Eavesdropping on Marine Mammal Conversations: An Activity Suitable for the Visually Impaired

BY MARY CARLA CURRAN, KATHLEEN PATTERSON, AND LAELA S. SAYIGH

ABSTRACT

Ever wonder how marine mammals communicate with each other in an expansive dark ocean? Most of their communication is through the sense of sound, and their vocalizations can travel great distances in the ocean. However, human-generated noise pollution can interfere with their communication. This student activity provides information about dolphin and whale species and examples of their vocalizations. It is engaging for all students, including those with visual impairment, as the lesson is auditory. We anticipate that the provided information will spark further interest in marine mammals and help develop a better awareness of interactions between organisms and their environment. The activity conforms to Next Generation Science Standards, National Science Standards, and includes Ocean Literacy Principles.

Keywords: Marine mammals, cetaceans, dolphins, whales, vocalization, communication, sound, noise pollution, visually impaired, blind

INTRODUCTION

Student opportunities for hands-on, experiential activities can be rare for a variety of reasons, including budget cuts, liability, and curricula focused on standardized tests. However, experiential learning is important for engendering interest in and appreciation for the environment (Bogner 1998; Poudel et al. 2005). Such learning activities are even rarer for visually impaired students, since educators tend to focus on the sense of sight to teach about science. This activity based on marine mammal sounds is engaging for all students but well-suited for those with visual impairment, as the lesson focuses on auditory skills and the graphs can be listened to.

Universal design for learning (UDL; http://www.cast.org/index.html; http://www.udlcenter.org) is a framework to optimize teaching based on scientific insights into how humans learn. It is based, in part, on engagement strategies (the “why” of learning—offering appropriate challenges and motivations for learning); representation (the “what” of learning—giving learners various ways to acquire information); and action and expression (the “how” of learning—showing how students know something). This activity provides options for the teacher to engage students using aural communication completely, a mix with visual communication, or incorporation of the sense of feel to maximize the ability to reach all students regardless of individual learning styles. Further, class assessment can be aural and/or via critical thinking discussion questions. Using charismatic megafauna such as dolphins and whales (cetaceans) has benefits, especially when trying to reach younger students. Marine mammals tend to elicit much interest, thus “priming” students to become concerned about the marine environment in general.

Marine mammals as a group are more reliant on sound for communication than most terrestrial mammals, due to the limited usefulness of vision in turbid water (Sayigh 2013; Sayigh and Janik 2017). Plus, sound travels much faster in water than in air, making it an efficient medium for communication (see the website “Discovery of Sound in the Sea” at https://dosits.org/ for detailed information about the science of sound, including how it moves through water and how marine mammals produce and receive sounds). Some marine mammals produce sound that is either above or below the range of human hearing, which is from 20 Hz to 20 KHz. Marine mammals use sound for all aspects of their lives, including for finding mates and maintaining contact with friends and relatives. Some whales, dolphins, and porpoises also use sounds known as echolocation for navigating and finding food (Au 2017). These click-like sounds produce echoes when they bounce off objects, providing information about their size, material, and distance. Given the importance of sound to marine mammals, they are particularly impacted by ocean noise (Aguliar de Soto et al. 2016). Thus, this activity provides an opportunity to teach students about the effects of noise on marine mammals, and how noise should be considered a type of pollution like more familiar types, such as trash and chemical runoffs.
Many sources of noise in the ocean can negatively impact cetaceans. Most prevalent is noise from seagoing vessels, but also important are military sonars used for submarine detection, air guns used in oil and gas exploration, and noise generated by construction of underwater structures such as wind and water turbines. Noise can prevent marine mammals from hearing sounds produced by other animals (a phenomenon known as “masking,” Erbe et al. 2016) or the echoes from their echolocation clicks. Some effects are more subtle and include changes to rate, pitch, and loudness of sounds (Hotchkin and Parks 2013; Tyack and Janik 2013). These changes might require more energy on the part of the sound producer, thus affecting their physiology in addition to the more obvious impacts on communication and echolocation.

