INQUIRY & INVESTIGATION

What Are Bottlenose Dolphins Doing on Land? An Activity Teaching the Scientific Method through the Unique Behavior of Strand Feeding

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ABSTRACT

*All scientists use the scientific method to investigate the unknown by developing a hypothesis, designing an experiment, collecting data, and interpreting findings. The purpose of this activity is to teach middle school students about the scientific method and foraging ecology as they investigate a foraging behavior (strand feeding) of bottlenose dolphins (*Tursiops truncatus*). We tested this activity on middle school students and found that the activity promoted student inquiry, ingenuity, and critical thinking as the students used the scientific method to answer questions about strand feeding.*

Key Words: *Strand feeding; scientific method; bottlenose dolphin;* Tursiops truncatus*; foraging.*

The bottlenose dolphin (*Tursiops truncatus*) is commonly found along coastal and offshore waters, making this species one of the best studied marine mammals in the United States (Wells & Scott, 2002). Bottlenose dolphins find food by using a variety of methods, such as herding fish into a tight group or using marine sponges as tools to dig for fish in sediment (Smolker et al., 1997; Gazda et al., 2005). In South Carolina and Georgia, bottlenose dolphins use a unique foraging behavior called "strand feeding" (Rigley et al., 1981; Petricig, 1995). At low tide, dolphins work together in groups of two to five to herd fish; then the dolphins create and move along a surge wave that strands the fish on mud banks (Rigley et al., 1981; Petricig, 1995; Duffy-Echevarria et al., 2008; S. Bowen-Stevens, pers. obs.). The dolphins consume the fish stranded on the mud banks before sliding back into the water (Rigley et al., 1981; Petricig, 1995). Marine scientists do not know whether there are certain environmental variables that are favorable for strand feeding. The slope of the mud bank, presence/absence of oysters, or docks may affect the ability of dolphins to catch fish.

This activity introduces the scientific method to students as they learn about a unique foraging behavior of bottlenose dolphins in the southeastern United States.

Teachers often do not have the time or resources to teach the scientific method (Aultman et al., 2010). Therefore, Aultman et al. (2010) provided a step-by-step process for teaching the scientific method while applying it to real data collected by scientists. We expanded on this template and applied the scientific method to a laboratory study that the students helped create. We designed and tested this activity to teach middle school students about the scientific method, predator–prey relationships, and the effect of habitat on foraging as they assess how mudbank types affect strand-feeding success. The students demonstrated scientific-inquiry and critical-thinking skills.

In this activity, students learn how scientists start with a question and develop a hypothesis. They design their study, conduct trials to collect data, and analyze and interpret the data to test their hypothesis. Students will think about how their results apply to the natural environment through discussion questions. We anticipate that students will gain a greater understanding of science and can apply this knowledge to future science-fair projects or test other predator–prey relationships. Classrooms throughout the country can participate because common materials are used. The activity is also suitable for high school students, given the modifications provided at http://dolphinstrandfeedingactivity.yolasite.com/. This project covers aspects of the *National Science Education Standards* (National Research Council, 1996), *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000), and *Ocean Literacy: The Essential Principles of Ocean Sciences K–12* (National Geographic Society, 2006).

○ Background

Teachers may present some of the following information about salt marshes, predator–prey relationships, and strand feeding. Students can also search for additional background material on bottlenose dolphins. Salt marshes are exposed to air at low tide and submerged with saltwater during high tide; thus, salt marshes are intertidal habitats. The water stirs up sediments and provides nutrients for algae and plants such as smooth cordgrass (*Spartina alterniflora*). Smooth cordgrass can tolerate saltwater and is found in the lower marsh area near the creeks and rivers, where it stabilizes the mud bank. At high tide, salt-marsh vegetation is a safe shelter for young fish; however, at low tide the water recedes and fish move into the creeks and rivers. Predators in the salt marsh include birds, large fish, and bottlenose dolphins. Sharks and other large fish

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will sometimes prey on juvenile fish as well as blue crabs. Hard substrates can serve as a hiding place or refuge for crabs to escape predation. Students can create informational brochures with vocabulary terms or construct models of a salt marsh to introduce them to the salt-marsh ecosystem (Fogleman & Curran, 2006, 2007).

