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Charleston Bump Expedition

Feeding in the Flow

Focus
Effect of water currents on food capture in corals

Grade Level
9-12 (Life Science)

Focus Question
How do water currents affect the food capture by particle feeders?

Learning Objectives
Students will be able to describe at least two ways in which current flow may affect food capture by particle-feeding organisms.

Students will be able to explain how interactions between current flow and the morphology of a particle-feeding organism may affect the organism's ability to capture food.

Students will be able to identify at least two environmental factors in addition to current flow that may affect the morphology of reef-building corals.

Materials
❒ Copies of "Data on Water Flow and Prey Capture by Three Corals," one 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, plus time for group discussion

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Charleston Bump
Habitat
Deep-water coral
Hard coral
Soft coral
Zooxanthellae
Microhabitat
Polyp
Nematocysts

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. 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, investigations about the effects of water movement on these corals is a high priority for the 2003 Ocean Exploration expedition to the Charleston Bump. In this activity, students will analyze data from previous research on water motion and feeding behavior of corals, and will infer how water currents and external morphology may affect the food capture of some particle-feeding organisms.

Learning Procedure

1. 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. Say that deep water corals are one of the most conspicuous organisms seen in previous visits to the Charleston Bump, and probably create microhabitats for other organisms by modifying water motion over the bottom.

2. Review the basic morphological features of corals. Be sure students understand that the corals we often see in pictures are colonies of individual animals called polyps. The polyps obtain food from the surrounding water with tentacles that contain stinging cells called nematocysts. Zooplankton and particulate materials are the primary food of most corals. Corals with large polyps can consume larger food items; even small fishes in some cases! Most shallow-water corals have symbiotic single-celled algae called zooxanthellae (pronounced zoh-zan-THEL-ee) living within their tissues. These symbionts are capable of photosynthesis, and supply some of the corals' nutritional requirements. Deep-water corals that live in virtual darkness do not have these

symbionts. The polyps of hard corals produce an internal skeleton of calcium carbonate, and the fused skeletons of many polyps make the coral "rock" that we find on coral reefs. Soft corals have a tough, flexible skeleton of protein material, but the basic structure of the individual coral polyp is very similar to that found in hard corals. Be sure students understand that coral colonies may grow in a variety of shapes: branches, boulders, plates, fans, whips, etc. Visit http://sanctuaries.nos.noaa.gov for more background information and images of corals and coral reefs.

3. Tell students that both shallow- and deep-water corals are often exposed to strong water motion. Have students brainstorm how water motion may affect corals. Extremely strong currents or waves can break the colonies or dislodge them from the bottom (branched growth forms are particularly vulnerable to this). Very strong water motion can also flatten the soft tentacles, making feeding more difficult. On the positive side, currents can bring food to the polyps (an important benefit for animals that cannot move around very much), and may also carrry away waste products, and keep sediment from settling on the surface of the corals.

4. Provide each student group with a copy of "Data on Water Flow and Prey Capture by Three Corals." You may want to have students use the internet or printed references to find out about the basic physical structure of the three species included on the data sheet. Alternatively, you can provide the following information:
   - *Madracis mirabilis* – small polyps (about 3-4 mm diameter); overall growth form is narrow branches, roughly the size of a pencil
   - *Montastrea cavernosa* – large polyps (about 11-14 mm diameter); overall growth form is boulders that range from fist-size to several meters in diameter
   - *Porities porites* – small polyps (about 3-4 mm diameter); overall growth form is branched, with individual branches about finger-size

   Tell students that researchers placed colonies of these three species in plankton-free underwater cages for 6-24 hours, then moved the colonies into underwater enclosures on reef areas that were exposed to different current strengths. The enclosures were screened to exclude zooplankton. Brine shrimp cysts ("eggs") were injected into the enclosures to study how well the corals could remove particulate material under different current strengths. The corals were allowed to feed on zooplankton for about 20 minutes, then were preserved so that the stomach contents of individual polyps could be examined.

5. Have student groups graph the experimental data to obtain information on how current flow correlates with food capture for each of the three coral species. Have each group prepare a short report summarizing their conclusions based on these graphs. Have each group present their conclusions and summarize the pooled results for the entire class. Students should recognize that increased current flow was correlated with increased particle (cyst) capture by *M. mirabilis* and *M. cavernosa*. Students may notice that *M. cavernosa* had fairly high capture rates, even at lower flow speeds. *P. porites* had low capture rates at all flow speeds, though the highest capture rates also occurred at flow rates of 9 -11 cm/sec and declined at the highest flow speeds.

6. Lead a discussion of these results. Increasing flow speeds would be expected to bring more food past the coral polyps in a given amount of time, and the fact that increasing capture rates were correlated with increasing flow suggests that the corals were able to take advantage of this.