For this activity, marine mammal sounds have been compiled from colleagues and from the Macaulay Library at the Cornell Lab of Ornithology and the Watkins Marine Mammal Sound Archive at the Woods Hole Oceanographic Institution (http://www.whoi.edu/watkinssounds/; Sayigh et al. 2016). This data archive contains recordings of almost every species of marine mammal, including cetaceans (whales and dolphins), seals, walruses, and manatees. Our K-12 activity provides examples that demonstrate the diversity of cetacean sounds and is suitable for visually impaired students, who will be able to recognize and match sounds to the appropriate species. These sound spectrograms were created in the software program Raven (Cornell Bioacoustic Research Program). Visually impaired students are often overlooked due to the emphasis of curriculum materials on visual learning. Exposure to this interactive activity may engender an interest in marine mammals and the marine environment in general that might not have developed otherwise.

The companion PowerPoint presentation is available for download at https://www.dropbox.com/s/gljsxv6dgmz3bw/Eavesdropping%20Manuscript%20ppt%2019Jan19%20FINAL.pptx#?d=0. Use this resource as a stand-alone document, along with the graphing exercise, for all the information needed to make this an educational lesson. The PowerPoint can be supplemented with plastic models of cetacean species if available, which provides a hands-on component that is useful for both sighted and visually impaired students by incorporating the sense of feel with the sense of sound, hence, enhancing multisensory learning. Information about anthropogenic influences in the marine environment is provided that will be useful in framing or discussing the inquiry-based questions provided in Table 1 on page 35. The activity addresses most, if not all, of the crosscutting scientific and engineering concepts identified by the National Research Council (2012): patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter: flows, cycles, and conservation; structure and function; and stability and change.

**Grade Level**
We have focused on middle school science classes for this activity; however, it is extremely versatile and has been presented to grade 1-12 students as well as adults. Bullet points provided on the presentation can be read aloud, modified based on audience level, or eliminated. It is the sound component that is most engaging. Text is provided for context and to elevate scientific understanding of the topic. The ability to see and/or interpret the graphs is unnecessary.

**Materials**
Access to a computer and projection system with good speakers is necessary. Additionally, we provided assessment questions (based on material in the presentation available online) that can be photocopied by the teacher or used by the students. This component is not necessary if students are being assessed based on their aural ability—a skill that is undervalued at a time when written work tends to be the main mechanism by which to evaluate students. It would be useful to provide one photocopy of the Name “Spectrogram” Sheet (see Table 2 on page 39) and a writing utensil for each student.

Optional: Plastic dolphin and whale models can be purchased from a variety of sources including Safari Ltd. (https://www.safariltd.com/) or through the Woods Hole Oceanographic Institution at shop.whoi.edu or http://shop.whoi.edu/Games-and-Toys/2070/Dept.

A replica of a sperm whale tooth (Figure 1) is available through Bone Clones. Link: https://boneclones.com/product/modern-sperm-whale-tooth-KO-213.

**FIGURE 1.** Examples of real baleen and a sperm whale tooth that can complement the activity. Courtesy of K. Patterson
### TABLE 1. INQUIRY-BASED ASSESSMENT  
(10 points each)

1. What is the largest animal to have ever lived on Earth? What does it eat? How does the relative size of its food compare to the size of its body?

2. Why do scientists change the speed of a vocalization?

3. How did the vocalizations change when the speed at which it was played increased?

4. What patterns did you hear (or see) within and among the vocalizations? How was echolocation different from some of the other sounds?

5. Why were some of the novel sounds during the listening quiz easier to match to the correct species than others? What did you use to identify the species correctly?

6. How would your life be different if you only used sound for communication?

7. What terminology used in this activity is similar to terms used by musicians? Were any of the sounds you heard “musical?” Explain what you mean.

8. Do you think you use products that are shipped via ocean vessels? Now that you are aware of the potential harm to marine mammals, can you think of ways to reduce your usage of these products if important to you?

9. Do you use oil and gas? If so, where does yours come from? Can you think of ways to reduce usage of these products if important to you?

10. Problem solving: What ideas do you have to reduce noise pollution in the ocean?
**Time Required**
The activity can be completed in one class period: usually 45-60 minutes, depending on the number of student questions. This is assuming that the Inquiry-Based Assessment questions (on page 35) will be either discussed as a group or assigned as homework.

