FNR-607-W

PURDUE UNIVERSITY
Discovery Park

Your Ecosystem Listening Labs (YELLs)

The Science of Soundscape Ecology
Student's Guide, Grades 5-8

6th 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

Earth has about a dozen major terrestrial biomes, and we are on a quest to discover how soundscapes vary across time and space within each of these major biomes. We record soundscapes in diverse national and international locations in order to learn about the dynamics of sound in the world’s different ecosystems.

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

AUTHORS AND CONTRIBUTORS

Dr. MaryAm Ghadiri

LEAD AUTHOR, EDITOR, DESIGNER, YELLS INSTRUCTOR

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.

Dr. Amandine Gasc

CO-AUTHOR, EDITOR

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.

Dante Francomano

CO-AUTHOR, EDITOR

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!

Dr. Kristen Bellisario

CO-AUTHOR, LEAD EDITOR

Kristen Bellisario is a classically-trained flutist specializing in modern music performance and analysis techniques. Her PhD research is focused on finding unique patterns in soundscapes and how animal communities respond to noise. Some of her recordings include howling coyotes, bats, and many grassland birds.

Dawn Oliver

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.

Benjamin Gottesman

EDITOR, SOUND COLLECTOR, YELLS INSTRUCTOR

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.

David Savage

EDITOR

David Savage is an avid bicyclist with a background in monitoring costal sealife. His PhD work focused on soundscape ecology and bioacoustics, with a particular focus on using acoustics as a monitoring/planning tool for smarter, cheaper conservation decisions.

Dr. Bryan Pijanowski

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.

Dr. Daniel Shepardson

PROJECT CO-INVESTIGATOR, ACADEMIC ADVISOR

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.

OTHER CONTRIBUTORS

Brandon Beatty
Lillie Berger
Zonda Bryant
Dr. Natalie Carroll
Meredith Cobb
Kenneth Elkins
Barbara Flagg
Kate Fraser
Matt Harris
Javier Lenzi
Brad Lisle
Jeff Migliozzi
Telaina Minnicus
Kristen Mori
Joe Price
Betsey Sennott
Jack VanSchaik
Lingzhi Wang

I Introduction

DR. BRYAN C. PIJANOWSKI
Director, Discovery Park Center for Global Soundscapes
University Faculty Scholar, Department of Forestry and Natural Resources
Principal Investigator, The NSF-sponsored Global Soundscape Project
Purdue University
West Lafayette, Indiana

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
Environmental Informal Learning Specialist
Discovery Park Center for Global Soundscapes
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana

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,

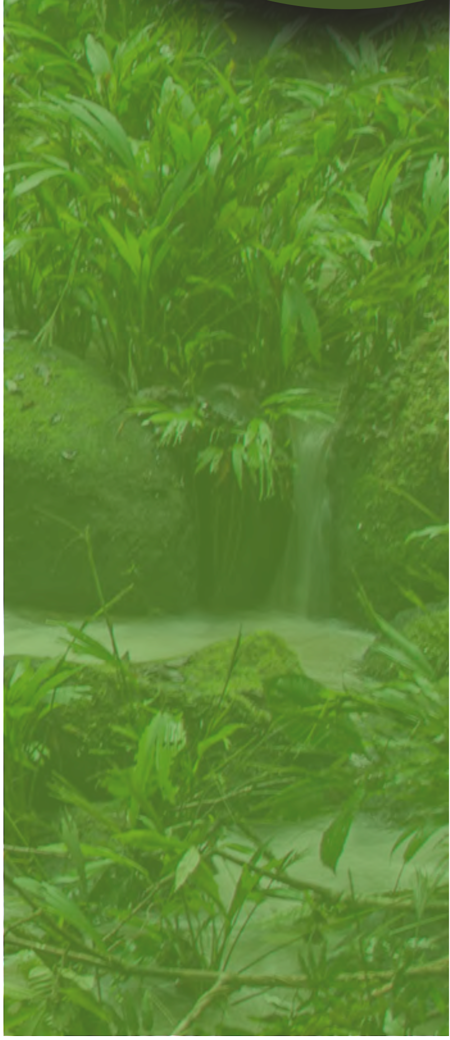


TABLE OF CONTENTS

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."

Activity 1:
Sound Production

In this activity, you will visit lab stations to explore different aspects of sound and record your observations. Read through the characteristics of sound and complete the worksheets (Worksheet 1.1, 1.2, and the Brain Dump).

Lab Station A:

Balloons and Frequency
Use balloons like vocal cords

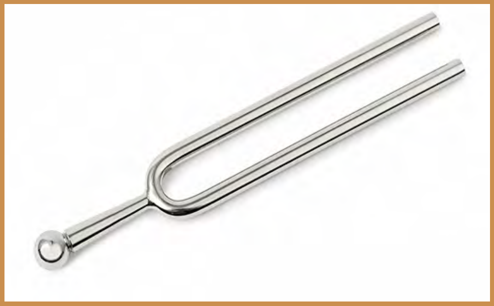
☐

Lab Station B:

Bottles with Water
Use water to make music

☐

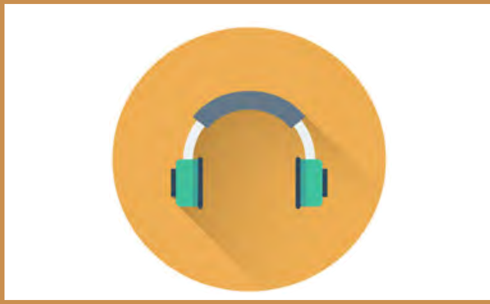
Lab Station C:



Tuning Fork
Watch sound vibrations travel

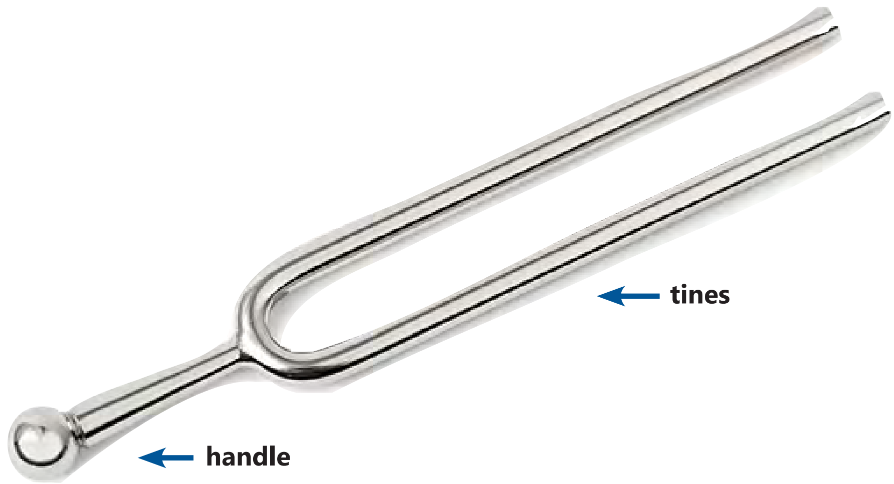
☐

Lab Station D:



Knowledge Check
Complete the worksheet

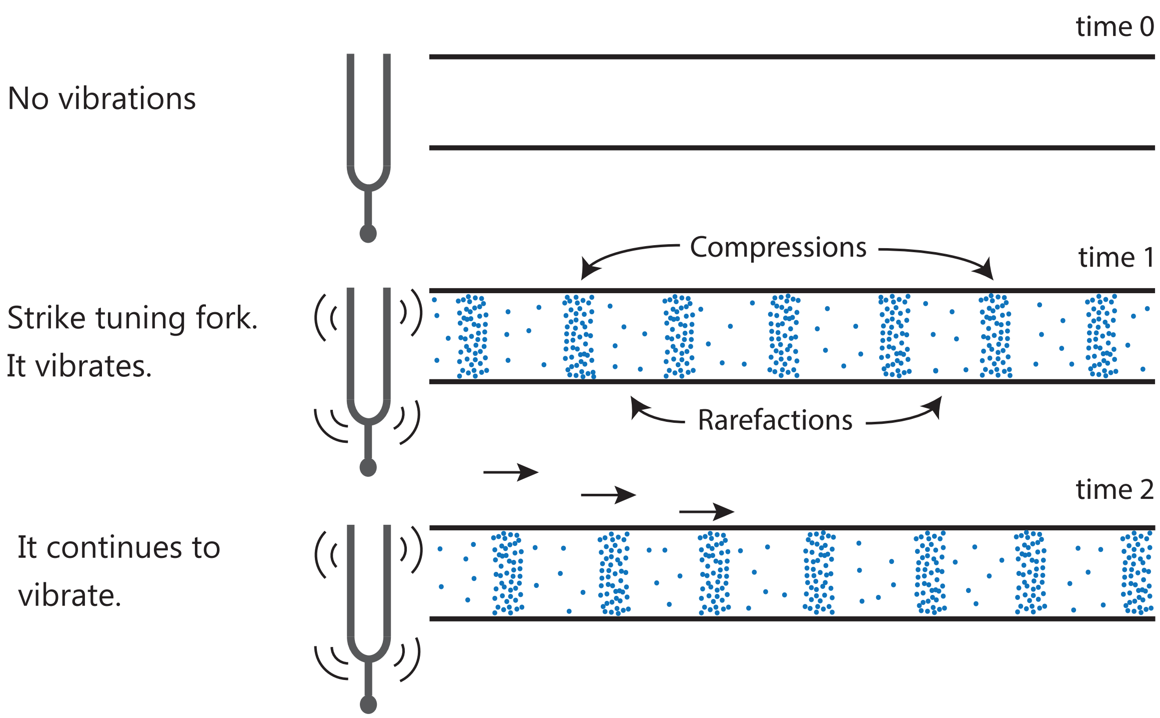
☐



Characteristics of Sound

Compression and Rarefaction

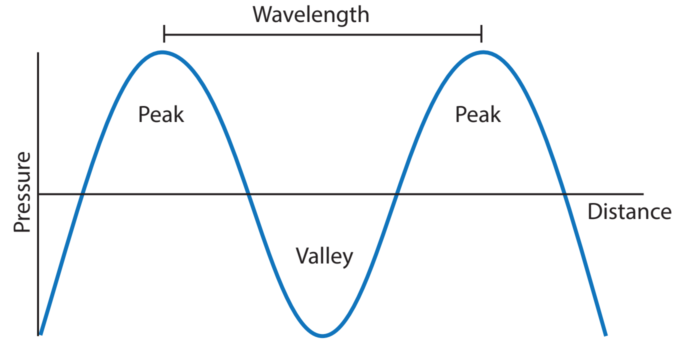
When a tuning fork vibrates, the motion of its tines compresses air molecules in the direction of that motion. That process is called compression. When the tines spring back, they create areas of low pressure that cause air molecules to spread out. That process is called rarefaction. Compression and rarefaction move sound pressure waves through different media—gases, liquids, and solids.



Characteristics of Sound(continued)

Wavelength

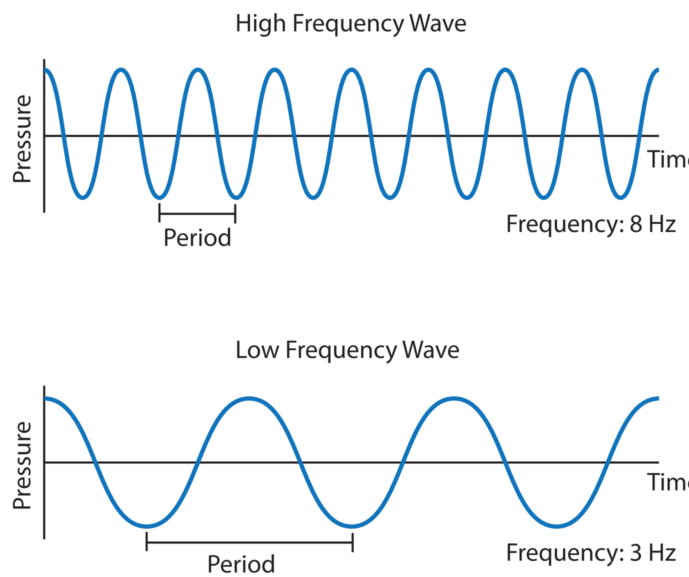
A sound's **wavelength** is the physical distance between two peaks of the wave.



Frequency (pitch)

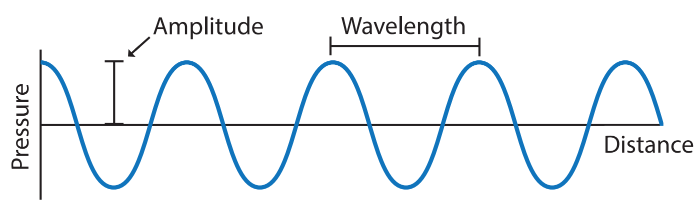
A sound's **frequency** is equal to the number of peaks that occur per second. The time between two peaks is the wave's **period**. The unit for measuring frequency is Hertz (Hz). Frequency in Hz is equal to the number of wave cycles per second.

Human hearing ranges from 20 Hz to 20,000 Hz. Sounds below this range are called infrasonic, and sounds above this range are called ultrasonic.

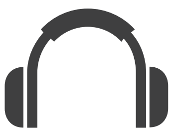
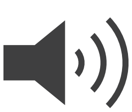


Amplitude

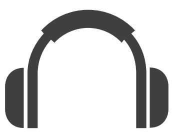
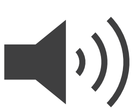
The **amplitude,** or loudness of a sound, is defined by how much pressure change is caused by compression or rarefaction. It is typically measured in units of decibels (dB).



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?

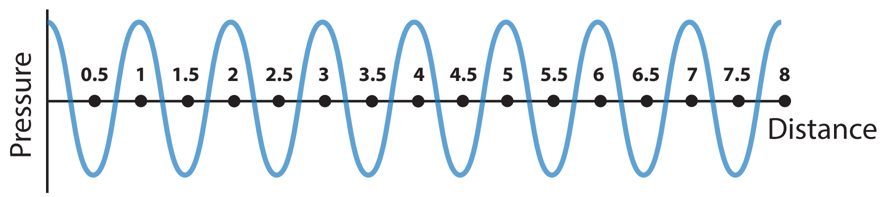
Worksheet 1.1 Sound Production Observation Form C

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?

