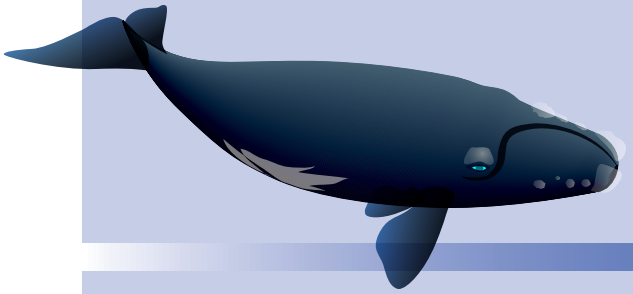


Extreme Animal Communication

Teacher Notes

Before You Start

Time Frame

- Activity: one class period
- Teacher prep time: less than 1 hour

Grade Level: 10-11

(Appropriate for grades 6-12, with extension activities.)

Materials Needed

- At least one computer with speakers attached. Ideally students would be organized into groups each with a computer and speakers or headphones.
- ***Raven Lite sound analysis software*** is available on the Sea of Sound DVD. It can also be downloaded for free: **birds.cornell.edu/brp/raven/RavenOverview.html**
- The ***Bat and Whale sound files*** for this activity are available on the DVD.
- A ***Raven Lite Quick Reference*** sheet for each group.
- One **calculator** per group, minimum.
- One **tape measure** per group, long enough to measure the classroom in meters.

Goal

Students should be able to report the frequency limits of human hearing (in Hertz) and name one animal that communicates using ultrasound and one animal that communicates using infrasound. Students should also understand the wavelength equation and be able to use it to calculate the wavelengths of sounds of known frequencies.

Learning Objectives

Students will:

- be able to demonstrate the presence of infrasound or ultrasound in a recording based on sound visualization techniques.
- be able to measure the frequencies of animal calls in the infrasonic and ultrasonic ranges and relate these to human hearing abilities.
- be able to convert frequency measurements into wavelength values and estimate how many wave cycles from a particular animal call would fit into their classroom.

Overview

This activity explores the extremes of animal sound communication by introducing students to animal sounds above and below the frequency thresholds of human hearing. By exploring ultrasonic bat sounds and infrasonic whale sounds using sound visualization software, students prove to themselves that these sounds really exist. They then measure the frequencies of the sounds and convert frequency into wavelength allowing them to estimate how many wave cycles will fit into their classroom. Blending physics content with biology, this activity also stimulates understanding of why animals might use communication systems radically different from our own.

Prior knowledge

Before beginning this activity, students should have familiarity with the following:

- **Audible:** Sounds that we can hear.
- **Frequency:** The number of peaks that pass by a single point in a given period of time (a rate). The most commonly used unit of sound frequency is Hertz (Hz) measured in cycles per second. For example 1500 Hertz = 1500 cycles per second. This means that 1500 peaks of the wave pass by a single point in one second. 1500 Hertz can also be represented as 1.5 Kilohertz (kHz) because 1000 Hz = 1 kHz.
- **Hertz:** The number of wave cycles per second. For example 1500 Hertz = 1500 cycles per second. 1 Hertz = 1000 Kilohertz.
- **Infrasonic:** Sounds at frequencies too low for the typical human ear to detect. The accepted range for infrasound is 0 – 20 Hertz.
- **Ultrasonic:** Sounds at frequencies too high for the typical human ear to detect. The accepted upper limit of humans with goof hearing is 20,000 Hertz.
- **Wavelength:** The distance between two peaks of a wave.

Background Information:

Animal communication is powerful theme in the science classroom. Because each species perceives the world through senses tuned specifically for their survival, any investigation of other animal's sensory worlds forces us to consider life from their point of view and to reconsider our understanding of the physical properties of their communication systems. The process of stepping outside human reference points is an important skill in science. One only has to think of the many natural phenomena not immediately obvious to the human senses that have been discovered through scientific inquiry—ultraviolet radiation, black holes, and photosynthesis. The world of bioacoustics holds sensory surprises such as bat and dolphin echolocation above the level of our hearing and whale and elephant vocalizations made in the infrasonic range well below our level of hearing. Sound visualization techniques allow us to detect these hidden surprises.

