On the Trail of a Whale

Student Activity Sheet

Name_____ Date_____ Class_____

We can often tell who is talking without even seeing them. Many times we can also tell where they are without looking. How do we do this?

In the ocean, whales and dolphins communicate using vocalizations. How do you think they tell each other apart? What can scientists learn about whales and dolphins by listening to their vocalizations?

PART A: WHALE SOUNDS

Materials:
Downloaded whale sounds
Data Table of Whale Sounds
"Discovery of Sound in the Sea" web site - http://omp.gso.uri.edu/dosits.htm

Procedure:
1. Listen to a series of whale sounds. What characteristics can you observe in order to compare the sounds to each other? (Hint: length of sound, pitch of sound, etc.) Record your observations in the "Description of Sound" column on the Whale Vocalizations Data Table.
2. Using the "Discovery of Sound in the Sea" Audio Gallery and the characteristics you observed, see if you can match the sounds you heard to the species in the gallery. Record your guess of each whale species in the column "Guess of Whale Species."
3. Break into groups of 4 to answer the following questions.

Discussion Questions:
1. Why do you think some of the characteristics you observed are different between the different species?

2. What might individual whale sounds teach scientists about whales?

3. If you were a marine biologist researching whales, how could you distinguish individual whales from each other? How could you follow an individual whale to observe its behaviors? Be careful – you must be able to follow the same whale. And don't forget that whales dive and are only at the sea surface about 20% of the time!

PART B: ON THE TRAIL OF A WHALE

Materials:
Master Data Chart for “On the Trail of a Whale”
Data Sheet for “On the Trail of a Whale”
Teacher Provided:
- floor-size cut-out of the eastern North Pacific Ocean
- nametags with yarn: labeled Whale, Whale Tracker, Sound Receiver
- blindfolds (optional)

Procedure:
1. You are a scientist who wants to track 5 individual whales in the North Pacific Ocean. The only equipment you have to work with are sound receivers. How many sound receivers would you need? Where would you place them in the North Pacific Ocean? Mark the positions of the Sound Receivers on the Master Chart of the North Pacific Ocean.
2. The teacher will lay out a floor-size cut-out of the eastern North Pacific and select the appropriate number of students to act as Sound Receivers. The Sound Receivers should go to their designated spot and put on blindfolds (or close their eyes if they are uncomfortable wearing a blindfold).
3. The teacher will select 5 Whales and 5 Whale Trackers. Each Whale will be assigned a unique vocalization (e.g., whistle, cluck, honk, etc.) and a number 1-5. Each Whale Tracker will be assigned to a Whale.
4. The Whales will move around the North Pacific Ocean and quietly make their unique vocalizations. When a Sound Receiver hears a Whale vocalizing, s/he should point in the direction they hear the Whale and identify which Whale they hear. If three or more Sound Receivers are pointing at the same Whale, the Whale Tracker stops his/her Whale and records the Whale’s position and which Sound Receivers detected the Whale on the Data Sheet. Once the data are recorded, the Whale continues moving around.
5. Continue recording Whales' positions as they move about the North Pacific Ocean. Once the Whale has been detected at five different locations, that Whale/Whale Tracker pair should return to their seats.
6. After the activity is completed, the Whale Trackers should plot the detection locations of their Whale on the Master Chart of the North Pacific Ocean.

Discussion Questions:
1. How effective was this method in localizing Whales?

