Charleston Bump Expedition

Eddies, Gyres and Drowning Machines

Focus
Effects of bottom topography on currents

Grade Level
9-12 (Physical Science/Earth Science)

Focus Question
How are water currents modified by physical obstructions within the flow?

Learning Objectives
Students will be able to describe at least three types of effect that physical obstructions may have on water flowing past the obstructions.

Students will be able to explain at least three ways in which current flow can be significant to benthic organisms.

Students will be able to explain how physical obstructions to current flow can create hazardous swimming conditions.

Materials
- ❒ Modeling clay
- ❒ 19-liter (5 gallon) glass or plastic containers, one or more for each student group
- ❒ Plastic or rubber tubing to construct a siphon, approximately 6 mm internal diameter; one for each of the 19-liter containers; should be long enough to reach from the 19-liter container to the food storage container or tray
- ❒ 1-inch binder clamps, one for each siphon
- ❒ Flow-control clamps, one for each siphon
- ❒ Clear food storage containers or trays, approximately 8 cm x 12 cm x 25 cm, one or more for each student group
- ❒ Plastic tubing, approximately 12 mm internal diameter, and plastic fitting to attach the tubing to the food storage container or tray
- ❒ Sink or bucket for collecting and disposing of water flowing out of the trays
- ❒ 100 ml graduated cylinder
- ❒ Colored sugar solution (dissolve 100 grams sugar in 1 liter of water, and add food dye to make a brightly colored solution); approximately 250 ml for each student group
- ❒ Pasteur pipets with rubber bulbs or small (1 – 5 cc) syringes (glass "medicine droppers" can also be used if the glass is heated in a gas flame and drawn out to a length of about 10 cm); two for each student group

Audio/Visual Materials
- ❒ Chalkboard, marker board, or overhead projector with transparencies for group discussions

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Charleston Bump
Current
Eddy

Gyre
Upwelling
Microhabitat
Low-head dam

Background Information

The Blake Ridge is a large sediment deposit located approximately 400 km east of Charleston, South Carolina on the continental slope and rise of the United States. The crest of the ridge extends in a direction that is roughly perpendicular to the continental rise for more than 500 km to the southwest from water depths of 2,000 to 4,800 m. About 130 km east of the Georgia-South Carolina coast, a series of rocky scarps, mounds, overhangs, and flat pavements rise from the surface of the Blake Plateau to within 400 m of the sea surface. This hard-bottom feature is known as the Charleston Bump. While the Blake Ridge has been extensively studied over the past 30 years because of the large deposits of methane hydrate found in the area, benthic communities on the continental shelf of the United States are virtually unexplored. (Visit http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm for more information about methane hydrates and why they are important). Although this area has been important to commercial fishing for many years, until recently it was generally assumed that benthic communities of the continental shelf were scattered and relatively unproductive, and that useful fisheries were the result of migrations from other areas and/or nutrients carried in from deeper or coastal waters. But once scientists actually began exploring the area more thoroughly, they found many diverse and thriving benthic communities.

The 2001 Islands in the Stream Expedition to the Charleston Bump found a series of very complex habitats, and numerous fishes and invertebrate species involved in communities that we are just beginning to understand. (Visit http://oceanexplorer.noaa.gov/explorations/islands01/log/sab_summary/sab_summary.html, and click on logs from September 27, 28, and 29 for more information). As the Gulf Stream flows around and over the Charleston Bump it is deflected, producing eddies, gyres, and upwellings. An eddy is an upstream current that forms behind an object in a current. As water flows around the object, it piles up on the upstream side and then flows in behind the object, creating a reverse current. A gyre is a current flowing in a circular pattern, often closed or nearly closed. An upwelling is a flow of water from deep to shallower water.