Teaching Tips

- You may wish to being this activity with some of the following focus questions:
  - Can animals make sounds that we can't hear?
  - What are the frequency limits of human hearing?
  - What is ultrasound and infrasound?
  - What are the wavelengths of ultrasound and infrasound?
- An effective hook for this activity would be to play an ultrasonic dog whistle for the class and ask students can hear it. Ask students to brainstorm what they think is happening.
- Another intriguing opener would be to show students the wonderful short video called "The Rat Tickler" showing the scientist Jaak Panskepp tickling his lab rats and recording their ultrasonic giggles with special equipment (**wnyc.org/shows/radiolab/episodes/2008/02/22**).
- Assessment: students should be able to report the frequency limits of human hearing (in Hertz) and name one animal that communicates using ultrasound and one animal that communicates using infrasound. They should also understand the wavelength equation and be able to use it to calculate the wavelengths of sounds of known frequencies.

Resources

- Wild Music: A traveling exhibition about the sounds and songs of life. This online sound activity allows you to compare the frequency range of sounds you can hear with the frequency range other animals can hear. **wildmusic.org/en/aboutsound/mosquito**
- Elephant Infrasound. An explanation of elephant infrasound from Cornell University's Elephant Listening Project. **birds.cornell.edu/brp/elephant/ELPFAQ.html**
- In your classroom: The sounds of silence. Infrasound activity on volcanoes and earthquakes. **pbs.org/kcet/wiredscience/education/2007/10/in-your-classroom-sounds-of-si.html**
- Behavior of Sound Waves: Reflection, Refraction, and Diffraction. A physics classroom tutorial that uses the bat example (including the wavelength equation to understand bat echolocation. **glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l3d.html**

National Science Education Standards

- **UNIFYING CONCEPTS AND PROCESSES:** Evidence, Models, and Explanation; Change, Constancy, and Measurement;
- **SCIENCE AS INQUIRY:** Understanding About Scientific Inquiry—mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.
- **PHYSICAL SCIENCE:** Interactions of Energy and Matter—waves, including sound and seismic waves, waves on water, and light waves have energy and can transfer energy when they interact with matter.
- **LIFE SCIENCE:** Behavior of Organisms—like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles.
- **SCIENCE AND TECHNOLOGY:** Understanding About Science & Technology—science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.

Ocean Literacy Principles

The ocean supports a great diversity of life and ecosystems (5).

Acknowledgments

By Mya Thompson, PhD at Cornell University under NSF grant DUE # 0532786. Sounds provided by Martyn Stewart of Nature Sound and the Cornell Bioacoustics Research Program. If reproducing the lesson, please cite Cornell Lab of Ornithology as the source and provide the following URL:

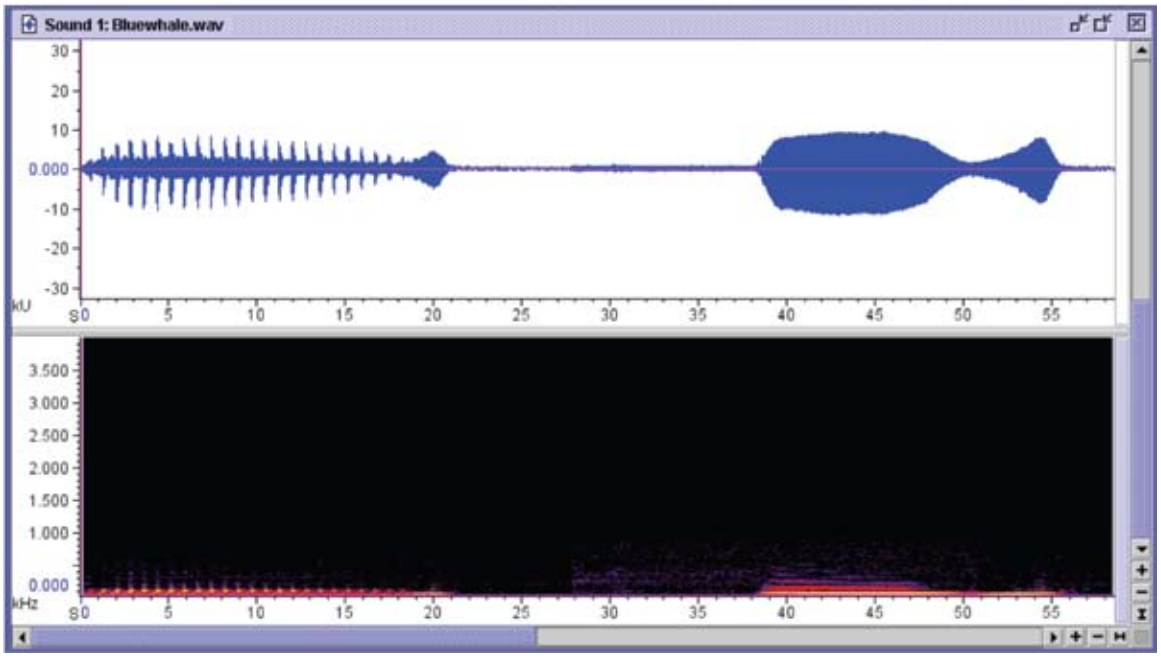
macaulaylibrary.org/physics/secondary.