2. What difficulties would scientists encounter using this method?

3. What can scientists learn by tracking whales?

Part A: Whale Sounds

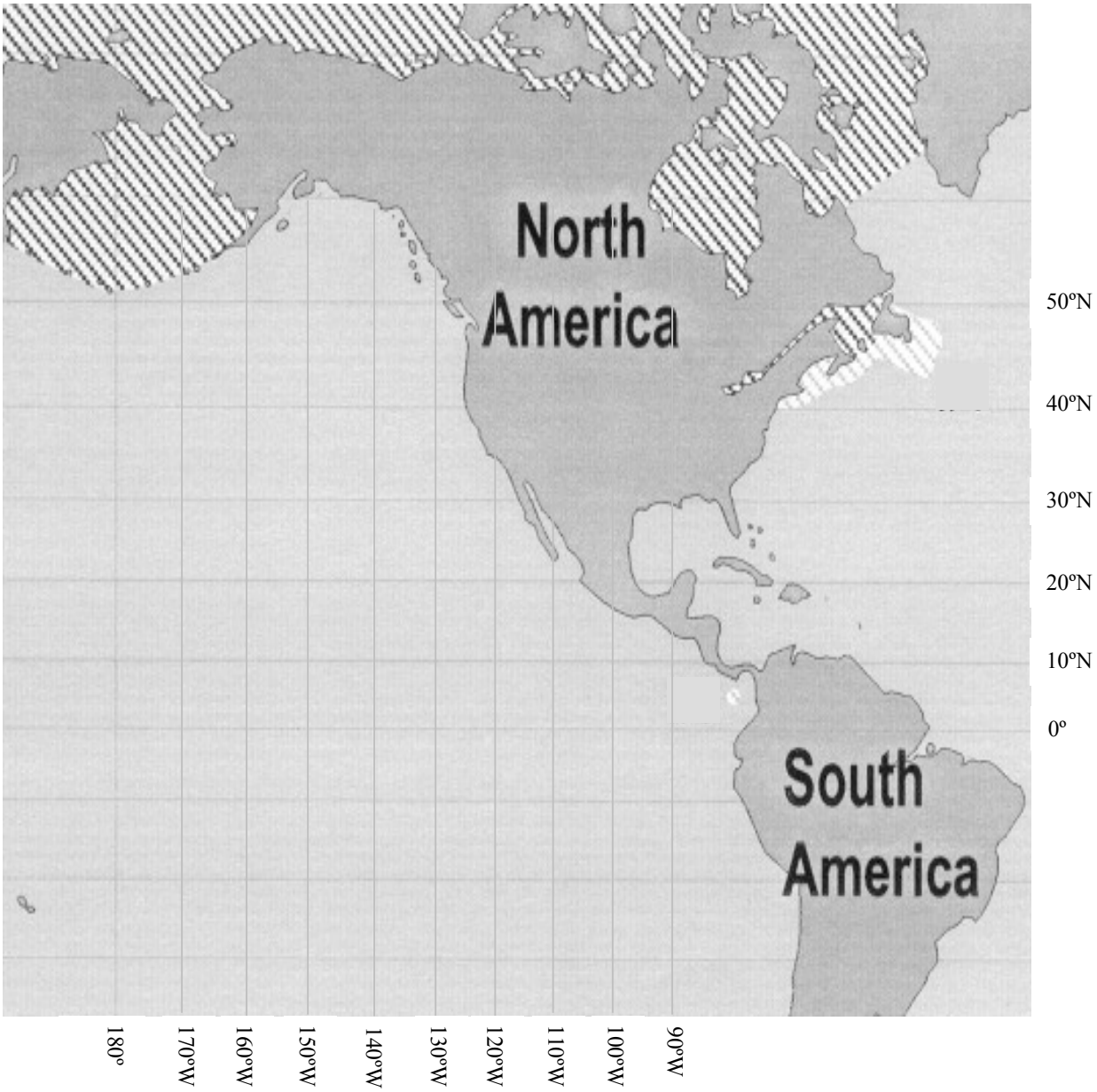
Whale Vocalizations Data Table

Sound #	Description of Sound	Guess of Whale Species	Accurate Whale Species
1			
2			
3			
4			

Part B: On the Trail of a Whale

"On the Trail of a Whale"

Master Data Chart:



R = Sound Receiver

Part B: On the Trail of a Whale

"On the Trail of a Whale" Data Sheet

Whale Number:_____
Whale Vocalization:_____

Detection Number	Sound Receivers	Whale Latitude	Whale Longitude
1			
2			
3			
4			
5			

Teacher Strategies

Grade Level: Grades 7-12

Time Required: This activity should be conducted over at least two 45-minute classes, with one class for Part A and one class for Part B.