These kinds of water circulation patterns are associated with increased concentrations of nutrients and marine organisms in many other areas of the Earth's oceans, and studies have shown that water motion has a major influence on the distributions of numerous organisms in coral communities. Because deep-water corals are one of the most conspicuous organisms in benthic communities on the Charleston Bump, obtaining information on water movement in these communities is a high priority for the 2003 Charleston Bump Expedition.

In this activity, students will make variously shaped objects from modeling clay, place these in a flume (a tray through which water is flowing), and then visualize the effect of the objects on water flow by injecting a small amount of colored sugar solution on the upstream side of the object. Students will examine boulders, branches, and other shapes of their choice, as well as shallow bench shapes to simulate "low head dams," which create serious hazards for swimmers in many areas.

Learning Procedure

[NOTE: Portions of this activity were adapted from "Form and Function in the Marine Environment" by Jeffrey Miller on the Access Excellence website at http://www.accessexcellence.org/AE/AEC/AEF/1995/miller_marine.html]

1. Prepare experimental flumes by attaching a plastic hose barb fitting to one end of each food storage containers or tray by drilling a hold near the top of the container or tray that will provide a snug fit for the fitting. Glue the fitting in place with silicone adhesive so that the pointed end of the fitting extends outward.

When the adhesive has set, attach a piece of plastic tubing (about 12 mm inside diameter) to provide a way to channel outflow from the flume to a sink or bucket.

2. Lead an introductory discussion of the Charleston Bump and the 2001 and 2003 Ocean Exploration expeditions to the area. The website for the 2001 Islands in the Stream expedition is: http://oceanexplorer.noaa.gov/explorations islands01/log/sab_summary/sab_summary.html; click on logs from September 27, 28, and 29. The website for the 2003 Charleston Bump expedition is: http://oceanexplorer.noaa.gov/explorations/explorations.html; click on "Charleston Bump." You may want to show students some images from the Ocean Explorer website and/or http://pubs.usgs.gov/of/of01-154/index.htm.

   Tell students that detailed surveys of the Charleston Bump are just beginning, but we can have a general idea of what to expect based on explorations in other deep-water, hard-bottom habitats. Explain that the Charleston Bump alters the flow of the Gulf Stream, and scientists expect that water motion has a significant influence on biological communities in the area.

3. Have student groups prepare experimental flumes for use:
   a. Fill a 19-liter (5 gallon) container with plain water.
   b. Connect a siphon from the water container to the flume. Use a 1-inch binder clamp to hold the siphon tubing onto the side of the flume. Attach a flow-control clamp to the tubing.
   c. Connect a piece of tubing to the outflow connector on the flume, and place the open end of tubing in a sink or bucket.
   d. Loosen the clamp on the siphon tubing, allow water to flow into the flume until it begins to flow out of the outflow tubing, then tighten the clamp.

4. Have students use modeling clay to construct shapes to be tested. These shapes should be sized so that they can be completely submerged in the flume. With the exception of the shallow dam, the width of the object should be no more than one-third the total width of the flume.

5. To study water flow around the shapes, place the object in the middle of the flume. Using a graduated cylinder to measure the volume of water flowing from the outflow tubing, adjust the clamp on the siphon until the outflow is about 100 ml per minute. Use a Pasteur pipette to inject a small amount of colored sugar solution into the water near the upstream side of the object. Observe the motion of the sugar solution as it moves over and around the object. The optimum flow rate and amount of injected sugar solution depend upon the volume of the flume and size of the object. Students should experiment with these parameters until they are able to see definite flow patterns in the sugar solution. Have students test each object with at least two different flow rates (e.g., 100 ml and 200 ml). Students should prepare written reports of their results, including simple diagrams illustrating the observed flow around each of the objects tested.

