Coral Growth: Photosynthesis & Calcification

Materials

For the leader:

Projector

Whiteboard to project data graph onto

For the activity:

Copy of coral data table

Computer program to graph in or graphing paper

Copy of student worksheet

Copy of coral images

Overview

Bacteria, algae, and plants make adjustments to the photosynthetic processes depending on the amount of light available to the organism, meaning they acclimate to their surroundings (photoacclimation). Scientists study photoacclimation within an organism to determine how the organisms acclimate to its surroundings. Scientists can use these data to hypothesize how different organisms will respond to future environmental changes, for example increased sea surface temperature from climate change.

In this activity students will investigate how light and carbon availability may effect coral growth. Corals use dissolved inorganic carbon from seawater to create its calcium carbonate skeleton and in the process releases carbon dioxide (**calcification**: $Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$). Therefore, corals much live in water that have sufficient quantities of dissolved carbon. Although corals are animals their symbiotic relationship with zooxanthellae, **photosynthetic** algae ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$), means that coral survivability also is influenced by light availability. If there is not enough light for the zooxanthellae to survive then the corals will also suffer. Interestingly, the carbon dioxide produced by corals during calcification can enhance the ability of zooxanthellae to complete photosynthesis. Therefore, corals and zooxanthellae can grow in areas with less carbon but are still limited by the amount of light available to them.

Using data from Dr. Tali Mass's research, students will plot the relationship between photosynthesis and depth as well as calcification and depth for corals in the Red Sea. They will use these data in combination with knowledge of morphological differences in corals with depth to brainstorm what might happen to corals as the sea surface temperature increases. The activity places a strong emphasis on teaching students how to look at multiple data sources to draw conclusions. The students first need to plot two data sources and then interpret the data with additional information for conclusions. Through gaining these data interpretation skills, students will also gain a better understanding of how scientists look at evidence when asking questions about the variables effecting coral growth/morphology and make predictions of future impacts of climate change and rising sea surface temperatures on corals.

Motivating Questions: **What do scientists study that effects coral growth? What does that information tell us about how corals will adapt to the changing climate?**

Take Home Message

Scientists use data from multiple variables to investigate potential causes of visible differences in coral growth. Gaining a better understanding of what influences coral growth under different conditions currently can guide scientists' predictions of future changes in coral growth due to climate change.

Engage: Lead the students in a discussion about what they know about	10 minutes

corals, zooxanthellae, and coral growth. Share the images of different coral morphology with depth.	
Explore: Students investigate data of photosynthesis and calcification with depth.	25 minutes
Make Sense: Students use the coral images, photosynthesis, and calcification data to make predictions about future impacts on corals with increasing sea surface temperatures.	10 minutes
Total:	**45 minutes**

Audience

High school students (9th-12th grade).

New Jersey Core Curriculum Content Standards - Science

Grade	Content Statement	CPI#
12	Mathematical tools and technology are used to gather, analyze, and communicate results	5.1.12.B.2
12	Empirical evidence is used to construct and defend arguments.	5.1.12.B.3
12	Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.	5.1.12.B.4
12	Chemical equilibrium is a dynamic process that is significant in many systems, including biological, ecological, environmental, and geological systems. Chemical reactions occur at different rates. Factors such as temperature, mixing, concentration, particle size, and surface area affect the rates of chemical reactions.	5.2.12.D.5
12	As matter cycles and energy flows through different levels of organization within living systems, and between living systems and the physical environment, chemical elements are recombined into different products.	5.3.12.B.1
12	Continual input of energy from sunlight keeps matter and energy flowing through ecosystems.	5.3.12.B.3
12	In both plant and animal cells, sugar is a source of energy and can be used to make other carbon-containing (organic) molecules.	5.3.12.B.5
12	Biological communities in ecosystems are based on stable interrelationships and interdependence of organisms.	5.3.12.C.1
12	Stability in an ecosystem can be disrupted by natural or human interactions.	5.3.12.C.2
12	Human activities have changed Earth's land, oceans, and atmosphere, as well as its populations of plant and animal species.	5.4.12.G.5

Preparation (15 minutes)

1. Write the motivating questions on the board:

   What do scientists study that effects coral growth? What does that information tell us about how corals will adapt to the changing climate?