Worksheet 1.2 Sound Production Knowledge Check Form

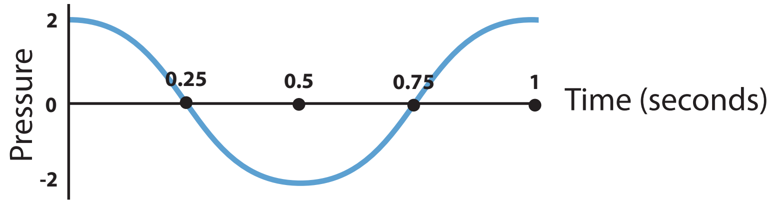
Section 1

1. What is the wavelength of the following sound? ______________________________

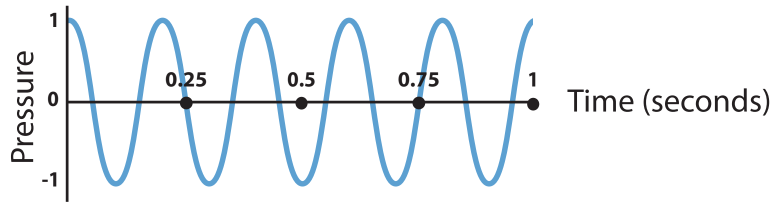


2. What is the frequency of the following waveforms? A __________ **B** __________

A)



B)



3. Which one of the above waveforms has a higher amplitude?

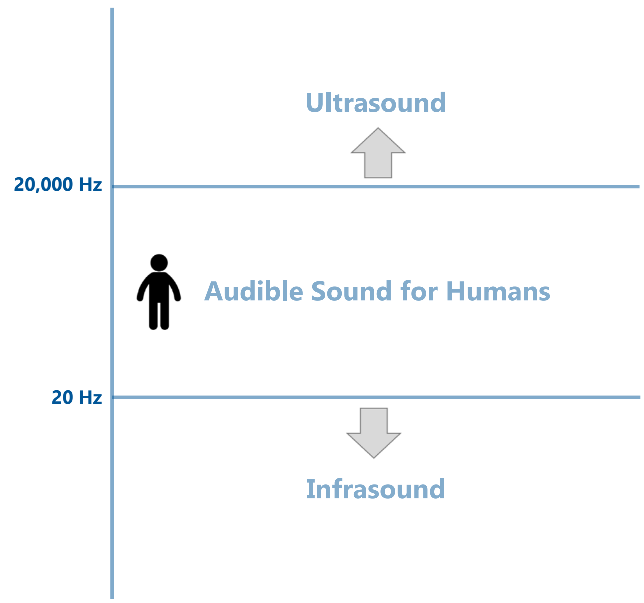
☐ **A** ☐ **B**

4. Look at the hearing range of a human in the table on page 19. It is between 20 Hz and 20,000 Hz. Can we hear the sounds represented on the above waveforms?

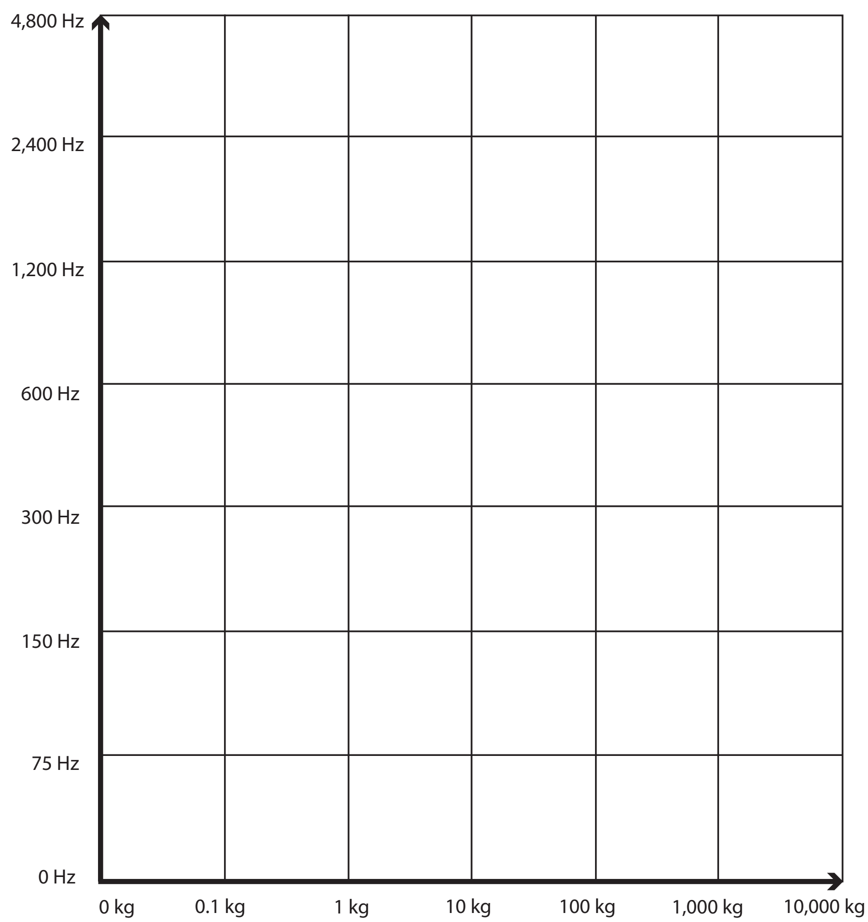
☐ **Yes** ☐ **No**

Worksheet 1.2 Sound Production Knowledge Check Form

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.



Worksheet 1.2 Sound Production Knowledge Check Form

Table 1.1: Section 2, Section 3:
Use the table of frequencies produced and body weights for Section 2 and Section 3.

	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

BRAIN DUMP!

Describe one of your favorite high-frequency sounds. What was the source of the sound? Where did you hear it?

Activity 2: Be a Molecule

In this activity, you will play a game that simulates how molecules move in different media (gas, liquid, or solid) and how sound travels differently based on objects found in the environment (tree trunks, branches, leaves and other objects that obsorb sound). Use the sound source cards and ear cutouts to play this game.

Characteristics of Sound Propagation

After a signal is produced, it moves from its source through the surrounding medium. That medium could be a gas, liquid, or solid. This process is called sound propagation. As sound travels, it is affected by the structure of the environment through which it travels. For instance, A bird song in a forest 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

Propagration Property
Dense tree trunks, branches, & leaves

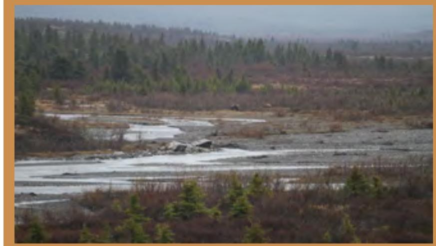
Temperate Forest

Propagration Property
Mix of trees with bushes and plants

Estuary

Propagration Property
Mix of trees with vernal ponds & ocean

Tundra



Propagration Property
Open rolling terrain with few trees

Scrubland

Propagration Property
Dry with bushes and few trees

Grassland

Propagration Property
Wide open land with grases & few trees

Chiricahua Mountains

Propagration Property
Dry mountains with bolders & plants

Desert

Propagration Property
Vast sandy environment with few plants

Dunes

Propagration Property
Wind driven ridges of sand

Temperate Wetland

Propagration Property
Vernal pools/ponds with varying plants

Polar Ice

Propagration Property
Extreme cold waters without plants

Oceans

Propagration Property
Coral Reefs with aquatic plants

Worksheet 2.1: Ear Cutouts

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

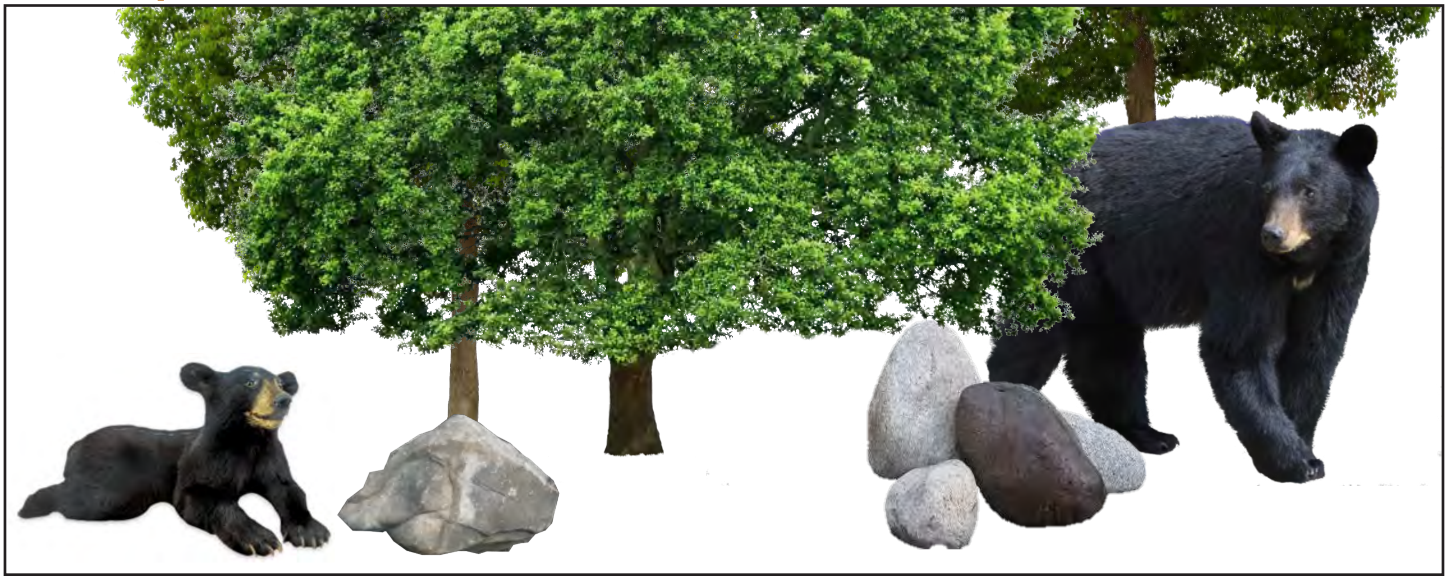
2. Describe the difference in how a mother bear might hear her cub in a grassland (2a) versus a temperate forest(2b). ____

____

____

2a: Grasslands

2b: Temperate Forest



Activity 3: Using Tools to Listen

In this activity, you will use different tools to change the way you hear a sound. Complete Worksheet 3.1 and the Brain Dump.

Characteristics of Reception

Sound is received when pressure changes in a medium are sensed by animals' organs or mechanical recording devices. Certain species are sensitive to sounds of specific frequencies and amplitudes. Some animals can hear sounds that humans cannot. Table 3.1 on the next page shows the frequency hearing ranges of different animals.

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:			

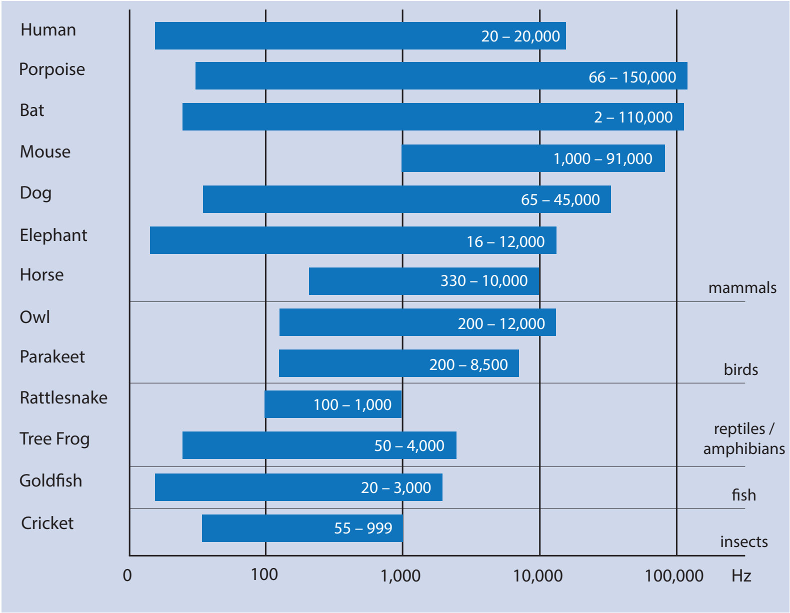
1A: How does your hearing change when you use the tools?

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?

Table 3.1: The range of frequencies commonly heard by different animals.



BRAIN DUMP!

How did the different listening devices affect your hearing experience? Were there any devices that you really did or did not like?

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.

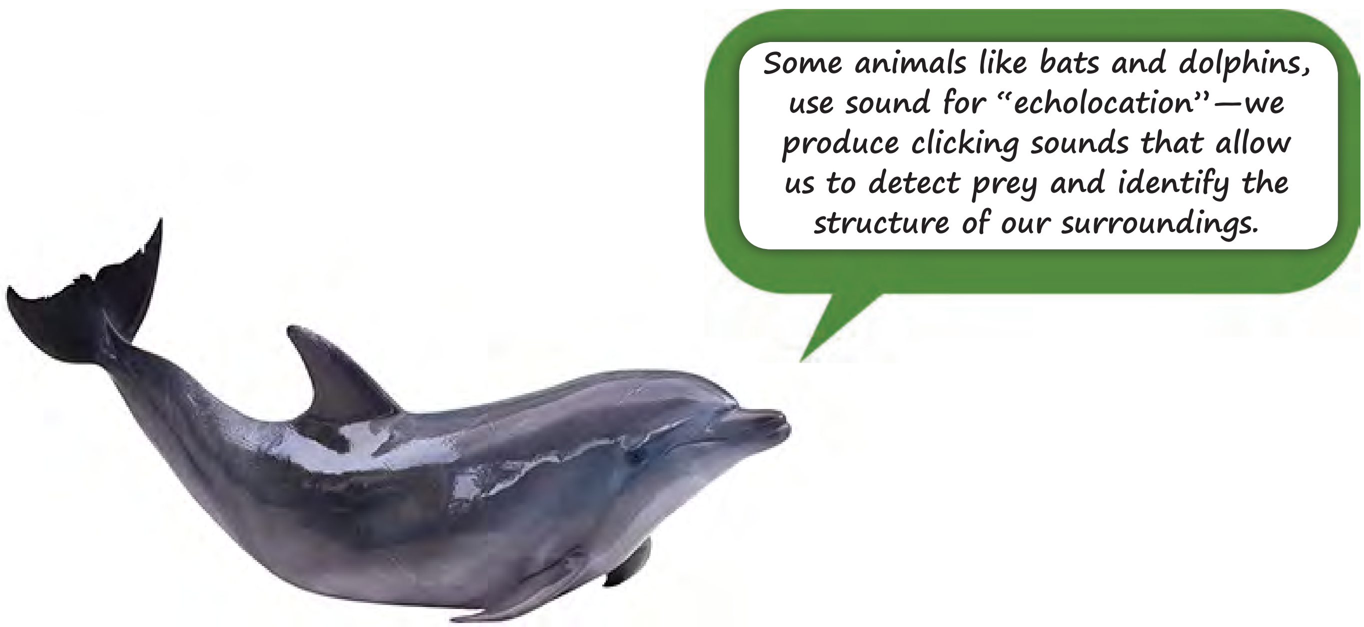
Activity 4: Animal Echo

In this activity, you will learn how different animals produce sounds. In part 1, use the Animal Echo cards (Worksheet 4.1) to mimic animal sounds using materials you find around you. In part 2, play a timed group game to see who can identify the animal sounds first.

