ocean explorer
oceanexplorer.noaa.gov

Northwestern Hawaiian Islands Exploration

Currents: Bad for Divers; Good for Corals

Focus
Deep-sea currents

Grade Level
9-12 (Earth Science)

Focus Question
How are deep-sea currents affected by submarine topography, and how do these effects influence precious coral communities?

Learning Objectives
Students will be able to describe, compare, and contrast major forces that drive ocean currents.

Students will be able to discuss the general effects of topography on current velocity.

Students will be able to discuss how velocity affects the ability of a current to transport sand.

Students will be able to explain why deep-sea precious corals are more frequently found in areas having strong currents.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the vocabulary list.

Atoll
Nautical
SCUBA
Exploration
ROV
Corals
Current
Influenced
Frictional drag
Pressure gradient
Salinity
Topography
Accelerated

There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It would be very helpful to copy the vocabulary list and hand it out to the students to read after the lesson. The Background Information and the Daily log entries for September 22 (see http://oceanexplorer.noaa.gov/explorations/02hawaii/logs/sep22/sep22.html) should be copied and given as an assignment to read the night before the lesson is planned as should the log entries for September 22. The directions for Steps #2-5 should be written on the board and distributed as a handout. The "Me" Connection should be assigned as homework.

Materials
- ❒ Water-tight window box (buy a light-colored box or paint inside white; fill holes in a plastic or fiberglass window box with plumbers putty), approximately 30 cm x 100 cm x 20 cm deep, with a 50 cm interval marked on the inside bottom of the box with paint or permanent marker, and an overflow outlet at one end (this should be at least 18 mm diameter) attached to a hose leading to a drain or waste water

receptacle, ideally one per student group
- ❒ 5-gallon capacity glass carboy or similar container equipped with a siphon and flow-control clamp attached to the end of the siphon, one per window box
- ❒ Large binding clips; one per window box
- ❒ Pasteur pipettes, one per student group
- ❒ Dye solution made with 20 drops food coloring in 250 ml water or use India ink
- ❒ Mixed sand (collected from several locations at a beach, or from a building or landscape materials supplier), about 150 ml per student group

Audio/Visual Materials
None

Teaching Time
Two 45-minute class periods

Seating Arrangement
Groups of four or five students

Maximum Number of Students
30

Key Words
Northampton Seamounts
Pisces IV
Gold coral
Bamboo coral
Black coral
Barotropic

Background Information
Nearly 70% of all coral reefs in U.S. waters are found around the Northwestern Hawaiian Islands, a chain of small islands and atolls that stretches for more than 1,000 nautical miles (nm) northwest of the main Hawaiian Islands. While scientists have studied shallow portions of the area for many years, almost nothing is known about deeper ocean habitats below the range of SCUBA divers. Only a few explorations have been made with deep-diving submersibles and remotely-operated vehicles (ROVs), and these have led to the discovery of new species and species previously unreported in Hawaiian waters. The possibility of discovering new species has commercial importance as well as scientific interest, since some of these species may produce materials of importance to medicine or industry. The Northwestern Hawaiian Islands are regularly visited by Hawaiian monk seals, one of only two species of monk seals remaining in the world (the Caribbean monk seal was declared extinct in 1994). Waters around the Northwestern Islands may be an important feeding area for the seals, which appear to feed on fishes that find shelter among colonies of deep-water corals. These corals are also of interest, because they include several species that are commercially valuable for jewelry. The 2002 Ocean Exploration Expedition to the Northwestern Hawaiian Islands included studies of ecological relationships between monk seals and the deepsea environments of the Northwestern Islands, as well as mapping the previously unexplored deep-sea regions around the islands, investigations of deepwater fishes, and exploration of deepwater habitats.

On September 22, 2002, the deep-diving submersible *Pisces IV* was pinned against an underwater cliff by a strong current 1,465 ft below the surface. After some tense moments, the submersible's pilot was able to break free (read more about this episode at http://oceanexplorer.noaa.gov/explorations/02hawaii/logs/sep22/sep22.html). By the end of the expedition, it appeared that these strong currents may have an important role in shaping the deep-sea habitat around the Northwestern Hawaiian Islands.

While surface currents are directly influenced by the frictional drag of wind moving over the ocean surface, purely wind-driven currents do not penetrate much below 100 m. In deeper waters, many deep-sea currents are the result of pressure gradients which are a function of density and water depth. Changes in seawater density are caused by changes in salinity and/or temperature. Although it might seem that water depth in a given location is constant, this is not absolutely true. Even without wind, the sea surface is not absolutely flat, but has a topography of broad mounds and valleys. Pressure gradients cause water to flow from regions of high pressure to low pressure, resulting in currents that are called barotropic currents. These currents are relatively slow-moving in the open ocean, but can be significantly accelerated near the bottom or in the vicinity of large solid objects, like seamounts.

This activity focuses on the effects of topography on currents, and how these effects may make some habitats more favorable for certain species.

