Bioacoustics

If you are doing this lesson in your classroom on your own, you can also download or play sounds from: https://www.fisheries.noaa.gov/national/science-data/sounds-ocean or http://voicesinthesea.ucsd.edu/

Background:

(excerpted/adapted from http://cetus.ucsd.edu/voicesinthesea_org/education.html lesson 4)

The ocean is a habitat where light does not penetrate very far. For whales, however, this vast 3-dimensional world is far from dark. The ocean is illuminated by sound, which travels much farther than light underwater. The sounds of waves and storms at the surface, of earthquakes and underwater landslides, of schooling fish, and of whales fill the underwater world. Whales use these natural sounds and sounds that they produce for just about every aspect of their lives. In these lessons, students will be learning about the importance of sound to marine mammals. This will provide background information on sound underwater and ways in which whales use it to navigate, to hunt for food, and to communicate with one another.

Sound energy travels as a wave. The frequency, or number of waves that travel past the ear in one second, is measured in hertz (Hz). Humans can hear sounds as low as 20Hz, or 20 waves passing the ear per second, and as high as about 20,000Hz. The intensity (loudness) of a sound is measured in decibels (dB). The softest sound a human with perfect hearing can detect is 0dB and the most intense sound a person can be exposed to without instant hearing damage is 160dB. Whales have acute hearing and can hear a much broader range of frequencies than people.

When you think about sound you often think of two things: the first is its pitch or tone. Different pitches on a piano or in the human voice represent different frequencies of sound—different repetition rates of wave cycles of sound. The other thing we think of is how loud a sound is. Loudness relates to a sound's intensity, which is a measure of amplitude of a wave (here, the height of the wave above zero.) A high amplitude wave carries a large amount of energy; a low amplitude wave carries a small amount of energy. The average amount of energy passing through a unit area per unit time in a specified direction is called the **intensity** of the wave. As the amplitude of the sound wave increases, the intensity of the sound increases. Sounds with higher intensities are perceived to be louder.

All whales produce sound. Just as no two species look or behave the same, no two species make the same set of sounds. Toothed whales, like dolphins and porpoises, make click-type sounds and most also produce whistles in the higher frequencies. Baleen whales, like right whales and fin whales, make a wide variety of lower frequency tones like upsweep or downsweep calls.

The clicks that toothed whales make are used for echolocation. This is a method of foraging (finding food) underwater in which the whale produces a sharp, impulsive sound like a clapping hand and then interprets the echoes from that click off of objects in the water. These echoes returning from all directions help the whale to form a 3-dimensional picture of its environment. Like an ultrasound used to create a sonogram of an infant in the womb, high frequency clicks give a large amount of detail and can even be used to investigate the inner layers of certain objects, like fish.

Dolphins, beaked whales, and porpoises generally make high-frequency clicks. The trade-off of higher frequencies underwater is that they don't travel as far as lower frequencies. Sperm whales make clicks that are lower and much more powerful than dolphins. Although they may not provide the high resolution of higher frequency clicks, these clicks travel much farther and help the whales to find patches of food from greater distances.

In addition to clicks, most toothed whales also produce whistle-type sounds. These are used for communication between animals in a group. Bottlenose dolphins, for example, make a wide variety of whistles to communicate with one another. Each dolphin also makes its own unique sound called a signature whistle. Scientists studying these signature whistles believe that they may be like a dolphin saying its name in order to identify itself to pod mates.

Whale researchers use sound recorded through underwater microphones, or hydrophones, as a method of detecting, tracking, and identifying whales. One way to analyze these signals from the hydrophone is to digitize them using a computer and to display them as a spectrogram. A spectrogram is a way to visualize sound like a picture. The computer draws an image of a sound over time that puts higher frequencies above lower ones, like the sheet music that musicians read. It also shows the intensity of the sounds by color or contrast. To see spectrograms of the clicks, whistles, tones, and sweeps produced by various species of marine mammals, please visit the Northeast Fisheries Science Center acoustics website: https://www.fisheries.noaa.gov/national/science-data/sounds-ocean or the Voices in the Sea website: http://voicesinthesea.ucsd.edu/.