Animal Sound Production

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.



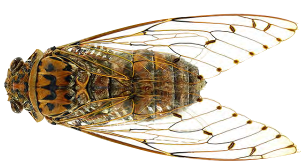
Methods of Sound Production

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 when sound bounces off of objects (called a reflection). Bats emit echolocation sounds through their mouth or nose and marine animals like sperm whales and dolphins use echolocation to navigate, communicate, and find food.

BRAIN DUMP!

Why might animals use such diverse methods to produce sounds?

Activity 5: Find Your Pair

In this activity, you will learn why animals produce sounds, and how different natural and human made sounds can affect animal sound production strategies. After reading about animal communication and the effects of noise, you will play a game followed by reflection questions. After the activity, complete the Brain Dump.

Animal Communication

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. Many animals make sounds to intimidate other animals and to display strength. A big cat roar is an example 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 monkey produce varied vocalizations according to the type of predator that is present. Other animals use sound to find food. Bats use echolocation, a high-frequency vocalization that bounces of objects in their surroundings and reflects back to the bat, revealing information about the surrounding environment.

The Effects of Noise

Noise is sound that blocks a receiver's detection or recognition of a signal. Noise masking can occur in any ecosystem, and it can be a serious problem, especially in ecosystems where the animal community's sounds are finely partitioned. Humans and our machines are a significant source of noise in many environments. Some animals, like those mentioned below, have been shown to adapt their communication to avoid or minimize noise masking.

The marmoset monkey increases the length of its call when the environment 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.

2 Animal Communication

Part 1: Communication
Why do animals produce sound?

Students will form pairs, put on blind folds, 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: REFLECTION

Was it easy to find your partner? Why or why not?

How did other sounds affect your search?

How might an animal make sounds so that it does not mask the sounds of other animals?

Why might animals produce sounds at different times of day?

Part 2: Noise

Repeat the same activity except this time human made sounds, like traffic, machinery or an airplane will be part of the soundscape.

PART 2: REFLECTION

Was it more difficult to find your pair in a noisy environment?

What did you do to find each other through the natural noise?

How might a noisy environment affect an animal?

What can animals do to overcome the effects of noise?

BRAIN DUMP!

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.

Activity 6:
Sound Bingo

In this activity, you will play a game that uses sounds from 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. After the game, complete the Test Your Knowledge Worksheet.

Soundscapes on Earth are composed of three broad categories of sounds:

- **Biophony**—the sounds produced by animals like frogs, wolves, geese, and crickets.
- **Geophony**—the sounds created by non-biological natural elements like wind, running water, and seismic events.
- **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.


The sounds of fish and birds are examples of biophony.


The sounds of moving water and a volcano are examples of geophony.


The sounds of people walking and an airplane flying are examples of anthrophony.

Worksheet 6.1: Bingo Card

B	I	N	G	O

Customize your own Bingo card using various sounds from the following table.

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

TEST YOUR KNOWLEDGE!

Imagine the sounds associated with each image, and label those sounds as biophony (B), geophony (G), or anthrophony (A).

BRAIN DUMP

List some of the common sounds around you. Are they biophony, geophony, or anthrophony?

Activity 7:
Sound Walk

In this activity, you will participate in a field activity that encourages you to open your ears and listen to the surround soundscapes.

About Sound Walks

Sound walks allow for intentional listening in an environment that has soundscapes. 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 listenting, people can develop a sense of place and grater attachement to nature and certain locations.

Activity Part 1:

Create a view finder and sound finder.

Activity Part 2:

Go on the soundwalk. Complete Worksheet 7.2.

1. Cover your ears.
2. Listen to the sound closest to you.
3. Listen to the sounds from each direction using your left ear, then right ear.
4. Listen to the sounds behind you.

I like to walk outdoors and listen to the soundscapes around me. This activity is called a sound walk, and you can go on a sound walk anytime and anywhere—during the day or night, in a park, in a forest, or even in a street!

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?

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

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	

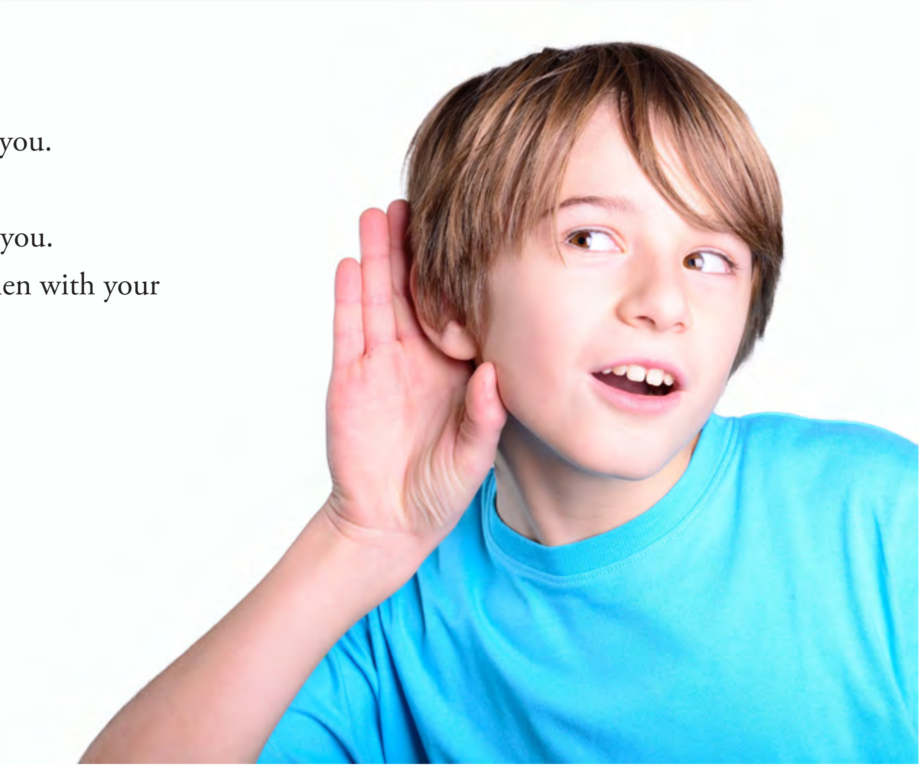
BRAIN DUMP

What is your favorite location? Describe its soundscape.

Warm up your ears!

Close your eyes, and listen to the sounds around you.

- Listen to the sound that is nearest to you.
- Now listen to the sound that is farthest from you.
- Focus on the sounds with your left ear and then with your right ear.
- Finally, listen to the sounds behind you.



Activity 8:
Sound Map

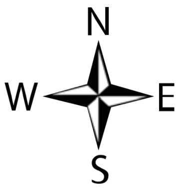
In this activity, you will make a sound map: an acoustic representation of a location. These maps can be two- or three-dimensional. They can be simple if they only map sound sources and their coverage, or they can be more complex if they include features like sounds' frequency, amplitude, duration, timbre, or pleasantness. Maps should also include the main physical elements of the landscape, such as trees, roads, or buildings. After the activity, complete the Brain Dump.

3 Soundscapes Around Us

How to make a sound map

- Immerse yourself in the soundscape.
- Mark an "X" in the center of your map to represent your location.
- Note the location, date, and time at the top of your page.
- Close your eyes, and listen intently for two minutes.
- Begin marking the sounds that you hear.
- Map out the direction and distribution of key sounds in your surroundings.
- Use different colors or symbols to signify different sound sources.

Worksheet 8.1: Blank Sound Map



BRAIN DUMP!

Draw a soundmap of a place you visit regularly (like your classroom or home). Then, listen and see if your soundmap matches the actual location.

Activity 9:
Sound Scavenger Hunt

In this activity, individuals or pairs will explore their surroundings to "collect" different sounds and soundscapes. Points are awarded based on the quality of the recording. Complete Worksheets 9.1, 9.2, 9.3. After the activity, complete the Brain Dump.

Instructions:

Step 1: Select your recording device (see list below, or choose one that you prefer).

Step 2: Listen for each sound on the scavenger hunt list. When you hear a sound record it. Then, write down where you heard it.

Step 3: Circle the icon that matches if you liked or disliked the sound.

Step 4: Circle how easy or hard it was to find the sound (use Worksheet 9.1 for Steps 1-4).

Repeat the scavenger hunt by collecting sounds that match a feeling (Worksheet 9.2).

Repeat the scavenger hunt by collecting custom sounds(Worksheet 9.3)

Recording Devices

Zoom H1 Handy Recorder

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

Portable Recording Device

This recorder is embedded into many handheld devices. Use the internal recording program to capture your own sounds.

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.


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? Here are some recommendations to make a great recording!

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	☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			
			☐	👍 👎	☺ ☹			

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
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			
		☐	👍 👎	☺ ☹			

BRAIN DUMP

What was one of your challenges in recording the sounds?

Activity 10: Soundscape Data Collection

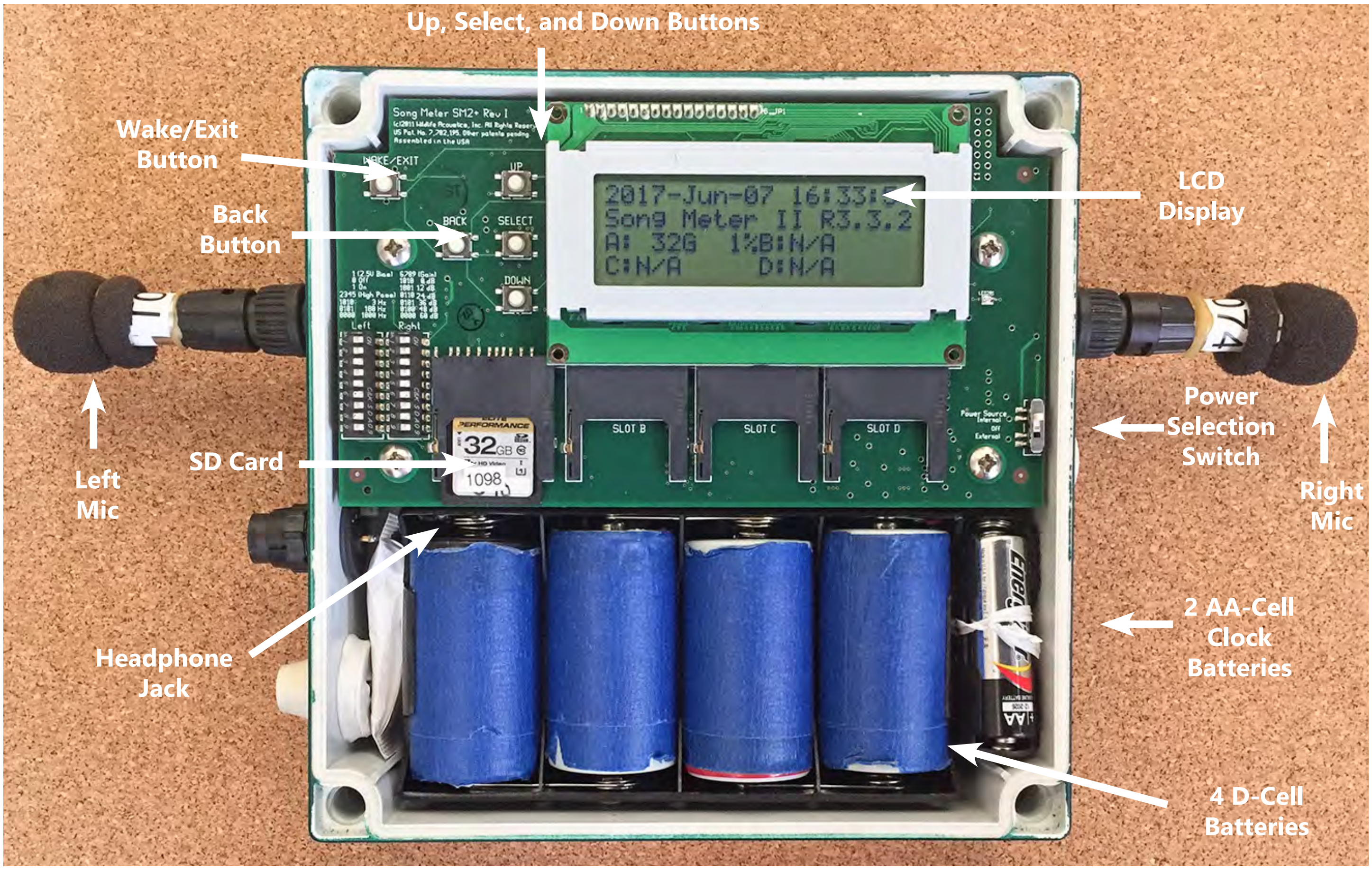
In this activity, you will design your own model of an automated acoustic recorder (Worksheet 10.1) and, learn how to use a real automated acoustic recorder to collect soundscape data to observe the temporal and spatial changes in soundscapes and hypothesize explanations for those changes (Worksheet 10.2). After the activity, complete the Test Your Knowledge worksheet.

About Soundscape Data Collection

Almost all scientists use some forms of technology to collect their data. Soundscape ecologists use microphones and recorders to record soundscapes. This technology helps answer scientific questions. 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.

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.



Part 2: Using a Recorder

Step 1

Open the Song Meter

Unscrew the four plastic screws on the corners of the casing with a large Phillips head screwdriver (for other recording devices use their manual).

Step 2

Turning it on

Insert four D-cell batteries. Insert two AA-cell batteries. Insert an SD card into the SD card slot (up to 4). Turn on the machine by moving the power selection switch up to the "Internal" position.

Step 3

Adjust the settings **(buttons are in all caps)**

Go to the main menu by pressing the button marked "SELECT." Scroll through the menu by using the buttons marked "UP" and "DOWN."

Return to higher level menu	"BACK"
Select time and date	"Settings", "time & date"
Change time or date	"UP" or " DOWN"

Step 4

Listen to live sounds

Plug standard 3.5 mm headphones into the headphone jack to listen to live sound before you start recording.

Activate headphone port	"UP" and "DOWN" "SELECT"
Monitor recording levels	Look at * symbols
Stop recording	"BACK"
Erase SD card	"Utilities", "Erase card"

Step 5

Set a recording schedule (duty cycle)

Navigate to "Schedule" in the main menu, and press "SELECT." Select "Daily" or "Advanced" at the cursor prompt.

1. Select "Daily"
2. "Add a new entry."
3. 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.
4. Navigate and change duration value as you did for the date using the "SELECT," "UP," and "DOWN" buttons.

Step 6

Start to record

Press the "WAKE/EXIT" button home screen. 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]."
To record immediately for one hour, press "BACK" until you arrive at the home screen. Press "UP" and "DOWN" simultaneously to begin recording. For more complex options see the Song Meter User Manual.

Step 7

Mount the Song Meter

Mount a Song Meter outdoors is to a small tree or post with sturdy wire so that the back side of the microphones are not obstructed.

