to analyze soundscapes in a scientific context, 3) generate hypotheses about soundscapes based on environmental information, 4) revise hypotheses after analyzing soundscape data, and 5) learn about the importance of soundscapes in human culture.

Materials:
- Case studies (Lab Stations 1-6)
- 6 case study audio libraries
- Computer with Audacity installed

Activity 13: Travel for Soundscape Studies

In this activity, students will learn about studies conducted by the research team at the Center for Global Soundscapes (CGS). Through these case studies, they will discover some scientific questions that soundscape ecologists are trying to answer and the different ways in which they collect data. Students will also learn how to answer these questions using audio data collected by CGS scientists.

The Center for Global Soundscapes is located at Purdue University in Indiana, USA. In this center, created in 2014, soundscape ecologists have three main missions:
1. Describe the diversity and dynamics of soundscapes in different locations.
2. Evaluate the impact of natural and human disturbances on soundscapes.
3. Understand the interconnection between soundscapes and people's lifestyles.

To accomplish these goals, soundscape ecologists bring their microphones and recorders to different ecosystems around the world and deploy them for periods ranging from a few days to a year or longer. They leave the equipment in the field and automatically collect the recordings in order to minimize human disturbance on the plants and animals of their study sites.

INSTRUCTOR DIRECTIONS

The variety of questions that scientists try to answer is presented here through different case studies, each of which focuses on a unique location.

Pre-Activity

Soundscape ecologists have conducted studies in many biomes. In this activity, different case studies have been provided to demonstrate the diversity of the research in this area. Each case study has been designed with a map, photos, and study description to guide students to a better understanding of the study area. Each group can complete one case study, or the groups can rotate and complete multiple case studies.

1. Set up one lab station per group with a computer with Audacity and the audio libraries for each case study.
2. Explain the role of research questions in a scientific study.
3. Explain to students the difference between a prediction and a hypothesis, and remind them that they will need to generate hypotheses in this activity.

Activity

1. Assign each group to a lab station(1-6).
2. Invite students to explore the information and images associated with the study and to write down their answers to the "Before Listening" questions.
3. Ask students to listen to the recordings and examine their spectrograms in Audacity (see Activity 12 for instructions on using Audacity).
4. Have each group write down their responses to the "After Listening" questions.
5. Rotate each group to a new case study if desired.
6. Finally, let each group share their responses to the research questions and present some evidence that they found to support their conclusions.
7. Ask students the key questions.

KEY QUESTIONS

Could you conduct any similar research locally?
Answers will vary.
What are some of the limitations of answering a research question with soundscapes?
Answer: In general, ecological research is challenging because there are many variables that may be influencing the topic of interest. Results can also be difficult to interpret due to high levels of natural variability. Additionally, automated acoustic recorders can fail in the field. Sometimes batteries or microphones die, and occasionally animals will damage equipment. Acoustic data can be difficult to interpret as well. While automated measurements can overcome some of this difficulty, they do not always provide a high level of insight.
Did you learn anything new that you did not previously know about soundscape studies? If yes, please explain.
Answers will vary.

POSSIBLE EXTENSIONS

Bring students to a new local area and conduct a short study either applying a research question from this activity or developing a new one. Discuss some of the challenges of using soundscape recordings as data, and ask what other types of data might facilitate interpretation of soundscape data. Visit iListen.org for enhanced interactive content featuring Tropical Rainforest, Grassland, and Coral Reef case studies.

ADAPTATIONS FOR ACCESSIBILITY

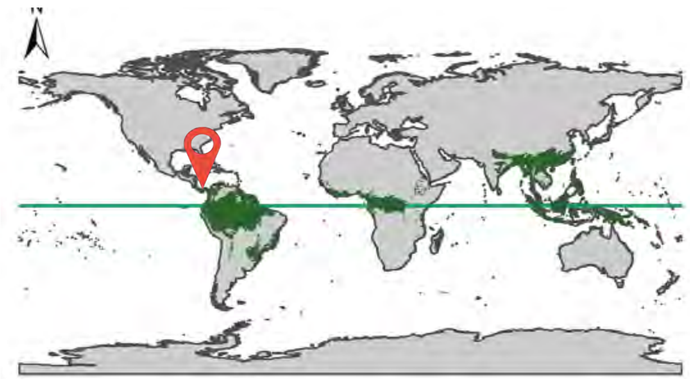
- Read aloud each research question, and then play the corresponding sound file several times.
- Ask students to collaborate to formulate hypotheses and answer the research questions.

BRAIN DUMP

Have students use the Brain Dump worksheet to answer before and after listening questions.

Lab Station 1: Tropical Rainforest Case Study

Let's go to Costa Rica!



La Selva Biological Research Station, Costa Rica

Soundscapes in Layers of the Rainforest:

Research Questions

- How do soundscapes change with the vertical structure of the forest?
- Which layer has the highest soundscape diversity?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.

What are some sound you think you will hear?
Answer will vary.

After Listening

- **How do soundscapes change with the vertical structure of the forest?**
  Answer: Different species live and communicate at different vertical levels in the tropical forests. Forest species are most audible at the level(s) in which they live.
- **Which layer has the highest soundscape diversity?**
  Answer will vary.
- **What are some of the challenges in this study?**
  Answer: The high density of the forest in Costa Rica makes it hard for scientists to get to different sites. Installing the acoustic equipment at different layers of the canopy is also challenging.

Climate and Biodiversity

Temperature: 20 to 25 °C (68 to 77 °F)
Precipitation: 2,000 to 10,000 mm (79 to 394 inches) of rain per year
Plants: Orchids, bromeliads, vines, strangler figs, giant tree ferns
Animals: Howler monkeys, toucans, anacondas, scarlet macaws, red-eyed tree frogs, blue morpho butterflies, army ants, leaf cutter ants, rufous motmots

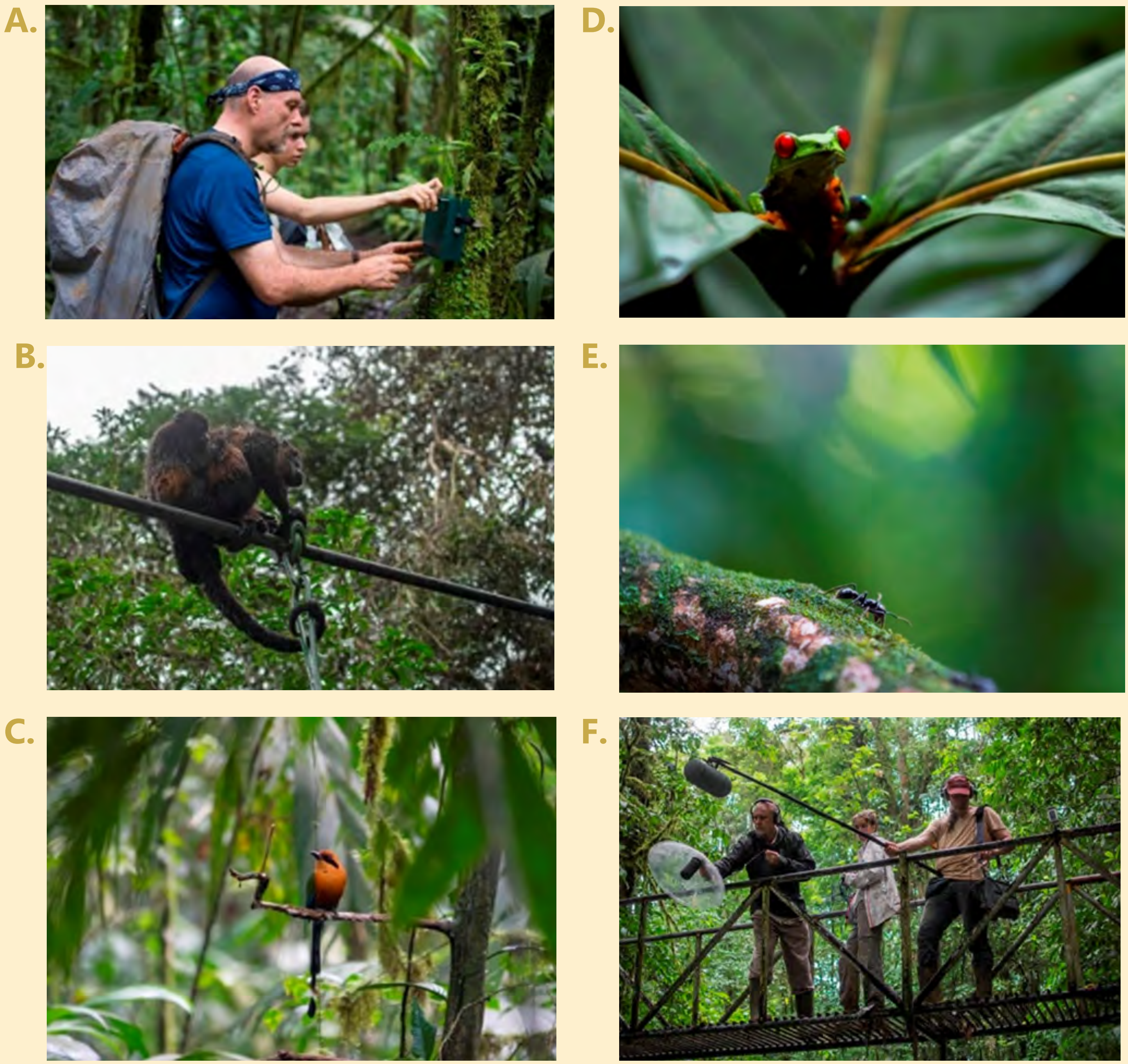
Facts

1. La Selva Biological Research Station is a nature reserve located in Costa Rica, and it is one of the oldest tropical field research stations in the world.
2. The vegetation structure is composed of three vertical layers. The understory layer receives small amounts of sunlight and has few plants. It is home to many animals such as leopards, jaguars, red-eyed tree frogs, and a variety of insects. The canopy layer is full of foliage from large trees, and this presents an abundant food supply to many animals such as spider monkeys, tree frogs, and toucans. The emergent layer has the tallest trees that reach above the canopy.

Soundscape Characteristics

Costa Rica has some of the highest levels of biodiversity anywhere in the world. Over 800 species of animals in La Selva make sounds, from large mammals such as howler monkeys, to small birds and insects.

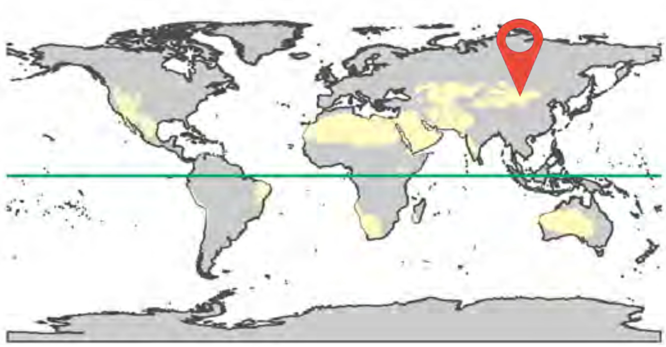
Lab Station 1: Tropical Rainforest Case Study (continued)



Different photos of the study area: A) scientists in the field deploying a Song Meter SM2, B) howler monkey, C) rufous motmot, D) red-eyed tree frog, E) leaf cutter ant, and F) scientists capturing the sound of a river with a parabolic microphone.

Lab Station 2: Grasslands Case Study

Let's go to Mongolia!



Humans and Soundscapes in a Grassland:

Research Question

How do Mongolian people express their connection with nature through soundscapes?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.
- **What are some sound you think you will hear?**
  Answer will vary.

After Listening

- **How do Mongolian people express their connection with nature through soundscapes?**
  Answer: Throat singers of Mongolia live in close contact with nature, and they are inspired by natural soundscapes, which they imitate in their songs.
- **What are some of the challenges in this study?**
  Answer: For foreign visitors, it is difficult to understand and interpret the meaning of Mongolian songs, so to begin to understand the culture, foreign researchers must immerse themselves within the culture for long periods of time.

