Exploring Whale Sounds in Stellwagen Bank National Marine Sanctuary

Lesson Specifications

Age

8-12

Timeframe

One 45-minute classroom session
One 90-minute pool mission

Materials

Lesson:

- Computer w/ internet
- Projector
- Table space
- Noise-making device
- Scrap paper
- Blindfolds

Scuba:

- All required scuba gear
- Underwater noisemakers per person
- One weight per buddy team

Key Words

marine mammal, underwater bank, echolocation, acoustic masking, whale, vocalization

Standards

PADI, SSI, NAUI, Ocean Literacy Principles 1 & 5

Bubble net feeding humpback whales. Photo: WHOI/NOAA

Humpback whales work together to feed on schools of sand lance. Photo: NOAA

Activity Summary

This lesson introduces students to Stellwagen Bank National Marine Sanctuary and the important living and nonliving resources it protects. Students investigate how whales use sound to communicate and gain information about their environment and how acoustic masking may affect whales. Students simulate using echolocation. Students practice buoyancy control, awareness of their environment and buddy, and air management while simulating the use of echolocation.

Learning Objectives

Students will be able to:

- Explain the importance of Stellwagen Bank National Marine Sanctuary, by using examples.
- Explain, by using examples, how whales use sound.
- Predict how acoustic masking might affect whales.

Essential Questions

- What important resources are protected by Stellwagen Bank National Marine Sanctuary?
- How do whales use sound to communicate and gather information about their environment?
- How might acoustic masking affect whales?

National Marine Sanctuary Diver Performance Requirements

At the surface, students will:

- Streamline gear prior to entry.
- Perform a comprehensive buddy check.
- Review necessary hand signals.
- Establish an air management plan.
- Perform a weight check and adjust weighting as necessary.

Underwater, students will:

- Demonstrate proper descent techniques and awareness of the environment.
- Demonstrate proper buddy awareness and air management.
- Demonstrate appropriate use of hand signals.
- Demonstrate appropriate buoyancy control.

A map of national marine sanctuaries and marine national monuments in the United States and its territories.

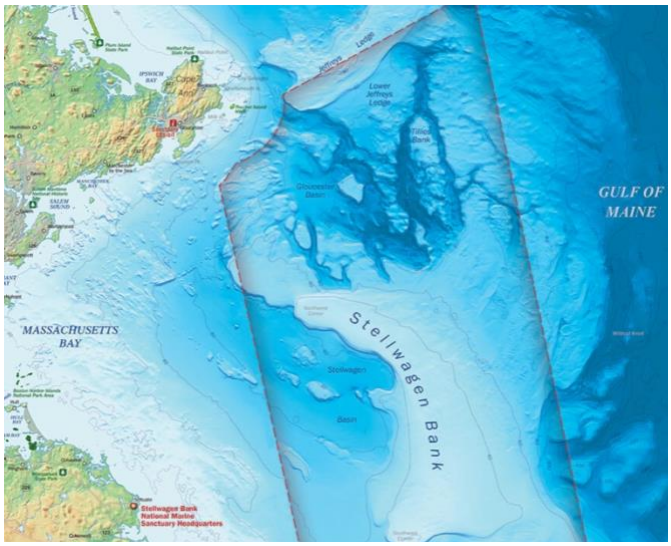
Background Information

Stellwagen Bank National Marine Sanctuary

Since 1972, NOAA's Office of National Marine Sanctuaries has served as the trustee for a network of underwater areas encompassing more than 620,000 square miles of marine and Great Lakes waters. The network includes a system of national marine sanctuaries, as well as Papahānaumokuākea and Rose Atoll marine national monuments. Few places on the planet can compete with the diversity of the National Marine Sanctuary System, which protects America's most iconic natural and cultural marine resources. The system works with diverse partners, treaty holders, and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. Healthy

aquatic ecosystems, whether fresh, brackish, or marine, are the basis for thriving recreation, tourism, and commercial activities that drive coastal economies.