1. 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.
2. Remove the Song Meter cover.
3. 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.
4. Twist the two loose ends of wire together, first by hand and then with a pair of pliers.
5. Press "WAKE/EXIT" to launch a programmed duty cycle or press "UP" and "DOWN" to begin recording immediately.
6. 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.

Worksheet 10.2: Site Information Form

Date:

Time:

GPS coordinates:

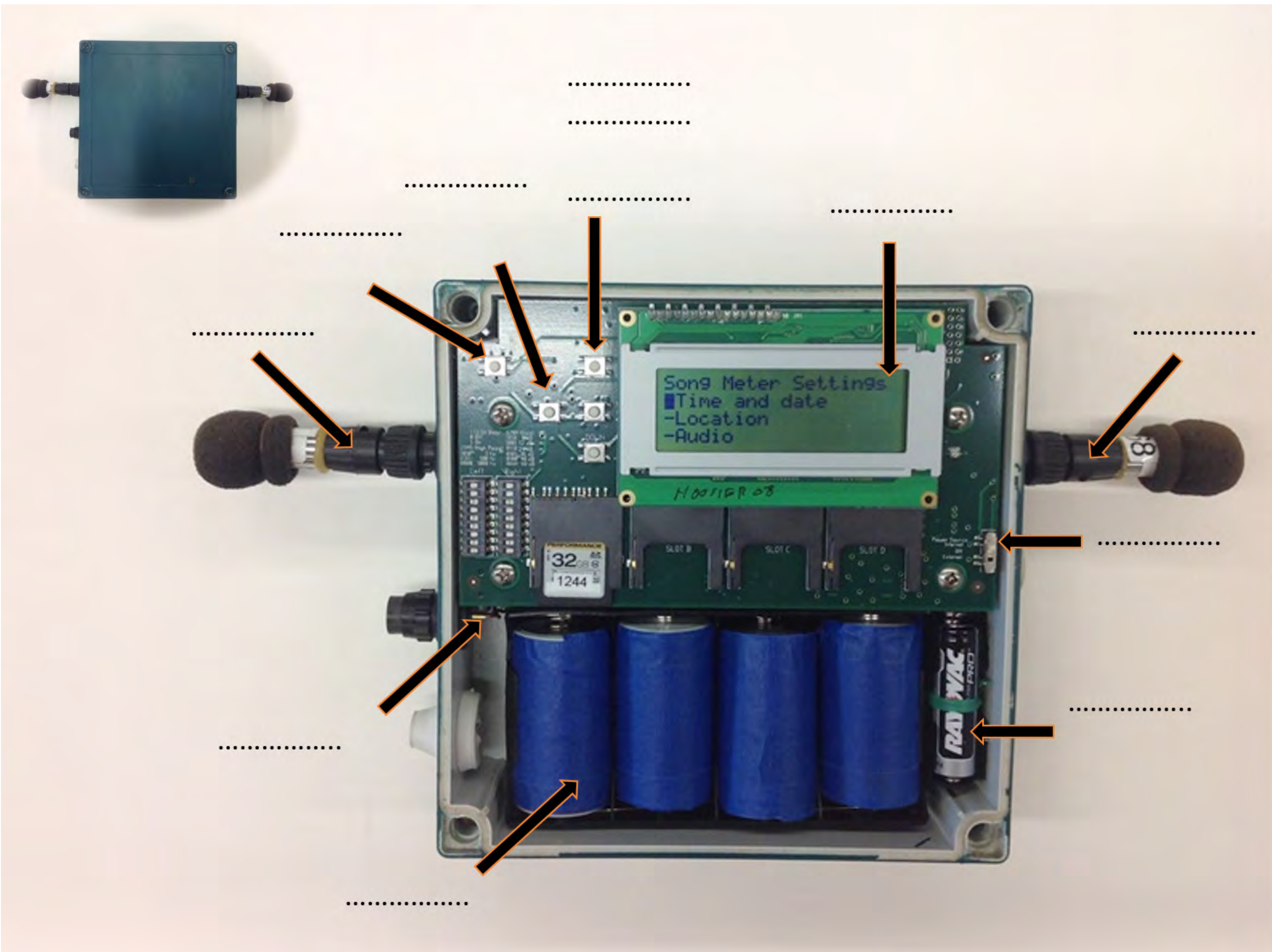
Song Meter serial number:

Mic numbers (optional):

Quick Drawing/Picture of the Landscape/Landmarks

TEST YOUR KNOWLEDGE!

Label different parts of a Song Meter.



Word bank

4 D-Cell Batteries	Wake/Exit Button	Up Button
Power Select Switch	Back Button	Right Mic
LCD Display	Headphone Jack	Select Button
Left Mic	2 AA-Cells Clock	Down Button
		Batteries

Chapter 4

ANALYZE AND EXPLORE SOUND

Soundscape ecologists use sound to answer a wide variety of scientific questions. These diverse questions require different types of study methods. This chapter focuses on developing scientific questions and study methods. Learn and discover the many ways to qualitatively and quantitatively describe sound and make sense of data to answer our scientific question!

About Study Methods

We explore three study methods in this chapter. A study method uses an experimental design plot to help compare and contrast sounds in the environment. A gradient in the canopy will record sounds at multiple layers in the forest (understory, middle story, and top canopy) or at different levels of a disturbance (least, moderate, or intense) such as in grazing patterns in a grassland.

About Soundscape Studies

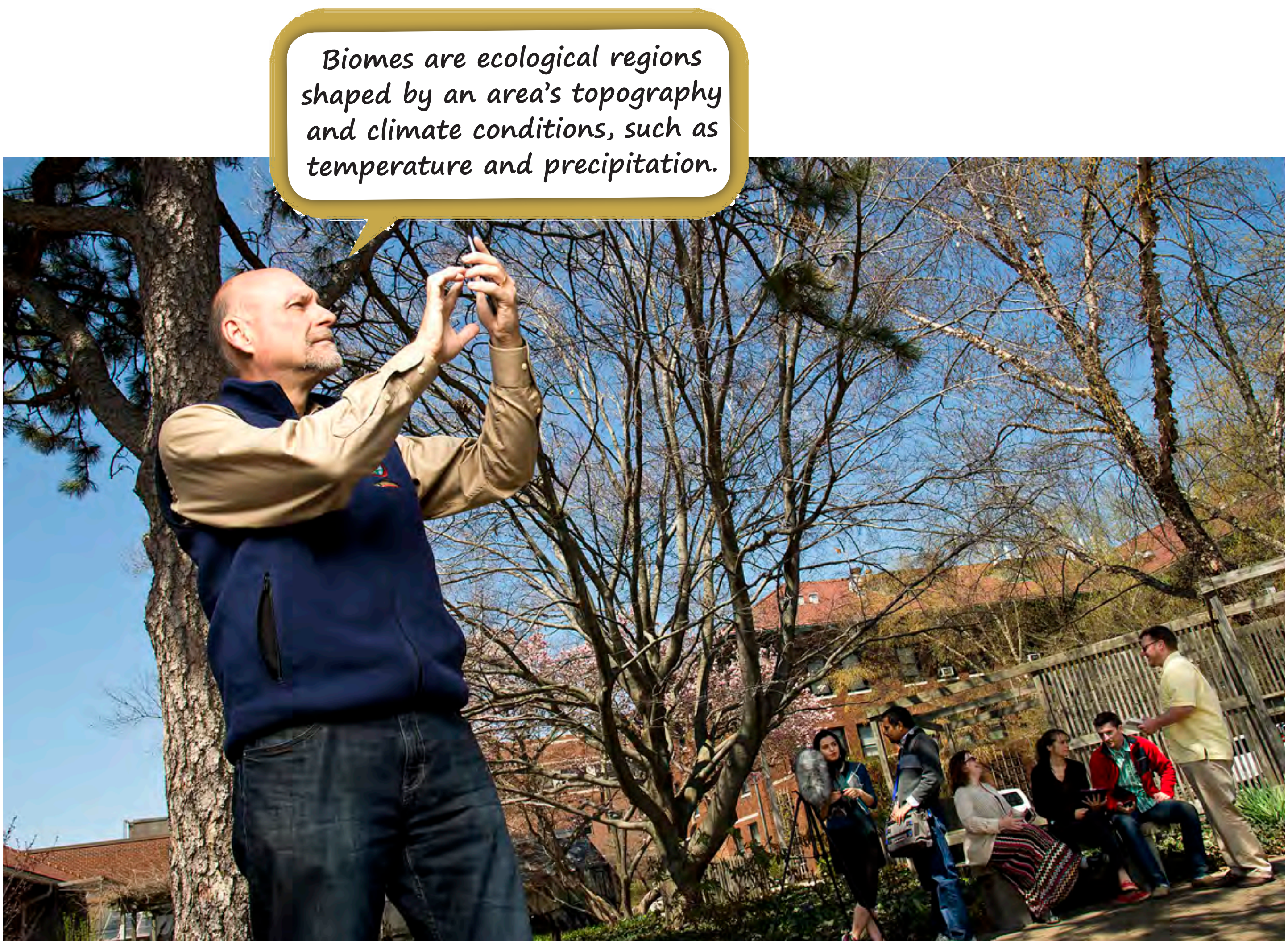
In this chapter, we will explore several different locations in four major biomes. Learn about the unique characteristics of these places. Then, complete an activity.

Activity 11:
Global Soundscapes

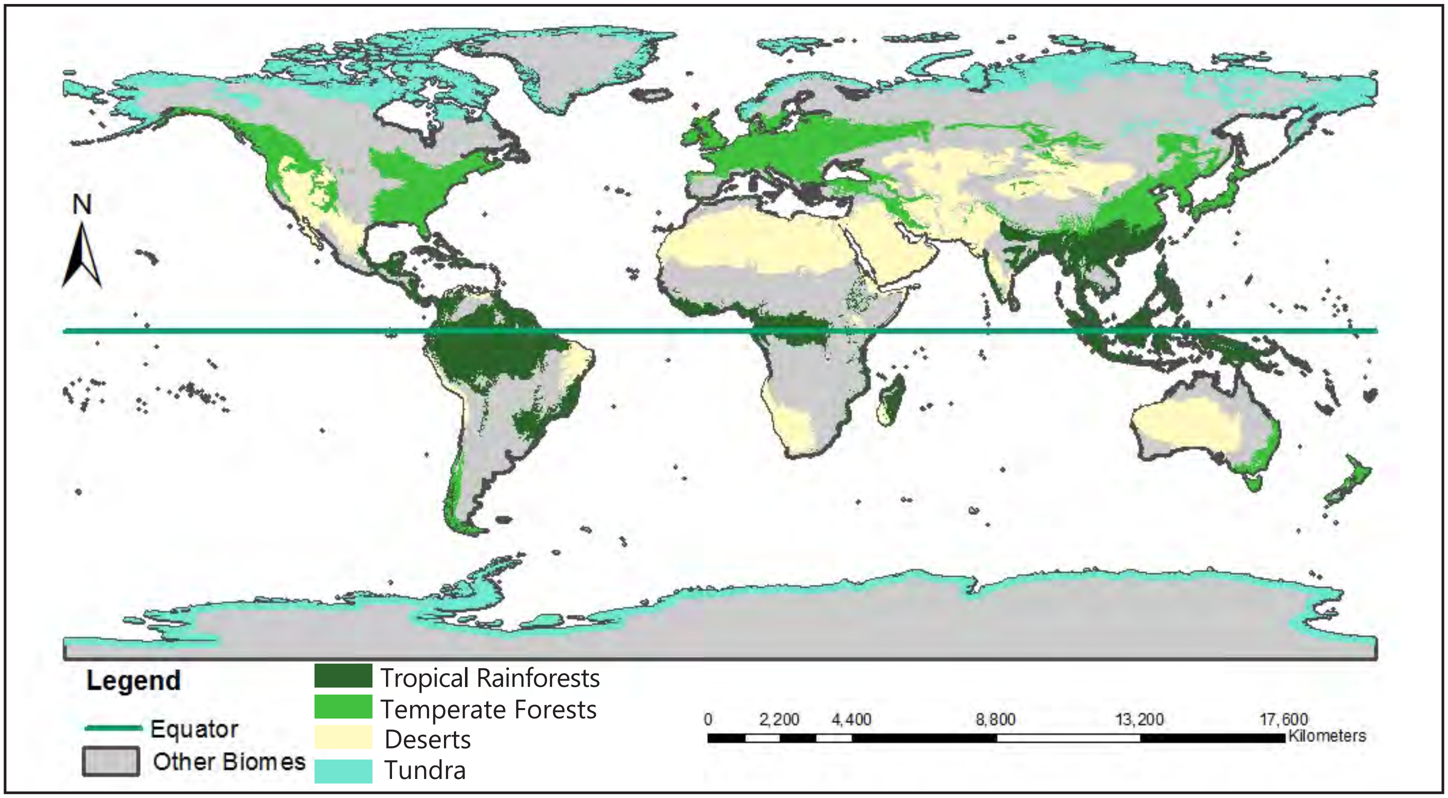
In this activity, you will learn about the location of biomes on Earth and the impact of climate, precipation, and temperature. Then, you will investigate the characteristis of major biomes' soundscapes by listening to those soundscapes. Complete Worksheet 11.1. Then, complete the Test Your Knowledge worksheet.

About 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.



Worksheet 11.1, Part 1: Place the Biome



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.

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.