Learning Procedure

1. Introduce the location of the Northwestern Hawaiian Islands, and point out some of the features that make this area important (discussed above). Discuss the major forces that drive ocean currents. Be sure students are able to distinguish between currents that are purely wind-driven (less than 100 m deep) and those that result from pressure gradients (due to changes in density and/or depth). Be sure students understand that the Coriolis force also has a significant effect on ocean currents. Have students read the log entries for September 22 (see web address above) and possibly other logs and background essays to develop a basic understanding of the 2002 Ocean Exploration Expedition to the Northwestern Hawaiian Islands.

2. Explain to students that they will be making observations on the effects of various objects on current flow. Have each student group create at least four model surfaces using polymer clay. These surfaces should include:
   (a) a surface that is almost flat, like a pancake (approximately 10 cm diameter);
   (b) a surface that has a rounded form with a gradual slope, like half of a hard-boiled egg (approximately 10 cm on the long axis);
   (c) a surface that is relatively narrow and steep, like a seamount; and
   (d) two steep columns whose total width is 3/4 of the width of the window box with only a narrow (approximately 1 cm) gap between the columns.

   The height of models (c) and (d) should be about 1/2 the depth of the window box.
   Bake the models according to manufacturer's instructions until the clay is hard.

3. Instruct students to study the effects of their model surfaces on water currents as follows:
   (a) Fill the window box about 3/4 full of water. Adjust the clamp on the siphon tubing so that water is flowing into one end at about 500 ml per minute. Attach the inflow tubing from the siphon to the window box with a binding clip so the end of the tubing is near the bottom of the window box.
   (b) Place one of the model surfaces in the window box so that it is nearest the inflow end, and so that the side of the model opposite the inflow is just touching the end of the 50 cm interval mark.
   (c) Fill a Pasteur pipette about half full with dye solution or India ink.
   (d) Being careful not to squeeze the rubber bulb, place the tip of the pipette just above the model surface at the end of the 50-cm mark. Gently squeeze a small amount of dye solution out of the pipette, and measure the time required for the dye plume to reach the other end of the 50-cm interval mark. Repeat this procedure placing the tip of the pipette at the end of the model nearest the inflow from the siphon. Repeat these steps twice more, and calculate the average flow rate in cm per second.
   (e) Repeat Steps (b) through (d) for each model surface.

4. Next, have students observe the effect of current flow on sand grains. Have each group pour about 50 ml of mixed sand into the window box and record their observations.

5. Have students increase the flow rate to about 1,000 ml per minute (you may need to have students refill the supply bottle prior to this step). Tell students to repeat Step #4 and record their observations.

6. Have each group present their results, and lead a discussion to analyze these results. Students should have observed that current flow is increased around steep objects or objects that confine the water flow to a narrow passage. This flow acceleration can cause large, slow flowing water masses to become extremely strong and rapid currents. This happens on land in areas prone to flash floods, and is the reason that tidal inlets are highly dangerous places to swim; it is also possible that similar mechanisms in the vicinity of the Northampton Seamounts pinned Pisces IV during the Northwestern Hawaiian Islands Expedition.

   Students should also have observed that smaller particles of sand tend to be carried farther by currents than larger particles, and that when speed of the current increases, the particle-carrying capacity of the current also increases. Ask students, "What implications do strong currents have for the suitability of a habitat for precious corals?" Students should recall from their reading of the Expedition logs that sand is thought to be a major problem for these corals. Point out that the physical structure of the corals is basically a large number of individual animals (polyps) living in little cups. It is not hard to visualize the problems that could be caused by these cups filling up with sand. Strong currents around parts of the Northampton Seamounts prevent the sand build-up seen at other sites, and sites exposed to strong currents had the greatest assemblages of precious coral species.

The BRIDGE Connection

www.vims.edu/bridge/pacific.html

The "Me" Connection

Tell students to imagine that they are visitors to one of the uninhabited Northwestern Hawaiian Islands. Have them write a short essay on what signs they might look for in potential swimming areas that could indicate the presence of dangerously-strong currents.

Connections to Other Subjects

English/Language Arts, Physics, Biology

Evaluation

Develop a grading rubric that includes skill in laboratory observations (Steps #2 through #5) and participation in discussions (Step #6). You may wish to have students prepare individual written analyses prior to group discussion.

Extensions

Visit http://topex-www.jpl.nasa.gov/ for lots of information, links, and activities related to sea surface monitoring by satellites, El Niño, and other oceanography topics.

Resources

http://oceanexplorer.noaa.gov – Follow the Northwestern Hawaiian Islands Expedition as documentaries and discoveries are posted each day for your classroom use.

http://www.soest.hawaii.edu/GGHCV/haw_formation.html – Hawaii Center for Volcanology Web site about the formation of the Hawaiian Islands

http://www.papahanaumokuakea.gov/– Information about the Northwestern Hawaiian Islands region

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
- Motion and forces

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

For More Information

Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Layout and design by Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

Problem links updated April 2011.