2. Make class copies of student worksheets for each student (at the end of this write-up).
3. Make copies of the different coral morphology images for each student group/table (at the end of this write-up).

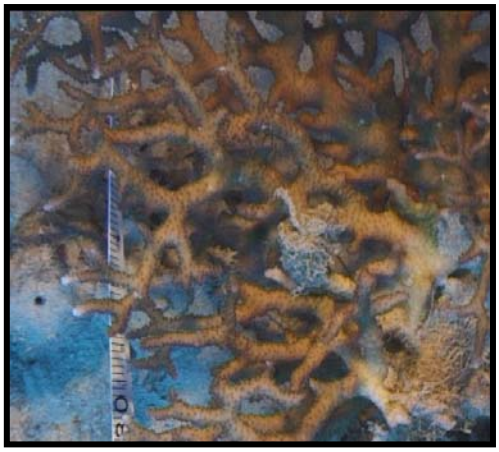


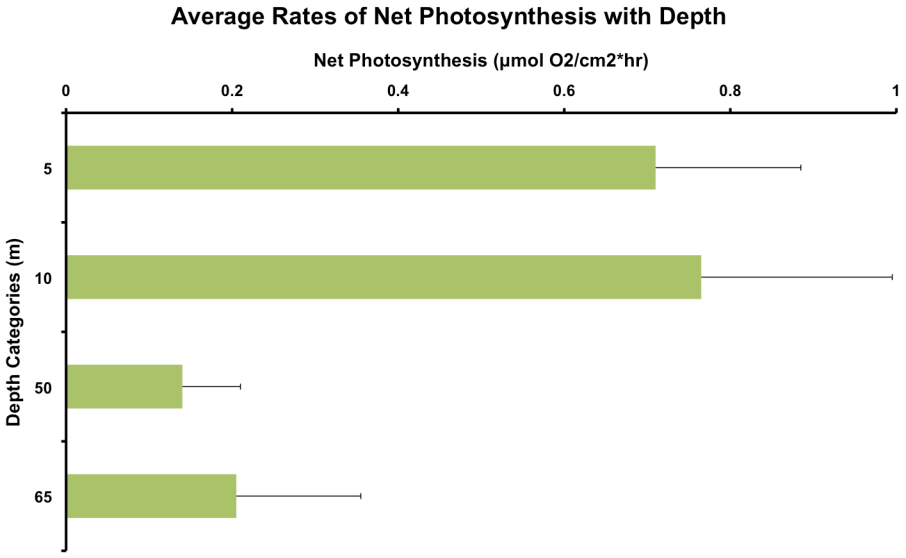
Figure 16: Colony morphology-Shallow water colonies are sub-spherical and whitish (left), deep water colonies are planar, with the upper part dark, while its bottom facing part is pale (right).

