Lophelia II 2012:
Deepwater Platform Corals Expedition

How Do Your Corals Grow?

Image captions/credits on Page 2.

lesson plan

Focus

Growth and structure of *Lophelia* coral colonies

Grade Level

5-6 (Life Science)

Focus Question

How can ocean explorers estimate the growth rate of *Lophelia* corals, and how does the branching structure of these corals affect their ability to take in food?

Learning Objectives

- Students will plan and carry out an investigation using models to explain how the branching structure of *Lophelia* coral colonies may affect the corals' ability to take in food.

- Students will communicate results of this investigation and cite evidence to support inferences about the relationship between structure of *Lophelia* coral colonies and the feeding function of individual coral polyps.

- Students will analyze and interpret data from photographic images and use concepts of proportion and scale to estimate the growth rate of *Lophelia* coral colonies.

Materials

For one student group:

- ❑ Materials for making models: modeling clay, plastic drinking straws, chenille pipe cleaners – each group will need a tennis ball-size piece of clay and ten straws and/or pipe cleaners
- ❑ Scissors for cutting straws and pipe cleaners
- ❑ Small aquarium or transparent plastic container, approximately 28 l (7 gal) capacity
- ❑ Large (about 20 cm (8 in) diameter) plastic funnel connected to approximately 50 cm (20 in) plastic tubing or garden hose (about 12 mm (1/2 in) diameter
- ❑ Diluted food coloring; ten drops in 500 ml (16 oz) water
- ❑ Rubber bulb pipet, about 25 cm (10 in) long
- ❑ Copies of the *Guide for Estimating Size from Underwater Images*, one for each student group
- ❑ Copies of Appendix A, enough so that each student group has five

images, or copies of the data file 5_6AppA (http://oceanexplorer.noaa.gov/explorations/12lophelia/edu/resources/media/5_6AppA) on computers to be used by students; see Learning Procedure, Step 1

- ❑ Copies of *Coral Growth Estimation Worksheet*, one for each student group
- ❑ (Optional) Copies of *ImageJ Basics*, one for each student group; see Learning Procedure, Step 1
- ❑ (Optional) Ruler, one for each student group; see Learning Procedure, Step 1

Audio-Visual Materials

- ❑ (Optional) Interactive white board

Teaching Time

Two or three 45-minute class periods, plus time for student research

Seating Arrangement

Groups of two to three students

Maximum Number of Students

30

Key Words

Lophelia
Coral growth

Background Information

Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

Two types of deepwater ecosystems are typically associated with rocky substrates or hardgrounds in the Gulf of Mexico: chemosynthetic communities and deep-sea coral communities. Most of these hard bottom areas are found in locations called cold seeps where hydrocarbons are seeping through the seafloor. Petroleum deposits are abundant in the Gulf of Mexico: in 2009, oil production from the Gulf accounted for 30 percent of U.S. domestic production and 11 percent of natural gas production. Because deepwater ecosystems are associated with hydrocarbon seeps, the presence of these ecosystems may indicate potential sites for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems whose importance is presently unknown. Since 2002, NOAA's Office of Ocean Exploration and Research (OER) has sponsored nine expeditions to locate and explore deep-sea ecosystems in the Gulf of Mexico.

Images from Page 1 top to bottom:
Colonies of *Lophelia* coral with outstretched feeding polyps were discovered on the eastern scarp of the West Florida Escarpment at approximately 400 meters. These corals and Cretaceous rocks hosted crabs and tubeworms (at right). Image courtesy of NOAA *Okeanos Explorer* Program, Gulf of Mexico Expedition 2012.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/leg2sum-1-hires.jpg

Tim Shank and Dave Lovalvo ensure science and operational objectives are met while exploring a shipwreck. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar30_update_hires.jpg

Anchor resting on the top of the Site 15429 wreck. *Lophelia* coral is also visible.
Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar29_hires.jpg

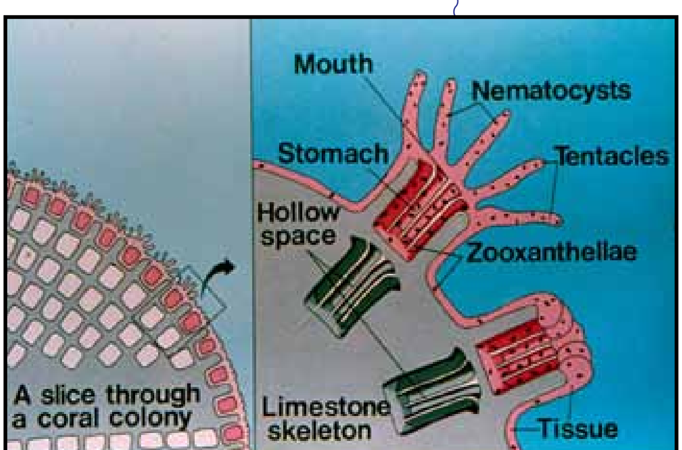
Photo mosaics are created using a series of photographs that overlap along a straight transect. Several transects are then "stitched" together to form the overall picture. Image courtesy of *Lophelia* II 2010 Expedition, NOAA-OER/BOEM.
http://oceanexplorer.noaa.gov/explorations/10*Lophelia*/logs/hires/mosaic_hires.jpg

These small oil droplets have seeped through the sediment and adhered to the top of methane hydrate. This image was taken at a depth of less than 1,000 m in the Gulf of Mexico. Image courtesy of Ian MacDonald, Texas A&M-Corpus Christi. http://oceanexplorer.noaa.gov/explorations/06mexico/logs/may08/media/oil_on_methane_600.html

Deepwater 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. The most common deep-sea reef-building coral in the Gulf is *Lophelia pertusa*.