Worksheet 11.1: Describe the Biome

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:

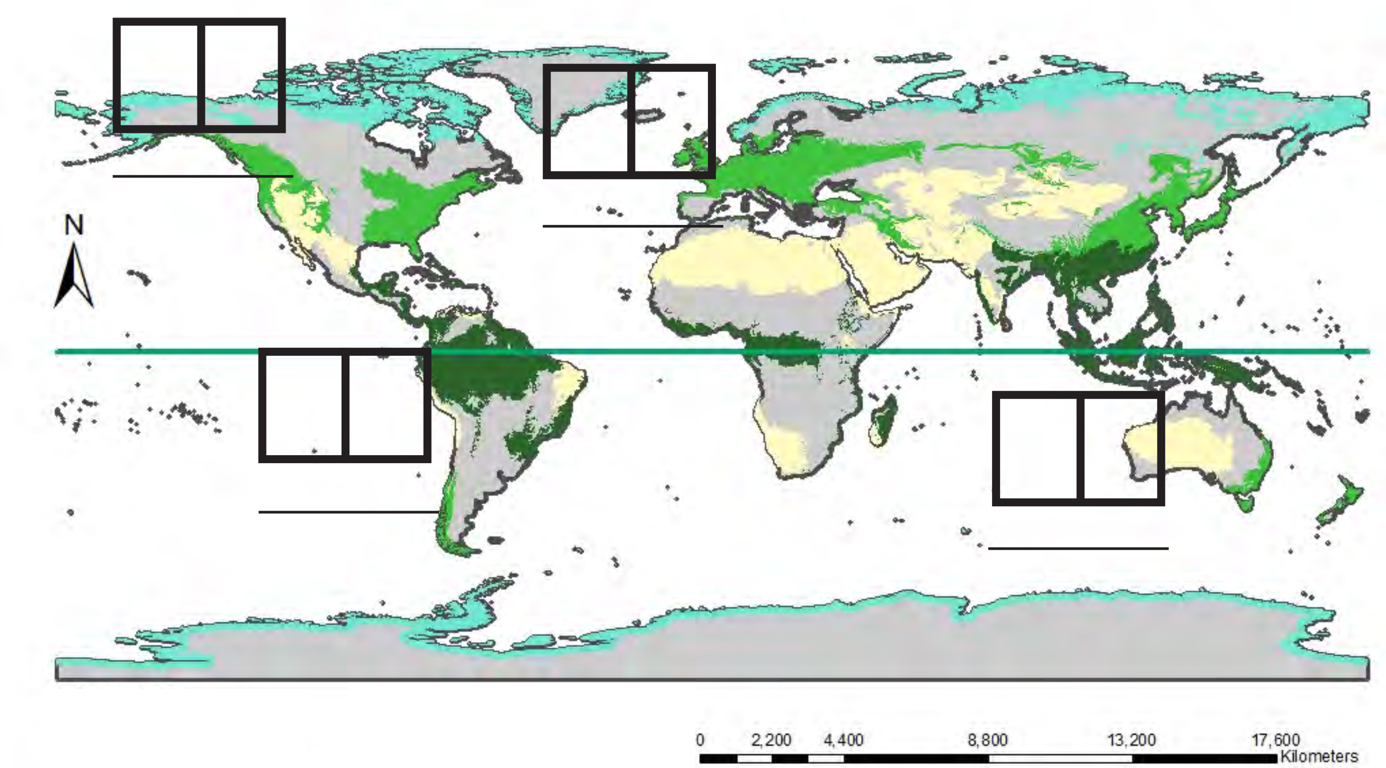
1. 20% of Earth's land surface is covered by deserts.
2. The largest desert is the Sahara Desert in North Africa.
3. Deserts only get 10% of the rain that rainforests receive.
4. The temperature changes drastically from day to night in a desert because there is very little surface or atmospheric water 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 11.2: 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.

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?	

Activity 12: Audio Visualization

In this activity, you will use software to visualize audio files. In Part 1, explore the play and stop function in the audio software. In Part 2, match up the sounds from different biomes with a frequency. In Part 3, answer questions. In Part 4, match a soundscape recording to a spectrogram. In Part 5, create a soundscape composition.

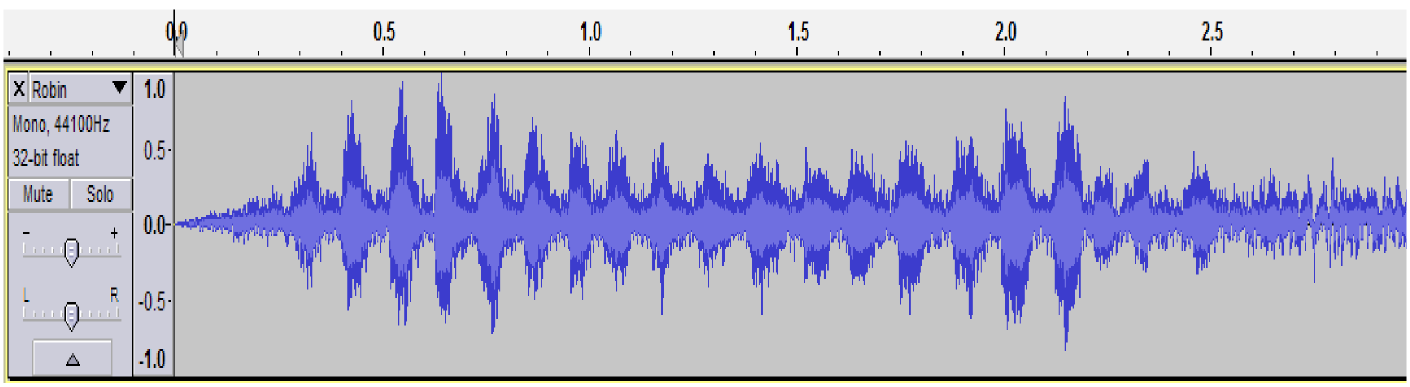
About Soundscapes and Spectrograms

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.

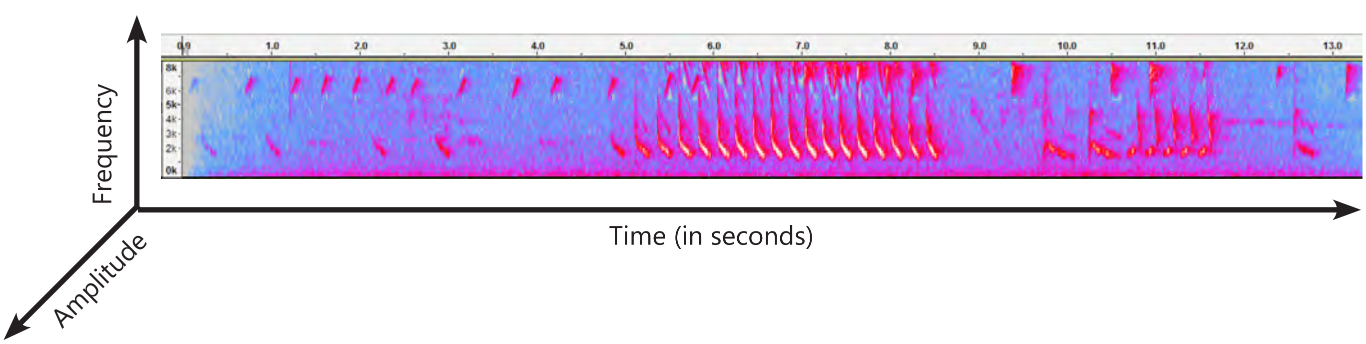
As a soundscape ecologist, I collect thousands of soundscapes in many biomes. It is not possible for me to listen to every sound, so I use special visualizations called spectrograms to help me "hear" the sound.

Worksheet 12: Pre-Activity

In this pre-activity, find the difference between an oscillogram and a spectrogram. Identify how to tell when a sound is soft or loud using the amplitude in the oscillogram. Identify the three axes in a spectrogram: frequency, amplitude, and time. The oscillogram and spectrogram in this pre-activity is the Northern Cardinal song.



An oscillogram presents the amplitude or loudness of the sound.



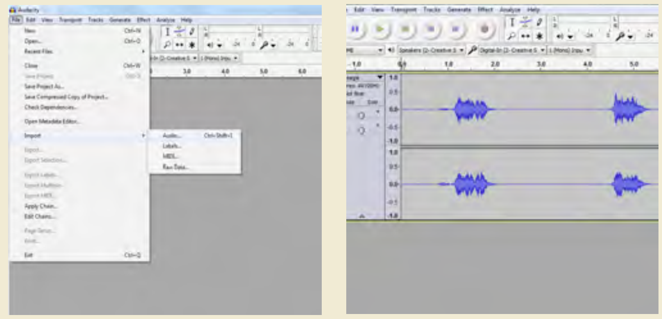
A spectrogram presents 1) time, shown on the x-axis, 2) frequency, shown on the y-axis, and 3) amplitude, shown in color.

Activity Part 1: Audio Visualization

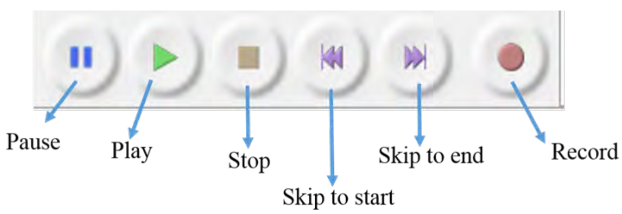
STEP 1

Import files into the sound visualization program

1. Drag each sound file separately from the Audacity Audio Library 1 to the Audacity icon, or import each file by selecting the menu option "File > Import" and selecting the file from its folder (Left figure).
2. 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) (right figure).
3. The buttons on the control panel, in order, are pause, play, stop, skip, skip to beginning, skip to



STEP 1: Import files into the visualization program



STEP 2

Listen to the sound

1. Hit the "Play" button for each sound while viewing it as an oscillogram.
2. Listen to each sound and watch the playhead move along the oscillogram (following figure).

STEP 2: Listen to the Sound.

Activity Part 2: Match 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.

- Drag an animal sound and a pure tone to the window (you will have two tracks in the same window).
- Play the animal sound. Then, play the pure tone. Then play both sounds simultaneously.
- Match all of the animal sounds with the correct pure tones.

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

Naming convention for each recording

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.)

Activity Part 3: Complex Soundscapes

Audacity Audio Library 3 has more complex soundscapes, with multiple sound sources making sounds at various frequencies and temporal patterns.

- Drag and drop the files from Audio Library 3 to the window.
- Listen to the audio files.
- Answer the following questions.

Part 3: Reflection

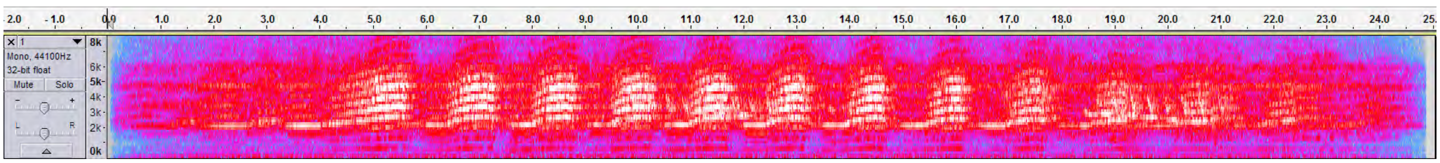
What is the difference between the recordings within this audio library and those in other libraries?

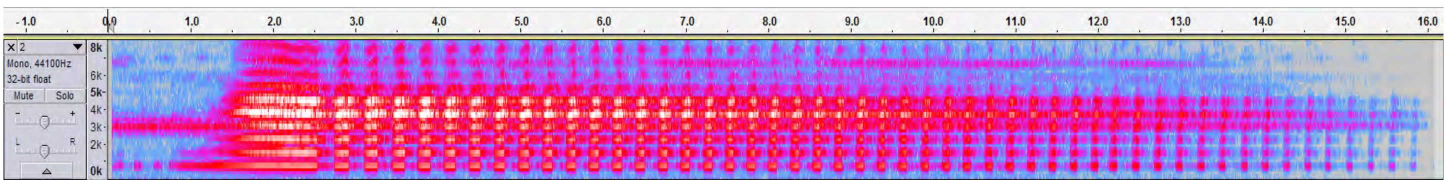
What are the sound sources in each recordings?

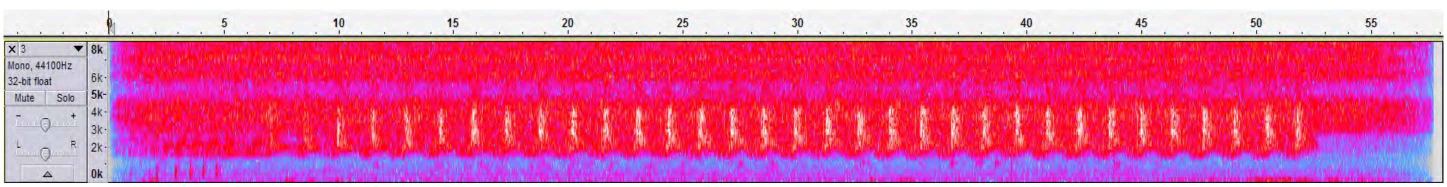
Are these sounds examples of geophony, biophony, or anthrophony?

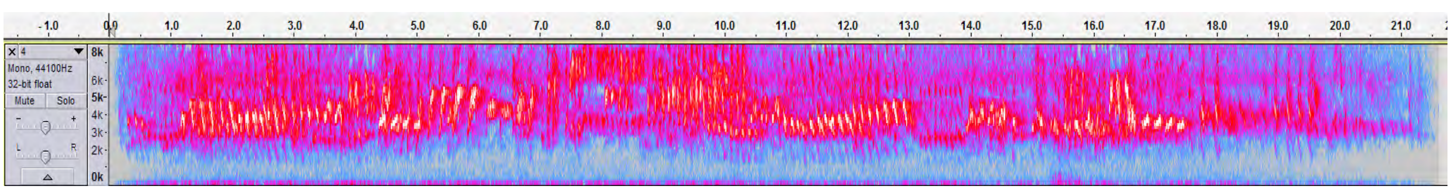
Worksheet 12.1, Activity Part 4: Match the Soundscape with the Spectrogram

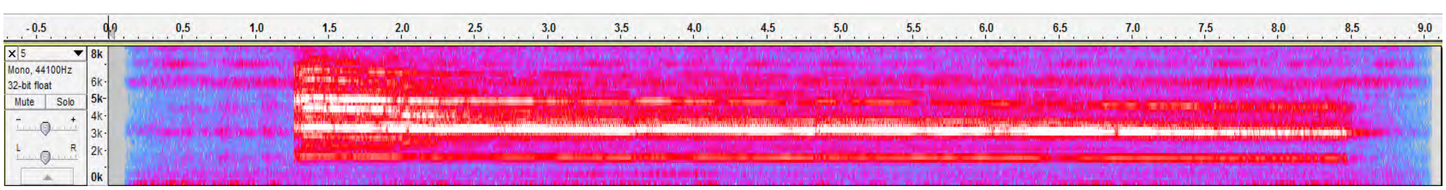
1. Listen to the audio files in Audacity Audio Library 4.
2. Label the spectrograms with the corresponding soundscape recordings.





