Teaching Units for High School Science Developed by
Duke University Graduate Students in Pharmacology 693/694

http://sites.duke.edu/rise/duke-courses/pharm-693694/

Prepared by Marie Perkins, Duke University

The Chemistry of Coral Bleaching

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The Chemistry of Coral Bleaching-Unit Plan

Stage 1—Desired Results

Established Goals

North Carolina Standard Course of Study:

- **Bio.2.1** Analyze the interdependence of living organisms with their environment.
- **Bio.2.2** Understand the impact of human activities on the environment.
- **Chm 3.1** Understand the factors affecting rate of reaction and chemical equilibrium
- **Chm.3.2** Understand the solutions and the solution process

Next Generation Science Standards

- ***PS1.B: Chemical Reactions –*** *Chemical processes, their rates and whether or not energy is stored or released.*
  - **HS-PS1-2:** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
  - **HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which reactions occur

Understandings:
Students will be able to . . .

- Analyze interactions in ecosystems and the result in the movement of matter and energy relating to the significance of each to maintain the health and sustainability of an ecosystem.
- Describe human activities (including pollution, global warming) and how they may impact the environment from one generation to the next.
- Explain various ways organisms interact with each other (through symbiosis) resulting in stability within ecosystems
- Classify substances using the hydronium and hydroxide concentrations
- Summarize the properties of acids and bases
- Chemically test for pH
- Identify trends using mathematical modeling to predict possible future occurrences
- Identify the parts of a coral
- Describe the relationship between pigment and color as it relates to corals and coral bleaching

Essential Questions:

- What are the effects of human activities on the overall health of coral reefs?
- How does the chemistry of the ocean affect the life of a coral?
- What is the importance of symbiotic relationships to ecosystem sustainability?
- How does the chemistry of corals relate to the chemistry of humans?
- What is photosynthesis and how is it important to coral health?
- What are some environmental triggers that cause coral bleaching?
- How does coral health depend on atmospheric carbon dioxide and climate change?

<table>
<tr><th colspan="2">Stage 2—Assessment Evidence</th></tr>
<tr><td>

Performance Tasks:

- *Anatomy of Coral Mini-Lab:* Students will construct and subsequently identify the parts of a coral polyp, which make up a coral.
- *Plant Pigment Identification Mini-Lab:* Students will extract pigments from the biological sources and obtain color profiles by altering the pH of the extracts
- *Corals and Chemistry Mini-Lab:* “Climate change and its effect on coral reefs” – students will evaluate the dependence of coral health on atmospheric carbon dioxide and the chemical reactions involved.
- *Forecasting Bleaching Events Mini-lab:* Students will use data to identify hot spots and predict bleaching events

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Other Evidence:

- Stop and think questions throughout the activities

</td></tr>
<tr><th colspan="2">Stage 3—Learning Plan</th></tr>
<tr><td colspan="2">

Learning Activities:

(Day 1)

- Teacher provides PowerPoint and lecture outlining the introduction to corals and coral reefs: identifying parts of a coral, types of coral, the importance of coral reefs to other organisms and human life, and the symbiotic relationship between zooxanthellae and coral
- *Anatomy of Coral Mini-lab*: Students will work in lab groups to build a coral polyp in order to understand the anatomy of a coral.
- *Plant Pigment Identification Mini-Lab:* Students will work in groups to extract pigments from the biological sources and obtain color profiles by altering the pH of the extracts

(Day 2)

- Teacher provides PowerPoint and lecture outlining environmental triggers of coral bleaching, photosynthesis and its importance in the symbiotic relationship between zooxanthellae and corals.
- *Corals and Chemistry Mini-lab* – Students will work in lab groups to perform a simple chemical experiment in order to evaluate the dependence of coral health on atmospheric carbon dioxide and the chemical reactions involved.
- *Forecasting Bleaching Events Mini-Lab:* Students will use data to identify hot spots and predict bleaching events

</td></tr>
</table>

Daily Lesson Plan- Day 1

Course Name:	**Standard Honors AP**
Unit Title: The Chemistry of Coral Bleaching	**Day: 1 of 2**

Relevant NC Standard Course of Study Goal(s):
- **Bio.2.1** Analyze the interdependence of living organisms with their environment.
- **Bio.2.2** Understand the impact of human activities on the environment.

Relevant Next Generation Science Standards
- **PS1.B: Chemical Reactions –** Chemical processes, their rates and whether or not energy is stored or released.

Specific Lesson Objectives

Students will understand:
- Interactions among living systems and with their environment result in the movement of matter and energy relating to the significance of each to maintain the health and sustainability of an ecosystem.
- The relationship between pigment and color as it relates to corals and coral bleaching

Students will know:
- The structure and chemical make-up of a coral
- The importance of coral reefs
- The relationship between pigment and color

Students will be able to:
- Extract pigments from biological samples
- Identify important functional groups fund in pigments

Key Vocabulary for this Lesson

- Coral
- Zooxanthellae
- Ecosystem
- Pigment
- Symbiosis
- Calcium Carbonate
- Polyp

Materials

Anatomy of Coral Mini-Lab
- Empty egg carton
- transparent tape

Plant Pigment Identification Mini-Lab
- Biological Samples for pigment extraction
- Water
- Pipet dropper
- Small test tube
- Chemicals: Water/ethanol (1:1), 1M HCl, Phosphate buffer, 1M NaOH
- Scissors
- Lab coat / goggles

Technology Needs
• Computer with projector

LESSON ACTIVITIES

Opening (Warm-Up, Anticipatory Set, Review, etc.)

- Warm-up – Students will discuss whether a coral is a living or non-living thing. Then discuss whether it is an animal or plant and what feature place them in chosen categories
- **Students should also begin to draw relationships between corals and other sea creatures that are related to corals such as jelly fish.**

Procedure: Include all sections that apply to this lesson; combine as necessary.

Section	Time	What the Teacher will do:	What the Students will do:
Statement of Objective & Purpose	2 2	Explain that the warm-up will be reevaluated during the course of the unit. Give an overview of the goals of the unit and the topics that will be covered;	Participate in warm-up. Listen
Warm up, Introduction and Mini-Lab	5 25	Warm-up. Lecture on "What is a Coral". Pay special attention to identifying the differences between hard coral and soft coral, and drawing relationships between coral and jelly fish (slides 1-2) Explain Anatomy of Coral Mini-Lab (slide 3)	Listen. Answer questions in PowerPoint. Students should build identical coral polyps in order to understand that all polyps of a coral are identical
Lecture	7 4	Lecture on Structural and chemical make-up of coral and the Reef builders (hard coral). Make strong references to the coral found in the Caribbean (mostly hard coral) (slides 4- 5) Lecture on the importance of coral reefs (slide 6)	Listen and use polyps created to identify parts of a coral Brainstorm and answer question: why are coral reefs important to humans and other sea animals?
Plant Pigment Identification Mini-Lab	40	Explain Plant Pigment Mini-Lab • Observe relationship between colors and pigment • Explain how to extract from biological samples • Point out common structural (chemical) features of pigments Pass out mini-lab handouts Observe students and circle classroom Give students time to clean lab area (slide 7)	Listen Complete lab

<table>
<tr><td>Closing/ Summary</td><td>5</td><td>Ask students where they think pigments are found in corals. And show pictures of what happens when they do (slides 8-10)</td><td>Respond to teacher prompts</td></tr>
<tr><th colspan="4">Assessment of Student Learning</th></tr>
<tr><td colspan="4">Student responses to closing questions
Student responses during mini-labs</td></tr>
<tr><th colspan="4">Differentiation Strategies*</th></tr>
<tr><th colspan="4">How will you adjust aspects of the lesson to accommodate student READINESS?</th></tr>
<tr><th colspan="2">Struggling Students:</th><th colspan="2">Gifted/Advanced Students:</th></tr>
<tr><td colspan="2">Lab time is a great chance for students to work in differently sized/abled groups</td><td colspan="2">Allowing students to explore the chemistry of pigments more is an excellent way to engage advanced students. This may include having them identify important structural components found in most pigments</td></tr>
<tr><th colspan="4">How will you adjust aspects of the lesson to accommodate students’ LEARNING PROFILES?</th></tr>
<tr><td colspan="4">Solo / group work
Kinesthetic and active lab
Oral and visual presentation and discussion</td></tr>
</table>

Daily Lesson Plan- Day 2

Course Name:	☐ **Standard** ☐ **Honors** ☐ **AP**
Unit Title: The Chemistry of Coral Bleaching	**Day: 2 of 2**

Relevant NC Standard Course of Study Goal(s):

- **Chm 3.1** Understand the factors affecting rate of reaction and chemical equilibrium
- **Chm.3.2** Understand the solutions and the solution process

Relevant Next Generation Science Standards

- **PS1.B: Chemical Reactions –** Chemical processes, their rates and whether or not energy is stored or released.

