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Life on the Edge: Exploring Deep Ocean Habitats

Faking It

Focus
Coriolis force

Grade Level
7-8 (Earth Science)

Focus Question
What is the Coriolis force, and what effects does it have on objects in motion?

Learning Objectives
Students will be able to describe and explain the Coriolis force.

Students will be able to compare and contrast conditions under which the Coriolis force has a significant impact on objects in motion with conditions under which the influence of the Coriolis force is negligible.

Materials
- ❒ Square plastic food storage container, approximately 750 ml capacity, with a 6 – 10 mm hole drilled in the center bottom
- ❒ Bucket, 3-4 liter capacity

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

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Continental shelf
Continental slope
Hard bottom
Lophelia pertusa
Gulf Stream
Coriolis force
Cyclonic rotation

Background Information
For hundreds of years, thousands of fishermen have harvested U.S. coastal waters of the Atlantic Ocean and Gulf of Mexico. Yet, the marine habitats of the adjacent outer continental shelves and slopes are poorly studied and in many cases completely unknown. Until recently, most scientists assumed that these habitats did not support large or productive biological communities. Although no one had actually visited the edges of the continental shelves for a first hand look, they believed that the extensive commercial fisheries depended upon migrations from other areas and/or nutrients carried in from deeper or coastal waters. But once they actually began exploring the area more thoroughly, scientists found many diverse and thriving benthic communities.

Between North Carolina and Florida, several unique habitats are found where the topography of the outer continental shelf is extremely rugged and swept by the powerful currents of the Gulf Stream. Hard or "live" bottom habitats support diverse biological communities that include valuable fish and invertebrate resources. On the edge of the continental shelf where depths range from 80 to 250 m, hard bottom communities provide the foundation for the food web of many commercially important species. But while scientists have studied many hard bottom communities within the range of SCUBA gear, they know very little about about the ecology of these communities in deeper waters.

Even deeper, on the middle of the continental slope, the deep-sea coral *Lophelia pertusa* forms another almost-unexplored habitat. Here, in depths of 400 to 700 m, branches of living coral grow on mounds of dead coral branches that can be several meters deep and hundreds of meters long. Unlike corals that produce reefs in shallower waters, *Lophelia* does not have symbiotic algae and receives nutrition from plankton and particulate material captured by its polyps from the surrounding water. *Lophelia* mounds alter the flow of currents and provide habitats for a variety of filter feeders. Scientists suspect that many other organisms may also inhabit deep-sea coral reefs, including commercially important fishes and crustaceans. But they don't know for sure, because most of the hard bottom and deep-sea coral habitats on the edge and slope of the continental shelf are still unexplored.

The 2003 Life on the Edge Expedition will search previously unexplored hard bottom habitats and deep coral banks on the edge and slope of the continental shelf adjacent to the coasts of North and South Carolina and define the biological communities living in these habitats. Strong currents associated with the Gulf Stream are expected to have a significant influence on these communities. This lesson focuses on the Coriolis force, how it affects the Gulf Stream, and some common misconceptions about other effects that the Coriolis force does NOT have. A secondary focus is to provide an amusing reminder that popular reporting of natural phenomena is not always accurate.

[Note: Portions of this lesson are based on "Bad Coriolis," part of a website by Alistair Fraser devoted to correcting misinformation about natural phenomena (which Fraser calls "bad science"). Visit http://www.ems.psu.edu/~fraser/BadScience.html for more discussion of common "scientific" misconceptions.]

Learning Procedure

1. Read "Bad Coriolis" at http://www.ems.psu.edu/~fraser/Bad/BadCoriolis.html. Practice the demonstration explained under "Do-it-yourself fakery."

2. Review the general geographic location and form of the continental shelf adjacent to the U.S. Atlantic coast. Tell students that very little is known about the ecology of the edge and slope of the shelf, but that recent explorations have found diverse and thriving benthic communities. Visit http://oceanexplorer.noaa.gov for more background information about the Life on the Edge Expedition.