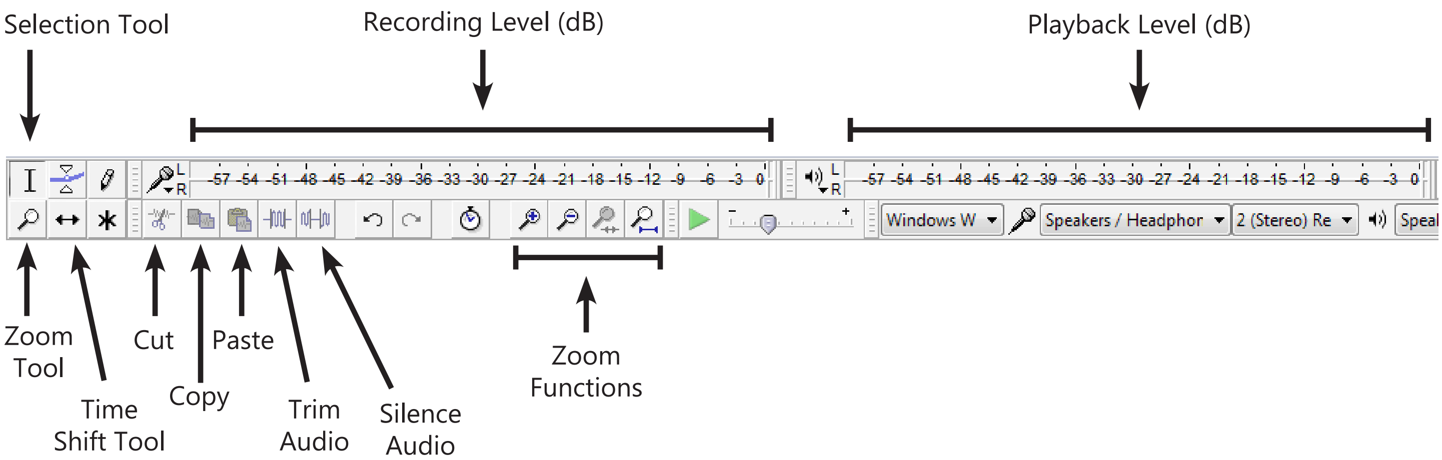






Activity Part 5: Create a Soundscape Composition

Sound Visualization Program Toolbar



Sound Visualization Program Menu

STEP 1

Create soundcape composition

1. Combine different sounds from any of the audio libraries to make your own innovative soundscape compositions.
2. Use the tools to cut and trim your sound (zoom tool, time shift tool, cut, copy, paste, trim audio, silence audio)
3. Experiment with Audacity's easy-to-use effects by exploring the ["Effects" menu located on the top menu bar.]

STEP 2

Save the soundcape compostion

1. After finishing your own soundscape, click on "File" "Export...," choose file name and save the file in a

TIPS

EFFECTS MENU

1. Reverse: plays the sound in reverse

2. Equalization: amplifies or reduces certain frequencies in the sound

3. Change Pitch: raises or lowers the pitch

4. Change Speed: raises or lowers the speed (pitch will be altered as well)

5. Change Tempo: raises or lowers the speed without affecting the pitch

6. 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

7. Fade Out: opposite of "Fade In"

Activity 13:
Travel for Soundscape Studies

In this activity, you will visit different lab stations where you will listen to sounds of different biomes. Complete the before listening and after listening questions on the Brain Dump for each of the six case study lab stations.

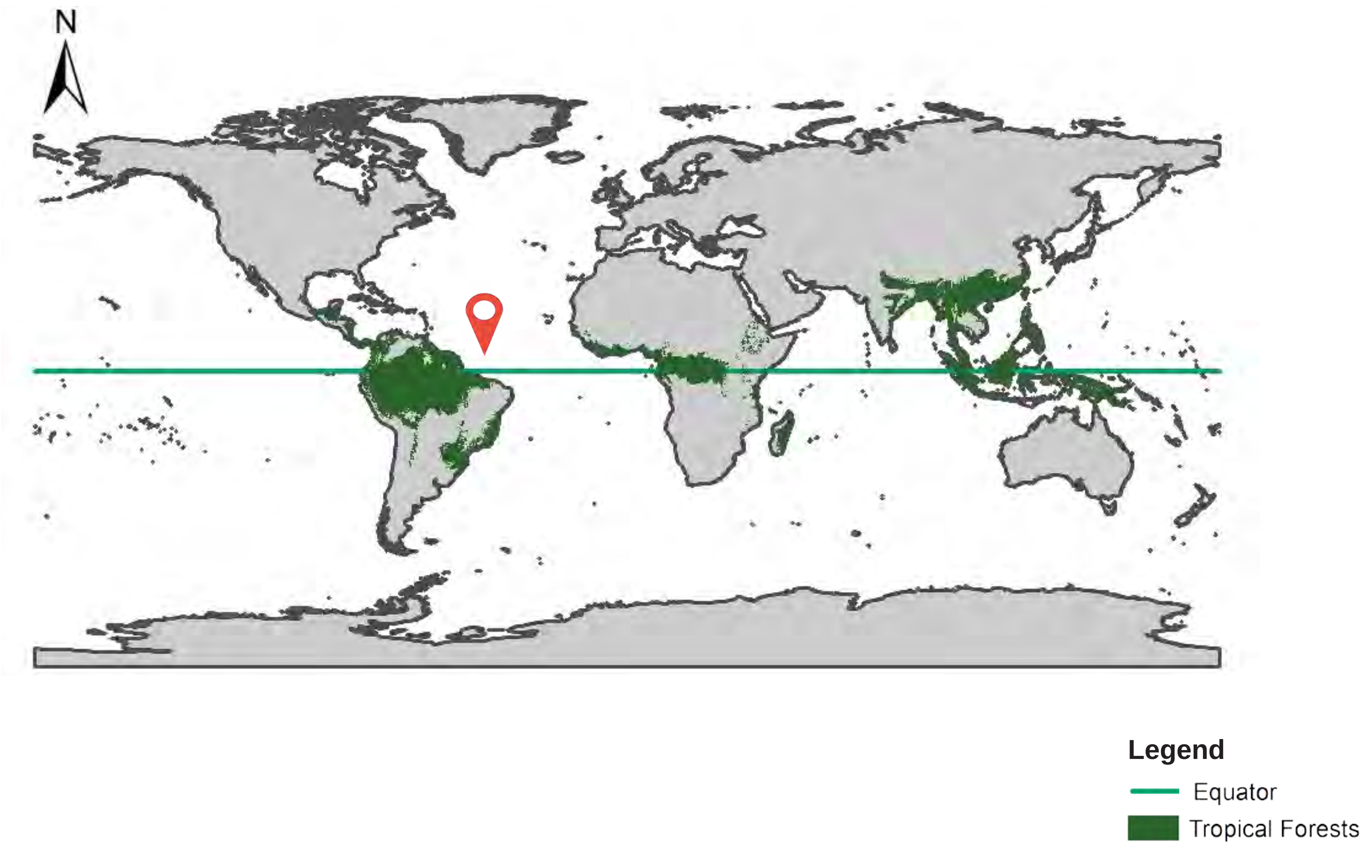
About Soundscape Studies

Scientists like soundscape ecologists are so curious. They have many scientific questions to explore the natural world. They ask questions like, "What is the imact of the noise on bird communication?" or, "How do diverse species of animals produce sounds in the dense rain forests of Costa Rica?" Their questions are about animal behavior, animal populations, or about environmental disturbances caused by humans or nature phenomena like a tornado. At first, scientists will make a prediction that is called "hypothesis". Then, they might travel to different ecosystems shere they record and analyze soundscapes to see if their hypotesis is accutrate.

Lab Station 1: Tropical Rainforest Case Study

Let's go to Costa Rica!

La Selva Biological Research Station



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

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening

- **How do soundscapes change with the vertical structure of the forest?**

- **Which layer has the highest soundscape diversity?**

- **What are some challenges in this study?**

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.

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.

BRAIN DUMP!

Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

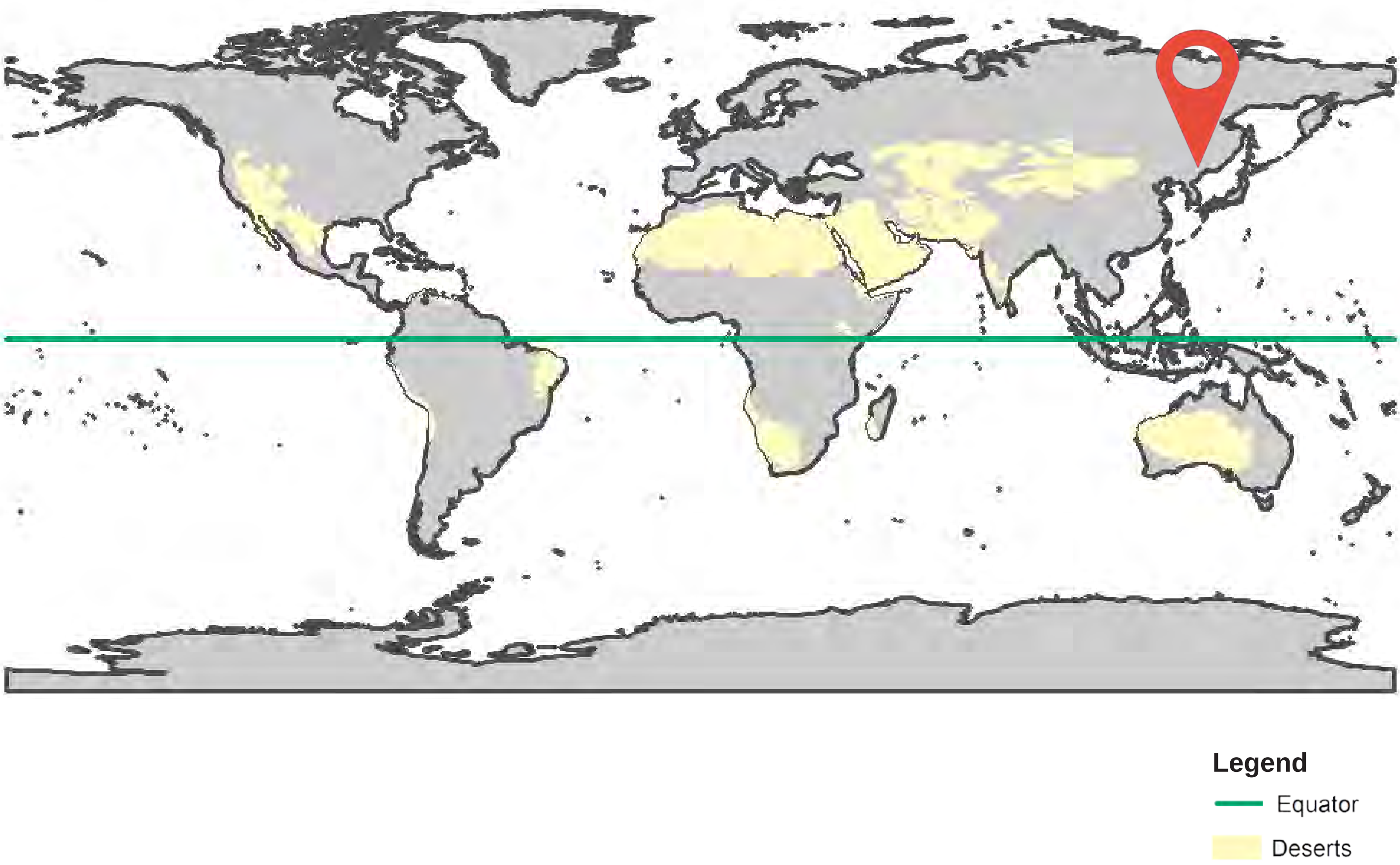
Before Listening

After Listening

Lab Station 2: Grassland Case Study

Let's go to Mongolia!

Govi-Altai



Climate and Biodiversity

Temperature: -40 to 38 °C (-40 to 100 °F)

Precipitation: 250 mm rain per year

Vegetation: Grand wormwood, edelweiss, peony, saxaul

Animals: Przewalski wild horse, saiga antelope, snow leopard, desert hedgehog, Siberian crane, tarbagan marmot

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening

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

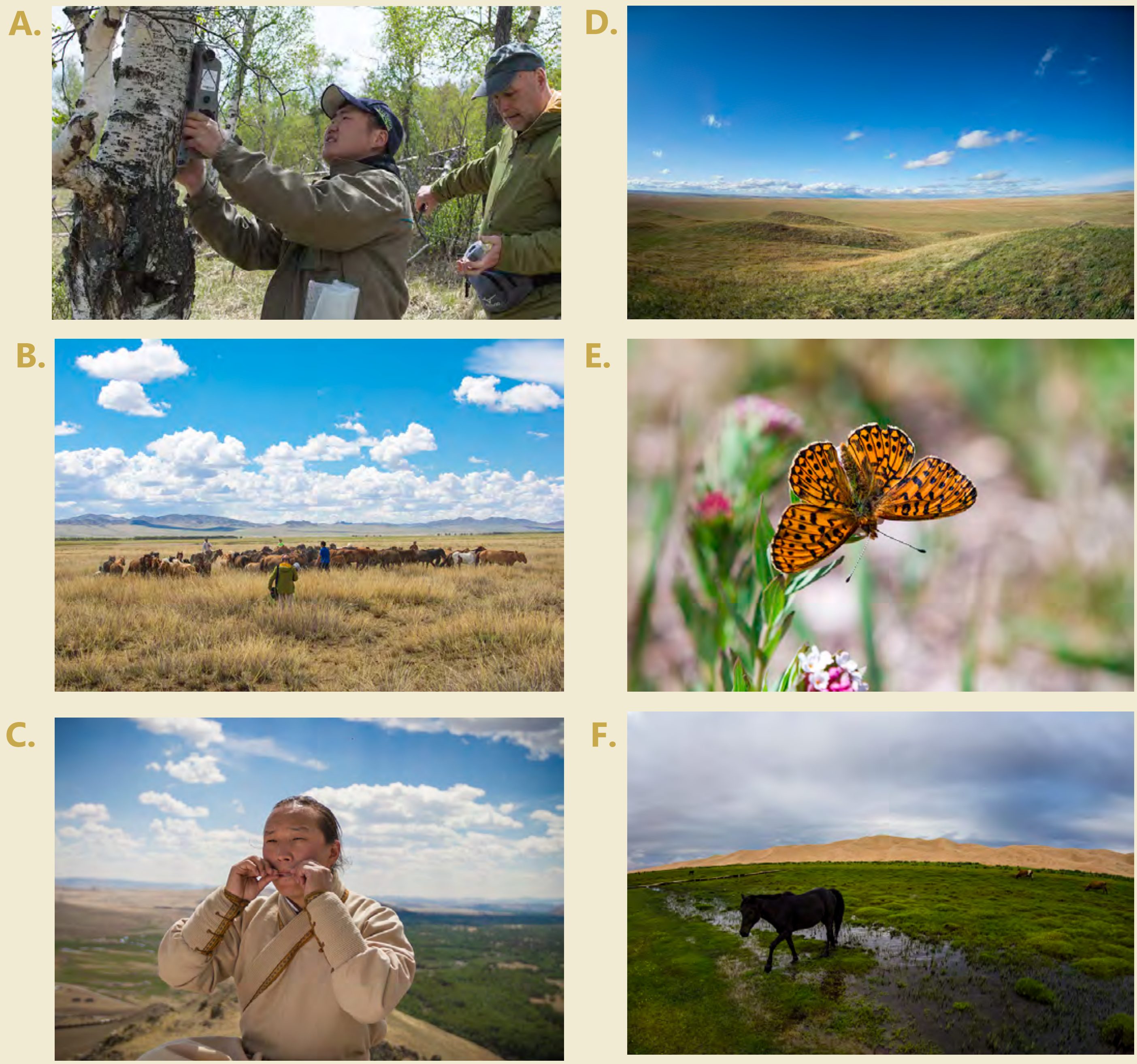
- **What are some challenges in this study?**

Facts

1. Part of the Mongolian population is nomadic and travels 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, 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.