Climate and Biodiversity

Temperature: -40 to 38 °C (-40 to 100 °F)
Precipitation: 250 mm (10 inches) of rain per year
Vegetation: Grand wormwood, edelweiss, peony, saxaul
Animals: Przewalski wild horse, saiga antelope, snow leopard, desert hedgehog, Siberian crane, tarbagan marmot

Facts

1. Part of the Mongolian population is nomadic and travel throughout the landscape as they herd their livestock.
2. The 4,300 meter (14,107 foot) high Altai Mountain Range, the Gobi desert, and the Eastern Steppe region are three distinct regions in Mongolia.
3. Throat singers in Mongolia are famous for multi-toned sounds they can produce while singing.

Soundscape Characteristics

Mongolian soundscapes are full of amazing sounds from larks, grasshoppers, marmots, and livestock like goats, sheep, and cows. Larks are birds that have some of the most complex songs of any bird. Mongolians believe that the sounds of their landscapes are special and they celebrate these sounds using a special kind of singing called throat singing.

Lab Station 2: Grasslands Case Study (continued)

A.

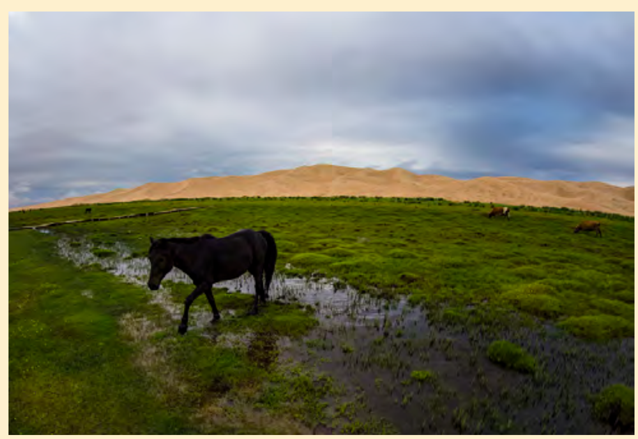
B.

C.

D.

E.

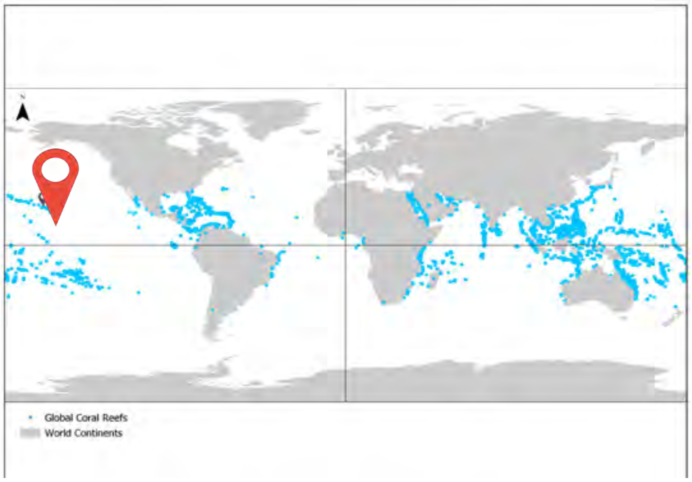
F.



Different photos of the study area: A) scientists in the field deploying a Song Meter SM3 for continuous recording, B) recording a herd of horses, C) throat singer playing a mouth harp, D) Eastern Steppe, E) butterfly in a grassland, and F) a horse in the Gobi Desert.

Lab Station 3: Coral Reef Case Study

Let's go to Hawaii!



Molokini Crater, Maui, Hawaii

Motorboat Noise and Soundscapes in a Coral Reef:

Research Question

How do sounds of animals change in an aquatic environment when noise is present or not present?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.
- **What are some sound you think you will hear?**
  Answer will vary.

After Listening

- **How does noise change the diversity of animal sounds in a marine environment?**
  Answer: There are less diverse animal sounds in an area that is impacted by noise. Some species are active in both places (ie. snapping shrimp), but others disappear from the soundscape.

- **What are some of the challenges in this study?**
  Answer: The marine environment is dangerous for humans to work in. To conduct a study, we must use special equipment like marine-specific sensors and SCUBA gear.

Climate and Biodiversity

Temperature: 66-92 °F (19-33 °C)
Precipitation: 17-18 inches of rain per year
Vegetation: Algae, seagrass
Animals: Parrotfish, snapping shrimp, corals, bulwer's petrel, humpback whale, green sea turtle, dolphins, grouper

Facts

1. The Hawaiian Island Chain (Hawaiian Archipelago) was formed by volcanoes rising up from the floor of the Pacific Ocean over the last 28 million years, and many islands are still growing as lava hardens into rock.
2. Coral reefs support a quarter of all marine species, as habitats where many fish species raise their young, and protect shorelines from dangerous storm surges.
3. There are many layers to the marine environment, from the shallow littoral zone near shore to the deep abyssal plain at the bottom of the open ocean.
4. The Molokini Crater supports more than 200 species of fish, 38 coral species, and 100 species of algae.

Soundscape Characteristics

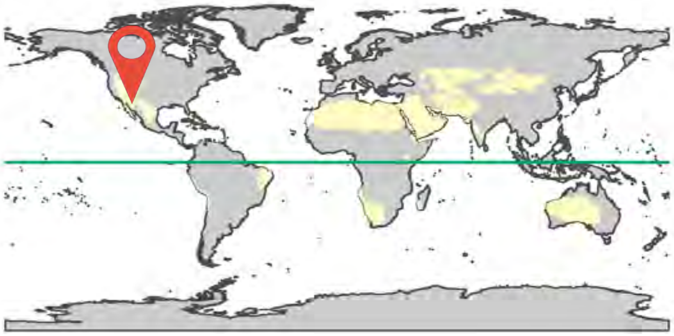
Sound travels more than five times faster in water than in air. This means that sounds can carry much farther in aquatic or marine environments than they do on land. Many marine organisms make sound, or even use sound to find or capture food. Low-pitched noise from human activities can affect marine environments that are very far away from the sound source.

Lab Station 3: Coral Reef Case Study (continued)

Different photos of the study area: A) A coral reef and some of the fish species found there including this grouper, B) Divers deploying an acoustic sensor in a reef, C) A boat, of the kind that might cause noise stress to a reef, D) A humpback whale breeching. Whales use sound to communicate underwater, E) A green sea turtle in Hawaii, and F) dolphins, which use high frequency sound to communicate and hunt.

Lab Station 4: Desert Case Study

Let's go to Arizona!



Chiricahua National Monument, Arizona, USA

Legend

Equator

Deserts

Wildfire Impacts on Desert Soundscapes:

Research Question

What is the difference between soundscapes in the areas impacted by wildfire (burned) versus non-impacted by wildfire (unburned)?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.
- **What are some sound you think you will hear?**
  Answer will vary.

After Listening

- **What is the difference between soundscapes in the areas impacted by wildfire (burned) versus non-impacted by wildfire (unburned)?**
  Answer: The community of cicadas depends on living trees and they are more abundant in the areas that are not impacted by wildfire. Therefore, we hear fewer cicadas at burned sites.
- **What are some of the challenges in this study?**
  Answer: The main challenge is accessibility, as the areas impacted by wildfire are usually located in windy and steep sites.

Climate and Biodiversity

Temperature: -4 to 38 °C (25 to 100 °F)
Precipitation: 250 mm (10 inches) of rain per year
Plants: Prickly pear cacti, saguaro cacti, ocotillos, elephant trees, desert sage, manzanita trees
Animals: Cactus wrens, deer, desert tortoises, bearded dragons, Arizona hairy scorpions, roadrunners, rattlesnakes, coyotes, cicadas, scrub jays, white-tailed deer, mountain spiny lizards

Facts

1. The Sky Islands are isolated mountains that are surrounded by lowlands.
2. The Sky Islands are biodiversity hot spots because these mountains contain ecological life zones that range from hot, dry deserts in the lowlands to grasslands, deciduous forests, and coniferous forests at higher elevations.
3. Every July and August, monsoons bring massive thunderstorms and a considerable amount of rain to this otherwise dry area.
4. Temperature varies drastically in this habitat. Days are very hot, and nights are very cold.
5. Fires naturally occur in many ecosystems due to lightning strikes, lava flows, and spontaneous combustion. In many cases, these fires fulfill valuable ecological functions by removing certain types of vegetation and allowing other types to regenerate.

Soundscape Characteristics

Soundscapes of Arizona are dominated by wind accentuated by complex rock formations and valleys. Rain and thunder are common sounds during the monsoon season but these sounds are absent throughout the rest of the year. Over 40 species of bats (which create ultrasonic sounds humans cannot hear) live here too.

Lab Station 4: Desert Case Study (continued)

Different photos of the study area: A) scientists in the field deploying a Song Meter SM2, B) landscape of the Sky Islands, C) scrub jays, D) Song Meter SM2 deployed for long-term recording, E) white-tailed deer, and F) mountain spiny lizards.

Lab Station 5: Temperate Forest Case Study

Let's go to Indiana!

Ross Biological Reserve, Indiana, USA

Legend

Equator

Temperate Forests

Seasonal Soundscape Change in the Temperate Forest:

Research Question

- How does soundscape diversity change in different seasons in the temperate forest at Ross Biological Reserve?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.
- **What are some sound you think you will hear?**
  Answer will vary.

After Listening

- **How does soundscape diversity change in different seasons in the temperate forest at Ross Biological Reserve?**
  Answer: The morning soundscapes in the temperate forests are dominated by birds, but depending on the season, bird activities change. Spring is the breeding season, in which birds vocalize the most. In winter, many birds migrate south and take their sounds with them.
- **What are some of the challenges in this study?**
  Answer: Understanding and analyzing these rich and diverse soundscapes requires skillful naturalists to identify the bird species from their sounds.

Climate and Biodiversity

Temperature: -30 to 30 °C (-22 to 86 °F)
Precipitation: 750 to 1,500 mm (30 to 59 inches) of rain per year
Plants: American beech, carpet moss, white oak, common primrose, lady fern
Animals: Bullfrogs, northern cardinals, raccoons, white-tailed deer, pileated woodpeckers, starlings, spring peepers, gray squirrels, American robin, cicadas

Facts

1. Temperate forests have four seasons: winter, spring, summer, and fall.
2. A large amount of trees are deciduous, meaning that they lose and regrow their leaves every year.
3. Temperate forests represent an important resource for animals and humans in terms of habitats and food.

Soundscape Characteristics

The soundscapes of Ross Biological Reserve and most temperate forests follow the rhythm of the seasons. Spring is mainly marked by the sounds of birds looking for mates and defining their territories. Summer soundscapes abound with insect and amphibian sounds, especially at night. Fall soundscapes are composed of the sounds of the dead leaves, falling nuts, and the occasional squall of deer. The sound of a forest covered by the snow in the winter is quite subdued because the snow absorbs a lot of sound and allows you to hear the soft songs of birds that did not migrate. The change in vegetation between seasons also changes the sound of the wind that blows through the leaves and branches.

Lab Station 5: Temperate Forest Case Study (continued)

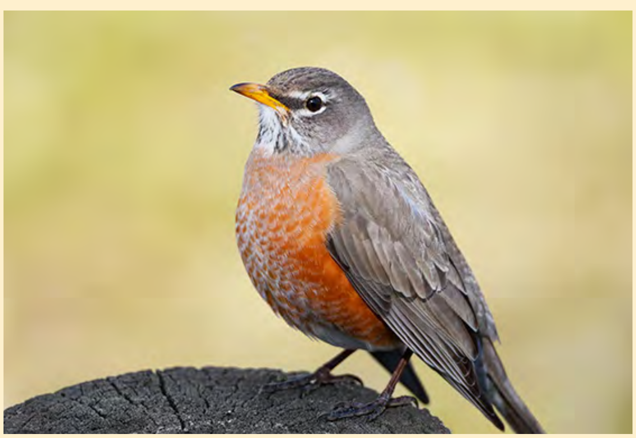
A.

D.

B.

E.

C.

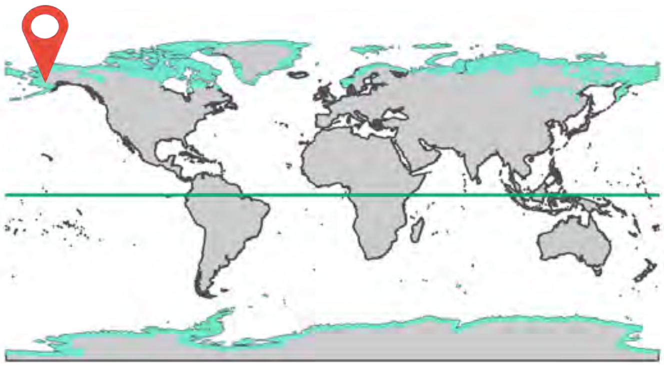


F.