Teacher Version

Part 1: Infrasound and Ultrasound

Blue whale:

The students should be seeing a screen that looks like this:



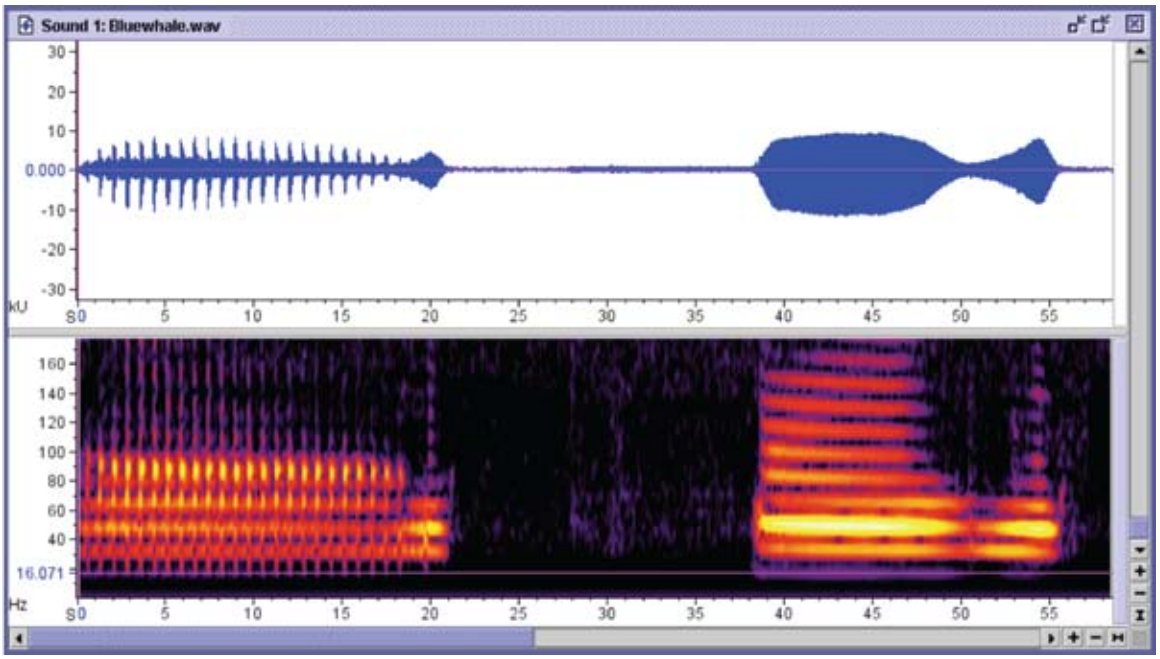
Can you hear it? *Maybe barely, a low throbbing*

Look at the sound graphs. Can you see it on the waveform? *Yes*

Now look at the spectrogram. It is hard to see the sound because it is so low-frequency. Try zooming in to the low frequencies by repeatedly clicking on the icon on the upper toolbar until you see ladder-like shapes appearing. What you see are two types of blue whale calls from the Pacific Ocean: first the trill and then the moan.

Teacher Version

The students should be seeing a screen that looks like this after zooming in:



Now try a little trick of the trade. Speed up the recording by typing 10 into the box labeled **rate** on the upper toolbar Rate: 10.

Now play it again, can you hear it? *Yes*

Describe in words what it sounds like.

The first sounds a bit like a mouth harp and the second sounds a bit like a foghorn.

Now, on the spectrogram of the second blue whale call, the moan, drag the horizontal pink line from the bottom of the spectrogram to the point on the y-axis where the lowest rung of the ladder-like shape appears. The frequency of this line is shown to you in blue on the y-axis.