Stellwagen Bank National Marine Sanctuary is a marine protected area located approximately 21 miles east of Boston, Massachusetts in the Atlantic Ocean. The 842mi² area stretches from three miles south of Cape Ann to three miles north of Cape Cod. The marine environment of Stellwagen Bank is one of the most biodiverse in the Gulf of Maine, with approximately 600 documented species. Stellwagen Bank is an underwater plateau at the mouth of Massachusetts Bay. The bank was formed as glaciers retreated during the end of the last ice age approximately 12,000 years ago, leaving behind large deposits of sand, gravel, and rock. At one point, Stellwagen Bank was above sea level, but as the glaciers continued to melt resulting in sea level rise, the bank was gradually submerged. Today, water depths to the top of the bank range from approximately 65 to 100 feet.



A map of Stellwagen Bank National Marine Sanctuary off the coast of Massachusetts.

Stellwagen Bank National Marine Sanctuary contains a variety of habitats with different substrates, including rocky, sandy, muddy bottoms, as well as rocky reefs and ledges. Each of these habitats is affected by four distinct seasons. Prevailing winds and currents result in upwelling, a process that brings cold, nutrient-rich waters to the surface, resulting in an abundance of phytoplankton that fuels a diverse food web. Copepods, a type of zooplankton, feed on the abundant phytoplankton and, in turn, provide a source of food for many species of filter-feeding whales, like right whales and humpback whales. Twenty-two species of marine mammals use sanctuary habitats resulting in one of the premier whale-watching destinations in the world. The sanctuary also supports robust recreational and commercial fisheries. Abundant populations of forage fish including sand lance (also known as sand eels), mackerel, and herring provide food for whales, sharks, sea birds, and commercially important fish like cod and bluefin tuna. The area's rocky reefs are home to numerous species of marine invertebrates, including sponges, lobsters, mussels, clams, and scallops. The rich marine resources of the Stellwagen Bank region helped support coastal Native American peoples for thousands of years, and, later, the fishing industry was a major factor in the growth of the nation. In addition, the area has seen heavy shipping traffic over the centuries. Numerous shipwrecks rest on the sanctuary's

Lobsters often find nooks and crannies in sanctuary shipwrecks that have become festooned with attached invertebrates. Photo: Matthew Lawrence/NOAA

seafloor as many vessels suffered tragic accidents while attempting to navigate the waters around the bank.

Diving Stellwagen Bank National Marine Sanctuary

The fishing vessel *Patriot* offers opportunities for exploration. Photo: Matthew Lawrence/NOAA

The strong currents and cold water of Stellwagen Bank dive sites are best suited for advanced divers. Much of the bank's shipwrecks lie deeper than recreational diver limits (130 feet). While diving in the sanctuary, divers should be aware of fishing gear that could present possible entanglement concerns and heavy boat traffic. Sanctuary regulations are in place to protect historic resources and marine mammals. Divers are not permitted to remove any object from a historic resource or dive in the vicinity of whales. Any boating activity that harms or causes a whale to change its behavior is also a violation of sanctuary regulations, the Marine Mammal Protection Act, and the Endangered Species Act, if applicable.