Although deepwater coral reefs are normally associated with hardgrounds, the corals that form them can also grow on artificial surfaces, including shipwrecks and petroleum production platforms. In 2008, there were more than 4,000 active platforms in the Gulf of Mexico, and thousands of others that are no longer active. The focus of the *Lophelia* II 2012: Deepwater Platform Corals Expedition is to investigate the biology and ecology of deepwater corals and associated organisms growing on oil production platforms.

Corals are members of the phylum Cnidaria whose members are characterized by having stinging cells (nematocysts) that are used for feeding and defense. Individual coral animals are called polyps, each of which has an internal skeleton made of limestone (calcium carbonate). In many corals species, including those that build reefs, the polyps form colonies composed of many individuals whose skeletons are fused together. In other species, the polyps live as solitary individuals. Each polyp has a ring of flexible tentacles surrounding an opening to the digestive cavity. The tentacles contain nematocysts that usually contain toxins used to capture prey or discourage predators. Corals are sessile (they stay in one spot) thus they are dependent upon currents to bring food within the reach of their tentacles. *L. pertusa* feeds on a variety of phytoplankton and zooplankton species, as well as dead materials.



Coral polyp diagram. Courtesy Mel Goodwin.

The skeletons of individual corals are basically cup-shaped and provide protection as well as support for soft tissues. The fused skeletons of colonial corals may form boulders, plate-like structures, or complex branches. Large coral reefs develop over hundreds of years; some *L. pertusa* reefs are estimated to be more than 8,000 years old. As the corals reproduce, the skeletons of new corals grow on top of the skeletons of corals that have died (the lifespan of a single polyp is estimated as 10 – 15 years). *L. pertusa* grows at a rate that has been estimated to range between 4-25 mm per year, and produces complex branches and bushy colonies. This growth form aids feeding by reducing fast currents that could otherwise deform the soft polyps, and also produces strong and complex physical structures. Occasionally, highly branched colonies may partially collapse, producing rubble that traps sediments that add to reefs' stability. Over time, repeated cycles of coral growth, collapse, and sediment entrapment can produce large reefs and mounds that provide habitats for many other species.

For more information about Deepwater Coral Reef Ecosystems in the Gulf of Mexico, please see the Expedition Education Module for the *Lophelia* II 2012: Deepwater Platform Corals Expedition.

In this lesson, students investigate some aspects of form and function in *L. pertusa*, and use photographic imagery to estimate the growth rates of corals living on oil platform structures.

Learning Procedure

1. To prepare for this lesson:
   (a) Review the introductory essay for the *Lophelia* II 2012: Deepwater Platform Corals Expedition, and the background essay on measuring growth rates in *L. pertusa* (http://oceanexplorer.noaa.gov/explorations/12Lophelia/welcome.html). Download one or more images of a *Lophelia* coral colony from this Web site, or from the Photo and Video Log for the *Lophelia* II 2010: Oil Seeps and Deep Reefs expedition (http://oceanexplorer.noaa.gov/explorations/10lophelia/logs/photolog/photolog.html). Also download a close-up image showing one or more individual polyps of *L. pertusa*.
   (b) Review Learning Procedure Steps 2 – 4. Step 3 may be made more open-ended by having students provide their own materials for making models, but this will require additional time to complete the activity. Practice creating a "water current" with the funnel and plastic tubing. This will be easier if you have an assistant to pour the water or hold the funnel.

   The growth rate estimation activity (Step 5) may be done with digital images on computers or from copies of the printed images included with this lesson. (However, numbers provided for the sample calculations on pages 14 and 15 are only valid for the

A frame-grab from high-definition video camera on the *Little Hercules* ROV showing live branches of *Lophelia pertusa* (in white) growing over dead branches (in brown). Image courtesy of the NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar28-2-hires.jpg

printed pages.) If you want to use digital images, students may use rulers to measure directly from computer screens or may use an image analysis program such as ImageJ (a note about ImageJ is included in the *Guide for Estimating Size from Underwater Images*). The latter has the advantage of introducing students to a powerful analytic tool, but requires additional time to download and install the program, and for students to become familiar with it. If you decide to use ImageJ you should download the program and the "ImageJ Basics" handout from http://rsbweb.nih.gov/ij/download.html and http://rsbweb.nih.gov/ij/docs/pdfs/ImageJ.pdf, respectively; and download digital images of Appendix A from http://oceanexplorer.noaa.gov/explorations/12lophelia/edu/resources/media/5_6AppA.

2. Briefly introduce the *Lophelia* II 2012: Deepwater Platform Corals expedition and describe deepwater coral communities. Be sure to mention the connection to hardgrounds and hydrocarbon seeps, and say that the presence of deepwater coral communities is often an indication that petroleum deposits may be nearby. Show students image(s) downloaded in Step 1a. Emphasize that a central purpose of this expedition is to provide information needed to protect these deepwater coral ecosystems. Tell students that while deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, very little is known about the ecology of these communities or the basic biology of the corals that produce them.