Different photos of the study area: A) a scientist changing batteries and SD cards in a Song Meter SM2 in November, B) winter landscape, C) American robin, D) fall landscape, E) scientists changing batteries and SD cards in a Song Meter SM2 in June, and F) cicadas.

Lab Station 6: Tundra Case Study

Let's go to Alaska!



Denali National Park, Alaska, USA

Legend
Equator
Tundra
Other Biomes

Daily Soundscape Variation in the Tundra:

Research Question

How do soundscapes change over the course of one day in the Alaskan tundra?

Before Listening

- **What factors in the ecosystem(use climate and biodiversity, facts, soundscape characteristc information, and photos to learn more) do you think might influence the soundscape?**
  Answer will vary.
- **What are some sound you think you will hear?**
  Answer will vary.

After Listening

- **How do soundscapes change over the course of one day in the Alaskan tundra?**
  Answer: Wind is audible during the day, and some birds are heard in the morning and even at night. Why? In May the days are very long. Songbirds will sing at midnight!
- **What are some of the challenges in this study?**
  Answer: Tundra is generally located in fairly remote areas, and because of its extremely cold weather throughout most of the year, scientists need special equipment to work and survive in the field. Many dangerous animals also live there, so scientists need to be careful!

Climate and Biodiversity

Temperature: -22 to 19 °C (-7 to 66 °F)
Precipitation: 376 mm (14.8 inches) of rain per year
Plants: Evergreens, mosses, lichens
Animals: Grizzly bear, gray wolves, caribou, moose, bald eagles, long-eared owls, red foxes, wolverines, snowshoe hares, snow geese, canada geese, arctic ground squirrels, fox sparrow, swallow, caribou

Facts

1. Denali is the highest mountain in North America and the park is bigger than many countries (~20,000 km^2 or 7,722 mi^2).
2. Wilderness is well conserved. Visitors are not allowed to leave any sign of human presence.
3. It is not rare to find grizzly bears and moose in the vast tundra, an open area near snowcapped mountains.

Soundscape Characteristics

The soundscapes of the tundra are dominated by wind, but bird sounds are common parts of the soundscape in the early morning. Sounds of melting ice and snow are common everywhere and they are highly varied. Sounds of avalanches are common in the early spring and are very similar to the sounds of earthquakes.

Lab Station 6: Tundra Case Study (continued)

A.

B.

C.

D.

E.

F.

Different photos of the study area: A) scientists in the field deploying a Song Meter SM2 for continuous recording, B) landscape of the tundra in the early summer, C) fox sparrow, D) swallow sitting on a camera next to a microphone array, E) landscape in the early summer, and F) caribou.

Expected Time: 60 – 120 minutes
Group Size: 2 – 3
Setting: Indoors and outdoors

Learning Objectives:

Students will: 1) quantify the consequences of noise for animal populations, 2) apply soundscape ecology knowledge by conducting a soundscape field study, and 3) quantitatively compare soundscape recordings

Materials:

- Worksheets 14.1 – 14.4
- Pencils
- Aldo Leopold Audio Library
- Recorder, smartphone, or tablet
- Recording app such as Record the Earth
- Decibel meter app such as Decibel X

Activity 14: Soundscapes and Road Noise

Human activities including landscape modification and pollution can have negative effects on biodiversity. Roads are one example of human-made infrastructure that can negatively impact wildlife by fragmenting habitats and producing noise that can mask animal communication.

Noise and Animal Communication

Many animals rely on sounds to communicate. Acoustic communication helps animals to select mates, defend territories, and alert others to the presence of predators. Effective communication is necessary to transfer all this information, but different natural and anthropogenic noise sources can mask these signals and impair communication. Roads are particularly noisy and pervasive. They exhibit frequency peaks between 700 and 1,300 Hz, and the low frequencies of road noise can propagate several miles beyond the roads' edges. Animal communication, behavior, and even local presence can be negatively impacted.

INSTRUCTOR DIRECTIONS

In this activity, students learn about roads' impacts on soundscape diversity and bird communication. They then investigate how scientists use different sets of data to answer an ecological research question.

Part 1: The Aldo Leopold Study

1. Divide students into groups of two to three.
2. Provide each group with a computer with Audacity installed.
3. Provide the Aldo Leopold Audio Library and the description of the Aldo Leopold Study.
4. Ask them to explore the description of the study and fill out the first three boxes of Observation Form A (Worksheet 14.3).
5. Ask them to make a graph in Observation Form A using the data provided in Worksheet 14.2, which relates the values of soundscape diversity (mainly due to birds' acoustic activity) with the distance to the road.
6. Ask students to explore the different data sources (the description of the Aldo Leopold Study, the map of the area (Worksheet 14.1), the table of soundscape diversity values (Worksheet 14.2), and the sound library) to answer the research question in the "Results" section of Observation Form A.
7. Bring the students together and let them share their results and how they were obtained.

Part 2: Conduct a Similar Study

1. Provide tools (either a recorder or a tablet and necessary apps) so that students can conduct a similar study.
2. Ask students to choose three different recording sites at different distances from a road or highway. It is recommended that sites be situated at least 40 meters apart so that the soundscapes will not be too similar.)
3. Have them collect all sounds at a certain time of a day in order to capture the same acoustic animal community and similar levels of traffic.
4. Send students to each site to record two sounds at each site.
5. Ask them to take notes of what is heard at each site, as journaling is one useful data collection technique.
6. Use a decibel meter app and have them record the decibel level (dB) of sound at each site.
7. Have students listen to each recording more than once and estimate the levels of geophony, biophony, and anthrophony on a scale of 1 to 3 (i.e. 1 = no geophony, 2 = moderate geophony, and 3 = high geophony). Data should be recorded in Observation Form B (Worksheet 14.4).
8. Bring the students together and let them share their experiences and results.

KEY QUESTION

What were some limitations in your study?
Answers will vary.
How might the impact of road noise be different in a different habitat like the desert?
Answer: Habitat structure influences the propagation of sounds through an environment. The current study was conducted in a forest, and tree leaves, branches, and trunks either absorb or reflect sounds. In a more open habitat like a desert, sounds can travel farther but are more likely to be influenced by other factors like wind.
Do you think the conclusions of this study would be similar if it was conducted at a road near you?
Answers will vary.

POSSIBLE EXTENSIONS

- Ask students to collect data at different times of day to see how soundscapes and the effects of the road can vary throughout the day.
- If multiple roads with different traffic levels are accessible, ask students to compare the effects between the different roads.
- Ask students to spend time at each study site and record their qualitative observations in a journal entry. Encourage them to imagine themselves as various animals living in the space.

ADAPTATIONS FOR ACCESSIBILITY

- Show the recorder to each individual student, and also teach each individual how to operate the recorder.
- One assistant per group may be needed for walking to different sites, helping students make recordings, and completing the observation forms.

Worksheet 14.1: Aldo Leopold Study (Wisconsin, United States)

The Aldo Leopold study was conducted in southern Wisconsin. This temperate forest is home to many bird species, especially during the birds' spring breeding season. [Around 1970, Interstate 90 (I-90) was built through the area.] Figure 14.1 shows the map of the area. For many years scientists have studied roads because of their impacts on ecosystems. Roads cause habitat loss and habitat fragmentation leading to increased edge effects—ecological processes that occur at the edges of landscape patches. The primary impact of roads on soundscapes is low frequency noise that can mask animals' communication over large distances. Traffic noise disturbs prey-predator relationships, pairing success, and also reproductive success.

Birds in forest ecosystems can be classified into three groups. "Forest specialist birds" are territorial and live in the middle of the forest. "Edge specialists" are a group that stays close to the edges between forests and open areas, and "generalist birds" are not especially dependent on forests, open areas, or their boundaries. Roads affect each group differently.

Aldo Leopold Study

Research Question

What are the impacts of the highway on bird population diversity and soundscape diversity? Bird population diversity is the range of different bird species in the area, and soundscape diversity is the diversity of sounds within a soundscape.

Data

- Sound recordings
- Bird species inventories
- Vegetation cover maps

Results

The results of this study showed that as distance to I-90 increased, biophony (primarily as a result of bird sounds) also increased. Birds far from the road vocalize more or communicate using more diverse calls. The road seems to have a negative effect on bird sound diversity.

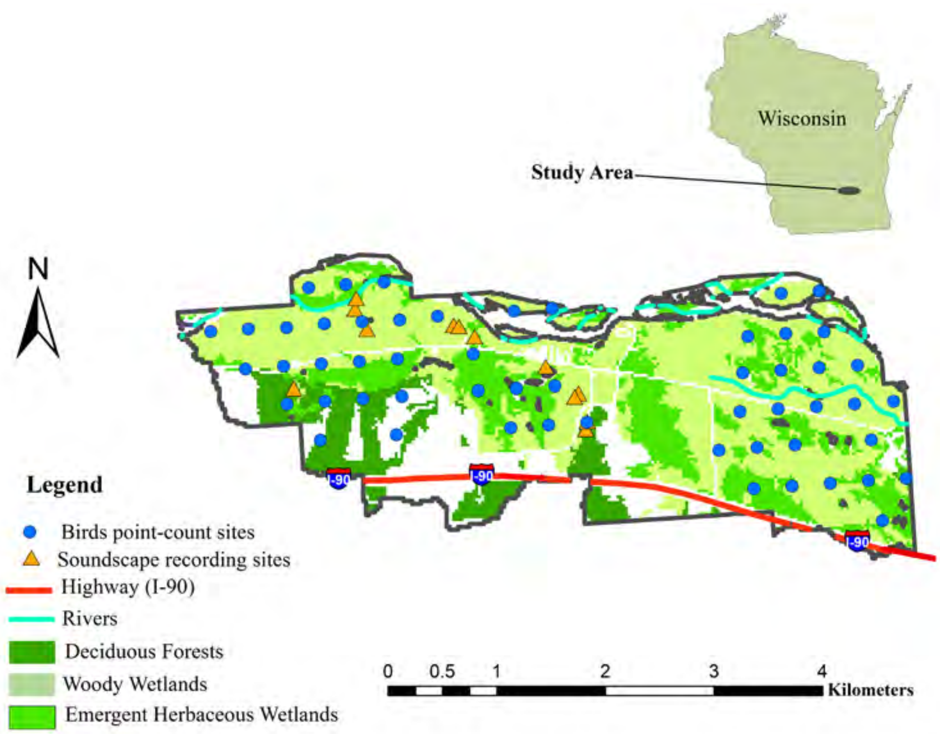


Figure 14.1. Map of the study area.

Worksheet 14.2: Table of Soundscape Diversity in Relation to Distance from I-90

Site	Soundscape Diversity (Mainly Due to Birds)	Distance from Interstate 90 (Meters)
1	2.21	908
2	2.45	1571
3	2.02	869
4	2.28	1162
5	2.09	1577
6	1.27	541
7	1.72	626
8	2.53	1564
9	2.35	1453
10	1.79	878
11	2.27	1785
12	2.96	1898

Worksheet 14.3: Soundscapes and Roads Observation Form A

Where is the research area located?

What is the research question?