Whales in Stellwagen Bank National Marine Sanctuary

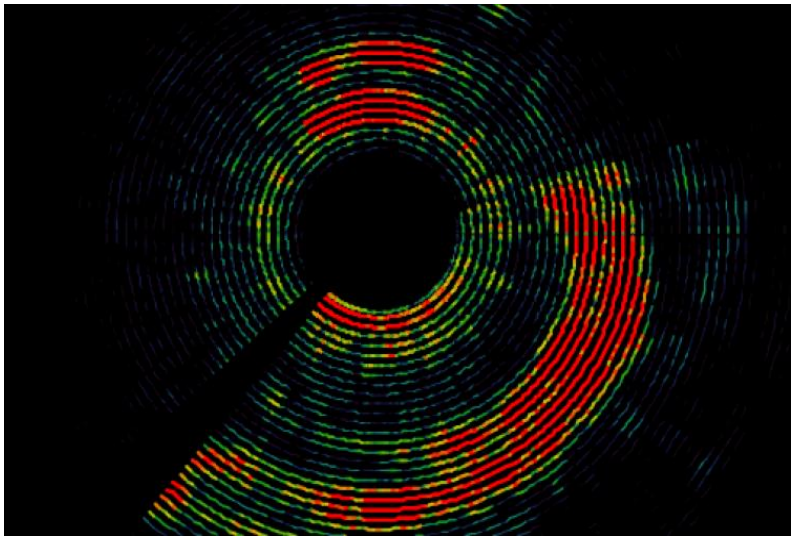
The waters off New England and around Stellwagen Bank once supported a whaling industry that, after depleting local waters, moved to other locations around the globe. Whales are now protected in U.S. waters and visitors to Stellwagen Bank National Marine Sanctuary are regularly treated to sightings of humpback, minke, and fin whales. During spring and fall, critically endangered North Atlantic right whales feed in these waters, but vessels are prohibited from approaching closer than 500 yards, making viewing difficult. Several other whale species can also be found in the sanctuary, including sei and pilot whales, with occasional sightings of sperm and blue whales in nearby waters. Small-toothed whales commonly seen are Atlantic white-sided dolphins, common dolphins, and harbor porpoises. Whale-watching is a multimillion-dollar industry that provides thousands of jobs. NOAA regulations are in place to protect whales and include fishing gear restrictions in right whale seasonal management areas (that encompass the sanctuary) to reduce entanglements, as well as speed restrictions and modifications to the Boston shipping lanes aimed at reducing boat strikes.

A whale is a general term for a group of marine mammals that includes dolphins and porpoises. There are two main groups of whales: baleen and toothed. Baleen whales have baleen, plates that sieve zooplankton and small fish from the water. Toothed whales have teeth and feed on fish, squid, and other marine mammals, such as seals and sea lions. Humpbacks, minke, and fin whales are baleen whales. Orca, dolphins, and porpoises are toothed whales. Whales are large-brained, highly social animals that use sound to communicate and socialize, plus to sense their surroundings, navigate, and locate prey. Sound travels much faster and farther in water than air, thus allowing whales to communicate and gather information over long distances and from all directions. Baleen whales use their larynx, the upper part of the trachea, or air passage, to produce sounds. Toothed whales can produce sounds using their larynx as well as specialized air sacs near their blowhole. The three main types of sounds made by toothed whales are clicks, whistles, and pulsed calls. Some vocalizations are

used for social communication and some sounds are used for echolocation, a way of using sound echoes to gather information about the environment. Baleen whales generate a variety of sounds that include grunts, growls, moans, cries, and trumpets. These vocalizations can be produced singly or linked together.

A humpback whale swims near the port side of a whale watch vessel. Photo: Anne Smrcina/NOAA