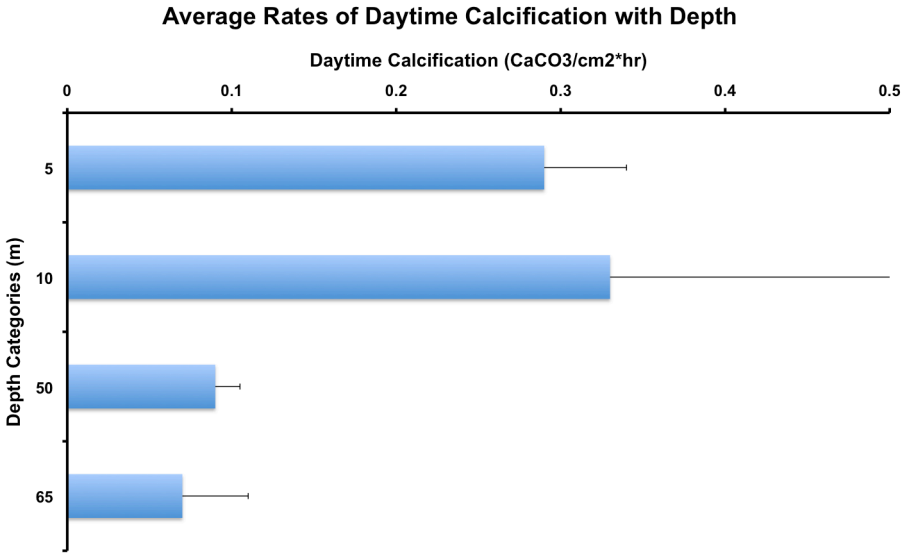
4. Write the chemical equations for photosynthesis and calcification on the board.

   Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

   Calcification: $Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$

5. Make or project a graph of the data on the board, but make sure it is hidden from the students.





Engage (10 minutes)

1. Lead the students in a discussion about corals, zooxanthellae, and coral growth.

Q. What do you know about corals? Where do they grow? What do they need to survive? Does one species always look the same?

Q. What do you know about symbiosis? Symbionts? Zooxanthellae? Where do they live? What do they need to survive? (Note – these questions will depend on what level of background knowledge your students have.)

Q. Why would scientists be interested in understanding changes in coral growth in current ocean conditions? What might this help us understand about corals in future ocean conditions?

2. Be accepting of all responses from the students.
3. After a minute or two, and depending on what the students already know, share some information with them that you feel they need to know to understand the activity of the day. (Note – it might be helpful to show the students the chemical equations for photosynthesis and calcification and review which organism performs which process.)
4. Then pass out the images of the different coral morphologies. Tell the students that both of the images are of the same species of the hard coral *Stylophora pistillata* in the Red Sea (just taken from different depths). Have the students brainstorm in small groups why the corals may look differently from one another.

Explore (25 minutes)

1. Explain to the students that they will be taking a closer look at two variables that affect coral growth in relation to depth. In fact they will be making their own plots of these variables with depth to look for patterns and trends in the data and looking for the relationship between this data and the differences in coral growth they observed in the images.
2. Explain the data preparation portion of the investigation to the students:
    a. In a few moments they will receive a data table of the average Net Photosynthesis, Daytime Calcification, and Depth categories from the Red Sea.

b. Before they obtain the data, however, they need to come up with a hypothesis about the relationship between photosynthesis and depth. They should use their prior knowledge about photosynthesis and light in the ocean, but should NOT look at the data.

c. Next, they need to come up with a hypothesis about the relationship between daytime calcification and depth. They should use their prior knowledge about calcification and carbon in the ocean, but should NOT look at the data.

3. Ask the students what did they decide about the relationship between photosynthesis and depth? What did they decide about calcification and depth? Call on different students or student groups to share their opinions. Allow them to discuss for a few minutes but stress that they do NOT need to come to a consensus as a class.

4. Explain the data plotting and interpretation portion of the investigation:

   a. First, the students should look at the photosynthesis and depth data. Then the students should look at the calcification and depth data.

   b. Ask the students:

      i. What kind of graph will we use? (Reverse bar graph)

      ii. What is the x-axis? (Net Photosynthesis or Daytime Calcification)

      iii. What is on the y-axis? (Depth)

   c. Then have the students plot the two data sources on different graphs. (Note – If possible, have your students also plot the standard deviation for the averages to support their understanding that there is always variation around an average value.)

   d. Have the students look at the two graphs to find trends and patterns and complete the student worksheet.

   e. Make sure to point out the chemical equations for photosynthesis and calcification on the board to the students for them to think about when completing the activity.

5. As the students finish their graphs and answering the questions on the student worksheet, ask them to write responses to:

   Q. How do the patterns of photosynthesis and calcification with depth relate to the observed differences in coral growth?