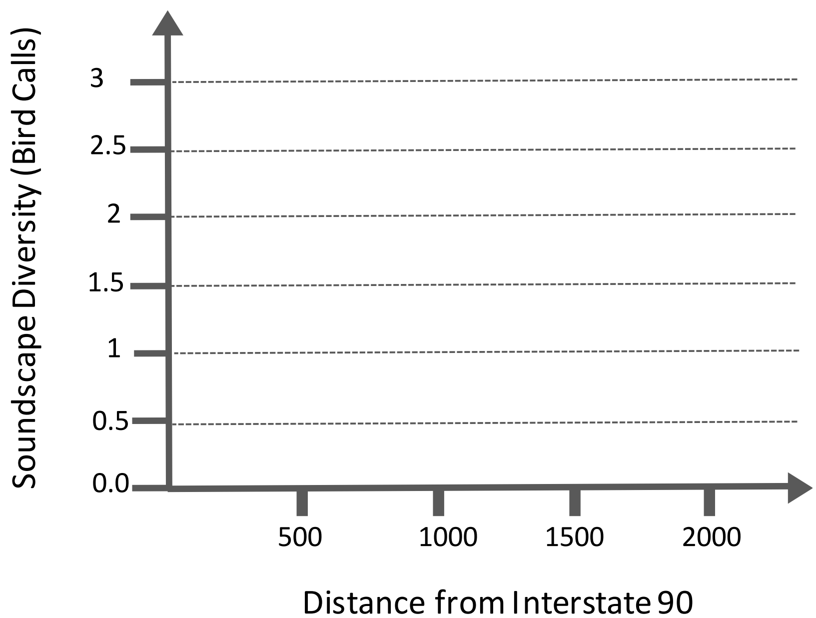
Data collection:
According to the map, how many sound recorders did the soundscape ecologist use?
(Answer: 12 recorders)

According to the map, how many sites were used to collect bird species inventories?
(Answer: 54 sites)

What is the name of the highway?
(Answer: Highway I-90)

In what type of ecosystem is this site located?
(Answer: Deciduous forests, woody wetlands, and emergent herbaceous)

Graph:



Explain your results:

Worksheet 14.4: Soundscapes and Roads Observation Form B

Where is the research area located?

What is the research question?

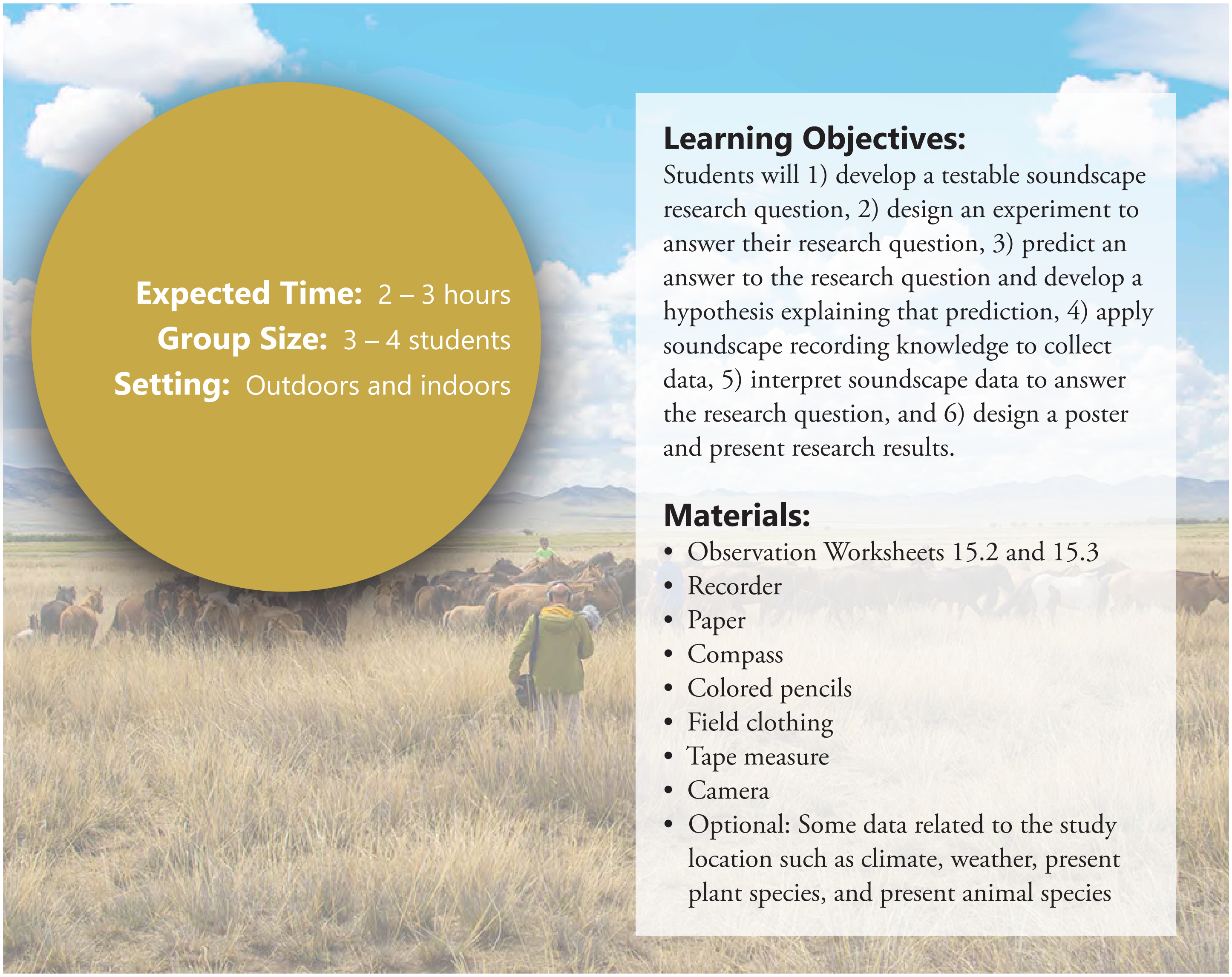
Data collection:
How many recording sites do you have?

How many sounds did you record?

What is the name of the road or highway?

In what type of ecosystem is this site located?

Site number	Recording number	Biophony	Geophony	Anthrophony



Expected Time: 2 – 3 hours
Group Size: 3 – 4 students
Setting: Outdoors and indoors

Learning Objectives:

Students will 1) develop a testable soundscape research question, 2) design an experiment to answer their research question, 3) predict an answer to the research question and develop a hypothesis explaining that prediction, 4) apply soundscape recording knowledge to collect data, 5) interpret soundscape data to answer the research question, and 6) design a poster and present research results.

Materials:

- Observation Worksheets 15.2 and 15.3
- Recorder
- Paper
- Compass
- Colored pencils
- Field clothing
- Tape measure
- Camera
- Optional: Some data related to the study location such as climate, weather, present plant species, and present animal species

Activity 15: Be a Scientist, a Real Soundscaper!

Biologists and ecologists study organisms and their complex interactions. Biological and ecological research is often a complicated and messy process. Many ecological and biological studies are non-experimental, field-based studies, and because so many factors influence biological and ecological processes, it is often difficult to determine which variables are relevant to a given research question. Typically, biologists and ecologists collect many forms of data in order to answer their research questions. For example, if scientists are interested in the impacts of logging on bird populations, they will sample the number of birds in logged and unlogged areas, but they will also collect other data such as the number of trees, average tree height, and average daily temperature at each research site.

The Scientific Method

Scientific research is conducted to answer questions objectively and without bias. From ecologists to physicists, scientists use the scientific method as the standard protocol for conducting research.

The first step of the scientific method is to develop a question based on careful observations. The scientists predict an answer to that question and develop a hypothesis that justifies that prediction. Scientists next design an experiment to test this hypothesis, and then they collect data according to the experimental design. After experimentation, scientists then analyze the collected data to generate results. These results are used to form a conclusion that either supports or refutes the hypothesis.

The scientific method follows these steps:

1. Ask a research question
2. Formulate a hypothesis
3. Design a study to test that hypothesis
4. Conduct the study and collect data
5. Analyze data and synthesize results
6. Draw a conclusion

Scientists can ask three main types of research questions: descriptive, comparative, and correlative. Table 15.1 shows some samples for each type of question.

Descriptive question:

Descriptive questions are common in newly developing fields, and they help scientists gather general information about a subject of interest. To learn about the dynamics of a temperate forest's soundscape, a descriptive question could be, "How does the soundscape change throughout a typical day?"

Comparative question:

A comparative question highlights differences. An example of a comparative question is, "How does the soundscape vary between logged and unlogged areas?"

Correlative question:

Scientists ask correlative questions to identify potential relationships between two or more variables. One such example is, "Is the number of vocalizing birds in a given site related to the site's distance from a highway?"

Type of Question	Sample Questions
Descriptive Question	How many _____ are there in a given area? How frequently does ______ happen in a given time period? What is the ______ [measurement] of ______ [object]?
Comparative Question	Is there a difference in ______ between group or condition #1 and group or condition #2? Is there a difference in _____ between different locations? Is there a difference in _____ between different times? How does _____ change over a given area or distance?
Correlative Question	What is the relationship between _____ and ______? Does ____ go up when _____ goes down? How does _____ change as _____ changes?

Table 15.1. Types of scientific questions.

Who is a soundscape ecologist?

Soundscape ecologists use environmental sounds to answer ecological questions. Soundscape ecologists travel to different locations such as deserts, forests, and oceans to collect sounds by deploying acoustic sensors. These soundscape recordings are one form of data that they collect, along with other information such as type and structure of vegetation, topography, and weather. Soundscape ecologists analyze these diverse forms of data to answer their scientific questions.

INSTRUCTOR DIRECTIONS

In this activity, students take on the role of scientists. They use their prior knowledge to develop research questions, and they conduct field work to connect their scientific theories with the realities of the natural world.

For this activity, students need some basic knowledge about soundscapes along with skills for recording sounds and interpreting spectrograms. They can gain this knowledge and these skills through the following activities: "Sound Walk" (Activity 7), "Sound Map" (Activity 8), and "Audio Visualization" (Activity 12).

Pre-Activity

Divide students into groups of 3 to 4, and define the different roles that they can adopt. Emphasize how soundscape ecology is an interdisciplinary science and how many soundscape ecologists have different specialized backgrounds and skillsets. Some potential roles include:

- Ecologist: Ecologists study nature—more specifically, the interactions between the plants, animals, and non-living features of ecosystems. They also consider human impacts on the environment. Ecologists tend to have skills involving data collection in the field, species identification, and digital data processing. Soundscape ecologists possess broad knowledge of ecosystems, soundscapes, and their interactive relationships.
- Analyst/statistician: Analysts and statisticians work with raw data to extract high-quality, relevant data, and they use that selected data to synthesize results and examine their significance. These individuals play a crucial role in soundscape ecology, as they take vast amounts of raw, seemingly ambiguous data and synthesize it into comprehensible, meaningful results.
- Engineer: Engineers apply scientific knowledge to design technological tools that are implemented in innumerable different arenas. Soundscape ecology relies on engineering for the development of data collection tools like automated acoustic recorders and for the development of data processing tools like computer hardware and software.
- Team leader: Team leaders help their team to define goals, and they then work with team members to achieve those goals. They coordinate the work of other team members and give them feedback and guidance when necessary.

Explain to students that they are all young scientists who need to collaborate in order to design and conduct their soundscape study. Walk them through the following steps to help them become soundscapers!

Activity Part 1: Research Question and Hypothesis

Objective: Choose a scientific question inspired by a sound walk (Some sample questions are provided in Worksheet 15.1).

1. Take students on a sound walk (Activity 7 explains sound walks).
2. Ask them to thoughtfully consider their surroundings with the goal of developing research questions related to that area.
3. Have students identify different sounds in the soundwalk section of Worksheet 15.2.
4. After the sound walk, ask students to brainstorm and discuss potential research questions with their group mates, and have them select and define one

research question that they will seek to answer. A research question should be defined so that it can be answered through feasible methods of data collection and analysis. The definition of this question is important, as its nuances will guide the study's methodology.

5. Ask students to develop a hypothesis regarding their research question. The data they will collect should either support or refute this hypothesis.
6. Ask students to record their research question and hypothesis on Worksheet 15.2.

Activity Part 2: Materials and Methods

Objective: Design a protocol to answer a research question.

1. After the instructor approves each group's research question, students will work in their groups to determine the types of data that they need to collect to answer their question such as audio recordings, weather data, vegetation types, proximity to landscape features like roads or rivers, time, and date.
2. Ask them to complete the "Experiment/Data Collection Protocol" section of Worksheet 15.3.
3. Ask each group to explain its research questions and its methods to the rest of the students and get feedback from the other groups.
4. Remind students to carry their notebooks in order to record observations or to add to their sound maps.
5. Here are some sample data that students should record in the field:
6. Location: reference to general habitat characteristics such as forest, desert, or city. When possible, students should also include specific place names and GPS coordinates or relative locations based on compass bearings.
7. Date and time: this information is essential, as it is one potential factor that determines soundscape variability.
8. Present species and their physical characteristics: different characteristics such as type of species, color, and measurements like length, height, or weight can be added to a report.
9. In addition to journaling, students can take photos and sketch pictures to help them remember their research sites in greater detail.
10. If students have access to a recording device, they should also determine the length of each audio recording (30 to 60 seconds is recommended) and their recording techniques. They can use smartphones or tablets to record sounds too, and they can take pictures of each site as well.
11. Explain the importance of collecting several recordings per site—this repetition limits the potential biasing effect of any one recording, and it better captures the soundscape variability of a site.
12. If students do not have access to a recording device, they can draw a spectrogram on Form 2 when they are in the field.

