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The Gulf of Mexico Deepwater Habitats Expedition

How Does Your (Coral) Garden Grow?

Focus
Growth rate estimates based on isotope ratios

Grade Level
9-12 (Life Science/Chemistry)

Focus Question
How can growth rates of corals be estimated from samples collected at a single point in time?

Learning Objectives
Students will be able to identify and briefly explain two methods for estimating the age of hard corals.

Students will learn how oxygen isotope ratios are related to water temperature.

Students will be able to interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

Materials
- ❒ Graph paper
- ❒ Copies of "Oxygen Isotope Ratios in *Lophelia* Coral Samples" and "Water Temperature in Trondheimsfjorden 1990 – 1995," one for each student or student group

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
30

Key Words
Lophelia pertusa
Isotope
$\delta^{18}O$
Deep-water coral

Background Information
Deep-water coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. In contrast, deep-water coral reefs near the coasts of Europe have been intensively studied, and scientists have found a great abundance and variety of species associated with these communities. *Lophelia pertusa* is the dominant coral species in these communities. Technically, *Lophelia* is ahermatypic (non-reef-building), but branches of living coral grow on mounds of dead coral branches that can be several meters deep and hundreds of meters long. Unlike hermatypic 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. Several commercially-important species are associated with *Lophelia* reefs in European waters, and scientists suspect that the same may

be true for deep-water reefs in the Gulf of Mexico. But they don't know for sure, because most of these communities are almost entirely unexplored.

Most reports of *Lophelia* reefs in the Gulf of Mexico were the result of investigations directed toward hydrocarbon seepage and/or chemosynthetic communities. Scientists studying deep-water reefs on the Norwegian continental shelf have found that many large *Lophelia* banks occur at sites where there were relatively high levels of light hydrocarbons present in the sediments. The reason for this correlation is not known, nor is it known whether a similar correlation exists in the hydrocarbon-rich Gulf of Mexico.

As scientists have begun to learn more about *Lophelia* reefs, there is increasing concern that these reefs and their associated resources may be in serious danger. Many investigations have reported large-scale damage due to commercial fishing trawlers, and there is also concern about damage that might result from exploration and extraction of fossil fuels. The primary objectives of the Gulf of Mexico Deepwater Habitats Expedition are:

- to locate deep-water coral reefs in the Gulf of Mexico;
- to describe biological communities and geological features associated with these reefs; and
- to improve our understanding of the ecology of *Lophelia* and deep-water reef communities.

One of the secondary objectives of this expedition is to begin to gather information about the growth rate of *Lophelia* corals. This information is critical to finding possible ways to restore damaged reefs, as well as to understanding interactions between *Lophelia pertusa* and other organisms in deep-reef communities. The skeleton of *L. pertusa* (and most other coral species) is made of a type of limestone (calcium carbonate) called aragonite. When pieces of the skeleton are sliced into cross-sections and examined with a microscope under polarized light, the sections appear to have zones in which the aragonite crystals are more dense, forming bands resembling growth rings in trees. Scientists generally believe that these bands are annual phenomena, and thus can be used to determine the growth rate of corals.

Another technique for estimating coral growth rate uses isotopes of oxygen, which are incorporated into the corals' calcium carbonate skeleton. Scientists have found that the ratio of the rare oxygen isotope ^{18}O to the common oxygen isotope ^{16}O in carbonate samples is inversely related to the water temperature at which the carbonates were formed; so high ratios of ^{18}O mean lower temperatures. Because the absolute abundance of an isotope is difficult to measure with sufficient accuracy, the isotope ratios in a sample are compared with those in a standard, and the results are expressed as delta values, abbreviated $\delta_{(x)}$ which is found by subtracting the isotopic ratio of the standard from the isotopic ratio of the sample, dividing the result by the ratio of the standard, and multiplying the 1,000 to give a result in parts-per-thousand (‰; also called "parts-per-mille").

This lesson is intended to introduce students to the concept of using oxygen isotope ratios to estimate coral growth rate, and to provide practice in manipulating and interpreting numerical data.

Learning Procedure

1. Briefly review Background Information on the Gulf of Mexico Deepwater Habitats Expedition, and deep-water reefs. Point out that these reefs have a high diversity of species and large number of individual organisms like coral reefs in shallower water, but are virtually unexplored in the Gulf of Mexico. Compare and contrast deep-water reef corals (e.g., *Lophelia pertusa*) with reef-building corals in shallow water [Visit http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_Lophelia.html for more background on *Lophelia* reefs]. Be sure students understand that these corals produce skeletons from calcium carbonate, and continue to grow and add to these skeletons throughout their lives. Be certain that

students understand the concept of isotopes, and explain that the ratio of oxygen isotopes varies with temperature. When oxygen, in both of its isotopic forms, is precipitated in the coral skeleton as calcium carbonate, a record is formed of the temperature at the time of precipitation (this record is sometimes referred to as a "climatological proxy").