   Q. How can these patterns help us make predications about the effects of increased sea surface temperature on coral growth?

Make Sense (10 minutes)

1. After a few minutes of writing their responses, tell the students that we are going to interpret and analyze the data as a class.

2. Have the students report out what patterns and trends they observed in the photosynthesis and calcification data with respect to depth. Make sure to have the students support their statements of the patterns and trends by stating what evidence they are using. Help the students see that while there is variation, photosynthesis and calcification decrease with depth.

3. Lead the students in a discussion about these observed trends and the coral growth differences with depth. Some discussion points you might want to hit on:
    a. Help the students think about what it means for coral growth at depth if both calcification and photosynthesis is decreased at depth.

        Corals are not able to grow as well because of many factors: a decreased efficiency in making their skeletal structures, which reduces the amount of carbon dioxide and water that they produce, which means there is less carbon dioxide available for the zooxanthellae to use during photosynthesis, additionally at greater depths there is less light, so the zooxanthellae are less able to complete photosynthesis, so they produce less sugar, lipids, and oxygen that the corals need to grow.

    b. Then help the students think about why it is important for scientists to understand these natural variations in coral growth across a depth gradient.

        By understanding these variations scientists are able to put together a clearer picture of what is the natural range of processes and adaptations that exist within a population. Understanding these variations enables scientists to observe new variations and make predictions about what might happen under different conditions in the future.

    c. Help the students think about what this means for coral growth if the sea surface temperature continues to rise with climate change so that corals can no longer live at the surface. (Note – this is a brainstorming activity, there are no correct answers.)

        In general if the sea surface temperature rises, corals will not be able to survive in the shallower areas of their range. Corals at a greater depth will be less affected, as it is cooler with depth, but those corals do not grow as well. Therefore, the shallow coral morphology may be lost and the surviving corals will not grow as well overall.

4. Once the discussion slows down, point to the motivating questions and ask:
   Q. What do scientists study that effects coral growth? What does that information tell us about how corals will adapt to the changing climate?
5. Ask students to share their ideas about the questions with a partner. After a minute, ask volunteers to share the ideas they discussed with the entire class. Be accepting of all responses from the students. This is your opportunity to make sure the students understand the "take home message".
6. Ask if the students have any final questions about the activity, graphing, or relationship between coral growth and climate.

Coral Growth: Photosynthesis & Calcification

Name: _____

Date: _____

Coral Data Table –

Depth (m)	Net Photosynthesis (µmol O2/cm2*hr)	Net Photosynthesis Standard Deviation (STD)	Daytime Calcification (µmol CaCO3/cm2*hr)	Daytime Calcification Standard Deviation (STD)
5	0.71	0.18	0.29	0.05
10	0.77	0.23	0.33	0.20
50	0.14	0.07	0.09	0.02
65	0.21	0.15	0.07	0.04

Use the data above, the images of the coral morphology, and the chemical equations for photosynthesis and calcification to answer the following questions.