Activity Part 3: Experimentation and Data Collection

Objective: Collect data according to an experimental protocol.

1. Explain how proper field techniques and consistent data collection are necessary for meaningful results.
2. Students should have appropriate clothing and research materials for fieldwork including boots, tablet, tape measure, recorders, pen, and notebook.
3. Ask students to collect data and complete Worksheet 15.3. This form will help them collect the necessary standardized data to answer their research question. Students can also create additional fields to add extra information if they require additional data to answer their question.

Activity Part 4: Analysis and Discussion

Objective: Interpret data to answer a research question.

1. Within groups, students should discuss their data and the potential relationships between the various forms of data they collected.
2. Ask students to create figures that illustrate their results and demonstrate the answer to their research

question. For example, if they are answering the question, "What is the difference in the soundscape between two sites at varying distances from a road?" Students can make a bar chart of the number of biophonic, geophonic, and anthrophonic sounds at each site (Figure 15.1), or draw a representative spectrogram of the soundscape of each site.

3. Ask students to produce diagrams of the relationship between different elements that affect and are affected by soundscapes.

Activity Part 5: Sharing and Presentation

Objective: Present data and draw a conclusion.

1. Provide the materials for students to make posters that present their studies (Figure 15.2).
2. Although it is important that presentations contain the following criteria, encourage creativity as well!

- Clearly state the initial research question (introduction).
- Briefly summarize the experimental protocol (methods).
- Present results using at least one figure, one table of sounds, one table of environmental variables, and one sound map (results).
- Feature some soundscape recordings (results).
- Make a slogan: present a message about the importance of this soundscape (discussion/ conclusion).
- Discuss the implications of the data and whether or not they were sufficient to answer the initial research question (discussion/conclusion).
- Feel free to decorate posters using collected natural materials, drawings, or photographs.

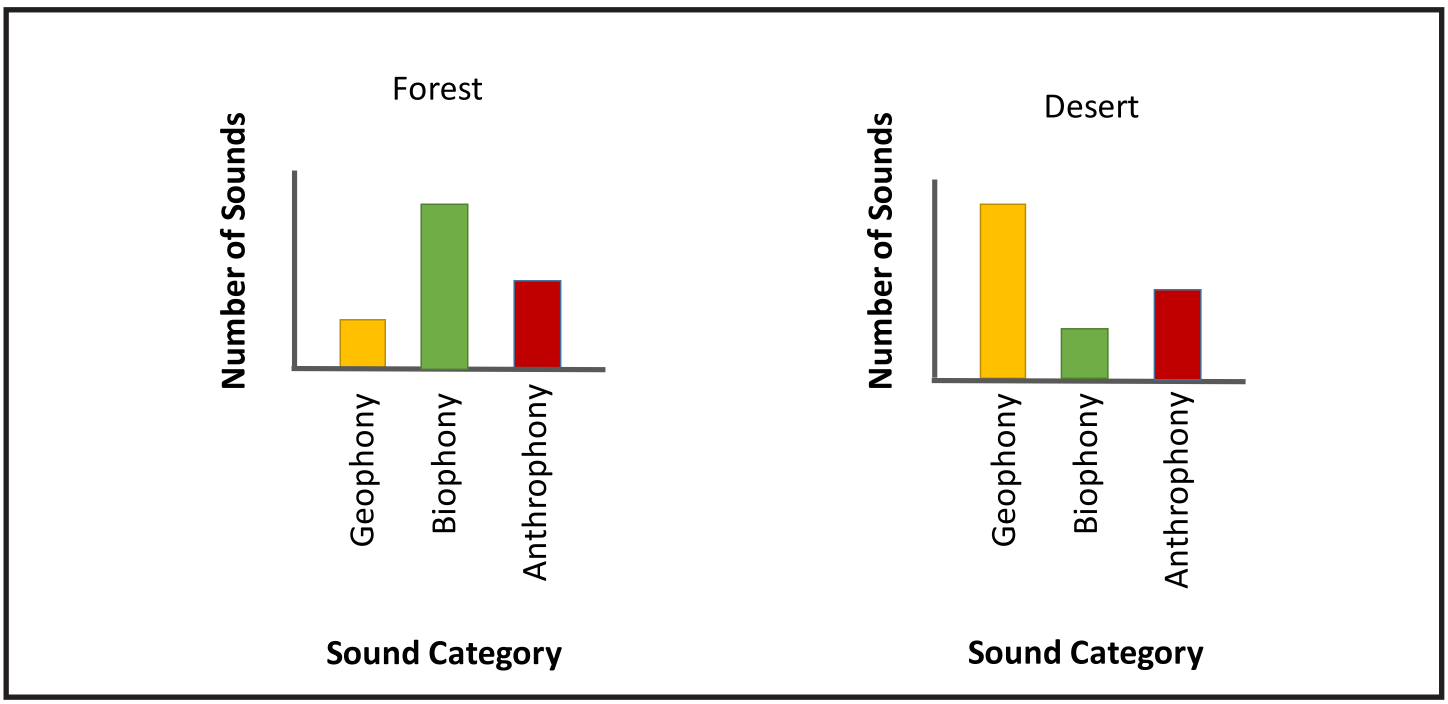


Figure 15.1. Bar chart representing the number of elements related to biophony, geophony, and anthrophony at each site.

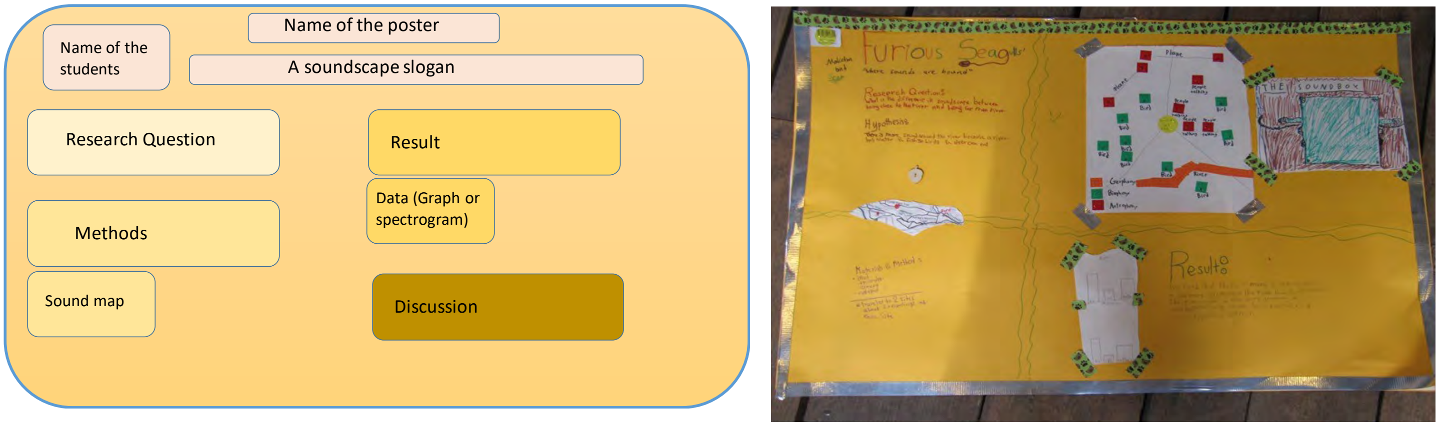


Figure 15.2. Poster template and poster made by students in a soundscape science camp.

POSSIBLE EXTENSIONS

- Ask each group to peer-review other groups' research designs. Would they do anything differently to answer the same research question?
- Ask students to discuss some of the challenges that they encountered (or could imagine encountering) in soundscape research and how they did (or would) address those challenges.
- If time allows, encourage students to expand the scope of their study in space and/or time to make their conclusions more broadly generalizable.
- Ask students if their methodologies would have to be altered to answer similar questions in different ecosystems or biomes.

ADAPTATIONS FOR ACCESSIBILITY

- One assistant per group may be needed for walking to different sites, helping students make recordings, and helping to complete the observation forms.
- Instead of making posters, students can describe their questions, hypotheses, methods, observations, and conclusions.
- Play each group's recordings to help them justify their answers.

KEY QUESTIONS

How can we better record soundscapes?
Answer: See the "How to Improve Recordings of Natural Sounds" section in Activity 9 (pg. 71).

When were the best times to record based on your research questions?
Answers will vary.

Which places had relatively consistent soundscapes, and what elements made them that way?
Answer: Places close to traffic noise (anthrophony) or flowing water (geophony) often have consistent soundscapes. Some insect species like cicadas can produce consistent biophony as well.

What were some features of the landscapes at your recording sites?
Answers will vary.

Did anything seem to be missing in the soundscapes?
Answers will vary.

How can we increase the quality of soundscapes in our surroundings?
Answers will vary.

Worksheet 15.1: Sample Research Questions

Descriptive Questions:

- How many types of sounds occur at a site and what are their characteristics (e.g. duration, frequency, and amplitude.)?
- How diverse is the soundscape at site X?
- How frequently do birds sing during the day? What other sounds are present when they sing?
- How does the soundscape change throughout the day?

Comparative Questions:

- What is the difference between the soundscapes at a site close to a road and a site far from the road?
- What is the difference between the soundscapes at a site in the middle of a forest and a site in an open area?
- What is the difference between the soundscapes at night and in the early morning?
- What is the difference between sounds made by animals and sounds made by weather?
- What are the levels of biophony at various sites? What might explain this variability?
- How do recorded soundscapes differ from soundscapes perceived live by humans?
- Which season has the greatest diversity of sounds?

Correlative Questions:

- How do soundscapes change when traffic noise increases?
- What is the relationship between vegetation structure and soundscapes?
- What is the effect of roads on soundscapes?
- How do soundscapes change as seasons change?

Worksheet 15.2: Be a Scientist Observation Form A

Team name:

Members:

Date:

Time:

Sound Walk

	Natural Sounds				Human-made Sounds	
	Biophony	Tally	Geophony	Tally	Anthrophony	Tally
Site Name	e.g., bird sounds		e.g., rain sounds		e.g., car sounds	

Sound Map

Worksheet 15.2: Be a Scientist Observation Form A (continued)

Species Inventory (List any local animal or plant species that you can identify.)

Vegetation & Environmental Features

1. Weather Conditions: ☐Cool ☐Hot ☐Wet ☐Dry
2. How many trees do you see in a 10-meter (30-foot) radius?
3. How many shrubs do you see in a 10-meter (30-foot) radius?

Digital Data

- Take a picture that shows the name of the site in the foreground and the site in the background.
- Take four pictures of the site from different directions.
- Make two or more soundscape recordings per site (30 – 60 sec).

Worksheet 15.3: Be a Scientist Observation Form B

Team name:

Members:

Date:

Time:

Research Question:

Hypothesis:

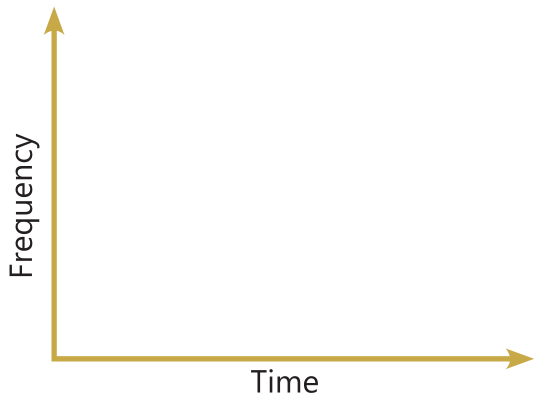
Experiment/Data Collection Protocol

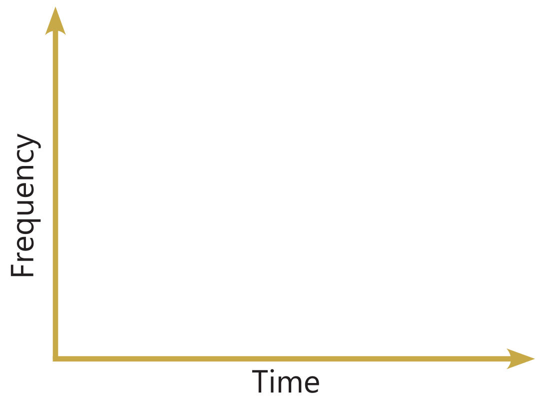
Answer the following questions before going to the field:

- What type of data do you need to collect?
- What equipment do you need?
- Where are you going to collect data?
- How many sites will you study?
- How many times will you visit each site?
- How many recordings will you make at each site?