Students could research the habitat, distribution, and basic biology of bottlenose dolphins before starting the activity. Useful websites include these two:

- http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/bottlenosedolphin.htm
- http://www.afsc.noaa.gov/nmml/education/cetaceans/bottlenose.php

Once students have a basic understanding, teachers should discuss strand feeding as seen in Figure 1. A video of strand-feeding behavior is available online at http://www.youtube.com/watch?v=78_edYWQTWs.

○ Materials

- 6 rectangular plastic containers that are 36 quarts (34 L) (1 container for each student group)
- 20 lb (9 kg) bag of potting soil
- Small shovel
- Objects to represent vegetation: twigs, toothpicks, straws, or rolled up pieces of paper
- Small broken shells or beads for oysters
- Popsicle sticks for docks
- Glue
- Block of wood: 4 cm width; 7 cm height; the ratio of block length to container width should be around 0.5; thus, multiply the width of the container by 0.5 to determine the length of the block (Figure 2)
- Water
- 50 pieces of foam per student group (cut from Craft Foam or Styrofoam plates) to represent fish; pieces should be no larger than 1 cm
- One toy dolphin 10–15 cm in length (or a similar object) per student group or have the students create a dolphin with clay

Figure 1. Four bottlenose dolphins (*Tursiops truncatus*) strand feeding near Savannah, Georgia. This photo was collected in accordance with the Marine Mammal Protection Act under NMFS Letter of Confirmation no. 14219.

- Drafting compass
- Strand Feeding Activity Handouts for each student, available at http://dolphinstrandfeedingactivity.yolasite.com/ (alternatively, all the relevant information is in the text here, so the teacher can create his or her own handout)
- Paper towels and soap for cleanup

○ Preparation

Divide the potting soil among the plastic containers. Mix the soil in each container with water (about 500 mL or 2 cups) to make mud. The mud should be solid enough to hold a shape. Optional: set up another container with only water for students to practice wave making.

○ Methods

The teacher can create an activity handout or find a sample handout at http://dolphinstrandfeedingactivity.yolasite.com/.

1. Once the students have acquired the background information, ask them to describe how different a salt marsh might look at high tide compared to low tide. Discuss the different types of mud banks exposed at low tide (Figure 3). Ask the students to list mud-bank types. They may come up with other kinds. Allow the students to share their list with the rest of the class and copy the list on the classroom board.
2. Ask students to answer the following questions on the handout: Do you think that bottlenose dolphins will only strand feed on certain types of mud banks along the creek edge of the salt marsh, or could the dolphins strand feed anywhere? Why? This is an opportunity to discuss hypotheses with the class. A hypothesis is similar to a guess, and there is no right or wrong answer. Encourage them by reiterating that scientists do not