   Ask students how they think *Lophelia* corals obtain their food. If they are unfamiliar with Cnidaria, briefly describe nematocysts, and how they are used to capture food. Be sure students understand that *Lophelia* corals are sessile, which means they have to depend upon water currents to bring food within reach of the tentacles and nematocysts. Call students' attention to the branching growth form of *Lophelia* colonies, and lead a discussion of how this structure might be related to how the corals take in their food. If necessary, remind them of the corals' dependence upon currents, and point out the soft, delicate structure of coral polyps. Students should realize (possibly with your help) that while *Lophelia* corals need currents to provide food, if currents are too strong they might make feeding difficult.

3. Tell students that their assignment is to plan and carry out an investigation using models to explain how the branching structure of *Lophelia* coral colonies may affect the corals' ability to take in food. Describe the materials that will be available with which to construct models, and also the equipment that will be available to test the models. State the maximum permissible size for the model, which depends upon the size of container available for testing. The planning phase of this assignment may be done in class

or as homework, but each student group should prepare a written description of their proposed model (with illustrations as necessary), and a description of the effect(s) that they expect a branching structure will have that might be related to corals' feeding.

Allow students to construct their models, then test each model by immersing it into an aquarium or plastic container that has been partially filled with water. Create a current by placing the open end of the plastic tubing into the container, then pouring water into the funnel. The height of the funnel above the aquarium will determine the strength of the current. Add a few drops of diluted food coloring near the end of the tubing to visualize the flow. Then add a few more drops into the flow upstream of the block. Students should see the coloring slow and eddy around the structure, simulating the motion of water around coral branches. You may need to remove some of the water from the container periodically if it becomes too full, or too densely tinted with food coloring.

When all groups have tested their models, each group should prepare and present a short presentation about how the branching structure of *Lophelia* coral colonies may affect the corals' ability to take in food, based on evidence that they obtained from testing their models. The emphasis of these presentations should be upon arguing from evidence and relating the structure of colonies to the feeding function of polyps. In general, students should recognize that the branched structure of the corals reduces current flow, which in turn causes suspended particles to become available to coral polyps and other organisms sheltering beneath the coral branches. The reduced flow is also less likely to deform the coral polyps, which have to be extended during feeding.

4. Review (if necessary) the concept of rate as it applies to change over time (Common Core State Standards for Mathematics, Grade 6: Ratios and Proportional Relationships). Show students Figure 4 from Appendix A, and ask how this image could be used to estimate the rate of coral growth. If students have difficulty with this question, ask what information would be needed to estimate growth rate from the image. Students should recognize that a measurement of the size of the coral colony is needed, as well as an estimate of how old it might be. If we assume that the colony began with a single individual attached to a structure, and then expanded uniformly from the point of attachment, the radius of the colony divided by the age of the colony provides a reasonable estimate of growth rate.

   Focus on the question of coral age, draw attention to the structure in the image that appears to be made by humans, and ask what this structure might be. Students should identify portions of a shipwreck or oil rig as being among the possibilities. Point out that as long as the specific ship or rig can be identified, the age of these structures is usually known.

Turn the discussion to the question of size. Students should recognize that a scale (such as a ruler) or other reference point of known size is needed in the image. Say that many underwater photography systems use a system of lasers to overcome this problem. These systems typically have two lasers whose beams are parallel and a known distance apart. This places two bright dots on the image that establish the scale. In Appendix A, Figure 1, the dots on the image are 10 cm apart. These images were made on shipwrecks whose date of sinking is known.

Figures 2 through 13 use the size of the structure (which was previously measured with the laser dot method) to establish the scale of the images. These images were made on oil platforms whose ages are known.

5. Provide each student group with five images (either printed or as digital files) a copy of the *Guide for Estimating Size from Underwater Images*, and a copy of the *Coral Growth Estimation Worksheet*. Say that their assignment is to estimate the growth rate of the corals in the images from the colony size and age of the structure. Students, correctly, may say that the corals may not be the same age as the structure, since the larva that began the colony could have settled anytime after the structure was in place. So, if we assume that the coral is the same age as the structure, the growth rate we calculate is the minimum rate that would result in the observed colony size (because if a coral is younger than the structure, it must have grown more rapidly to achieve the size recorded in the image).

When each group has completed their measurements, compare students' results with the data in Table 1. The emphasis of this activity should be on the analysis and

Table 1
Estimates of Coral Growth Rate from Figures 1 – 13

Rig/Wreck	Coral No.	Structure Diameter (cm)	Depth (m)	Radius (cm)	Min Growth Rate (cm/year)
Gulf Penn	Coral–1	laser dots	--	75 cm	1.12
Rig A	Coral_3	14.3	396	28.14	1.88
Rig A	Coral_23	14.3	403	22.83	1.52
Rig A	Coral_28	14.3	378	22.22	1.48
Rig A	Coral_33	14.3	384	21.62	1.44
Rig B	Coral_15	60.9	390	37.2	4.13
Rig B	Coral_90	60.9	420	28.22	3.14
Rig B	Coral_94	60.9	423	28.02	3.11
Rig B	Coral_95	60.9	393	27.99	3.11
Rig C	Coral_5	320	336	48.2	2.84
Rig C	Coral_6	267	359	47.89	2.82
Rig C	Coral_24	137	359	42.3	2.49
Rig C	Coral_38	107	315	39.69	2.33

interpretation of image data, and on understanding how scale and proportion are applied to estimate coral size and growth. Students' estimates do not need to exactly match the data in Table 1, but they should be reasonably close.