Worksheet 15.3: Be a Scientist Observation Form B (continued)

Draw the Spectrogram of the Soundscapes





Extra Notes

TOPIC INDEX

Name of Activity	NGSS Standard	Duration (A, B, C, D)	Physic of Sound				Natural Soundscape				Ecology					Biodiversity		
			Frequency	Pitch	Speed	Spectrogram	Definition	Geophony	Biophony	Anthrophony	Ecosystems	Environmental Quality	Ocean/Marine	Sustainability	Human Activity	Animal Communication	Prey-Predator	Adaptation
Activity 1.Sound Production	PS4	A	•	•	•													
Activity 2. Be a Molecule	PS4	A	•	•	•													
Activity 3. Using Tools to Listen	PS4	A	•	•	•													
Activity 4. Animal Echo	LS4	A														•	•	•
Activity 5. Find Your Pair	LS2	A	•	•	•				•							•		•
Activity 6. Audio Bingo	LS4	A					•	•	•	•								
Activity 7. Sound Walk	LS4	A					•	•	•	•	•	•						
Activity 8. Sound Map	ESS	B						•	•	•	•							
Activity 9. Sound Scavenger Hunt	ESS	A	•					•	•	•	•				•			
Activity 10. Soundscape Data Collection	PS4	A/B	•			•	•	•	•	•	•	•		•	•			
Activity 11. Global Soundscapes	LS2	A					•	•	•	•	•	•	•	•	•	•		
Activity 12. Audio Visualization	PS4	C	•	•	•	•					•	•	•		•			
Activity 13. Travel for Soundscape Studies	LS2	B					•	•	•	•	•	•	•	•	•			
Activity 14. Soundscape and Roads	LS2	C	•	•		•				•	•	•				•	•	•
Activity 15. Be a Scientist, a Real Soundscaper	PS4	C				•	•	•	•	•	•	•			•	•		

Duration: A= up to 60 minutes, B: 60-90 minutes, C= >90 minutes

SKILL INDEX

Name of Activity	Indoor or Outdoor	Field Investigation	Gather		Organize	Research	Analyze	Interpret						Discussion	Present	Apply	STAM Area Skills			
			Observation	Listening				Classification	Comparison	Construction	Description	Evaluation	Generalization				Science	Technology	Engineering	Math
Activity 1. Sound Production	I		◄	◄								◄					◄			
Activity 2. Be a Molecule	I/O		◄	◄													◄			
Activity 3. Using Tools to Listen	I/O	◄	◄	◄												◄	◄			
Activity 4. Animal Echo	I/O			◄													◄			
Activity 5. Find Your Pair	I			◄			◄					◄					◄			
Activity 6. Audio Bingo	I			◄	◄			◄			◄			◄			◄			
Activity 7. Sound Walk	O	◄	◄	◄	◄			◄			◄		◄				◄			
Activity 8. Sound Map	O	◄	◄	◄	◄	◄		◄		◄			◄	◄	◄		◄		◄	
Activity 9. Sound Scavenger Hunt	I/O	◄	◄	◄	◄				◄			◄		◄	◄	◄	◄			
Activity 10. Soundscape Data Collection	I/O	◄	◄	◄	◄	◄	◄		◄	◄		◄	◄	◄		◄		◄	◄	
Activity 11. Global Soundscapes	I			◄					◄		◄	◄	◄				◄			
Activity 12. Audio Visualization	I			◄		◄	◄	◄	◄		◄	◄	◄				◄	◄		◄
Activity 13. Travel for Soundscape Studies	I			◄		◄			◄		◄	◄			◄		◄			
Activity 14. Soundscape and Roads	I/O	◄		◄		◄	◄		◄		◄	◄		◄	◄	◄	◄	◄		◄
Activity 15. Be a Scientist, a Real Soundscaper	I/O	◄	◄	◄	◄	◄	◄		◄	◄	◄	◄		◄	◄	◄	◄	◄		◄

ASSESSMENT STRATEGY

Name of Activity	Observation	Produce	Communication: Verbal	Communication: Written	Communication: Drawn
Activity 1.Sound Production	▲			▲	
Activity 2. Be a Molecule			▲		
Activity 3. Using Tools to Listen				▲	
Activity 4. Animal Echo			▲		
Activity 5. Find Your Pair			▲		
Activity 6. Audio Bingo	▲				
Activity 7. Sound Walk		▲		▲	▲
Activity 8. Sound Map		▲			
Activity 9. Sound Scavenger Hunt	▲	▲			
Activity 10. Soundscape Data Collection	▲				
Activity 11. Global Soundscapes	▲			▲	
Activity 12. Audio Visualization			▲	▲	
Activity 13. Travel for Soundscape Studies	▲		▲		
Activity 14. Soundscapes and Road Noise			▲	▲	
Activity 15. Be a Scientist, a Real Soundscaper			▲	▲	▲

GLOSSARY

Acoustic Niche Hypothesis
The hypothesis that animals differentiate their sounds in time, frequency, and/or timbre in order to avoid overlap with other individuals or species in their area

Amplitude
The magnitude of pressure changes, which can be measured in various ways

Anthrophony
The sounds produced by humans and human-built machines

Audacity
A free computer program that enables simple audio processing and sound visualization

Base map
A simple map that represents basic landscape features

Biomes
Large areas of the earth that are grouped based on their similar climates and organisms

Biophony
The sounds produced by non-human animals

Body movement
Sound production by moving all or part of the body

Climate
Long-term (≥ 30 years) measurements of climatic conditions

Clipping
A feature of some recordings that occurs when sounds exceed the amplitude that the microphone or recorder can tolerate

Comparative question
A question involving the comparison between two things

Compression (a)
The phase of a pressure wave at which molecules of the transmitting medium are closest together

Compression (b)
The reduction of an audio file size that may or may not diminish audio quality

Correlative question
A question involving the relationship between two or more trends

Decibel
A unit expressing the amplitude of a sound

Descriptive question
A question involving the description of something

Duty cycle
A recording schedule that specifies the time at which and duration for which recordings will be made

Echolocation
The emission and reception of sounds used to determine the structure and nature of an organism's surroundings

Edge effects
The ecological effects resulting from dynamics unique to the boundaries and transitions between habitat types

Edge specialists
Animals that are adapted for life on habitat boundaries and transitions

Field recording
A recording of naturally occurring sounds made outside of a recording studio

Forest specialists
Animals that are adapted for life in forests

Fragmentation
The division of natural habitats into smaller, less connected pieces

Frequency
The number of times per unit of time that points of maximum or minimum pressure in a pressure wave pass a given point

Gain
Amplifying the output signal from the microphone before that signal is recorded

Generalists
Animals that are adapted for life in a wide variety of habitat conditions

Geophony
The sounds created by geological or atmospheric processes

Hertz
A unit expressing frequency as the number of pressure peaks per second

Hypothesis
The ecological or biological mechanism that justifies a prediction

Information
Any signal or cue that reduces uncertainty about a situation

Infrasound/Infrasonic
Sound with a frequency below the lower limit of human hearing (~20 Hz)/the adjective used to describe such sounds

Lossless
A description of audio file formats in which audio quality is undiminished, despite the fact that the file size may be reduced

Medium
Any substance through which sound travels

Microphone
A device used to capture pressure changes and convert them to electrical signals

Mono
A type of recording that records a single channel of sound

Niche
A physical space or functional role used by an organism to reduce competition

Noise
Sound that impedes communication or interferes with life functions

Noise masking
Sound overlapping in time, frequency, and timbre with an organism's sound intended for communication

Oscillogram
A sound visualization that shows time on the x-axis and instantaneous pressure on the y-axis

Percussion
Sound production by striking all or part of the body against itself or another object

Physiology
The physical functioning of an organism

Pinna (plural pinnae)
The outer part of the ear that directs sound into the ear canal and influences how an organism perceives the direction and timbre of sound

Pitch
Perceived frequency; while similar, "frequency" and "pitch" are not exactly synonymous

Prediction
An educated guess about what will happen in an experiment or field study that is based on a hypothesis

Rarefaction
The phase of a pressure wave at which molecules of the transmitting medium are farthest apart together

Recorder
A device used to store the electrical signals generated by a microphone; most contemporary recorders convert those signals to a digital format

Sampling rate
In digital audio, the number of times per second at which pressure is recorded; generally measured in Hz or kHz (1 kHz, or kilohertz, equals 1,000 Hz)

Sense of place
A personal conception of a place based on one's personal experiences

Song Meter
An automated acoustic recorder made by Wildlife Acoustics for long-term field deployment

Sound
A pressure wave generated by vibrating objects that travels through a medium

Sound map
An image depicting the nature and location of sound sources in a certain area

Sound production
Causing an object to vibrate

Sound propagation
The movement of a pressure wave through a medium

Sound reception
The detection of pressure changes through an organ or a microphone

Sound visualization
A method of depicting audio visually

Sound walk
An intentional listening exercise in which participants walk quietly through an environment listening to the sounds around them

Soundscape
The collection of all sounds occurring in one place over a given period of time

Soundscape ecology
A branch of science examining the composition and dynamics of soundscapes, the sonic interactions within a soundscape, and the interactions between soundscapes and other natural and human processes

Spectrogram
A sound visualization that show time on the x-axis, frequency on the y-axis, and amplitude on the z-axis (often as a color gradient)

Stereo
A type of recording that records two separate channels of sound, generally referred to as the left and right channels, that provides spatial information about the sound sources

Stridulation
Sound production by scraping two body parts together

Scientific method
The method by which most scientific inquiry is conducted, consisting of six steps: 1) formulating a research question, 2) formulating a hypothesis, 3) designing a study to test that hypothesis, 4) conducting the study and collecting data, 5) analyzing data and synthesizing results, and 6) drawing conclusions

Translation
The psychological process through which physical vibrations of an organ are perceived as information

Tremulation
Sound production by shaking all or part of the body

Tympanic membrane/tympanum
The thin piece of tissue in the ear canal that vibrates in response to sound

Ultrasound/Ultrasonic
Sound with a frequency above the upper limit of human hearing (~20,000 Hz)/the adjective used to describe such sounds

Vocalization
Sound production by forcing air over a vibrating membrane

Wavelength
The physical distance between two consecutive points of maximum (or minimum) pressure in a pressure wave; "Wavelength" and "period" address similar concepts, but wavelength refers to distance, while period refers to time

Weather
Short-term measurements of climatic conditions

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Hands of the Future, Inc.
National Science Foundation
Perkins School for the Blind