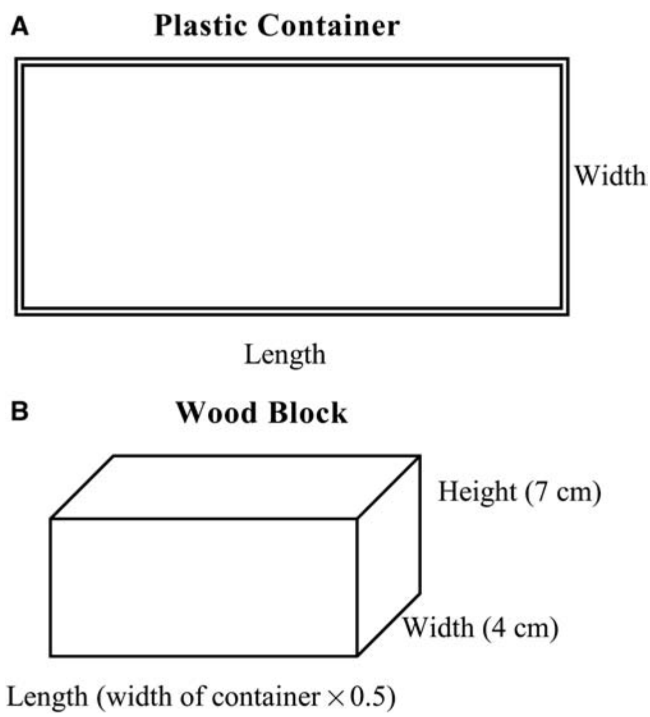

Figure 2. (A) Diagram of the plastic container and **(B)** dimensions of the wooden block. Figure not to scale.

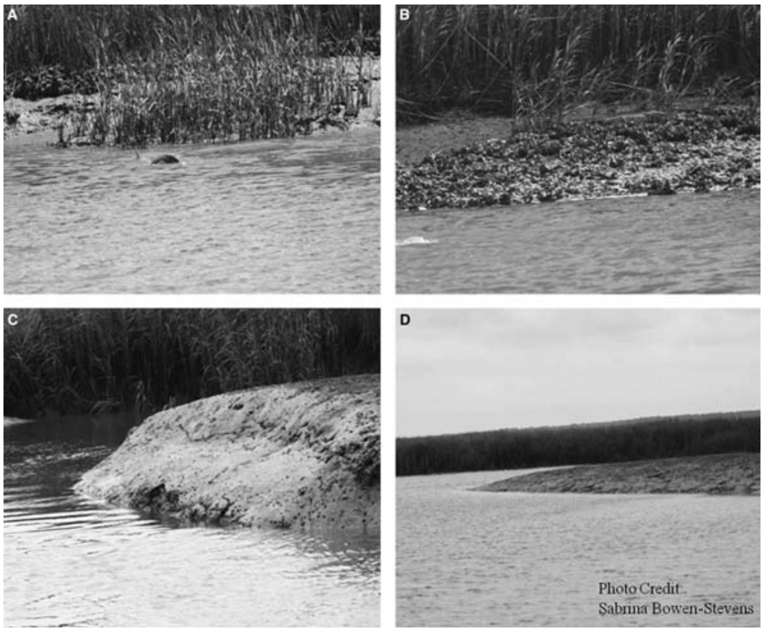

Figure 3. Examples of mud banks with **(A)** vegetation, **(B)** oysters, **(C)** a steep slope, and **(D)** a shallow slope. Mud banks could also contain docks, driftwood, and rocks.

even know the answer yet. Explain how scientists test hypotheses with replicated experiments that will support or refute the hypothesis posed. Have the students write their hypothesis.

3. Show the students the plastic containers with mud, beads/shells, material serving as vegetation, foam pieces, popsicle sticks, compass, and toy dolphin. Ask the class to brainstorm about how to use these items to test their hypotheses. Through discussion and some assistance the class might conclude that:

- Plastic containers with mud will represent different types of mud banks.
- Broken shells/beads will represent oysters or rocks on the mud bank.
- Twigs, toothpicks, straws, or rolled-up pieces of paper will represent smooth cordgrass.
- Popsicle sticks can be glued together to make a dock (provide a few photos of some docks to give the students ideas) or driftwood.
- Craft foam or Styrofoam pieces will represent fish.
- The block of wood will be used to simulate the dolphin behavior by creating the wave similar to how dolphins create a wave to strand feed.
- The toy dolphin will represent a group of dolphins on the mud bank after the wave has been created.

Ask the students if the dolphin would be able to reach all the fish on the exposed mud bank. The answer should be no; thus, there needs to be a way to measure fish near the dolphin. The compass should be used to create a circle of the same area for each type of mud bank to represent fish that the dolphin consumed.