The BRIDGE Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, scroll over "Ocean Science Topics," then "Human Activities," then click "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay about why it might be personally important to protect deepwater coral reef ecosystems.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Student presentations, answers to worksheet questions, and class discussions provide opportunities for assessment.

Extensions

1. Have student groups pool their data from Step 4, and look for trends such as variation among different rigs.

2. Have students read the background essay on *Lophelia* growth rate measurement (see Step 1), then describe the benefits and drawbacks of each method discussed.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 6, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Deep-Sea Benthos, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Life on the Hardbottom
(from the *Lophelia* II 2010 Expedition)
http://oceanexplorer.noaa.gov/explorations/10lophelia/background/edu/media/loph10_hardbottoms56.pdf

Focus: Hardbottom Biotopes in the Gulf of Mexico (Life Science)

Students define and contrast the terms biotope, habitat, and ecosystem; explain what hardgrounds are; describe major biotopes associated with hardgrounds in the Gulf of Mexico; and give examples of at least three species associated with each biotope.

The Robot Ranger
(from the *Lophelia* II 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09ranger.pdf

Focus: Robotic Analogues for Human Structures (Distance Estimation) (Life Science/Physical Science)

Students describe how humans are able to estimate the distance to visible objects, and describe a robotic system with a similar capability.

Entering the Twilight Zone
(from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/zone.pdf

Focus: Deep-sea habitats (Life Science)

Students describe major features of cold seep communities, list at least five organisms typical of these communities, infer probable trophic relationships within and between major deep-sea habitats, describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major deep-sea habitats and list at least three organisms typical of each habitat.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/edu/guide/gomdse_edguide.pdf – Educators' Guide for the Gulf of Mexico Deep-Sea Ecosystems Education Materials Collection.

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system.

http://www.gulfallianceeducation.org – Extensive list of publications and other resources from the Gulf of Mexico Alliance

Fisher, C., H. Roberts, E. Cordes, and B. Bernard. 2007. Cold Seeps and Associated Communities of the Gulf of Mexico. *Oceanography* 20(4):118-129; available online at http://www.tos.org/oceanography/archive/20-4_fisher.html

Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). 2008. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - *Lophelia* Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; http://fl.biology.usgs.gov/coastaleco/

Standards Correlations

Relationship to A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas

The objectives of this lesson integrate the following Practices, Crosscutting Concepts, and Core Ideas:

Objective: Students will plan and carry out an investigation using models to explain how the branching structure of *Lophelia* coral colonies may affect the corals' ability to take in food.

Practices:

2. Developing and using models
3. Planning and carrying out investigations

Crosscutting Concepts:

6. Structure and function

Core Ideas:

LS1.A: Structure and Function
LS1.C: Organization for Matter and Energy Flow in Organisms

Objective: Students will communicate results of this investigation and cite evidence to support inferences about the relationship between structure of *Lophelia* coral colonies and the feeding function of individual coral polyps.

Practices:

7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts:

6. Structure and function

Core Ideas:

LS1.A: Structure and Function
LS1.C: Organization for Matter and Energy Flow in Organisms

Objective: Students will analyze and interpret data from photographic images and use concepts of proportion and scale to estimate the growth rate of *Lophelia* coral colonies.

Practices:

4. Analyzing and interpreting data
5. Using mathematics and computational thinking

Crosscutting Concepts:

3. Scale, proportion, and quantity

Core Ideas:

LS1.B: Growth and Development of Organisms

Correlations to Common Core State Standards for Mathematics

6.RP – Understand ratio concepts and use ratio reasoning to solve problems.

Correlations to Common Core State Standards for English Language Arts

RI.4 – Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings.

W.1 – Write arguments to support claims with clear reasons and relevant evidence.

SL.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own creativity

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

Guide for Estimating Size from Underwater Images

Underwater robots are our eyes into Earth's deep ocean. As digital imaging technology continues to improve, views through these robot eyes are beautiful and fascinating (see, for example, http://oceanexplorer.noaa.gov/okeanos/media/slideshow/flash_slideshow.html and http://oceanexplorer.noaa.gov/okeanos/media/slideshow/video_playlist.html).

One problem with most images from underwater robots is that they are two-dimensional, so it can be very difficult to accurately judge the size of organisms and ecosystem features. To overcome this problem, underwater photography systems use a system of lasers. Digital still cameras typically have two lasers whose beams are parallel and a known distance apart. This places two bright dots on each image that establish the scale of the image. In Figure A, the dots near the lower center of the image are 10 cm apart. Using a ruler, you can measure the distance between these dots which is about 23 mm. Suppose you want to know the width of the body of the white anemone on the right side of Figure A. Measure this distance, which turns out to be about 17 mm. Since you know that a measured distance of 23 mm is equal to an actual distance of 100 mm, you can set up an equation to find the actual width of the anemone:

$$\frac{23\text{ mm (measured)}}{100\text{ mm (actual)}} = \frac{17\text{ mm (measured)}}{X\text{ mm (actual)}}$$

So,

$$X \bullet 23\text{ mm (measured)} = 17\text{ mm (measured)} \bullet 100\text{ mm (actual)}$$

Then,

$$X = \frac{17\text{ mm (measured)} \bullet 100\text{ mm (actual)}}{23\text{ mm (measured)}} = 73.9\text{ mm (actual)}$$