Ask students why *M. cavernosa* seemed to have fairly high capture rates at lower current speeds. One explanation is that the low, boulder-shaped growth form of this species can take advantage of particles that settle out of the water column by gravity, adding to the particles obtained through direct capture by the polyps' tentacles. Another factor might be the larger size of the *M. cavernosa* polyps.

Ask why rates of particle capture by *P. porites* seemed to decline at flow speeds above 11 cm/sec. A possible explanation is that the polyps' tentacles were flattened or collapsed at the high flow speeds, reducing their effectiveness in capturing particles. Tell students that tentacles of *M. mirabilis* have been found to collapse at flow rates of 10 - 15 cm/sec, but colonies of this coral have still been able to capture particles from flows of 40-50 cm/sec. The explanation for this apparent contradiction lies in interactions between current flow and the coral's morphology: branches of the coral colony modify water movement so that polyps on the downstream side of the colony are not flattened, and may even benefit from eddies that concentrate particles in the downstream area.

Remind students that corals also feed on zooplankton, and ask whether they would expect current flow to have a similar effect on capture rates for these animals. A major difference between zooplankton and particles is that most zooplankton can swim, and often have behaviors that allow them to escape from predators. For some species of zooplankton, though, studies have shown that increased current flow is also correlated with increased capture by coral polyps.

Ask students to think of other environmental factors that might affect the growth form of corals. High rates of sedimentation, for example, would favor upright or branched growth forms that could shed sediment more easily than horizontal or boulder-shaped growth forms. Corals that contain zooxanthellae may benefit from growth forms (like flattened plates) that maximize exposure to light.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Ecology," then "Coral" for resources on corals and coral reefs. Click on"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 humans are adapted to specific physical conditions in their environment.

Connections to Other Subjects

English/Language Arts, Life Science, Earth Science

Evaluation

Written reports prepared in Step 5 provide opportunities for assessment. You may also want to have students prepare individual or group analyses of the pooled data in Step 6 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 researchers 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.biol.sc.edu/coral/ – More lessons and activities related to corals

http://www.biol.sc.edu/~helmuthlab/ - Discussion and references on other coral reef studies

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.

Helmuth, B., K. P. Sebens, and T. L. Daniela. Morphological variation in coral aggregations: branch spacing and mass flux to coral tissues. Journal of Experimental Marine Biology and Ecology 209:233-259.

Sebens, K.P. , S.P. Grace , B. Helmuth, E.J. Maney Jr ., and J.S. Miles. 1998. Water flow and prey capture by three scleractinian corals, *Madracis mirabilis*, *Montastrea cavernosa* and *Porites porites*, in a field enclosure. Marine Biology 131:347-360.

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

Content Standard C: Life Science
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

Content Standard F: Science in Personal and Social Perspectives
- Natural resources

For More Information

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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

Student Handout

Data on Water Flow and Prey Capture by Three Corals

(adapted from Sebens, et al., 1998)

Madracis mirabilis		*Montastrea cavernosa*		*Porites porites*	
Flow Speed (cm/sec)	Cyst Capture *	Flow Speed (cm/sec)	Cyst Capture *	Flow Speed (cm/sec)	Cyst Capture *
1.1	0.1	2.5	0.8	2.5	0.0
1.9	0.2	3.2	6.5	3.4	1.3
2.5	0.5	3.3	6.6	3.4	1.8
3.2	0.5	3.7	4.5	3.4	3.8
3.6	0.2	3.9	4.4	4.0	0.0
4.1	0.5	4.0	1.5	4.0	0.3
4.5	0.3	4.1	1.4	4.0	1.1
4.6	0.7	4.2	1.7	5.5	0.4
5.0	1.1	4.3	5.5	5.6	0.3
5.1	1.0	4.4	3.5	5.7	0.5
5.2	0.8	4.4	1.0	5.8	0.0
5.5	1.9	4.4	2.0	5.8	0.2
6.1	0.7	5.4	4.8	6.1	0.0
6.4	1.1	5.4	1.0	6.1	0.3
6.5	0.9	5.8	1.0	6.1	0.5
7.1	2.8	5.8	1.2	6.1	0.6
7.1	2.7	7.8	0.5	7.0	0.7
7.4	0.8	8.1	2.0	8.2	0.5
7.5	1.2	8.3	5.0	8.6	2.1
7.6	1.2	9.5	4.5	8.7	3.0
7.6	2.1	9.5	7.0	10.2	0.3
8.2	1.7	10.0	10.0	10.2	2.8
8.5	0.5			10.2	4.5
9.5	4.0			10.2	4.7
10.1	0.4			10.2	6.3
10.1	7.0			10.3	0.5
				11.5	0.8
				12.0	0.8
				12.5	0.5

* – Number of cysts captured per polyp during a 20-minute experiment