What is the lowest frequency of the blue whale moan?

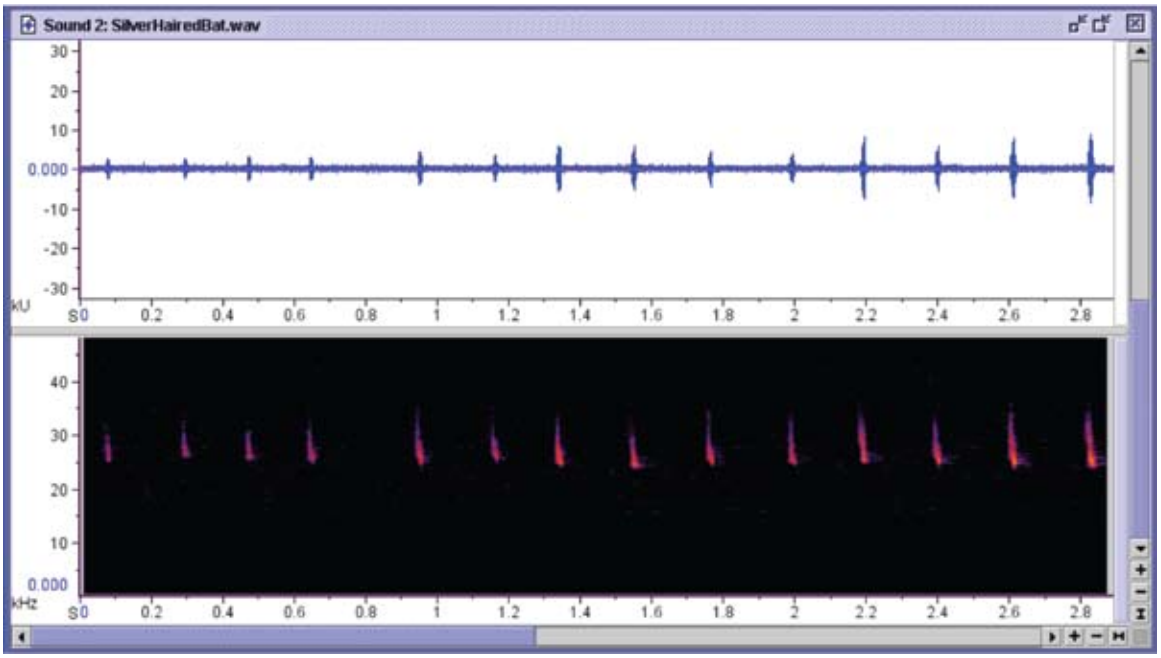
~16 Hz, the pale purple line is lowest frequency (see above diagram)

Is this in the infrasonic range? *Yes!*

Teacher Version

Silver-Haired Bat

The students should be seeing a screen that looks like this:



Can you hear it? *No*

Look at the sound graphs. Can you see it on the waveform? *Yes*

Can you see it on the spectrogram? *Yes*

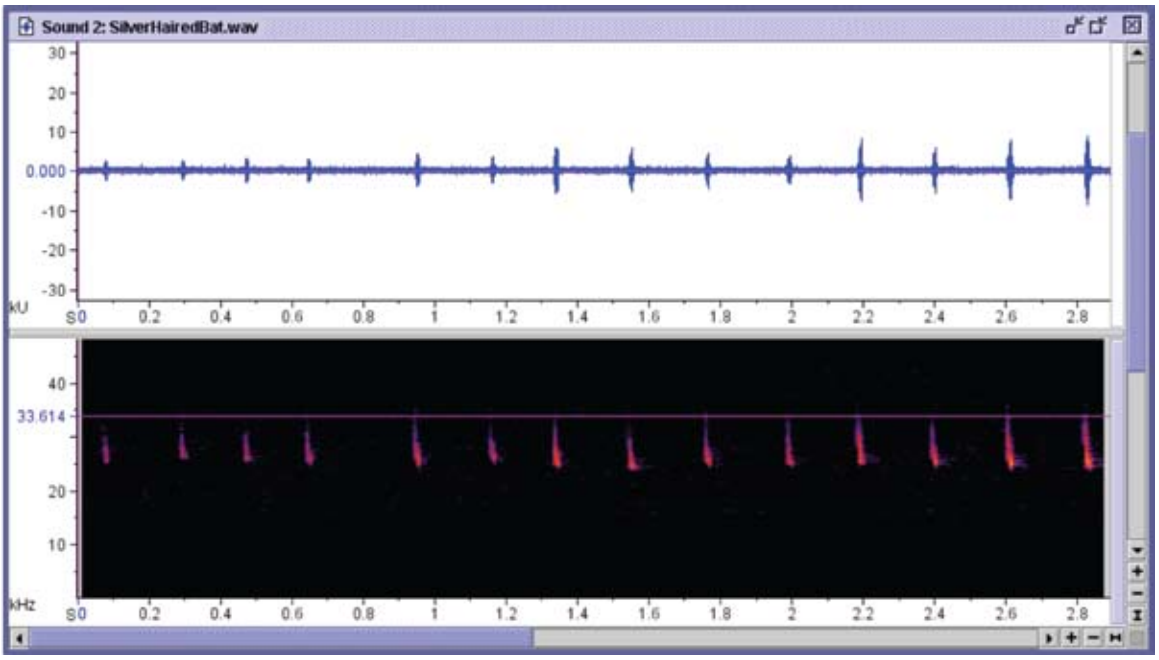
Now to translate these sounds into our hearing range, slow down the recording by 10 times by typing .1 into the box labeled **rate** on the upper toolbar Rate: .1.

