Giants of the Depths • *Sound in the Sea* Lesson Plan

by Bill Andrake

In this episode, Jonathan travels to Dominica, an island in the Caribbean, for an underwater encounter with Sperm whales. The very deep waters around Dominica attract these whales, who are able to navigate the dark depths and locate prey using echolocation. For social animals such as whales, the use of sound is extremely important for communicating with others and sensing their environment in the absence of light.

Science Lesson: Sound in the Sea
Grade Level: 6-8
Time: Three or four (45-50 min) class periods. (Introduction, Activity, Follow-up)

Introduction

Animals' abiltity to sense sound is important to their survival on many levels. Social animals need it to communicate and to find each other. It is used to sense danger or locate prey. Underwater sound is especially important as light from the surface disappears quickly with depth or can get blocked and scattered by material in the water, greatly reducing visibility and limiting vision. Whales and dolphins rely heavily on echolocation to find prey and navigate dark waters. We have our version of echolocation called SONAR for "seeing" underwater. Even fish make sounds for attracting mates or scaring off predators.

But, what is sound? How does sound travel so well in water when light does not? In this activity we will examine the nature of sound and sound underwater.

Science Standards

National Science Education Standards
• Physical Science: Transfer of Energy
Ocean Literacy Principles
• Principle #5: The ocean supports a great diversity of life and ecosystems.

Objectives

- To gain a better understanding of what sound is and how it travels.
- To better understand how energy is transferred by waves.
- To provide a foundation for exploring how and why sounds differ from one another.
- To understand why sound travels better and faster underwater than in air.
- To improve students' appreciation of why sound is so important to life in aquatic ecosystems.

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Eliciting Prior Knowledge

Ask students:

- What is sound?
- What are vibrations?
- How is sound made?
- How fast does sound travel?
- How do our ears receive sound?
- Could you "hear" without ears?
- What are the properties of sounds that we can use to describe them?
- Do fish hear? Do they have ears? How might they detect sound?
- Does it travel the same way or speed through all materials?
- Why is sound important to animals in nature?
- Do we hear better underwater or in the air?
- How is sound blocked or absorbed?

Helpful Vocabulary

Acoustic: Having to do with sound

Echolocation: An outgoing sound waves travel through the water to the bottom of an object(s) where it is reflected back towards the source and received. The quicker the sound returns to the receiver the closer the object.

Frequency: The number of waves passing a point per second. In sound, frequency is detected as "pitch." Low pitch is low frequency and high pitch sounds are sound waves with a high frequency.

Intensity: The strength or power of the energy.

Longitudinal Wave: As energy is transferred through a medium, the materials in the medium get squeezed together and then expand along the same direction as the wave. Also known as *Compression Wave*.

Medium: Material through which energy passes. Example air: water, etc.

Molecules: Tiny particles made from two or more atoms chemically combined in a specific way. Water molecules (H2O) are two atoms of Hydrogen bonded to one atom of Oxygen.

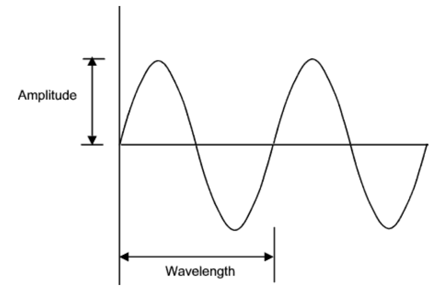
Reflection: Energy waves bounce off a surface. An echo is the reflection of sound waves.

Sonar: (**So**und **N**avigation **a**nd **R**anging) A system that sends out underwater sound waves and uses echolocation to detect objects underwater or measure the distance to the bottom of a body of water. Sonar is an important tool for measuring depth and mapping the sea floor.

Speed: Distance traveled in a certain time, e.g. miles per hour, meters per second.

Transverse Wave: As energy is transferred through a medium, the material moves perpendicular (side to side… up and down) to the direction of the wave.

Wave: A disturbance that transfers energy as it travels through a medium from one location to another. It is important to note that the medium through which the wave travels experiences some sort of motion as the wave passes, but the particles in the medium do not travel with the wave.



Wavelength: The distance between corresponding parts of successive waves such as crest to crest or trough to trough.

Activity: How Does Sound Travel?

Background:

Sound is energy that travels in *waves* through a *medium* such as water or air. Sound happens when something disturbs or pushes particles (*molecules*) in the medium. This "disturbance" or energy continues to be passed along from particle to particle in the medium, sent out in all directions, similar to ripples on a pond's surface after tossing in a small rock.