Specific Lesson Objectives

Students will understand:

- Properties of acids and bases
- The dependence of coral health on atmospheric carbon dioxide and the chemical reactions involved
- The dependence of coral health on symbiotic zooxanthellae

Students will know:

- The structure and chemical make-up of a coral
- The definition of coral bleaching
- The relationship between zooxanthellae and coral bleaching
- Environmental factors affecting coral bleaching

Students will be able to:

- Chemically test for pH
- Identify trends using mathematical modeling to predict possible future occurrences

Key Vocabulary for this Lesson

- UV radiation
- Zooxanthellae
- Coral bleaching
- Ocean Acidification
- Symbiosis
- Calcium Carbonate
- Photosynthesis

Materials

Corals and Chemistry

- 3 large clear jars
- 2 empty baby food jars / group of 4 students
- 1 straw/ student
- 1 red cabbage
- Household acids (vinegar/lemon juice)
- Household bases (baking soda/ammonia-based cleaning product
- Corals and Chemistry worksheet

Using Satellite Data to Forecast Bleaching Events

- Work sheets

Technology Needs

- Computer with projector

LESSON ACTIVITIES

Opening (Warm-Up, Anticipatory Set, Review, etc.)			
• Warm-up – Students will discuss how corals lose their color and subsequent bleaching occurs			
Procedure: Include all sections that apply to this lesson; combine as necessary.			
Section	**Time**	**What the Teacher will do:**	**What the Students will do:**
Statement of Objective & Purpose	2 2	Explain that the warm-up will be reevaluated during the course of the unit. (slides 12-13 can be used for pictures) Give an overview of the goals of the unit and the topics that will be covered;	Participate in warm-up. Listen
Warm up, Introduction and Mini-Lab	15 36	Warm-up. Lecture on what is coral bleaching, importance of zooxanthellae and some of the environmental factors that trigger bleaching. Ask students to provide balanced photochemical equation. (slides 14-18) Explain Ocean acidification and the Corals and Chemistry Mini-Lab (slides 19-20) Perform demonstration Pass out hand out, observe students, circle class room	Listen. Answer questions in PowerPoint and balance chemical equation Students should complete mini lab and understand how ocean acidification works
Lecture and Mini-lab	5 25	Lecture on temperature and have students think of why this is a major concern (Slide 21) Using Satellite Data to Forecast Bleaching Events Pass out mini-lab handouts	Listen and answer prompts Complete worksheet for Mini-Lab
Coral Bleaching vs. Coral death	5	Lecture on the differences between coral bleaching and coral death. Explain that bleached corals can become healthy again if the environmental factors that caused bleaching are not prolonged (reversible). However, this does not apply to dead coral (irreversible) (slide 23)	Listen Based on diagram is slide 23: which process is reversible or irreversible
Closing/ Summary	5	Reinforce importance of protecting corals	Respond to teacher prompts

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<tr><th>Struggling Students:</th><th>Gifted/Advanced Students:</th><th>English Language Learners:</th></tr>
<tr><td>Lab time is a great chance for students to work in differently sized/abled groups</td><td>Advanced students can further explore the chemistry of the ocean. This can include discussions on salt, oxidation and ocean acidification</td><td>Teacher’ discretion</td></tr>
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Name: ________________________ Anatomy of Coral Mini-Lab Date:_____________

Background

Visible from outer space, the Great Barrier Reef off the eastern coast of Australia, is the world's largest coral reef system and the world's biggest single structure made by live organisms. If you were to move in for a closer look, you would see that the Great Barrier Reef is actually composed of thousands of smaller individual reefs. Getting closer still, you would find that each of these smaller reefs is made up of many coral heads, which themselves are made up of up to millions of tiny organisms called polyps.

Over the course of many years, stony coral polyps can create massive reef structures. Reefs form when polyps secrete skeletons of calcium carbonate ($CaCO_3$). Most stony corals have very small polyps, averaging 1 to 3 millimeters in diameter, but entire colonies can grow very large and weigh several tons. As they grow, these reefs provide structural habitats for hundreds to thousands of different vertebrate and invertebrate species. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cup, or calyx, in which the polyp sits.

Introduction

Anatomy of Coral introduces students to anatomy/biology of the individual coral polyps that join together to form reefs. This activity should take approximately 20 minutes. Students will construct a simple model of coral anatomy and processes using egg carton cups and other common craft materials

After completing this project, students will be able to:

- Identify the parts of a coral polyp
- Explain the importance of $CaCO_3$ to reef building

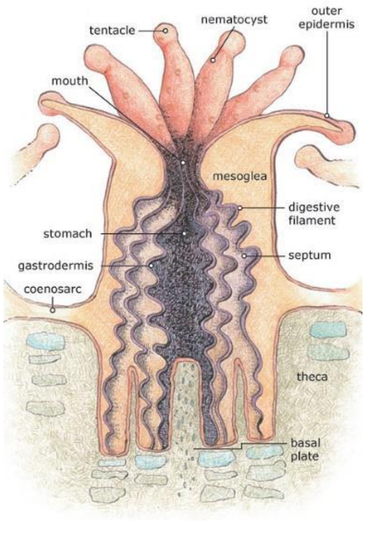

Figure 1. Diagram of the anatomy of a single coral polyp

Polyps are made of an outer cell layer called **epidermis** ("ep-ih-DERM-iss") and an inner cell layer called **gastrodermis** ("gas-tro-DERM-iss"), with a jelly-like substance called **mesoglea** ("mez-oh-GLEE-uh") in between. Each polyp makes its own cup-shaped skeleton called a **calyx**("KAY-lix)" from limestone (calcium carbonate). The base of the calyx is called the **basal plate**, and the outer walls of the calyx are called the**theca** ("THEE-kuh"). Vertical partitions called **septa** (plural form of septum) extend part-way into the cup from the inner surface of the theca. The outer surface of the theca is covered by the soft tissues of the coral. Polyps have a **mouth** surrounded by a ring of arms called **tentacles**. The tentacles have stinging cells called **nematocysts** ("nee-MAT-oh-sists") that polyps use to capture food. Most corals are carnivorous, and feed on small floating animals or even fish. Many corals also feed by collecting very small bits of floating material on strings of mucous, which they pull into their mouths. Food is digested by **digestive filaments** in the stomach. Waste is expelled through the mouth. Most reef-building corals have very small polyps, about one to three millimeters in diameter. Individual polyps in a coral colony are connected by a thin band of living tissue called a **coenosarc** ("SEE-no-sark").

Name: _________________________ Anatomy of Coral Mini-Lab Date:______________

Materials

Each student or small group of students will need:

- 3" x 3" sticky notes (i.e. Post-It® notes)
- pencils or pens
- transparent tape
- scissors
- egg carton cups
- additional craft supplies (i.e., markers, construction paper, glue, etc.)

Here's how to build your polyp model

Place the sticky note on a tabletop so the sticky edge is facing up and away from you. Place a pencil on the edge of the note nearest you and roll the paper loosely around the pencil. Press on the sticky portion to make the tube.

Use tape to close off one end of the tube and hold the note in its new shape.

Use scissors to make 4 evenly spaced cuts about halfway down from the top of the cylinder.

Name: _________________________ Anatomy of Coral Mini-Lab Date:______________

One at a time, roll the cut strips back around your finger to give them a slight curl, opening the top of the cylinder.

Use a pencil to poke a hole in the bottom of the egg cup. Enlarge the hole slightly by working and rotating the pencil through the material.

Insert the bottom of the tube into the egg cup.

Admire your model coral polyp.

Name: _________________________ Anatomy of Coral Mini-Lab Date:______________

Activity Sheet (*answers*)

1. Identify each of the following parts of a coral polyp (see Figure 1) by writing their corresponding letters below.

tentacle	*b*
nematocyst (stinging cells)	*c*
mouth	*d*
outer epidermis	*a*
stomach	*e*

2. Now, write the name of each of the structures identified in question 1 directly on the corresponding part of your model.

3. On your models identify the parts that would contain $CaCO_3$ by writing "$CaCO_3$".

$CaCO_3$ should be written on the egg carton cup.