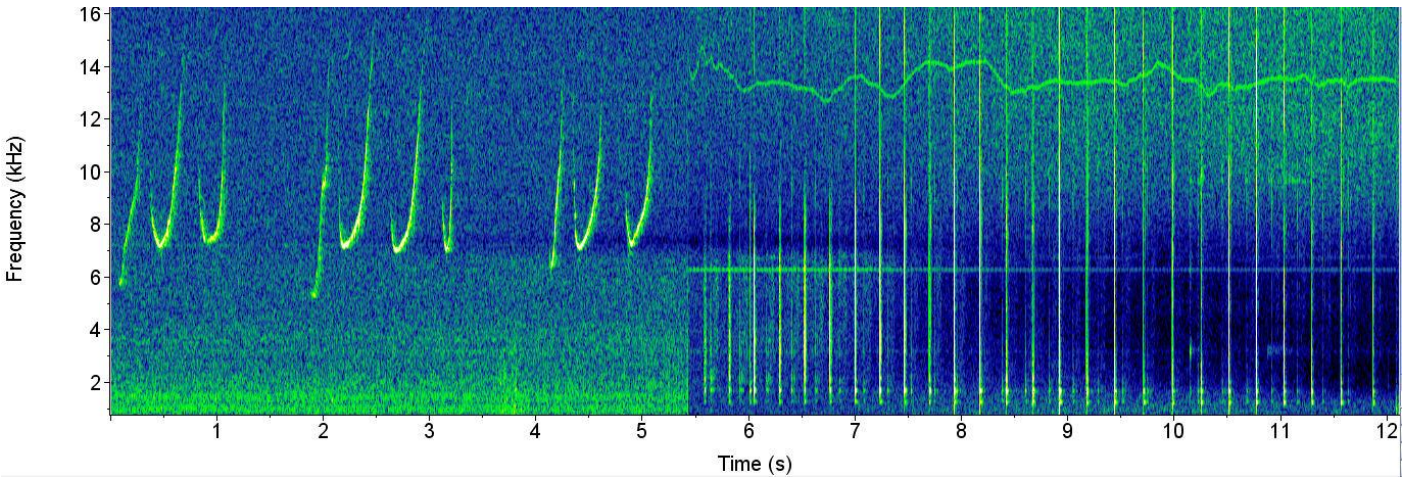

Fig.1: Spectrogram of white-beaked dolphin whistles and clicks. Frequency is displayed top to bottom while time is displayed left to right. More intense sounds are bright green.

Humans also introduce sounds into the ocean. Exploration for undersea natural resources, naval sonar, geophysical research, marine industry, fishing activities, and ships of all types produce sounds. In some areas, these man-made sounds are so loud that they may have an effect on a whale's ability to communicate or to navigate. While the effects of increasing noise pollution in the ocean are not well known, certain types of sound, like high-intensity military sonar, appears to cause injury to highly-

sensitive species like the beaked whales. This is another reason that it is important to understand how whales use sound.

Lesson:

Introduce yourself and explain that the Coast, Oceans, And STewardship (COAST) program is a partnership between the NOAA Fisheries Northeast Fisheries Science Center and Woods Hole Sea Grant. Show students (**slide 1**) where we are located in Woods Hole.