Standards Addressed:

The Rhode Island Science Framework
- The Nature of Technology - Technology and Science, Grades 6-8 (Benchmark 2 of 3)
- The Living Environment - Diversity of Life, Grades 6-8 (Benchmark 3 of 5)
- The Living Environment - Interdependence of Life, Grades 6-8 (Benchmark 1 of 2)
- The Nature of Technology - Technology and Science, Grades 9-12 (Benchmark 1 of 3 and Benchmark 3 of 3)

Middle School Performance Standards
- S2(c) Life Science Concepts
- S4(b) and (d)

High School Performance Standards
- S2(f)
- S4(b) and (d)

National Science Education Standards
- Teaching Standards A, B, C, D, and E
- Content Standards A, C, E, and G (Grades 5-8)
- Content Standards A, C, and E (Grades 9-12)

Objectives:
1. Observe that different whales make different vocalizations
2. Discover how scientists can track whales by listening for their vocalizations

Background Information:
1. Identifying the **sound source**: If you listen closely, each individual person sounds a little different. They may talk a little higher or a little lower (different **frequency**), or they may talk faster or slower, or they may have an accent. So without even looking, we can figure out who is talking. The same thing is true about most whales and dolphins. Many species have vocalizations that only they make, and some populations even have "accents" that distinguish them from other populations of the same species (e.g., killer whales, humpback whales).
2. Locating the sound source: We can tell where someone who is talking is located without looking. This is because we have two ears – two separate **sound receivers**. When someone is talking, each ear hears or receives the sound at a different time because our ears are a different distance away from the person talking (the difference being the size of your head). Scientists call this time difference the **time-of-arrival**

difference. Our brain turns that time difference into a distance and direction. This gets complicated when a sound comes from directly above your head because then the sound reaches your ears at the same time. To prevent that problem, you'd need at least three sound receivers. Does anyone have three ears? I hope not! However, scientists are using underwater listening stations that the U.S. Navy placed over much of the North Pacific and North Atlantic. If the scientists are lucky, they may be able to hear whales vocalizing on three or more sound receivers. They would then use the same process to locate the vocalizing whale as we do to find the talking person. Since the vocalization arrives at each receiver at a different time, the time-of-arrival difference between each pair of sound receivers can be calculated. Scientists can then draw lines (hyperboles) that represent equal time differences between each pair of hydrophones. Where the lines cross is their best guess at where the whale was when it vocalized. "X" does mark the spot!

If you would like to do an extension in your classroom, it is much simpler to locate a ship that pings to and receives a ping from a **transponder** using the method of **triangulation** (see http://omp.gso.uri.edu/dosits/people/navigatn/1.htm) than to introduce the mathematics of calculating time-of-arrival differences.

INSTRUCTIONAL STRATEGIES

Preparation:

1. Download the whale vocalizations included on the "Discovery of Sound in the Sea" web site for Part A of the activity.
2. Create a cut-out of the eastern North Pacific for Part B of the activity. The most important component is that it is large enough for the students to move about without running each other over. Some suggestions include using a football field with the yard markers as latitude lines and string lengthwise on the field for longitude lines. Some schools have charts of the U.S. on their playground. Otherwise you will need to create an outline of the eastern North Pacific with paper. Use tape on the chart for the latitude and longitude lines. The minimum space should be 5 feet for each 10 degrees of latitude or longitude.

Assessing Prior Knowledge:

Introduce the activity with the brainstorming questions at the beginning of the Student Activity Sheet. Test the students' ability to identify the speaker and locate him/her without looking. Let them brainstorm how they are able to do this. Feed this discussion into the brainstorming questions in the second paragraph of the introduction - how whales and dolphins accomplish the same tasks, and what scientists can learn about the animals by listening to their vocalizations.