1. Describe the overall pattern of photosynthesis and depth.

2. Describe the overall pattern of calcification and depth.

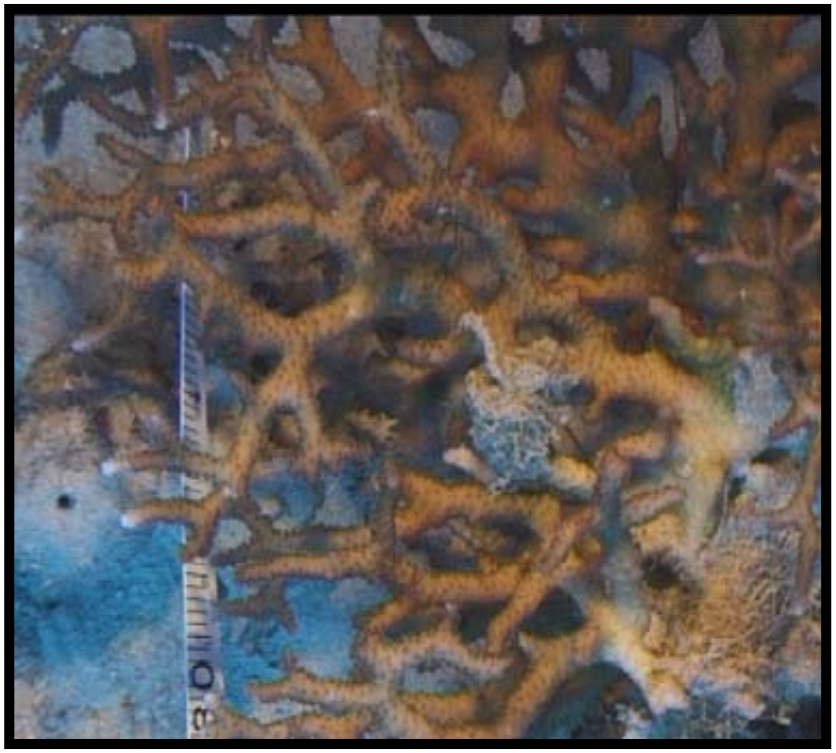
3. How are photosynthesis and calcification related?

Writing Prompts:

Q. How do the patterns of photosynthesis and calcification with depth relate to the observed differences in coral growth?

Q. How can these patterns help us make predictions about the effects of increased sea surface temperature on coral growth?

Coral Growth: Photosynthesis & Calcification
Coral Images



Images of the hard coral *Stylophora pistilla* in the Red Sea. Images of this coral were taken in shallow water (top picture) and in deep water (bottom picture).

Coral Growth: Photosynthesis & Calcification Worksheet – Answer Key

Name: _____

Date: _____

Use the data above, the images of the coral morphology, and the chemical equations for photosynthesis and calcification to answer the following questions.

1. Describe the overall pattern of photosynthesis and depth.

The average rate of net photosynthesis decreases with depth.

2. Describe the overall pattern of calcification and depth.

The average rate of daytime calcification decreases with depth.

3. How are photosynthesis and calcification related?

Both photosynthesis and calcification require dissolved inorganic carbon. Corals use calcium (Ca^{2+}) and bicarbonate (HCO_3^-) from the seawater to form calcium carbonate ($CaCO_3$) to form their skeletal structures. In the process, water (H_2O) and carbon dioxide (CO_2) are released into the water. Zooxanthellae in the corals use carbon dioxide (CO_2) and water (H_2O) from the seawater to form glucose ($C_6H_{12}O_6$) and oxygen (O_2).

Writing Prompts:

Q. How do the patterns of photosynthesis and calcification with depth relate to the observed differences in coral growth?

The differences in the morphology of the corals in shallow vs. deep areas could be due to the reduced light intensity and thus the corals must acclimate to the different light levels. At depth, the corals are more horizontal and fan shaped to maximize the amount of light harvesting by the zooxanthellae. Also the fan shape provides more volume to projected area, which increases the exposure of the corals to calcium and bicarbonate in the water. Therefore, the corals change their shape to maximize the photosynthesis and calcification potential in areas where it is limited. In addition, the corals at greater depths are a darker color due to an increased amount of pigment that can harvest light for photosynthesis in the zooxanthellae. Therefore, the zooxanthellae have also adapted to the more light limited conditions at greater depths to maximize their ability to photosynthesize.

Q. How can these patterns help us make predictions about the effects of increased sea surface temperature on coral growth?

With increased sea surface temperatures corals will die at the surface. While some marine organisms, like fish, are able to move into waters that are more suitable for their physiological needs by moving deeper or farther north, corals are not able to move like that. Corals are stationary creatures. Also, corals do not grow as well at deeper depths due to the limited light availability. So if all of the corals at the surface die, then we will only be left with the deep coral growth patterns.