4. What part of the model represents the animal? Where would you find zooxanthellae?

The animal in your model is the sticky note. The zooxanthellae will be found in the gastrodermis (inner layer) which is the inner part of the sticky note (in between the layers of sticky notes and other versions of this answer are also acceptable)

5. What improvements can you think of to make the model more realistic?
Answers will vary. Some possible answer may include:

-Clay in between the layers of sticky note to represent the mesoglea
-Draw circles on the tentacles to represent the nematocyst

Student's Edition: Adapted from Earth Lab Projects by Erin Bardar and LuAnn Dahlman

Name: ________________________ Anatomy of Coral Mini-Lab Date: ______________

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- Explain the importance of $CaCO_3$ to reef building

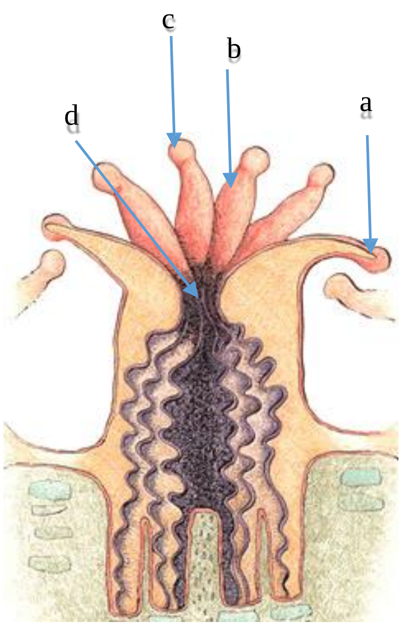

Figure 1. Diagram of the anatomy of a single coral polyp

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Name: ________________________ Anatomy of Coral Mini-Lab Date: ______________

Materials

Each student or small group of students will need:

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- transparent tape
- scissors
- egg carton cups
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Here's how to build your polyp model

Place the sticky note on a tabletop so the sticky edge is facing up and away from you. Place a pencil on the edge of the note nearest you and roll the paper loosely around the pencil. Press on the sticky portion to make the tube.

Use tape to close off one end of the tube and hold the note in its new shape.

Use scissors to make 4 evenly spaced cuts about halfway down from the top of the cylinder.

Name: _________________________ Anatomy of Coral Mini-Lab Date: _______________

One at a time, roll the cut strips back around your finger to give them a slight curl, opening the top of the cylinder.

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Insert the bottom of the tube into the egg cup.

Admire your model coral polyp.

Name: ________________________ Anatomy of Coral Mini-Lab Date: ______________

Activity Sheet

1. Identify which letter corresponds with each of the following parts of a coral polyp in figure 1.

tentacle	___
nematocyst (stinging cells)	___
mouth	___
outer epidermis	___
stomach	___

2. What does each part of your model represent? On your models identify the parts that would contain $CaCO_3$ by writing "$CaCO_3$".

3. What part of the model represents the animal? Where would you find zooxanthellae?

4. What improvements can you think of to make the model more realistic?

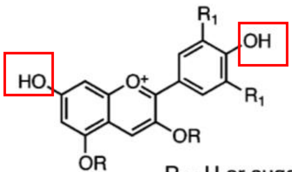
Name: ________________________ Plant Pigmentation Mini-Lab Date: ____________

Objective

Analyze extracts from botanical sources to determine the pigments responsible for the colors in several common fruits and vegetables

Introduction

As you have learned, coral bleaching is the disassociation of the coral and its symbiont, zooxanthellae, and/or loss of chlorophyll within the alga, resulting in a loss in the animal's pigmentation. In this activity we will learn about pigmentation. In general, many plant (such as algae)-produced compounds are colored or pigmented. Anthocyanins (Figure 1), members of the flavonoid family of natural products, are responsible for the colors of many flowers, fruits, and leaves yielding a range of colors from orange to blue.



The color of these pigments varies greatly depending upon the number of hydroxyl group (in red box) substitutions and the pH of the solution. Figure 2 illustrates how the pH of the environment affects the observed color of an anthocyanin.

Figure 1. Basic structure of common anthocyanins

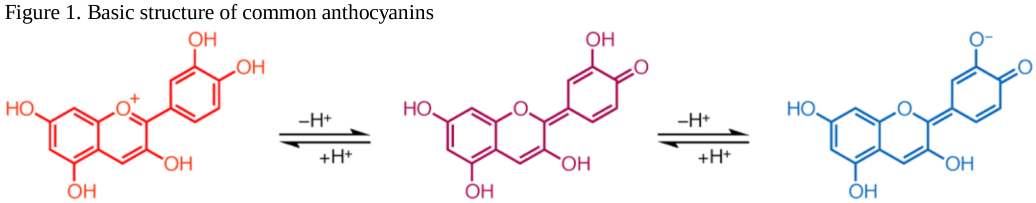


Figure 2: Cyanin undergoes dramatic color changes upon exposure to solutions of varying pH values

Equipment and Chemicals (Teacher's notes in *italics*)

- Small plastic test tube (5 test tubes needed for each biological sample)
- Wood or plastic stir stick to pulverize the botanical sample
- Pipet or dropper to divide solutions
- Water
- Water/ethanol (1:1) solution
- *1 M aqueous HCl (pH 0) or distilled white vinegar pH ~3
- 0.5 M phosphate buffer (pH 7.4)
- *1 M aqueous NaOH (pH 14) or saturated aqueous baking soda pH ~9
- Small scissors
- Vegetable peeler
- Microbalance for weighing pigments
- cyanin chloride (*this can be bought from various chemical distributors, i.e. Sigma Aldrich*)
- delphinidin chloride (*aglycone form*)
- pelargonidin chloride (*aglycone form*)

Name: ________________________ Plant Pigmentation Mini-Lab Date: ____________

- malvin chloride

**** if 1 M HCl or NaOH are used, students should use gloves and a lab coat***

Biological Samples (*between 3-5 different samples/group is adequate*)

- Red cabbage
- Red radish
- Cranberries
- Red rose
- Concord grape juice
- Blackberries
- Blueberries

Experimental Procedures (for students with teacher's notes in *italics*)

Preparation of Standard Pigment Profiles

1. Weigh out ~0.5mg of pigment and dissolve into 2mL water/ethanol (1:1)
2. Divide the solution into 4 test tubes (0.5mL/test tube). This should give concentrations of the standard pigment solutions to be ~0.25mg/mL
3. Each test tube is treated with one of the following solutions:
    a. Test tube 1: 0.5 mL water and one drop 1 M HCl (~50 µL)
    b. Test tube 2: 0.5 mL water
    c. Test tube 3: 0.5 mL 0.5 M phosphate buffer, pH 7.4
    d. Test tube 4: 0.5 mL water and one drop 1 M NaOH (~50 µL)
4. Swirl or flick test tubes (in order to agitate) and record color observations.
5. Test the pH of the solutions (*Use of pH indicator strips will be suitable for testing pH*)

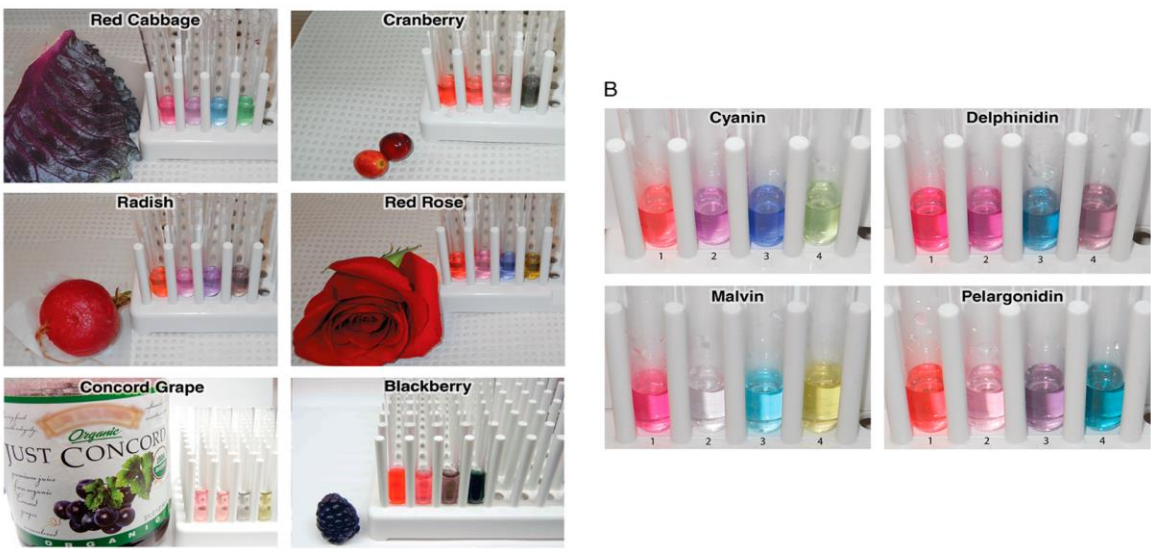


Figure 3. The pH profiles of the materials. Students compare their results (A) with those of the profiles generated from a pure standard of the major pigments present in these plants (B).