Sound waves transport this energy by pushing *molecules* into each other, squeezing or compressing them together for an instant. Then as this wave of compression passes the molecules return to their original position or "*equilibrium*." This wave of compression continues moving away from the source of the sound in all directions. As it passes, the molecules move back and forth (from compression to equilibrium) but only the energy travels through the medium, not the particles in the medium.

This type of wave is known as a longitudinal or compression wave. In this case the motion of the particles vibrate back and forth along the same direction as the wave. In this activity you will get a sense for how sound waves travel through a medium using a toy slinky.

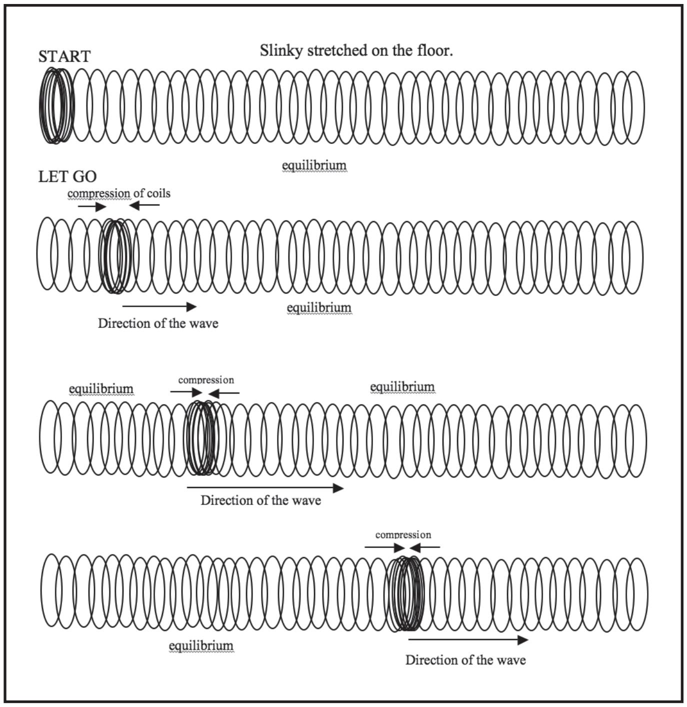
Materials: A toy slinky and a computer with on-line access.

Procedure: Working in teams of two on the floor, with a student holding each end, stretch a slinky in a straight line so that there is roughly 1 to 1.5 inches between coils. The slinky will stretch to a length of about 8 - 10 feet (depending on its size).

One student will generate compression or longitudinal waves down the slinky. while the other will hold their end securely in place. *Note: Do not let go of the slinky! If the coils get tangled, you will have a mess!*

To generate a wave, pull a coil or two of the slinky toward you. When ready release that coil.

Refer to the diagram on the next page to help explain how the wave travels through the slinky.



As you observe the movement of the energy through the slinky, answer the following questions.

1. Describe how the energy generated is passed through the slinky. ______________________________

____

____

2. After the wave passes through the slinky, did the coils move from where they started on the floor? ________

3. Then what exactly is traveling through the slinky?______________________________________

____

(Remember…When a wave travels through a medium, only the disturbance or energy travels away from the source, not the particles in the medium.)

4. Was there an echo in your slinky demonstration?________ Explain:_________________________

____

____

5. Why is this type of wave called a "compression wave?" ______________________________

____

6. At one point in the video, *Giants of the Depths,* Jonathan describes the pounding in his chest from the sounds emitted from the whales. What exactly was he feeling? ______________________________

____

7. Would you consider the energy through the slinky in this activity to be traveling at a high speed? _________

____

8. This wave moves through the slinky at about 10 feet per second.
   - What is the speed in feet per minute?_________________
   - What is the speed in feet per hour? ___________________
   - Calculate the speed of this wave through the slinky in miles per hour. *(1 mile = 5280 feet)*___________

Follow-up and Extensions

You can compare compression waves with other types of wave energy and read clear explanations of how waves work with excellent animations by visiting "Acoustics Animations" from Dr. Dan Russell. Kettering University applied physics. 2002. At the following links:

http://www.kettering.edu/physics/drussell/Demos/waves-intro/waves-intro.html

http://www.teachersdomain.org/asset/lsps07_int_waves/

Sound vs. Light in the Sea

Light and other forms of electromagnetic energy do not travel well through materials as they are made of atoms and molecules. Atoms and molecules absorb, block or scatter this energy.

Water and gasses are clear, but they're still made of molecules that want nothing better to do than absorb this energy. Thus, water and even air hamper the conduction of light, no matter how clear. It's interesting that electromagnetic energy such as light can travel through the vacuum of space for trillions of miles, but can't penetrate even the clearest water for more than a few hundred feet. The vast majority of the sea is in total darkness.