**Safety**
This activity can be safely completed while students listen to marine mammal sounds embedded in the PowerPoint presentation (see link on page 34). If the teacher has models of animals or their body parts, students should handle them with care, especially if there are sharp areas. This is particularly important if working with the visually impaired.

The graphing activity requires paper and a writing utensil, both of which can have sharp parts.

**STANDARDS**
Middle school standards are provided below, although this activity has been shared with students in elementary through high school. The graphing exercise reinforces many of the standards that require plotting or modeling.

### Next Generation Science Standards (NGSS Lead States 2013)
- **MS-LS2 Ecosystems: Interactions, Energy, and Dynamics**
  - Performance Expectations: MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
  - Science and Engineering Practices: MS-LS2-1: Interdependent relationships in ecosystems.
  - Crosscutting Concepts: MS-LS2.5: Science addresses questions about the natural and material World.

- **MS-LS4-1; HS-PS1-2: Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- **MS-ESS3-3 Earth and Human Activity:** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

- **MS-PS3 Energy**

### National Science Education Standards (National Research Council 1996):
- **Life Science**
  - Characteristics of organisms
  - Organisms and environments

### Ocean Literacy Principles (National Marine Educators Association 2013)
- **Principle 5:** The ocean supports a great diversity of life and ecosystems
  - 5F. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

- **Principle 6:** The ocean and humans are inextricably interconnected.
  - 6D. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity lead to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

  - 6G. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

**ACTIVITY**

The novelty of this activity is that it can be conducted completely aurally, providing accessibility to visually impaired students, if the teacher chooses not to complete the student-graphed name “spectrogram” (described on page 39), although students with some vision were able to complete the exercise. The PowerPoint was purposely constructed with sharp contrast and large print. Several versions of the colored spectrograms were presented to visually impaired students during testing, and we used the coloration scheme that they selected as the easiest for them to see if they had some vision.
First, the teacher can share the background information about marine mammals provided in the activity or ask some questions to assess student knowledge prior to the activity such as:

- What are marine mammals?
- Where do they live?
- What are some examples of marine mammals?
- What is the subgroup of marine mammals called that contains whales and dolphins?
- How do they communicate?
- Have you ever seen one?

Alternatively, the teacher can begin the PowerPoint presentation, which starts with some background information and with an introductory question to name the two types of cetaceans (Figure 2). Questions can also be asked throughout.

Optional: The teacher can showcase the plastic models before or during the presentation so that students can look at or feel the shape of each species (Figure 3), enforcing multisensory learning.

Background information is provided within the PowerPoint presentation as is the aural assessment (see below).

Assessment
Assessment for this activity is a listening quiz in which students have to match each vocalization to a cetacean species (Figure 4). We provided several options. The first column of sounds contains vocalizations that the students had not heard but that are from the same individual or species as the ones that they heard; these are the hardest to identify and, if the intention is to use them, they should be played instead of or after the other easier clips. This challenge will test their deductive reasoning skills. The second column of sounds is also challenging because only a small portion from the middle of each clip can be heard. The third column contains the easiest sounds because they are the exact, entire audio clips used in the activity. The teacher has many options to decide how long or challenging this portion is. The teacher can award the number of points for correct answers based on the number of questions asked.
The listening quiz can be supplemented with crosscutting inquiry-based questions in the provided assessment (Table 1 on page 35). The questions become more challenging towards the end, but the teacher can select a subset of questions that are most appropriate for his/her class.

**Constructing a “Spectrogram” and its Assessment**

Once the students have learned about cetacean sounds and communication, both orally and/or through the spectrogram graphics provided in the PowerPoint, the students can make a “spectrogram” of their name using the handout (Table 2 on page 39). The students will plot the letters of their name on the y-axis, with letters further along in the alphabet (e.g. “z”) being plotted at a higher “frequency” (Figure 5). The teacher can assess their plotting ability if this is preferred over, or in addition to, using the listening quiz in the PowerPoint. Although the graph is not really how a student’s name sounds when pronounced, it is interesting to discuss. Therefore, it would be fun for students to sing out what their name would sound like if it were.