   Review the general location and circulation pattern of the Gulf Stream. Ask students to list some ways that the Gulf Stream may affect biological communities on the edge and slope of the continental shelf adjacent to the coasts of North and South Carolina.

3. Tell student groups that their assignment is to write a short report (no more than one page) on what the Coriolis force is, what causes it, and how it affects the Gulf Stream. Say that they may use written or internet resources to research the question. The idea is for students to find out that:
   - The Coriolis force is caused by the Earth's rotation;
   - The Coriolis force causes objects moving in the northern hemisphere to be deflected to the right of the direction of motion; and

- This deflection causes north-flowing water off the southeastern U.S. coast to gradually turn to the east, producing the overall flow pattern of the Gulf Stream.

4. Lead a group discussion of students' results, and list information about the Coriolis force on a marker board or overhead transparency. In addition to the points listed above, students may also have discovered that the Coriolis force produces the opposite effects in the southern hemisphere, and that the effect of the Coriolis force is more pronounced at higher latitudes (the Coriolis force is zero at the equator). Students may attribute other phenomena to the Coriolis force as well, such as influencing the flow of water down the drain of a bathtub or toilet. List these "facts" as well, without comment at this point.

5. Be sure students have a reasonably clear understanding of how the Earth's rotation produces the Coriolis force. You may want to use the "Dishpan Analogy" described at the end of this lesson. Students should understand that "cyclonic rotation" means that rotation of air or water is caused by the rotation of the underlying Earth, and is in the same direction as the Earth's rotation.

6. Conduct the demonstration practiced in Step 1, turning to your left to introduce a counterclockwise rotation to water in the pan, then allowing the water to drain through the hole. Next, repeat the demonstration, but turn to your right to introduce a clockwise rotation.

7. Invite students to explain the results of this demonstration. Eventually, they should realize that the Coriolis force has nothing to do with the rotation of the draining water. Point out that the Coriolis effect is only significant on a very large scale (hundreds or thousands of kilometers), and that the rotation direction of draining water is caused by the geometry of the container and motion imparted to the water before it begins to drain.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Physics," then "Currents" for resources on the Gulf Stream.

The "Me" Connection

Have students write a short essay on how the Coriolis force affects them personally, even though it only is significant at very large scales.

Connections to Other Subjects

English/Language Arts, Physical Science

Evaluation

Written reports prepared in Step 3 provide an opportunity for formal evaluation. You may want to offer additional credit to the student group that can be the first to satisfactorily explain the results of the demonstration in Step 6.

Extensions

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

Visit http://www.k12science.org/curriculum/gulfstream/ for more activities on the Gulf Stream.

Resources

http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_lophelia.html – Background on *Lophelia* reefs from the 2001 Islands in the Stream Expedition

http://www.k12science.org/curriculum/gulfstream/ – The Gulf Stream Voyage website developed and managed by the Center for Improved Engineering and Science Education (CIESE) at Stevens Institute of Technology in Hoboken, New Jersey http://fermi.jhuapl.edu/student/phillips/ – Background information on the Gulf Stream

http://kingfish.coastal.edu/marine/gulfstream – Tutorial on the Gulf Stream

http://www.imcs.rutgers.edu/mrs/education/education.htm – Rutgers Coastal Ocean Observation Lab with classroom activities

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"

National Science Education Standards

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

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

For More Information

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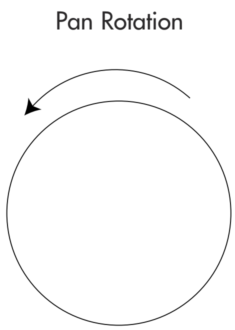
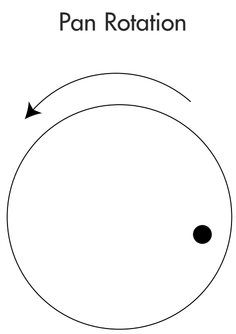
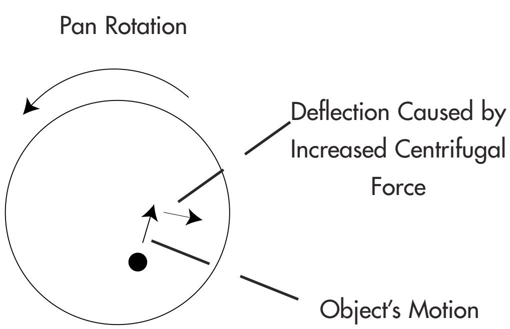
The Dishpan Analogy