Procedural Tips - Part A:

1. Play the whale vocalizations that you downloaded. Mark down the order of the species that you are using. Do not tell the students anything about the whale species yet. Encourage them to make their own observations about what the vocalizations sound like and record their observations in the Data Table for Whale Vocalizations. Some descriptions could be “pulse,” “moan,” “song,” buzz,” “ping,” etc.
2. Once the students have made their observations, give them access to the "Discovery of Sound in the Sea" web site, and let them try to match the sounds they heard to the species in the Audio Gallery. After the students have guessed the species, you can play the downloaded vocalizations again and give them a final chance to change their guesses of the species. Once they have made their final decisions, tell them the correct species (have them record the species in the “Accurate Whale Species” column of the data table) and let them listen to the differences on the web site.
3. Have students break into groups of 4 and answer the discussion questions, then discuss them together (see Answers to Discussion Questions for Activity A that follow).

Procedural Tips - Part B:

1. You introduced Part B (On the Trail of a Whale) during the last discussion question of Part A. Now the students must become researchers. They need to determine how many sound receivers to use and where to place them in the North Pacific to track 5 individual whales. You can let them ask you questions to help them design this task. Some questions the students may ask are: Where can the whales move? [Answer: anywhere within the marked-out area] How far do the receivers detect whales? [Answer: Visit the Cornell Lab of Ornithology web site (link is included in the resources section at the end of this activity) for more on the Navy’s SOSUS receivers. A rough estimate for blue and fin whales is 1000 miles where 1 deg of latitude is 60 miles, and 1 deg of longitude is 60 miles times the cosine of the latitude]. Put the master chart on an overhead and mark the locations of the sound receivers by numbering them (e.g., SR1, SR2, etc.).
2. Lay out the floor-size cut-out of the North Pacific. Have the students choose who will act as Sound Receivers. Give them each a nametag and have them go to their designated spots. Select 5 Whales and 5 Whale Trackers. Each Whale should be assigned a unique vocalization and a number. The Whale will move around the North Pacific and quietly make their unique vocalization. The Sound Receivers should be blindfolded or keep their eyes closed. Their task is to track individual whales. When they hear a Whale, they should point in the direction of the Whale with one hand and note the Whale Number by raising their other arm and listing the Whale Number with their fingers.
3. If three or more Sound Receivers are pointing at the same Whale and identifying the correct Whale Number, that Whale's Whale Tracker stops his/her Whale and records the Whale's position and which Sound Receivers detected the Whale on the Data Sheet. Once the data are recorded, the Whale continues moving around.

4. The Whales and Whale Trackers continue playing until the Whale has been detected at five different locations. After the activity is completed, the Whale Trackers should plot the detection locations of their Whale on the master chart.

Answers to Discussion Questions for Activity A:

1. The different vocalizations allow the species to tell each other apart so they can find individuals to mate with, feed with, help protect each other, etc.
2. Since scientists are able to tell the species apart by the sounds they make, they can use their vocalizations to determine their distribution, relative abundance, how deep they dive (if they are vocalizing while they are diving), etc. Scientists are also able to hypothesize about the frequencies to which species are sensitive by assuming that they can hear at the frequencies they vocalize.
3. Students may have some quick answers, but make sure they break down the problem – first they must find the animal they are looking for, then they must follow that individual animal throughout its habitats, day and night. Possible answers: (a) watch it as it comes to the surface for a breath. [Teacher: But then what do you do when it dives and you can't see it anymore? And how do you know that the next whale you see is the same one you saw earlier?] (b) you could take pictures of the whale as it surfaces – some whales have distinct markings that allow scientists to differentiate individual animals. [But again, you need to guess where the animal will surface next, and then accurately identify the whale each time it surfaces. Plus, this requires lots of time on the ocean in a boat – very expensive. Any other ideas?] If the students do not come up with sound/vocalizations on their own, lead them down that path with the following discussion: Okay, let's break down the problem. We've determined that we need to have some way of keeping track of individual animals while they dive and when they are at the surface. So if we can't see them, what other senses do we have available to us? [Senses: taste, touch, sight, smell, sound]. That's right: we could use sound. Use this question to prepare the students for the second part of the activity where they will be researchers trying to track 5 individual whales.