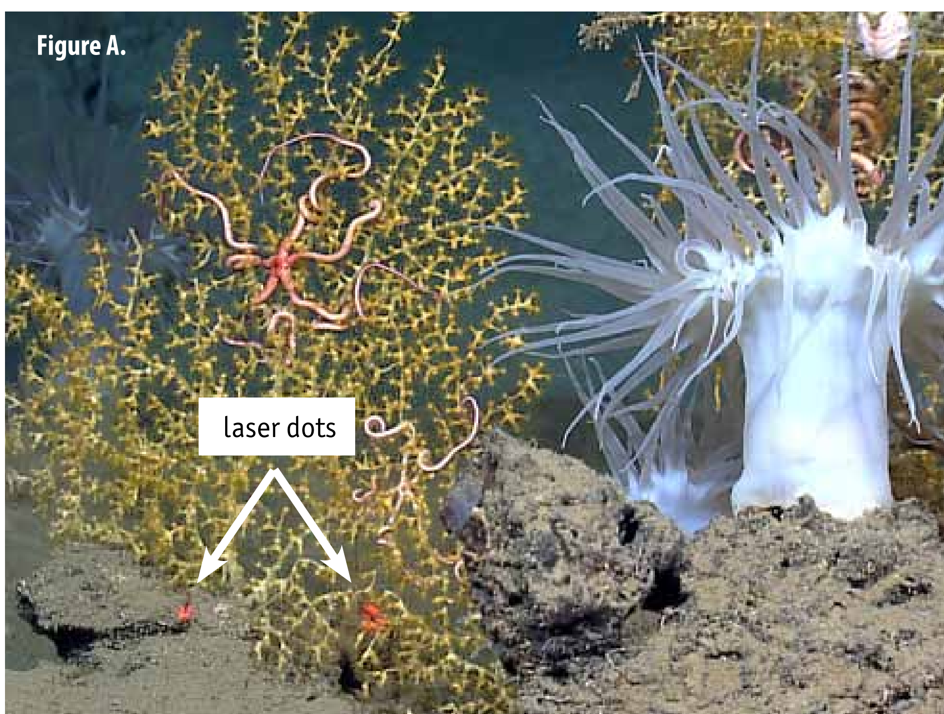

Figure A. A brittlestar living on a paramuricid coral adjacent to a large white anemone. This community is on the edge of a carbonate rock in Mississippi Canyon lease block 297. From the *Okeanos Explorer* Gulf of Mexico 2012 Expedition. Image courtesy of NOAA *Okeanos Explorer* Program.

If you know the size of one object in an image, you can use that information to estimate the size of other objects. Figure B is an image of a *Lophelia* coral colony growing on part of an oil rig. The diameter of the structure (green line in Figure B) is 14.3 cm. If you measure the green line, you find its length is about 2.2 cm. If you measure the diameter of the coral colony (blue line in Figure B), you find it is about 6.1 cm long. Now you can set up an equation to find the actual diameter of the coral colony:

$$\frac{2.2 \text{ cm (measured)}}{14.3 \text{ cm (actual)}} = \frac{6.1 \text{ cm (measured)}}{X \text{ cm (actual)}}$$

So,

$$X \bullet 2.2 \text{ cm (measured)} = 6.1 \text{ cm (measured)} \bullet 14.3 \text{ cm (actual)}$$

Then,

$$X = \frac{6.1 \text{ cm (measured)} \bullet 14.3 \text{ cm (actual)}}{2.2 \text{ cm (measured)}} = 39.7 \text{ cm (actual)}$$

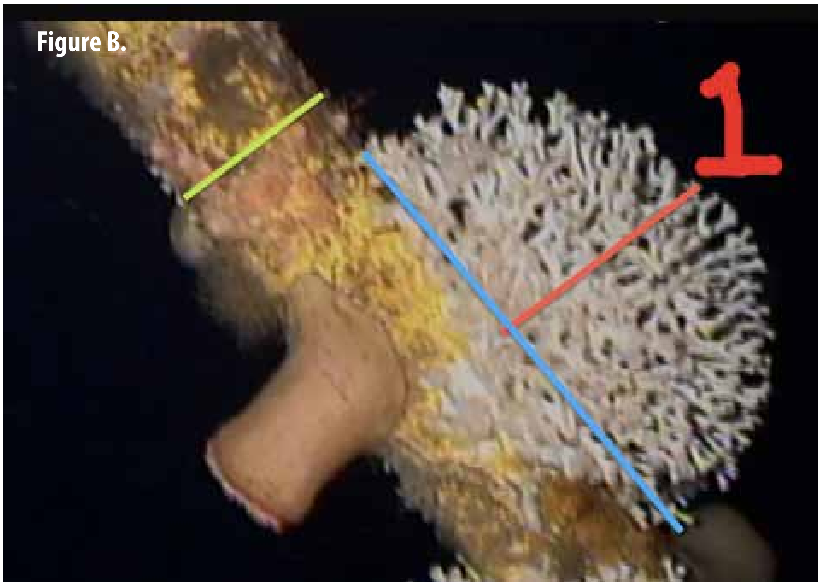

Figure B. A colony of *Lophelia pertusa* growing on an oil platform structure in the Gulf of Mexico. This structure had been in the water for 14 years when the image was made. Image courtesy of Chuck Fisher Lab, Penn State University.