4. Once the students have identified how the items will be used to test the hypotheses, they should write down the steps of the experiment. The experiments can be completed with groups of four students. During the experiments, the teacher can supervise and make sure that the students are following their steps. The experiment should be similar to the following:

- Four students will be needed to test each type of mud bank that was written on the board. Assign the following roles to each member of the group: data recorder, fish counter, fish dropper, and wave creator.
- The students could work together to design and construct the mud bank.
- Once the students finish creating the mud bank, they should add water to the container. The water should not cover more than 1/4 of the mud bank.
- The fish dropper will place 50 fish in the water.
- The wave creator will produce one wave using the block of wood. Since this requires some coordination, a container with only water could be used for the students to practice.
- Once the wave has been created, the fish counter will count the fish on the mud bank and report the findings to the data recorder, who will write down the number (Table 1A).
- The wave creator will place the toy dolphin in the center of the mud bank with the fluke, or tail, of the dolphin still in the water (Figure 4). Dolphins strand feed on their right side; thus, the dolphin in the habitat should be lying on its right side (Rigley et al., 1981; Petricig, 1995).
- The fish dropper will use a compass to draw a circle with a radius of 2 cm in the mud around the head of the toy dolphin. The non-pencil end of the compass will be placed near the head of the dolphin, and the pencil end of the compass will be used to draw a circle in the mud around the dolphin (Figure 4).
- The fish counter will report the number of fish inside the circle to the data recorder, who will add it to the table (Table 1A).
- The group will restore the mud bank to the pre-wave state.
- These steps should be repeated for four or five trials, with students switching roles.

5. After the students clean up the experiment, groups can work together to calculate the average number of fish on the mud bank and average number of fish near the dolphin (Table 1B). These averages will need to be shared with the entire class so that each student will have this information on their table (Table 1B). Show the students how to calculate the proportion of fish that were

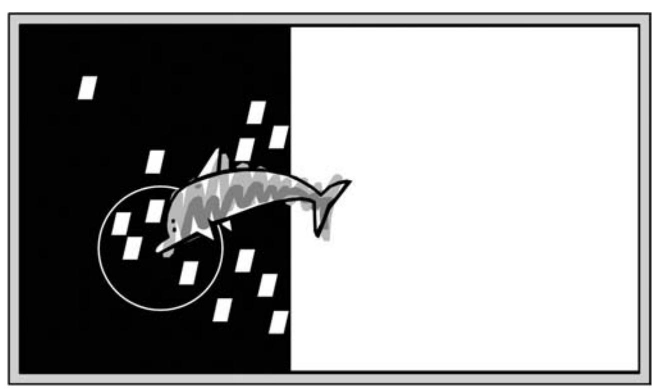

Figure 4. Habitat display with fish (small white squares), dolphin position, and circle to represent fish that the dolphin consumed.

Table 1. (A) Data collection table and (B) table for calculated averages and percentages.

A

Trial #	Number of "Fish" on Bank	Number of "Fish" Near Dolphin
1		
2		
3		
4		
5		
Average		

B

Mud-Bank Type	Average "Fish" on Bank	Percentage of "Fish" on Bank	Average "Fish" Near Dolphin	Percentage of "Fish" Near Dolphin

stranded on the bank and turn that into a percentage. Repeat the calculation for fish near the dolphin.

Percentage of fish on the mud bank = # of fish on bank ÷ total # of fish (N = 50) × 100
Percentage of fish near dolphin = # of fish near the dolphin ÷ total # of fish (N = 50) × 100

For example, if 50 fish were placed in the water and 13 fish were stranded on the bank, but only 4 were within the 2-cm circle of the dolphin, then the percentage of the fish on the mud bank would be 26% ([13 ÷ 50] × 100). The percentage of fish near the dolphin would be 8% ([4 ÷ 50] × 100).