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.

BRAIN DUMP!

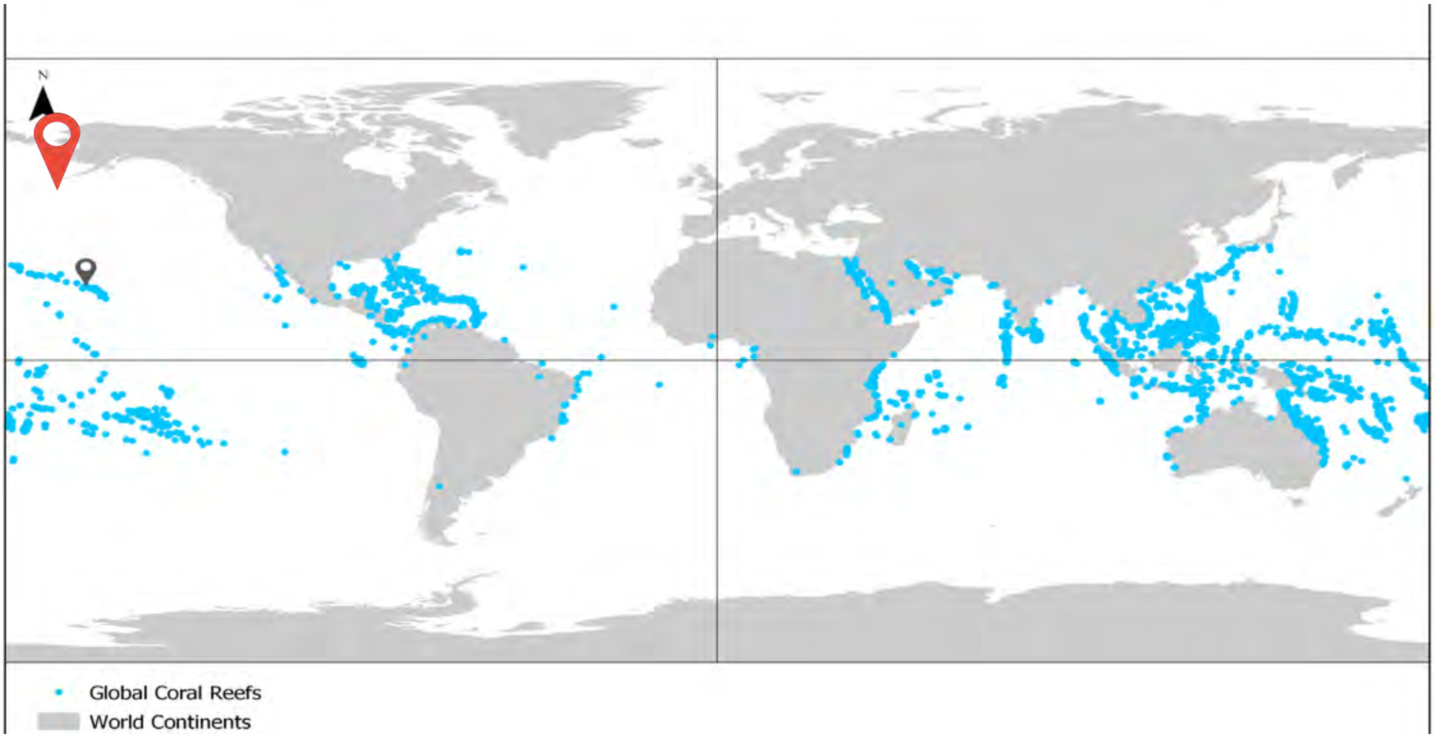
Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

Before Listening

After Listening

Lab Station 3: Coral Reef Case Study

Let's go to Hawaii!



Molokini Crater, Maui, Hawaii

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

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening
- **How does noise change the diversity of animal sounds in a marine environment?**

- **What are some challenges in this study?**

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.

A.

B.

C.

D.

E.

F.

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.

BRAIN DUMP!

Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

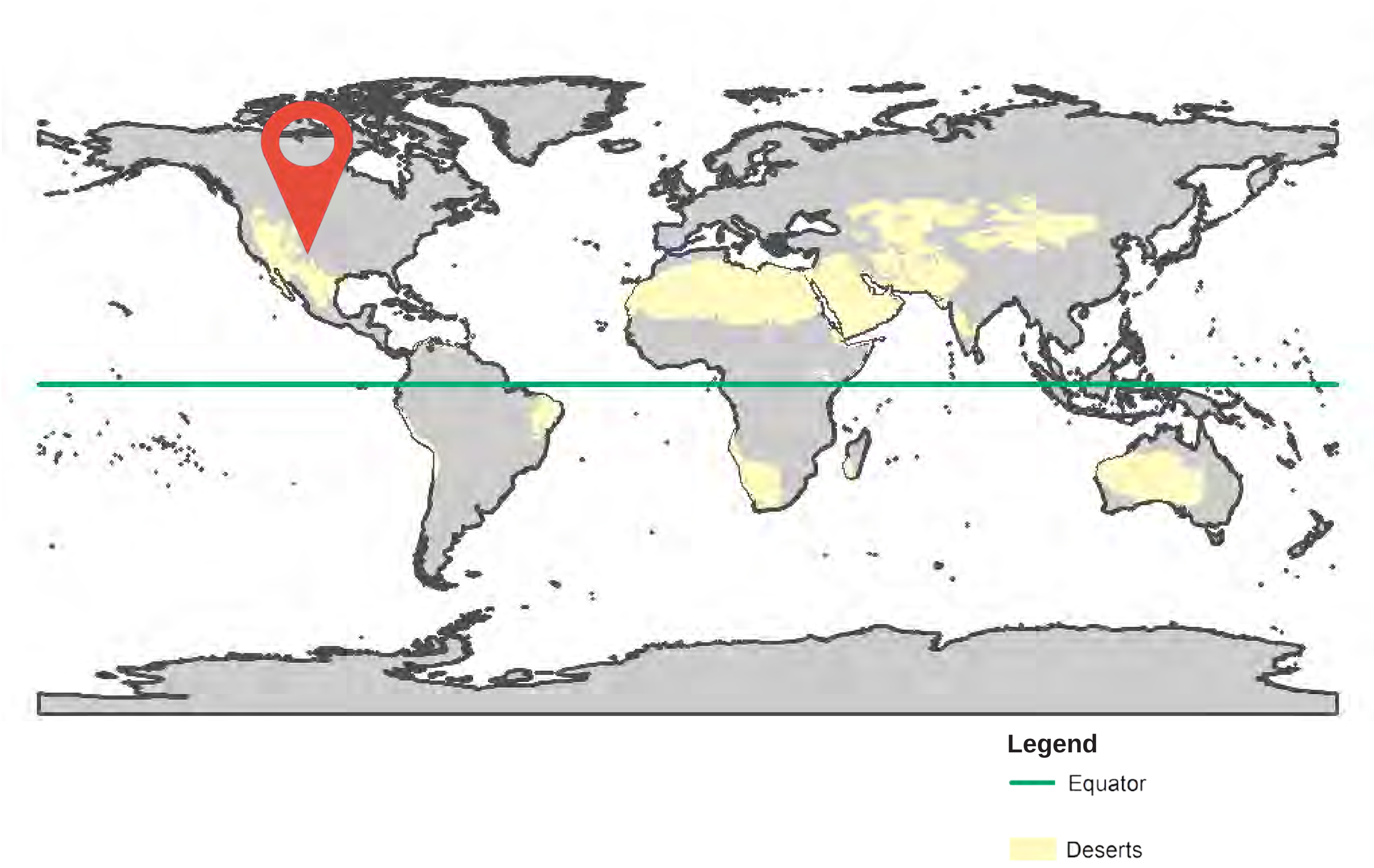
Before Listening

After Listening

Lab Station 4: Desert Case Study

Let's go to Arizona, USA!

Chiricahua National Monument



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, palm trees

Animals: Cactus wrens, deer, desert tortoises, bearded dragons, Arizona hairy scorpions, roadrunners, rattlesnakes, coyotes, cicadas, scrub jays, white-tailed deer, mountain spiny lizards

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening

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

- **What are some challenges in this study?**

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 (Figure 13.2).

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

BRAIN DUMP!

Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

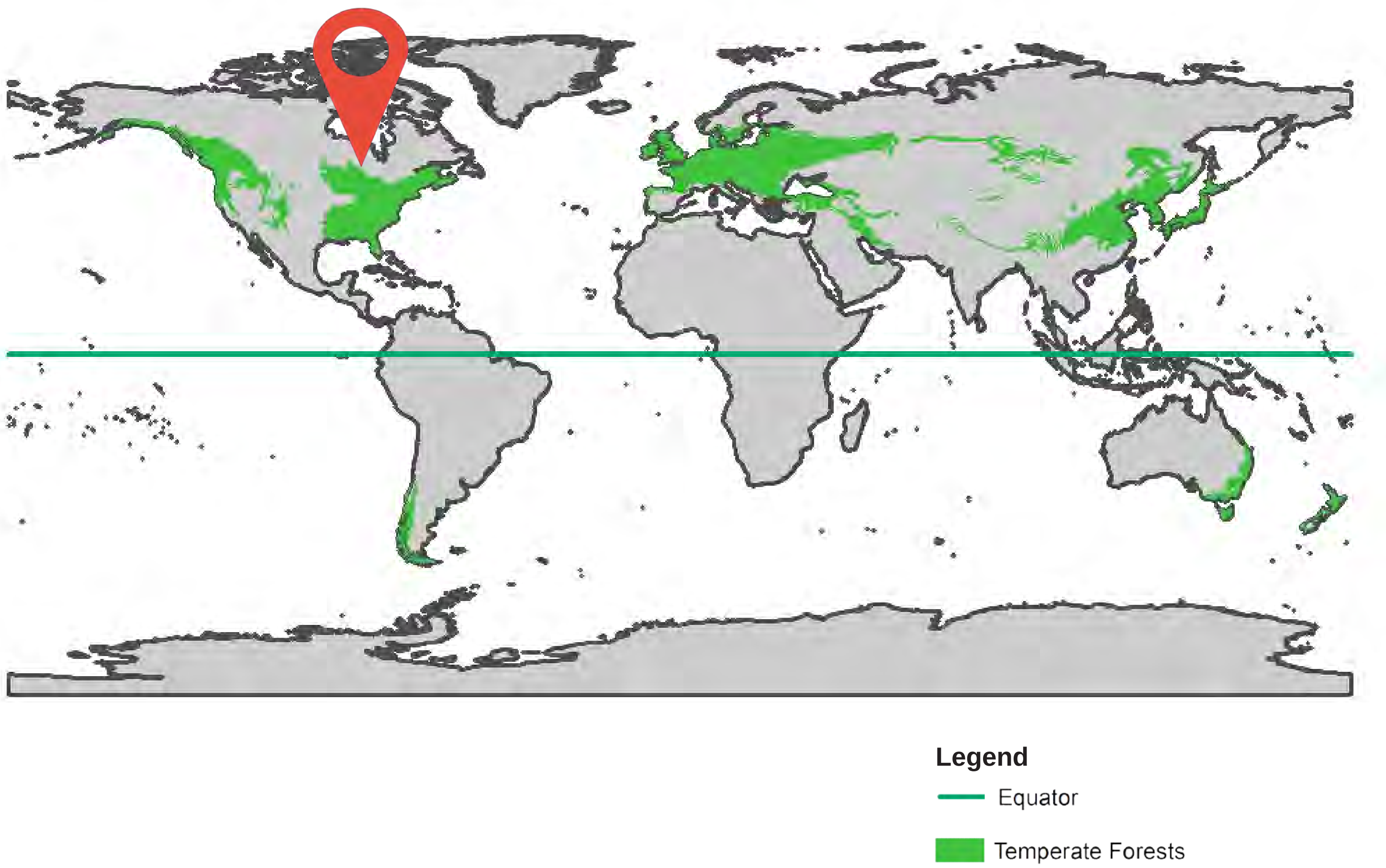
Before Listening

After Listening

Lab Station 5: Temperate Forest Case Study

Let's go to Indiana!

Ross Biological Reserve



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

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening

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

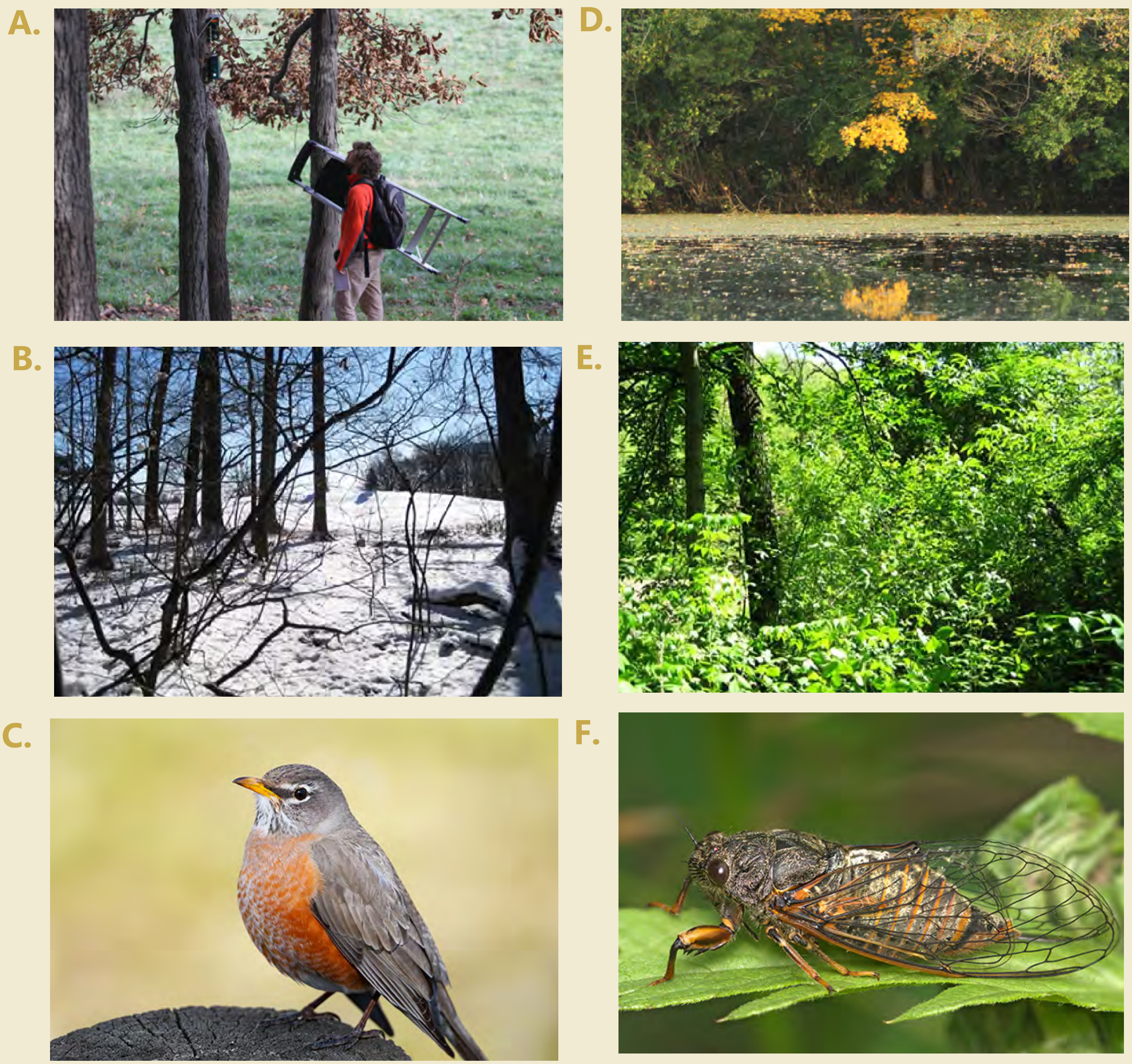
- **What are some challenges in this study?**

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.