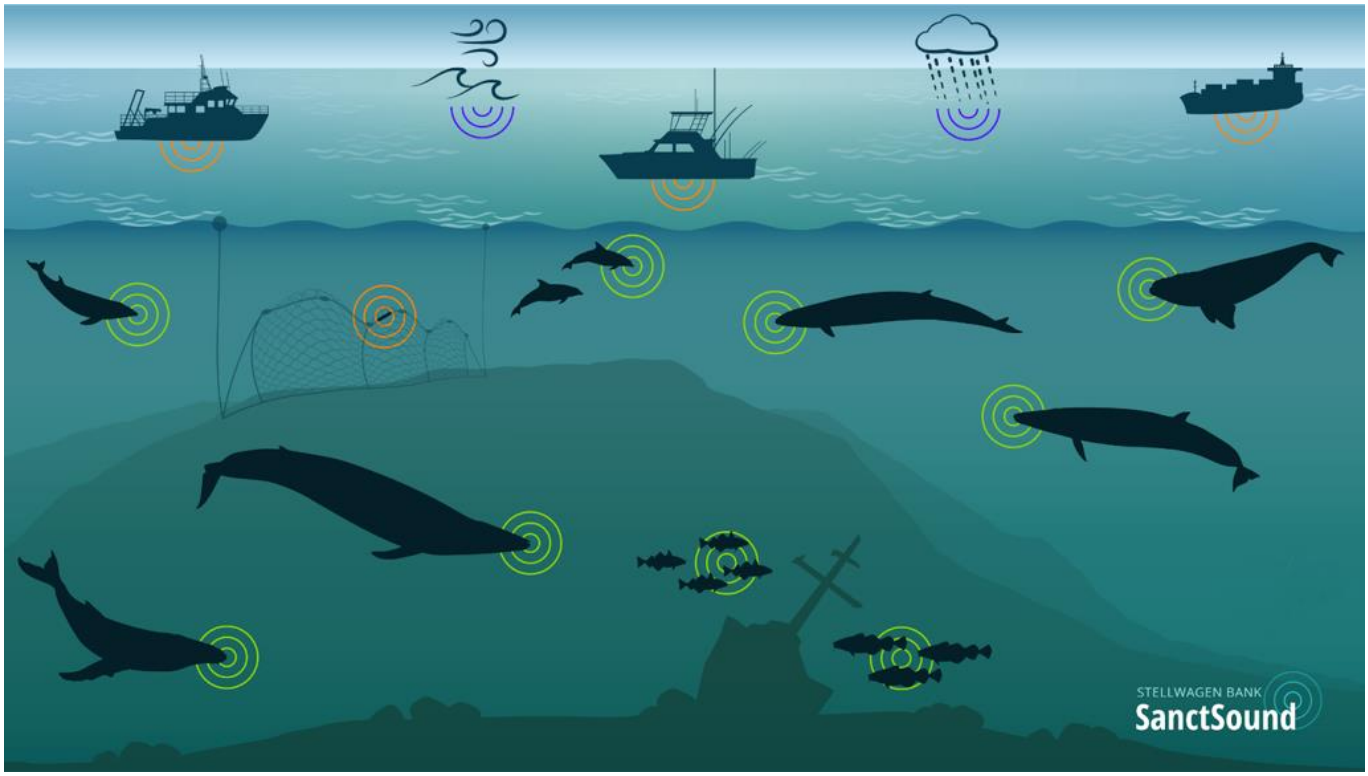
In general, toothed whales, such as dolphins in the sanctuary, use clicks to echolocate in order to navigate, find prey, and identify objects. When the sound waves of the click bounce off of an object, they return to the whale as an echo, allowing it to identify the shape of the object and its location. Whistles are vocalizations used during social activities. Baleen whales do not use echolocation, but do use sound to communicate and coordinate activities. The right whale is identified by its distinctive social upcall (which is a sound that drops in pitch and then rises quickly and looks like a check mark when visualized in a spectrogram). Humpback whale songs, commonly produced in the breeding grounds, have also been detected in the sanctuary, where the males may be practicing the year's version of the song. Whales may also use their tails and fins to make loud slapping noises on the surface of the water to communicate. The sound can be heard for hundreds of feet below the surface and may be a territorial display or hunting technique.



A visual depiction of a humpback whale vocalization when the sound waves are made into a picture called a spectrogram. Spectrogram: Northeast Fisheries Science Center's Passive Acoustic Research Group.

Communicating with, and being able to detect, sound is critical for whale survival. However, human-caused ocean noise is increasing. Human-caused ocean noises

include sounds produced for specific purposes, such as sonar and seismic air guns used to find oil and gas deposits. Human-made noise also includes unintentional sounds from vessel traffic and construction activities, like that associated with coastal construction or off-shore wind farms. Scientists are concerned about the potential impacts of this "sound pollution" on marine species. In whales, exposure to these noises can cause behavioral changes, like changes to dive/rest intervals, feeding behavior, or migration routes, as well as hearing loss. There is some evidence to suggest that noise pollution may be linked to strandings. Increased ocean noise can make it more difficult for whales to communicate, navigate, and hear important sounds from predators and prey and may be a significant problem for mothers who need to keep in close contact with their calves. This is called acoustic "masking," when noise interferes with the whale's ability to detect sound. The specific impacts of masking on whales are currently being studied and are likely detrimental to their survival.