We can use this measurement to estimate the growth rate of the coral colony. We assume that a coral larva settled and began to grow as soon as the structure was placed in the water, and that the coral colony grew steadily outward from the place where the larva settled. Since the coral colony grew in many directions at the same time, we use the radius of the colony to estimate the rate at which the colony grew in one direction. The radius of the colony is 19.9 cm. We know the structure had been in the water for 14 years when the image was made. So if the colony grew 19.9 cm in 14 years, the minimum growth rate was 19.9 cm ÷ 14 yr = 1.42 cm/yr.

You can do more sophisticated analyses with image analysis software. ImageJ is a very powerful image analysis program developed by the National Institutes of Health, and is free to the public. Links for downloading, tutorials, and full documentation are available at: http://rsbweb.nih.gov/ij/index.html. In ImageJ you can open a digital image and set the scale simply by drawing a line along a known distance (such as laser dots), then entering this distance in a drop-down window. Now any other object in the image can be measured and ImageJ will automatically display the actual size of the object.

Coral Growth Estimation Worksheet

Rig	Age of Rig	Coral No.	Diameter of Structure (cm)		Diameter of Coral Colony (cm)		Radius of Coral Colony (cm)	Minimum Growth Rate (cm/yr)
			Measured	Actual	Measured	Actual		

Calculations (if necessary!):

Appendix A

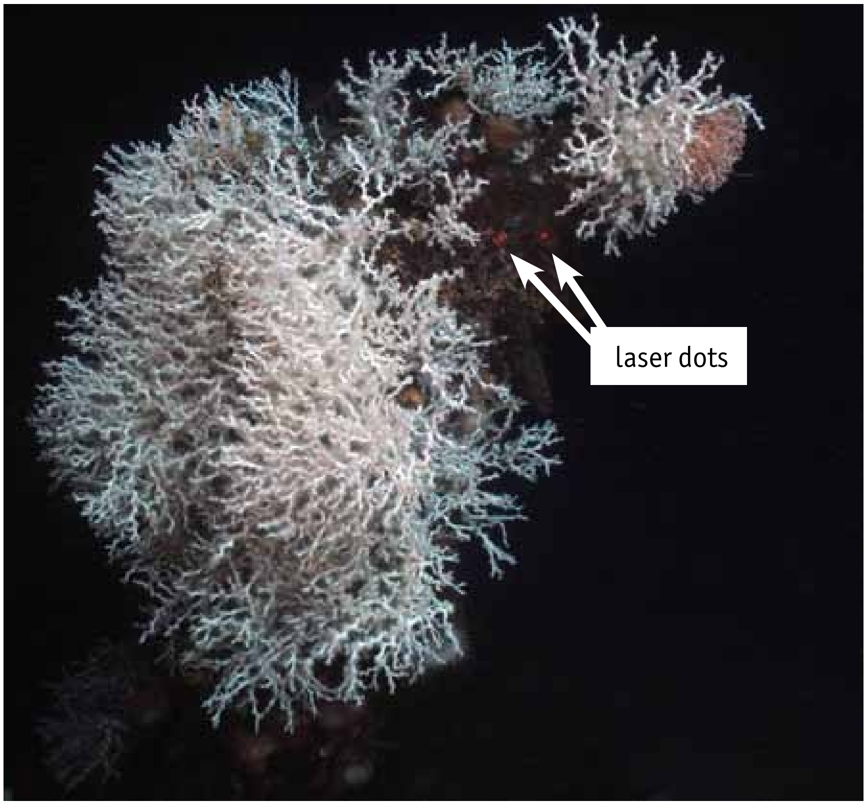

Figure 1. *Lophelia* colony growing on wreck of the tanker Gulf Penn, sunk by a submarine on May 13, 1942. Image made in 2010. Image courtesy of *Lophelia* II 2010 Expedition, NOAA-OER/BOEM.

Note: The red numbers on the following images are irrelevant to the activity.

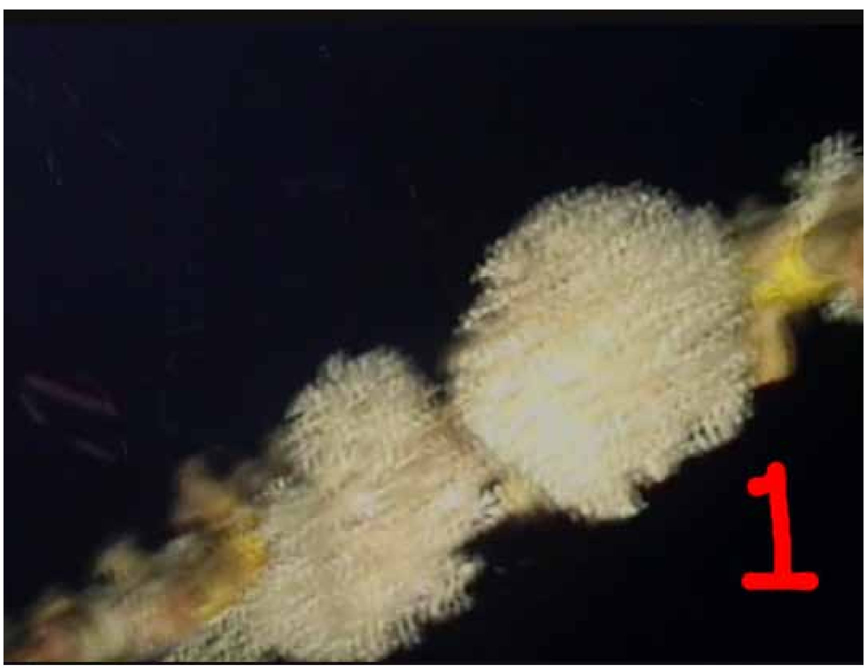

Figure 2. *Lophelia* coral #3 growing on Rig Platform A. Structure Diameter = 14.3 cm. Image made 15 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