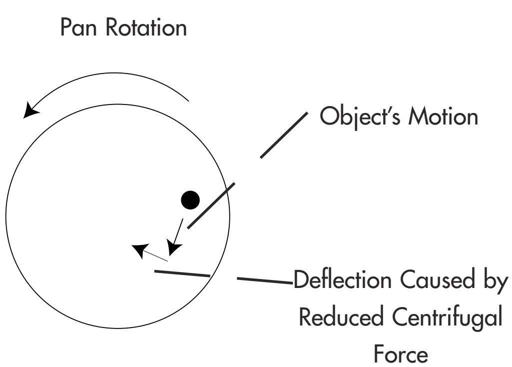
Imagine a dishpan partly filled with water, resting on a turntable or "lazy susan." Suppose we rotate the turntable in a counterclockwise direction, the same way the Earth appears to rotate if we are looking straight down at the North Pole.



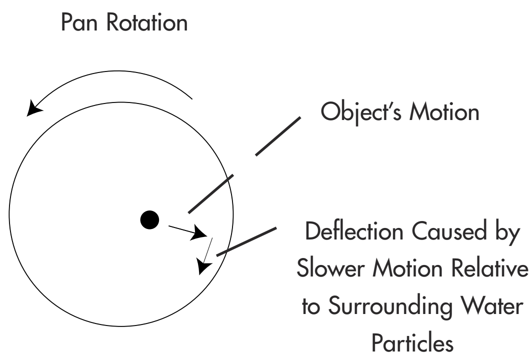
Imagine an object floating somewhere between the middle of the dishpan and the edge of the pan. The object has the same rotation as the water in the pan, and appears to be motionless relative to the surrounding water particles.



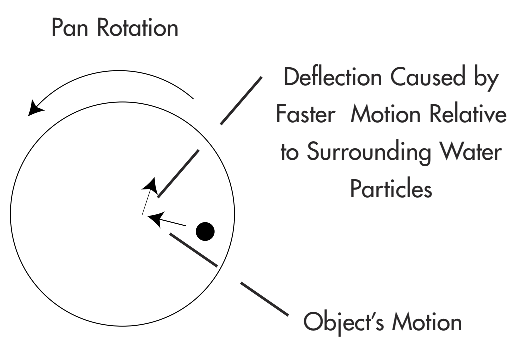
Now suppose the object moves in the direction shown. The motion of the object is added to the velocity the object already had due to the rotation of the dishpan, so the object will speed up relative to the surrounding water particles. Centrifugal force on the object will increase, so it will be deflected toward the outside of the pan. This deflection is to the right of the object's direction of motion.



Next, suppose the object moves in the opposite direction. Now the object's motion opposes the velocity the object already had due to the rotation of the dishpan, so the object will slow down relative to the surrounding water particles. Centrifugal force will now be reduced on the object, so it will be deflected toward the center of the pan. This deflection, again, is to the right of the object's direction of motion.



Let's return to the floating object in Step 2, motionless relative to the surrounding water particles. Suppose the object moves toward the outside of the dishpan. Water particles toward the outside of the pan are moving faster than those closer to the center of the pan. Since our object started out closer to the center of the pan, its velocity is less than the water particles farther outside, so the object lags behind these particles. As a result, the object is deflected to the right of its motion relative to the surrounding water particles.



Finally, suppose the object moves toward the center of the dishpan. Water particles nearer the center of the pan are moving more slowly than those toward the outside of the pan. Since our object started out farther away from the center of the pan, its velocity is greater than the water particles closer to the center, so the object moves ahead of these particles. Once again, the object is deflected to the right of its motion relative to the surrounding water particles.