Name: ________________________ Plant Pigmentation Mini-Lab Date: ____________

Preparation of Botanical Source Pigment Profile (*between 3-5 samples/group is adequate*)

1. 0.5 – 1g of each botanical source is required to conduct an experiment.
   - Harvest rose petals by carefully cutting each petal from the flower without including the sepal. A single petal provides sufficient material.
   - Cut the cabbage into small strips (two 1-inch strips per student).
   - the skin of one radish
   - the peel of four cranberries
   - one-half of a blackberry
   - 1 mL of grape juice.
2. Place the biological sample into a plastic test tube and add 2mL of the water/ethanol (1:1) solution
3. Carefully crush the solution (with any blunt plastic or wooden object) until it becomes the color of the sample.
4. Place ~0.5mL of solution into 4 different test tubes each
5. Add the following solutions to each test tube as described below
   a. Test tube 1: 0.5 mL water and one drop 1 M HCl (∼50µL) or distilled vinegar
   b. Test tube 2: 0.5 mL water
   c. Test tube 3: 0.5 mL 0.5 M phosphate buffer, pH 7.4
   d. Test tube 4: 0.5 mL water and one drop 1 M NaOH (∼50 µL) or baking soda solution
6. Agitate the test tubes as done before.

   Now you will obtain your pigment profiles and compare them to those of the known pigment standards in order to assign the represented pigment in each biological sample.

   Pick the pigment that best represents your sample.

Name: ________________________ Plant Pigmentation Mini-Lab Date: ____________

Objective

Analyze extracts from botanical sources to determine the pigments responsible for the colors in several common fruits and vegetables

Introduction

As you have learned, coral bleaching is the disassociation of the coral and its symbiont, zooxenthellae, and/or loss of chlorophyll within the alga, resulting in a loss in the animal's pigmentation. In this activity we will learn about pigmentation. In general, many plant (such as algae)-produced compounds are colored or pigmented. Anthocyanins (Figure 1), members of the flavonoid family of natural products, are responsible for the colors of many flowers, fruits, and leaves yielding a range of colors from orange to blue.

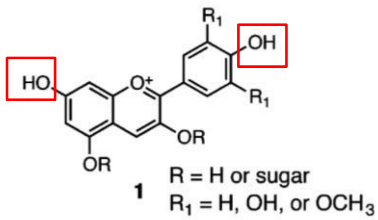


Figure 1. Basic structure of common anthocyanins

The color of these pigments varies greatly depending upon the number of hydroxyl group (in red box) substitutions and the pH of the solution. Figure 2 illustrates how the pH of the environment affects the observed color of an anthocyanin.

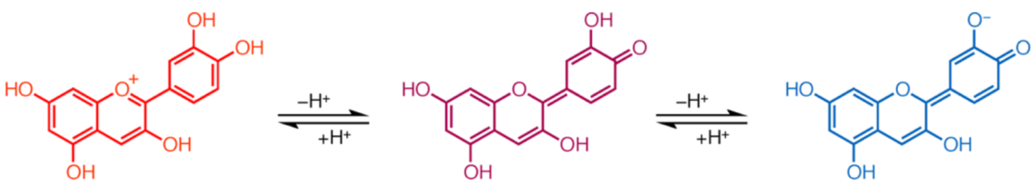


Figure 3. The pH profiles of the materials. Students compare their results (A) with those of the profiles generated from a pure standard of the major pigments present in these plants (B).

Equipment and Chemicals

- Small plastic test tube (5 test tubes needed for each biological sample)
- Wood or plastic stir stick to pulverize the botanical sample
- Pipet or dropper to divide solutions
- Water
- Water/ethanol (1:1) solution
- *1 M aqueous HCl (pH 0) or distilled white vinegar pH ~3
- 0.5 M phosphate buffer (pH 7.4)
- *1 M aqueous NaOH (pH 14) or saturated aqueous baking soda pH ~9
- Small scissors
- Vegetable peeler
- Microbalance for weighing pigments
- cyanin chloride
- delphinidin chloride

Adapted from: *J. Chem. Educ.* **2013**, 90, 755−759

Name: ________________________ Plant Pigmentation Mini-Lab Date: ____________

- pelargonidin chloride
- malvin chloride

Biological Samples (as many as necessary)

- Red cabbage
- Red radish
- Cranberries
- Red rose
- Concord grape juice
- Blackberries
- Blueberries

Experimental Procedures

Preparation of Standard Pigment Profiles

1. Weigh out ~0.5mg of pigment and dissolve into 2mL water/ethanol (1:1)
2. Divide the solution into 4 test tubes (0.5mL/test tube). This should give concentrations of the standard pigment solutions to be ~0.25mg/mL
3. Each test tube is treated with one of the following solutions:
    e. Test tube 1: 0.5 mL water and one drop 1 M HCl (~50 µL)
    f. Test tube 2: 0.5 mL water
    g. Test tube 3: 0.5 mL 0.5 M phosphate buffer, pH 7.4
    h. Test tube 4: 0.5 mL water and one drop 1 M NaOH (~50 µL)
4. Swirl or flick test tubes (in order to agitate) and record color observations.
5. Test the pH of the solutions

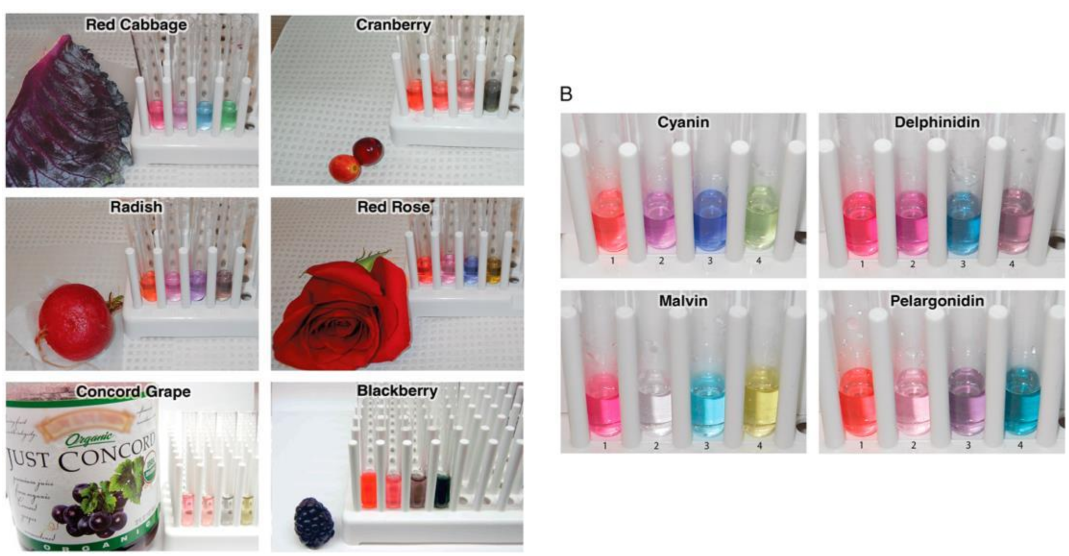


Figure 3. The pH profiles of the materials. Students compare their results (A) with those of the profiles generated from a pure standard of the major pigments present in these plants (B).

Name: ________________________ Plant Pigmentation Date: ____________

Mini-Lab

Preparation of Botanical Source Pigment Profile

1. 0.5 – 1g of each botanical source is required to conduct an experiment.
    - Harvest rose petals by carefully cutting each petal from the flower without including the sepal. A single petal provides sufficient material.
    - Cut the cabbage into small strips (two 1-inch strips per student).
    - the skin of one radish
    - the peel of four cranberries
    - one-half of a blackberry
    - 1 mL of grape juice.
2. Place the biological sample into a plastic test tube and add 2mL of the water/ethanol (1:1) solution
3. Carefully crush the solution (with any blunt plastic or wooden object) until it becomes the color of the sample.
4. Place ~0.5mL of solution into 4 different test tubes each
5. Add the following solutions to each test tube as described below
    e. Test tube 1: 0.5 mL water and one drop 1 M HCl (∼50µL) or distilled vinegar
    f. Test tube 2: 0.5 mL water
    g. Test tube 3: 0.5 mL 0.5 M phosphate buffer, pH 7.4
    h. Test tube 4: 0.5 mL water and one drop 1 M NaOH (∼50 µL) or baking soda solution
6. Agitate the test tubes as done before.