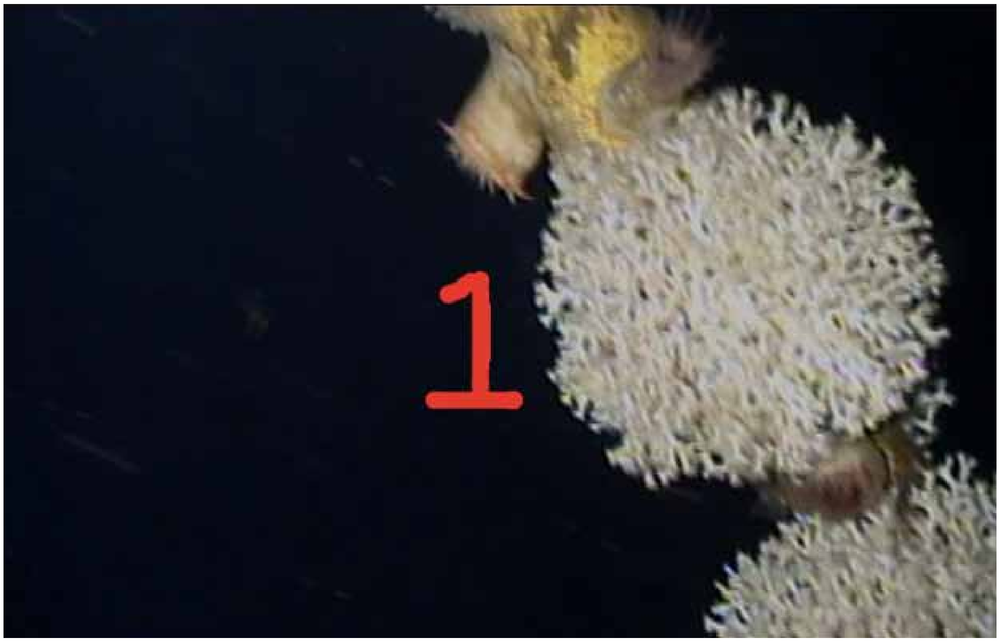

Figure 3. *Lophelia* coral #33 growing on Rig Platform A. Structure Diameter = 14.3 cm. Image made 15 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

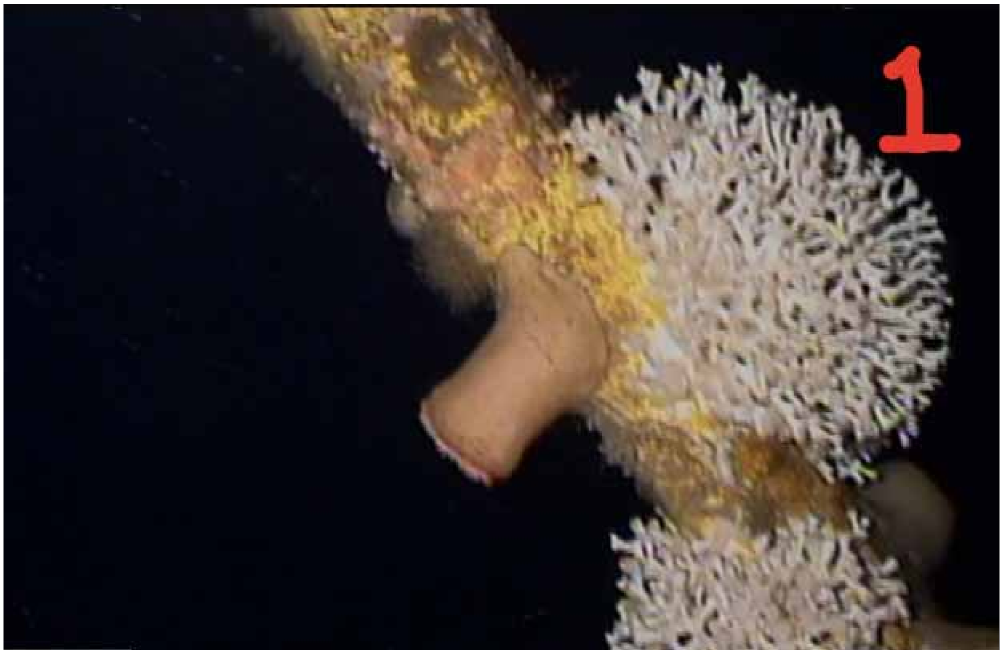

Figure 4. *Lophelia* coral #23 growing on Rig Platform A. Structure Diameter = 14.3 cm. Image made 15 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 5. *Lophelia* coral #28 growing on Rig Platform A. Structure Diameter = 14.3 cm. Image made 15 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 6. *Lophelia* coral #94 growing on Rig Platform B. Structure Diameter = 60.9 cm. Image made 9 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 7. *Lophelia* coral #95 growing on Rig Platform B. Structure Diameter = 60.9 cm. Image made 9 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 8. *Lophelia* coral #15 growing on Rig Platform B. Structure Diameter = 60.9 cm. Image made 9 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 9. *Lophelia* coral #90 growing on Rig Platform B. Structure Diameter = 60.9 cm. Image made 9 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