Introduction (5 minutes):

Questions to ask while showing the slideshow intro (***Always ask the questions, generate answers and THEN show the slide with information****):

1. We'll be talking about marine mammals and sound today. What is sound? (You can ask each student to loosely put their hand around their throat and call out a word so that they can feel the vibration of their vocal cords.) **(slide 2)**

2. (**Skip this slide with younger grades**) What words or terms do you use when describing sound? When you think about sound you often think of two things **(slide 3)**: the first is its pitch or tone. Different pitches on a piano or in the human voice represent different frequencies of sound. The other thing we think of is how loud a sound is. Loudness relates to a sound's intensity, which is a measure of amplitude of a wave. As the amplitude of the sound wave increases, the intensity of the sound increases. Sounds with higher intensities are perceived to be louder

Activity 1:

BLIND FIND

Goals:

- Demonstrate the large amount of information contained in sound.
- Demonstrate how sound is used to gather information.

Materials:

- Blindfold

1. Have the class form a circle facing inward.

2. Demo the activity by putting the blindfold on the teacher. Put him or her in the middle of the circle. The teacher in the middle of the circle will be trying to identify a student in the circle using sound only.

3. Spin the blindfolded person twice, then point him or her at someone in the circle. The person in the circle should say, 'Hi _____' (blindfolded person's name) in his/her normal voice.

4. The blindfolded person can say hello and ask the person in the circle any question other than one that would identify them. For example, they can ask, "What did you have for dinner last night?"

5. Using this information, the blindfolded person is to make his/her best guess at who is talking to him/her, then respond "Hi _____" (the name of who he/she thinks it is)

6. Let several students try.

7. Repeat steps 4-7 but play the ship noise from the speakers at the same time (**slide 4**).

8. Have the students discuss the following questions as a class:

    a) Were students surprised with their success in identifying people in the circle?

    b) What were some of the things that they could tell about the speaker, just in those two words? (*Male or female, age, identity, are they sick or healthy, emotions, where are they in relation to the blindfolded student*?)

    c) How did having the extra ship noise affect how well the student could gather information? How do you think ship noise affects whales in the ocean?

Introduction (5 minutes):

Now that we know a little more about sound, we're going to focus on marine mammal sounds and how we use their vocalizations to study them and learn more about different species.

1. What is a marine mammal? (**slide 5**)

2. What do marine mammals use sound for? List their ideas on the board. **(slide 6)**
    - Remind students that *using sounds of many types (clicks, whistles, songs), whales can determine many things about each other and their surroundings without having to use their eyes. 100-foot visibility underwater is extraordinarily rare. The underwater world is often too dark or murky to rely on eyesight alone. Sound also travels much farther in water than air* (**slide 7**). (excerpted from http://cetus.ucsd.edu/voicesinthesea_org/education.html, lesson 4)

3. Why is it important that we can identify marine mammals by their sound? It may be too dark to see the animal, the weather may make it difficult to see, or the animal may not come up out of the water. **(Demo with slide 8. You can hear the animal but not see it.)**

Activity 2:

WHOSE SOUND IS IT ANYWAY?

Goals:

- To describe how whales use vocalizations as part of their common behaviors
- Demonstrate how we can identify marine mammals by their vocalizations
- Describe how sound can be used in marine mammal conservation

Materials:

- 26 laminated pictures of a whale, 26 laminated pictures of a dolphin, 26 laminated pictures of a seal
- Slide show of spectrograms
- Sounds can be downloaded from https://www.fisheries.noaa.gov/national/science-data/sounds-ocean

1. Explain to the students that they will be an acoustician (bioacoustic scientist) trying to identify the animal sounds their hydrophones are picking up (a hydrophone is an underwater recording device).

2. First we will listen to some marine mammal sounds in our sounds library and look at their spectrograms. A spectrogram is a picture of the sound. As they listen to the sounds, ask them what each sound sounds like (example: the humpback whale sounds like a haunted house, the bearded seal sounds like an alien) and describe the pitch. Also ask them to compare the sounds. Does the bottlenose dolphin sound more like the Atlantic Spotted Dolphin or the Minke Whale? (**slides 9 & 10**)

3. Tell the students we are now going to play a game. Give each student a whale picture, dolphin picture, and seal picture. Tell them you are going to show them a spectrogram and play them a sound. They will have to hold up the picture of the marine mammal they think made the sound.