    Now you will obtain your pigment profiles and compare them to those of the known pigment standards in order to assign the represented pigment in each biological sample.

    Pick the pigment that best represents your sample.

CORALS AND CHEMISTRY

DESCRIPTION

This lesson plan helps students understand how increased carbon dioxide (CO_2) emissions from the burning of fossil fuels is changing the acidity (pH) of the ocean and affecting coral reefs and other marine animals. Students conduct an experiment to see whether CO_2 is making the oceans more basic or acidic.

BACKGROUND

The world's oceans play a vital role in keeping the Earth's carbon cycle in balance. As people add more greenhouses gases to the atmosphere by burning fossil fuels, the oceans respond by absorbing more CO_2. When CO_2 is absorbed by seawater, chemical reactions occur that reduce the pH of seawater, causing the water to become more acidic. These chemical reactions are called "ocean acidification."

Over the last few decades, the amount of CO_2 dissolved in the ocean has increased all over the world, and so has ocean acidity. Increasing acidity is a problem because it reduces the availability of chemicals needed to make calcium carbonate, which corals, shellfish, some types of plankton, and other creatures rely on to produce their hard skeletons and shells.

Coral reefs are created in shallow tropical waters by millions of tiny animals called corals. Each coral makes a skeleton for itself, and over time these skeletons build up to create coral reefs. Protecting coral reefs is very important because they provide food and habitat for many kinds of fish and marine animals, serve as natural breakwaters against storms and hurricanes, and provide fishing and recreational opportunities for millions of people.

MATERIALS

- Three large, clear jars or cups for the educator demonstration
- Two small, clear jars with lids (such as baby food jars) for each group of four students in the class
- One straw for each student in the class
- 1 red cabbage
- Enough red cabbage juice (see instructions for how to prepare under "Advance Preparations") to fill each small jar about 1 inch high and each large jar about 2 inches high)
- Common household acid (vinegar or lemon juice)

TIME: 45 to 60 minutes

LEARNING OBJECTIVES:

Students will:

- Learn that corals and other marine animals need a certain pH range to thrive
- Learn that increased amounts of CO_2 in the atmosphere from the burning of fossil fuels are changing the pH of the ocean
- Investigate whether increased amounts of CO_2 in the atmosphere are making our oceans more basic or more acidic
- Learn how a change in oceanic pH is impacting coral reefs

NATIONAL SCIENCE STANDARDS:

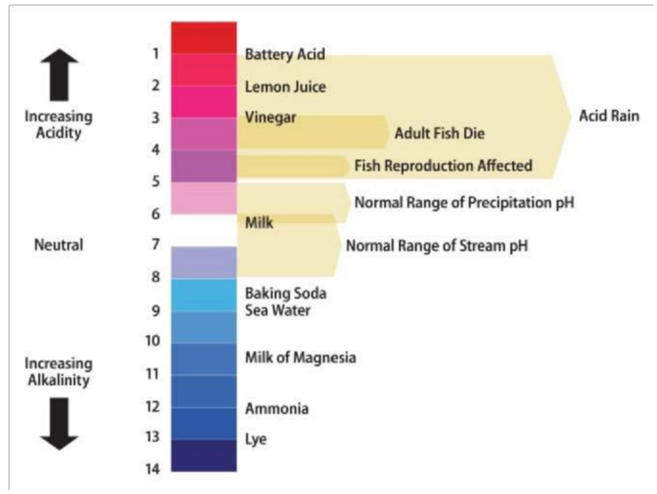
- Content Standard A: Science as inquiry
- Content Standard B: Physical science
- Content Standard C: Life science

ADAPTED FROM:

California Academy of Sciences: http://www.calacademy.org/teachers/resources/lessons/coral-and-chemistry.

- Common household base (baking soda or ammonia-based cleaning product)
- "Corals and Chemistry" worksheet (one copy per group of four students)
- Video of coral (optional): http://www.youtube.com/watch?v=MwjtChtIOA8 focuses on coral systems and their importance, while http://www.youtube.com/watch?v=9EaLRcVdTbM provides an overview of the ocean acidification process and the effects on corals and shellfish

pH Scale



A pH unit is a measure of acidity ranging from 0 to 14

The lower the number, the more acidic the substance.

Image source: U.S. EP A

The Science Behind Ocean Acidification

CO_2 chemically reacts with water to form carbonic acid, as shown by the chemical :

$CO_{2(aq)}$ + H_2O ↔ $\mathbf{H_2CO_3}$

carbon dioxide + water ↔ carbonic acid

Almost immediately, carbonic acid breaks apart to form bicarbonate ions ($H_2CO_3^-$), carbonate ion s (CO_3 and hydrogen ions (H+) as shown by the chemical equation below:

H2CO_3 ↔ HCO^{3-} + H^+ ↔ CO_3^{2-} + $2H^+$

carbonic acid ↔ bicarbonate + hydrogen ↔ carbonate + hydrogen

The presence of hydrogen ions from dissolved carbonic acid is what makes the water more acidic.

VOCABULARY

Acid:
A substance that increases the hydrogen ion concentration in a solution, which decreases the solution's value.

Base:
A substance that reduces the hydrogen ion concentration in water, which increases the solution's pH value.

Carbon dioxide (CO_2):
A colorless, odorless greenhouse gas. It is produced naturally when dead animals or plants decay, and it is used by plants during photosynthesis. People are adding carbon dioxide into the atmosphere, mostly by burning fossil fuels such as coal, oil, and natural gas. This extra carbon dioxide is the main cause of today's climate change.

Carbonic acid:
An acid that forms when carbon dioxide dissolves in seawater. Extra carbonic acid is making the oceans more acidic, which can make it harder for corals and shellfish to build their skeletons and shells.

Corals:
Corals are tiny animals that make their own skeletons. Over time, these skeletons build up to create coral reefs, which provide habitat for fish and many other ocean creatures.

Habitat:
The place or environment where a plant or animal naturally lives and grows.

pH:
A measure of the acidity of a solution; described on a scale ranging from 0 (most acidic) to 14 (most basic). Pure water has a pH of about 7, which is considered neutral. The pH scale is based on powers of 10, which means a substance with a pH of 3 is 10 times more acidic than a substance with a pH of 4.

INSTRUCTIONS

Advance Preparations

1. Cut the red cabbage into pieces and boil with the lid on until the water is a dark color.
2. Strain the cabbage. Save the cabbage juice and discard the rest.
3. Pour a small amount of cabbage juice into each small jar. Fill each jar less than 1 inch high.
4. Pour a slightly larger amount of cabbage juice into the three larger jars. Fill each jar no more than 2 inches high.

Educator Demonstration

Red cabbage juice is a pH indicator

Control Acid Base

Part 1: Educator Demonstration

1. Give a brief explanation of how people are adding CO_2 to the atmosphere through activities that burn fossil fuels, like driving cars, using electricity, and manufacturing products.
2. Discuss how the ocean plays a vital role in regulating the amount of CO_2 in the atmosphere. As more CO_2 is added to the atmosphere from the burning of fossil fuels, the ocean absorbs more CO_2 to stay in balance.
3. Explain that the acidity of a substance can be measured by its pH. Tell the students that they will be performing an experiment to determine whether the ocean is becoming more acidic or more basic.
4. In front of the class, show the three large jars of cabbage juice. Tell students that the jars contain water in which red cabbage has been boiled. Red cabbage is a natural pH indicator, meaning that it changes color to indicate changes in pH.
5. Show students the household acid (vinegar or lemon juice) and ask "Is this acidic or basic?" Show students the household base (baking soda or ammonia-based cleaning product) and ask "Is this acidic or basic?"
   [Answer: Vinegar and lemon juice are acidic. Baking soda and ammonia cleaning product are basic.]
6. Pour some of the acid to one of the large jars with cabbage juice and some of the base to the second large jar. (The last jar of cabbage juice will serve as the control.) Make sure to add enough of the acid and base that you see a color change. Discuss what this test means.
   [Answer: Acids reduce the pH of the cabbage juice, making it more pink/red. Bases increase the pH of the cabbage juice, making it more blue/green.]

Student Experiment

Will the CO_2 from my breath make the cabbage juice more acidic or basic?