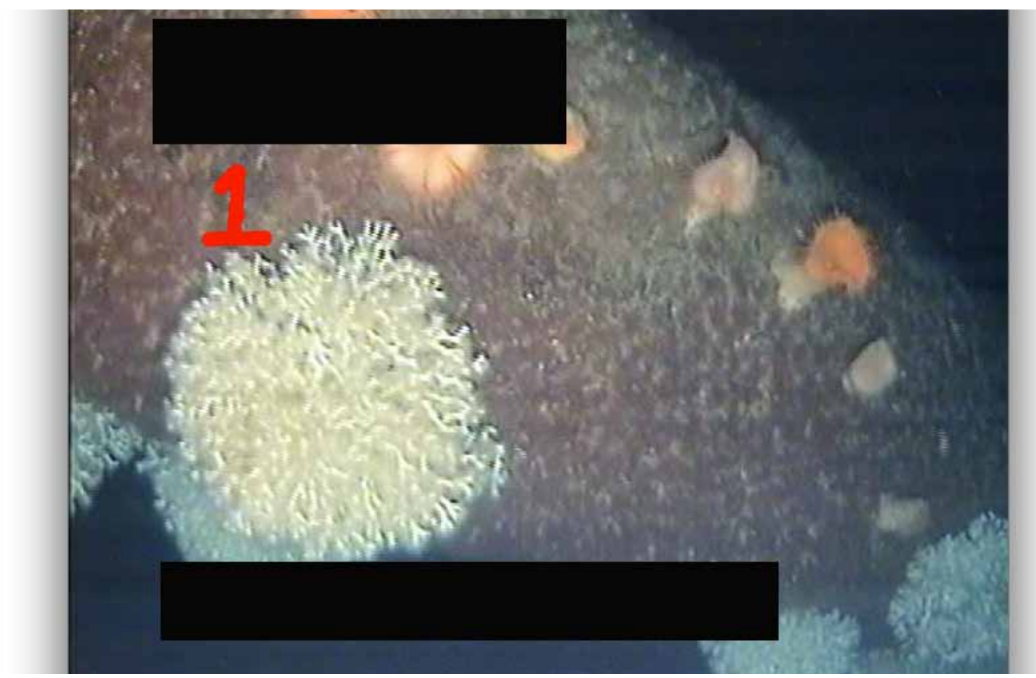

Figure 10. *Lophelia* coral #24 growing on Rig Platform C. Structure Diameter = 137.2 cm. Image made 17 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 11. *Lophelia* coral #38 growing on Rig Platform C. Structure Diameter = 106.7 cm. Image made 17 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

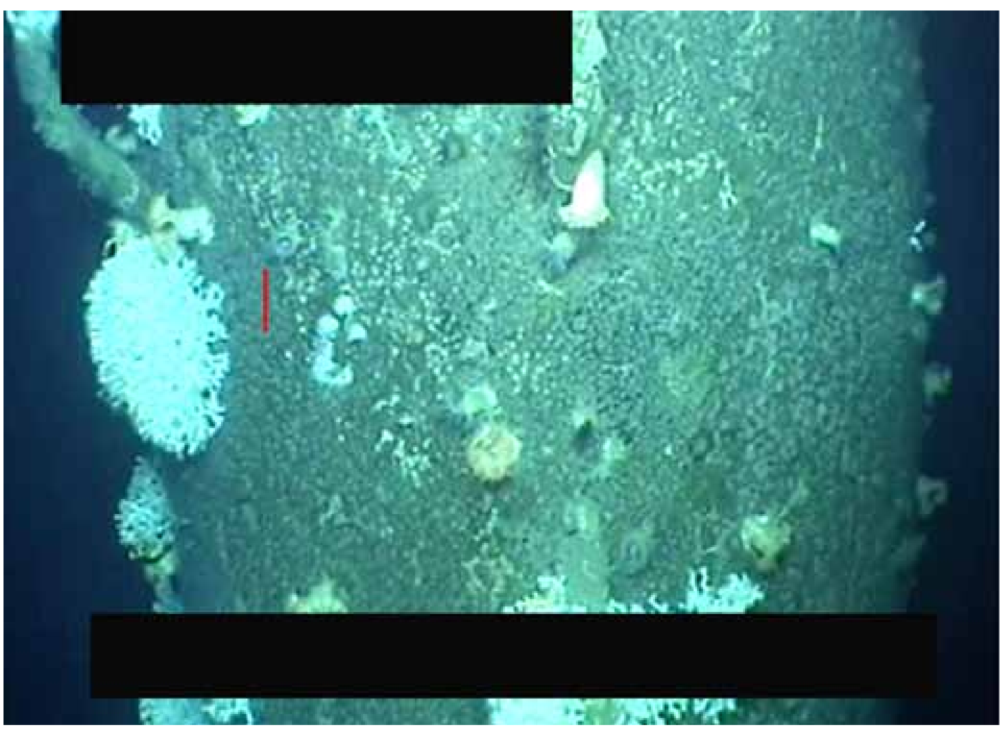

Figure 12. *Lophelia* coral #5 growing on Rig Platform C. Structure Diameter = 320 cm. Image made 17 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.

Figure 13. *Lophelia* coral #6 growing on Rig Platform C. Structure Diameter = 267 cm. Image made 17 years after structure was placed in the water. Image courtesy Chuck Fisher Lab, Penn State University.