Answers to Discussion Questions for Activity B:

1. This question will have a lot to do with how many Sound Receivers the class determined they needed. At least 3 Sound Receivers must jointly detect a Whale for it to be localized, so if there aren't 3 receivers, no whales will ever be localized. If this occurs, you can restart the activity with more receivers. With enough receivers, this method should be effective in detecting Whales.
2. Difficulties: Receivers spread too far apart to hear whales when using multiple receivers; Receivers in wrong location; May not be able to determine which whale you are hearing, etc.
3. Scientists can learn where whales go at what times of the year, and approximately how many whales there are in a certain area.

Extensions:

1. Have extra students chatter in background (corresponds to an increase in ambient noise in the ocean)
2. Have an extra student be a tanker, an earthquake, etc. that travels/occurs throughout the North Pacific - how much harder is it for the receivers to hear the whales?
3. Have the whales vocalize less often
4. Assign the Whales specific species (ie. humpback, blue) and compare the real migration patterns of that species to the student-made migrations.
5. Have sound receivers only track certain whale species
6. Have the students create the map of the North Pacific Ocean

Physics or Math:
- Triangulation [see background information and link]

Language Arts:
- Have students write about the species
- Prepare skits about the species annual cycles/migrations

For Elementary Grades:
- Instead of having the Whale Tracker record the data on the data sheet, tape a circle on the floor where the Whale was located. Write the numbers of the Sound Receivers on the circle.

Post Activity Assessment:

- Have the students trace the migration paths for each whale. Discuss why these paths are accurate/inaccurate to actual whale migrations.

- Have the students research actual species of whales, sound receivers (ie. hydrophone arrays, SOSUS), or whale trackers (ie. specific marine researchers) depending on what they were assigned to. The students should write papers pertaining these topics.

Vocabulary:

Frequency
: The number of wavelengths in a second. The frequency determines the pitch of a sound.

Sound receiver
: A device that listens to, and may record, sounds.

Sound source
: Something that creates sound.

Species
: A group of animals that are genetically different enough from other groups of animals that they typically cannot interbreed.

Time-of-arrival difference
: The difference in time from when a sound arrives at one sound receiver to when it arrives at another sound receiver.

Transponder
: An object that receives a signal and then immediately sends out a signal.

Triangulation
: One method for calculating the position of a sound source in the ocean by determining its distance from three or more transponders.

Resources/References:

http://birds.cornell.edu/brp/IUSS.html - information on the Navy's SOSUS receivers; how scientists have been able to detect some whale species on SOSUS, and even track a blue whale for 43 days.

McDonald, M. A., J. A. Hildebrand, and S. C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. Journal of the Acoustical Society of America 98(2), Pt. 1: 712-721.

Moore, S. E., K. M. Stafford, M. E. Dahlheim, C. G. Fox, H. W. Braham, J. J. Polovina, and D. E. Bain. 1998. Seasonal variation in reception of fin whale calls at five geographic areas in the North Pacific. Marine Mammal Science 14(3): 617-627.

Watkins, W. A. and W. E. Schevill. 1972. Sound source localization by arrival-times on a non-rigid three-dimensional hydrophone array. Deep-Sea Research 19: 691-706.

This activity was developed by Kathy Vigness Raposa during the *Discovery of Sound in the Sea* Teacher Institute. University of Rhode Island, Office of Marine Programs, 2002.