4. Play the first "Who am I" sound (**slide 11**), have the students hold up the picture of their guess. Questions to ask: What does this sound like? What made you guess what you did?

5. Give them a few hints about the animal making the vocalization (**slide 12**) and ask them to guess again (**slide 13**).

6. Show them the picture of the actual marine mammal they were hearing (**slide 14**).

7. Follows steps 4-6 four more times with the **slides 15 through 30**. Judge the time you have left to decide if you will do each mystery sound or only a few. Make sure you leave time for the last activity.

Discussion:

1. Why is it important for us to know what sounds each marine mammal makes?
   - *Sometimes we cannot see the marine mammals, but we can hear them. That allows us to identify what species of marine mammals are in the local area. If we have hydrophones in different areas we can get information such as marine mammal movement patterns, distance from shore, what their soundscape and how much ambient noise there is, and which species are acoustically active.*

2. What is an example of how can you use whale vocalizations to protect them? Show them the Right Whale Listening Network (**slide 31**). Tell them that they are looking at buoys along the shipping lanes into Boston Harbor. These buoys are recording underwater sound in real time, and transmitting via satellite to a remote location that is programmed to detect North Atlantic right whale (NARW) calls. If a NARW call is detected the program will indicate that there is a whale in the area. Ship crew can put the app on their iPads and smartphones so they know whether there are endangered right whales around and when and where they need to slow down to avoid collisions.

Activity 3:

WHALE MORSE CODE

(adapted from OIMB GK12 Curriculum: http://pages.uoregon.edu/oimb/Academics/GK12/fifthgrade.html)

Goals:

- To describe how whales use vocalizations as part of their common behaviors.
- To distinguish between echolocation and communication.
- To demonstrate how excess sound in the ocean can affect a whale's ability to use vocalizations.

Materials:

- Communication Codes: 5 copies of 7 different codes (one strip per student). Determine the number of pods you will have (e.g. 6 pods with 4 students in each pod). You will need a different code for each pod and enough strips with the same code for each member of a pod. For those codes where reading the code upside down will result in the wrong code, arrows indicate the direction the code needs to be read, from left to right. Ideally, there are 3-5 students in each pod depending on the size of your class.
- One buzzer for each student. *Note:* For teachers using this lesson on their own without buzzers, you can have students use codes made by saying "beep, buzzzzz, etc"

1. Ask the students why they think different species of whales might have different vocalizations or calls (*to tell each other apart, different hunting and feeding strategies, different social patterns, etc*.)? Distinguish between vocalizations and echolocation. Echolocation is the process by which animals emit sounds and are able to detect objects, including food, when the

sound waves return to them (like a submarine's sonar). Vocalization is using sounds to communicate.

2. Ask the students why different populations within one whale species, such as the orcas, might have different dialects, or types, of calls? (*E.g. feed on different prey, to tell one pod from another*.)

3. Explain to the students that each of them is an orca (**slide 32**), and they will be searching for their "pods". As orcas use squeaks to communicate and keep track of each other, the students will do the same, with buzzers.

4. Explain the Morse code briefly to the students. Dashes are LONG, and Dots are SHORT. Draw several examples of brief Morse codes on the board, and have the students recite the code out loud. For example, draw .._. on the board and, all together, have the students recite "short short looooooong short". Continue practicing until the students understand how to read a code.

5. Give each student a Communication Code. At this point, the students should NOT know who else is in their pod. Advise the students that their code needs to be kept secret, so that their neighbors don't know what their code is.

6. Have the students look again at their Communication Code, and have them figure out (silently) what their code is. Make sure they are reading the code in the direction of the arrow. They need to commit their code to memory for the activity. Give them enough time to do so.

7. Hand a buzzer to each student. Have the students practice a sample Morse code you put on the board. Have the students practice several times before beginning the communication activity.