Control Experiment

Part 2: Student Experiment

CORALS AND CHEMISTRY

Divide the class into groups of four and pass to each group the two small jars (and lids) with the red cabbage juice inside, the straws, and one "Corals and Chemistry" worksheet.

1. Tell students that they are going to perform an experiment to mimic CO_2 absorption by oceans by blowing air into one of these jars. As the students exhale CO_2 into the cabbage juice water, some of it will be absorbed, become dissolved, and change the pH of the water.

2. Based on the demonstration they just saw, ask each group of students to develop a hypothesis about what they think will happen when they blow into the two jars. Ask them to write their hypothesis in the space provided on the "Corals and Chemistry" worksheet.
   [Answer: The increased CO_2 from my breath will reduce the pH of the cabbage juice and make it more acidic (pinkish).]

3. Have one student from each group place his or her straw in one of the jars and then cover it with a lid to prevent spraying the juice. This is the **experimental jar**. Tell each group of students to blow lightly into the jar by taking turns. Each student should use his or her own straw. The second jar is the **control jar**. Put a lid on it, and do not blow into it.

4. ***Optional:*** While the students are taking turns blowing into the jars, show them a short video about coral reefs, such as this YouTube video that shows how coral reefs provide the foundational ecosystem for millions of marine animals and plants: http://www.youtube.com/watch?v=MwjtChtIOA8.

5. After four to six minutes, the color of the cabbage juice in the experimental jar should change from a dark purple to a purple-pink as the water becomes more acidic. Tell students to write down their results on the "Corals and Chemistry" worksheet.

6. Discuss the following questions as a class:

   - How is increased CO_2 in the atmosphere affecting oceans and coral?
     [Answer: As long as we keep putting extra CO_2 in the atmosphere, the ocean will continue to become even more acidic. Increasing ocean acidity makes it harder for corals to build skeletons and for shellfish to build the shells they need for protection.]

   - Why is it important to protect corals?
     [Answer: Coral reefs are important because they provide food and habitat for many kinds of fish and marine animals. They also provide fishing and recreational opportunities for millions of people, and they protect the land from hurricane and storm waves.]

EXTENSION

Coral reefs in many parts of the world's oceans are struggling to survive. A number of factors, in addition to ocean acidity, are to blame, including increasing sea temperature and pollution. Have students take the "Expedition to the Great Barrier Reef" (see http://www.epa.gov/climatechange/students/expeditions/ temp-acidity/index.html) either in class or as a homework assignment. This 8-minute video explores how changes in ocean temperature and acidity threaten coral reefs. The video pauses to ask students questions, providing an interactive learning experience.

CORALS AND CHEMISTRY WORKSHEET

NAME: ____ DATE: ______________________________

Hypothesis:

Will the increased carbon dioxide from my breath make the cabbage juice more acidic (pinkish) or more basic (greenish)?

Results:

What happened to the cabbage juice in the control jar?

What happened to the cabbage juice in the experimental jar?

Has the pH of the cabbage juice in the experimental jar changed?

CORALS AND CHEMISTRY WORKSHEET—ANSWER KEY

Hypothesis:

Will the increased carbon dioxide from my breath make the cabbage juice more acidic (pinkish) or more basic (greenish)?

[Correct hypothesis: Blowing my breath into the cabbage juice will lower its pH and make it more acidic.]

Results:

What happened to the cabbage juice in the control jar?

[Answer: The control jar did not change color.]

What happened to the cabbage juice in the experimental jar?

[Answer: The cabbage juice in the experimental jar became more pinkish.]

Has the pH of the cabbage juice in the experimental jar changed?

[Answer: Yes, the pH of the cabbage juice in the experimental jar has decreased (become more acidic).]

Using Satellite Data to Forecast Bleaching Events

By Tyler Christensen

NOAA Coral Reef Watch

Satellite Imagery Worksheet

The main condition that is linked to coral bleaching is unusually high water temperature. Your assignment is to use satellite data to investigate whether this condition occurred in the Caribbean during early Fall 2005. You will be assigned to one of four locations:

- Bermuda, located at 32.0°N/64.5°W
- Lee Stocking Island (Bahamas), located at 23.5°N/76.5°W
- west coast of Puerto Rico, located at 18.0°N/67.5°W
- US Virgin Islands, located at 18.0°N/65.0°W

A. <u>What were the local conditions at your reef on September 2nd, 2005?</u>

Find your reef on the Sea Surface Temperature figure. This map shows the temperature of the ocean waters, measured from some of NOAA's satellites. The data are broken up into squares that are 50 km on a side.

1. **What was the temperature at your reef on that day?**

Now find your reef on the Coral Reef HotSpot figure. This map shows temperature anomalies. In this case, the anomaly is the temperature above the warmest monthly mean for each location. If your area is white, temperatures are less than the average for the warmest month. Warm colors indicate the number of degrees above the average for the warmest month.

2. **Was your site unusually warm? If so, what was the anomaly?**

B. <u>How hot was the whole late Summer / early Fall season?</u>

Find your reef in the Sea Surface Temperature (SST) Time Series figure. These graphs give the yearly temperature pattern for each of the four reef sites, measured by NOAA satellites. **Note** that both 2004 and 2005 are plotted on the same graph.

The SST for the site is shown in dark blue. The dashed light-blue line shows the average temperature for the warmest month. One degree above that is the threshold temperature for coral bleaching, shown as the solid light-blue line. When the temperature at the reef exceeds this threshold, the corals are thermally stressed.

3. **Based on the 2005 temperature graph for your site, answer these questions:**
   a. **What was the highest temperature?**

   b. **How long did the temperature stay at or above the bleaching threshold?**

The solid red line at the bottom of the graph shows the Degree Heating Weeks (DHW) for that site throughout the year. The DHWs show the accumulation of thermal stress the corals have seen in the last 3 months—how hot the water has been for how long. This is a good measure of how stressed the corals are.

4. **How high did the DHWs get?**

The dashed red lines show two DHW bleaching thresholds. When the value gets above 4, we expect to see significant coral bleaching. Values above 8 indicate that we expect severe coral bleaching, and some coral mortality as a result.

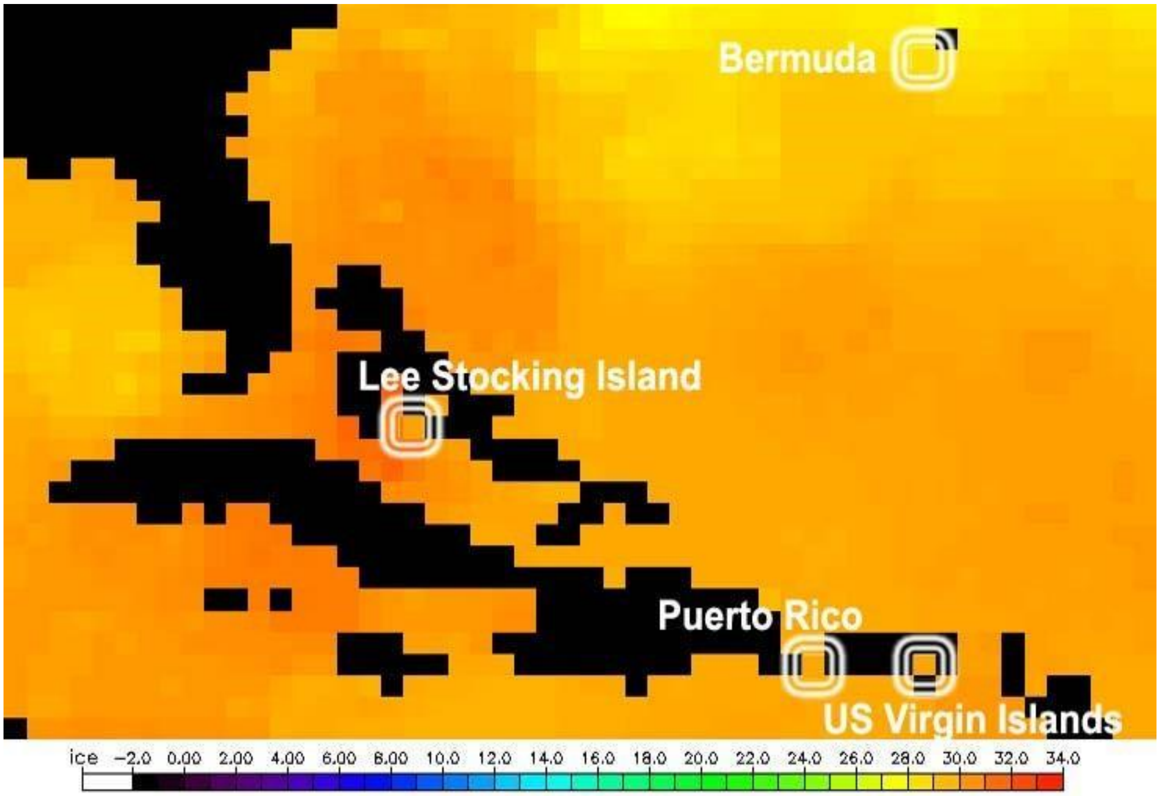
5. **Do you expect that there was coral bleaching at your reef site in 2005? How severe?**

C. <u>How stressed was your reef site compared to other reefs in the Caribbean region?</u>
Find your reef on the Maximum Degree Heating Weeks (DHW) figure. DHWs measure the accumulated thermal stress on the reef. The figure shows the maximum DHW values experienced during 2005.