SOUND REFERENCES

Sound File	Citation	ID of the Sound Collector
Activity 4: Animal Echo		
Barred Owl.mp3	CGS	
Bats.mp3	https://freesound.org/people/felix.blume/sounds/245768/	Felix Blume
Beaver Tail Splashing.mp3	https://www.pond5.com/sound-effects/1/beaver-tail-slap.html#1	Pond5
Black Capped Chickadee.mp3	https://freesound.org/people/wildear1/sounds/94848/	www.wildearthvoices.com
Bottlenose Dolphin.mp3	https://www.pond5.com/sound-effects/1/bottlenose-dolphin.html#1	Pond5
Bullfrog.mp3	Ben Gottesman	Ben Gottesman
Canada Geese.mp3	CGS	Center for Global Soundscapes
Cicadas.mp3	Ben Gottesman	Ben Gottesman
Coyotes.mp3	CGS	Center for Global Soundscapes
Crickets.mp3	Ben Gottesman	Ben Gottesman
Gorilla.mp3	https://www.pond5.com/sound-effect/8754842/gorilla-grunt.html	Pond5
Howler monkey.mp3	CGS	Center for Global Soundscapes
Humpback Whale Call-SoundBible.com-1090143239.mp3	https://freesound.org/people/listeningtowhales/sounds/325565/	Compass Recordings
Lion.mp3	https://www.pond5.com/sound-effect/67014871/animals-lion-close-roar.html	Lion
Mallard Duck.mp3	https://www.freesound.org/people/dobroide/sounds/31835/	dobroide
Northern Cardinal.mp3	CGS	Center for Global Soundscapes
Pileated Woodpecker.mp3	https://www.pond5.com/sound-effect/8717887/birdpileatedwoodpecker.html#1	Pond5
Rattlesnake.mp3	Ben Gottesman	Ben Gottesman
Elk.mp3	https://www.pond5.com/sound-effect/12713551/elk-bugling.html	Pond5
Ring Tailed Lemur.mp3	Ben Gottesman	Ben Gottesman
Sheep.mp3	https://freesound.org/people/felix.blume/sounds/386446/	Felix Blume
Spring Peepers.mp3	Ben Gottesman	Ben Gottesman
White Stork.mp3	https://www.pond5.com/sound-effect/8671817/whitestorkbill62090.html	Pond5
Whooping Crane.mp3	https://www.pond5.com/sound-effect/8671624/whoopingcranere6090.html	Pond5

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
Activity 5: Find Your Pair		
Anthrophony Airplane.mp3	http://soundbible.com/1600-Small-Airplane-Long-Flyby.html	Mike Koenig
Anthrophony Cars.mp3	Ben Gottesman	Ben Gottesman
Anthrophony People Talking.mp3	Ben Gottesman	Ben Gottesman
Anthrophony Cargo Train.mp3	https://freesound.org/people/Heigh-hoo/sounds/69005/	Heigh-hoo
Anthrophony Industrial Sewing Machine.mp3	https://freesound.org/people/temawas/sounds/133048/	temawas
Anthrophony Israeli Market.mp3	Ben Gottesman	Ben Gottesman
Alligator.mp3	http://www.fws.gov/video/sound.htm	National Park Service
Bald Eagle.mp3	Ben Gottesman	Ben Gottesman
Bats.mp3	https://freesound.org/people/felix.blume/sounds/245768/	Felix Blume
Bees.mp3	Ben Gottesman	Ben Gottesman
RedSquirrel.mp3	Ben Gottesman	Ben Gottesman
Cows.mp3	Ben Gottesman	Ben Gottesman
Coyotes.mp3	CGS	Center for Global Soundscapes
Cricket.mp3	CGS	Center for Global Soundscapes
Fly.mp3	Ben Gottesman	Ben Gottesman
Gecko.mp3	CGS	Center for Global Soundscapes
Howler Monkey.mp3	CGS	Center for Global Soundscapes
Owl.mp3	CGS	Center for Global Soundscapes
Sandhill Cranes.mp3	Ben Gottesman	Ben Gottesman
Sheep.mp3	https://freesound.org/people/felix.blume/sounds/140199/	Felix Blume
Sparrow.mp3	https://freesound.org/people/felix.blume/sounds/386034/	Felix Blume
Geophony Borneo.mp3	CGS	Center for Global Soundscapes
Geophony Gentle River.mp3	Ben Gottesman	Ben Gottesman
Geophony Rain.mp3	https://freesound.org/people/thorvandahl/sounds/184213/	thorvandahl
Geophony River.mp3	Ben Gottesman	Ben Gottesman
Geophony Waves.mp3	Ben Gottesman	Ben Gottesman
Geophony Wind and Creaking Trees.mp3	https://freesound.org/people/felix.blume/sounds/197286/	Felix Blume

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
Activity 6: Audio Bingo		
ANTHRO Airplane.mp3	https://freesound.org/people/cliftonmcarlson/sounds/251962/	Clift Carlson
ANTHRO Applause.mp3	http://www.freesound.org/people/joedeshon/sounds/119027/	joedeshon
ANTHRO Breaking Plate.mp3	Ben Gottesman	Ben Gottesman
ANTHRO Clock.mp3	http://www.freesound.org/people/Tewkesound/sounds/140152/	Tewkesound
ANTHRO Creaking Door.mp3	http://www.freesound.org/people/Corsica_S/sounds/123600/	Corsica_S
ANTHRO Eating Carrot.mp3	https://freesound.org/people/iamshort/sounds/181271/	iamshort
ANTHRO Evil Laughter.mp3	http://www.freesound.org/people/acekasbo/sounds/120762/	acekasbo
ANTHRO Fireworks.mp3	https://freesound.org/people/felix.blume/sounds/140350/	Felix Blume
ANTHRO Footsteps.mp3	http://www.freesound.org/people/mikaelfernstrom/sounds/68687/	mikaelfernstrom
ANTHRO Laughing Baby.mp3	https://freesound.org/people/Iamgiorgio/sounds/371302/	Iamgiorgio
ANTHRO Soda Bottle.mp3	http://www.freesound.org/people/jwsoundfoley/sounds/207562/#comments	jwsoundfoley
ANTHRO Traffic.mp3	https://www.pond5.com/sound-effect/56186488/street-ambience-traffic-horns-india.html	Pond5
ANTHRO Train.mp3	https://freesound.org/people/delta_omega_muon/sounds/130076/	delta_omega_muon
ANTHRO Typing.mp3	http://www.freesound.org/people/brettkux/sounds/179385/	brettkux
ANTHRO Vibrating Phone.mp3	http://soundbible.com/1994-Phone-Vibrating.html	Sound Explorer
ANTHRO Yawning.mp3	https://freesound.org/people/Fortyseven203/sounds/240139/	Fortyseven203
BIO Bees.mp3	Ben Gottesman	Ben Gottesman
BIO RedSquirrel.mp3	Ben Gottesman	Ben Gottesman
BIO Cicadas.mp3	Ben Gottesman	Ben Gottesman
BIO Crows.mp3	Ben Gottesman	Ben Gottesman
BIO Dogs.mp3	https://freesound.org/people/Juan_Merie_Venter/sounds/327666/	Juan Merie Venter
BIO Dolphins.mp3	https://www.pond5.com/sound-effects/1/bottlenose-dolphin.html#1	Pond5
BIO Horse.mp3	https://freesound.org/people/n_audioman/sounds/321950/	n_audioman
BIO Lemurs.mp3	Ben Gottesman	Ben Gottesman

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
BIO Lions.mp3	https://www.pond5.com/sound-effect/67014871/animals-lion-close-roar.html	Pond5
BIO Rattlesnakes.mp3	Ben Gottesman	Ben Gottesman
BIO Roosters.mp3	https://freesound.org/people/cocoricosound/sounds/164615/	cocoricosound
BIO Snapping Shrimps.mp3	https://freesound.org/people/digifishmusic/sounds/45437/	Digifish Productions
BIO Starlings.mp3	Ben Gottesman	Ben Gottesman
GEO Avalanche.mp3	https://www.pond5.com/sound-effect/72975782/snow-avalanche-2-big.html	Pond5
GEO Breaking Ice.mp3	https://freesound.org/people/humanoide7000/sounds/329744/	humanoide7000
GEO Bubbles.mp3	https://freesound.org/people/spookymodem/sounds/202094/	spookymodem
GEO Falling Tree.mp3	CGS	Center for Global Soundscapes
GEO Hail.mp3	http://www.freesound.org/people/joly1/sounds/81452/	joly1
GEO Lightning.mp3	http://www.freesound.org/people/NoiseNoir/sounds/238302/	NoiseNoir
GEO River.mp3	Ben Gottesman	Ben Gottesman
GEO Splashing Water.mp3	https://freesound.org/people/InspectorJ/sounds/352101/	InspectorJ
GEO Thunder.mp3	https://www.pond5.com/sound-effect/8891520/thunder.html	Pond5
GEO Waterfall.mp3	http://www.freesound.org/people/Corsica_S/sounds/184731/	Corsica_S
GEO Wildfire.mp3	https://freesound.org/people/Dynamicell/sounds/17548/	Dynamicell
GEO Wind.mp3	https://freesound.org/people/felix.blume/sounds/217506/	Felix Blume
Parrots.mp3	CGS	Center for Global Soundscapes
Sound_Bird.mp3	CGS	Center for Global Soundscapes
Sound_Cicadas (Borneo).mp3	CGS	Center for Global Soundscapes
Sound_Rain.mp3	https://freesound.org/people/club%20sound/sounds/104280/	club sound
Sound_Sparrow.mp3	CGS	Center for Global Soundscapes
Sound_Tiger Roar.mp3	https://www.pond5.com/sound-effect/8701047/animal-tiger.html	Pond5
Sound_Wind.mp3	https://freesound.org/people/felix.blume/sounds/135193/	Felix Blume
Soundscape _ Birds and traffic.mp3	CGS	Center for Global Soundscapes
Soundscape_Bird and thunder.mp3	CGS	Center for Global Soundscapes

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
Soundscape_Cicadas and birds(Costa Rica).mp3	CGS	Center for Global Soundscapes
Soundscape_Cicadas and Howler monkey (Costa Rica).mp3	CGS	Center for Global Soundscapes
Soundscape_Different Birds (Temprate forest IN).mp3	CGS	Center for Global Soundscapes
Soundscape_Geese and frogs (Wetland IN).mp3	CGS	Center for Global Soundscapes
Soundscape_Rain and frogs (Wetland IN).mp3	CGS	Center for Global Soundscapes
Soundscape_Spring Peepers at night (Wetland IN).mp3	CGS	Center for Global Soundscapes

Sound File	Citation	ID of the Sound Collector
Activity 11: Global Soundscapes		
Desert1.mp3	CGS	**Center for Global Soundscapes**
Desert2.mp3	CGS	Center for Global Soundscapes
Desert3.mp3	CGS	Center for Global Soundscapes
Desert4.mp3	CGS	Center for Global Soundscapes
Taiga1.mp3	CGS	Center for Global Soundscapes
Taiga2.mp3	CGS	Center for Global Soundscapes
Temperate forest1.mp3	Ben Gottesman	Ben Gottesman
Temperate forest2.mp3	Ben Gottesman	Ben Gottesman
Tropical forest1.mp3	Ben Gottesman	Ben Gottesman
Tropical forest2.mp3	Ben Gottesman	Ben Gottesman
Tropical forest3.mp3	CGS	Center for Global Soundscapes
Tropical forest4.mp3	CGS	Center for Global Soundscapes

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
Activity 12: Audio Visualization:		
Airplane and Bird.mp3	CGS	**Center for Global Soundscapes**
Birds.mp3	http://www.freesound.org/people/kangaroovindaloo/sounds/204804/	kangaroovindaloo
Coyote.mp3	CGS	Center for Global Soundscapes
Northern Cardinal.mp3	CGS	Center for Global Soundscapes
Thunder.mp3	CGS	Center for Global Soundscapes
Wind.mp3	CGS	Center for Global Soundscapes
Bald Eagle.mp3	Ben Gottesman	Ben Gottesman
Bird.mp3	CGS	Center for Global Soundscapes
Bullfrog.mp3	Ben Gottesman	Ben Gottesman
Coyote.mp3	CGS	Center for Global Soundscapes
Siamong Monkey.mp3	Ben Gottesman	Ben Gottesman
Alaska_20140810.mp3	CGS	Center for Global Soundscapes
Borneo_20140209.mp3	CGS	Center for Global Soundscapes
Costa Rica 20150422.mp3	CGS	Center for Global Soundscapes
Indiana_20120501.mp3	CGS	Center for Global Soundscapes
Nebraska 20150321.mp3	CGS	Center for Global Soundscapes
Alarmers tropical cops 20140218.mp3	CGS	Center for Global Soundscapes
Isolated trumpeter 20140314.mp3	CGS	Center for Global Soundscapes
Natures rowingmachine20130208.mp3	CGS	Center for Global Soundscapes
Onecrazybird 20140210.mp3	CGS	Center for Global Soundscapes
Shrieking me out 20140117.mp3	CGS	Center for Global Soundscapes
ANTHRO Applause.mp3	http://www.freesound.org/people/joedeshon/sounds/119027/	joedeshon
ANTHRO Baby Laugh.mp3	https://freesound.org/people/Iamgiorgio/sounds/371302/	Iamgiorgio
ANTHRO Door Creak.mp3	http://www.freesound.org/people/Corsica_S/sounds/123600/	Corsica_S
ANTHRO Eating Carrot.mp3	https://freesound.org/people/iamshort/sounds/181271/	iamshort
ANTHRO Evil Laugh.mp3	http://www.freesound.org/people/acekasbo/sounds/120762/	acekasbo
ANTHRO Fireworks.mp3	https://freesound.org/people/felix.blume/sounds/140350/	Felix Blume
ANTHRO Footsteps.mp3	http://www.freesound.org/people/mikaelfernstrom/sounds/68687/	mikaelfernstrom
ANTHRO Pinball.mp3	Ben Gottesman	Ben Gottesman
ANTHRO Plate Smash.mp3	Ben Gottesman	Ben Gottesman
ANTHRO Smartphone Vibrate.mp3	http://soundbible.com/1994-Phone-Vibrating.html	Sound Explorer