8. The search for the pods begins! Have the students squeak out their communication code to each other and group together as a pod as they find their other members. After a minute you can play the ship noise to add complexity **(slide 33)**. Recognize the first pod to find all 5 (or 4, or 3, depending on how many codes were passed out) of its members.

9. Have the students return their buzzers and sit down to discuss the activity.

10. Discuss with the students the difficulties of finding all their pod members, and discuss the difficulties that orcas might have when confronted with different pods coming together.

11. Review the difference between echolocation and communication. *Echolocation is the process by which animals emit sounds and are able to detect objects, including food, when the sound waves return to them (like a submarine's sonar).* What the students experienced today was very different: they used vocal sounds to communicate.

12. How would other sounds, like ship noise, affect the ability of an orca to find their pod mates?

Conclusion:

1. Just to review, why do marine mammals make sound?

2. Why is it important to distinguish species by sound?

3. How can sound damage marine mammals (**slides 34 and 35**)?

Scientist Spotlight:

Here are some of our scientists who do bioacoustics research right now!

Slide 36: Sofie Van Parijs looks at sound in the ocean. Some of her projects include:

1. Ocean noise (imagine looking at a map of the ocean that shows all the sounds made by whales, weather, and humans): looking at the cumulative effects of human activities on marine life.
2. Marine mammal acoustic behavior: which species are doing what (what are they saying, and where are they saying it?).
3. Cod: how can we use acoustics to help protect a highly overfished species (North Atlantic Cod)?
4. Gliders: using technology to gain better access. Gliders are autonomous and can be programmed to follow a certain track and record underwater sound.
5. Outreach: coming to talk to you about all that she does!

Slide 37: Laela Sayigh

1. Anthropogenic noise: how does the noise that humans contribute to the ocean affect marine mammal communication
2. Dolphin call structure and function: what do dolphin whistles look like?
3. Non-invasive tags: given the challenges of studying species that spend most of their time underwater, how can we use new technologies to study dolphin communication?
4. Teaching and Outreach: Laela teaches at Hampshire College and shares what she does with students like you!
5.

Slide 38: These images show some of the ways we study marine mammals. We may anchor recorders in specific locations on the seafloor, work from small boats, or even do aerial surveys from airplanes.

How can each student help protect the marine mammals in our backyard? (**slide 39**) Click on any of the yellow words to show a quick conservation video clip.

Additional Activities if you have extra time:

1. Have a pair of students face each other and start talking about a subject of your choice. Then have another pair of stand directly behind each student already talking and converse with each other over the first pair. Think of how each additional pair talking makes it more difficult to

hear your partner. This is what marine mammals have to deal with when trying to communicate with all the other animals and ocean noise activities surrounding them!

2. CALL MATCHING: http://voicesinthesea.ucsd.edu/games.html

Lesson Link to Massachusetts State Science Curriculum Standards

*All of the lessons reinforce the scientific method by asking students to observe, predict, hypothesize, participate in an experiment or activity, sort/classify, and make conclusions.

Kindergarten through 2nd grade:

(a) LS2 – Compare and contrast mammals with marine mammals and discuss how animals in these groups are more similar to each other than animals in other groups.
(b) LS6 – Recognize that marine mammals interact with their environment through their five senses with a focus on sound.

3rd through 5th grade:

(a) LS1 – Classify marine mammals according to their physical characteristics (vocalizations or sounds) that they share.
(b) LS5 – Differentiate between observed vocalizations of marine mammals that are fully inherited and regional/pod specific "dialects" that are affected by location.
(c) LS8 – Describe how marine mammals meet some of their needs (mating, feeding, locating pod members) in the marine environment by using their vocalizations in response to information received from the environment.
(d) LS10 – Give examples of how humans are causing changes in the marine environment (modifying shipping lanes, decreasing human made noise) to ensure the survival of marine mammals.
(e) PS1 – Sort marine mammals by observable properties (vocalizations or sounds).