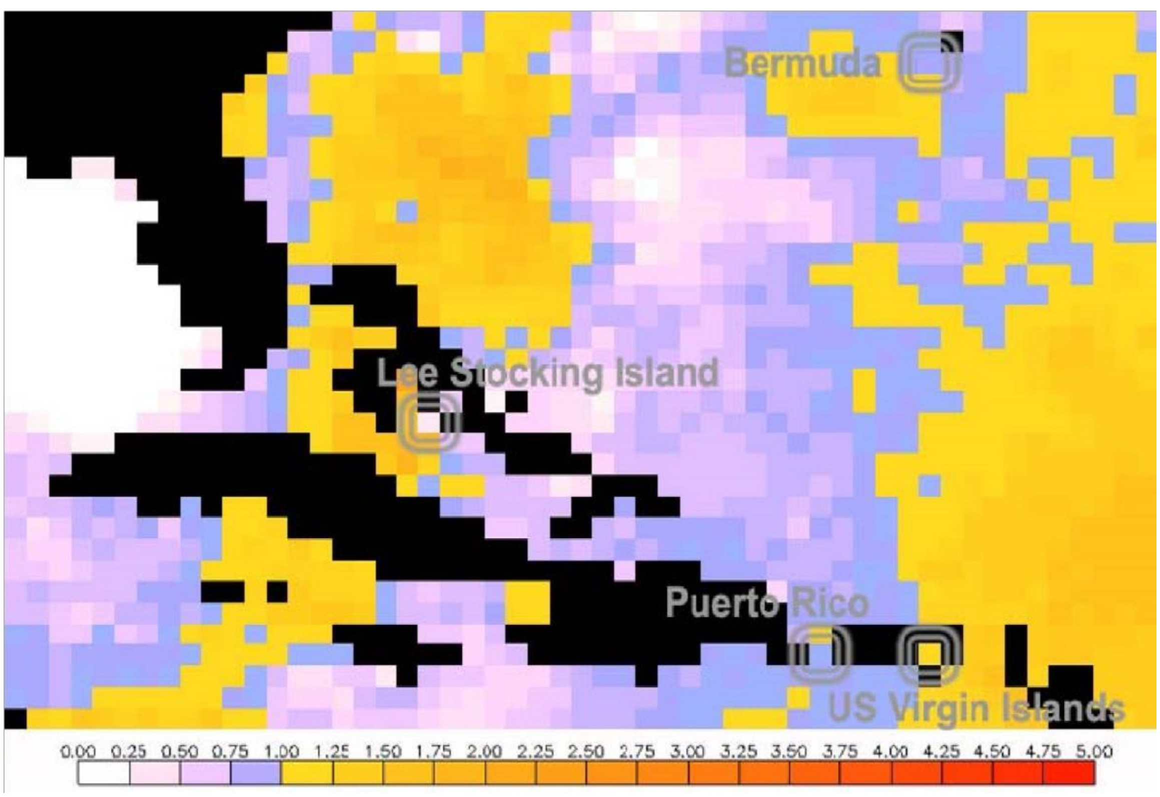
6. **How did the thermal stress at your site compare to the stress experienced by the other three reefs highlighted in this exercise?**

7. **How severe was the bleaching at your site compared to the other three reefs?**

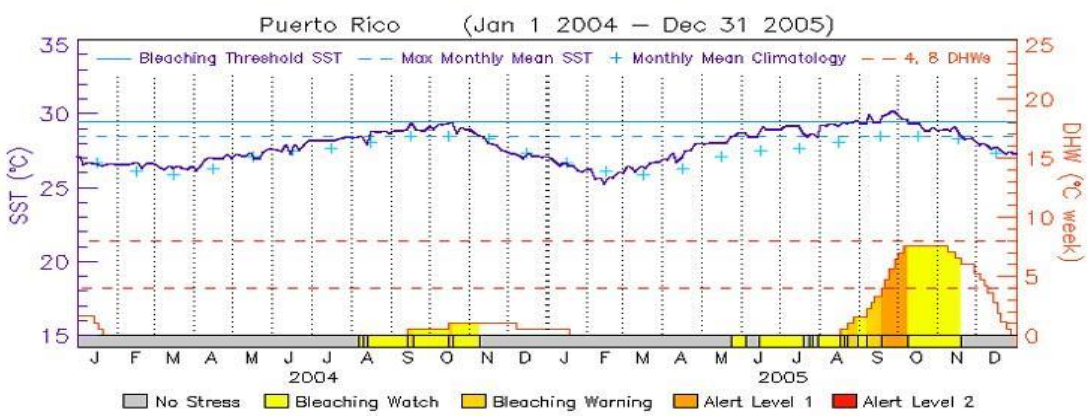
Sea Surface Temperature, September 2nd, 2005