Now play it again, can you hear it? *Yes*

Describe in words what it sounds like: *It sounds a bit like a bird chirping.*

Teacher Version

Now, on the spectrogram of the bat calls, drag the horizontal pink line from the bottom of the spectrogram to the point on the y-axis where the highest frequency in a bat call appears. The frequency of this line is shown to you in blue on the y-axis.



What is the highest frequency of the Sliver-haired bat call?

~33 Kilohertz = 33,000 Hz (see above diagram, watch the scale it changes to Kilohertz when viewing high-frequency sound!)

Is this in the ultrasonic range? *Yes!*

Teacher Version

Part 2: Wavelengths of Extreme Animal Sounds

$\lambda = v/f$
λ = wavelength (meters/cycle)
v = speed of sound (meters/second or m/s)
f = frequency (cycles/second = Hertz)

Speed of sound:	**Air**	**Seawater**
Range	325-355 m/s	1400-1700 m/s
Average	340 m/s	1550 m/s

Calculate the wavelength of the lowest frequency in the blue whale call you measured using the formula above.

1550 meters/second / 16 cycles/second = 97meters/cycle

How many meters is the longest wall of the classroom?

Let's say the room is 6m (about 20 ft).

Roughly how many of these sound waves could fit into your classroom (if it were underwater)?

A very tiny fraction of one wave cycle! 6 m / 97 m = 0.0

Calculate the wavelength of the highest frequency in the bat call using the formula above.

340 meters/second / 33,000cycles/second = 0.01 meters/cycle!

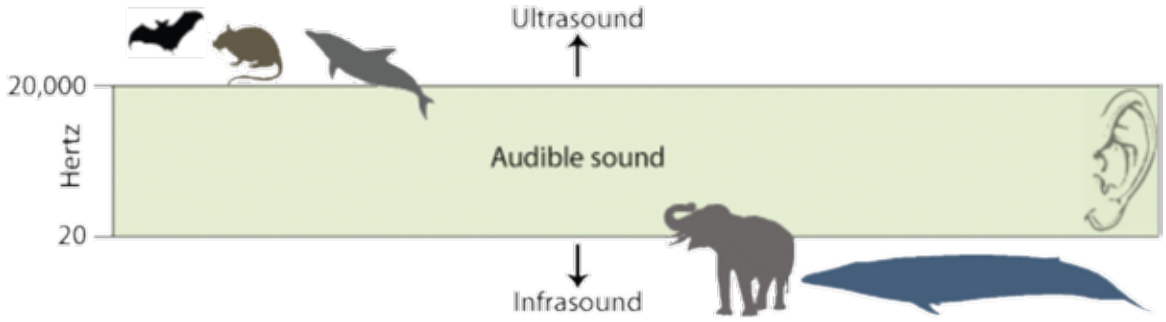
Roughly how many of these sound waves could fit into your classroom?

6 m / 0.01 m = 600 wave cycles, wow!

Student Version

Extreme Animal Communication!