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
ANTHRO Soda Bottle.mp3	http://www.freesound.org/people/jwsoundfoley/sounds/207562/#comments	jwsoundfoley
ANTHRO Tick Tock.mp3	http://www.freesound.org/people/Tewkesound/sounds/140152/	Tewkesound
ANTHRO Typing.mp3	http://www.freesound.org/people/brettkux/sounds/179385/	brettkux
ANTHRO Yawn.mp3	https://freesound.org/people/Fortyseven203/sounds/240139/	FortySeven203
BIO Bats.mp3	https://freesound.org/people/felix.blume/sounds/245768/	Felix Blume
BIO Bees.mp3	Ben Gottesman	Ben Gottesman
BIO Bottlenose Dolphin.mp3	https://www.pond5.com/sound-effects/1/bottlenose-dolphin.html#1	Pond5
BIO RedSquirrel.mp3	Ben Gottesman	Ben Gottesman
BIO Cicadas.mp3	Ben Gottesman	Ben Gottesman
BIO Cockledoodledoo.mp3	https://freesound.org/people/cocoricosound/sounds/164615/	cocoricosound
BIO Crows.mp3	Ben Gottesman	Ben Gottesman
BIO Dog Bark.mp3	https://freesound.org/people/Juan_Merie_Venter/sounds/327666/	Juan Merie Venter
BIO Horse Gallop.mp3	https://freesound.org/people/YleArkisto/sounds/342329/	YleArkisto
BIO Lemur.mp3	Ben Gottesman	Ben Gottesman
BIO Lion.mp3	https://www.pond5.com/sound-effect/67014871/animals-lion-close-roar.html	Pond5
BIO Rattlesnake.mp3	Ben Gottesman	Ben Gottesman
BIO Snapping Shrimp.mp3	https://freesound.org/people/digifishmusic/sounds/45437/	Digifish Productions
BIO Starlings.mp3	Ben Gottesman	Ben Gottesman
GEO Bubbles.mp3	https://freesound.org/people/spookymodem/sounds/202094/	spookymodem
GEO Hail.mp3	http://www.freesound.org/people/joly1/sounds/81452/	joly1
GEO Iceberg.mp3	Ben Gottesman	Ben Gottesman
GEO icy River.mp3	Ben Gottesman	Ben Gottesman
GEO Lava.mp3	http://www.freesound.org/people/e__/sounds/172630/	e__
GEO Lightning Strike.mp3	http://www.freesound.org/people/NoiseNoir/sounds/238302/	NoiseNoir
GEO River.mp3	Ben Gottesman	Ben Gottesman
GEO Thunder.mp3	https://freesound.org/people/felix.blume/sounds/155147/	Felix Blume

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
GEO Tree Falling.mp3	CGS	Center for Global Soundscapes
GEO Water Splash.mp3	https://freesound.org/people/dobroide/sounds/127611/	dobroide
GEO Waterfall.mp3	http://www.freesound.org/people/Corsica_S/sounds/184731/	Corsica_S
GEO Wildfire.mp3	http://www.freesound.org/people/Dynamicell/sounds/17548/	Dynamicell
GEO Wind.mp3	https://freesound.org/people/felix.blume/sounds/217506/	Felix Blume

Sound File	Citation	ID of the Sound Collector
Activity 13: Travel for Soundscape Studies		
Bird.mp3	CGS	**Center for Global Soundscapes**
Crane.mp3	CGS	Center for Global Soundscapes
Ducks Splashing.mp3	CGS	Center for Global Soundscapes
Frog.mp3	CGS	Center for Global Soundscapes
Mongolian Horses.mp3	CGS	Center for Global Soundscapes
River Bird.mp3	CGS	Center for Global Soundscapes
Throat Singer.mp3	CGS	Center for Global Soundscapes
LOW1.mp3	CGS	Center for Global Soundscapes
LOW1.mp3	http://www.xeno-canto.org/	Marcelo Araya-Salas
LOW2.mp3	CGS	Center for Global Soundscapes
LOW3.mp3	CGS	Center for Global Soundscapes
LOW3.mp3	Naturesongs	Doug Von Gausig
MID1.mp3	CGS	Center for Global Soundscapes
MID2.mp3	CGS	Center for Global Soundscapes
MID3.mp3	CGS	Center for Global Soundscapes
MID3.mp3	http://www.xeno-canto.org/154168	Marcelo Araya-Salas
MID3.mp3	http://www.xeno-canto.org/274615	Peter Boesman
TOP1.mp3	CGS	Center for Global Soundscapes
TOP1.mp3	http://www.xeno-canto.org/45139	Scott Olmstead
TOP1.mp3	https://freesound.org/people/soundbytez/sounds/99237/	Soundbytez
TOP2.mp3	CGS	Center for Global Soundscapes
TOP2.mp3	http://www.xeno-canto.org/72434	Andrew Spencer
TOP3.mp3	CGS	Center for Global Soundscapes
TOP3.mp3	http://www.xeno-canto.org/72434	Andrew Spencer
TOP3.mp3	http://www.xeno-canto.org/154057	Marcelo Araya-Salas
April_6AM.mp3	CGS	Center for Global Soundscapes

SOUND REFERENCES, continued

Sound File	Citation	ID of the Sound Collector
August_6AM.mp3	CGS	Center for Global Soundscapes
December_6AM.mp3	CGS	Center for Global Soundscapes
February_6AM.mp3	CGS	Center for Global Soundscapes
January_6AM.mp3	CGS	Center for Global Soundscapes
July_6AM.mp3	CGS	Center for Global Soundscapes
June_6AM.mp3	CGS	Center for Global Soundscapes
March_6AM.mp3	CGS	Center for Global Soundscapes
May_6AM.mp3	CGS	Center for Global Soundscapes
November_6AM.mp3	CGS	Center for Global Soundscapes
October_6AM.mp3	CGS	Center for Global Soundscapes
September_6AM.mp3	CGS	Center for Global Soundscapes
DenaliPoint1_20140524_00am.mp3	CGS	Center for Global Soundscapes
DenaliPoint1_20140524_6am.mp3	CGS	Center for Global Soundscapes
DenaliPoint1_20140524_12pm.mp3	CGS	Center for Global Soundscapes
DenaliPoint1_20140524_18pm.mp3	CGS	Center for Global Soundscapes
DenaliPoint2_20140524_00am.mp3	CGS	Center for Global Soundscapes
DenaliPoint2_20140524_6am.mp3	CGS	Center for Global Soundscapes
DenaliPoint2_20140524_12pm.mp3	CGS	Center for Global Soundscapes
DenaliPoint2_20140524_18pm.mp3	CGS	Center for Global Soundscapes

Sound File	Citation	ID of the Sound Collector
Activity 14: Soundscapes and Road Noise	CGS	Center for Global Soundscapes
Far Road 1_ 3.Jul.2012.mp3	CGS	Center for Global Soundscapes
Far Road 2_ 11.Jul.2012.mp3	CGS	Center for Global Soundscapes
Far Road 3_ 12.Jun.2012.mp3	CGS	Center for Global Soundscapes
Far Road 4_ 13.Jun.2012.mp3	CGS	Center for Global Soundscapes
Far Road 5_ 27.Jun.2012.mp3	CGS	Center for Global Soundscapes
Near Road 1_ 3.Jul.2012.mp3	CGS	Center for Global Soundscapes
Near Road 2_ 11.Jun.2012.mp3	CGS	Center for Global Soundscapes
Near Road 3_ 12.Jun.2012.mp3	CGS	Center for Global Soundscapes
Near Road 4_ 13.Jun.2012.mp3	CGS	Center for Global Soundscapes
Near Road 5_ 27.Jun.2012.mp3	CGS	Center for Global Soundscapes

RESOURCES

Internal CGS Resources

CGS Educational Resources Overview—video from the 2017 National Science Teachers Association National Conference
https://www.youtube.com/watch?v=VwbM1Myv0I0

CGS Website
https://centerforglobalsoundscapes.org/

Global Soundscapes: A Mission to Record the Earth—trailer for the interactive theater show
https://vimeo.com/182787882

The iListen Portal—sound files for use in the YELLs, exploratory student activities, and teacher resources
https://www.ilisten.org/

Record the Earth—a citizen science recording app and website
https://www.recordtheearth.org/index.php

External Resources Referenced in this Guide

Audacity—free audio visualization and editing software
http://www.audacityteam.org/

Decibel X—sound level meter
http://www.skypaw.com/decibel10.html

Wildlife Acoustics—a company selling automated acoustic recorders
https://www.wildlifeacoustics.com/
https://www.wildlifeacoustics.com/support/documentation (user manuals)

Zoom—a company selling non-automated acoustic recorders
https://www.zoom.co.jp/products/field-video-recording/field-recording

Additional External Resources

Educational Resources, Activities, and Lesson Plans: Discovery of Sounds in the Sea
http://www.dosits.org/

Exploring Nature Science Education Resource
http://www.exploringnature.org/

Learn NC: BioMusic
http://www.learnnc.org/lp/editions/biomusic/contents

NeoK12: Ecosystems for Kids
http://www.neok12.com/Ecosystems.htm

NeoK12: Sound
http://www.neok12.com/Sound.htm

Soundscape Explorations
http://soundexplorations.blogspot.com/2011/09/education-teaching-children-about.html

Wild Music: A Traveling Exhibition about the Sounds and Songs of Life
http://www.wildmusic.org/

W. K. Biological Station: Classroom Resources
http://www.kbs.msu.edu/education/k-12/classroom-resources/

Sound Sources

Avisoft Bioacoustics
http://www.avisoft.com/

FindSounds
http://www.findsounds.com/

freesound
http://www.freesound.org

Research Labs

The Cornell Lab of Ornithology: Bioacoustics Research Program
http://www.birds.cornell.edu/brp/

Michigan State University: Remote Ecological Assessment Laboratory
http://www.real.msu.edu/

Queensland University of Technology: Ecoacoustics Research Group
https://www.ecosounds.org/

Scripps Institution of Oceanography (various labs)
https://scripps.ucsd.edu/

US National Park Service: Natural Sounds Program
https://www.nps.gov/subjects/sound/index.htm

Woods Hole Oceanographic Institution: Ocean Acoustics and Signals Lab
http://acoustics.whoi.edu/index.html

Professional Societies and Organizations

Acoustical Society of America
http://acousticalsociety.org/

Ecological Society of America
https://www.esa.org/esa/

Global Sustainable Soundscapes Network
https://www.facebook.com/GlobalSustainableSoundscapesNetwork/

International Bioacoustics Council
http://www.ibac.info/

International Society of Ecoacoustics
https://sites.google.com/site/ecoacousticssociety/about

TED Talks about Soundscapes

A Mission to Record the Earth—Kristen Bellisario
https://www.youtube.com/watch?v=RG0_jwelsCc&t=2s

How Human Noise Affects Ocean Habitats—Kate Stafford
https://www.youtube.com/watch?v=t-K6bn9sc50&feature=youtu.be

The Voice of the Natural World—Bernie Krause
https://www.youtube.com/watch?v=uTbA-mxo858&t=267s

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Discovery Park

Center for Global Soundscapes

www.centerforglobalsoundscapes.org