On the other hand, sound requires matter in order to be transmitted. Sound cannot travel in outer space as there are no molecules to vibrate and pass along compression waves. In fact sound travels better in materials that are more dense, where molecules are more tightly packed. This is why the speed of sound in water is roughly five times faster in water than in air.

Life has proven that it evolves ways to sense its surroundings with the energy available. Many living things have features for sensing "visible light"; plants utilize it as an energy source for photosynthesis. Visible light is the form of electromagnetic energy that is most available to us from our star, the Sun. Perhaps if our sun bathed us in infra-red energy or ultra-violet, more life might have evolved ways to "see the world" using these forms of electromagnetic radiation.

Sound travels well in water and is a more versatile and useful form of energy in the deep than light. So it makes sense that many undersea animals have adaptations for using sound to communicate and sense their surroundings. This is especially true for whales and dolphins who can "see" in the darkness using echolocation, and have advanced vocalizations to communicate with other individuals to navigate, coordinate a hunt, or simply find each other.

A comprehensive resource for helping with lessons dealing with sound in the ocean is the *Discovery of Sound in the Sea* web site developed by the University of Rhode Island's (URI) Office of Marine Programs (OMP).
Accessed at http://www.dosits.org/

The Audio Gallery in this web site has an extensive collection of sounds emitted by animals in the sea from croaking fish to the echoes of Sperm whales. There are even the sounds of earthquakes and lightning recorded underwater.

To access this gallery go to: http://www.dosits.org/audio/interactive/

"Seeing" with Sound

(Refer to the video *Giants of the Depths*)

Just as we see the world as light reflects off objects, whales and dolphins "see" in the sea with reflected sound waves or echoes in a process called echolocation. Echolocation is very sophisticated in these animals and has allowed them to hunt and locate prey in areas that are not accessible to visual feeders.

At the 3 minute mark in the video *Giants of the Depths* there is an animation of echolocation which you can review to get a sense as to how this process works.

In echolocation, whales send out pulses or "clicks" through the water that reflect or bounce off of objects underwater, returning to the whale. The faster they return, the closer the object.

Calculating the distance from an object with echolocation

The distance from an object with reflected sound underwater can be calculated in the following manner:

Distance = (speed of the sound) x (the time it takes to return) ÷ 2

(Why do you divide the product of these two measurements by 2?)

Just how fast is sound underwater? The speed of sound waves underwater depends on depth, temperature, and salinity. but the average speed is about 1500 meters/second. That's a little under 1 mile per second. (1500 meters = 0.93 miles) At this speed it is roughly 5 times faster than the speed of sound in air which takes about 5 seconds to go 1 mile.

Calculating the speed of sound underwater in miles per hour.

The average speed of sound underwater is 0.93 miles per second.

1. How many seconds are there in a minute? _____ in an hour? _________

2. So, what is your estimated speed of sound underwater? ____________ miles per hour.

3. What is the calculated speed of sound underwater in miles per hour? _________ mph

(show your calculation)

4. Write the formula for finding the distance to an object using echolocation.

____

5. Using the approximate speed of 1 mile per second, if pulses take 0.2 seconds to return to a whale after bouncing of an object underwater, how far away is the object? Show your calculation below:

At 1500 meters per second an echo takes 0.1 seconds to return to the whale after being sent out into the water.

6. How far away is the object that's reflecting the sound ? Show your calculation below:

We have our own version of echolocation aboard ships called *sonar* which stands for "sound navigation and ranging." This technology emits a pulse of sound waves in a given direction. A computer then measures the time it takes for the waves to travel outward, bounce off an object and return. It then determines the distance that the ship is from the object. Ships use this technology to measure depth. Many echoes returning from the sea floor can be analyzed by computers and turned into maps or images of the seafloor at depths too deep be imaged with light from the surface.

Calculating depth using sonar: (use the same formula for determining distance with echolocation)

Example: At 1500 meters per second, a sonar pulse takes 4 seconds to return to the ship after being sent toward the bottom.

7. What is the depth of ocean at this location? (Show your calculation)

More Resources on Sonar and Navigation with Sound

Discovery of Sound in the Sea. Navigation.

http://www.dosits.org/people/navigation/measurewaterdepth/

Journey to Puna Ridge. A web site documenting an oceanography cruise that explored the deep sea off of the coast of Hawaii along the Puna Ridge in 1998.

http://www.punaridge.org/doc/factoids/Sound/Default.htm

As mentioned earlier *Discovery of Sound in the Sea* web site (http://www.dosits.org/) has a number of resources for extending the lessons presented here, including classroom activities and tutorials.