**Extensions and Cross-Curricular Applications**

See the website “Discovery of Sound in the Sea” at https://dosits.org/ for detailed information about the science of sound, including how it moves through water and how marine mammals produce and receive sounds.

Explore the collection of sounds provided in the WHOI Watkins Marine Mammal Sound Database at http://cis.whoi.edu/science/B/whalesounds/index.cfm.

Those interested in further information about marine mammal communication can visit a variety of education centers including the Woods Hole Oceanographic Institution (WHOI) Ocean Science Discovery Center, where we created an interactive kiosk (a duplicate of which is located at the New Bedford Whaling Museum) that complements a display of other marine mammal research being conducted at the WHOI. Such research includes advancements in our understanding of marine mammal communication, hearing, and physiology. The exhibit includes models of some technologies being used to study marine mammals, including a digital...
TABLE 2. NAME “SPECTROGRAM” SHEET

Graph your name by plotting each letter in order. For example, if your name is Sue, go up to “S” in the space provided in Letter Order 1, then up more to “U” in the 2nd space, then down to “E” in the 3rd space.
acoustic tag (DTAG), which is a non-invasive suction-cup attached tag that records sounds and movements of the animal wearing it. Visitors can handle the models and learn about how they work. There are also descriptions and demos of state-of-the-art technologies, such as digital acoustic monitors, gliders, and hexacopters. The center hosts approximately 25,000 visitors each year, including school groups, home schoolers, and any folks interested at any age.

**Reflections**
We tested this activity at several schools and a variety of grade levels over the course of several years. Both sighted and visually impaired students thoroughly enjoyed listening to the wide array of vocalizations made by marine mammals. The visually impaired students were very good at correctly identifying the sounds the first time played during the aural quiz and at picking out nuances in the sounds, including slight changes in pitch. They also asked many detailed questions about how the sounds were collected and processed. Most students laughed at the comparisons their classmates made to sounds they are familiar with in their day-to-day lives (usually related to bodily functions). Students also did not realize that pollution is more than plastic and other debris in the ocean—shipping traffic, oil exploration, and military operations can all negatively impact the ability of marine mammals to communicate, stay together in a group, and reproduce.

Our original prototype activity compared differences among vocalizations of different individuals of the same species, focusing primarily on individually distinctive whistles of dolphins. In this case, the important part of the vocalization is the characteristic pitch contour (or pattern of pitch changes over time) and not the number of repetitions of the contour. However, students often focused on the number of repetitions, or on background noise (including echolocation clicks, human voices, waves), rather than on the pitch contour. Based on this experience, we geared the activity toward identifying and classifying calls from a variety of different species, rather than focusing on subtle features within a species.

The difficulty level of the quiz can be modified depending on the capabilities of the class. Both sighted and visually impaired students may have different levels of competency in identifying sounds, especially if no written material is permitted. In fact, the lesson could be taught without any visual cues at all (in other words, the teacher can present the facts provided on the PowerPoint without projecting the information). Instead, only aural information, including the vocalizations, could be shared. Sighted students might find this quite challenging, since they are used to the crutch of having written material to study by.

**Conclusions and/or Implications for Teaching**
Students enjoyed listening to cetacean sounds and were very good at matching sounds to the correct species during the quiz. In fact, they were often better than adults attending as chaperones, as educators listening in, or participants in educational/scientific conferences. Students were able to describe sounds using their own experiences and often related sounds to musical instruments, creaking objects like doors, or bodily functions (generating a lot of laughter). Deep sounds were often compared to noises made by animals perceived to be vicious (including certain dinosaurs), or what they thought aliens would sound like. Several students became interested in marine mammals and noise pollution and wrote a follow-up paper about the subject for a classroom assignment.

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**RESOURCES**

**Other K-12 Activities Using Marine Mammals as a Model**
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Thompson, J., M.C. Curran, and T. Cox. (2016). “Capture” me if you can: Estimating abundance of dolphin populations. *Science Activities*, 53(2): 49-67.

**Other K-12 Activities that can be Modified for Visually Impaired Students**

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**Videos**

The video *Sonic Seas* is one resource that includes information about the negative impact of human-produced sound on marine mammals: [https://www.sonicsea.org/film](https://www.sonicsea.org/film)

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