Different photos of the study area: A) scientists in the field deploying a Song Meter SM2, B) temperate forests' winter landscape, C) American robin, D) temperate forests' fall landscape, E) landscape in early summer, and F) cicada.

BRAIN DUMP!

Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

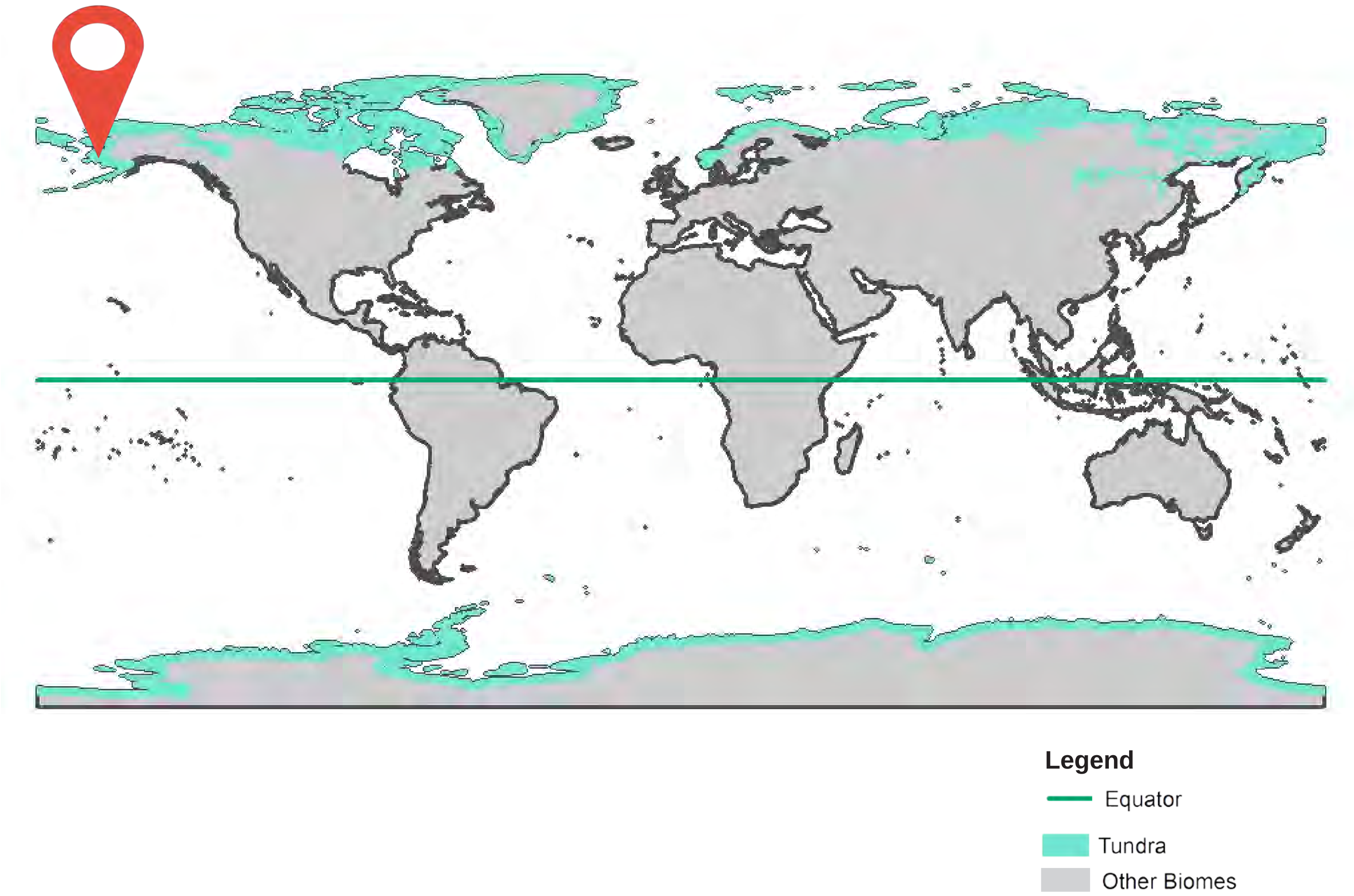
Before Listening

After Listening

Lab Station 6: Tundra Case Study

Let’s go to Alaska!

Denali National Park



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

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 characteristics information and photos to learn more) do you think might influence the soundscape?**

- **What are some sounds you think you will hear ?**

After Listening
- **How do soundscapes change over the course of one day in the Alaskan tundra?**

- **What are some challenges in this study?**

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.

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 ealy summer, C) sparrow, D) swallow siting on a camera next to a microphone array, E) landscape in the early summer, and F) caribou.

BRAIN DUMP!

Use the research questions panel from this case study. Answer the questions for the Before Listening section. Then, listen to the sounds and read the facts. Then, answer the questions for the After Listening section.

Before Listening

After Listening

Activity 14: Soundscapes and Road Noise

In this activity, you will conduct a simulated research study about bird diversity and soundscape diversity near a road that has loud noise. Explore the different data sources to answer the research question in Worksheet 14.1. Refer to Worksheets 14.1-14.4.

Instructions:

1. Read the description of the Aldo Leopold Study (Worksheet 14.1, Worksheet 14.2).
2. Listen to Aldo Leopold Audio Library.
3. Complete the first four boxes of Worksheet 14.3 and make a graph (last box of Worksheet 14.3) using the data provided in the Aldo Leopold Study table (Worksheet 14.2).
4. Then conduct your own research and answer the questions on Worksheet 14.4.

About Soundscapes and Road Noise

Did you know that 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 masks animal communication.

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. The temperate forest study sites were located in three main habitat types: deciduos forest, woody wetlands, and emergent herbaceous wetlands. [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 depende

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.

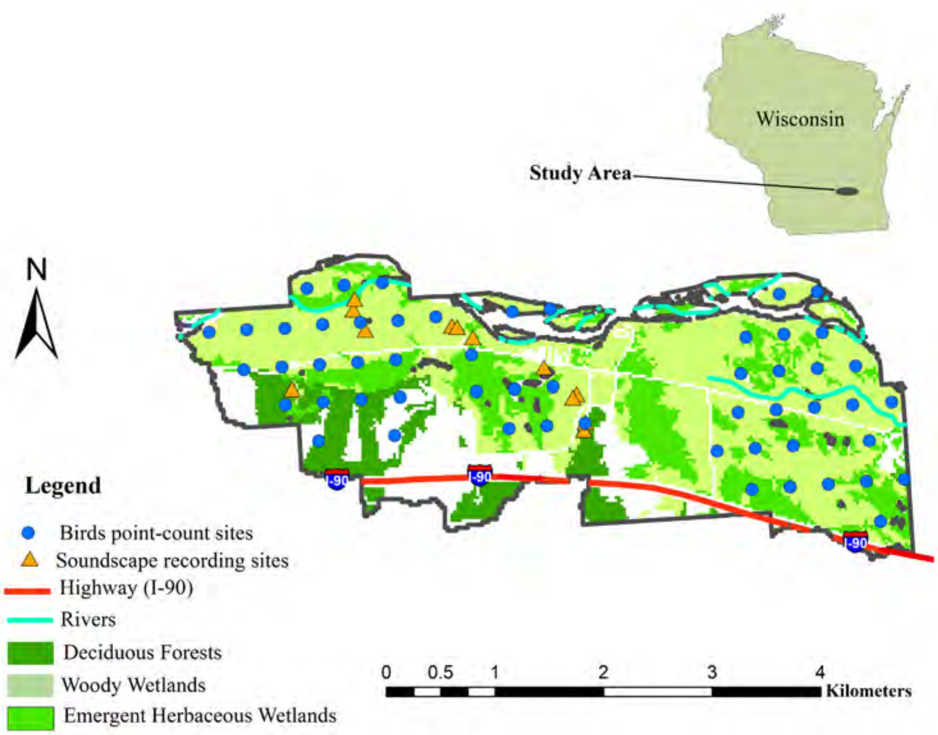


Figure 14.1. Map of the study area.

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

I am a wood thrush, and I live in the forest. Many animals like me rely on sounds to communicate. I really don't like roads. They are noisy and hard to avoid, especially because road noise extends several kilometers beyond the roads' edges.

Worksheet 14.3: Soundscapes and Road Noise Observation Form A

Where is the research area located?

What is the research question?

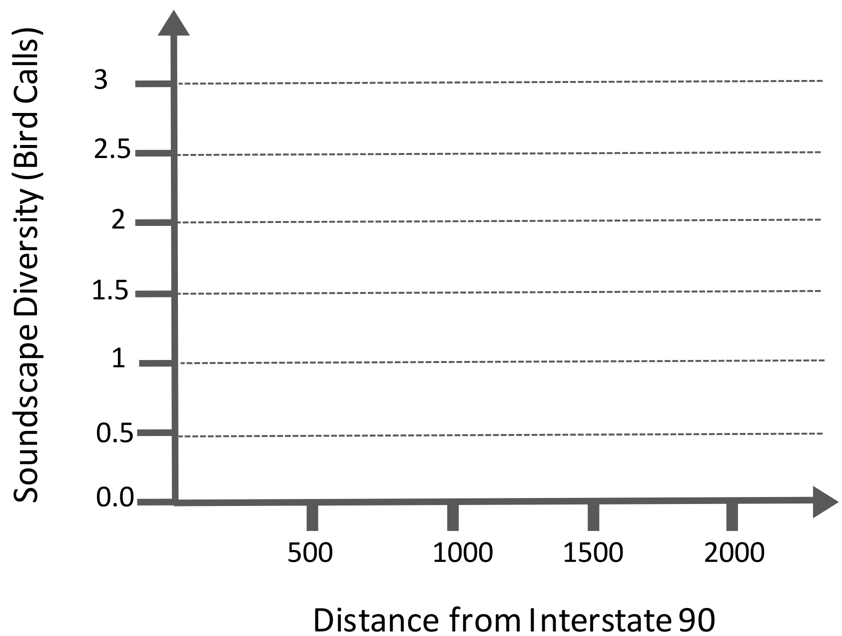
Data collection:
According to the map, how many soundscape recording sites did the soundscape ecologist use?

According to the map, how many sites were used to collect bird species inventories?

What is the name of the highway?

In what type of habitat are these sites located?

Graph:



Explain your results:

Worksheet 14.4: Soundscapes and Road Noise 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	Decibel Level	Biophony (scale 1-3)	Geophony (scale 1-3)	Anthrophony (scale 1-3)

Activity 15:
Be a Scientist, a Real Soundscaper!

In this activity, you will use the scientific method to conduct your own soundscape study. To complete this activity, follow steps 1-5.

About the Scientific Method

Scientific research is conducted to answer questions. From ecologists to physicists, all scientists use standard scientific methods as the central protocol for conducting research. Here are the steps of the scientific method:

- Ask a research questions
- Formulate a hypothesis
- Design a study to test that hypothesis
- Conduct the study and collect data
- Analyze data and synthesize results

Want to be a soundscape ecologist? Follow these steps:

Step 1: Choose a scientific question
- Go for a sound walk with your groupmates.
- Fill out Worksheet 15.1.
- Brainstorm and discuss potential research questions.
- Develop a preducation and hypothesis regarding your research question.

Step 2: Materials and Methods
- Finalize the research question with your instructor.
- Fill out Worksheet 15.2.
- Make a list of all the items on the supply list that you can take to the field.

Step 3: Collect data according to an experimental protocol
- Wear appropriate clothing and bring all necessary materials for fieldwork.
- Remember that proper field techniques are needed for consistent data collection
- Be consistent with the length of each audio recording.
- Try to make several recordings at each site.

Step 4. Interpret data to answer your research question
- Discuss your data with your group members.
- Fill out Worksheet 15.3.
- Make figures that illustrate your results and demonstrate the answer to the research question.

Step 5: Sharing and presenting data
- Make a poster that presents your scientific research project.
- Be as creative as possible.
- Your poster can have many different sections, but try to incorporate these suggestions:
    - Put your group's name on the poster.
    - Make a soundscape related slogan.
    - Clearly state the initial research question.
    - Briefly summarize the experimental protocol.
    - Present results using at least one figure, one table of sounds, one table of environmental variables, and one sound map.
    - Feature some soundscape recordings.
- Discuss the implications of the data with other groups.
- Decorate posters using collected natural materials, drawings, or photographs.

Worksheet 15.1: Be a Scientist Observation Form A

Team name:

Members:

Date:

Time:

Sound Walk

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

Sound Map

Worksheet 15.1 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 15.2: Be a Scientist Observation Form B

Team name:

Members:

Date:

Time:

Research Question:

Hypothesis:

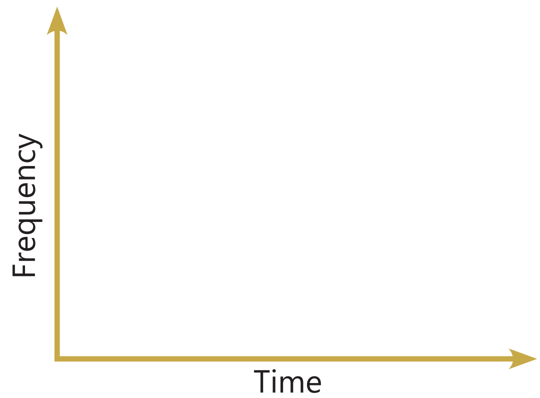
Experiment/Data Collection Protocol

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 C

Draw the Spectrogram of the Soundscapes



Extra Notes

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

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

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

Decibel
A unit expressing the amplitude of a sound

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

Fragmenting
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

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

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

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 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

The 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

Timbre
The character of a sound that results from its component frequencies, but is independent of its overall frequency and amplitude

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