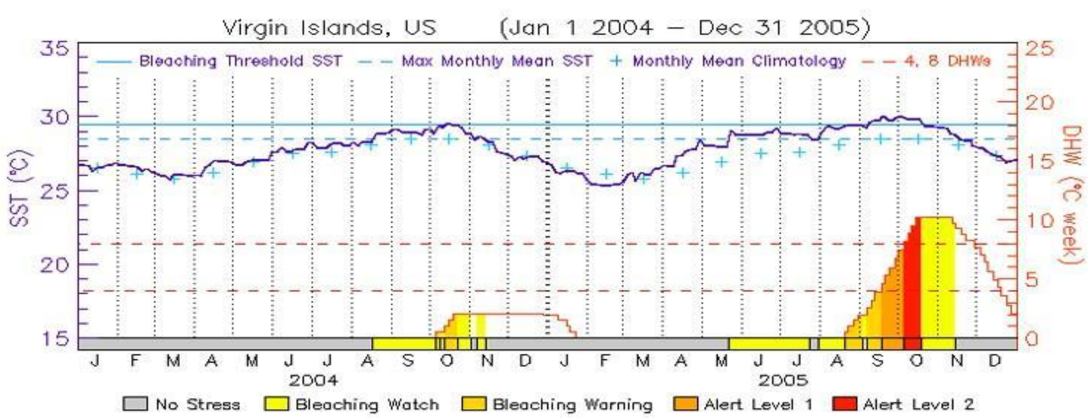


Coral Reef Hotspot, September 2nd, 2005

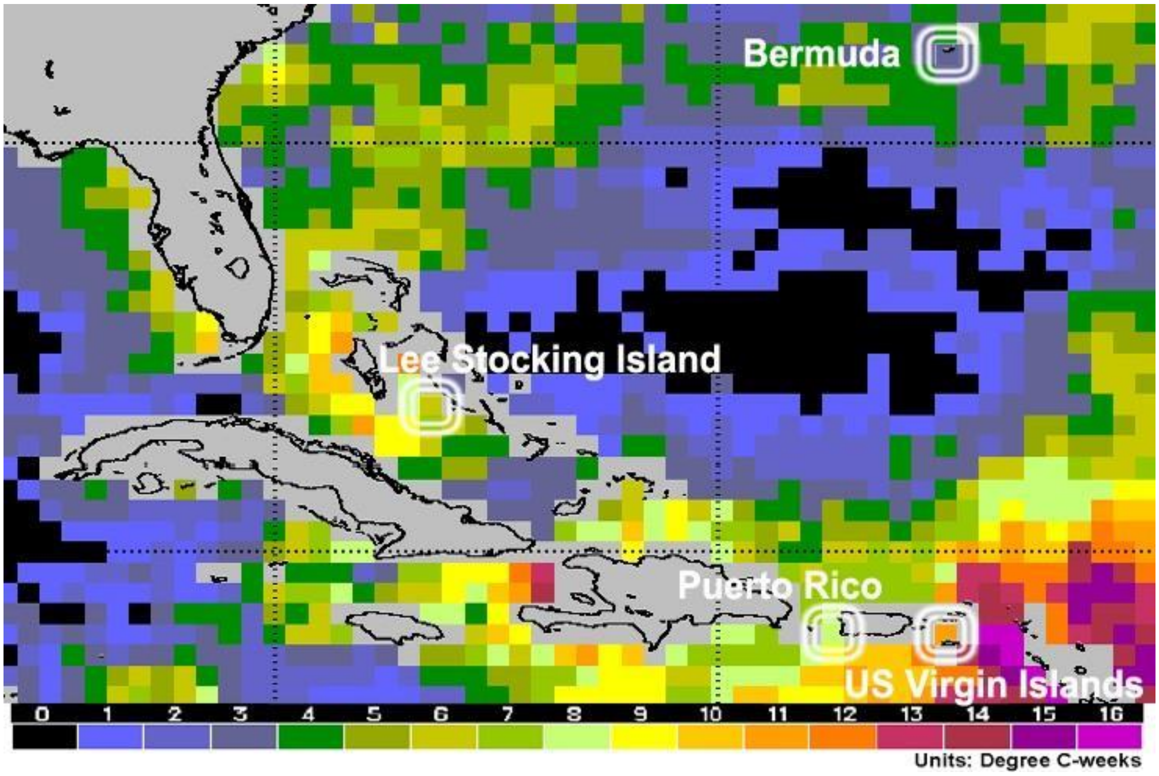


Sea Surface Temperature Time Series





2005 Maximum Degree Heating Weeks



Satellite Imagery Resources Online

Current and past Sea Surface Temperatures, Coral Bleaching HotSpots, Degree Heating Weeks and time series can be found at:

http://coralreefwatch.noaa.gov/satellite/

Sea Surface Temperature images (NOAA Coral Reef Watch)

http://www.osdpd.noaa.gov/PSB/EPS/SST/sst_50km.html Sea Surface Temperature time series are found at:

http://coralreefwatch.noaa.gov/satellite/current/sst_series_24reefs.html Maximum DHW image, plus more on the 2005 Caribbean bleaching event:

http://coralreefwatch.noaa.gov/caribbean2005/

NOAA Coral Reef Watch education resources:
http://coralreefwatch.noaa.gov/satellite/education/index.html

All of NOAA's coral reef educational resources: http://coralreef.noaa.gov/outreach/welcome.html

Satellite Imagery Worksheet—ANSWERS

A. What were the local conditions at your reef on September 2nd, 2005?

1. **What was the temperature at your reef on that day? B**: 28°C; **LSI**: 30°C; **PR**: 29°C; **USVI**: 29°C

2. **Was your site unusually warm? If so, what was the anomaly? B**: +0.75°C; **LSI**: +0.25°C; **PR**: +0.75°C; **USVI**: +1°C

B. How hot was the whole late Summer / early Fall season?

3a. What was the highest temperature?
B: 28.5°C; **LSI**: 31°C; **PR**: 30.5°C; **USVI**: 30°C

3b. How long did the temperature stay at or above the bleaching threshold? B: about a month; **LSI**: 1 month, then a decrease, then another month; **PR**: 2 months; **USVI**: 3½ months

4. **How high did the DHWs get?**
B: 3 DHW; **LSI**: 6 DHW; **PR**: 8 DHW; **USVI**: 11 DHW

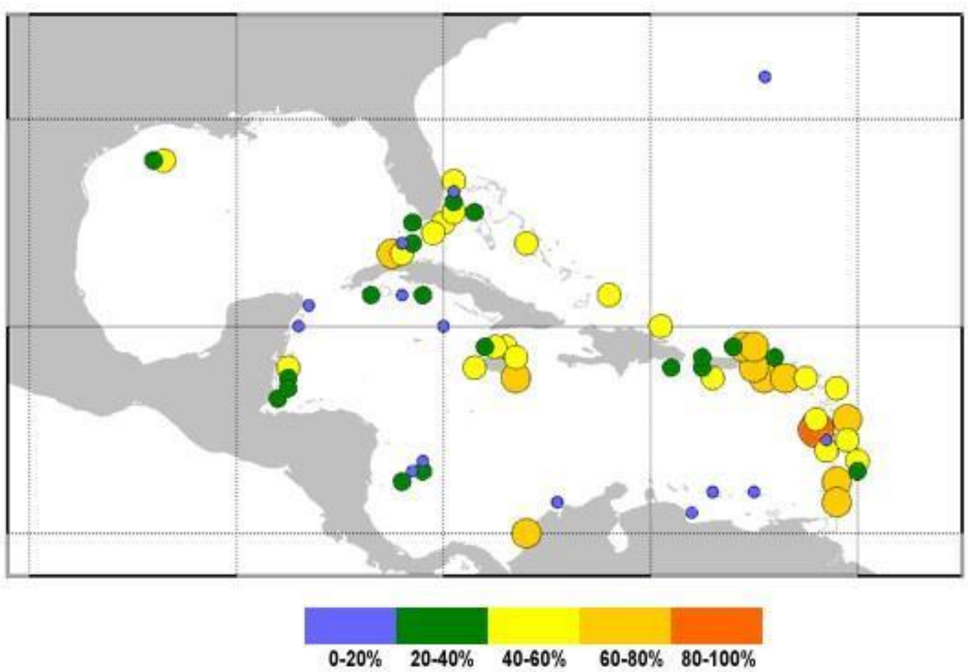
5. **Do you expect that there was coral bleaching at your reef site in 2005? How severe?**
B: mild, if any; **LSI**: moderate; **PR**: severe; **USVI**: very severe

C. How stressed was your reef site compared to other reefs in the Caribbean region?

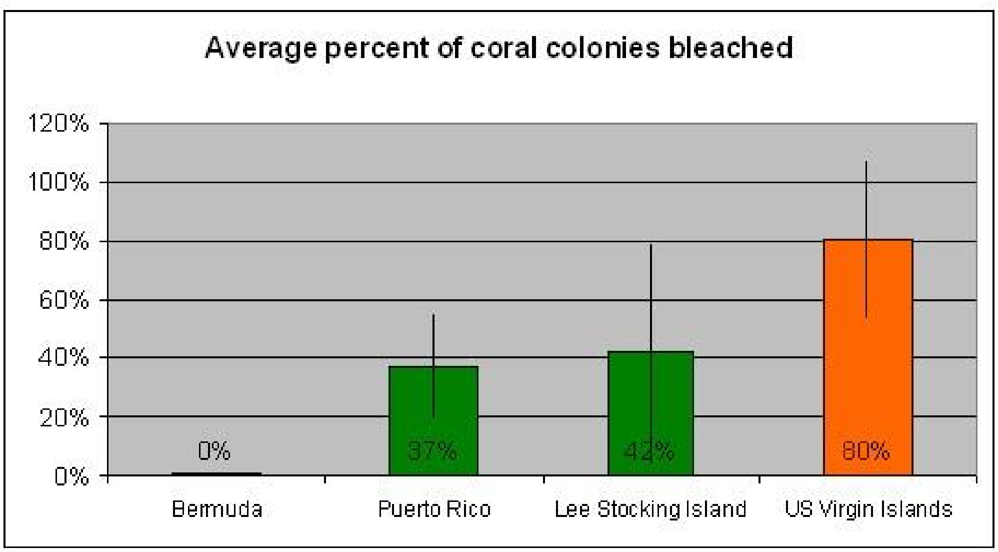
6. **How did the thermal stress at your site compare to the stress experienced by the other three reefs highlighted in this exercise?**
B < LSI < PR < USVI or **B < LSI = PR < USVI**

7. **How severe was the bleaching at your site compared to the other three reefs?**
B < LSI < PR < USVI or **B < LSI = PR < USVI**

So how bad was the bleaching, really?



Regional observations from over 1500 on-site surveys conducted during the 2005 bleaching event. Each dot represents the average percentage of the coral colonies bleached at that location.



Bleaching surveys within 50 km of the four sites in this exercise. As expected, the bleaching was worst in the US Virgin Islands, where about 80% of the coral colonies were bleached. Puerto Rico had 37% of colonies bleached; LSI had 42%. Note that there is a lot of variability in the data (shown by the error bars); Puerto Rico and the Lee Stocking Island were statistically identical. In Bermuda the bleaching was very light: less than 1% of coral colonies bleached.

Thermal stress: B < LSI < PR < USVI

Actual bleaching data: B < LSI = PR < USVI

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