6. Have each group present their results. Lead a group discussion of what happens when water flows around the kinds of shapes tested, and how alteration of water flow might be important to benthic organisms on the Charleston Bump. Typically, water becomes turbulent as it flows past an obstruction, and gyres ("swirls") and eddies (reverse currents) develop downstream of the obstruction. These disturbances to the overall direction of flow can have important benefits to benthic organisms. Eddies and gyres can create small regions where water movement is significantly reduced, making it easier for organisms to

maintain position in the water and for filter feeding organisms to use delicate anatomical structures (such as tentacles) to obtain food. These flow modifications can also concentrate nutrients, plankton and particulate matter, increasing the feeding efficiency of organisms that consume these materials. Flow modifications may result from non-living objects (e.g., rocks), or from living organisms such as sponges and corals. Branched corals have been shown to greatly reduce water flow in areas with strong currents and waves, creating numerous "microhabitats" for other organisms. Even short projections from a smooth surface can create significant "drag" that produces a thin layer of calmer water near the surface.

Upwellings can be produced in a similar way when a deep current encounters an obstruction that "steers" the water in an upward direction. The flumes in this lesson are too shallow to simulate upwelling conditions, but students may see some upward deflection as the colored sugar solution passes over boulder-like objects.

Discuss the special case of shallow dams. While these objects are not directly relevant to studies at the Charleston Bump, they are common features in many waterways that are popular for swimming, and may pose a personal threat to students at some point in their lives. Many people are unaware of the very dangerous conditions created by these structures, and the many drownings they have caused. According to Bechdel and Ray (1997), these dams:

> "… form the perfect hydraulic: they are regular, difficult to see from upstream, and almost impossible to get out of without help.
>
> An important feature by which to recognize a hydraulic at the base of a low-head dam is the boil line. This marks the boundary between the water flowing back upstream and the downstream flow. The water in the backwash is white, frothy, and aerated, while the water flowing downstream is darker and smooth. At the line where the two meet, the water appears to be boiling up. Anything that gets farther upstream than the boil line will be pulled into the hydraulic by the backwash… Several firemen and search-and-rescue personnel who were not aware of these hazards have drowned while attempting to rescue people from the hydraulics below low-head dams… With good reason low-head dams are called "drowning machines."

The BRIDGE Connection

www.vims.edu/BRIDGE/ – Click on "Ocean Science" in the navigation menu to the left, then "Physics" in the navigation menu, then "Currents" for resources on ocean currents.

The "Me" Connection

Have students write a short essay on ways in which knowledge about flow patterns such as eddies, gyres, and upwellings could be important to their own lives.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics

Evaluation

Written reports prepared in Step 5 provide opportunities for assessment. You may also want to have students include inferences about the potential significance of their observations to life on the Charleston Bump prior to discussion with the class as a whole.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Charleston Bump Expedition discoveries, and to find out what explorers are learning about deep-water hard-bottom communities.

Resources

http://oceanica.cofc.edu/activities.htm – Project Oceanica website, with a variety of resources on ocean exploration topics

http://pubs.usgs.gov/of/of01-154/index.htm – U.S. Geological Survey Open-File Report 01-154 "Sea-Floor Photography from the Continental Margin Program"

http://oceanexplorer.noaa.gov/explorations/islands01/log/sab_summary/sab_summary.html – Summary report of the 2001 Islands in the Stream Expedition

http://www.accessexcellence.org – Access Excellence website, with a lesson plans on a variety of subjects

Sebensa, K. P., J. Witting, and B. Helmuth. 1997. Effects of water flow and branch spacing on particle capture by the reef coral *Madracis mirabilis* (Duchassaing and Michelotti). Journal of Experimental Marine Biology and Ecology 211:1-28. – An example of how water flow affects the feeding efficiency of a branching coral

Bechdel, L. and S. Ray. 1997. River Rescue: a manual for whitewater safety. Appalachian Mountain Club Books, Boston.

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Motions and forces
- Interactions of energy and matter

Content Standard C: Life Science
- Interdependence of organisms
- Behavior of organisms

Content Standard D: Earth and Space Science
- Energy in the Earth system

Content Standard F: Science in Personal and Social Perspectives
- Personal and community health
- Natural and human-induced hazards

For More Information

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