The PBS series NOVA has put resources on "Teacher's Domain" for Massachusetts Educators. From the episode, "Subs, Secrets, and Spies" there is a background essay, discussion questions, and an educational quiz on sound. It can be accessed at:

http://www.teachersdomain.org/resource/phy03.sci.phys.mfe.under/
or
http://www.pbs.org/wgbh/nova/subsecrets/ (click on "Sounds Underwater.")

The PhET Interactive Simulations project at the University of Colorado provides a free website of fun, interactive simulations that can be used to help teach lessons in sound.

The following simulation lets you see sound waves. You can adjust the frequency or volume so you can see and hear how the wave changes.

http://phet.colorado.edu/en/simulation/sound

The "Wave on a String" simulation (click below) allows you to generate transverse waves through a string. You can adjust frequency, amplitude, and tension on the string. It's helpful in understanding how waves transfer energy.

http://phet.colorado.edu/sims/wave-on-a-string/wave-on-a-string_en.html

Answer Key to "How Does Sound Travel?" Activity

Questions after the activity generating waves through a slinky.

1. Describe how the energy generated is passed through the slinky.

   A: The coils in the slinky are compressed and then return to their original "equilibrium" position, as the wave or energy is passed through the slinky.

2. After the wave passes through the slinky, did the coils move from where they started on the floor?
   A. No

3. Then what exactly is traveling through the slinky?
   A. The energy or disturbance travels through the slinky, but the slinky doesn't change its location.

4. Was there an echo in your slinky demonstration? Explain.
   A. YES After the wave reaches the end of the slinky it returns to the person who generated the wave.

5. Why is this type of wave called a "compression wave?"
   A. The energy compresses or squeezes the coils as it travels through the slinky.

6. At one point in the video *Giants of the Depths,* Jonathan feels the pounding in his chest from the echoes emitted from the whales. What exactly was he feeling?
   A. Jonathan was feeling the compression waves from the pulses emitted by the whales. The waves traveled through the water, transferring this energy to his chest, which Jonathan felt as pressure.

7. Would you consider the energy through the slinky in this activity to be traveling at a high speed?
   A. Answer may vary…but it appears pretty fast. This wave moves through the slinky at about 10 feet per second.

   • What is the speed in feet per minute? 600 feet per minute
   • What is the speed in feet per hour ? 600 feet/minute x 60 min/hr = 36,000 feet/hr
   • Calculate the speed of this wave through the slinky in miles per hour ?

   36,000 feet/hr. ÷ 5280 feet/mile = 36,000 feet/hr. x 1mile/5280 feet
   = 36,000 miles/5280 hrs.
   = 6. 8 miles/hr *(not really that fast!)*

Answers to "Seeing with Sound"

Calculating the speed of sound underwater in miles per hour.

The average speed of sound underwater is 0.93 miles per second.

1. *How many seconds are there in a minute?* 60 *In an hour?* 3600

2. *So, what is your estimated speed of sound underwater?* ~3600 miles per hour.

3. *What is the calculated speed of sound underwater in miles per hour?* (show your calculation)
   3600 seconds / hour x 0. 93 miles/sec. = 3, 348 miles/hour (that's fast!)

4. *Write the formula for finding the distance to an object using echolocation.*
   Distance = speed of the sound x the time it takes to return ÷ 2

5. *Using the approximate speed of 1 mile per second if pulses take 0.2 seconds to return to a whale after bouncing of an object underwater, how far away is the object?*

Show your calculation below:

Distance = speed of the sound x the time it takes to return ÷ 2
Distance = 1 mile/second x 0. 2 seconds ÷ 2
Distance = 0. 2 miles ÷ 2 = 0.1 miles (the object is 0. 1 miles away)
At 1500 meters per second an echo takes 0.1 seconds to return to the whale after being sent out into the water.

6. *How far away is the object that's reflecting the sound?*

Show your calculation below:

Distance = speed of the sound x the time it takes to return ÷ 2
Distance = 1500 meters/second x 0. 1 seconds ÷ 2
Distance = 150 meters ÷ 2 = 75 meters (the object is 75 meters away)

Calculating depth using sonar: (use the same formula for determining distance with echolocation)
At 1500 meters per second, a sonar pulse takes 4 seconds to return to the ship after being sent toward the bottom.

7. *What is the depth of ocean at this location?* (Show your calculation)
   Depth = speed of the sound x the time it takes to return ÷ 2
   Depth = 1500 meters/second x 4 seconds ÷ 2
   Depth = 6000 meters ÷ 2 = 3000 meters (the bottom is 3000 meters below the ship)