2. Distribute copies of "Oxygen Isotope Ratios in *Lophelia* Coral Samples" and "Water Temperature in Trondheimsfjorden 1990 – 1995" Have students or student groups plot these ratios as a function of distance from the outer skeleton edge ($\delta^{18}O$ on the y-axis). Students should prepare a second graph of water temperature as a function of sampling date (water temperature on the y-axis).

   To facilitate interpretation of these data, the scales of the x- and y-axes on both graphs should be adjusted so that the graphs are about the same physical size. Students also need to realize that measurements nearest to the outer edge of the coral skeleton are sampling the most recently produced portions of the skeleton. So, if the origin of the x-axis of the $\delta^{18}O$ graph is zero, the origin of the x-axis of the temperature graph should be August 1995, and the right-hand edge of this x-axis should be January 1990. You may want to suggest these points to students, or let them figure it out for themselves (this could also be part of your evaluation rubric).

   If the scales of the two graphs are properly adjusted, students should be able to see a correspondence between water temperature and $\delta^{18}O$ (highest $\delta^{18}O$ values correspond to lowest water temperatures). This will be particularly evident if students plot $\delta^{18}O$ values on an inverse scale, with +1.0 at the origin of the y-axis and -1.0 near the top of the axis. So the two highest $\delta^{18}O$ values ($\delta^{18}O$ = 0.64 and 0.73 at 12.2 mm and 8.0 mm from the skeleton edge, respectively) could reasonably be matched with the lowest temperatures (6.83°C and 7.05° C in July 1994 and May 1993, respectively). The difference in distance from the skeleton edge represents the growth that occurred between May 1993 and July 1994. So the growth rate would be:

   (12.2 mm – 8.0 mm) ÷ 14 months = 0.3 mm/month = 3.6 mm/year

   Students should determine growth rate in this way for at least three intervals (for example, they could match the two lowest $\delta^{18}O$ values with the two highest temperatures; or the lowest and highest $\delta^{18}O$ values with the highest and lowest temperatures; etc). Have students calculate the average of their results. The researchers who did this study reported an average annual growth rate of 5.5 mm, and also found that the growth rate gradually decreased toward the edge of the skeleton (i.e., the coral grew more slowly as it got older).

   Students should prepare a brief written report summarizing their analyses to accompany their graphs.

The BRIDGE Connection

http://www.vims.edu/bridge/reef.html

The "Me" Connection

Have students write a short essay describing why it is important (or is not important) to study communities such as deep-water reefs. If students think this kind of work is unimportant, remind them that many of the most promising anti-cancer drugs are being developed from sessile benthic invertebrates (see http://oceanexplorer.noaa.gov/explorations/explorations.html and click on "Bioprospecting" for more information)

Connections to Other Subjects

English/Language Arts, Chemistry, Earth Science

Evaluation

Written reports and graphs provide opportunities for assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Gulf of Mexico Deepwater Habitats Expedition discoveries, and to find out what explorers are learning about deep-water coral communities.

Resources

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

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/uploads/oceana_coral_report.pdf — Background on deep-water coral reefs

Mortensen P. B. and H. T. Rapp. 1998. Oxygen and carbon isotope ratios related to growth line patterns in skeletons of *Lophelia pertusa* (L) (Anthozoa, Scleractinia): Implications for determination of linear extension rates. Sarsia 83:433-446. – The technical journal article upon which this activity is based

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
- Structure of atoms
- Chemical reactions

Content Standard C: Life Science
- The cell
- Behavior of organisms

Content Standard D: Earth and Space Science
- Geochemical cycles

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

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:
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Student Handout

Oxygen Isotope Ratios in *Lophelia* Coral Samples

(collected from Trondheimsfjorden, Norway; August 1995; adapted from Mortensen & Rapp, 1998)

Sample No.	Distance from Outer Skeleton Edge (mm)	$\delta^{18}O$
1	5.2	0.66
2	6.5	0.41
3	8.0	0.73
4	9.35	0.34
5	10.45	0.53
6	11.55	0.27
7	12.2	0.64
8	13.7	0.47
9	14.6	0.56
10	15.65	-0.09
11	16.95	-0.10
12	18.25	-0.43
13	19.55	-0.17
14	20.85	-0.57
15	22.15	-0.32
16	23.45	-0.28
17	24.8	-0.62
18	26.25	-0.60
19	27.75	-0.62
20	29.25	-0.32
21	30.7	-0.49
22	32.1	-0.62
23	33.35	-0.34
24	34.45	-0.57

Student Handout

Mean Monthly Water Temperature in Trondheimsfjorden 1990 – 1995

Month	Water Temperature (depth = 200 m; °C)
1990	
Jan	7.80
Mar	7.64
May	7.53
Jul	7.62
Sep	7.68
Nov	7.82
1991	
Jan	7.83
Mar	7.82
May	7.79
Jul	7.76
Sep	7.80
Nov	7.96
1992	
Jan	7.95
Mar	7.64
May	7.59
Jul	7.60
Sep	7.65
Nov	7.80
1993	
Jan	7.82
Mar	7.20
May	7.05
Jul	7.09
Sep	7.12
Nov	7.38
1994	
Jan	7.28
Mar	7.32
May	7.12
Jul	6.83