6. Next, everyone can work together to discuss the best type of graph with the appropriate axes to represent the results of their study. The students should make a bar graph with the mud-bank types on the x axis and percentage of fish on the y axis (Figure 5). There will be two bars for each mud-bank type to represent the percentage of fish on the mud bank and percentage of fish near the dolphin (Figure 5).
7. The students can answer discussion questions after the graph is finished (Figure 6). Ask the students if their hypothesis was correct or incorrect and discuss why. Lead a conversation about how animals use feeding habitats or strategies to obtain the most food for the least amount of effort/energy or risk (in this case, oysters or rocks on the slope may trap more fish, but injure the dolphin). Additional modifications to the activity are available online at http://dolphinstrandfeedingactivity.yolasite.com/, where students can investigate the effects of group size on individual foraging success and calculate dolphin feeding coverage on the mud bank.

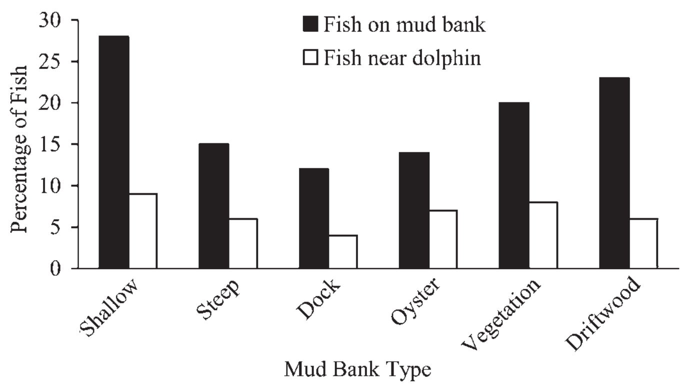

Figure 5. Sample graph of percentages of fish on mud bank and near dolphin from student experiments for each type of mud bank tested. Results from other experiments may be different.

○ Assessment

While testing this activity, our students were graded on completeness, correct calculations, and creativity of the answers to the discussion questions. Using student responses to the handout available at http://dolphinstrandfeedingactivity.yolasite.com/, we found that students could create a hypothesis, design methods, collect results, and interpret those results. If the results of the trials had differences in percentages of fish on the mud bank and fish caught, then some students had problems with explaining this discrepancy (question 3; Figure 6). We suggest breaking down the problem into smaller questions if needed. Responses to some questions ranged from a single sentence to a paragraph (e.g., question 6; Figure 6). The teacher will need to make sure that students give a full explanation as if they were actually going to conduct the study.

○ Conclusion

This activity introduces the scientific method to students as they learn about a unique foraging behavior of bottlenose dolphins in the southeastern United States. Students will have developed a hypothesis, designed and conducted an experiment, analyzed and interpreted results, and discussed their conclusions. This activity was tested on 7th-grade classes, and the students showed ingenuity, math skills, and teamwork. For instance, students came up with using Popsicle sticks, originally provided for the dock, as driftwood. The background, introduction, and discussion questions broadened student knowledge about the salt-marsh ecosystem and

Strand Feeding Activity Handout

Discussion Questions

1. Which mud bank type had the highest percentage of fish on the mud bank? (2 pts.)
2. Which mud bank type had the highest percentage of fish near the dolphin? (2 pts.)
3. Is the mud bank with the highest percentage of fish on bank the same as the mud bank with the highest percentage of fish the dolphin caught? If not, why? (3 pts.)
4. Using your results, which mud bank would be the best for strand feeding and why? (3 pts.)
5. Do docks affect the number of fish that strand on the mud bank or number of fish the dolphin catches? If there is a creek with many docks, will the dolphins be successful in catching fish by strand feeding or will the fish be more successful with escaping from the dolphins? (4 pts.)
6. If you were a scientist conducting research on dolphins, how could you compare differences in strand feeding on various mud bank types in the salt marsh? (5 pts.)
7. Think of another predator.Design an experiment to test what habitator behavior causes this predator to catch more prey (4 pts.)

Figure 6. Discussion questions from Strand Feeding Activity Handout available at http://dolphinstrandfeedingactivity.yolasite.com/.

bottlenose dolphins. Further discussions among students revolved around the experimental error that was created by inconsistency in how the strand-feeding waves were generated. In conclusion, the students enjoyed getting muddy as they learned about how the scientific method applies to strand feeding by bottlenose dolphins.

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