Did you know that some animals make sounds that we can't hear? Bats, rats, dolphins, elephants and whales all make sounds that are not audible to us even when we are very close to them. This is not because the sounds are made quietly, but instead because our ears are not sensitive to very high and very low pitch (frequency) sound. Humans with good hearing can only hear frequencies from about 20 Hertz (wave cycles per second) to about 20,000 Hertz. This may seem impressive, but some animals like elephants and whales communicate at frequencies below 20 Hz, in what we call the infrasonic range. Others like bats, rats and dolphins communicate at frequencies above 20,000 Hertz, in the ultrasonic range.



In this investigation, you will:

- Explore recordings of some extreme animal sounds: Silver-haired bat calls and Blue whale calls.
- Use computer software to visualize sound and manipulate playback speed to help you hear frequencies you normally can't detect.
- Measure the wavelength of bat and whale sound and figure out how many bat and whale sound waves will fit inside your classroom.

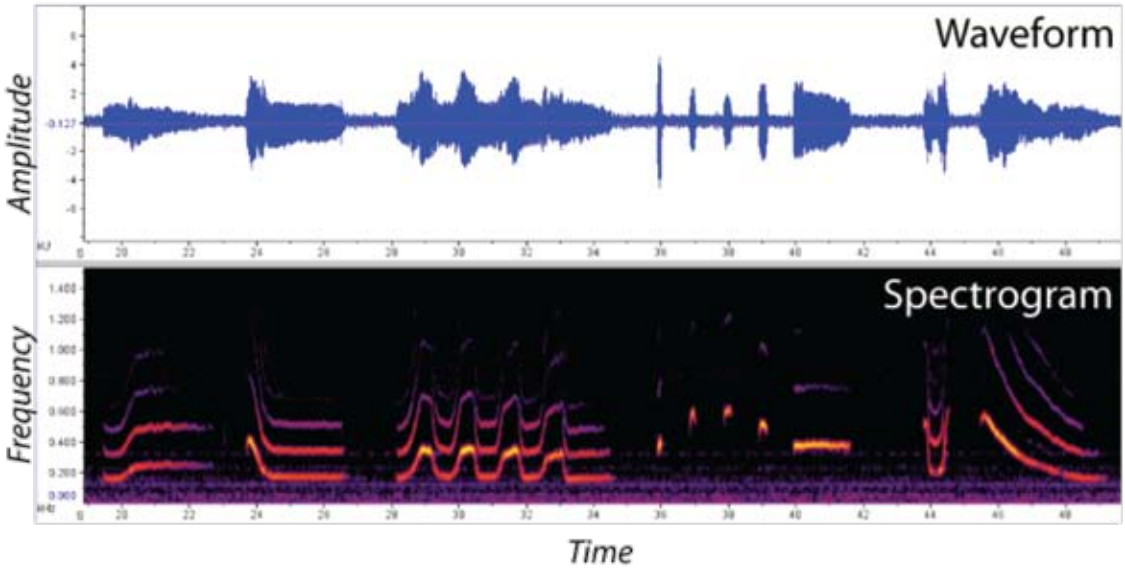
Materials:

Computer with speakers or headphones and Raven Lite software, Sound files of the Silver-haired bat and the Blue whale, Calculator, Tape measure (with meters)

Student Version

Part 1: Infrasound and Ultrasound

Open the program Raven Lite by selecting it from the list of installed programs or clicking on the icon. Now open the BlueWhale.wav file. You can open sound files either by dragging them into the Raven program window or by using the **File** menu and selecting **Open Sound Files** and finding the folder on your computer where your teacher is storing the sound files. You will now see two sound graphs. It should look similar to the diagram of the human voice below.



The top graph is called a waveform and it shows you the loudness (amplitude) of the sound on the y-axis as time progresses on the x-axis. The bottom graph is a spectrogram showing you the frequency (pitch) of the sound on the y-axis as time progresses on the x-axis. Louder sounds are shown with brighter colors in the spectrogram.

Blue Whale

	Blue whales are the largest animals on earth. They are 23 - 30 meters long (75 -100 feet) and can weigh as much as 150 tons. They feed roughly 4 tons of small shrimp-like animals called krill per day. Blue whales were hunted almost to extinction before laws protecting them were passed. Blue whales use sound to communicate long distances underwater. At certain depths and sea conditions, these sounds can be heard by other whales hundreds and perhaps even thousands of miles away.

Make sure the sound is working on your computer either through speakers or through headphones and play the Blue whale recording by clicking the right-pointing grey triangle on the upper toolbar. You can stop the playback by clicking the grey square .