The marine soundscape illustrates the sound contributions in Stellwagen Bank National Marine Sanctuary from geologic sources (such as waves and weather), biological sources (such as fishes, marine mammals), and human sources (such as ships, pinger, and echosounders). Image: NOAA

Vocabulary	
acoustic masking	Additional marine sounds, often caused by humans, that can make it more difficult for marine mammals to communicate and navigate
echolocation	the signal used to determine the location of objects via reflected sound
marine mammal	a group of ocean-dwelling, air-breathing, warm-blooded animals characterized by mammary glands which produce milk for their young
underwater bank	an underwater plateau; often the site of upwelling which supports diverse food webs
upwelling	a wind-driven process where cold, nutrient rich water from the ocean floor moves upwards to replace warmer, nutrient-depleted surface waters

Vocabulary	
whale	a group of marine mammals, and includes dolphins and porpoises; baleen whales have a filter-feeding system inside their mouth and eat zooplankton and small fish; toothed whales have teeth and eat fish and/or other marine mammals
vocalization	the production of sound using vocal folds in the larynx, the upper portion of the trachea or windpipe

Preparation – *Classroom*

Review slide deck. Be aware of important information, as well as suggestions for instruction, located in slide notes.

For the echolocation simulation, provide each buddy team access to multiple pieces of scrap paper and one blindfold. The instructor needs a noise-making device. In this activity, we will refer to the animal as a dolphin, since the large baleen whales of Stellwagen Bank do not use echolocation.

Procedure

Introduction

Follow the prompts in the slide deck notes to introduce the following concepts:

- What are national marine sanctuaries and why are they important?
- Where is Stellwagen Bank National Marine Sanctuary and what resources does it protect?
- How do whales use sound?
- How might whales be affected by acoustic masking?

Activity

1. Distribute pieces of scrap paper and a blindfold to each student pair.
2. Designate one person to be the “dolphin” and one person to be the “echo.” Explain that each student will get to fill both roles.
3. Explain that students will be simulating the use of echolocation. The dolphin will need to place her/his/their index finger on an “x” drawn on a piece of scrap paper. The paper should be placed somewhere within arm’s reach on a flat surface in front of the “dolphin.” The x should be about the size of a quarter. The role of the “dolphin” will be to locate the “x” (simulating the capture of a fish) and the role of the “echo” will be to respond to the sounds of the dolphin to guide them to capture the fish.
4. Direct each student to come up with a sound (must be made using their voice, but can't be a word) that represents the “click” they will procure for echolocation.
5. In their teams, direct students to come up with sounds (must be made using their voice, but can't be words) that signal directions (left, right, forward, backward). These sounds will be produced by the echo in response to the “click” off the dolphin.
6. Give students time to decide on, and practice, their sounds.

7. Set-up and explain the simulation. Model the simulation procedure for the students prior to having them attempt it themselves:
    a. Clear space on a flat surface. Mark the paper with the 'x'. Position the dolphin and echo pairs side-by-side.
    b. Blindfold the dolphins. Instruct them not to remove their blindfold or get up until directed to do so.
    c. Instruct the echo to place the paper on the flat surface somewhere within arm's reach of the dolphin.
    d. Instruct the dolphin to extend its arm with the index finger pointing down.
    e. Have the dolphin make its "click." The echo should respond using the agreed upon sound in order to move the dolphin closer to the target. The dolphin should click five times and each time the echo should respond appropriately. After the fifth click and echo, prompt the dolphin to place its index finger down. The echo can then help the dolphin remove the blindfold and observe how close they are to the target.
    f. Switch roles and repeat.
    g. Run the simulation another time while the instructor uses the noisemaker to simulate sound pollution and acoustic masking.

Debrief

Discuss the simulation by using the questions below (also on slide #14). *Accept all reasoned responses*.

- How successful were you in using echolocation? Respond from both the perspective of the dolphin and the echo.
- What was challenging? Respond from both the perspective of the dolphin and the echo.
- Was your success impacted by acoustic masking? Why or why not?
- How does this simulation successfully model the use of echolocation by dolphins and other toothed whales?
- How could this simulation be improved?