Student Version

Can you hear it? _____

Look at the sound graphs. Can you see it on the waveform? _____

Now look at the spectrogram. It is hard to see the sound because it is so low-frequency.

Try zooming in to the low frequencies by repeatedly clicking on the icon on the upper toolbar until you see ladder-like shapes appearing. What you see are two types of blue whale calls from the Pacific ocean: first the trill and then the moan. But these sounds were very hard to hear right?

Now try a little trick of the trade. Speed up the recording by typing 10 into the box labeled **rate** on the upper toolbar Rate: 10.

Now play it again, can you hear it? _____

Describe in words what it sounds like. _____

_____

Why can you hear it when you speed up the recording? Because you are tricking your ear into thinking that the sound waves are arriving at your eardrum faster than they do in real life. If sound waves arrive at speeds faster than 20 wave cycles per second (Hertz) then we can hear it.

Now, on the spectrogram of the second blue whale call, the moan, drag the horizontal pink line from the bottom of the spectrogram to the point on the y-axis where the lowest rung of the ladder-like shape appears. The frequency of this line is shown to you in blue on the y-axis.

What is the lowest frequency of the blue whale moan? _____

Is this in the infrasonic range? _____

If you were able to hear these sounds without speeding them up, then you have good hearing and/or good speakers or headphones. But this does make sense, because you probably noticed from your analysis that parts of these blue whale sounds (the upper rungs of the ladder) are within the range of human hearing.

Student Version

Silver-Haired Bat

Silver-haired bats live all over North America, even in your backyard. They can live up to 12 years and are about 30 cm long (12 inches). They feed at night on small insects, especially moths. They detect their prey in the dark using echolocation, by sending out high-frequency sounds and then listening for the sound patterns that bounce back at them as it hits their prey.

Now open the Silver-haired bat recording (SilverHairedBat.wav) and play it by clicking the right-pointing grey triangle on the upper toolbar. You can stop the playback by clicking the grey square  .

Can you hear it? _____

Look at the sound graphs. Can you see it on the waveform? _____

Can you see it on the spectrogram? _____

Now to translate these sounds into our hearing range, slow down the recording by 10 time by typing .1 into the box labeled **rate** on the upper toolbar 

.

Now play it again, can you hear it? _____

Describe in words what it sounds like. _____

_____

Why can you hear the chirp-like sounds when you slow down the bat recording? The wave cycles of the bat sounds are arriving at our ear too quickly for us to sense them so you have to trick the ear so that the waves are slowed down below the rate of 20,000 wave cycles per second. People interested in bats often use little electronic devices called bat detectors, which automatically slow down bat sounds to find them at night.

Now, on the spectrogram of the bat calls, drag the horizontal pink line from the bottom of the spectrogram to the point on the y-axis where the highest frequency in a bat call appears. The frequency of this line is shown to you in blue on the y-axis.

What is the highest frequency of the Sliver-haired bat call? _____
(Watch the scale it has changes to Kilohertz, kHz, because we are at high-frequencies 1Hz = 1000 kHz)

Is this in the ultrasonic range? _____

Do you know some adults that can't hear cell phone rings anymore? This is because their high-frequency hearing sensitivity has gotten worse with age. So the ultrasonic range for them starts lower than for young people without hearing loss.

Part 2: Wavelengths of Extreme Animal Sounds

$\lambda = v/f$
λ = wavelength (meters/cycle)
v = speed of sound (meters/second or m/s)
f = frequency (cycles/second = Hertz)

Speed of sound:	Air	Seawater
Range	325-355 m/s	1400-1700 m/s
Average	340 m/s	1550 m/s

Calculate the wavelength of the lowest frequency in the blue whale call you measured using the formula above. _____

How many meters is the longest wall of the classroom? _____

Roughly how many of these sound waves could fit into your classroom? (if it were underwater)

_____

Calculate the wavelength of the highest frequency in bat call using the formula above.

_____

Roughly how many of these sound waves could fit into your classroom? _____

Vocabulary:

Audible: Sounds that we can hear.

Frequency: The number of peaks that pass by a single point in a given period of time (a rate). The most commonly used unit of sound frequency is Hertz (Hz) measured in cycles per second. For example 1500 Hertz = 1500 cycles per second. This means that 1500 peaks of the wave pass by a single point in one second. 1500 Hertz can also be represented as 1.5 Kilohertz (kHz) because 1000 Hz = 1 kHz.

Hertz: The number of wave cycles per second. For example 1500 Hertz = 1500 cycles per second. 1 Hertz = 1000 Kilohertz.

Infrasonic: Sounds at frequencies too low for the typical human ear to detect. The accepted range for infrasound is 0–20 Hertz.

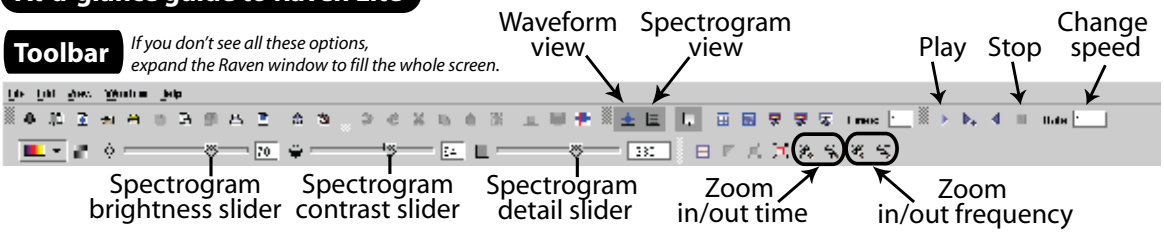
Ultrasonic: Sounds at frequencies too high for the typical human ear to detect. The accepted upper limit of humans with goof hearing is 20,000 Hertz.

Wavelength: The distance between two peaks of a wave.

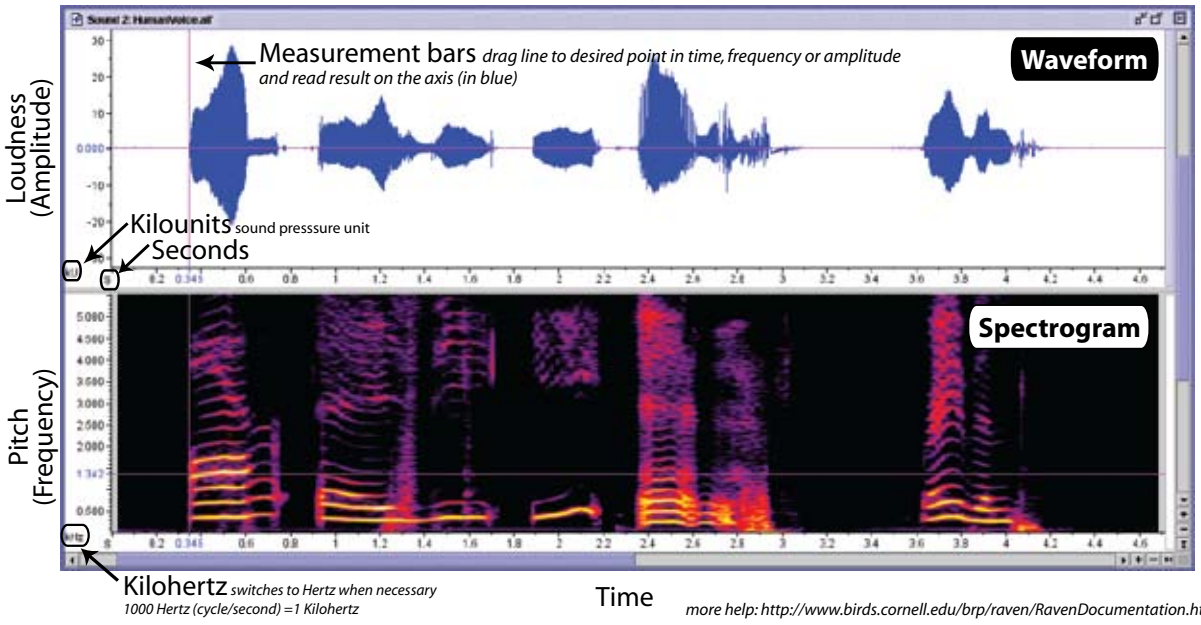
Student Version

At-a-glance guide to Raven Lite

Toolbar *If you don't see all these options, expand the Raven window to fill the whole screen.*



Sound display *To open a sound, drag it onto the Raven window or select 'Open sound file' from the file menu. Raven automatically adjusts the display for you, but you may wish to change it.*



more help: http://www.birds.cornell.edu/brp/raven/RavenDocumentation.html