Preparation – *Pool Mission*

Gather a weight, or other negatively buoyant object, for each team and an underwater noisemaker for each student. Obtain a noisemaker for the instructor.

Procedure

1. Remind students of the echolocation simulation conducted in the classroom. They will transfer their learning to the pool where again one student will simulate the dolphin and the others, the echo.
2. Instead of vocalizations, they will decide upon sounds made with their noisemakers to represent the echolocation click and the informational echoes. Instead of being blindfolded, the student

who is representing the dolphin will close their eyes. Give students time to decide on, and practice, their sounds.

3. Have buddy teams on their knees in the pool. Once positioned, have the echo direct the dolphin to close their eyes. The echo then places the weight somewhere within arm's reach either in front or to the side of the dolphin. The dolphin should reach their arm out with the index finger pointed down and use the noisemaker to click. The echo should respond appropriately. After the fifth click and echo, prompt the dolphin to open their eyes while holding their arm and finger still. Make note of how closely the dolphin is pointing to the weight.
4. Switch roles and repeat.
5. Run the simulation another time while the instructor uses the noisemaker to simulate sound pollution and acoustic masking.

Dive Briefing

- Explain the simulation procedure and objectives. Model the procedure above water prior to student participation. Make sure buddy teams are clear on how they will signal to each other when it is time for the dolphin to open and close their eyes. Emphasizes the importance of safety (air and buddy checks) and good buoyancy control. These objectives are more important than the objective of the simulation. A student may always open their eyes if necessary to address an issue.
- Prior to entry, perform all standard safety and weight checks.

Dive

Participate in the echolocation simulation as outlined in the procedure.

Debrief

Upon completion of the pool mission, assess student understanding by asking the following questions. *Accept all reasoned responses.*

- How well did you pay attention to your buddy and air? Why do you feel this way?
- How successful were you in using echolocation? Respond from both the perspective of the dolphin and the echo.
- What was challenging? Respond from both the perspective of the dolphin and the echo. Compare and contrast the underwater experience to that in the classroom.
- Was your success impacted by acoustic masking? Why or why not?
- How does this simulation successfully model the use of echolocation by toothed whales?
- How could this simulation be improved?

Education Standards	
Dive Industry Standards	PADI Seal Team SSI Scuba Ranger NAUI Junior Scuba Diver or Passport Diver
Ocean Literacy Principles	#1: The Earth has one big ocean with many features. (a,h) #5: The ocean supports a great diversity of life and ecosystems. (e,f,h)

Additional Resources

Resources linked in the slide deck:

- Introduction to National Marine Sanctuaries Video
- Banks 101 Video
- Upwelling Animation
- 360° Video of Dive on Schooner *Paul Palmer*
- Whale Watching in Stellwagen National Marine Sanctuary Video
- Humpback Species Spotlight Video
- Humpback Sounds
- Bottlenose Dolphin Sounds

Additional Resources:

NOAA's Ocean Guardian Dive Club
This site contains links to the Ocean Guardian Diver module and other sanctuary specific modules.
https://sanctuaries.noaa.gov/education/ocean_guardian/dive-club/

NOAA's Office of National Marine Sanctuaries http://sanctuaries.noaa.gov/
This site contains information on each of the sites in the National Marine Sanctuary System.

Stellwagen Bank National Marine Sanctuary https://stellwagen.noaa.gov/
This site will provide background on Stellwagen Bank National Marine Sanctuary, ways people can visit, and the work they are doing.

Virtual Dives in Stellwagen Bank National Marine Sanctuary
https://sanctuaries.noaa.gov/vr/stellwagen-bank/

Sound Studies in Stellwagen Bank National Marine Sanctuary
https://stellwagen.noaa.gov/science/passive_acoustics.html

Dolphin Signature Whistles in Stellwagen Bank National Marine Sanctuary
https://sanctuaries.noaa.gov/news/apr20/eavesdropping-on-dolphins-stellwagen-bank-national-marine-sanctuary.html

Whales and Sound
https://www.fisheries.noaa.gov/feature-story/whales-world-sound
https://www.fisheries.noaa.gov/national/science-data/sounds-ocean

For More Information

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